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Project report

God's Window Skywalk

Groundwater Exploration & Geohydrological Assessment for the Environmental Impact Assessment

1001604

Mapulana Canyon (Pty) Ltd

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Glossary

Term	Definition
%	Percentage
CDT	Constant Discharge Test
DEA	Department of Environmental Affairs
DRO	Diesel Range Organics
DWAF	Department of Water Affairs & Forestry
DWS	Department of Water & Sanitation
EA	Environmental Authirisation
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMP	Environmental Management Program
GA	General Authorisation
GQM	Groundwater Quality Management
GRDM	Groundwater Resource Directed Measures
GRO	Gasoline Range Organics
GRU	Geohydrological Response/ Resource Unit
Ha	Hectare
K	Hydraulic Conductivity
km	Kilometer
km^2	Square Kilometer
l/h	liters/hour
l/s	liters/second
LDPE	Low density polyethylene
m	meter
m/d	Meters per day
m^3	Cubic Meters
m^3/a	Cubic Meters/annum
m^3/ha/a	Cubic Meters/hectare/annum
MAE	Mean annual Evaporation
mamsl	meters above mean sea level

Term	Definition
MAP	Mean Annual Precipitation
mbcl	meters below casing level
mbgl	meters below ground level
ML/d	Mega Liter/day
mm/a	Millimeters/annum
Mm^3/a	Million Cubic Meters/annum
mS/m	Millisiemens per meter
NEMA	National Environmental Management Act
NGA	National Groundwater Archive
nm	not measured
MTPA	Mpumalanga Tourist and Parks Agency
NWA	National Water Act
^oC	Degrees Centigrade
SABS	South African Bureau of Standards
SACNASP	South African Council for Natural Scientific Professions
SANAS	South African National Accreditation System
SANS	South African National Standards
SWL	Static water level
T	Transmissivity
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
WARMS	Water Use Authorization & Registration Management System
WRC	Water Research Commission
WULA	Water Use License Application

Compliance with Appendix 6 of the 2014 EIA Regulations (GNR 982 of December 2014)

App. 6	Content requirement of the 2014 EIA Regulations	Report Section	Page
(a)	Details of (i) the specialist who prepared the report; and (ii) the expertise of that specialist to compile a specialist report, including a curriculum vitae;	App. G	
(b)	a declaration that the specialist is independent in a form as may be specified by the competent authority;	App. G	
(c)	an indication of the scope of, and the purpose for which, the report was prepared;	4	16
(cA)	an indication of the quality and age of base data used for the specialist report;	9	25
(cB)	a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change;	12 13.1	43 53
(d)	the duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment;	9.2 9.3 9.4 9.5 9.6 9.7	25 27 30 31 31 36
(e)	a description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used;	6	17
(f)	details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternatives;	8.7.1	24
(g)	an identification of any areas to be avoided, including buffers;	8.7.1	24
(h)	a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	8.7.1	24
(i)	a description of any assumptions made and any uncertainties or gaps in knowledge;	5	17
(j)	a description of the findings and potential implications of such findings on the impact of the proposed activity or activities;	12	43
(k)	any mitigation measures for inclusion in the EMPr;	13.2	54
(l)	any conditions for inclusion in the environmental authorisation;	13.2 14	54 56
(m)	any monitoring requirements for inclusion in the EMPr or environmental authorisation;	13.1	53

App. 6	Content requirement of the 2014 EIA Regulations	Report Section	Page
(n)	a reasoned opinion— (i) whether the proposed activity, activities or portions thereof should be authorised; (iA) 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, any avoidance, management and mitigation measures that should be included in the EMPr, and in the case of a closure activity, the closure plan;	14	56
(o)	a description of any consultation process that was undertaken during the course of preparing the specialist report,	1	13
(p)	a summary and copies of any comments received during any consultation process and where applicable, all responses thereto; and	NA	NA
(q)	any other information requested by the competent authority.	NA	NA

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Executive Summary

Mapulana Canyon (Pty) Ltd (hereafter referred to as Mapulana Canyon), in partnership with the Mpumalanga Tourist and Parks Agency (MTPA) via a Public Private Partnership agreement proposes the development of a new tourist attraction, called the "God's Window Skywalk" at God's Window in the Blyde River Canyon Nature Reserve, Mpumalanga, hereafter also referred to as "the site". The development will include (but is not limited to) a skywalk, a sky bridge, restaurants and dining areas, an auditorium, administrative offices and the upgrading of existing walkways.

The MTPA was granted an environmental authorisation (EA) by the Department of Forestry, Fisheries and the Environment (DFFE) to develop the God's Window Skywalk project on 5 June 2015, with reference number 14/12/16/3/3/3/88. Due to various delays in the start of construction, including the finalisation of the Public Participation Process (PPP) and change in architectural designs, and since the Environmental Impact assessment (EIA) regulations were amended during this period, the project needs to undergo a new EIA process to ensure the EA is valid, applicable and addresses all current impacts and aspects related to the proposed development.

Zutari (Pty) Ltd (hereafter referred to as Zutari) was appointed by Mapulana Canyon (Pty) Ltd as the independent Environmental Assessment Practitioner (EAP) to manage the new application for an Environmental Authorisation (EA) and Water Use License Application (WULA) for this project. The proposed project requires an EA in terms of the National Environmental Management Act (Act No 107 of 1998) (NEMA) and its EIA Regulations (2014 as amended in 2017).

Zutari was also appointed to undertake a groundwater exploration program at the proposed development and to compile specialist geohydrological assessments in support of the WULA and EIA. The water is intended for the construction and operation of the God's Window Skywalk. Groundwater will be abstracted through boreholes to supply the project of water during construction and operation and as part of the EA, the water use needs to be licenced. A Water Use License Application (WULA) has been initiated and is currently in process.

The aim of the geohydrological assessment is to determine the potential impact the proposed project may have on groundwater

This report, which will be available during the Public Participation Process for review and comments, summarises the findings of the groundwater exploration program and assesses the potential impact the proposed project may have on groundwater. It was structured to adhere to the applicable "Specialist Report" requirements contained in Appendix 6 of the EIA Regulations (2014).

The most important findings of the assessment are summarised in the following table:

Geohydrological Characteristics	Skywalk
Geology:	Sedimentary rocks of the upper parts of the Wolkberg Group (Transvaal Sequence) consisting mainly of quartz and shale.
Aquifer Types:	Secondary, fractured hard rock aquifers.
Aquifer Classification:	Minor Aquifer System
Borehole Yields:	0.3 – 0.8 L/s
Depth to Water Table:	2.36 – 87.20 meters below ground level
Groundwater Quality:	Major ions and trace elements generally comply with (SANS 241-1:2015, edition 2) drinking water standards. TDS of 0 - 35 mg/l.

Geohydrological Characteristics	Skywalk
Regional Groundwater Use:	No groundwater use
Mean Annual Rainfall:	2390 mm/a
Recharge:	95-135 mm/a (6% - 9% of MAP)
Recharge to GRU:	0.107 Mm^3/a
Registered Groundwater Use within GMU:	0
Groundwater available for abstraction from GRU:	0.062 Mm3/a
Water Demand:	0.0292 Mm^3/a
Cumulative Sustainable Yield from boreholes:	0.030 Mm^3/a

Based on the field work, interpretation of available and newly acquired data, the construction and operation of the Skywalk and associated infrastructure will have an overall “negligible – negative” impact on the investigated geohydrological environment after implementation of appropriate mitigation measures. During the rating and ranking procedure of impacts, all identified impacts could be countered by appropriate mitigation.

With regards to the Water Use License Application and the water balance results, it is recommended to apply for an allocation of 0.0292 Mm^3/annum which places the application in Category A (small scale abstractions <60% recharge to the GRU). The three tested boreholes will be able to supply in 100% of the demand, as well as the applied volume.

From a water quality point of view, the majority of the parameters analysed for comply with the SANS241 drinking water limits. Low pH values in the Spring and elevated Iron and Zink concentrations in borehole SWBH2 exceed the SANS241 drinking water limits. A water treatment specialist will need to evaluate the water quality and recommend treatment options for the intended use.

It is understood that borehole SAFCOL1 are not located within the Blyderivierspoort Nature Reserve, which is managed by MTPA, but within the Blyde Nature Reserve proclaimed under the National Forest Act and manged by South African Forestry Company SOC Limited (SAFCOL). The necessary registrations of servitudes, authorisations and approvals will need to be obtained from SAFCOL to legally incorporate the water use from this borehole into the projects water demand.

It is the assessor’s professional opinion that adequate information was available to appropriately assess the impact of the proposed development on the geohydrological environment and that the activity may be authorised. It is however imperative that the proposed “Groundwater Monitoring Program and Groundwater management Framework be incorporated into the Environmental Management Program. Production boreholes should be equipped as follow:

- Installation of a 32 mm LDPE observation pipe from the pump depth to the surface, open at the bottom. This allows for a ‘window’ of access down the borehole which enables manual water level monitoring and can house an electronic water level logger if required.
- Installation of a sampling tap (to monitor water quality).
- Installation of a flow volume meter (to monitor abstraction rates and volumes).
- The appropriate borehole pump must be installed, i.e. not an over-sized pump that is choked with a gate valve. If the monitoring shows that more water can be abstracted, then duty cycles (i.e. the duration of pumping time) may be increased, and not the flow rate.

1 Introduction

Mapulana Canyon (Pty) Ltd (hereafter referred to as Mapulana Canyon), in partnership with the Mpumalanga Tourist and Parks Agency (MTPA) via a Public Private Partnership agreement proposes the development of a new tourist attraction, called the "God's Window Skywalk" at God's Window in the Blyde River Canyon Nature Reserve, Mpumalanga, hereafter also referred to as "the site". The development will include (but is not limited to) a skywalk, a sky bridge, restaurants and dining areas, an auditorium, administrative offices and the upgrading of existing walkways.

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The aim of the geohydrological assessment is to determine the potential impact the proposed project may have on groundwater

This report, which will be available during the Public Participation Process for review and comments, summarises the findings of the groundwater exploration program and assesses the potential impact the proposed project may have on groundwater. It was structured to adhere to the applicable "Specialist Report" requirements contained in Appendix 6 of the EIA Regulations (2014)[2].

2 Details of Assessor & Declaration of Independence

Refer to Appendix G of this report for the Curriculum Vitae of Louis Stroebel, which highlights his experience and expertise, as well as a signed "Declaration of Independence".

[1] The DFFE was referred to as the Department of Environmental Affairs (DEA) at that time.
[2] Environmental Impact Assessment Regulations, 2014 published under Government Notice No. 982 in Government Gazette No. 38282 of 4 December 2014

3 Geographical Setting

3.1 Site Location

The site earmarked for the proposed development is located approximately 7km northeast at God's Window in the Blyde River Canyon Nature Reserve, Mpumalanga (Map 1, Appendix A).

The site is located on state owned land:

- National Government of the Republic of South Africa (De Houtbosch 503-KT)
- Provincial Government of Mpumalanga (Lisbon 531-KT, Portion 2)

The production boreholes are not located on the same property on which the site is located:

- Boreholes SWBH1 and SWBH2 (Quartzkop No.533-KT)
- Borehole SAFCOL1 (Remainder of Lisbon 531-KT)

3.2 Topography and Drainage

The site falls within quaternary catchment B60B within the Olifants Water Management Area. The site itself is located on the edge of the Mpumalanga Drakensberg Escarpment at an elevation of ~1650mamsl and is characterised by gently sloping topography towards the south west.

The catchment area in which the production boreholes are located also falls within quaternary catchment B60B, but drainage within this local catchment differs from drainage at the site. The eastern portion slopes towards the west while the western portion slopes towards the north west. The catchment is drained by an unnamed stream flowing in northerly direction.

3.3 Climate

The project area is located in a warm and temperate region where the warmest month of the year is January, with an average temperature of 19.0 °C and July being the coldest month, with temperatures averaging 11.1 °C.

Meteorological data obtained from SamSam Water Climate Tool[3] is presented in Figure 1. The area is within the summer rainfall area and most of the rainfall occurs from November to March. Figures of 1062 mm for the mean annual precipitation (MAP) and 1499 mm for the mean annual evaporation (MAE) is reported. The MAE exceeds the MAP, resulting in a negative moisture index.

[3] https://www.worldclim.org/ & Global Aridity Index and Potential Evapotranspiration Climate Database v2

description	PET	precipitation
01 - January	148	184
02 - February	125	181
03 - March	127	125
04 - April	108	75
05 - May	105	25
06 - June	94	18
07 - July	101	17
08 - August	116	14
09 - September	138	37
10 - October	143	83
11 - November	138	133
12 - December	151	170
Total	1,499	1,062

Figure 1. Precipitation and Evaporation within the project area

Further rainfall data was acquired from the Mpumalanga Tourism & Parks Agency (MTPA). Rainfall data recorded at God's Window for the period of 1983-2002 (18 years) is presented in Figure 2. For this 18-year period the calculated average was 2390 mm/a.

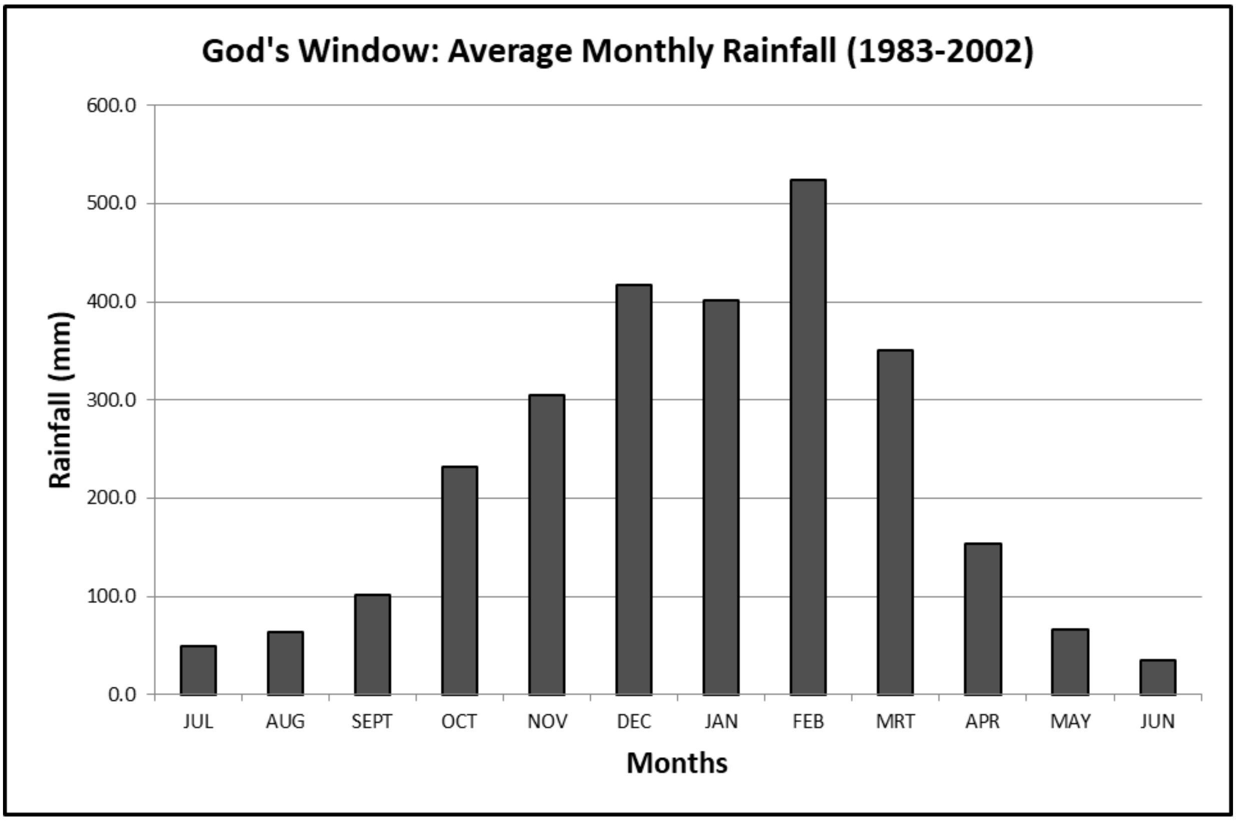

Figure 2. Rainfall data recorded at God's Window from 1983-2002

4 Scope and Objectives

The overall scope of this Geohydrological Assessment is to establish production boreholes to supply the project of construction and operational water and to ultimately produce a technical report with the main objective being:

- Determine the impact of the proposed project on the surrounding geohydrology and any geohydrological features, as well as to recommend mitigation measures to reduce the significance of potential negative impacts (required as part of the specialist studies for the EIA).

The Scope of Work consisted of:

- Desktop assessment
- Complete an assessment of the groundwater use in the area by means of a hydrocensus up to a maximum distance of a 1km radius from the site boundaries.
- Complete a geohydrological characterization of the groundwater within the project area.
- Yield and quality testing of an existing borehole located on Komatiland property ((Remainder of Lisbon 531-KT).
- Conduct a groundwater exploration program (geophysical surveys & borehole drilling).
- Evaluate newly drilled boreholes in terms of yield and quality.
- Perform a Rapid Reserve Determination in support of a Water Use License Application (WULA) in terms of Section 21 of the National Water Act (NWA), 1998 (Act 36 of 1998)[4].

[4] South African National Water Act (Act 36 of 1998)

- Evaluate predicted impacts emanating from the proposed development on the receiving geohydrological environment during construction and operation.
- Propose measures to mitigate the negative impacts.
- Develop a monitoring program as part of an environmental management plan.
- Document the above findings in a format to adhere to the applicable "Specialist Report" requirements contained in Appendix 6 of the EIA Regulations (2014).

This report is not intended to be an exhaustive description of the assessment, but rather serves as a specialist geohydrological assessment to evaluate the overall geohydrological character of the site, to inform the impact assessment, and propose mitigation measures where applicable.

5 Assumptions & Limitations

The geohydrological appraisal is based on previous studies, available literature for the study area and newly acquired data while executing the groundwater exploration program. The main assumptions are based on 1: 500 000 regional scale Geographic Information System (GIS) datasets. Available data was sourced from relevant groundwater databases and sources. The Aquifer vulnerability, yield and quality data is predominantly accurate albeit mapped at a regional scale. However, field work was carried out to assess the accuracy of the regional data sets.

The main limitation is that groundwater available for abstraction from the Groundwater Resource Unit (GRU) was based on relative short term rainfall records (18 years) and the calculated sustainable yield of the boreholes are based on data acquired during a short-term constant discharge test and does not account for the temporal variability of the water table. The sustainable yield of a borehole may change for various reasons (lower than average rainfall and declining water table, increased abstraction within the groundwater resource, unknown geological boundary conditions, etc.). Continuous groundwater monitoring is critical to provide essential data needed to evaluate changes in the resource over time; as well as the long-term sustainability and status of an aquifer. The seasonal fluctuation of water levels will only be known once the groundwater monitoring data covers both the wet and dry season and that the area do not receive either above or below expected average rainfall figures during this monitoring period.

6 Methodology

The work completed for the purposes of establishing production boreholes and compiling a geohydrological report as part of the EIA comprised the following:

6.1 Desk Study

Undertake a desk study of existing information available from relevant literature, the National Groundwater Archive (NGA)[5] and published geological and geohydrological maps and reports available in the public domain to describe the geohydrological conditions within the project area.

In addition to the above aeromagnetic data was acquired for the purpose of interpretation and selecting suitable geological structures to be explored for borehole development.

[5] http://www3.dwa.gov.za/NGANet/Security/WebLoginForm.aspx

6.2 Site Visit & Hydrocensus

A site visit was conducted to familiarise the project team with the site layout, access and plan and arrange the necessary logistics for the ground geophysical surveys. A hydrocensus was carried out within the project area as well as the adjacent area within a 1km radius from the site boundaries to identify legitimate groundwater users, the groundwater potential and quality. Where possible, groundwater levels were also measured to assist in the understanding of groundwater flow within the project area.

6.3 Ground Geophysical Survey

Selected target structures picked from the geological and airborne magnetic data was followed up on the ground by a combination of magnetic & resistivity techniques to locate and site drilling positions for the possible establishment of production boreholes.

6.4 Borehole Drilling

After interpretation of the ground geophysical data, drilling targets were selected. Drilling was done according to the Department of Water Affairs (DWA) Guidelines for Community Water Supply. Drilling of boreholes were supervised by a SACNASP registered geohydrologist, and details such as water strikes, meters of casing installed, the geological profile and blow yields were recorded.

6.5 Test Pumping

A step test followed by a forty-eight-hour constant discharge test was conducted on the newly drilled boreholes. Test pumping was conducted as per SANS 10299-4:2003 standards[6]. The data was scientifically analysed to calculate the sustainable yield of the tested boreholes. Water samples were collected during the pump test and submitted for the analysis of the major ions and trace elements.

6.6 Aquifer Vulnerability Assessment

The national scale groundwater vulnerability map, which was developed according to the DRASTIC methodology (DWAF, 2005)[7] and recompiled in 2013 was used to assess the project area in terms of "Aquifer Vulnerability". Aquifer Vulnerability can be defined as *"the likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer".*

6.7 Water Balance & Reserve Determination

The "Reserve" and groundwater available for abstraction was calculated through a "Rapid Reserve Determination" using the "Groundwater Resources Directed Measures" software[8] developed by the then Department of Water Affairs and Forestry (DWAF).

[6] South African National Standard. Development, maintenance and management of groundwater resources. Part 4: Test-pumping of water boreholes (SANS 10299-4:2003, edition 1.1). ISBN 978-0-626-32920-4.
[7] DWAF, 2005. Groundwater Resources Assessment Project, Phase II (GRAII). Department of Water Affairs and Forestry, Pretoria.
[8] "Groundwater Resources Directed Measures" Software (Version 4.0.0.0 & 2.3.2.0). Department of Water Affairs, Water Research Commission & North West University (2010 & 2013).

6.8 Aquifer Characterisation

The aquifer(s) underlying the project area was classified in accordance with “A South African Aquifer System Management Classification”[9] developed by the Water Research Commission and the former Department of Water Affairs and Forestry to provide guidance on the level of protection required.

6.9 Impact Assessment

The methodology to determine the significance of the potential impacts of groundwater abstraction was developed in 1995 and has been continually refined to date through the application of it to over four hundred Environmental Impact Assessment (EIA) processes. The methodology is broadly consistent to that described in the Environmental Impact Assessment Regulations[10] in terms of the NEMA[11].

The risk associated with the groundwater abstraction for the property pertains to the construction and operational phase. Each impact was assessed individually and graded using a numerical system on the following factors:

- Duration
- Extent
- Intensity
- Probability.

The values assigned to each factor was used to calculate the significance of each impact. Each individual impact was assessed and re-assessed after the appropriate mitigation was applied.

The “Impact Assessment Methodology” is presented in Appendix B.

6.10 Reporting

A technical report was compiled summarising the findings of the above-mentioned tasks to inform and contribute towards the EIA Report. The report was structured to adhere to the applicable “Specialist Report” requirements contained in Appendix 6 of the EIA Regulations (2014).

[9] Department of Water Affairs and Forestry & Water Research Commission (1995). A South African Aquifer System Management Classification. WRC Report No. KV77/95.
[10] Environmental Impact Assessment Regulations, 2014 published under Government Notice No. 982 in Government Gazette No. 38282 of 4 December 2014
[11] National Environmental Management Act, 1998 (Act No. 107 of 1998) (“NEMA”)

7 Regional & Local Geology

Based on the 1:250 000 geological map[12], the study area is underlain by sedimentary rocks of the upper parts of the Wolkberg Group (Transvaal Sequence) (Map 2 in Appendix A). The rocks outcrop in a thin band along the escarpment as a prominent part of the Drakensberg, where they dip regionally inwards towards the base of the Transvaal basin. These rocks have been extensively folded and are responsible for the magnificent scenery observed in the area.

The upper part of the Wolkberg Group consists of the following formations:

- Sadowa Formation consisting of dark-grey to brown, well-bedded, micaceous shale with lenticular quartzite layers.
- Mabin Formation consisting of white, grey to reddish brown, medium- to fine-grained quartzite with pebble fans and interlayered shale layers.
- Selati Formation consisting of laminated micaceous and graphitic shale, locally interlayered with sandy shale, flagstone and quartzite.

On a local scale, no linear structure or fault lines are shown on the geological map. A potential NE-SW striking fault line, occurring to the north of the site opposite the R534 road, was inferred from aerial imaginary and magnetic data. The areas along the fault lines were the main targets during groundwater exploration.

8 Regional Geohydrology

Both the lithology and structural geology have a major bearing on the groundwater potential of the area. In their pristine state, the consolidated geological units have negligible groundwater potential. It is the secondary structural features that give the units groundwater potential. These secondary structures are usually associated with faults, fractures and weathering which gives rise to discrete zones of secondary permeability.

Unless otherwise stated, the published 1:500 000 General Hydrogeological Map[13] and associated explanatory booklet[14] was used as basis to describe the regional geohydrological conditions.

8.1 Aquifer Types & Borehole Yields

The majority of the aquifers within the Wolkberg Group, which rests unconformably on the basement rocks, can be described as secondary, fractured hard rock aquifers. Surficial soils in the area are very thinly developed and are not considered to have any significant groundwater potential.

Groundwater is often found in fractures related to various stresses, such as tension, compression, or off-loading. It occurs mostly in mountainous areas which is usually inaccessible to drilling rigs. Owing to its inaccessibility and limited and restricted occurrence, the groundwater resources of the Wolkberg Group are often regarded as insignificant with the groundwater potential not well known. It is expected to be low with the hydrogeological map indicating that a successful borehole in the area typically yield between 0.1 to 0.5 ℓ/s. These statistics is believed to be optimistic and that the groundwater potential could be lower as low yielding and dry boreholes are poorly recorded.

[12] Geological Map (2430 Pelgrim's Rest), 1:250 000 scale. Council for Geoscience, 1986.
[13] 1:500 000 Hydrogeological Map (Phalaborwa 2330). Department of Water Affairs & Forestry (1998).
[14] An Explanation of the 1:500 000 General Hydrogeological Map – Phalaborwa 2330. WH du Toit & M van Lelyveld, October 2014.

8.2 Depth to Water Table

Being close to the escarpment, deep water levels (> 50mbgl) can be expected, becoming shallower as one moves in a westerly direction and away from the escarpment.

8.3 Groundwater Use

Groundwater is mainly used for domestic purposes in rural areas where no other reliable source of water is available.

8.4 Groundwater Flow Direction

Generally, groundwater elevations mimic surface topography, and groundwater flows from higher lying ground towards lower lying springs or valleys (drainage lines). It can therefore be safely assumed that the regional groundwater flow direction will be in a westerly direction towards lower lying drainage lines. Locally speaking, groundwater flow in the local catchment in which the production boreholes are located will be towards the west and north west towards an unnamed stream flowing in northerly direction (Map 5, Appendix A).

8.5 Groundwater Quality

Based on water quality data acquired for six boreholes drilled within the Wolkberg Group, groundwater generally exhibits a slightly alkaline nature and displays a magnesium–sodium–calcium–bicarbonate–chloride character. Electrical Conductivity (EC) values are variable, and the sample size is too small to draw conclusions on the expected water quality.

8.6 Groundwater Recharge & Baseflow

Groundwater recharge is dependent firstly on rainfall. A measure of the rainfall that is available for recharge is provided by mean annual effective rainfall. Effective rainfall is that part of the daily rainfall that seeps into the ground after allowing for losses through interception by vegetation and by storm runoff. Of the effective rainfall, only a small fraction infiltrates down to the saturated zone. The major part is lost through evaporation from the soil and transpiration by the vegetation.

The mean annual precipitation and annual recharge figures for the study area is presented in Table 1. Vegter's (1995)[15] recharge and baseflow maps were used to obtain a first estimate of regional recharge and groundwater contribution to rivers and streams (baseflow). The recharge and baseflow figures were then verified and refined using the RECHARGE[16] spreadsheet and baseflow ultimately verified with dry season flow measurements.

The abundance of springs along the escarpment proves that groundwater is being recharged and that it produces base flow.

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[15] Vegter, J.R. (1995). An explanation of a set of national groundwater maps; WRC Report No. TT 74/95. Water Research Commission, Pretoria.

[16] Van Tonder, G. J. & Xu, Y. (2000). RECHARGE - Excel based software to quantify recharge. Department of Water Affairs and Forestry, Pretoria, South Africa. Unpublished.

Table 1. Regional Rainfall, Recharge & Baseflow

Precipitation, Recharge & Baseflow	
Mean Annual Precipitation (mm):	1500
Annual Recharge (mm):	95-135
Percentage Recharge of MAP:	6 - 9%
Annual Baseflow (mm):	25 53
Percentage Baseflow of MAP:	2% -3.5%

The flow in the unnamed stream, was measured on the 15th of July 2022 at a weir directly downstream of the local catchment (S 24.86829, E 30.885367), which will be representative of the dry season flow, and also baseflow (location presented in Map 5, Appendix A). The flow was measured to be 5140 L/h (45 026 m^3/a). If the area (107 ha) of the local catchment is brought into consideration, the measured flow relates to 42mm/a, which corresponds with Vegter's (1995) range of baseflow figure of 25-53mm/a.

Figure 3. Measured flow (15 July 2022) at the weir in the unnamed stream directly downstream of the local catchment.

8.7 Aquifer Vulnerability

The national scale Groundwater Vulnerability Map, which was developed according to the DRASTIC methodology (DWAF, 2005) and recompiled in 2013 was used to assess the aquifers underlying the site in terms of "Aquifer Vulnerability". Aquifer Vulnerability can be defined as *"the likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer"*.

The DRASTIC method takes into account the following factors:

- D = depth to groundwater (5)
- R = recharge (4)
- A = aquifer media (3)
- S = soil type (2)
- T = topography (1)
- I = impact of the vadose zone (5)
- C = conductivity (hydraulic) (3)

The number indicated in parenthesis at the end of each factor description is the weighting or relative importance of that factor.

Aquifer Vulnerability is rated as follows:

Green represents the least vulnerable region that is only vulnerable to conservative pollutants in the long term when continuously discharged or leached
Yellow represents the moderately vulnerable region, which is vulnerable to some pollutants, but only when continuously discharged or leached.
Red represents the most vulnerable aquifer region, which is vulnerable to many pollutants except those strongly absorbed or readily transformed in many pollution scenarios.

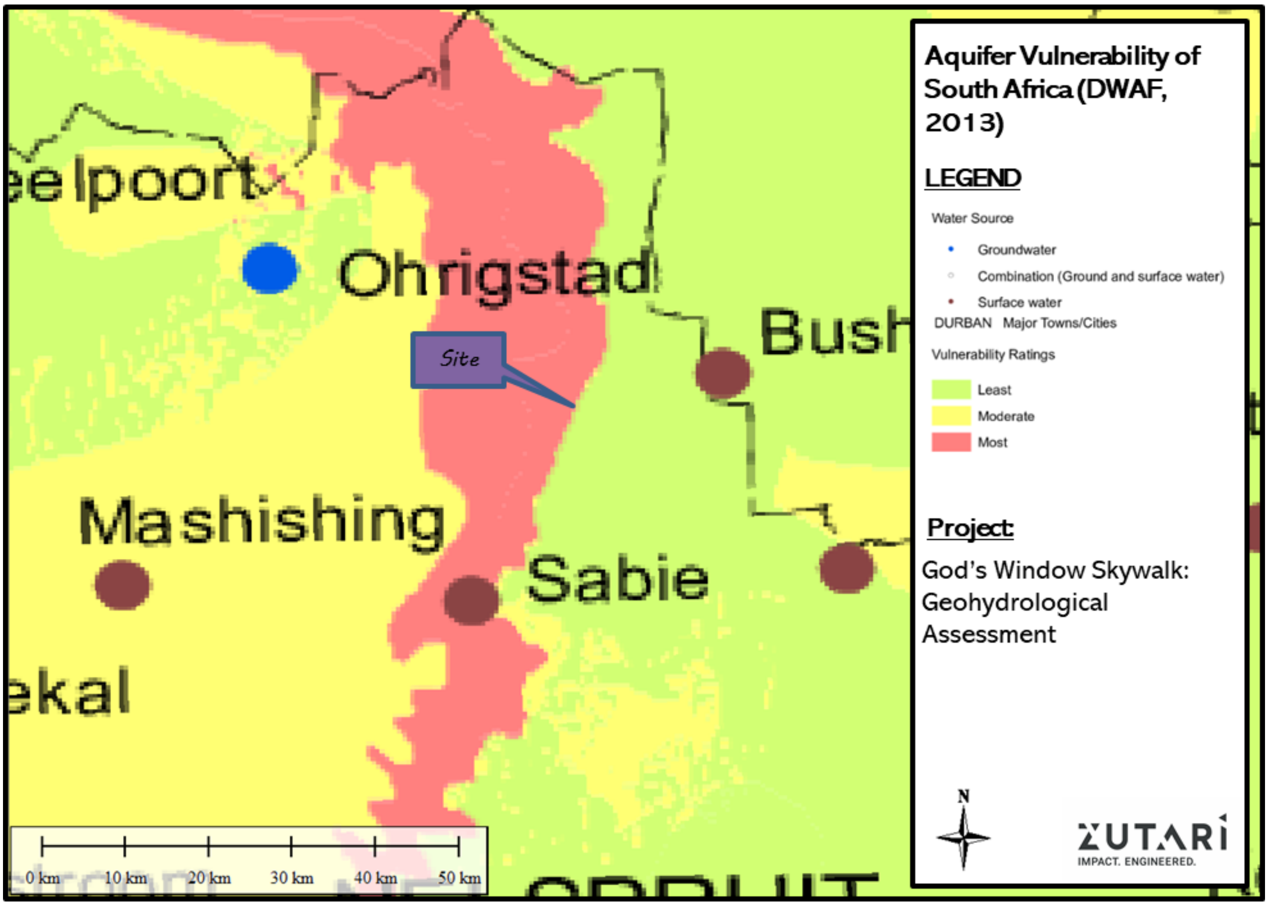


Figure 4. Regional groundwater vulnerability for the study area (DWAF, 2013).

The vulnerability of the aquifers within the project area is rated as “most vulnerable to pollutants”.

8.7.1 Sensitivity Maps & Buffer Zones

Due to the absence of sensitive geohydrological features (preferential flow lines along dykes/faults) within the site boundaries and a deep water table (>80mbgl), there is no need to delineate sensitivity maps or buffer zones from a geohydrological point of view.

Wetlands occur within the grassland area located opposite the R534 in which the production boreholes are located. These wetlands will be delineated as part of the specialist Ecological/Wetland studies and sensitivity maps and buffer zones defined. The “pre-development/baseline” water levels in the production boreholes needs to be maintained to ensure that the aquifer sustains baseflow to rivers/streams draining the area, as well as the sensitive grassland and delineated wetlands in which the boreholes are located.

Alternative drilling positions to establish production boreholes were considered, but drilling targets were restricted to positions inferred from the geophysical surveys and selected based on the potential to yield adequate water. Other determining factors were farms and their jurisdictions and terrain accessibility with regard to a drilling rig.

Groundwater contamination can potentially emanate from activities associated with the Site Offices and Construction Camp during construction and should not be constructed within the delineated wetlands or associated buffer zones.

8.8 Delineation of the Geohydrological Response Unit

A “Geohydrological Response Unit” (GRU), also referred to as a “Groundwater Resource Unit”, is defined as a groundwater system that has been delineated or grouped into a single significant water resource based on one or more characteristics that are similar across that unit. Criteria to map a GRU would include:

1. Areas of similar geology;
2. Groundwater elevations generally mimic surface topography, and groundwater flows from higher lying ground towards lower lying springs or valleys (drainage lines), therefore surface water catchment boundaries may be used as surrogate for groundwater divides;
3. Rivers/Streams acting as a constant head boundary;
4. Impermeable dykes/lineaments acting as no-flow boundaries; and lastly
5. Expert judgement and interpretation.

For this study area there are clear drainage features that enable the definition of a more localised aquifer (i.e. a GRU) which was delineated using the following features:

- Quaternary catchment boundary to the east;
- Drainage line to the west; and
- Drainage line and topographical high to the north.

The extent of the GRU is shown in Map 3 in Appendix A. The mapped GRU covers a total area of 107 ha.

9 Site Specific Assessment

9.1 Existing Groundwater Information

9.1.1 National Groundwater Archive

A search of the National Groundwater Archive (NGA), which provides data on borehole positions, groundwater chemistry and yield, when available, was carried out to identify proximal boreholes. These sites are then typically verified in the field and provide background information on the area, should they exist. A desktop hydrocensus was carried out up to a 1km radius from the site. No boreholes were listed within a 1km radius and the radius was increased to 5km with still no boreholes listed. This database was thus not used during this assessment.

9.1.2 Water Use Authorization & Registration Management System (WARMS)

WARMS data (updated 26 April 2022) was acquired for the study area to establish the volume of lawful groundwater use within the GRU. No registered groundwater users were listed within the delineated GRU.

9.2 Hydrocensus

A hydrocensus was conducted on 2 February 2022 to establish groundwater use within the larger project area. The hydrocensus extended to a maximum distance of ~1km from the site boundaries. Any information pertaining to the abstraction, yield and water levels were sought.

A total of three boreholes and one spring, which currently supplies God's Window of potable water were identified. A summary of the most important data pertaining to the identified boreholes are summarised in Table 2. The borehole locations are presented in Map 5 in Appendix A.

From the hydrocensus data, it can be concluded that that there is minimal groundwater use in the area. It is understood that the "SAFCOL" boreholes supplied water to "Gods Window" in the past.

Table 2. Details of boreholes identified during the hydrocensus

BH nr	Coordinates Decimal Degrees (WGS84)	Depth (m)	Estimated Yield (l/s)	SWL (mbgl)	Equipment (Water Use)	Owner
HCBH1	S 24.87697 E 30.88753	120	Seepage	87.24	Submersible installed at 64m (not in use)	MTPA
SAFCOLa	S 24.86898 E 30.88582	27	Unknown	4.90	None	SAFCOL
SAFCOLb	S 24.86903 E 30.88575	65	Unknown	5.91	None	SAFCOL
SPRING	S 24.87123 E 30.89193	nm	1	nm	Pump (Domestic)	MTPA

HCBH1

SPRING

SAFCOLb

SAFCOLa

Figure 5. Photos of Boreholes visited during hydrocensus

9.3 Geophysical Survey

Borehole siting is primarily concerned with the location of geological discontinuities, as higher borehole yields are generally associated with such features. Apart from direct geological observation, which is the most satisfactory method of borehole location where it can be practised, potential groundwater bearing discontinuities can be located either by remote sensing methods or surface geophysical methods.

Existing aeromagnetic data was acquired for the area and interpreted for the purpose of delineating suitable geological structures which was evaluated and verified with ground geophysical surveys.

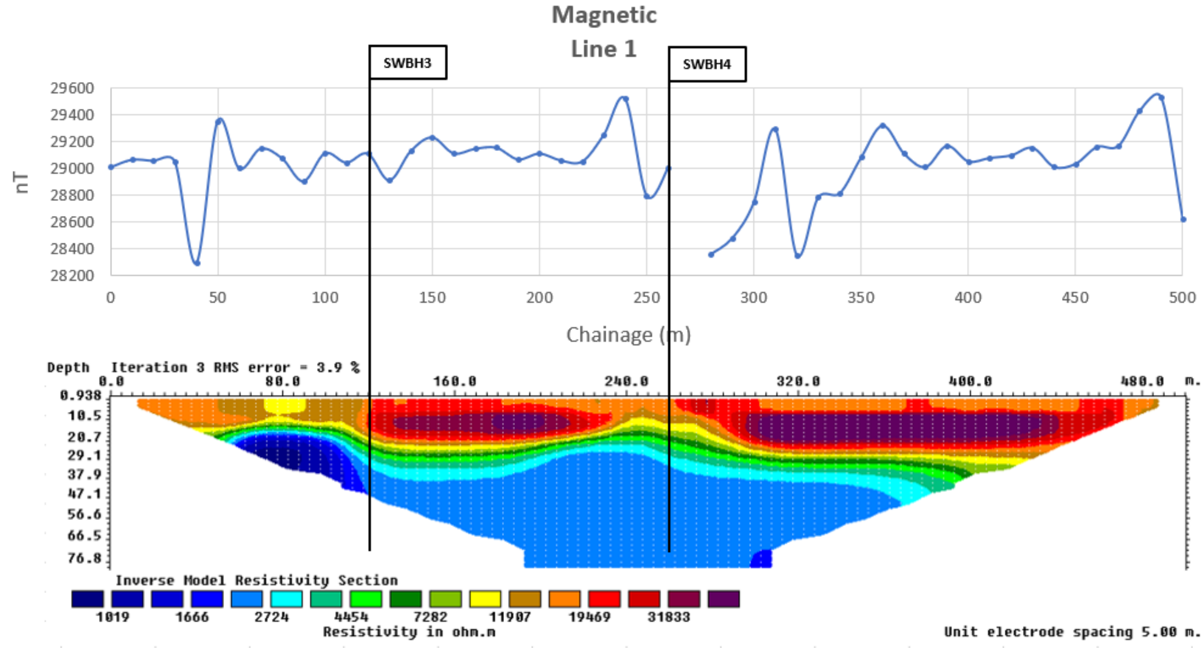
A combination of the magnetic (G5 Proton Magnetometer) and two-dimensional electrical resistivity tomography (ABEM Lund 2000) were conducted on pre-identified traverses perpendicular to interpreted fault lines. Faults as inferred from the magnetic data, ground geophysical traverses and drilling targets are presented in Map 4 in Appendix A.

Four drilling targets were identified. A land surveyor was appointed to confirm the farms on which the targets are located as drilling was only permitted within the boundaries of the Blyderivierspoort Nature Reserve and in which the Skywalk Project will be developed. The land surveyor also marked and staked the drilling positions in the field. A description of the farms and sketch plan is presented in Appendix F.

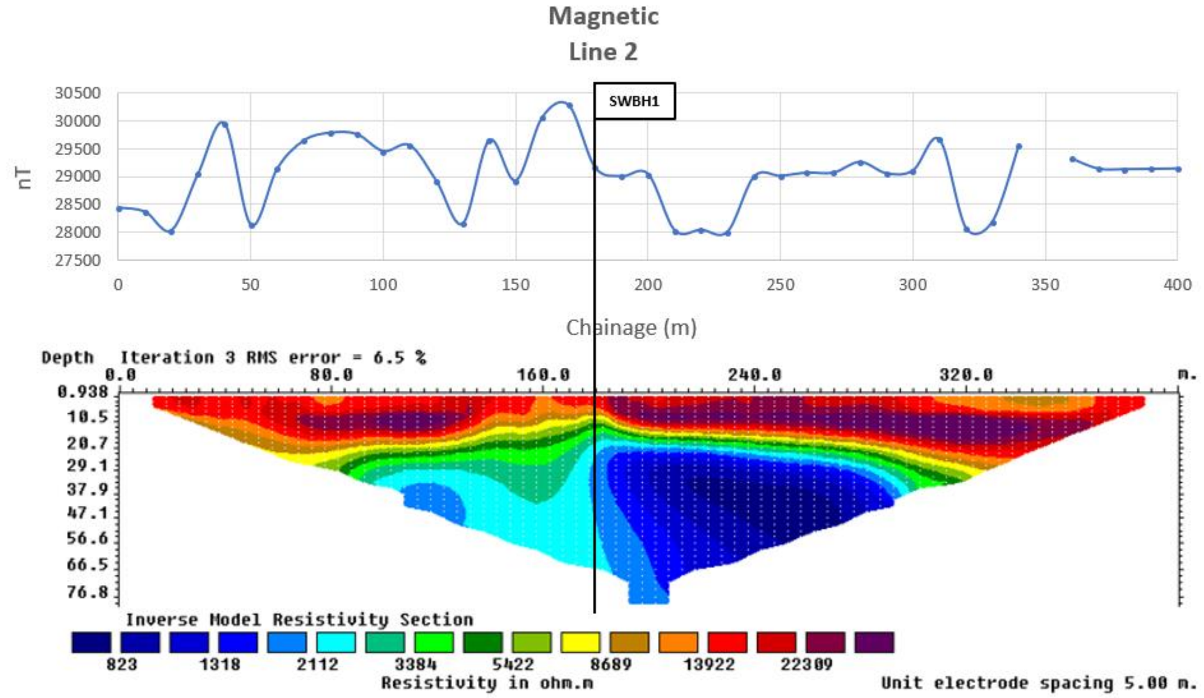
A summary of the results and the geophysical profiles are presented in Table 3 and Figure 6 respectively.

Table 3. Results of the ground geophysical survey

Traverse	Line chainage (m)	Target nr. (numerically prioritised)	Coordinates Decimal Degrees (WGS84)		Proposed Drilling Depth (m)
			S	E	
Line 1	120	SWBH3	24.86856	30.88908	80
	260	SWBH4	24.86865	30.89048	80
Line 2	180	SWBH1	24.86821	30.89083	80
Line 3	90	SWBH2	24.86657	30.89134	80
Line 4	No drilling target.				



Magnetic
Line 1
SWBH3
SWBH4
nT
Chainage (m)
Depth Iteration 3 RMS error = 3.9 %
Inverse Model Resistivity Section
1019 1666 2724 4454 7282 11907 19469 31833
Resistivity in ohm.m
Unit electrode spacing 5.00 m.



Magnetic
Line 2
SWBH1
nT
Chainage (m)
Depth Iteration 3 RMS error = 6.5 %
Inverse Model Resistivity Section
823 1318 2112 3384 5422 8689 13922 22309
Resistivity in ohm.m
Unit electrode spacing 5.00 m.

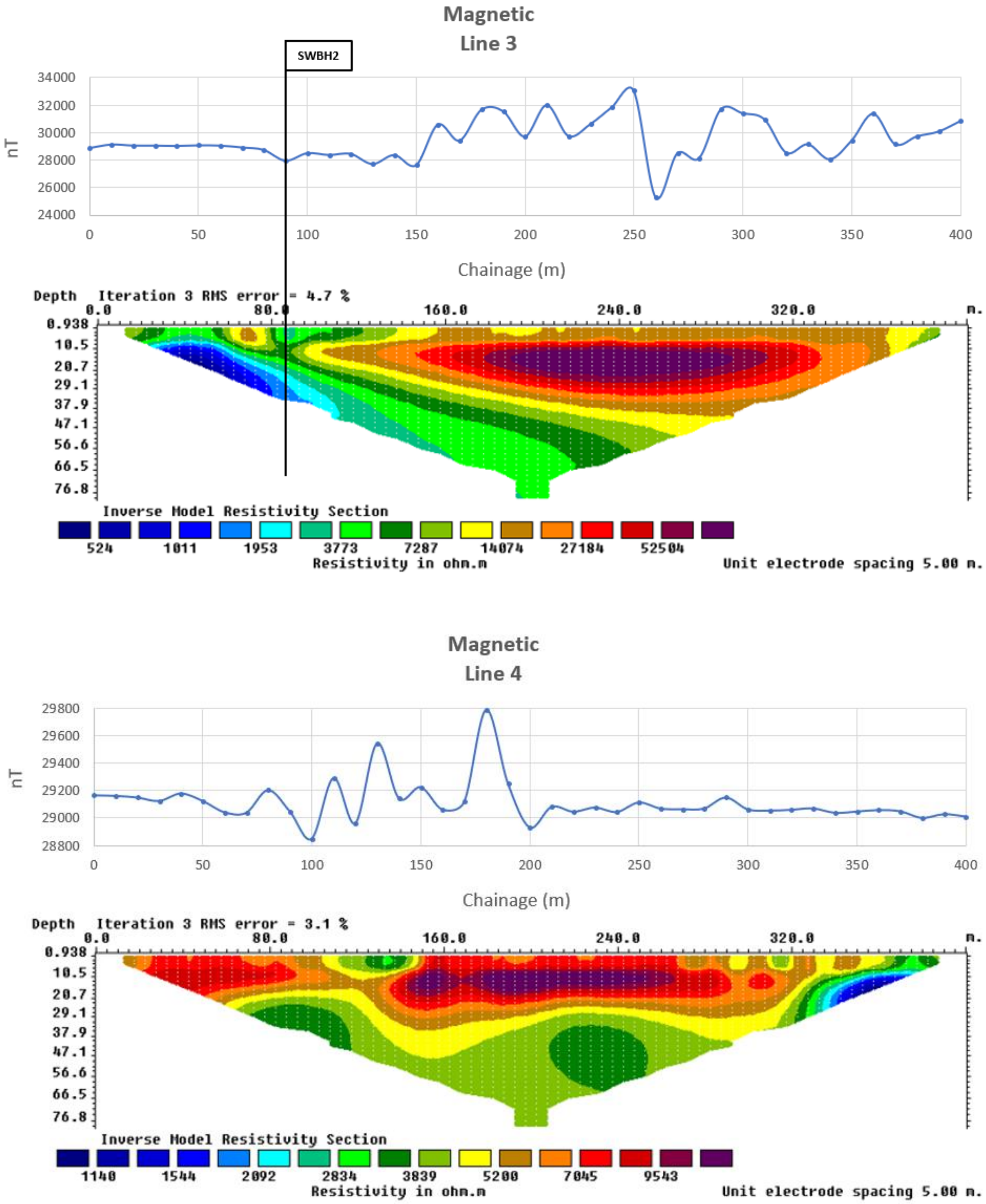


Figure 6. Ground geophysical profiles

9.4 Borehole Drilling

A total of four boreholes were drilled between 24 May and 16 July 2022. The drilling order followed the prioritised targets, except for target SWBH3 which was not drilled as it falls outside of the project boundaries. A new borehole (SAFCOL1) was drilled within 5m of the existing SAFCOLb borehole after a “orange brown sludge” was pumped from this borehole during yield testing and the borehole possibly collapsed.

Drilling of the boreholes was supervised by a SACNASP registered geohydrologist. No casing was installed in dry/low yielding boreholes and boreholes terminated when unfavourable formations for yielding groundwater were encountered. Borehole numbers correspond with proposed drilling targets presented in Table 3. The location of the boreholes are presented in Map 4 in Appendix A. Details of the boreholes are presented in Table 4 and geological and construction logs in Appendix C.

Table 4. Details of newly drilled boreholes

BH nr.	Coordinates Decimal Degrees (WGS84)		Final Depth (m)	Casing installed (Screens)	Water strike(s) (mbgl)	Blow Yield (l/h)
	S	E				
SWBH1	24.86821	30.89083	90	0-18m (3-18m)	6-14	18 000
SWBH2	24.86657	30.89134	100	0-84m (9-84m)	10-13	1800
SWBH4	24.86865	30.89048	42	0m	9-13	1 800
SAFCOL1	24.86906	30.885795	47	0-47 (24-47)	26, 41	3600

Figure 7. Photos taken during drilling of borehole SWBH1 (left) and borehole VSP-BH4 (right).

9.5 Test Pumping

9.5.1 Description of a Pump Test

The efficient operation and utilisation of a borehole requires insight into and an awareness of its productivity and that of the groundwater resource from which it draws water. This activity, which is also known as test pumping, provides a means of identifying potential constraints on the performance of a borehole and on the exploitation of the groundwater resource. It also provides data to calculate aquifer parameters such as Transmissivity (T) values.

An attempt to test the existing borehole (SAFCOLb) was unsuccessful as the borehole produced an “orange brown sludge” during testing and the test had to be terminated. As previously mentioned, a new borehole (SAFCOL1) was drilled adjacent (within 5m) to this borehole.

Boreholes SWBH1, SWBH2 and SFACOL1 were pump tested.

The following tests were performed on the three boreholes: (1) stepped discharge test followed by a (2) constant discharge test (CDT) and (3) recovery monitoring.

9.5.1.1 Stepped Discharge Test

Also known as a step drawdown test, is performed to assess the productivity of a borehole. It also serves to more clearly define the optimum yield at which the borehole can be subjected to constant discharge testing. The test involves pumping the borehole at three or more sequentially higher pumping rates each maintained for an equal length of time, generally not less than 60 minutes. The magnitude of the water level drawdown in the borehole in response to each of these pumping rates is measured and recorded in accordance with a prescribed time schedule.

9.5.1.2 Constant Discharge Test

A constant discharge test is performed to assess the productivity of the aquifer according to its response to the abstraction of water. This test entails pumping the borehole at a single pumping rate which is kept constant for an extended period. In this instance the boreholes were pumped for a minimum of 24 hours, up to a maximum of 48 hours.

9.5.1.3 Recovery Monitoring

This test provides an indication of the ability of a borehole and groundwater system to recover from the stress of abstraction. This ability can again be analysed to provide information with regards to the hydraulic properties of the groundwater system and arrive at an optimum yield for the medium to long term utilisation of the borehole.

9.6 Results and Data Interpretation

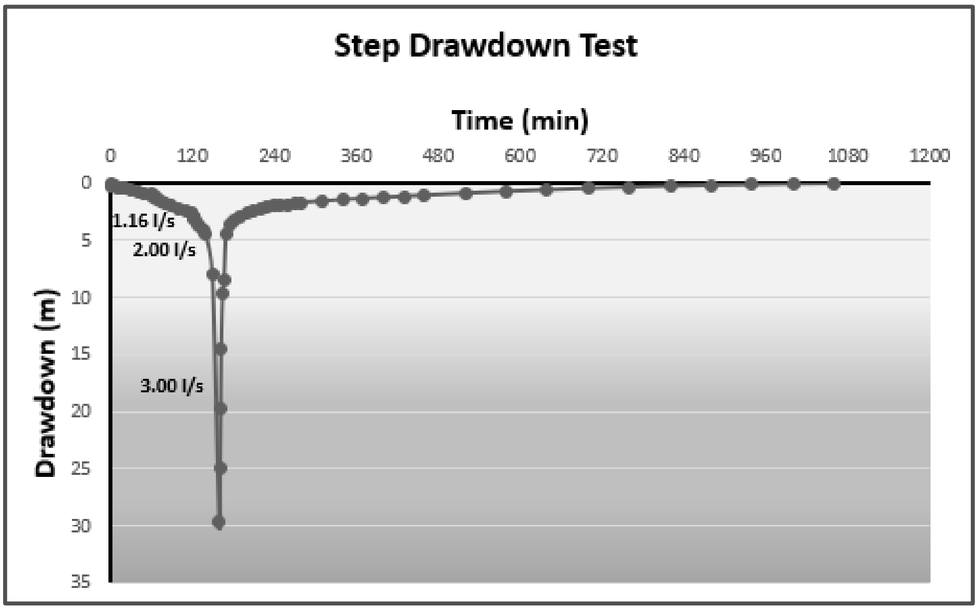
The data acquired during the pump tests were analysed and the sustainable yield of the tested boreholes calculated using a combination of the Flow Characterization Method (FC-Method)[17] developed by the Institute for Groundwater Studies from the University of the Free State, recovery data and expert judgement. The FC-Method calculates the sustainable yield of a borehole by using derivatives, boundary information and error propagation.

The pumptesting data for the tested boreholes are presented in Appendix D.

[17] FC program for Aquifer Test Analysis (2013 version). Prof. Gerrit van Tonder, Fanie de Lange and Modreck Gomo. Institute for Groundwater Studies, University of the Free State.

Table 5. Summary of the pump testing results for borehole SWBH1

Pumptesting Results: SWBH1							
Step Drawdown Test							
SWL (mbgl)	**Borehole Depth (m)**	**Pump Depth (mbgl)**	**Available Drawdown (m)**	**Step**	**Duration (min)**	**Pumping Rate (l/s)**	**Drawdown (m)**
2.05	89.6	35.00	32.95	**Step 1**	60	1.00	0.93
				Step 2	60	2.00	2.61
				Step 3	40	3.00	29.72
				Step 4	0	0.00	0.00
				Recovery	900	0	0 (0%)
Constant Discharge Test							
SWL (mbgl)	**Pump Depth (mbgl)**	**Available Drawdown (m)**	**Pumping Rate (l/s)**	**Duration (min)**	**Drawdown (m)**	**Recovery time (min)**	**Recovery (m)**
3.58	34.44	30.86	0.38	1783	30.86	840	0 (100%)



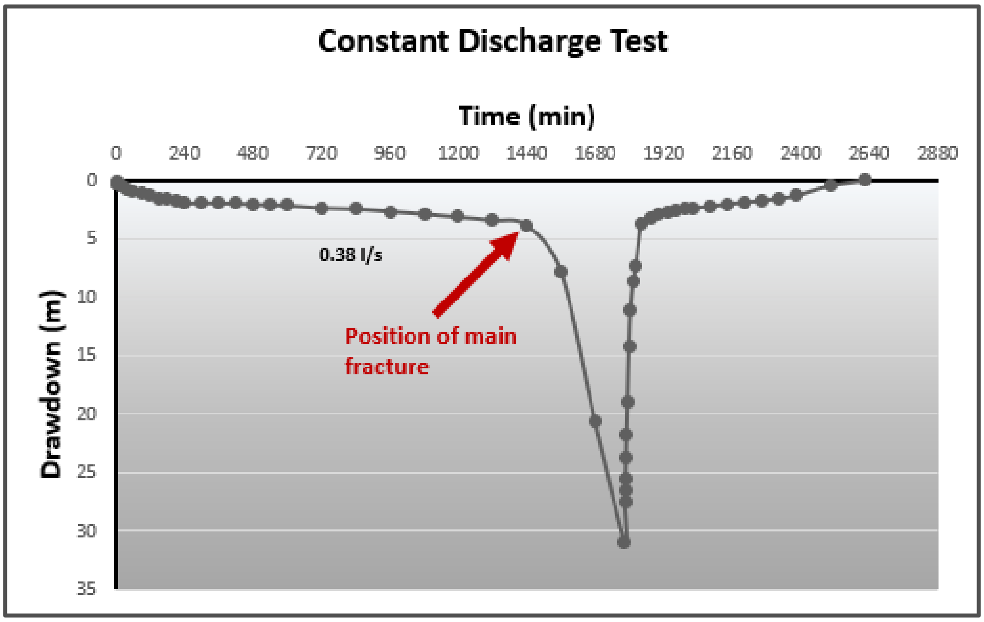
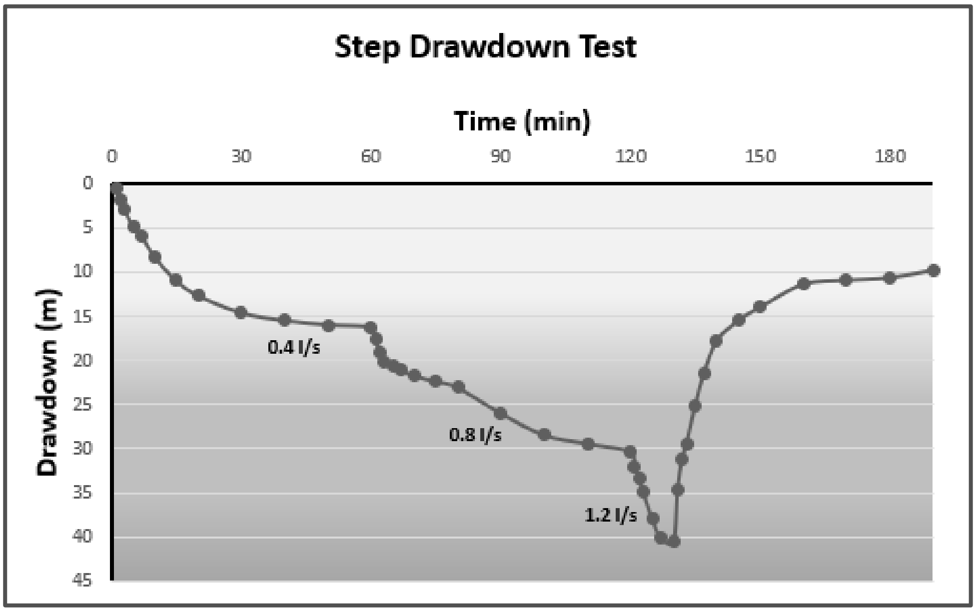


Figure 8. Drawdown plots for the Step and Constant Discharge Test for borehole SWBH1

Table 6. Summary of the pump testing results for borehole SWBH2

Pumptesting Results: SWBH2							
Step Drawdown Test							
SWL (mbgl)	**Borehole Depth (m)**	**Pump Depth (mbgl)**	**Available Drawdown (m)**	**Step**	**Duration (min)**	**Pumping Rate (l/s)**	**Drawdown (m)**
39.56	84.15	80.15	40.59	**Step 1**	60	0.40	16.25
				Step 2	60	0.80	30.38
				Step 3	60	1.20	40.59
				Step 4	60	0.00	0.00
				Recovery	60	0	9.75 (76%)
Constant Discharge Test							
SWL (mbgl)	**Pump Depth (mbgl)**	**Available Drawdown (m)**	**Pumping Rate (l/s)**	**Duration (min)**	**Drawdown (m)**	**Recovery time (min)**	**Recovery (m)**
49.31	80.15	30.84	0.50	2880	10.5	300	0 (100%)



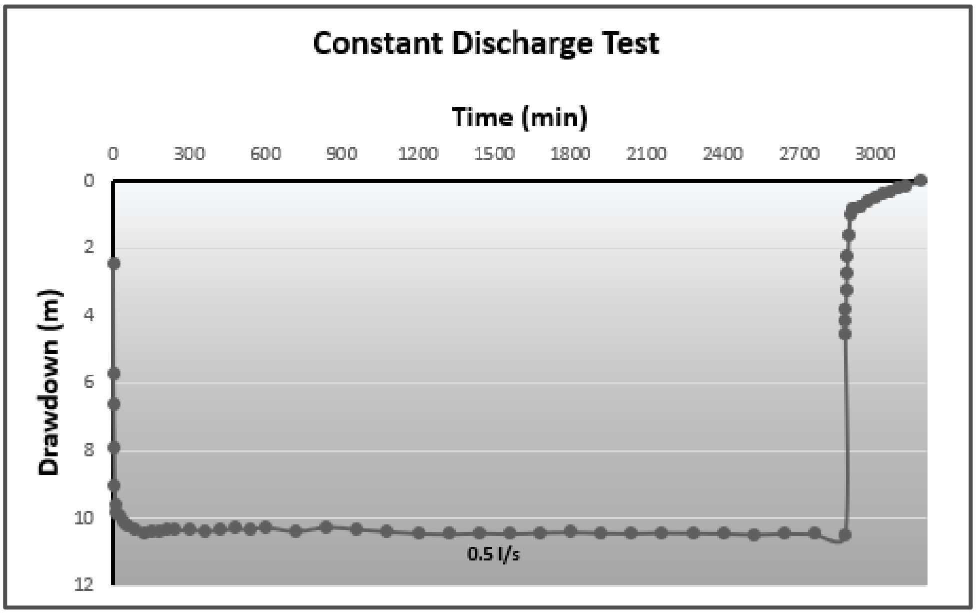


Figure 9. Drawdown plots for the Step and Constant Discharge Test for borehole SWBH2

Table 7. Summary of the pump testing results for borehole SAFCOL1

Pumptesting Results: SAFCOL1							
Step Drawdown Test							
SWL (mbgl)	**Borehole Depth (m)**	**Pump Depth (mbgl)**	**Available Drawdown (m)**	**Step**	**Duration (min)**	**Pumping Rate (l/s)**	**Drawdown (m)**
9.40	44.22	43.00	33.60	**Step 1**	60	0.25	1.33
				Step 2	60	0.50	2.91
				Step 3	60	0.75	5.89
				Step 4	60	1.00	9.40
				Step 5	60	1.25	12.73
				Step 6	60	1.53	16.65
				Recovery	180	0	1.04 (94%)
Constant Discharge Test							
SWL (mbgl)	**Pump Depth (mbgl)**	**Available Drawdown (m)**	**Pumping Rate (l/s)**	**Duration (min)**	**Drawdown (m)**	**Recovery time (min)**	**Recovery (m)**
10.95	43.00	32.05	1.11	2880	25.32	1440	1.08 (96%)

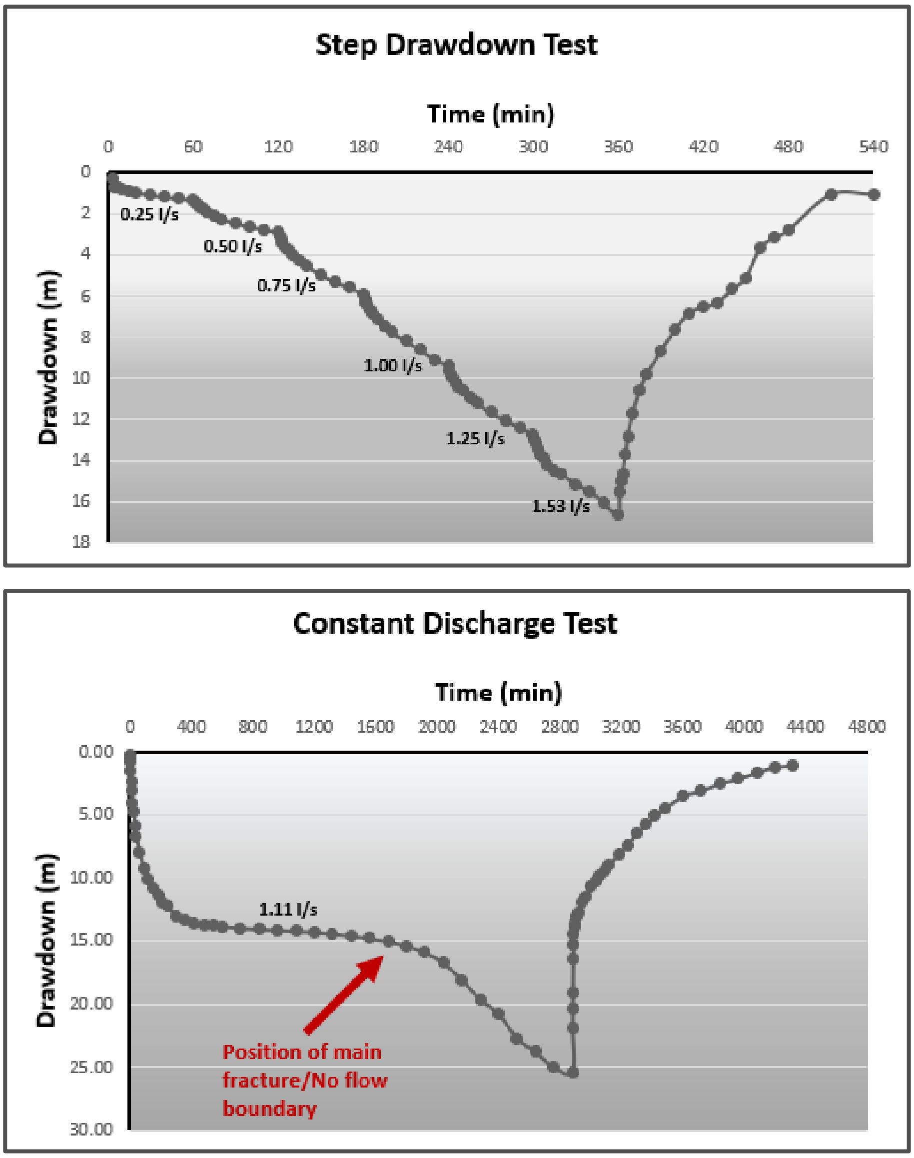


Figure 10. Drawdown plots for the Step and Constant Discharge Test for borehole SAFCOL1

The calculated sustainable yields for the tested boreholes together with the necessary information to equip the boreholes are presented in Table 8.

Table 8. Management Recommendations for the tested boreholes

Borehole nr.	Coordinates (WGS84)		Depth (m)	Inside Dia. (mm)	Static Water Level (mbgl)	#Dynamic WL (mbgl)	Sustainable Yield (l/h) Pumping 14 hours/day	Proposed depth of pump installation (mbgl)	Volume/day (m^3)
	S	E							
SWBH1	24.86821	30.89083	89	171	2.36	6	1000	10	14.00
SWBH2	24.86657	30.89134	84	121	39.56	60	1800	75	25.20
SAFCOL1	24.86907	30.88580	44	171	9.40	23	3000	35	42.00
								Total Volume (m^3/day)	**81.20**
								Total Volume (Mm^3/annum)	**0.030**

 # Dynamic water level - Level at which the water level in the borehole stabilises after continuous pumping. To be used to calculate hydraulic heads when sizing submersible pumps.

Based on the above sustainable yield calculations, it is suggested that a cumulative maximum volume of 81.20 m^3/day (0.030 Mm^3/annum) can be abstracted from the three tested boreholes.

Pumptests were conducted during the dry season (April – September) when the static water level is expected to be lower than during the wet season (October – March). The yield of a borehole is mainly dependant on the aquifer transmissivity. This is a function of the aquifer permeability multiplied with the saturated thickness. Permeability is an intrinsic property of the aquifer and will not change. However, the static water level and consequently the saturated thickness may change. One can thus safely assumed that the pumptesting results will represent the “worst case scenario” and that yields may increase during the wet season.

In order to understand seasonal water table fluctuations, waterlevel loggers were installed in boreholes SWBH1 and SWBH2 and pre-programmed to record daily water levels which will give a better understanding of seasonal fluctuations as more data becomes available.

Figure 11. Water level loggers installed in boreholes to measure long term seasonal fluctuations.

9.7 Groundwater Quality

Water samples were collected from the spring which currently supplies God's Window with water, the borehole located at God's Window (HCBH1) as well as the three tested boreholes. Samples were collected towards the end of the constant discharge tests and submitted for the analysis of the major ions and trace elements. The water quality results were compared with the SABS drinking water standards (SANS 241-1:2015, edition 2) (Table 9). Water is classified unfit for human consumption if the Standard Limits are exceeded.

Except for a low pH value in the Spring and elevated Iron and Zink in SWBH2, all the parameters that were analysed, do comply with SANS 241 drinking water standards. A water treatment specialist will need to evaluate the water quality and recommend treatment options for the intended use.

The laboratory reports are presented in Appendix E.

Table 9. Water quality results compared to SANS 241-1:2015 (edition 2) drinking water standards

Sample Nr.	SWBH1	SWBH2	SAFCOL1	HCBH1	SPRING	Standard Limits
pH	6.19	6.45	6.06	8.29	4.73	5.0 - 9.7
EC	2	4	2	6	2	170
TDS	10	23	16	35	0	1200
T-Alk	5	13	14	27	4	~
Cl	1.9	2.1	0.0	3.1	1.8	300
SO_4	0.0	4.7	0.7	0.0	0.0	250
NO_3-N	0.32	0.32	0.25	0.41	0.00	11
NH_4-N	0.14	0.20	0.00	0.21	0.25	1.5
F	0.00	0.35	0.00	0.00	0.00	1.5
Ca	1.02	2.39	1.81	6.76	0.84	~
Mg	0.75	2.10	1.43	3.47	0.67	~
Na	1.04	1.24	1.13	1.27	0.96	200
K	0.44	0.56	0.91	1.69	0.00	~
Al	0.00	0.00	0.00	0.00	0.02	0.3
Fe	0.00	0.80	0.10	0.00	0.00	0.3
Mn	0.00	0.00	0.03	0.00	0.00	0.1
Cr	0.00	0.00	0.00	0.00	0.00	0.05
Cu	0.00	0.00	0.00	0.00	0.00	2
Ni	0.00	0.00	0.00	0.00	0.00	0.07
Zn	0.00	0.56	0.04	0.00	0.00	0.05
Cd	0.00	0.00	0.00	0.00	0.00	0.003
Pb	0.00	0.00	0.00	0.00	0.00	0.01
Turbidity	1.14	0.42	1.78	1.16	0.50	5
TOC	2.8	2.5	2.5	1.4	4.5	10

Notes
Yellow = Acceptable
Exceeds standard limits
Blank = Not Analysed
0 = below detection limit of analytical technique

10 Reserve Determination & Water Balance

The sustainable volume of groundwater that can be abstracted from the aquifer(s) were determined using the GRDM software (version 4.0.0.0 (2010) and 2.3.2.0 (2013)) as basis. It takes the reserve into account when calculating the volume of water available for abstraction.

The assessment was done on a "rapid" level. The data used for the calculation was derived from the WRC90 dataset contained in the "GRDM" software driven by the Resource Directed Measures from the Department of Water and Sanitation. The site falls within quaternary catchment B60B and the default values, except where updated information was available, were used in the assessment in order to develop some guidance on the potential impact of the abstraction on the overall groundwater use in the catchment. It must be stated that the results achieved for the quaternary catchment is not necessarily applicable on the delineated Groundwater Resource Unit (GRU) due to compartmentalisation. Geological lineaments may act as no-flow boundaries while rivers/streams may act as constant head boundaries subdividing the quaternary catchments in smaller GRU's with different exploitation potentials. The results of the GRU should rather be considered when allocating a volume of groundwater for abstraction for this specific project.

10.1 Introduction

Definition of Reserve*: "The quantity and quality of water required to supply basic needs of people to be supplied with water from that resource and to protect aquatic ecosystems in order to secure ecologically sustainable development and use of water resources"*.

To be able to quantify the groundwater component of the Reserve, the following relationship must be solved:

$$GW_{allocate} = (Re + GW_{in} - GW_{out}) - BHN - GW_{Bf}$$

where:	$GW_{allocate}$	=	groundwater allocation
	Re	=	recharge
	GW_{in}	=	groundwater inflow
	GW_{out}	=	groundwater outflow
	BHN	=	basic human needs
	GW_{Bf}	=	groundwater contribution to baseflow

Under the National Water Act (Act No. 36 of 1998) the water use must be authorised. The water will be abstracted from borehole(s), stored in a reservoir(s) and used as a source of potable water for construction and operation. Under these circumstances, the following (ground) water use is recognised as being relevant to the licence application:

- Section 21 (a) – taking water from a resource.

10.2 Water Demand and Abstraction Classification

The calculated water demand for the project will be 0.0292 Mm^3/annum. DWS categorises water use licence applications in three categories based on the amount of recharge that is used by the applicant in relation to the specified property:

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

10.3 Assessment on Quaternary Level

The project falls within quaternary catchment B60B and the most salient parameters relevant to this catchment is presented in Table 10:

Table 10. Most salient parameters relevant to catchment B60B

Area km^2	Protected Area (km^2)	GA ($m^3/ha/a$)	Recharge (Mm^3/a)	Population	Basic Human Need (Mm^3/a)	EWR Baseflow (Mm^3/a)	Reserve (Mm^3/a)	Current use (Mm^3/a)
302.2	15.4	0	25.53	1000	0.01	16	16.01	0

The values used in Table 10 originates from data contained in the GRDM software and the "current use" represents registered groundwater users as contained in the WARMS data base (updated 25 April 2022).

10.3.1 Stress Classification

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.

Stress Index = Abstraction/Recharge

= 0/25.53

= 0

The quaternary catchment is classified as Category A, which is described as "unstressed' in terms of abstraction/recharge (Table 11).

Table 11. Guideline for determining the level of stress[18]

Present Status Category	Description	Stress Index (abstraction/recharge)
A	Unstressed or slightly stressed	<0.05
B		0.05 - 0.20
C	Moderately Stressed	0.20 – 0.40
D		0.40 – 0.65
E	Highly Stressed	0.65 – 0.95
F	Critically Stressed	>0.95

[18] Groundwater Resources Directed Measures Manual (WRC Report No TT299/07, April 2007)

10.3.2 Reserve and Water available for allocation

The following table summarizes the calculated reserve and water available for abstraction from the quaternary catchment.

Table 12. A summary of the Water Balance within the quaternary catchment

Quantification of Reserve: B60B	
Human Need:	
Population	1000
Basic human need [l/d/p]	25
Basic human need total [Mm³/a]	0.01
Recharge:	
Recharge [Mm³/a]	25.53
Baseflow:	
Baseflow [Mm³/a]	16.00
☐ Maint. low flow [Mm³/a]	0.00
☑ EWR [Mm³/a]	16.00
Flow:	
Net Flow [Mm³/a]	0.00
Reserve:	
Reserve as % recharge	62.7
Groundwater allocation [Mm³/a]	9.52
Current abstraction [Mm³/a]	0.00

From Table 12 it becomes evident that a significant percentage (62.70%) of the groundwater recharge is allocated to the “Reserve” and that 9.52 Mm³/a is available for allocation.

10.4 Assessment on Groundwater Resource Unit Level

If the calculation is based on the GRU delineated for the project, the following emerges:

Table 13. Water Balance within the Groundwater Resource Unit

Area	**Surface Area (ha)**	**Groundwater Recharge to GRU using recharge figure of** 100 mm/a
GRU	107	107000 **m³/a**
Recharge to GRU		0.107 **Mm³/a** 293 **m³/day** 3.4 **l/second**
Registered Use (WARMS)		0.0 **m³/a**
RESERVE	Basic Human Need	200.0 **m³/a**
	Base Flow (EWR)	42.0 **mm/a** 44940 **m³/a**
Groundwater available for abstraction		61860 **m³/a** 0.062 **Mm³/a** 169479 **l/day** 2.0 **l/second**
Application (WULA)		0.0292 **Mm³/a**
WULA as % of Groundwater available in GRU		47.20 **%**

Taking the project water demand and recharge to the GRU into account, it would be fair to apply for the full demand of 0.0292 Mm³/annum. An application of 0.0292 Mm³/annum (47.20% of the recharge to the GRU) places the application in Category A (small scale abstractions – <60 % recharge to the GRU) (see section 10.2).

The three tested boreholes will be able to supply in 100% of the demand, as well as the applied volume.

11 Aquifer Classification

The aquifer(s) underlying the project area were classified in accordance with "A South African Aquifer System Management Classification, December 1995" by Parsons. Classification has been done in accordance with the following definitions for Aquifer System Management Classes:

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

Based on the available information it can be concluded that aquifer system in the study area can be classified as a "Minor Aquifer System". Although boreholes do not produce large quantities of water and limited to no abstraction of groundwater takes place, the aquifers are important in supplying base flow for rivers and maintaining the ecological reserve.

In order to achieve the Groundwater Quality Management Index a points scoring system, as presented in Table 14 and Table 15 below, was used.

Table 14. Ratings for the Aquifer System Management and Second Variable Classifications

Aquifer System Management Classification		
Class	Points	Study area
Sole Source Aquifer System:	6	
Major Aquifer System:	4	
Minor Aquifer System:	2	2
Non-Aquifer System:	0	
Special Aquifer System:	0 – 6	
Second Variable Classification (Weathering/Fracturing)		
Class	Points	Study area
High:	3	
Medium:	2	
Low:	1	1

Table 15. Ratings for the Groundwater Quality Management (GQM) Classification System

Aquifer System Management Classification		
Class	Points	Study area
Sole Source Aquifer System: Major Aquifer System: Minor Aquifer System: Non-Aquifer System: Special Aquifer System:	6 4 2 0 0 - 6	2
Aquifer Vulnerability Classification		
Class	Points	Study area
High: Medium: Low:	3 2 1	3

The vulnerability, or the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer, in terms of the above, is classified as high (section 8.7). The level of groundwater protection based on the Groundwater Quality Management Classification:

GQM Index = Aquifer System Management x Aquifer Vulnerability

= 2 X 3 = 6

Table 16. GQM index for the study area

GQM Index	Level of Protection	Study Area
<1 1 - 3 3 - 6 6 - 10 >10	Limited Low Level Medium Level High Level Strictly Non-Degradation	6

The ratings for the Aquifer System Management Classification and Aquifer Vulnerability Classification yield a Groundwater Quality Management Index of 6 for the study area, indicating that "Medium to High" groundwater protection is required. Reasonable and sound groundwater protection measures are imperative to ensure that no over abstraction and cumulative pollution affects the aquifer, even in the long term. The reserve needs to be maintained to ensure that the aquifer sustains baseflow to rivers/streams draining the area and maintaining the sensitive grassland in which the boreholes are located.

The values in Table 14 are naturally subjective but based on the aquifer descriptions given previously. The importance of each aquifer should provide guidance on the protection to be assigned to each area.

12 Impact Assessment

The risk associated with the proposed development pertains to the construction and operational phase only. It is not envisaged that decommissioning of the development will be required, and risks associated with the decommissioning phase was therefore not assessed.

Each impact was assessed individually and graded using a numerical system to calculate the significance of each impact. Each individual impact was assessed and re-assessed after the appropriate mitigation was applied. A compressive summary of the assessed impacts, mitigation and significance of each impact is listed in the tables below.

12.1 Description of potential impacts

The most significant activities which can potentially impact on groundwater and considered as part of the impact assessment is listed below and the significance calculation spreadsheets presented in tables. The “Ref” number for each spreadsheet corresponds with the “Activity number” listed below.

12.1.1 Construction Phase

1. Generation of waste.
2. Generation of grey and brown waste water.
3. Accidental spills of hazardous materials stored and handled.
4. Lowering of the groundwater table due to groundwater abstraction from boreholes.

12.1.2 Operational Phase

5. Generation of domestic waste.
6. Generation of grey and brown waste water.
7. Development will have impermeable surfaces (paving roads, etc.) enhancing storm water run-off which will reduce direct recharge to groundwater beneath these surfaces.
8. Lowering of the groundwater table due to groundwater abstraction from boreholes.

12.1.3 Cumulative Impacts

After implementation of appropriate mitigation measures, all identified impacts were rated as “negligible negative with mitigation”. Therefore, no cumulative impacts to groundwater with other projects are anticipated.

12.2 Construction Phase

Ref:	1			
Project phase	**Construction**			
Impact	**Groundwater Contamination**			
Description of impact	**Waste generated during construction activities. These wastes will typically consist of materials disposed of during maintenance and servicing of vehicles and heavy machinery, domestic waste generated by construction workers on site, building rubble and discarded building materials. Improper storage and handling can contaminate soil & groundwater.**			
Mitigatability	High	Mitigation exists and will considerably reduce the significance of impacts		
Potential mitigation	**Good housekeeping practises. Disposal of waste at a licensed landfill site.**			
Assessment	**Without mitigation**		**With mitigation**	
Nature	Negative		Negative	
Duration	Medium term	Impact will last between 5 and 10 years	Brief	Impact will not last longer than 1 year
Extent	Local	Extending across the site and to nearby settlements	Limited	Limited to the site and its immediate surroundings
Intensity	High	Natural and/ or social functions and/ or processes are notably altered	Negligible	Natural and/ or social functions and/ or processes are negligibly altered
Probability	Almost certain / Highly probable	It is most likely that the impact will occur	Unlikely	Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur
Confidence	High	Substantive supportive data exists to verify the assessment	High	Substantive supportive data exists to verify the assessment
Reversibility	Medium	The affected environment will only recover from the impact with significant intervention	High	The affected environmental will be able to recover from the impact
Resource irreplaceability	Medium	The resource is damaged irreparably but is represented elsewhere	Medium	The resource is damaged irreparably but is represented elsewhere
Significance	**Minor - negative**		**Negligible - negative**	
Comment on significance	After the implementation of mitigation measures, the significance of the impact becomes negligible.			
Cumulative impacts	Since the impact is negligible negative with mitigation, cumulative impacts to groundwater with other projects are not anticipated.			

Ref:	2			
Project phase	**Construction**			
Impact	**Groundwater Contamination**			
Description of impact	**Generation of grey and brown water discharge, uncontrolled release to environment.**			
Mitigatability	High	Mitigation exists and will considerably reduce the significance of impacts		
Potential mitigation	**Adequate ablution facilities. Refrain from discharging grey and brown water to the environment.**			
Assessment	**Without mitigation**		**With mitigation**	
Nature	Negative		Negative	
Duration	Medium term	Impact will last between 5 and 10 years	Brief	Impact will not last longer than 1 year
Extent	Limited	Limited to the site and its immediate surroundings	Limited	Limited to the site and its immediate surroundings
Intensity	Moderate	Natural and/ or social functions and/ or processes are moderately altered	Low	Natural and/ or social functions and/ or processes are somewhat altered
Probability	Likely	The impact may occur	Probable	The impact has occurred here or elsewhere and could therefore occur
Confidence	High	Substantive supportive data exists to verify the assessment	High	Substantive supportive data exists to verify the assessment
Reversibility	High	The affected environmental will be able to recover from the impact	High	The affected environmental will be able to recover from the impact
Resource irreplaceability	Low	The resource is not damaged irreparably or is not scarce	Low	The resource is not damaged irreparably or is not scarce
Significance	**Minor - negative**		**Negligible - negative**	
Comment on significance	After the implementation of mitigation measures, the significance of the impact becomes negligible.			
Cumulative impacts	Since the impact is negligible negative with mitigation, cumulative impacts to groundwater with other projects are not anticipated.			

Ref:	3			
Project phase	**Construction**			
Impact	**Groundwater Contamination**			
Description of impact	**Accidental spills of materials stored and handled. Large volumes of potentially hazardous materials (e.g. diesel, lubricants, oils, etc.) will be stored and handled at the construction site. Spillages can contaminate soil & groundwater.**			
Mitigatability	High	Mitigation exists and will considerably reduce the significance of impacts		
Potential mitigation	**Storage and handling of materials as per industry specifications. Adequately trained persons in Emergency Spill Response Procedures.**			
Assessment	**Without mitigation**		**With mitigation**	
Nature	Negative		Negative	
Duration	On-going	Impact will last between 15 and 20 years	Brief	Impact will not last longer than 1 year
Extent	Local	Extending across the site and to nearby settlements	Limited	Limited to the site and its immediate surroundings
Intensity	Very high	Natural and/ or social functions and/ or processes are majorly altered	Low	Natural and/ or social functions and/ or processes are somewhat altered
Probability	Likely	The impact may occur	Probable	The impact has occurred here or elsewhere and could therefore occur
Confidence	High	Substantive supportive data exists to verify the assessment	High	Substantive supportive data exists to verify the assessment
Reversibility	Medium	The affected environment will only recover from the impact with significant intervention	High	The affected environmental will be able to recover from the impact
Resource irreplaceability	Medium	The resource is damaged irreparably but is represented elsewhere	Low	The resource is not damaged irreparably or is not scarce
Significance	**Moderate - negative**		**Negligible - negative**	
Comment on significance	After the implementation of mitigation measures, the significance of the impact becomes negligible.			
Cumulative impacts	Since the impact is negligible negative with mitigation, cumulative impacts to groundwater with other projects are not anticipated.			

Ref:	4			
Project phase	**Construction**			
Impact	**Lowering of groundwater table**			
Description of impact	**Over-abstraction of groundwater from boreholes is likely to lead to lowering of groundwater levels and ultimately the depletion of the groundwater resource over time. Will negatively impact sensitive grassland and wetlands if hydrodinamics and interaction between aquifers and wetlands are significantly disturbed.**			
Mitigatability	High	Mitigation exists and will considerably reduce the significance of impacts		
Potential mitigation	**Yield testing of boreholes as per "SANS 10299-4:2003" standards. Do not exceed calculated sustainable yield of boreholes. Groundwater level monitoring - reduce abstraction in the event of anomolous lowering of groundwater levels. The reserve needs to be maintained to ensure that the aquifer sustains baseflow to rivers/streams draining the area and maintaining the sensitive grassland in which the boreholes are located.**			
Assessment	**Without mitigation**		**With mitigation**	
Nature	Negative		Negative	
Duration	On-going	Impact will last between 15 and 20 years	Brief	Impact will not last longer than 1 year
Extent	Local	Extending across the site and to nearby settlements	Limited	Limited to the site and its immediate surroundings
Intensity	Very high	Natural and/ or social functions and/ or processes are majorly altered	Very low	Natural and/ or social functions and/ or processes are slightly altered
Probability	Likely	The impact may occur	Unlikely	Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur
Confidence	Medium	Determination is based on common sense and general knowledge	High	Substantive supportive data exists to verify the assessment
Reversibility	Medium	The affected environment will only recover from the impact with significant intervention	High	The affected environmental will be able to recover from the impact
Resource irreplaceability	Low	The resource is not damaged irreparably or is not scarce	Low	The resource is not damaged irreparably or is not scarce
Significance	**Moderate - negative**		**Negligible - negative**	
Comment on significance	After the implementation of mitigation measures, the significance of the impact becomes negligible.			
Cumulative impacts	Since the impact is negligible negative with mitigation, cumulative impacts to groundwater with other projects are not anticipated.			

12.3 Operational Phase

Ref:	5			
Project phase	**Operation**			
Impact	**Groundwater Contamination**			
Description of impact	**Improper storage and handling of waste can contaminate soil & groundwater if not disposed of properly.**			
Mitigatability	High	Mitigation exists and will considerably reduce the significance of impacts		
Potential mitigation	**Removal of Domestic Waste on a regular basis by accredited contractor and disposed/recycled at licensed landfill/recycling facility.**			
Assessment	**Without mitigation**		**With mitigation**	
Nature	Negative		Negative	
Duration	Medium term	Impact will last between 5 and 10 years	Brief	Impact will not last longer than 1 year
Extent	Local	Extending across the site and to nearby settlements	Limited	Limited to the site and its immediate surroundings
Intensity	High	Natural and/ or social functions and/ or processes are notably altered	Negligible	Natural and/ or social functions and/ or processes are negligibly altered
Probability	Almost certain / Highly probable	It is most likely that the impact will occur	Unlikely	Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur
Confidence	High	Substantive supportive data exists to verify the assessment	High	Substantive supportive data exists to verify the assessment
Reversibility	Medium	The affected environment will only recover from the impact with significant intervention	High	The affected environmental will be able to recover from the impact
Resource irreplaceability	Medium	The resource is damaged irreparably but is represented elsewhere	Medium	The resource is damaged irreparably but is represented elsewhere
Significance	**Minor - negative**		**Negligible - negative**	
Comment on significance	After the implementation of mitigation measures, the significance of the impact becomes negligible.			
Cumulative impacts	Since the impact is negligible negative with mitigation, cumulative impacts to groundwater with other projects are not anticipated.			

Ref:	6			
Project phase	**Operation**			
Impact	**Groundwater Contamination**			
Description of impact	**Generation of grey and brown water discharge, uncontrolled release to environment.**			
Mitigatability	High	Mitigation exists and will considerably reduce the significance of impacts		
Potential mitigation	**Formal sewage system and adequate treatment. Effluent to be treated to quality which conforms to license conditions/standards before discharged to environment.**			
Assessment	**Without mitigation**		**With mitigation**	
Nature	Negative		Negative	
Duration	On-going	Impact will last between 15 and 20 years	Brief	Impact will not last longer than 1 year
Extent	Local	Extending across the site and to nearby settlements	Limited	Limited to the site and its immediate surroundings
Intensity	High	Natural and/ or social functions and/ or processes are notably altered	Low	Natural and/ or social functions and/ or processes are somewhat altered
Probability	Likely	The impact may occur	Unlikely	Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur
Confidence	High	Substantive supportive data exists to verify the assessment	High	Substantive supportive data exists to verify the assessment
Reversibility	Medium	The affected environment will only recover from the impact with significant intervention	High	The affected environmental will be able to recover from the impact
Resource irreplaceability	Low	The resource is not damaged irreparably or is not scarce	Low	The resource is not damaged irreparably or is not scarce
Significance	**Minor - negative**		**Negligible - negative**	
Comment on significance	After the implementation of mitigation measures, the significance of the impact becomes negligible.			
Cumulative impacts	Since the impact is negligible negative with mitigation, cumulative impacts to groundwater with other projects are not anticipated.			

Ref:	7			
Project phase	**Operation**			
Impact	**Reduced recharge to aquifers**			
Description of impact	**Construction of roads, parking areas, etc. enhancing storm water run-off which will reduce direct recharge to underlying aquifers.**			
Mitigatability	Medium	Mitigation exists and will notably reduce significance of impacts		
Potential mitigation	**The parking area and access roads to boreholes will be constructed using permeable paving blocks. Rainwater will infiltrate through the permeable paving blocks and into a unique sub-base below the paving layer. The water will flow within the sub-base and released downstream into the natural environment in a controlled manner.**			
Assessment	**Without mitigation**		**With mitigation**	
Nature	Negative		Negative	
Duration	On-going	Impact will last between 15 and 20 years	Brief	Impact will not last longer than 1 year
Extent	Limited	Limited to the site and its immediate surroundings	Very limited	Limited to specific isolated parts of the site
Intensity	Low	Natural and/ or social functions and/ or processes are somewhat altered	Very low	Natural and/ or social functions and/ or processes are slightly altered
Probability	Probable	The impact has occurred here or elsewhere and could therefore occur	Unlikely	Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur
Confidence	Medium	Determination is based on common sense and general knowledge	Medium	Determination is based on common sense and general knowledge
Reversibility	High	The affected environmental will be able to recover from the impact	High	The affected environmental will be able to recover from the impact
Resource irreplaceability	Low	The resource is not damaged irreparably or is not scarce	Low	The resource is not damaged irreparably or is not scarce
Significance	**Minor - negative**		**Negligible - negative**	
Comment on significance	The recharge of the groundwater resource unit (GRU) taking place at the development is insignificantly small in comparison with the total recharge area of the GRU.			
Cumulative impacts	Since the impact is negligible negative with mitigation, cumulative impacts to groundwater with other projects are not anticipated.			

Ref:	8			
Project phase	**Operation**			
Impact	**Lowering of groundwater table**			
Description of impact	**Over-abstraction of groundwater from boreholes is likely to lead to lowering of groundwater levels and ultimately the depletion of the groundwater resource over time. Will negatively impact sensitive grassland and wetlands if hydrodinamics and interaction between aquifers and wetlands are significantly disturbed.**			
Mitigatability	High	Mitigation exists and will considerably reduce the significance of impacts		
Potential mitigation	**Yield testing of boreholes as per "SANS 10299-4:2003" standards. Do not exceed calculated sustainable yield of boreholes. Groundwater level monitoring - reduce abstraction in the event of anomolous lowering of groundwater levels. The reserve needs to be maintained to ensure that the aquifer sustains baseflow to rivers/streams draining the area and maintaining the sensitive grassland in which the boreholes are located.**			
Assessment	**Without mitigation**		**With mitigation**	
Nature	Negative		Negative	
Duration	On-going	Impact will last between 15 and 20 years	Brief	Impact will not last longer than 1 year
Extent	Local	Extending across the site and to nearby settlements	Limited	Limited to the site and its immediate surroundings
Intensity	Very high	Natural and/ or social functions and/ or processes are majorly altered	Very low	Natural and/ or social functions and/ or processes are slightly altered
Probability	Likely	The impact may occur	Unlikely	Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur
Confidence	Medium	Determination is based on common sense and general knowledge	High	Substantive supportive data exists to verify the assessment
Reversibility	Medium	The affected environment will only recover from the impact with significant intervention	High	The affected environmental will be able to recover from the impact
Resource irreplaceability	Low	The resource is not damaged irreparably or is not scarce	Low	The resource is not damaged irreparably or is not scarce
Significance	**Moderate - negative**		**Negligible - negative**	
Comment on significance	After the implementation of mitigation measures, the significance of the impact becomes negligible.			
Cumulative impacts	Since the impact is negligible negative with mitigation, cumulative impacts to groundwater with other projects are not anticipated.			

12.4 Summary of assessed impacts

Table 17. Summary of assessed impacts

Ref:	Project phase	Impact	Without mitigation						With mitigation					
			Nature	Duration	Extent	Intensity	Probability	Significance	Nature	Duration	Extent	Intensity	Probability	Significance
1	Construction	Groundwater Contamination	Negative	Medium term	Local	High	Almost certain / Highly probable	Minor - negative	Negative	Brief	Limited	Negligible	Unlikely	Negligible - negative
2	Construction	Groundwater Contamination	Negative	Medium term	Limited	Moderate	Likely	Minor - negative	Negative	Brief	Limited	Low	Probable	Negligible - negative
3	Construction	Groundwater Contamination	Negative	On-going	Local	Very high	Likely	Moderate - negative	Negative	Brief	Limited	Low	Probable	Negligible - negative
4	Construction	Lowering of groundwater table	Negative	On-going	Local	Very high	Likely	Moderate - negative	Negative	Brief	Limited	Very low	Unlikely	Negligible - negative
5	Operation	Groundwater Contamination	Negative	Medium term	Local	High	Almost certain / Highly probable	Minor - negative	Negative	Brief	Limited	Negligible	Unlikely	Negligible - negative
6	Operation	Groundwater Contamination	Negative	On-going	Local	High	Likely	Minor - negative	Negative	Brief	Limited	Low	Unlikely	Negligible - negative
7	Operation	Reduced recharge to aquifers	Negative	On-going	Limited	Low	Probable	Minor - negative	Negative	Brief	Very limited	Very low	Unlikely	Negligible - negative
8	Operation	Lowering of groundwater table	Negative	On-going	Local	Very high	Likely	Moderate - negative	Negative	Brief	Limited	Very low	Unlikely	Negligible - negative

13 Groundwater Monitoring Program & Management Framework

13.1 Groundwater Monitoring Program

The main objective of the proposed and discussed mitigation measures, pertaining to the identified impacts, is to maintain and monitor the regional groundwater table and quality to:

- Ensure that the aquifer sustains baseflow to rivers/streams draining the GRU and maintaining the sensitive grassland in which the boreholes are located.
- Ensure that no groundwater contamination occurs.

A groundwater monitoring program was developed. The three on-site production boreholes need to be included in the network and are summarised in Table 18 below.

Table 18. Monitoring Boreholes

BH nr	Objective
SWBH1, SWBH2, SAFCOL1	Impact Monitoring

Table 19 below presents the parameters and frequency that should form part of the groundwater monitoring program. It is proposed that the data should be captured into an appropriate electronic database for easy retrieval and submission to the relevant authority as required and reviewed by a geohydrologist on an annual basis to ensure the source is utilised in a sustainable manner. The current water quality status quo (generally complies to SANS 241-1:2015-Drinking Water Standards) should be maintained. Under average rainfall conditions, static water levels should be maintained although normal seasonal fluctuations should be taken into account when evaluating water level monitoring data.

Table 19. Proposed Monitoring Requirements

<table>
<tr><th>Class</th><th>Parameter</th><th>Frequency</th><th>Motivation</th></tr>
<tr><td rowspan="2">Physical</td><td>Static groundwater levels</td><td>Monthly</td><td>Time dependant data is required to understand the regional groundwater flow dynamics.
A lowering in the static water levels may indicate that the aquifer is utilised in an unsustainable way and abstraction rates need to be decreased.
Conditions of the Water Use Licence.</td></tr>
<tr><td>Groundwater abstraction volumes</td><td>Monthly</td><td>Calculate monthly & annual abstraction volumes.
Conditions of the Water Use Licence.</td></tr>
<tr><td>Chemical</td><td>Major ions and trace elements.</td><td>Bi-Annually</td><td>Changes in chemical composition may indicate areas of groundwater contamination and be used as an early warning system to implement management/remedial actions.
To determine whether the water is fit for human consumption/intended use.
Conditions of the Water Use Licence.</td></tr>
</table>

13.2 Groundwater Management Framework

Table 20. Groundwater Management Framework to mitigate impacts associated with the construction phase.

Ref.	Action	Objective	Management & Mitigation
1	Generation of domestic waste	Protection of soil, groundwater and surface water from contamination.	1. Good housekeeping practises. 2. Responsible handling of waste streams and disposal at a licensed landfill site.
2	Generation of grey and brown water discharge	Protection of soil, groundwater and surface water from contamination.	1. Provide adequate portable chemical sanitary facilities and have them emptied on regular intervals by an appropriately registered service provider. 2. Refrain from discharging grey and brown water in buffer zone areas as indicated in "Sensitivity Map". Refrain from developing sanitation systems in buffer zone areas as indicated in "Sensitivity Map", except where "zero discharge" systems are used.
3	Accidental spills of materials stored and handled	Protection of soil, groundwater and surface water from contamination.	1. Creation of appropriate management plans including site specific risk assessments and material handling procedures. 2. Fuel containers exceeding 200 litres capacity should be stored in a manner that will prevent escape of contents to the environment in the case of accidents. 3. Fuel containers should be stored in a secure weatherproof building or within a secondary containment compound. 4. Above fuel storage installations should adhere to the relevant SABS specifications. 5. Provision of spill kits. 6. Training of workers on risks associated with handling hazardous materials and use of spill kits.
4	Abstraction of groundwater from boreholes	Maintain regional groundwater table to ensure that the aquifer sustains baseflow to rivers/streams draining the area and maintaining the sensitive grassland in which the boreholes are located.	1. Yield testing of boreholes as per “SANS 10299-4:2003" standards. Do not exceed calculated sustainable yield of boreholes. 2. Groundwater level monitoring - reduce abstraction in the event of anomalous lowering of groundwater levels.

Table 21. Groundwater Management Framework to mitigate impacts associated with the operational phase.

Ref.	Action	Objective	Management & Mitigation
5	Generation of domestic waste	Protection of soil, groundwater and surface water from contamination	1. Good housekeeping practises. 2. Responsible handling of waste streams and disposal at a licensed landfill site.
6	Generation of grey and brown water discharge	Protection of soil, groundwater and surface water from contamination	1. Formal sewage system and adequate treatment. 2. Effluent to be treated to quality which conforms to license conditions/standards before discharged to environment.
7	Construction of roads, parking areas, etc. enhancing storm water run-off which will reduce direct recharge to underlying aquifers.	Limit reduced recharge to underlying aquifers.	1. The parking area and access roads to boreholes will be constructed using permeable paving blocks. Rainwater will infiltrate through the permeable paving blocks and into a unique sub-base below the paving layer. The water will flow within the sub-base and released downstream into the natural environment in a controlled manner.
8	Abstraction of groundwater from boreholes	Maintain regional groundwater table to ensure that the aquifer sustains baseflow to rivers/streams draining the area and maintaining the sensitive grassland in which the boreholes are located.	1. Yield testing of boreholes as per “SANS 10299-4:2003" standards. Do not exceed calculated sustainable yield of boreholes. 2. Groundwater level monitoring - reduce abstraction in the event of anomalous lowering of groundwater levels.

14 Conclusions & Recommendations

Based on the field work, interpretation of available and newly acquired data, the construction and operation of the Skywalk and associated infrastructure will have an overall "negligible – negative" impact on the investigated geohydrological environment after implementation of appropriate mitigation measures. During the rating and ranking procedure of impacts, all identified impacts could be countered by appropriate mitigation.

Based on the water balance results, it is recommended to apply for an allocation of 0.0292 Mm^3/annum which places the application in Category A (small scale abstractions <60% recharge to the GRU). The three tested boreholes will be able to supply in 100% of the demand, as well as the applied volume.

From a water quality point of view, the majority of the parameters analysed for comply with the SANS241 drinking water limits. Low pH values in the Spring and elevated Iron and Zink concentrations in borehole SWBH2 exceed the SANS241 drinking water limits. A water treatment specialist will need to evaluate the water quality and recommend treatment options for the intended use.

It is understood that borehole SAFCOL1 are not located within the Blyderivierspoort Nature Reserve, which is managed by MTPA, but within the Blyde Nature Reserve proclaimed under the National Forest Act and manged by South African Forestry Company SOC Limited (SAFCOL). The necessary registrations of servitudes, authorisations and approvals will need to be obtained from SAFCOL to legally incorporate the water use from this borehole into the projects water demand.

It is the assessor's professional opinion that adequate information was available to appropriately assess the impact of the proposed development on the geohydrological environment and that the activity may be authorised. It is however imperative that the proposed "Groundwater Monitoring Program and Groundwater management Framework be incorporated into the Environmental Management Program. Production boreholes should be equipped as follow:

- Installation of a 32 mm LDPE observation pipe from the pump depth to the surface, open at the bottom. This allows for a 'window' of access down the borehole which enables manual water level monitoring and can house an electronic water level logger if required.
- Installation of a sampling tap (to monitor water quality).
- Installation of a flow volume meter (to monitor abstraction rates and volumes).
- The appropriate borehole pump must be installed, i.e. not an over-sized pump that is choked with a gate valve. If the monitoring shows that more water can be abstracted, then duty cycles (i.e. the duration of pumping time) may be increased, and not the flow rate.

15 References

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Appendix A: Maps

Appendix B: Impact Assessment Methodology

Appendix C: Borehole Logs

Appendix D: Pumptesting Records

Appendix E: Laboratory Reports

Appendix F: Land Surveyor Assessment

Appendix G: CV of Assessor & Declaration of Independence

In diversity there is beauty and there is strength.

MAYA ANGELOU

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