GCS Newcastle Office
1 Karbochem Rd, Newcastle, 2940
Cell: +27 (0) 71 102 3819 **Fax:** +27 (0) 31 764 7140 **Web:** www.gcs-sa.biz

The development of three Solar Photovoltaic (PV) facilities and associated infrastructure (Phases 1, 2 and 3) between De Aar & Hanover, Emthanjeni Local Municipality, Pixley Ka Seme District Municipality, Northern Cape Province, South Africa

Geohydrological Assessment Report

Version - Final 1

31 January 2023

Ecoleges

GCS Project Number: 22-0401

Client Reference: De Aar Solar GW

GCS (Pty) Ltd. Reg No: 2004/000765/07 Est. 1987
Offices: Johannesburg (Head Office) | Durban | Gaborone | Lusaka | Maseru | Windhoek | Ostrava | **Newcastle**
Directors: AC Johnstone (CEO) | M Van Rooyen | H Botha | W Sherriff (Financial) N Marday (HR)
Non-Executive Director: B Wilson-Jones
www.gcs-sa.biz

GEOHYDROLOGICAL ASSESSMENT

Report
Version – Final 1

31 January 2023

Ecoleges

22-0401

DOCUMENT ISSUE STATUS

Report Issue	Final Rev 3		
GCS Reference Number	GCS Ref - 22-0401		
Client Reference	De Aar Solar GW		
Title	The development of three Solar Photovoltaic (PV) facilities and associated infrastructure (Phases 1, 2 and 3) between De Aar & Hanover, Emthanjeni Local Municipality, Pixley Ka Seme District Municipality, Northern Cape Province, South Africa **Geohydrological Assessment Report**		
	Name	**Signature**	**Date**
Author **(Technical Director)**	Hendrik Botha (MSc, PriSciNat)	31/01/2023 4:33:03 Pr.Sci.Nat (400139/17)	31 January 2023

DECLARATION OF INDEPENDENCE

GCS (Pty) Ltd was appointed to conduct this specialist groundwater study and to act as the independent groundwater specialist. GCS objectively performed the work, even if this results in views and findings that are not favourable. GCS has the expertise in conducting the specialist investigation and does not have a conflict of interest in the undertaking of this study. This report presents the findings of the investigations which include the activities set out in the scope of work.

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

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

Requirements from Appendix 6 of GN 326 EIA Regulation 2017	Chapter
(a) Details of: (i) The specialist who prepare the reports; and (ii) the expertise of that specialist to compile a specialist report including a curriculum vitae	Document Issue (Page ii) Appendix B.
(b) Declaration that the specialist is independent in a form as may be specialities by the competent authority	Appendix B.
(c) Indication of the scope of, and purpose for which, the report was prepared	Section 1.
(cA) Indication of the quality and age of base data used for the specialist report	Sections 1, 2 and 4 and 5.
(cB) A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change	Section 6
(d) Duration, Date and seasons of the site investigation and the relevance of the season to the outcome of the assessment	Section 1.4.
(e) Description of the methodology adopted in preparing the report or carrying out the specialised process include of equipment and modelling used	Section 4
(f) Details of an assessment of the specifically identified sensitivity of the site related to the proposed activity or activities and its associate's structures and infrastructure, inclusive of a site plan identifying alternative	Sections 1, 2, 4 and 5
(g) Identification of any areas to be avoided, including buffers	Section 8.1
(h) Map superimposing the activity and associated structures and infrastructure on environmental sensitivities of the site including areas to be avoided, including buffers	Sections 1, 3, 5 and 6
(i) Description of any assumptions made and uncertainties or gaps in knowledge	Section 1, 4
(j) A description of the findings and potential implications of such findings on the impact of the proposed activity including identified alternatives on the environment or activities	Section 8.
(k) Mitigation measures for inclusion in the EMPr	Section 8.2
(l) Conditions for inclusion in the environmental authorisation	Refer to recommendations in Section 7.
(m) Monitoring requirements for inclusion in the EMPr or environmental authorisation	Refer to recommendations in Section 7.
(n) Reasoned opinion – (i) as to 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, and avoidance, management, and mitigation measures should be included in the EMPr, and where applicable, the closure plan	Section 8.3.
(o) Description of any consultation process that was undertaken during preparing the specialist report	*None required.*
(p) A summary and copies of any comments received during any consultation process and where applicable all responses thereto	*None required.*
(q) Any other information requested by the competent authority	*None required.*

CONTENTS PAGE

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

BF	**Baseflow**
BH	Borehole
BHN	Basic Human Needs
d	day
DMEA	Department of Mineral and Environmental Affairs
DTM	Digital Terrain Model
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
E	East
G3	Best Practice Guidelines: Monitoring
G4	Best Practice Guidelines: Impact Prediction
GCS	GCS Water and Environment (Pty) Ltd
GPS	Global Positioning System
GRAII	Groundwater Resource Assessment Ver. 2
GRDM	Groundwater Resource Directed Measures
GRIP	Groundwater Resource Information Project
GW	groundwater
IGRD	Intermediate Groundwater Reserve Determination
IWULA	Integrated Water Use License Application
K	potassium
km	kilometre
K-value	hydraulic conductivity
l	litres
m	metres
MAE	Mean Annual Evaporation
Mag	magnetometer
mamsl	metres above mean sea level
MAP	Mean Annual Precipitation
MTS	Main Transmission Sub-station
mbgl	metres below ground level
nT	magnetic intensity
NWA	National Water Act, 1998
PV	Photovoltaic
Re	Recharge
Rem	Remainder
SPR	Source-Pathway-Receptor Model/Principle
SRTM	Shuttle Radar Topography Mission
T	Transmissivity
W	West
WL	Water level

1 INTRODUCTION

GCS Water and Environment (Pty) Ltd (GCS) was appointed by Ecoleges Environmental Consultants (Ecoleges) to undertake a geohydrological assessment for the development of three Solar Photovoltaic (PV) facilities (Phases 1, 2 and 3) between De Aar & Hanover, Emthanjeni Local Municipality, Pixley Ka Seme District Municipality, Northern Cape Province, South Africa (refer to Figure 1-2). The project falls within quaternary catchment D62D of the Orange Water Management Area (WMA) (DWS, 2016).

This geohydrological assessment is aimed at supplementing the EIA and WULA for the proposed development, in terms of probable groundwater-related risk.

1.1 Project background

In 2016 Ecoleges undertook an S&EIA for the development of a 225 MW Solar PV facility between Hanover and De Aar in the Northern Cape. Three alternative footprints (PV01, PV02, PV03) were investigated during the assessment process. The central footprint (PV02) was identified as the preferred option because of its lower environmental impact and proximity to an existing 400kV Eskom powerline when compared with PV01 and PV03. The National Department of Environmental Affairs granted an environmental authorisation (DEA Reference: 14/12/16/3/3/2/998) on 16th April 2018. The activity must commence on the PV02 footprint within five years from the date of issue.

An amendment to increase the capacity (not the footprint) of the facility to 300 MW due to technological advancements in solar photovoltaic efficiency and electrical output was granted on 24th November 2020.

A second amendment was granted in 2021 for the inclusion of containerised lithium-ion battery Storage and dual-fuel backup generators with associated fuel storage.

The competent authority was the National Department of Environmental Affairs because the application was part of the REIPPP or RMIPPP BID rounds, which formed part of a Strategic Infrastructure Project (SIP) as described in the National Development Plan, 2011. Soventix SA (Pty) Ltd was an unsuccessful bidder. However, the applicant has since partnered with another company, Solar Africa, with 1.5 GW in private renewable energy offtake agreements, making it economically feasible to develop two more 300 and 400 MW facilities (Phases 2 and 3, respectively).

Solar Africa will therefore apply for an environmental authorisation to develop an additional 300MW on the PV03 footprint (Phase 2) that was considered during the initial S&EIA. It is proposed to connect this second phase to the substation that forms part of the authorised facility on PV02.

Additionally, Soventix is also busy with an application for environmental authorisation to develop Phase 3, which involves the development of a third 400 MW Solar Photovoltaic (PV) facility on the remainder of Farm Goede Hoop 26C and Portion 3 of Farm Goede Hoop 26C. The two additional Solar PV facilities (Phase 2 and 3) will feed into the authorised Main Transmission Sub-station (MTS) on the Phase 1 footprint. Consequently, the expansion of the MTS, inclusion of a 132 kV switching yard, additional access road and staging area, requires a third Part 2 amendment to the existing environmental authorisation (EA Reference: 14/12/16/3/3/2/998), which is currently sitting with the competent authority for decision. The additional activities and associated infrastructure require additional water use authorisations in the form of General authorisation for specifically Section 21 (a), (b), (c), (i) & (g). Another Part 1 amendment is also currently underway following the sale of shares and project rights by Soventix SA to SolarAfrica Energy (SAE). Change of details and responsible party of the water use authorisations are also being applied for.

As the current project scope has grown beyond what was originally envisaged for Phase 1 (now known as Sun Central Cluster 1), additional authorisations will be required to allow necessary road upgrades to the MTS, due to the size and weight of the MTS transformers and associated transport vehicles and to ensure compliance with Eskom minimum road requirements.

Additionally, a Cost Estimate Letter (CEL) issued by Eskom during the baseline S&EIA in 2016, made provision for Loop-In, Loop-Out (LILO) into the 400 kV transmission closest to the MTS (known as Line 2).

Subsequently, Eskom has notified SolarAfrica Energy (SAE), that the project now needs to utilise Line 1, a parallel transmission line approximately 2.5 km away from Line 2 (refer to Figure 1-1). The project will initially utilise Line 2 and in future, due to the anticipated expansion of the MTS, also Line 1.

As additional activities, the following is also proposed:

- **Floodlights** and a **telecommunications tower** will be added to the Dx (Cluster 1 Switching Station) footprint and MTS footprint.
- **A pipeline** will be laid underground from BH13/BH14 and through an active channel (S21(c) & (i)) (a tributary of the Brak River) to an abstraction point located at the shortest distance to the nearest road. Boreholes 13 & 14 are alongside one another.

The geohydrological assessment is required to supplement the EIA for the proposed phase 1, phase 2 and 3 developments as groundwater use is proposed for the construction and operational phases.

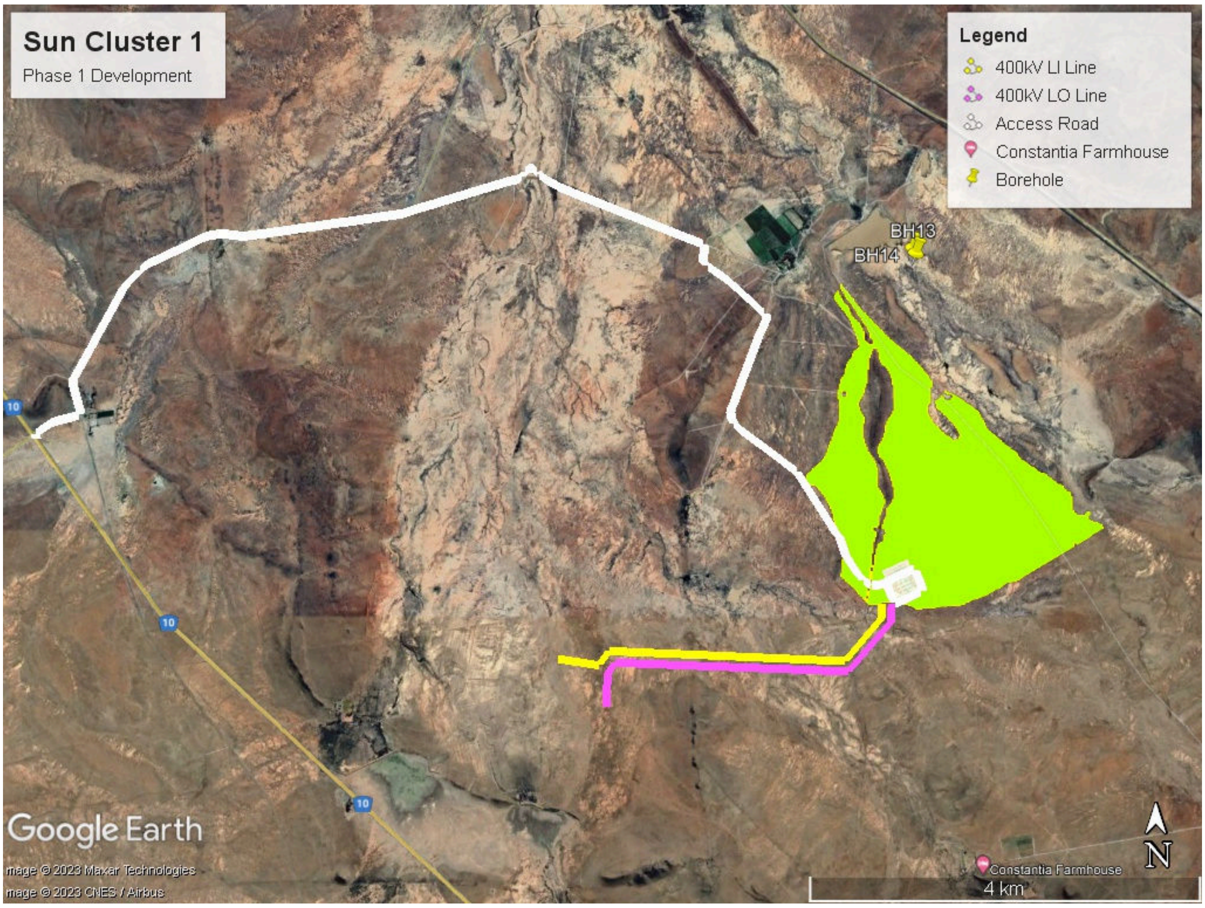


Figure 1-1: Access roads, LILO transmission line and boreholes - Sun Cluster 1

1.2 The objective of this report

The geohydrological study aimed to identify the in-situ geohydrological conditions of the site and focus on evaluating existing groundwater users, identifying potential borehole drilling positions, evaluating aquifer types and likely impacts on the groundwater regime as a result of the proposed PV developments. Subsequently, the potential impact on the groundwater aquifer, existing water users and surrounding water bodies will be determined.

The main objectives of the geohydrological report will be to determine how all three developments will impact their respective or shared underground aquifers, specifically:

- Determine if there is enough groundwater to support demand during construction and operation without deteriorating the ecological reserve or impacting other water users, both within the short and long term, given the anticipated increase in the frequency of extreme events, including drought, resulting from climate change
- Concerning Phase 3, please determine if the two (2) existing boreholes (on Portion 3 and the Remainder of Farm Goede Hoop 26C) will be enough to supply the predicted demand during construction and operation given their yields or rates of abstraction.
- Inform the Water Use License Application (WULA) for abstraction S21(a) from boreholes.

- Identify and quantify the perceived impacts and propose mitigations to be included in the EMPr.

1.3 The layout of this report

The report has been structured, as far as possible, as per *Annexure D of the Government Gazette (GN267 of 24 March 2017)* applicable to geohydrological studies for environmental impacts assessment/water use license applications. The report further considers A*ppendix 6 of EIA regulations*.

1.4 Study relevance to the season in which it was undertaken

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

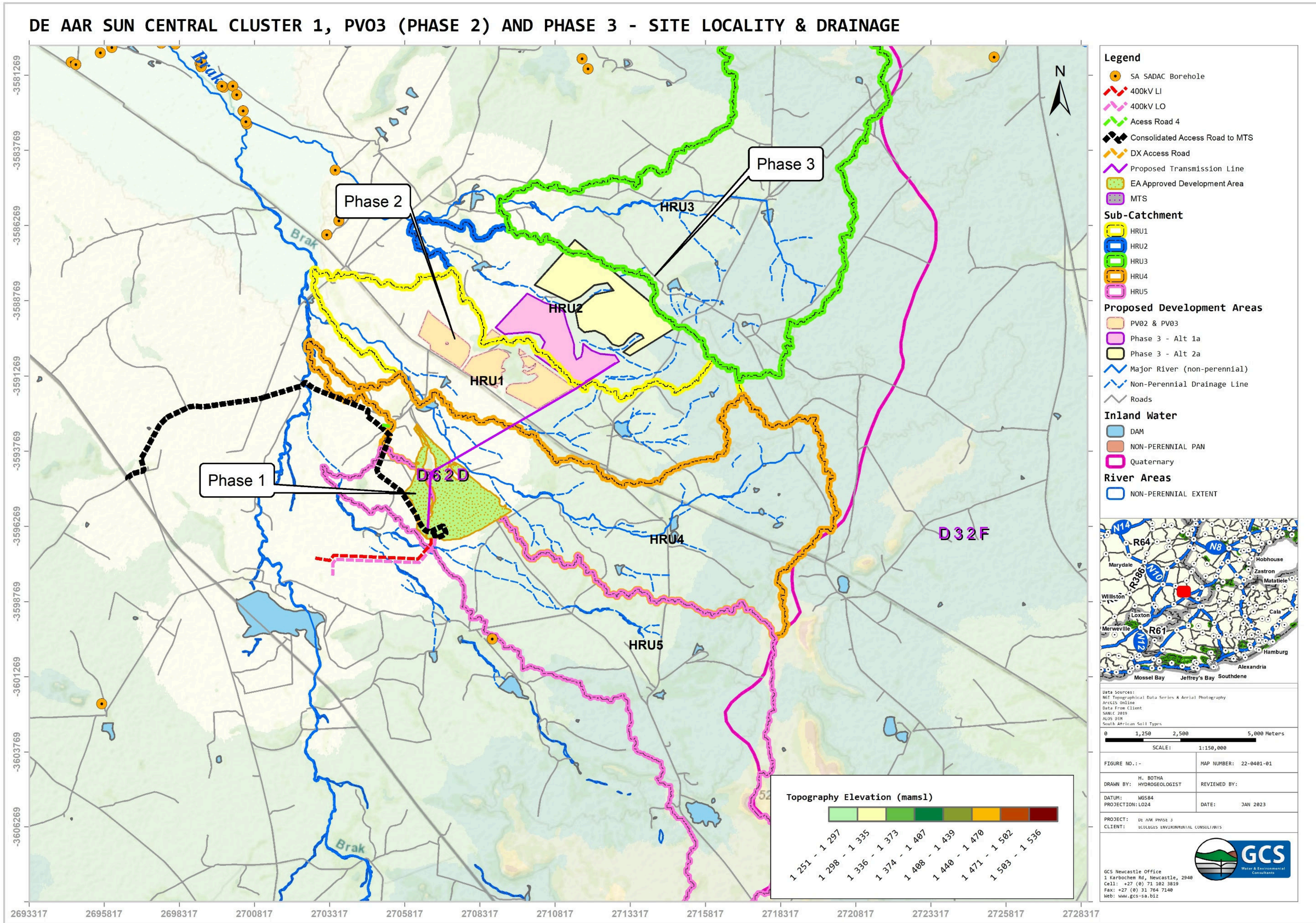


Figure 1-2: Site locality - Proposed PV02 (Phase 1), PVO3 (Phase 2) and Phase 3

2 SITE OVERVIEW

As mentioned previously, the project falls within quaternary catchment D62D of the Orange Water Management Area (WMA) (DWS, 2016). The topography of the study area is generally flat with elevations on the site typically ranging from 1310 to 1370 metres above mean sea level (mamsl).

2.1 Sub-catchments / hydrological response units (HRUs)

Five (5) hydrological response units (HRUs) describe the natural drainage for the study area (using a 1:10 000 stream count and 20m DTM fill) – refer to Figure 1-2. The HRUs delineated correspond well to known non-perennial rivers and drainage lines associated with the project area.

Drainage in the HRUs is towards the north-west in the form of a multitude of non-perennial drainage lines, which drains towards the non-perennial Brak River, situated approximately 6km downstream west of the site. No recognised non-perennial streams are associated with the site. However, the footprint of the proposed development was cut due to there being recognized high-sensitivity ecological zones. There are several in-stream water storage dams associated with the non-perennial streams in the study area. Several known windpumps are situated in the development area and are primarily used for livestock watering. These areas have also been flagged as no-go areas.

2.2 Land cover and slope

Thicket low shrubland, fynbos, succulent karoo, natural lakes, natural rock surfaces and dune sand types dominate the sub-catchment (DEA, 2019) – refer to Figure 2-5. The land cover data were used to classify land types into 4 groups, as presented in Table 2-1. The slope rise (%) for each HRU was determined using an ALOS 30mDTM and can be seen in Figure 2-6.

Table 2-1: Sub-catchments and summary of land cover types

Sub-Catchment		HRU1	HRU2	HRU3	HRU4	HRU5
Area (km²)		30.08	45.62	50.29	21.738	53.932
Longest Drainage Line (km)		9.92	15.91	17.87	4.87	9.47
Average Slope (%)		0.46%	0.45%	0.48%	0.56%	0.45%
Slope (%)	<3	78.56%	80.65%	74.33%	82.01%	80.17%
	3-10	19.88%	18.19%	22.01%	16.51%	19.02%
	10-30	1.49%	1.13%	2.94%	1.48%	0.81%
	>30	0.07%	0.02%	0.72%	0.00%	0.00%
Land Cover	Thick bush & plantation	0.02%	0.24%	0.01%	0.00%	0.01%
	Light bush & farmlands	93.67%	94.78%	91.76%	97.25%	94.66%
	Grasslands	1.48%	0.25%	1.82%	0.00%	2.44%
	No Vegetation	4.84%	4.72%	6.41%	2.75%	2.89%

2.3 Local geology

According to the 3024 Colesberg – 1:250 000 Geological map series and 1:1 000 000 series geology map for the greater project area (DMEA, 1998; ESRI Geology Map Series, 2022), the geology of the study area can be described as flat-lying sedimentary rocks of the Karoo Supergroup, which have been intruded by innumerable sills and dykes of dolerite – refer to Figure 2-7.

The lithology of the site is as follows (DMEA, 1998):

- Quaternary aged alluvium:
  - These are water-transported sediments, primarily from the weathering of the underlying sedimentary rock, that are deposited along major and secondary rivers in the project area. The alluvium, where it is thick enough, may likely yield water throughout the year even for dry ephemeral streams.
- Sedimentary rock of the Adelaide Sub-Group, of the Beaufort Group (Pa):
  - The Adelaide Subgroup is divided into four formations of which the Koonap, Middleton, and Balfour Formations form part of the proximal facies and the Normandien.
  - Formation that of the distal facies (north-eastern area of the Karoo Basin). The Subgroup attains a maximum thickness of approximately 5 000 m in the south-eastern area of the Karoo Basin and rapidly decreases towards the north to approximately 800 m. The Koonap and Middleton Formations form a single fining upward unit consisting of mudstone and sandstones, where the red mudstones of the Middleton Formation distinguish it from the lower- and upper-lying formations (Koonap & Balfour Formations). The mudstones of the rest of the Adelaide Subgroup are generally greenish-grey. The mudrocks of the Adelaide Subgroup are generally massive and blocky weathering except in parts of the Normandien Formation where horizontal lamination is common. The sandstones of the Normandien Formation are coarse-to-very coarse-grained whereas the other Formations consist of fine- to very fine-grained sandstones (Lourens, 2013).
- Sedimentary rock off the Tierberg sub-Group, of the Ecca Group (Pt):
  - The Tierberg Formation occurs in the western and northern regions of the Karoo Basin where it conformably overlies the Collingham Formation (south of 32°E) and the Whitehill Formation (north of 32°E) and grades upward into the Waterford Formation, or where it is absent, into the Adelaide Subgroup of the Beaufort Group.

    - The Formation consists predominantly of dark grey to greenish-grey shale with interbedded siltstone and very- to fine-grained sandstone towards the top of the Formation with yellowish tuff beds up to 10 cm thick in the lower part of the succession. The thickness of the Tierberg Formation reaches a maximum of approximately 750 m along the western margin of the basin, thinning to about 350 m towards the northeast. The Formation is the chronological equivalent of the Collingham, Vischkuil, Laingsburg, Ripon and Fort Brown Formations in the south of the Karoo Basin (Lourens, 2013).
- Dolerite dykes and sills (Jd):
    - Dolerite occurrences are sandwiched between the sedimentary rock associated with the project area, and in some areas have intruded to be above the sedimentary rock in isolated sills. The intrusions followed existing bedding planes or fault zones, in the form of thin or thick dykes. The zones associated with the contact between the dolerite rock and host rock are often targeted for groundwater development, specifically in the Karoo Basin.

2.4 Soils

According to the Land types of South Africa databases (ARC, 2006), the soils in the area fall within the Ae land type. These are typically freely drained, red, eutrophic, apedal soils that comprise >40% of the land type (yellow soils comprise <10%). Calcrete soils are also prevalent as a result of the climatic conditions and underlying parent material.

2.5 Climate

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

2.5.1 Temperature

The average yearly temperature (refer to Figure 2-1) for the project area ranges from 15 to 36 C (high) and -4 to 16 °C (Low). The study area is situated in a cold semi-arid (steppe) climate (BSk) as per the Köppen Climate Classification (Kottek, et al., 2006). Hence, the area receives more rainfall in the high-sun half of the year (October through March in the Southern Hemisphere). The area falls within a spring-to-summer rainfall area.

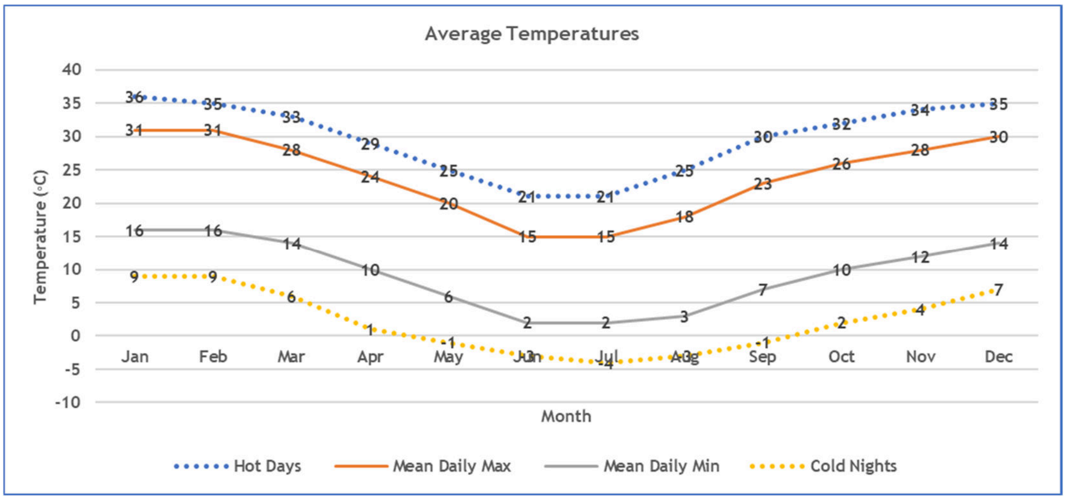


Figure 2-1: Average yearly temperatures (Meteoblue, 2021)

2.5.2 Wind speed and direction

Figure 2-2 shows the wind rose for the project area (the site used as a reference site) and presents the number of hours per year the wind blows from the indicated direction. Wind generally blows from all directions, with predominant stronger winds more frequently coming from ESE, ENE and W directions.

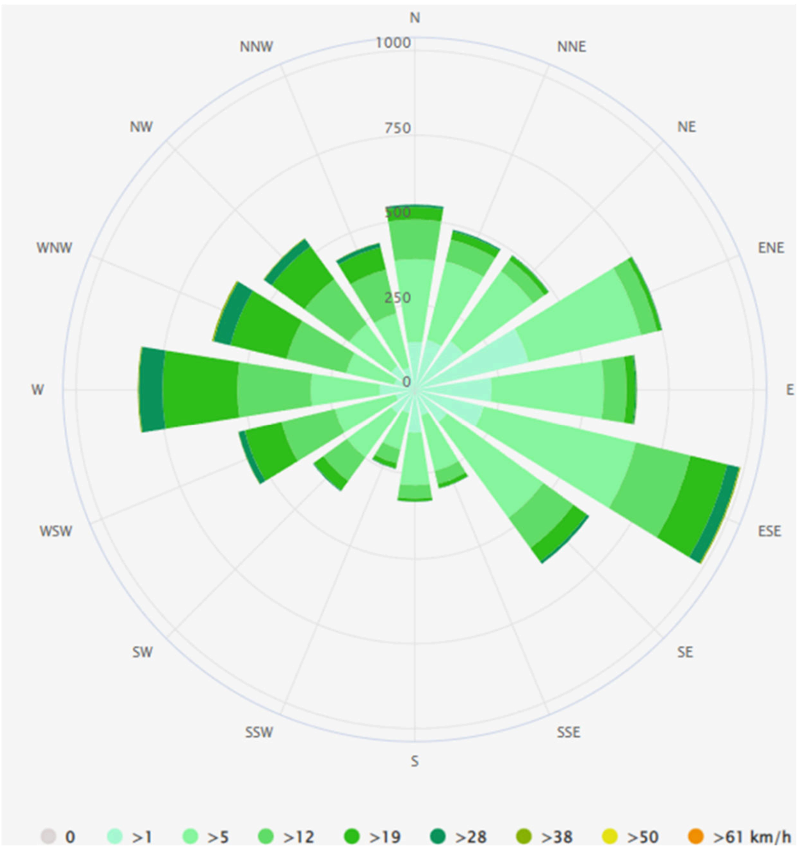
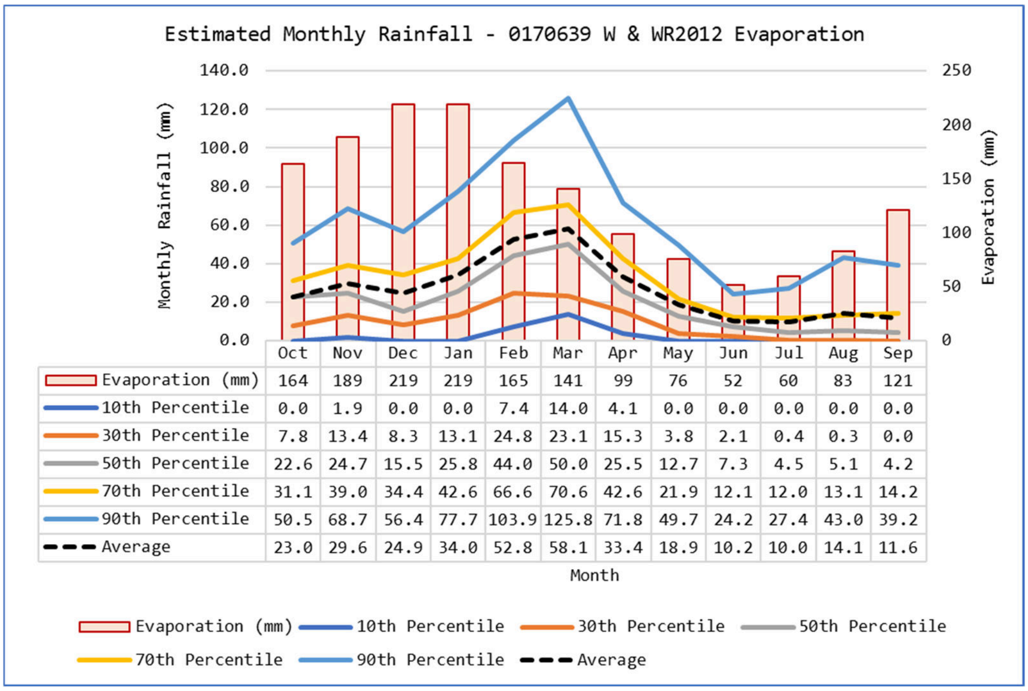


Figure 2-2: Wind rose (Meteoblue, 2021)

2.5.3 Rainfall and evaporation

The project area is situated in rainfall zone D6C. The rainfall data used to calculate Mean Annual Precipitation (MAP) was obtained from rainfall station 0170639W (station Rooiwal situated 12km N of the site). Available rainfall data suggest a MAP ranging from 112.4 (30^{th} percentile) to 738.9 (90^{th} percentile) mm/yr, based on a historical record of 69 years (i.e., 1920 to 1989). The average rainfall is in the order of 320 mm/yr. Design rainfall data (Station: Rooiwal) suggest a MAP in the order of 319 mm/yr - hence the data is in the same order of magnitude. Monthly rainfall for the site is likely to be distributed as shown in Figure 2-3, below.

The site falls within evaporation zone 17A, of which Mean Annual Evaporation (MAE) ranges from 2 000 to 2 150 mm/yr. The MAE far exceeds the MAP for the site, which implies greater evaporative losses when compared to incident rainfall. Due to evaporation being about 85% more than local rainfall, non-perennial streams and rivers will only have water when there are flooding events (i.e., 1:2, 1:5, 1:50 and 1:100 year flood events). Monthly evapotranspiration for the site is likely to be distributed as shown in Figure 2-3, below.

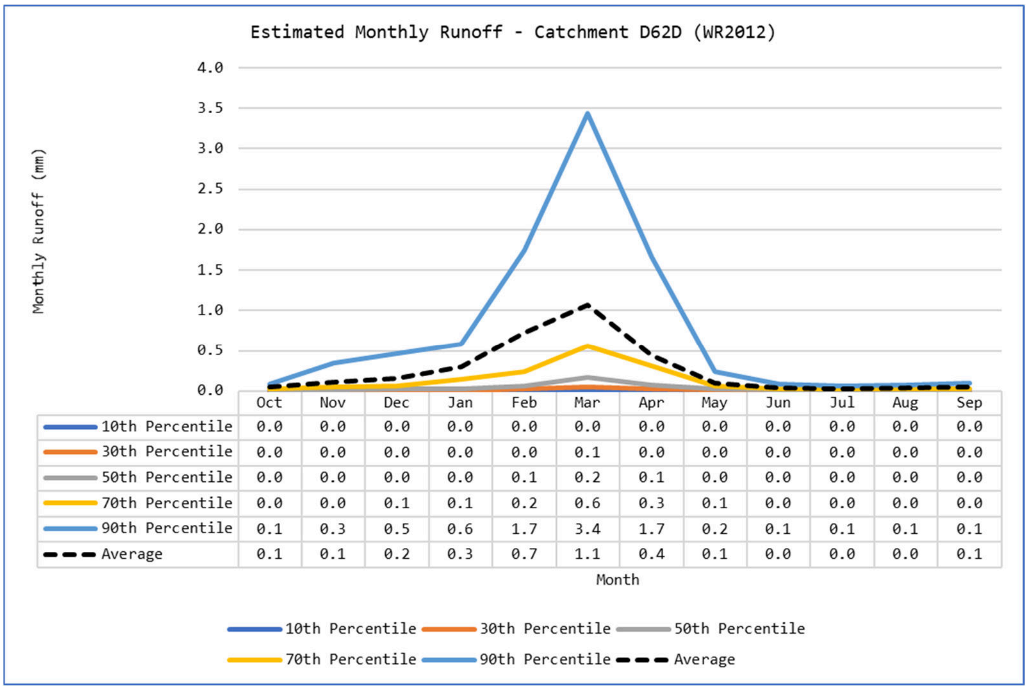


	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Evaporation (mm)	164	189	219	219	165	141	99	76	52	60	83	121
10th Percentile	0.0	1.9	0.0	0.0	7.4	14.0	4.1	0.0	0.0	0.0	0.0	0.0
30th Percentile	7.8	13.4	8.3	13.1	24.8	23.1	15.3	3.8	2.1	0.4	0.3	0.0
50th Percentile	22.6	24.7	15.5	25.8	44.0	50.0	25.5	12.7	7.3	4.5	5.1	4.2
70th Percentile	31.1	39.0	34.4	42.6	66.6	70.6	42.6	21.9	12.1	12.0	13.1	14.2
90th Percentile	50.5	68.7	56.4	77.7	103.9	125.8	71.8	49.7	24.2	27.4	43.0	39.2
Average	23.0	29.6	24.9	34.0	52.8	58.1	33.4	18.9	10.2	10.0	14.1	11.6

Figure 2-3: Rainfall distribution (station 0170639W) (WRC, 2015)

2.5.4 Runoff

Runoff from natural (unmodified) catchments in Catchment D62D is simulated in WR2012 as being equivalent to 3.1 mm/yr over the surface area (WRC, 2015). This is equal to approximately 0.9% of the MAP and amounts to approximately 7.4 Mm^3/yr over the surface of the quaternary catchment. Runoff is directly related to rainfall intensity, and longer precipitation events, closure rainfall occurrences/frequencies and precipitation intensity events will drive runoff formation. Monthly runoff is distributed as shown in Figure 2-4, below.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
10th Percentile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30th Percentile	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
50th Percentile	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0
70th Percentile	0.0	0.0	0.1	0.1	0.2	0.6	0.3	0.1	0.0	0.0	0.0	0.0
90th Percentile	0.1	0.3	0.5	0.6	1.7	3.4	1.7	0.2	0.1	0.1	0.1	0.1
Average	0.1	0.1	0.2	0.3	0.7	1.1	0.4	0.1	0.0	0.0	0.0	0.1

Figure 2-4: Simulated runoff for quaternary catchment D62D (WRC, 2015)

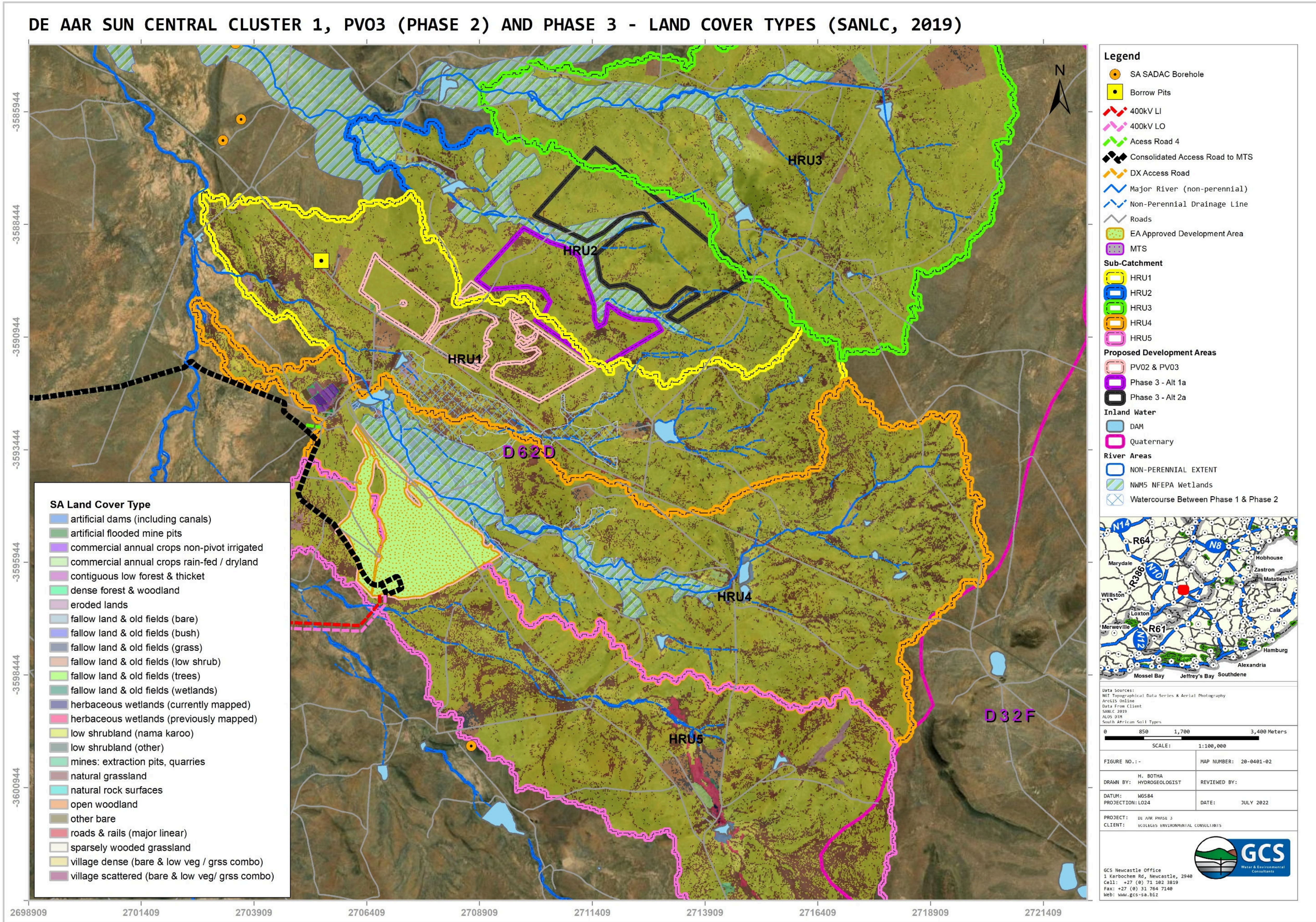


Figure 2-5: Sub-catchment land cover

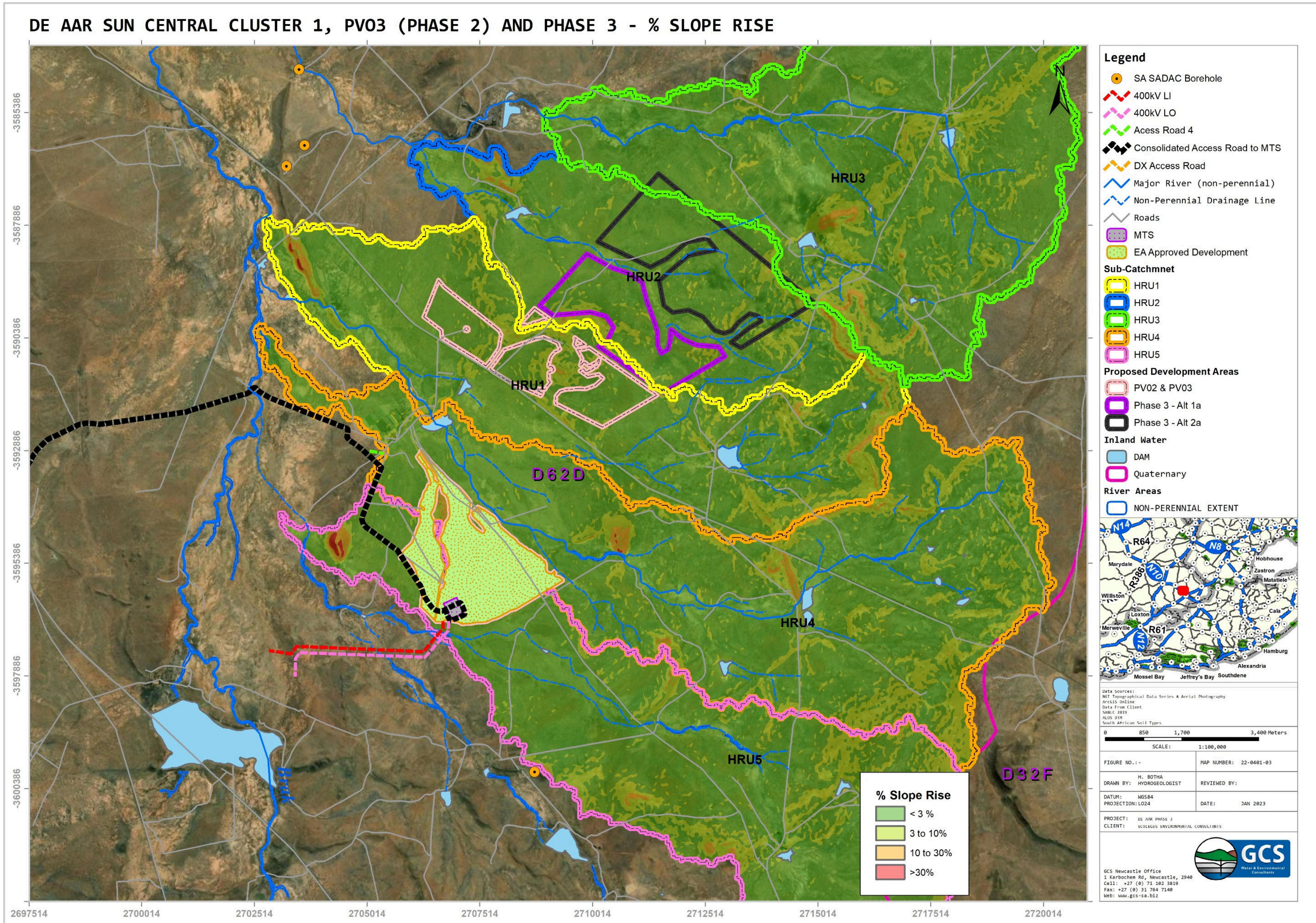


Figure 2-6: Sub-catchment slope rise (%)

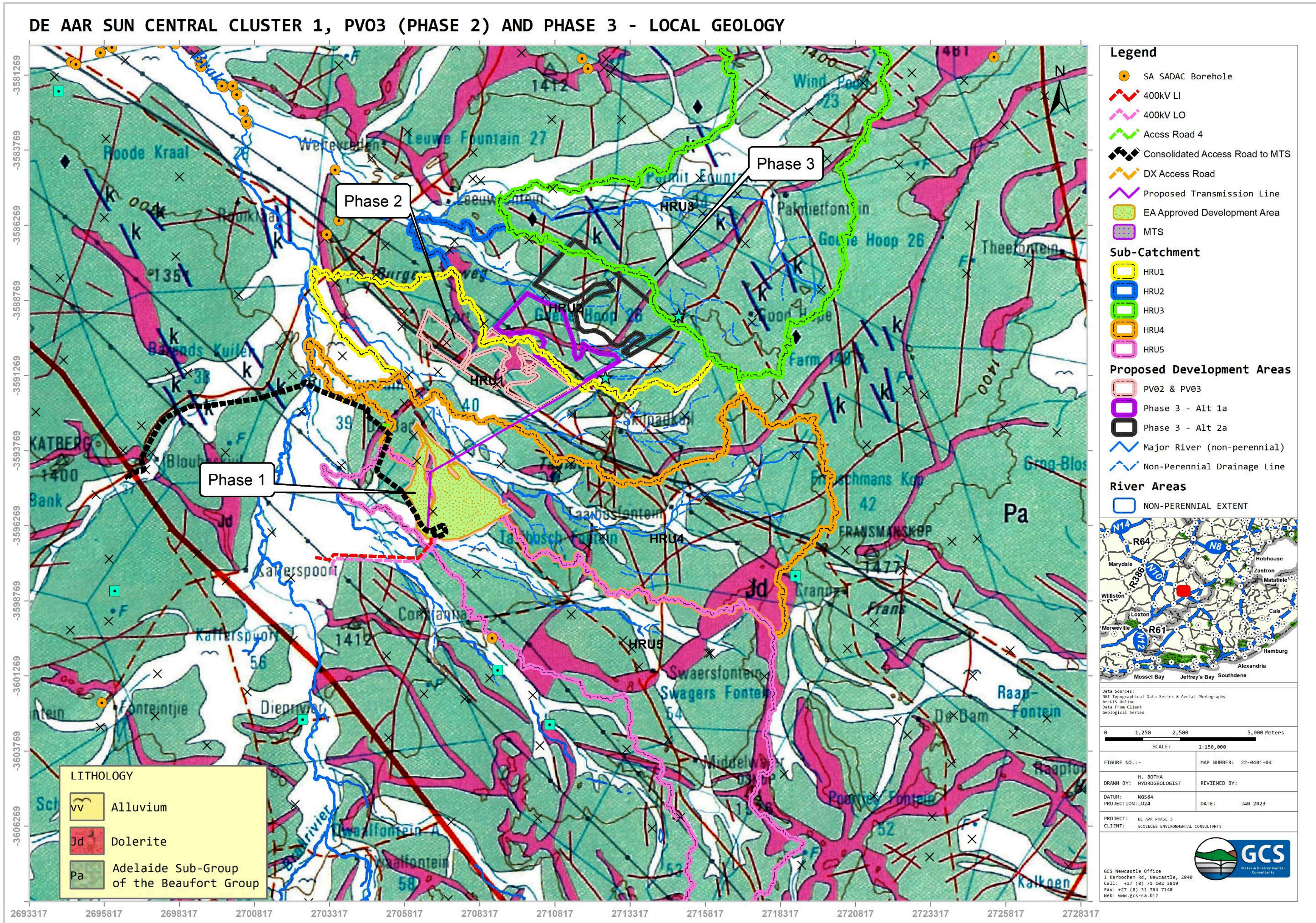


Figure 2-7: Local geology

3 SCOPE OF WORK

The scope of work completed, was as follows:

1. **Baseline hydrology review:**
    a. Hydro-meteorological data collection and analysis.
    b. Catchment delineation and drainage characteristics.
    c. Determination of catchment hydraulic and geometric parameters.
2. **Desktop assessment**
    a. All available reports relating to the site were assessed, including a review of all geohydrology, hydrology, hydrochemistry, and geology literature data.
    b. A desktop-level hydrocensus was conducted. The National Groundwater Archive (NGA, 2022), Groundwater Resource Information Project (GRIP, 2016) and the Southern African Development Community Groundwater Information Portal (SADAC GIP) databases were assessed to identify existing groundwater users in the area.
3. **Field investigation:**
    a. A site walk-over assessment was undertaken to map sensitive groundwater-surface water interaction zones identified on a desktop level. Water quality samples were collected to illustrate the hydrochemical status of the aquifer in the area.
    b. A groundwater hydrocensus was conducted within a 2.5 km radius of the proposed development areas (within the sphere of influence / sub-catchment).
    c. A geophysical survey with the use of the magnetic method was conducted in several areas, to identify potential future groundwater drilling positions for supplementary groundwater for the construction and operational phases of the project.
    d. Several constant drawdown pump tests were conducted on boreholes that were identified for water use as part of this project (in Phases 1, 2 and 3). The aim was to determine the sustainable yields and volumes attainable from the tested boreholes.
4. **Hydrogeological and geological conceptual model:**
    a. A hydrogeological and geological site conceptual model was developed with data obtained for the study area.
5. **Hydrogeological risk and impact assessment:**

   a. A preliminary risk assessment was conducted based on the source-pathway-receptor principle.

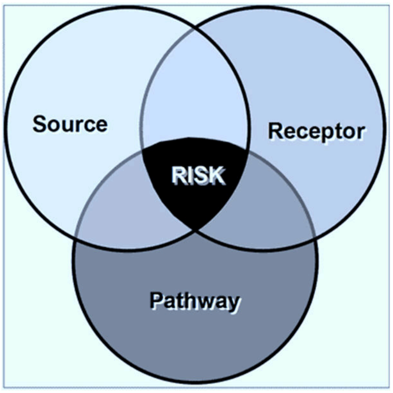
6. **Monitoring plan:**
   a. A groundwater monitoring plan, with mitigation measures, was developed for the site based on the baseline assessment of the site conditions.

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

4 METHODOLOGY

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

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



The approach will be used to assess:

1. How the existing/proposed site activities could impact groundwater *Quality*; and
2. How the existing/proposed site activities could affect the groundwater *Quantity*.

4.1 Literature review

The following sources will be evaluated to provide an overview of the geohydrological conditions of the project area:

- Groundwater Resource Information Project (GRIP, 2016) borehole data.
- National Groundwater Database Archives (NGA, 2022) borehole data.
- SADC Groundwater Information Portal (SADAC GIP, 2022) borehole data.
- 2924 Bloemfontein – 1:500 000 Hydrogeological map series (Meyer, P.S., Chetty, T., Jonk, F., 2002).
- 3024 Colesberg – 1:250 000 Geological map series (DMEA, 1998).
- Literature on similar geology and hydrogeology:
  - A South African Aquifer System Management Classification (Parsons, 1995);

- Aquifer Classification of South Africa (DWA, 2012);
- Karoo Aquifers: Their Geology, Geometry and Physical Properties. Water Research Council (WRC) Report No: 457/1/98 (Botha, et al., 1998);
- Karoo Groundwater Atlas Volume 2 (Woodford, 2013); and
- The relationship between South African geology and geohydrology (Lourens, 2013).

- GCS internal database and reports for the project area.
- Data generated in the field.

4.2 Groundwater users in the study area (desktop overview)

Based on available South African and National groundwater databases for the project area and considering a **15km** buffer area around the proposed development, several groundwater users were identified. Table 4-1 lists the boreholes identified and their location is shown in Figure 2-7.

Table 4-1: Boreholes identified in the project area – desktop level (only boreholes with data presented)

ID	Source	Latitude (WGS84) Decimal Degrees	Longitude (WGS84) Decimal Degrees	Elevation (mamsl)	Water Level (mbgl)
777324	SADAC GIP	-30.74499	24.20733	1274	10.6
777370	SADAC GIP	-30.74499	24.20733	1274	5.9
777383	SADAC GIP	-30.74249	24.20955	1272	10
777469	SADAC GIP	-30.74249	24.20899	1272	6
777470	SADAC GIP	-30.74249	24.24261	1299	5.4
777471	SADAC GIP	-30.74249	24.20927	1272	5.7
777643	SADAC GIP	-30.72594	24.21844	1272	6.8
777645	SADAC GIP	-30.72594	24.21853	1272	6.8
777648	SADAC GIP	-30.72667	24.21899	1271	6.6
777649	SADAC GIP	-30.72667	24.21899	1271	6.7
777650	SADAC GIP	-30.72667	24.21899	1271	6.7
777651	SADAC GIP	-30.72667	24.21899	1271	6.6
777652	SADAC GIP	-30.7461	24.22038	1277	8.1
777690	SADAC GIP	-30.72584	24.21844	1272	6.8
777691	SADAC GIP	-30.72667	24.21899	1271	6.6
777692	SADAC GIP	-30.72667	24.21899	1271	6.7
777747	SADAC GIP	-30.73361	24.33289	1349	4.6
777748	SADAC GIP	-30.73361	24.3329	1349	5.2
777749	SADAC GIP	-30.73362	24.33289	1349	4.6
777751	SADAC GIP	-30.73363	24.33289	1349	4.6
777752	SADAC GIP	-30.73361	24.33292	1351	4.6
777755	SADAC GIP	-30.73365	24.33289	1349	4.6
777756	SADAC GIP	-30.73361	24.33294	1351	6.1
777757	SADAC GIP	-30.73366	24.33289	1349	6.1
777758	SADAC GIP	-30.73361	24.33295	1351	6.1
777759	SADAC GIP	-30.73367	24.33289	1349	6.1
777762	SADAC GIP	-30.73368	24.33289	1349	4.8
777767	SADAC GIP	-30.68361	24.3329	1444	9
777768	SADAC GIP	-30.68363	24.33289	1444	5
777772	SADAC GIP	-30.71265	24.28776	1318	9
777773	SADAC GIP	-30.72627	24.34646	1354	7.1
777779	SADAC GIP	-30.71246	24.27811	1311	9.6
777785	SADAC GIP	-30.72667	24.34178	1350	0.2
777789	SADAC GIP	-30.71125	24.27621	1310	5.7
777790	SADAC GIP	-30.70806	24.27567	1311	5
777795	SADAC GIP	-30.70389	24.26762	1305	3.8
777799	SADAC GIP	-30.70667	24.2765	1308	6.1
777802	SADAC GIP	-30.74805	24.36678	1369	7.7
777814	SADAC GIP	-30.74777	24.36678	1369	13.9

ID	Source	Latitude (WGS84) Decimal Degrees	Longitude (WGS84) Decimal Degrees	Elevation (mamsl)	Water Level (mbgl)
777822	SADAC GIP	-30.8261	24.18344	1318	3.4
777823	SADAC GIP	-30.8261	24.18344	1318	3.3
777824	SADAC GIP	-30.8261	24.18344	1318	3.4
777825	SADAC GIP	-30.8261	24.18344	1318	3.4
777826	SADAC GIP	-30.8261	24.18344	1318	4.4
777827	SADAC GIP	-30.76944	24.24594	1283	4.2
777828	SADAC GIP	-30.76851	24.24556	1284	4.1
777829	SADAC GIP	-30.76944	24.24594	1283	4.3
777830	SADAC GIP	-30.76944	24.24594	1283	4.7
777831	SADAC GIP	-30.7636	24.23816	1282	5.2
777832	SADAC GIP	-30.7636	24.23816	1282	25.6
777833	SADAC GIP	-30.7636	24.23816	1282	3.8
777834	SADAC GIP	-30.7636	24.23816	1282	4.3
777835	SADAC GIP	-30.7636	24.23816	1282	3.6
777836	SADAC GIP	-30.76944	24.24594	1283	10.1
777837	SADAC GIP	-30.76944	24.24594	1283	3.7
777842	SADAC GIP	-30.76155	24.22288	1278	6.7
777843	SADAC GIP	-30.76055	24.23094	1280	6
777847	SADAC GIP	-30.76333	24.23399	1277	7.7
777848	SADAC GIP	-30.76333	24.23399	1277	5.3
777850	SADAC GIP	-30.76249	24.22288	1283	6.4
777851	SADAC GIP	-30.76249	24.22288	1283	6.4
777852	SADAC GIP	-30.76888	24.20844	1281	7.3
777853	SADAC GIP	-30.76055	24.23094	1280	5.5
777854	SADAC GIP	-30.76194	24.22288	1278	5.8
777855	SADAC GIP	-30.8261	24.18344	1318	3.4
777856	SADAC GIP	-30.8261	24.18344	1318	3.4
777857	SADAC GIP	-30.8261	24.18344	1318	3.3
777858	SADAC GIP	-30.8261	24.18344	1318	3.4
777859	SADAC GIP	-30.8261	24.18344	1318	4.4
777860	SADAC GIP	-30.75916	24.22761	1275	6.2
777863	SADAC GIP	-30.81277	24.28345	1299	3.5
777864	SADAC GIP	-30.81277	24.28345	1299	3.2
777866	SADAC GIP	-30.81277	24.28345	1299	3.5
777867	SADAC GIP	-30.81277	24.28345	1299	3.8
777868	SADAC GIP	-30.7961	24.28595	1297	3.4
777869	SADAC GIP	-30.7961	24.28595	1297	3.4
777870	SADAC GIP	-30.80916	24.28706	1302	6.3
777872	SADAC GIP	-30.80916	24.28706	1302	6.1
777873	SADAC GIP	-30.77471	24.25262	1285	4.6
777874	SADAC GIP	-30.77444	24.25205	1284	4.7
777875	SADAC GIP	-30.77444	24.25539	1287	5.9
777876	SADAC GIP	-30.77666	24.2565	1286	2.4
777877	SADAC GIP	-30.78083	24.25845	1286	3.5
777880	SADAC GIP	-30.78083	24.25845	1286	3.3
777881	SADAC GIP	-30.78083	24.25845	1286	3.2

4.3 Field investigation

The field investigation took place from 23 to 27 May 2022, with follow-up pump test work the week of 19 to 22 July 2022. A photographic log of photos taken during the field investigation is available in **Appendix A**. The following summarises the findings and work completed:

1. A hydrocensus was undertaken within the project area and within a 2.5km radius of the proposed development areas, within the sub-catchments associated with the project. The sub-catchments form the sphere of influence for the hydrogeology flow regime and can be considered conceptual aquifer boundaries.

    a. 28 boreholes were identified in the study area, of which 13 are used for livestock watering and 6 for domestic use.

    b. Eight (8) samples were collected and submitted to a SANS-accredited laboratory for analytical screening.

2. A geophysical assessment with the use of magnetic methods was undertaken in 3 areas (near PV02 (Phase 1), PVO3 (Phase 2) and Phase 3) to identify potential high-yielding drilling target areas.
   a. A total of 34 potential drilling targets were identified, of which all are considered low to moderately feasible, except 4 targets assigned higher feasibility based on the geophysical data collected.
3. Six (6) boreholes were tested, two (2) in Phase 1 (Solar BH5 and BH13), two (2) in Phase 2 (Solar BH1 and Solar BH2), and two (2) in Phase 3 (BH4 and BH5). The testing findings are summarised in Section 4.3.

4.3.1 Field hydrocensus boreholes

Table 4-3 provides a summary of the hydrocensus boreholes identified in the project area. As stated above, the majority of the boreholes are used for livestock watering. The boreholes were identified to target the known dolerite dykes which exist in the project area. The farm De Bad has a high groundwater potential, and it should further be noted that there are three (3) springs (known as Die Fontein, Die Bad Fontein and Huis Fontein) which feed two (2) livestock watering dams near the main farmhouse (refer to Table 4-2). Boreholes identified in the project area are shown in Figure 4-1.

Table 4-2: Summary of springs identified in the project area

ID	Latitude (WGS84) Decimal Degrees	Longitude (WGS84) Decimal Degrees	Comment
Spring / Fontein	-30.8552	24.30640	78 688 l/hr (Die Bad)
Die Fontein	-30.8557	24.31200	120 000 l/hr (piped to dam)
Huis Fontein	-30.8594	24.30520	17 000 l/hr

Table 4-3: Summary of field hydrocensus boreholes identified in the project area *grey are pump tested

ID	Area	Latitude (WGS84) Decimal Degrees	Longitude (WGS84) Decimal Degrees	Elevation (mamsl)	Collar (m)	Water Level (mbcl)	Comment
Farmhouse Windmill	Phase 1	-30.859824	24.304545	1317	0.3	3	Pumps to water storage dam for irrigation.
Farmhouse Borehole 1	Phase 1	-30.86006	24.304732	1317	0.69	3.79	pumps to a water storage tank for domestic use.
Farmhouse Borehole 2	Phase 1	-30.860176	24.304801	1319	0.255	3.03	pumps to a water storage tank for domestic use.
Farmhouse Borehole 3	Phase 1	-30.859783	24.30565	1319	0.44	2.68	Not Used (backup)
Farmhouse Borehole 4	Phase 1	-30.859707	24.305267	1319	0.43	2.47	pumps to a water storage tank for domestic use.
Community Borehole 1	Phase 1	-30.861158	24.302765	1318	0.2	4.57	pumps to a water storage tank used by farm workers.
Livestock Borehole 1 (Solar Pump)	Phase 1	-30.861823	24.302079	1319	0.2	3.195	Used for livestock watering
Livestock Borehole 2	Phase 1	-30.861699	24.302989	1320	0.46	4.34	Used for livestock watering
Livestock Borehole 3	Phase 1	-30.861712	24.303115	1320	0.2	4.36	Not Used (backup)
Livestock Borehole 4	Phase 1	-30.861785	24.30308	1320	0.2	4.4	Not Used (backup)
Community Borehole 2	Phase 1	-30.860281	24.30396	1320	0.2	2.31	Not Used (backup)
Solar Borehole 1 (BH1)	Phase 2	-30.851277	24.334566	1333	0	4.28	Used for livestock watering. pH = 6, EC = 600 uS/cm, Temp = 12.7. Auto logger installed at 12m.
Windmill 1 (BH4)	Phase 3	-30.828809	24.348689	1332	0.2	4.15	Used for livestock watering. pH = 6.3, EC = 650 uS/cm, Temp = 9.6.
Windmill 2 (BH5)	Phase 3	-30.824873	24.368173	1350	0.12	8.84	pH = 6.4, EC = 530 uS/cm, Tep = 7.3

ID	Area	Latitude (WGS84) Decimal Degrees	Longitude (WGS84) Decimal Degrees	Elevation (mamsl)	Collar (m)	Water Level (mbcl)	Comment
Windmill 3	Phase 2	-30.835772	24.330404	1333			No access to WL or Quality
Solar Borehole 2 (BH2)	Phase 2	-30.840681	24.319462	1321	0.28	11	Used for livestock watering. pH = 6.5, EC = 740 uS/cm, Temp = 18.3. Auto Logger installed at 20m.
Field Borehole 1	Phase 1	-30.856031	24.307938	1319	0.26	4.45	Not Used (backup)
Old Windmill 1	Phase 1	-30.854071	24.31068	1317			No access to WL or Quality
Borehole 14	Phase 1	-30.859271	24.317607	1322	0.515	3.77	Not Used. Near Phase 1. Can be used if required. Drilled into the same dolerite dyke as BH13 and will likely yield the same as BH13. No influence was noted during pumping.
Solar Borehole 6	Phase 1	-30.856677	24.306986	1318	0.43	6.52	Used for livestock watering
Borehole Dam Backup 1	Phase 1	-30.856589	24.306435	1316	0.2	4.75	Not Used (backup)
Solar Borehole 7	Phase 1	-30.856959	24.307939	1320	0.34	5.51	Used for livestock watering
Solar Borehole 3	Phase 1	-30.857577	24.30863	1321	0.44	5.62	Used for domestic and livestock
Solar Borehole 3.2 (Backup)	Phase 1	-30.857645	24.308698	1321	0.47	4.78	Not used (Backup)
Windmill 4	Phase 1	-30.8636	24.307778	1321			No access to WL or Quality
Solar Borehole 4	Phase 1	-30.871571	24.310588	1330	0.25	12.265	Used for livestock watering at a yield of 0.5 l/sec. Can be used if required.
Solar Borehole 5	Phase 1	-30.88434	24.31464	1335	0	16.6	Used for livestock watering. pH = 6.8, EC = 810 uS/cm, Temp = 16.8
Borehole 13	Phase 1	-30.859654	24.317973	1321	0.56	3.725	Not used. Near Phase 1. Can be used if required. Pump tested. Pump installed @ 24mbgl, depth of hole 28m. pH = 6.9, EC = 670 uS/cm, Temp = 19.9

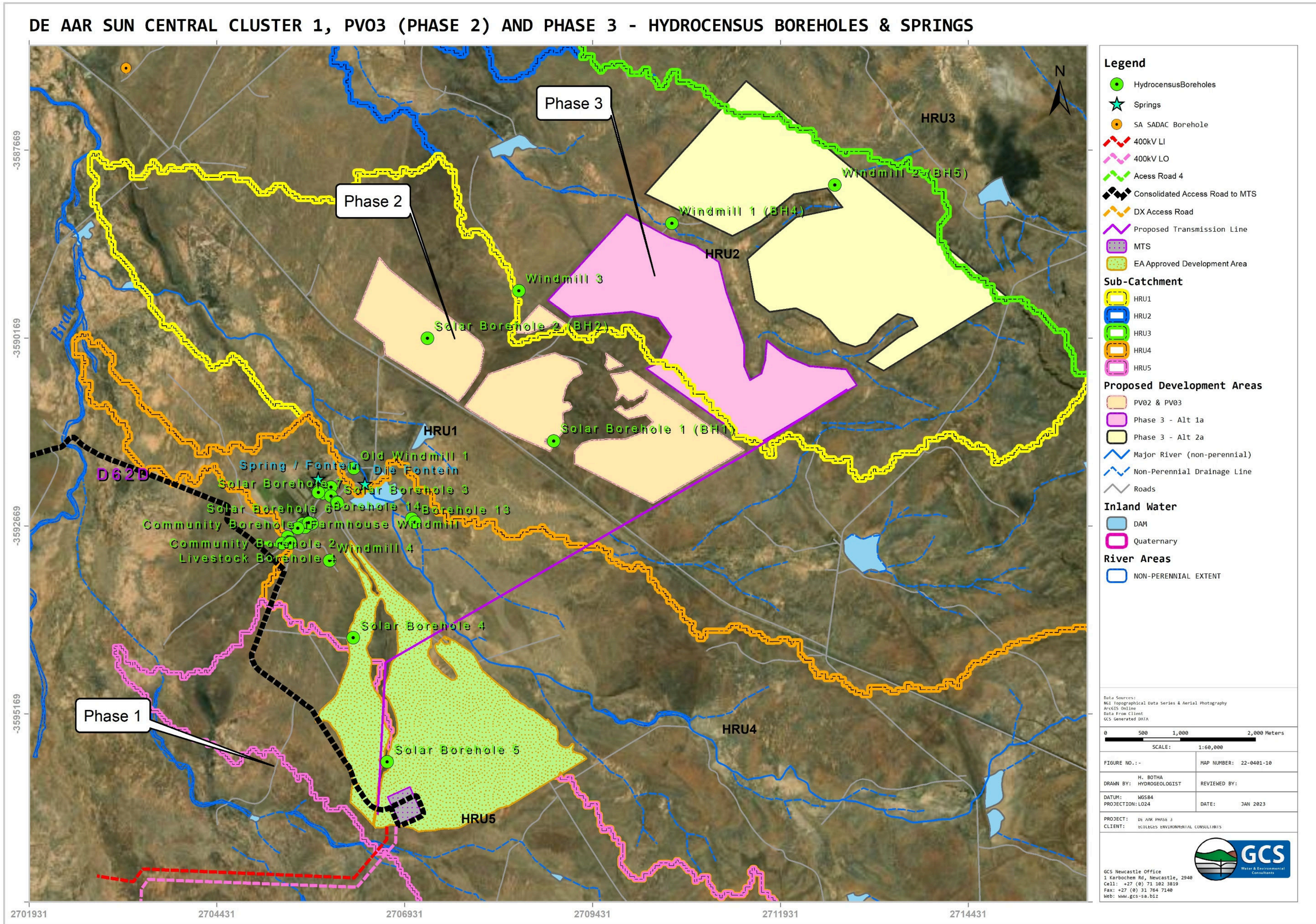


Figure 4-1: Boreholes and springs identified in the project area

4.3.2 Geophysical assessment findings

The geophysical investigation aimed to identify likely dolerite contact zones or lineaments that may intersect/underlie the study area. These are known preferential flow paths for groundwater movement. The detailed geophysical investigation methodology and data interpretation are available in **Appendix B**. The findings are briefly summarised as follows:

- Five (5) Magnetic (Mag) profiles were completed. The Mag traverse varied from approximately 200 m in length. Mag readings were taken at 5 m intervals. The spatial orientation of the survey and resulting profile lines are indicated in Figure 4-2 and Figure 4-3.
- Based on the findings of the geophysical investigation and viewed in context to the local geology, several likely contact zones between the host sandstones/mudstone and intrusive rock bodies (dykes) are observed.
- The following drilling positions (refer to Table 4-4) can be considered for future water supply – high feasibility. The boreholes target the contacts between the dolerite dykes identified in the survey areas and the host rock. Table 4-5 presents low – medium feasibility drilling positions identified during the survey.

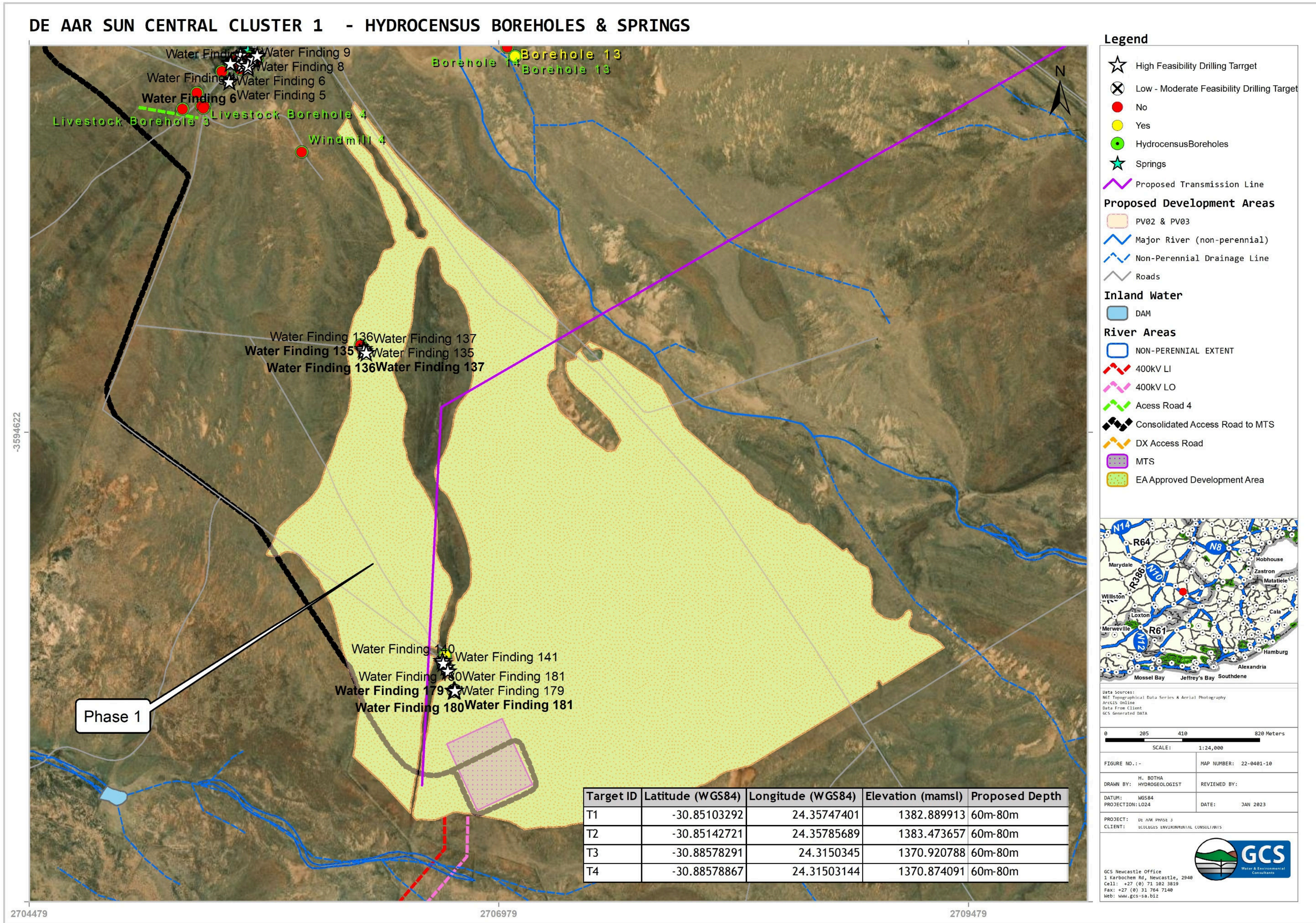
Table 4-4: Proposed drilling targets – higher feasibility

Target ID	Latitude (WGS84)	Longitude (WGS84)	Elevation (mamsl)	Proposed Depth
T1	-30.851	24.35747	1382.89	60m-80m
T2	-30.8514	24.35786	1383.474	60m-80m
T3	-30.8858	24.31503	1370.921	60m-80m
T4	-30.8858	24.31503	1370.874	60m-80m

Table 4-5: Proposed drilling targets – low to moderate feasibility

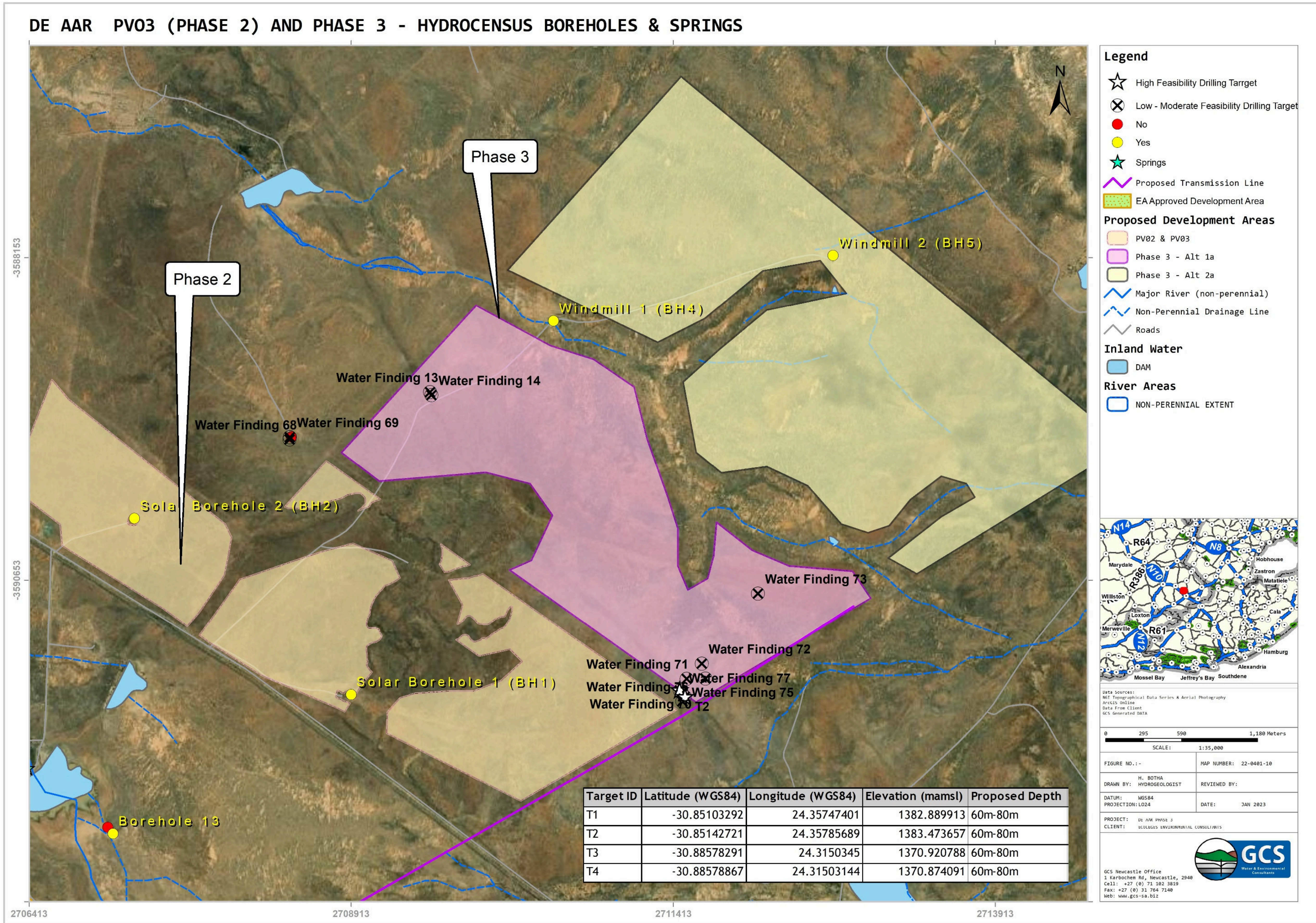
Target ID	Latitude (WGS84)	Longitude (WGS84)	Elevation (mamsl)	Proposed Depth
Water Finding 1	-30.85991	24.30440	1346.898	60m-80m
Water Finding 2	-30.85961	24.30485	1355.575	60m-80m
Water Finding 3	-30.86004	24.30501	1353.19	60m-80m
Water Finding 4	-30.85997	24.30490	1336.318	60m-80m
Water Finding 5	-30.86069	24.30433	1368.5	60m-80m
Water Finding 6	-30.86069	24.30431	1348.851	60m-80m
Water Finding 7	-30.86014	24.30521	1345.082	60m-80m
Water Finding 8	-30.86004	24.30521	1331.912	60m-80m
Water Finding 9	-30.85973	24.30551	1352.111	60m-80m
Water Finding 10	-30.85977	24.30548	1347.81	60m-80m
Water Finding 11	-30.85962	24.30565	1349.03	60m-80m
Water Finding 12	-30.85994	24.30437	1346.752	60m-80m
Water Finding 13	-30.83309	24.34007	1368.452	60m-80m
Water Finding 14	-30.83326	24.34017	1368.253	60m-80m
Water Finding 68	-30.83593	24.33028	1367.299	60m-80m
Water Finding 69	-30.83580	24.33030	1366.997	60m-80m
Water Finding 70	-30.85103	24.35748	1381.794	60m-80m
Water Finding 71	-30.85033	24.35797	1378.153	60m-80m
Water Finding 72	-30.84942	24.35902	1377.608	60m-80m
Water Finding 73	-30.84520	24.36294	1378.253	60m-80m
Water Finding 74	-30.85032	24.35928	1383.109	60m-80m
Water Finding 75	-30.85142	24.35783	1384.496	60m-80m
Water Finding 76	-30.85168	24.35767	1382.768	60m-80m
Water Finding 77	-30.85115	24.35761	1386.292	60m-80m
Water Finding 135	-30.87172	24.31073	1363.774	60m-80m
Water Finding 136	-30.87181	24.31076	1361.936	60m-80m

Target ID	Latitude (WGS84)	Longitude (WGS84)	Elevation (mamsl)	Proposed Depth
Water Finding 137	-30.87188	24.31086	1361.995	60m-80m
Water Finding 138	-30.88483	24.31469	1375.912	60m-80m
Water Finding 139	-30.88458	24.31450	1371.679	60m-80m
Water Finding 140	-30.88467	24.31455	1369.041	60m-80m
Water Finding 141	-30.88500	24.31477	1369.499	60m-80m
Water Finding 179	-30.88580	24.31504	1371.427	60m-80m
Water Finding 180	-30.88580	24.31506	1371.296	60m-80m
Water Finding 181	-30.88579	24.31511	1371.959	60m-80m



Target ID	Latitude (WGS84)	Longitude (WGS84)	Elevation (mamsl)	Proposed Depth
T1	-30.85103292	24.35747401	1382.889913	60m-80m
T2	-30.85142721	24.35785689	1383.473657	60m-80m
T3	-30.88578291	24.3150345	1370.920788	60m-80m
T4	-30.88578867	24.31503144	1370.874091	60m-80m

Figure 4-2: Geophysical investigation areas and proposed drilling targets (Phase 1)



Target ID	Latitude (WGS84)	Longitude (WGS84)	Elevation (mamsl)	Proposed Depth
T1	-30.85103292	24.35747401	1382.889913	60m-80m
T2	-30.85142721	24.35785689	1383.473657	60m-80m
T3	-30.88578291	24.3150345	1370.920788	60m-80m
T4	-30.88578867	24.31503144	1370.874091	60m-80m

Figure 4-3: Geophysical investigation areas and proposed drilling targets (Phase 2 and Phase 3)

4.3.3 Borehole yield testing

Constant discharge (CRD) and recovery tests were performed on the following boreholes:

- Solar BH3 in area PV1.
- Borehole 4 (BH4) in area Phase 3.
- Borehole 5 (BH5) in area Phase 3.
- Borehole 13 (BH13) in area PV1.
- Solar BH1 in area PV2.
- Solar BH2 in area PV2.

The results of pump test results and sustainable yields are summarised in Table 4-6. The flow characterisation (FC) method developed by the Institute of Groundwater Studies (IGS) was applied to the pump test data to evaluate the sustainable yield. The FC analyses of each borehole testing are available in Table 4-7 to Table 4-12. Based on the pump test data generated, an **8-hour abstraction is recommended**. However, smaller-size pumps (as indicated below) can be installed if 24hr pumping is required. This is however not advised, as the boreholes may be overpumped, decreasing the borehole life and increasing the probability of pump failure.

As part of the pump testing and data gathered, the following boreholes can be considered as additional water sources. Though these boreholes have not been pump tested, indicative yields based on field observations, local hydrogeology and pump test data for nearby boreholes are presented:

- **Borehole BH14 in Phase 1**
  - Expected yield 6 l/sec for 8 hours/day (172.8 m^3/day)
  - No interference on nearby BH13 was anticipated.
- **Solar BH4 in Phase 1**
  - Expected yield 0.5 l/sec for 8 hours/day (14.4 m^3/day).

Table 4-6: Summary of aquifer test results

BH ID		BH 13 (PV1)	Solar BH1 (PV2)	Solar BH2 (PV2)	BH 4 (Phase 3)	BH 5 (Phase 3)	Solar BH5 (PV1)
Date Started		26 May 2022	24 May 2022	25 May 2022	20 July 2022	19 July 2022	21 July 2022
Date Completed		26 May 2022	25 May 2022	26 May 2022	21 July 2022	20 July 2022	21 July 2022
Latitude	(WGS84)	-30.859654	-30.851277	-30.8406	-30.8288	-30.8250	-30.8843
Longitude	(WGS84)	24.317973	24.334566	24.3194	24.3486	24.3681	24.3146
Water Level	Metres below collar level (mbch)	3.725	4.049	10.24	3.32	8.84	10.23
Pump Depth	Metres below ground level (mbgl)	24	13	22	10	25	18
Available drawdown	(m)	20.275	8.72	11	6.68	16.16	7.77
Time Pumped	(min)	300min	480min	480min	750min	600min	80min
Rate (Q)	(L/s)	0.947	0.16	0.152	1.5	1.56	0.28
Pumped to	(m)	4.525	4.415	10.978	4.34	13.48	17.61
Total Drawdown	(m)	0.8	0.366	0.738	1.02	4.64	7.38
BH Depth	(mbgl)	28	14	24	11	42	18
Saturated thickness (est.)	(m)	10m	10m	10m	10m	>30m	10m
Rec time	(min)	60min	900min	900min	180min	12min	20min
Total Rec	(m)	3.91	4.049	10.24	3.38	8.64	10.23
% Recovery	(%)	95%	100%	100%	98%	102%	100%
Q Sustain	l/sec	6.64	0.45	0.21	6.58	5.11	0.23
Rec Pump Time	Hours	8.00	8.00	8.00	8.00	8.00	8.00
Q Sustain Total	m^3/day	191.23	12.96	6.05	189.50	147.17	6.62
Q Sustain Total	m^3/month	5736.96	388.80	181.44	5685.12	4415.04	198.72
Q Sustain	l/sec	3.83	0.26	0.12	3.80	2.95	0.13
Rec Pump Time	Hours	24.00	24.00	24.00	24.00	24.00	24.00
Q Sustain Total	m^3/day	330.91	22.46	10.37	328.32	254.88	11.23
Q Sustain Total	m^3/month	9927.36	673.92	311.04	9849.60	7646.40	336.96

Table 4-7: FC Analyses BH 13

Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)	Late T (m^2/d)	S	AD used
Basic FC	3.83	1.15	53	47.2	5.00E-03	20.3

Recommended abstraction rate (L/s)	3.83	for 24 hours per day
Hours per day of pumping	8	6.64 L/s for 8 hours per day
Amount of water allowed to be abstracted per month	9927.36	m^3
A borehole could satisfy the basic human need of	13236	persons
Is the water suitable for domestic use (Yes/No)	Yes	

Comments
The borehole is suitable for domestic water supply. A pump with a maximum yield of 6.64 l/sec can be installed, and the yield is estimated at 8 hours per day of pumping.

Table 4-8: FC Analyses Solar BH1

Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)	Late T (m^2/d)	S	AD used
Basic FC	0.26	0.07	126	5.4	5.00E-03	8.7
Recommended abstraction rate (L/s)		**0.26**	for 24 hours per day			
Hours per day of pumping	8	0.45	L/s for	8	hours per day	

Amount of water allowed to be abstracted per month	673.92	m^3
A borehole could satisfy the basic human need of	899	persons
Is the water suitable for domestic use (Yes/No)	Yes	

Comments
The borehole is suitable for domestic water supply. A pump with a maximum yield of 0.45 l/sec can be installed, and the yield is estimated at 8 hours per day of pumping.

Table 4-9: FC Analyses Solar BH2

Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)	Late T (m^2/d)	S	AD used
Basic FC	0.12	0.06	12	1.3	5.00E-03	11.0
Recommended abstraction rate (L/s)		**0.12**	for 24 hours per day			
Hours per day of pumping	8	0.21	L/s for	8	hours per day	

Amount of water allowed to be abstracted per month	311.04	m^3
A borehole could satisfy the basic human need of	415	persons
Is the water suitable for domestic use (Yes/No)	Yes	

Comments
The borehole is suitable for domestic water supply. A pump with a maximum yield of 0.21 l/sec can be installed, and the yield is estimated at 8 hours per day of pumping.

Table 4-10: FC Analyses BH 4

Method		Sustainable yield (l/s)		Std. Dev	Early T (m^2/d)		Late T (m^2/d)		S	AD used
Basic FC		7.40		4.08	99		78.9		5.00E-03	6.7
FC inflection point		0.70		0.26						0.9
Cooper-Jacob		3.60		2.33			115.8		5.00E-03	6.7
Barker		3.47		2.46	K_f =	135		S_s =	7.90E-06	6.7
Average Q_sust (l/s)		3.8		2.75	b =	0.99	Fractal dimension n =		2.03	
Recommended abstraction rate (L/s)				3.80	for 24 hours per day					
Hours per day of pumping			8	6.58	L/s for	8	hours per day			
Amount of water allowed to be abstracted per month				9849.6	m^3					
A borehole could satisfy the basic human need of				13133	persons					
Is the water suitable for domestic use (Yes/No)				Yes						
Comments										
The Borehole is suitable for domestic water supply. A pump with a maximum yield of 6.58 l/sec can be installed, and the yield is estimated at 8 hours per day of pumping.										

Table 4-11: FC Analyses BH 5

Method		Sustainable yield (l/s)		Std. Dev	Early T (m^2/d)		Late T (m^2/d)		S	AD used
Basic FC		1.90		1.28	88		11.5		5.00E-03	16.6
FC inflection point		1.48		0.06						4.3
Cooper-Jacob		6.70		4.33			105.4		5.00E-03	16.6
Barker		1.71		1.61	K_f =	11		S_s =	1.00E-07	16.6
Average Q_sust (l/s)		2.95		2.51	b =	3.70	Fractal dimension n =		2.03	
Recommended abstraction rate (L/s)				2.95	for 24 hours per day					
Hours per day of pumping			8	5.11	L/s for	8	hours per day			
Amount of water allowed to be abstracted per month				7646.4	m^3					
A borehole could satisfy the basic human need of				10195	persons					
Is the water suitable for domestic use (Yes/No)				Yes						
Comments										
The borehole is suitable for domestic water supply. A pump with a maximum yield of 5.11 l/sec can be installed, and the yield is estimated at 8 hours per day of pumping.										

Table 4-12: FC Analyses Solar BH5

Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)		Late T (m^2/d)		S	AD used
Basic FC	0.11	0.07	16		1.1		5.00E-03	7.8
FC inflection point	0.26	0.01						6.0
Cooper-Jacob	0.06	0.04			1.5		5.00E-03	7.8
Barker	0.08	0.09	K_f =	47		S_s =	1.00E-07	7.8
Average Q_sust (l/s)	**0.13**	**0.09**	b =	0.12	Fractal dimension n =		2.00	

Recommended abstraction rate (L/s)	**0.13**	for 24 hours per day	

Hours per day of pumping	8	0.23	L/s for	8	hours per day	

Amount of water allowed to be abstracted per month	336.96	m^3
A borehole could satisfy the basic human need of	449	persons
Is the water suitable for domestic use (Yes/No)	Yes	

Comments
The borehole is suitable for domestic water supply. Pump with a maximum yield of 0.23 l/sec for 8 hours per day or a lower yielding pump of about 0.13 l/sec for 24 hours per day pumping.

4.4 Hydrochemistry

The following section supplies an overview of the groundwater hydrochemistry for the project area. Data were derived from field and literature sample data.

4.4.1 Catchment based hydrochemistry

The groundwater quality for the region will be variable and will depend on the underlying geology and hydrogeology characteristics associated with groundwater recharge (i.e., older rock and aquifers with ion exchange will have higher EC, and recently recharged more permeable younger rocks will have lower EC). Literature and available hydrogeology maps for the area (refer to Figure 4-4) suggests that the electrical conductivity (EC) for the underlying aquifers generally ranges from 70 to 300 mS/m (milli Siemens/metre). The pH for the region ranges from 6 to 8. This means that groundwater abstracted from the aquifer can generally be used for domestic and recreational use (DWAF, 1996b).

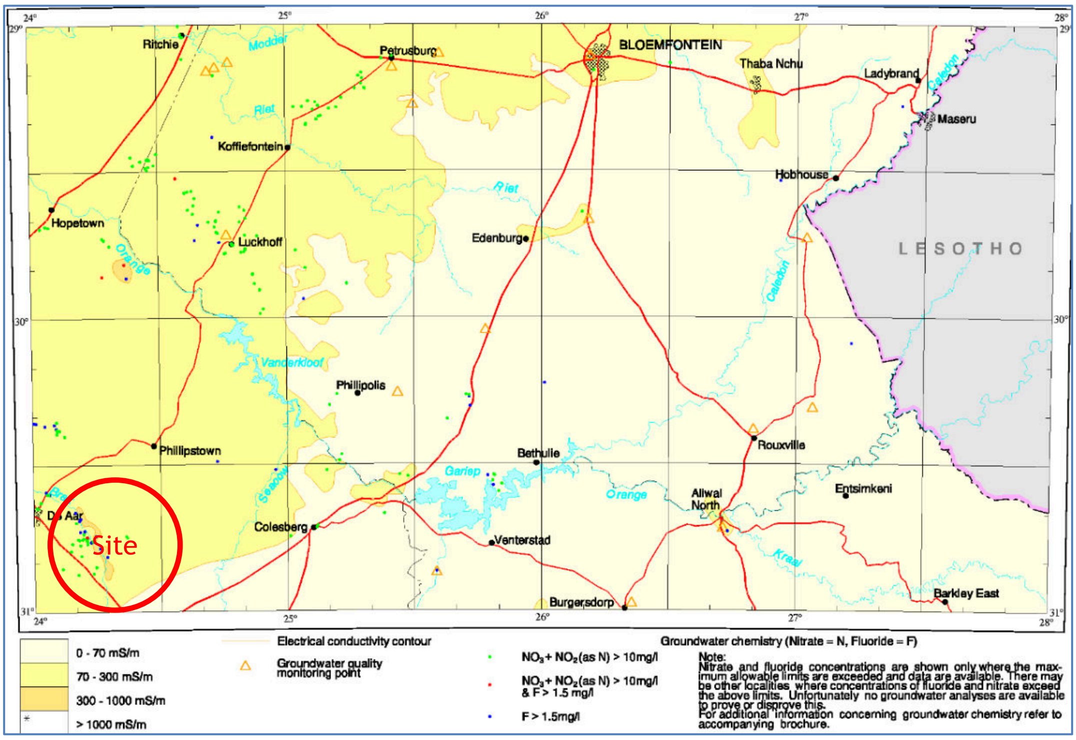


Figure 4-4: Groundwater quality (Meyer, P.S., Chetty, T., Jonk, F., 2002)

4.4.2 Field sample procedure

Surface water samples were collected and handled as follows:

- Samples were taken in 1 L polyethene containers.
- No stagnant water was sampled.
- Samples were not filtered or preserved with acid; and

- Samples were kept at a cool temperature and out of direct sunlight during storage and transport to Talbot Laboratories (SANS No. T0122), to slow down potential chemical reactions.

4.4.3 Field sample water quality

Eight (8) samples were collected from boreholes visited during the field hydrocensus. The sample was submitted to Talbot and Talbot (Pty) Ltd Laboratories (Accreditation No. T0122) for sample analysis. Refer to **Appendix C** for the analysis certificate. The analytical results are listed in Table 4-13. The results are compared against DWAF1996 target water quality values for portable use.

From the data retrieved, the following is noted:

- All samples exhibit neutral pH conditions;
- Electrical conductivity (EC) is high for all samples, with only sample windmill 2 falling within the DWAF threshold for aesthetic effects. High EC indicates a high salt load, which could result in scaling on solar panels if applied and left to evaporate. For cleaning purposes, the water would need to be wiped from the panels before it is allowed to evaporate. Otherwise, water softeners or deionisation plants will be required.
- Ca and Mg are observed to be high for most samples, with Na being high in only one sample (treated farmhouse water).
- Dissolved metals analysed are generally below the DWAF thresholds for aesthetic effects.
- The high dissolved salt content will likely cause scaling in piping exposed to heat, or in utensils used to boil water.

A piper plot of the data gathered is presented in Figure 4-5. From the piper plot, the following is noted:

- The treated water sample is the only sample that shows a deficiency of Ca and Mg and hence is an outlier. The water is pre-treated to reduce its hardness before domestic use at the farmhouse.
- The sample spread is towards the middle centre of the left ternary diagram and towards the left corner of the right ternary diagram. Hence, the samples are dominated by Ca, Mg, Cl, NO_3 and HCO_3 ions.
- The samples plot towards the left of the centre rhombus, and hence can be described as Ca-HCO_3 water. These are typically shallow fresh groundwater types or recently recharged groundwater.

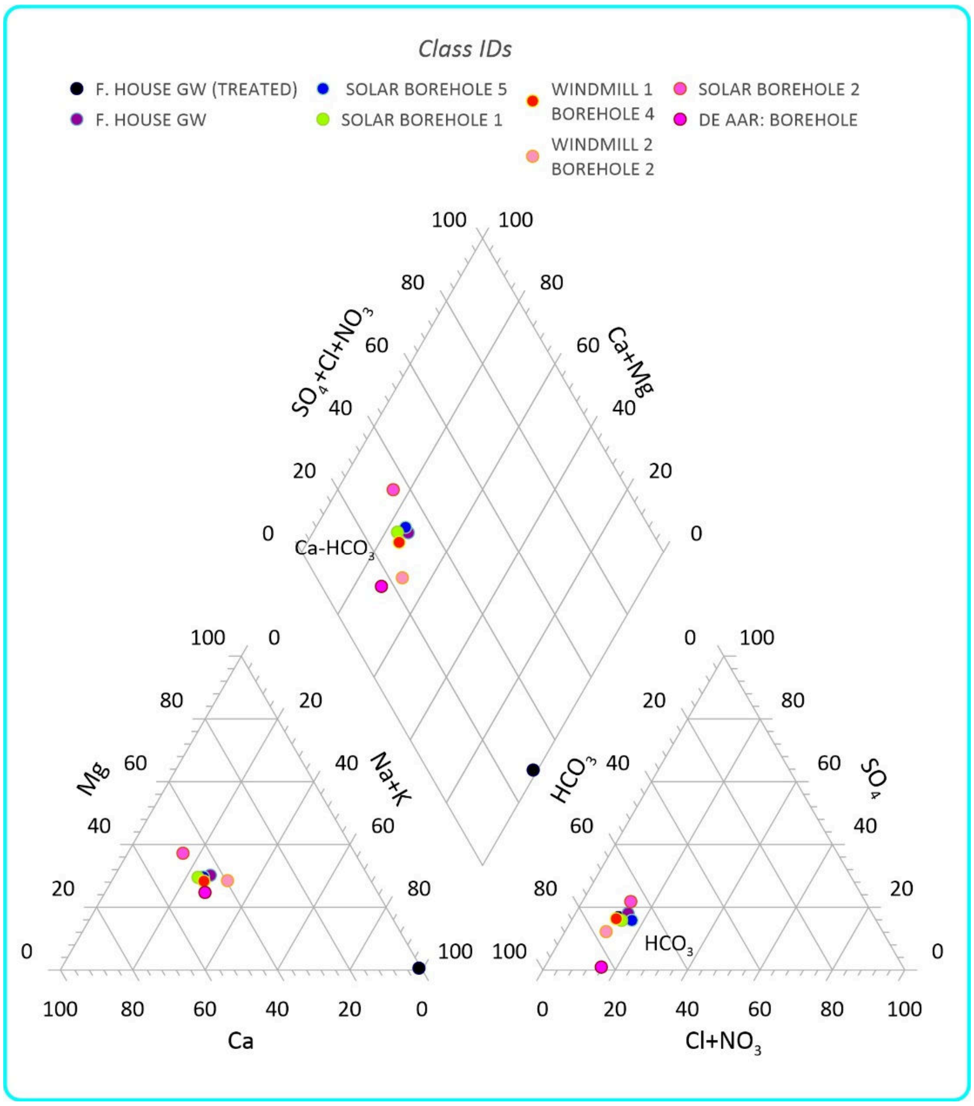


Figure 4-5: Piper plot

Table 4-13: Summary of field hydrochemistry data

Determinant	Unit	DE AAR: F. HOUSE GW (TREATED) 26.05.2022	DE AAR: F. HOUSE GW 26.05.2022	DE AAR: SOLAR BOREHOLE 5 25.05.2022	DE AAR: SOLAR BOREHOLE 1 24.05.2022	DE AAR: WINDMILL 1 BOREHOLE 4 24.05.2022	DE AAR: WINDMILL 2 BOREHOLE 5 24.05.2022	DE AAR: SOLAR BOREHOLE 2 24.05.2022	DE AAR: BOREHOLE 13 25.05.2022	DWAF 1996 Domestic Use - TWQR
pH at 25°C	pH units	7	6.8	6.7	6.7	7	7.1	6.9	6.9	4 - 9
Electrical Conductivity at 25°C	mS/m	85.2	76.6	82.7	74.4	71.2	59.7	79.3	75.5	0 - 70
Total Dissolved Solids at 180°C	mg/ℓ	464	452	466	416	386	304	474	402	>450
Bicarbonate Alkalinity*	mg HCO_3^-/ℓ	301	303	331	299	283	251	305	313	ns
Total Alkalinity	mg $CaCO_3$/ℓ	301	303	331	299	283	251	305	313	ns
Dissolved Calcium	mg Ca/ℓ	1.37	81	94	87	78	55	95	89	0 - 32
Dissolved Magnesium	mg Mg/ℓ	<0.63	34	37	33	29	24	45	28	0 - 30
Sodium	mg Na/ℓ	223	54	57	48	48	50	34	58	0 - 100
Potassium	mg K/ℓ	0.35	3.62	2.38	2.13	2.02	1.44	1.94	1.84	0 - 50
Chloride	mg Cl/ℓ	28	35	42	30	25	19	33	34	0 - 100
Fluoride	mg F/ℓ	0.9	1.02	0.76	1.22	0.92	0.97	0.66	0.49	0 - 1
Nitrate	mg N/ℓ	5.07	4.95	9.71	7.33	5.03	4.73	6.75	<0.25	0 - 6
Sulphate	mg SO_4/ℓ	55.6	64	61.4	52.7	51	31.7	80.7	<2.5	0 - 200
Dissolved Aluminium	µg Al/ℓ	<10	19	18	18	64	<10	<10	31	<150
Dissolved Iron	µg Fe/ℓ	22	17	21	44	149	17	11	23	<100
Dissolved Manganese	µg Mn/ℓ	<5	<5	<5	<5	<5	<5	<5	<5	<50

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

5 PREVAILING GROUNDWATER CONDITIONS

The following section supplies an overview of the prevailing geohydrological conditions encountered in the project area. The data were derived from available literature sources and completed fieldwork.

5.1 Aquifer Characteristics, Classification, and Groundwater Recharge

The general aquifer characteristics and aquifer classification are summarised in Table 5-1.

Table 5-1: Aquifer characteristics and classification

Characteristics	Aquifer Classification
The aquifer host rock is characterised by argillaceous rocks (sedimentary rocks consisting of shale, mudstone and subordinate siltstone) of the Beaufort Group and Ecca Groups. The aquifers have low to medium hydraulic conductivity (K-value) and porosity (n-value). The aquifer is mainly secondary. The aquifer can be referred to as being primarily intergranular and fractured (Meyer, P.S., Chetty, T., Jonk, F., 2002). Groundwater is typically encountered in: o Bedding planes in shale or interbedded sandstone of the Beaufort Group; and o Jointed and fractured contact zoned between sedimentary rocks and dolerite dyke (Meyer, P.S., Chetty, T., Jonk, F., 2002). Recharge to the underlying aquifer is estimated to be in the order of 2.6% of the MAP (320 mm) which falls within quaternary catchment D62D (DWAF, 2006). The aquifer's weathered zone is reported to be approx. 37 m thick, with the fractured zone approx. 79 m thick (DWAF, 2006). The combined aquifer thickness is estimated to be in the order of 117 m. The aquifer is an important contributor to groundwater baseflow to streams and rivers, specifically perennial rivers. non-perennial rivers act as recharge areas for the underlying aquifer systems (Meyer, P.S., Chetty, T., Jonk, F., 2002).	Available literature and site observation data suggest that three (3) aquifers exist in the area: 1. Unconfined aquifers associated with alluvium, of the non-perennial streams associated with the project area. 2. A shallower semi-unconfined aquifer system associated with weathered Beaufort sediments; and 3. A deeper confined intergranular and fractured aquifer network is associated with the older Beaufort sediments and Karoo basement rock. The aquifer underlying the project area is classified as a **Major Aquifer** system (Parsons, 1995). This means that the aquifer is generally targeted for commercial, residential, and agricultural use, in the absence of their being surface water and/or sustainable alternatives. This aquifer underlying the site can be regarded as a moderate-yielding aquifer, with reported yields ranging from 0.5 to 2 l/sec - Class D3 aquifer. Yields may increase to a range of >5 l/sec for successful boreholes drilled into geological contacts or intrusive rock contacts (Meyer, P.S., Chetty, T., Jonk, F., 2002).

5.2 Saturated zone hydraulic conductivity

Literature suggests that the saturated hydraulic conductivity (K-values) of the Beaufort Group sediments vary between 1 x 10^{-1} and 1 x 10^{-3} m/day (Botha, et al., 1998). Larger K values are expected for dolerite contact zones, gravel deposits associated with alluvium zones, and fault zones. The pump test data suggest that the T values for the boreholes tested range from 12 to 126 m^2/day. These boreholes are drilled into dolerite contact areas, and hence illustrate the potential for greater groundwater velocities within the contact areas. Hence, groundwater movement is slower in the host aquifer rock compared to the fractured zones.

5.3 Depth to Groundwater

According to WR2012 (Bailey & Pitman, 2015) and DWAF GRAII (DWAF, 2006) data, the groundwater level in the study area on average is in the order of 6.9 mbgl (metre below ground level). Available hydrocensus data suggest the water table ranges from 0.2 to 25.6 mbgl, and on average is in the order of 5.7 mbgl.

Figure 5-1 plots of available groundwater elevation data for the area. There is a good relationship (R = 99.3 %), between groundwater and topography elevation which suggests that the regional groundwater table mimics the topography. The data suggest that groundwater levels are shallower close to non-perennial and perennial streams where groundwater contributes to streamflow as baseflow seepage. These areas are typically prominent groundwater-surface water interaction areas.

Bayesian interpolation of available groundwater level data was applied to the area to conceptualize the groundwater flow. Figure 5-3 indicates the generated Bayesian interpolated groundwater elevations for the area. The data suggest that the general groundwater movement is towards the NW.

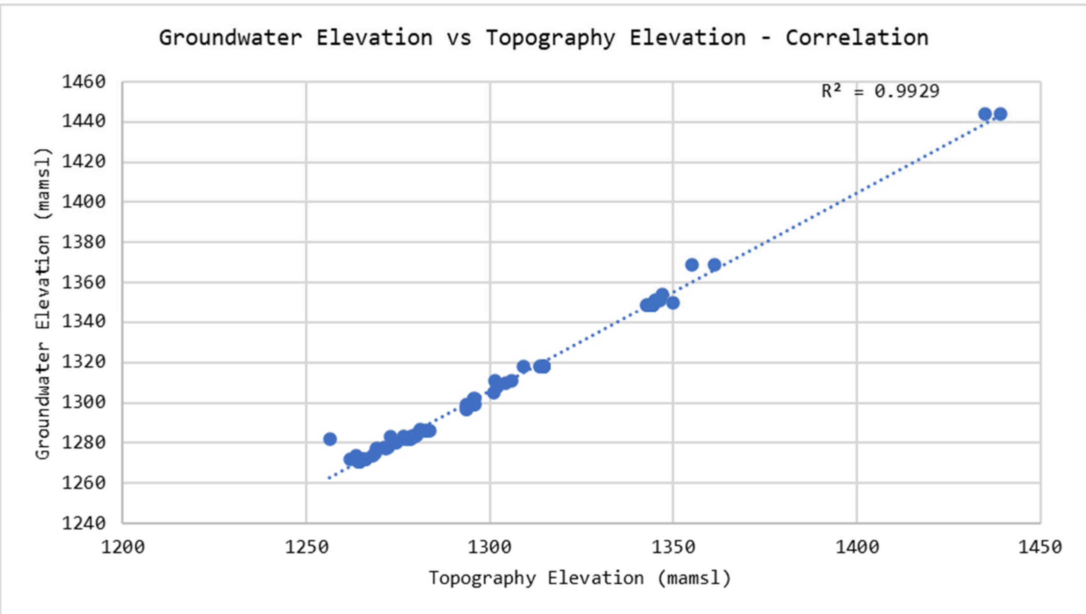


Figure 5-1: Groundwater elevation vs topography elevation correlation

5.4 Groundwater quantity

Intermediate groundwater Reserve Determination (IGRD) was conducted for the study area to establish the groundwater reserve. The IGRD aims to quantify the likely impact of the site on the groundwater reserve.

It is necessary, from a groundwater point of view, to quantify the groundwater reserve in terms of potential impacts associated with the development (i.e., areas that may become impermeable or increased runoff will reduce groundwater recharge, and aquifer dewatering will further impact the groundwater reserve).

The IGRD considers the following parameters:

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

The data used for the calculation was derived from the WRC 90 Water Resources of South Africa 2012 Study (WR2012) and GW Resource Assessment Ver. 2 (GRAII) datasets.

In the anticipated impacts on the groundwater, the reserve was further evaluated by evaluating future rainfall changes and the impacts on groundwater recharge (CSIR, 2019). Projected changes in annual average rainfall throughout Pixley Ka Seme over the period 2021-2050 under the RCP 8.5 were used in the estimate.

5.4.1 Quaternary catchment

Data from relevant hydrogeological databases, including the Groundwater Resource Directed Measures (GRDM), was obtained from the Department of Water and Sanitation and associated Aquiworx software (Aquiworx, 2015). The borehole falls within quaternary catchment D62D as indicated in Table 5-2.

The projected rainfall decrease for the area as a result of climate change is estimated to decrease by as much as 150mm, reducing the total rainfall to about 170 mm/yr by 2050. It should be noted that the projected changes in the annual average number of extreme rainfall days throughout the district over the period 2021-2050 under the RCP 8.5 scenario suggest either a decrease or increase in rainfall events. It is anticipated that under the scenarios put forth, the groundwater resources in the project area may become completely replenished in the event of 1:50 and 1:100-year storm events that occur in the project area. As a climate change scenario, the 170mm annual rainfall for the area is used.

Table 5-2: Summarised Quaternary Catchment Information (Aquiworx, 2015)

Scenario	Quaternary Catchment	Total Area (km²)	Recharge (mm/a)	Rainfall (mm/a)	Baseflow (mm/a)
Base Case	D62D	2396.847	2.6%	320	0 [Pitman]
Climate Change	D62D	2396.847	2.6%	170	0

5.4.2 Estimated water demand vs attainable

The following provides a summary of the estimated water demand for the phases associated with the project (EcoLeges, 2022) – *excludes dust suppression*:

- Phase 1: Total usage required = unknown.
  - Solar BH5 and Borehole 13 have been identified for water use. The sustainable abstraction yield for these boreholes is in the order of 197 m^3/day for 8 hours of pumping, and 342 m^3/day for 24-hour pumping (not recommended based on available yield testing).
- Phase 2a & 2b: Total usage required = unknown.
  - Solar BH1 and Solar BH2 have been identified for water use. The sustainable abstraction yield for these boreholes is in the order of 19 m^3/day for 8 hours of pumping, and 32 m^3/day for 24-hour pumping (not recommended based on available yield testing).
- Phase 3:
  - Construction = 22.05 m^3/day;
  - Construction and operation (overlap) = 27.45 m^3/day; and
  - Operation = 13.4 m^3/day.
  - Windmill boreholes 4 and 5 have been identified for water use. The sustainable abstraction yield for these boreholes is in the order of 336.67 m^3/day for 8 hours of pumping, and 583.2 m^3/day for 24-hour pumping (not recommended based on available yield testing).

It is advised that water be pumped to dedicated storage tanks from the boreholes to build up a reserve, whereafter the boreholes are only used to top up the storage tanks. Allowing boreholes to rest/recover between pumping cycles will help to decrease the impact on the aquifer reserve.

It should further be noted that dust suppression will take place at all phases. The estimated dust suppression for the phases will be high during construction and will reduce significantly (to zero) for the operational phase. The estimated dust suppression volume for Phase 3 alone is about 674.4 m^3/day (EcoLeges, 2022). It is understood that a soil binding additive will be added, to further reduce the required dust suppression water volumes.

5.4.3 Water balance calculation

The groundwater balance and the reserve determination on a sub-catchment scale were as follows:

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

Where:

- $GW_{available}$ = Available GW for use.
- Re = Effective recharge to the aquifer.
- BF = Baseflow to surface water streams.
- EU = Existing GW abstraction/use (identified on sub-catchment, excluding applicant).
  - EU assumes a median aquifer yield of 0.1 to 0.5 l/sec borehole noted in the study area.
- BHN = Basic Human Needs.
- PU = Proposed Use.

A limitation of the water balance calculation is that it does not consider transboundary aquifer systems, which may be present in the study area. These systems will often add more water to the system, as water is transferred across HRUs, via the fractures / intergranular preferential flow paths. This phenomenon is difficult to determine and required aerial magnetic or gravity survey data, pup test data of all known boreholes within a given area and drilling logs. Hence, transboundary aquifer flow is not included in this static water balance calculation.

5.4.4 Base case water balance

The base case water balance for the sub-catchments associated with the project area is summarised in Table 5-3. From the water balance calculations undertaken, the following is noted:

- HRU1
  - There is a surplus amount of 243 355.22 m^3/yr (666.73 m^3/day) available, after the allocation of the proposed PU.
- HRU2
  - There is a surplus amount of 54 824.94m^3/yr (150.21 m^3/day) available, after the allocation of the proposed PU.

- HRU3
    - There is a surplus amount of 448 714.24 m^3/yr (1 229.35 m^3/day) available. No abstraction is planned for this sub-catchment.
- HRU4
    - There is a surplus amount of 98 450.63 m^3/yr (269.73 m^3/day) available, after the allocation of the proposed PU.
- HRU5
    - There is a surplus amount of 416 010.85 m^3/yr (1 139.76 m^3/day) available, after the allocation of the proposed PU.

Therefore, it is estimated that there is enough groundwater available on a sub-catchment level to sustain the **proposed 8-hour abstraction** from the designated boreholes and the sub-catchments they fall in.

It should be noted that dust suppression will also take place at all phases of the project. Dust suppression will likely be very high, and the water not used as part of the construction phase estimate (presented in Section 5.4.2.) will be allocated to dust suppression. The demand will depend on the frequency of spraying events for dust suppression. It is recommended that environmentally safe binding liquids be considered to decrease water use volumes. As long as dust suppression and operational water use volumes taken from groundwater resources in the sub-catchments are within the surplus estimates, the impact on the groundwater reserve will likely be minimum.

Table 5-3: Base case water balance calculations

HRU1		
Area	30.08	km^2
Rainfall	320.00	mm/yr
BF	0.00	mm/yr
Aquifer Recharge		
Re	8.32	mm/yr
Re to Aquifer	250293.14	m^3/yr
Existing Use (EU)		
Old Windmill 1	None	m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
Total EU Day	0.00	m^3/day
Total EU Year	0.00	m^3/yr
Basic Human Needs		
BHN	0.00	m^3/day
BHN	0.00	m^3/yr
Base Flow		
BF	0.00	m^3/yr
Available	250293.14	m^3/yr
Proposed Use (PU)		
Solar Borehole 1 (BH1)	12.96	m^3/day
Solar Borehole 2 (BH2)	6.05	m^3/day
Total PU Day	19.01	m^3/day
Total PU Year	6937.92	m^3/yr
Nett Balance	243355.22	m^3/yr

HRU2		
Area	21.74	km^2
Rainfall	320.00	mm/yr
BF	0.00	mm/yr
Aquifer Recharge		
Re	8.32	mm/yr
Re to Aquifer	180863.82	m^3/yr
Existing Use (EU)		
Windmill 3	8.64	m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
Total EU Day	8.64	m^3/day
Total EU Year	3153.60	m^3/yr
Basic Human Needs		
BHN	0.00	m^3/day
BHN	0.00	m^3/yr
Base Flow		
BF	0.00	m^3/yr
Available	177710.22	m^3/yr
Proposed Use (PU)		
Windmill 1 (BH4)	189.50	
Windmill 2 (BH5)	147.17	
Total PU Day	336.67	m^3/day
Total PU Year	122885.28	m^3/yr
Nett Balance	54824.94	m^3/yr

HRU3		
Area	53.93	km^2
Rainfall	320.00	mm/yr
BF	0.00	mm/yr
Aquifer Recharge		
Re	8.32	mm/yr
Re to Aquifer	448714.24	m^3/yr
Existing Use (EU)		
None		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
Total EU Day	0.00	m^3/day
Total EU Year	0.00	m^3/yr
Basic Human Needs		
BHN	0.00	m^3/day
	0.00	m^3/yr
Base Flow		
BF	0.00	m^3/yr
Available	448714.24	m^3/yr
Proposed Use (PU)		
None		
Total PU Day	0.00	m^3/day
Total PU Year	0.00	m^3/yr
Nett Balance	448714.24	m^3/yr

HRU4		
Area	45.62	km^2
Rainfall	320.00	mm/yr
BF	0.00	mm/yr
Aquifer Recharge		
Re	8.32	mm/yr
Re to Aquifer	379541.51	m^3/yr
Existing Use (EU)		
Farmhouse Windmill	8.64	m^3/day
Farmhouse Borehole 1	43.20	m^3/day
Farmhouse Borehole 2	43.20	m^3/day
Farmhouse Borehole 3	43.20	m^3/day
Farmhouse Borehole 4	43.20	m^3/day
Community Borehole 2	43.20	m^3/day
Field Borehole 1	43.20	m^3/day
Borehole 14	43.20	m^3/day
Solar Borehole 6	43.20	m^3/day
Borehole Dam Backup 1	43.20	m^3/day
Solar Borehole 7	43.20	m^3/day
Solar Borehole 3	43.20	m^3/day
Solar Borehole 3.2 (Bac	43.20	m^3/day
Windmill 4	8.64	m^3/day
Solar Borehole 4	43.20	m^3/day
Total EU Day	578.88	m^3/day
Total EU Year	211291.20	m^3/yr
Basic Human Needs		
BHN	0.00	m^3/day
	0.00	m^3/yr
Base Flow		
BF	0.00	m^3/yr
Available	168250.31	m^3/yr
Proposed Use (PU)		
Borehole 13	191.23	
Total PU Day	191.23	m^3/day
Total PU Year	69799.68	m^3/yr
Nett Balance	98450.63	m^3/yr

HRU5		
Area	50.29	km^2
Rainfall	320.00	mm/yr
BF	0.00	mm/yr
Aquifer Recharge		
Re	8.32	mm/yr
Re to Aquifer	418428.61	m^3/yr
Existing Use (EU)		
None		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
		m^3/day
Total EU Day	0.00	m^3/day
Total EU Year	0.00	m^3/yr
Basic Human Needs		
BHN	0.00	m^3/day
	0.00	m^3/yr
Base Flow		
BF	0.00	m^3/yr
Available	418428.61	m^3/yr
Proposed Use (PU)		
Solar Borehole 5	6.62	
Total PU Day	6.62	m^3/day
Total PU Year	2417.76	m^3/yr
Nett Balance	416010.85	m^3/yr

c

5.4.5 *Climate change considerations (by 2025)*

The water balances for the sub-catchments considering climate change by 2050 are summarised in Table 5-3. From the water balance calculations undertaken, the following is noted:

- HRU1
  - There is a surplus amount of 126 030.31m^3/yr (345.29 m^3/day) available, after the allocation of the proposed PU.
- HRU2
  - There is a deficit amount of -29 954.96 m^3/yr (-82.07 m^3/day) available, after the allocation of the proposed PU.
- HRU3
  - There is a surplus amount of 238 379.44m^3/yr (653 m^3/day) available. No abstraction is planned for this sub-catchment.
- HRU4
  - There is a deficit amount of -79 459.45m^3/yr (-217 m^3/day) available, after the allocation of the proposed PU.
- HRU5
  - There is a surplus amount of 219 872.44m^3/yr (602 m^3/day) available, after the allocation of the proposed PU.

Based on the predicted climate change, HRU2 and HRU4 will not be able to meet the demand by 2050 for construction phase water uses, at the proposed PU. Water abstraction rates would need to be considerably decreased nearing the 2050 mark.

As stated previously in the report, the operational phase water volumes for Phase 3 are estimated in the order of 13.4 m^3/day, hence, if PU is decreased to only the required amount, the deficit may be avoided.

Table 5-4: Water balance considering climate change

HRU1			HRU2			HRU3			HRU4			HRU5		
Area	30.08	km^2	Area	21.74	km^2	Area	53.93	km^2	Area	45.62	km^2	Area	50.29	km^2
Rainfall	170.00	mm/yr	Rainfall	170.00	mm/yr	Rainfall	170.00	mm/yr	Rainfall	170.00	mm/yr	Rainfall	170.00	mm/yr
BF	0.00	mm/yr	BF	0.00	mm/yr	BF	0.00	mm/yr	BF	0.00	mm/yr	BF	0.00	mm/yr
Aquifer Recharge			Aquifer Recharge			Aquifer Recharge			Aquifer Recharge			Aquifer Recharge		
Re	4.42	mm/yr	Re	4.42	mm/yr	Re	4.42	mm/yr	Re	4.42	mm/yr	Re	4.42	mm/yr
Re to Aquifer	132968.23	m^3/yr	Re to Aquifer	96083.90	m^3/yr	Re to Aquifer	238379.44	m^3/yr	Re to Aquifer	201631.43	m^3/yr	Re to Aquifer	222290.20	m^3/yr
Existing Use (EU)			Existing Use (EU)			Existing Use (EU)			Existing Use (EU)			Existing Use (EU)		
Old Windmill 1	None	m^3/day	Windmill 3	8.64	m^3/day	None		m^3/day	Farmhouse Windmill	8.64	m^3/day	None		m^3/day
		m^3/day			m^3/day			m^3/day	Farmhouse Borehole 1	43.20	m^3/day			m^3/day
		m^3/day			m^3/day			m^3/day	Farmhouse Borehole 2	43.20	m^3/day			m^3/day
		m^3/day			m^3/day			m^3/day	Farmhouse Borehole 3	43.20	m^3/day			m^3/day
		m^3/day			m^3/day			m^3/day	Farmhouse Borehole 4	43.20	m^3/day			m^3/day
		m^3/day			m^3/day			m^3/day	Community Borehole 2	43.20	m^3/day			m^3/day
		m^3/day			m^3/day			m^3/day	Field Borehole 1	43.20	m^3/day			m^3/day
		m^3/day			m^3/day			m^3/day	Borehole 14	43.20	m^3/day			m^3/day
		m^3/day			m^3/day			m^3/day	Solar Borehole 6	43.20	m^3/day			m^3/day
		m^3/day			m^3/day			m^3/day	Borehole Dam Backup 1	43.20	m^3/day			m^3/day
		m^3/day			m^3/day			m^3/day	Solar Borehole 7	43.20	m^3/day			m^3/day
		m^3/day			m^3/day			m^3/day	Solar Borehole 3	43.20	m^3/day			m^3/day
		m^3/day			m^3/day			m^3/day	Solar Borehole 3.2 (Bac	43.20	m^3/day			m^3/day
		m^3/day			m^3/day			m^3/day	Windmill 4	8.64	m^3/day			m^3/day
		m^3/day			m^3/day			m^3/day	Solar Borehole 4	43.20	m^3/day			m^3/day
Total EU Day	0.00	m^3/day	Total EU Day	8.64	m^3/day	Total EU Day	0.00	m^3/day	Total EU Day	578.88	m^3/day	Total EU Day	0.00	m^3/day
Total EU Year	0.00	m^3/yr	Total EU Year	3153.60	m^3/yr	Total EU Year	0.00	m^3/yr	Total EU Year	211291.20	m^3/yr	Total EU Year	0.00	m^3/yr
Basic Human Needs			Basic Human Needs			Basic Human Needs			Basic Human Needs			Basic Human Needs		
BHN	0.00	m^3/day	BHN	0.00	m^3/day	BHN	0.00	m^3/day	BHN	0.00	m^3/day	BHN	0.00	m^3/day
BHN	0.00	m^3/yr	BHN	0.00	m^3/yr		0.00	m^3/yr		0.00	m^3/yr		0.00	m^3/yr
Base Flow			Base Flow			Base Flow			Base Flow			Base Flow		
BF	0.00	m^3/yr	BF	0.00	m^3/yr	BF	0.00	m^3/yr	BF	0.00	m^3/yr	BF	0.00	m^3/yr
Available	132968.23	m^3/yr	Available	92930.30	m^3/yr	Available	238379.44	m^3/yr	Available	-9659.77	m^3/yr	Available	222290.20	m^3/yr
Proposed Use (PU)			Proposed Use (PU)			Proposed Use (PU)			Proposed Use (PU)			Proposed Use (PU)		
Solar Borehole 1 (BH1)	12.96	m^3/day	Windmill 1 (BH4)	189.50		None			Borehole 13	191.23		Solar Borehole 5	6.62	

HRU1			HRU2			HRU3			HRU4			HRU5		
Solar Borehole 2 (BH2)	6.05	m^3/day	Windmill 2 (BH5)	147.17										
Total PU Day	19.01	m^3/day	Total PU Day	336.67	m^3/day	Total PU Day	0.00	m^3/day	Total PU Day	191.23	m^3/day	Total PU Day	6.62	m^3/day
Total PU Year	6937.92	m^3/yr	Total PU Year	122885.28	m^3/yr	Total PU Year	0.00	m^3/yr	Total PU Year	69799.68	m^3/yr	Total PU Year	2417.76	m^3/yr
Nett Balance	126030.31	m^3/yr	Nett Balance	-29954.98	m^3/yr	Nett Balance	238379.44	m^3/yr	Nett Balance	-79459.45	m^3/yr	Nett Balance	219872.44	m^3/yr

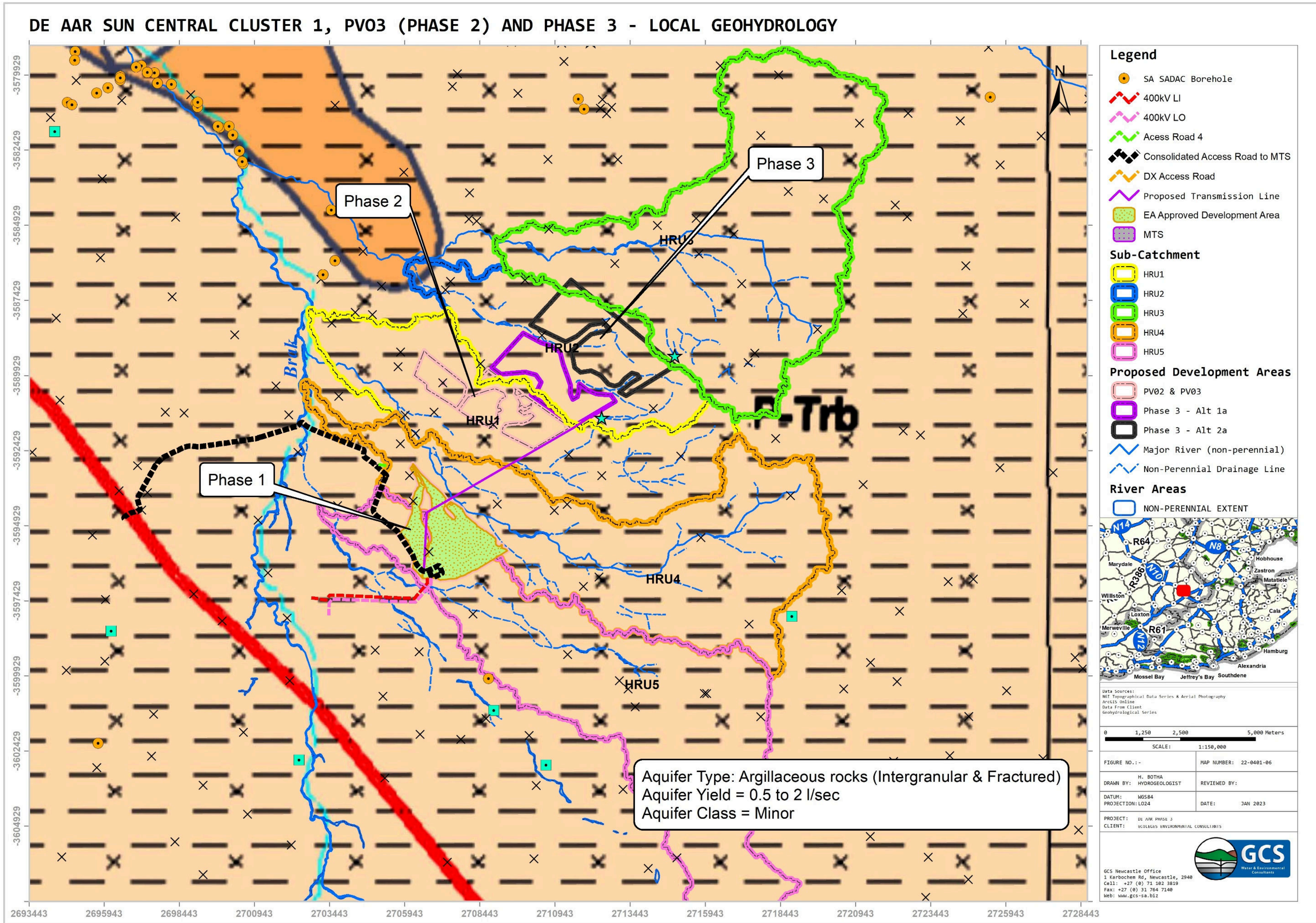


Figure 5-2 Local hydrogeology

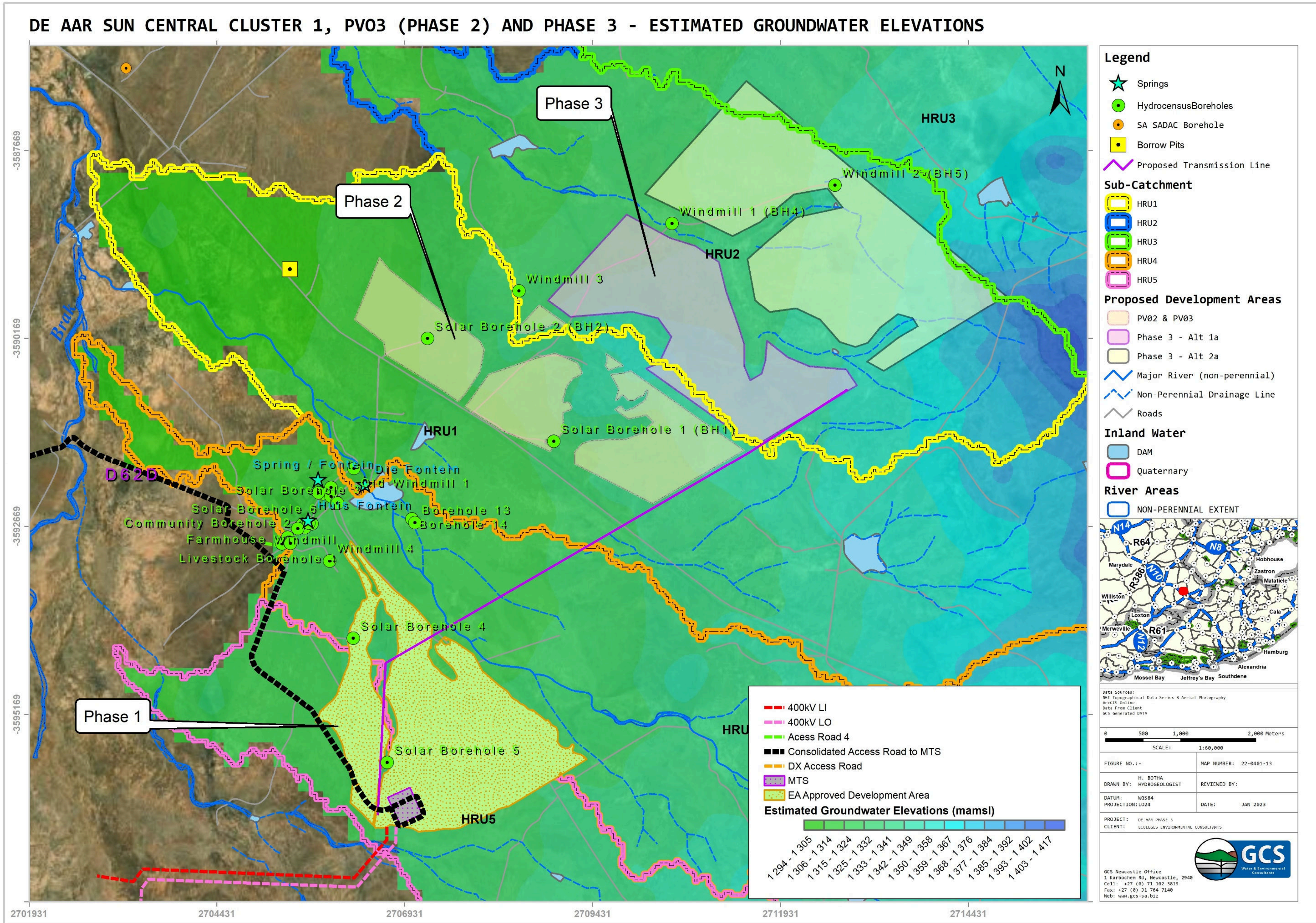


Figure 5-3: Estimated groundwater elevations

6 PRELIMINARY RISK AND IMPACT ASSESSMENT

In this section, the anticipated hydrogeological risks concerning the proposed solar development and the groundwater abstraction at the site were assessed. The Source – Pathway- Receptor (SPR) model (DWAF, 2008) was considered to quantify and illustrate the potential groundwater risks.

6.1 Site conceptual model

The site conceptual model (SCM) developed focused on the site, and broader study area and is illustrated in Figure 6-1. Based on the groundwater data collected, it is confirmed that three (3) aquifers exist in the area:

- Unconfined aquifers associated with paleo drainage as well as flood plains of non-perennial river systems (about 5 to 10m thick) – not associated with the study area but closer to the Brak River;
- A shallower semi-unconfined aquifer system associated with weathered Beaufort sediments; and
- A deeper confined intergranular and fractured aquifer network is associated with the older Beaufort and Ecca sediments, of the Karoo Group.

The aquifers underlying the project area can be regarded as moderate-yielding aquifers, with reported yields ranging from 0.5 to 2 l/sec. From available literature data, the weathered zone for the area is estimated to be in the order of 10m thick, followed by a subsequent thicker fractured aquifer zone. Based on available groundwater levels for the study area, the groundwater table is placed in the order of 5 mbgl, when considering a regional-scale water table. Groundwater is found within the bedding planes in shale or interbedded sandstone and jointed and fractured contact zoned between sedimentary rocks and dolerite dyke. As such, where these structures daylight in low-laying topographical areas, springs will be produced fed by the groundwater within the contacts. The groundwater table mimics the topography and groundwater flows from high-lying areas (water divides) to low-lying areas.

The main source of groundwater recharge is rainfall. The rainfall infiltrates into the ground to become groundwater through the Vadose Zone. The water then moves both vertically and horizontally in the weathered zone of Beaufort Group, with greater interflow in a horizontal direction within the weathered zone matrix. Water flowing horizontally in the soil and the weathered zone will enter the non-perennial streams associated with the project area as base flow whereas water vertical flow will contribute to groundwater recharge. Even though the rivers may become dry, there may still be a significant baseflow within the alluvium material associated with the flood plains.

Based on the nature of the project (raised PV solar arrays on pipe stand, and vegetation kept intact during the construction and operational phase of the project) a negative impact in terms of groundwater recharge to aquifer is expected to be marginal. Rainwater from the PV solar arrays will be allowed to percolate, and free drainage of runoff will take place, rather than stormwater conveyance.

As part of the construction activities associated with this project, there may be some disturbance of the vadose zone soils (i.e., road development, preparation of solar array fixtures to the ground). Poor quality seepage from machinery and servicing vehicles entering the project area or used to develop the solar arrays could lead to soil contamination of the vadose zone which could percolate to the shallow aquifer.

Available data suggest that water production boreholes in the project area dewater the fractured aquifer zone, rather than the weathered aquifer zone. This is due to the observation that existing boreholes intercept dolerite dyke contact areas. Where a series of boreholes are drilled in the same contact, and close to each other (<500m), borehole interference may likely occur as the fractures are simultaneously dewatered. Over-production may lead to fracture failures which will lead to borehole collapse. However, due to the degree of fracturing being unknown, the anticipated impact cannot be pre-determined. As a good practice, it is advised that all new boreholes drilled in the project area be pump tested, and interference (if any) be evaluated by long-duration pump tests (including the proposed holes for water supply in this report). In terms of development, limited impacts are anticipated based on available pump test data and proposed abstraction volumes.

6.2 Estimated groundwater pollution migration velocities

Based on available data and Darcy's Law[1] for groundwater flow through a saturated medium and aquifer hydraulic conductivity (K), the following pollution migration rates are likely:

1. Shallow weathered aquifer zones:
    a. K-values for the aquifer rock in the study area typically range from 1 x 10^{-1} to 1 x 10^{-3} m/day for intergranular and fractured aquifer zones
    b. The estimated seepage velocity within the aquifer zones is estimated to range from 9 x 10^{-5} to 0.0096 m/day. The estimated groundwater seepage velocity is very slow.
2. Deeper aquifer zones (host rock):
    a. The K values for the matrix rock will be in the same order as for the shallow weathered aquifer zones.
3. Fractured aquifer contacts:
    a. The T-values >100 m/day are expected.
    b. Migration velocities are greater than those compared to the rock matrix.
    c. the groundwater velocities may increase by several orders if the host rock is fissured and if the fissures are connected. To quantify the potential seepage migration through these zones, one would need to undertake aquifer tests on boreholes drilled into these fractured areas.

The weathered aquifer zone is likely the only zone that will be impacted due to the proposed activities.

[1] Darcy's Flow (Q) = kiA
Darcy Velocity (v) = ki/θ
Where k = hydraulic conductivity (m/day), i = hydraulic head is in the order of 0.029 A = flow cross sectional area, θ = effective porosity of flow media (ranges from 0.2 to 0.3).

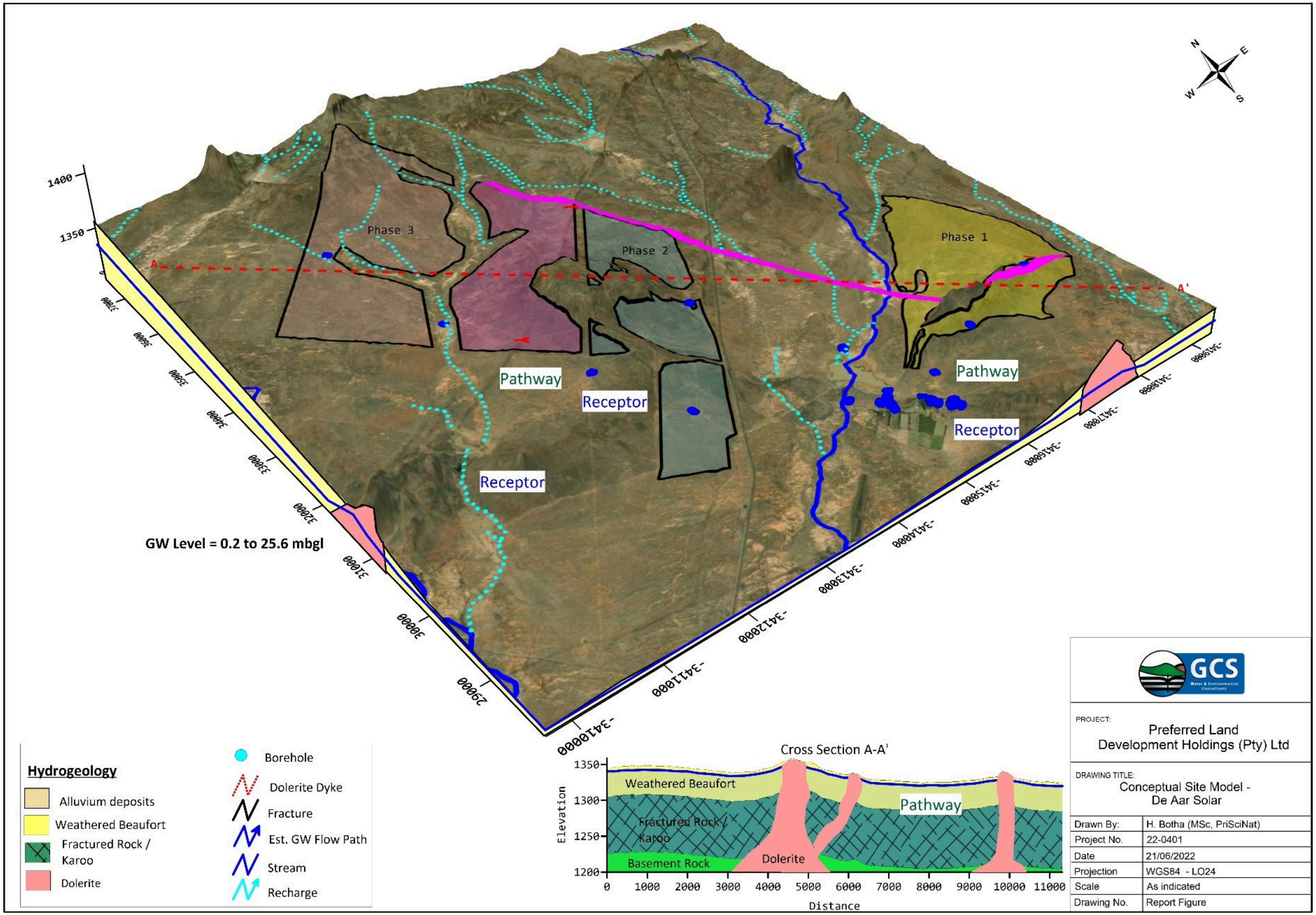


Figure 6-1: Site conceptual model (SCM)

6.3 Impacts on the groundwater reserve

The potential radius of influence of pumping for each borehole [identified for GW use during this study] was determined by applying the Cooper-Jacob equation (1):

$$\boldsymbol{Radius\ of\ Influence}\ (r_e) = 1.5\sqrt{\frac{Tt}{S}}$$ **Equation 1**

Where:

T = aquifer transmissivity (m^2/day)

t = exploitation time/pumping time (days); and

S = aquifer storativity.

The estimated radius of influence for pump-tested boreholes is listed in Table 6-1 and Table 6-2 presents predicted impact radii for non-tested boreholes. The predicated pumping radius of influence for the boreholes ranges from 200 to 2400m. During pumping, no interference on surrounding holes was noted. It is therefore anticipated that the boreholes are drawing from the fractured aquifer network or contact zones, which are not connected.

Table 6-1: Summary of the radius of influence for pump-tested boreholes

Parameter	Units	BH 13 (PV1)	Solar BH1 (PV2)	Solar BH2 (PV2)	BH 4 (PV3)	BH 5 (PV3)	Solar BH5 (PV1)
T	m^2/day	47.2	5.4	1.3	46.5	105	1.5
t	days	121.67	121.67	121.67	121.67	121.67	121.67
s		0.01	0.01	0.01	0.01	0.01	0.01
Tt		5742.67	657.00	158.17	5657.50	12775.00	182.50
Tt/s		1148533.33	131400.00	31633.33	1131500.00	2555000.00	36500.00
Square Root (Tt)	m	1071.70	362.49	177.86	1063.72	1598.44	191.05
The radius of Influence	*m*	*1607.54*	*543.74*	*266.79*	*1595.58*	*2397.66*	*286.57*

Table 6-2: Summary of the likely radius of backup boreholes (not tested)

Parameter	Units	Solar BH4 (PV1)*	BH 14 (PV1)*
T	m^2/day	3.5	40
t	days	121.67	121.67
s		0.01	0.01
Tt		425.83	4866.67
Tt/s		85166.67	973333.33
Square Root (Tt)	m	291.83	986.58
The radius of Influence	*m*	437.75	1479.86

* Data derived from nearby tested boreholes.

6.3.1 Scale of abstraction

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

Small-scale abstractions (<60% recharge) Category A

Medium-scale abstractions (60-100% recharge) Category B

Large-scale abstractions (>100% of recharge) Category C

The scale of abstraction is summarised in Table 6-3 (base case) and Table 6-4 (climate change). The proposed abstraction rate is based on the 8-hour recommended pumping. It can be seen that by 2050 HRU2 and HRU4 will be over-taxed, due to climate change. However, it should be noted that operational use will be far less than the construction phase, and as such the PU for the boreholes can be adjusted to maintain small or low-scale classes.

Table 6-3: The estimated scale of abstraction for the proposed PU for the boreholes in this report (base case)

Component	HRU1	HRU2	HRU3	HRU4	HRU5
Re (m^3/yr)	250 293.14	180 863.82	448 714.24	379 541.51	418 428.61
Use (m^3/yr)	6937.92	126 038.88	0.00	281 090.88	2417.76
Abs. Scale	0.03	0.70	0.00	0.74	0.01
Class	Small Scale	Medium-Scale	Small Scale	Medium-Scale	Small Scale

Table 6-4: The estimated scale of abstraction for the proposed PU for the boreholes in this report (climate change by 2050)

Component	HRU1	HRU2	HRU3	HRU4	HRU5
Re (m^3/yr)	132 968.23	96083.90	238 379.44	201 631.43	222 290.20
Use (m^3/yr)	6937.92	126 038.88	0.00	281 090.88	2417.76
Abs. Scale	0.05	1.31	0.00	1.39	0.01
Class	Small Scale	Large Scale	Small Scale	Large Scale	Small Scale

6.3.2 Water quantity stress index

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

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

- Where water demands are approaching or exceed the available supply.
- Where water quality problems are imminent or already exist; or
- Where water resource quality is under threat.

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

The modified stress index is as follows:

Stress Index = Proposed Abstraction / (Recharge - Baseflow)

The stress index and classes described in Table 6-5 are a guide for determining the level of stress of a groundwater resource unit, based on abstraction, baseflow, and recharge (modified after (Parsons & Wentzel, 2007).

Table 6-5: Guide for determining the level of stress of a groundwater resource unit

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

The estimated stress of the proposed abstraction on a sub-catchment level is summarised in Table 6-6 (base case) and Table 6-7 (climate change). The same remarks as per the scale of abstraction are noted.

Table 6-6: Level of the stress of proposed abstraction (base case)

Component	HRU1	HRU2	HRU3	HRU4	HRU5
Proposed Abstraction	6937.92	122 885.28	0.00	69799.68	2417.76
Re - BF	250 293.14	180 863.82	448 714.24	379 541.51	418 428.61
Stress Index	0.03	0.68	0.00	0.18	0.01
Class	A	D	A	B	A

Table 6-7: Level of the stress of proposed abstraction (climate change)

Component	HRU1	HRU2	HRU3	HRU4	HRU5
Proposed Abstraction	6937.92	122 885.28	0.00	69799.68	2417.76
Re - BF	132 968.23	96083.90	238 379.44	201 631.43	222 290.20
Stress Index	0.05	1.28	0.00	0.35	0.01
Class	B	F	A	C	A

6.4 Hydrogeological risk and impacts

In terms of the proposed development, several risks during the construction and operational phase were identified. The potential impacts identified and environmental significance for the construction and operational phase are listed in Table 6-8 and Table 6-9. Closure phase risk will highly likely be similar to that of the construction phase.

Based on the SPR model applied to the site (refer to Figure 6-2), the following potential geohydrological risks are identified:

- Construction phase risk (development of roadway, MTS, construction of standpipes and arrays for PV panels, construction of sub-stations, the establishment of stream crossings and culverts and erection of transmission lines).
    - Leakages from construction and contractor vehicles accessing the site may cause soil pollution (i.e., un-inspected vehicles dripping oils/hydrocarbons onto soils may cause contamination of soil and surface water resources).
    - Disturbing soils (land capability) due to some vegetation clearing may promote sedimented runoff during storm events.
    - Excavation of borrow pits for road building material may cause temporary sedimentation during storm events.
    - Disturbing sediments associated with streams to install dedicated stream crossings and road culverts may promote sediment runoff.
    - Dewatering of the aquifer via groundwater boreholes (only if overproduced).
- The operational phase of the PV farm:
    - Oil spillage from parked vehicles (service vehicles), may seep into the aquifer via the vadose zone.
    - Sedimentation runoff from areas where no stormwater management measures are implemented; or where vegetation is not maintained.
    - Dewatering of the aquifer via groundwater boreholes (only if overproduced).

The risk assessment for both the construction and post-construction phases of the project is considered marginal, with mostly reversible and manageable impacts. The largest risk of geohydrology is the proposed groundwater abstraction activities. As groundwater is a very important resource for locals in the area, care should be taken not to overproduce from boreholes chosen for this project; and there is a limited impact on existing livestock/domestic watering already implemented. The risk of poor-quality seepage via the vadose zone and impacts on groundwater water quality is predicted to be marginal, and will only be a problem if the developing contractor allows leaking vehicles onto the site, or cause deliberate environmental harm.

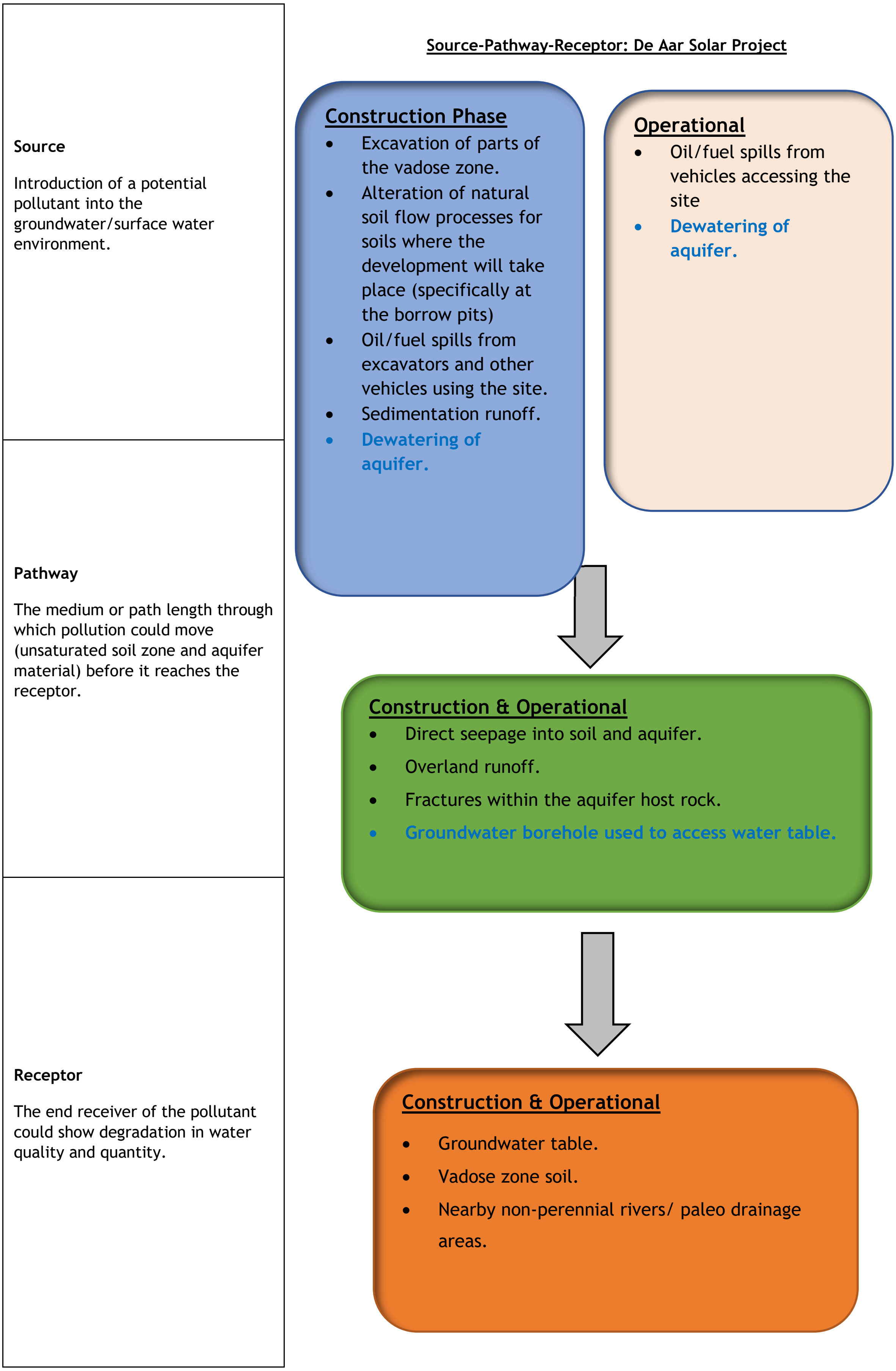


Figure 6-2: De Aar Solar Project - SPR

6.5 Existing impacts

Based on the existing land use and the field investigation undertaken, as well as the unique geohydrology for the project area, no existing anthropogenic impacts were noted. The area is a greenfield site, with livestock (sheep and cattle) being the main user of the land. The impact of borehole interference was also not observed during the limited pump testing performed or brought to GCSs attention by the landowner.

6.6 Cumulative impacts

As all activities will take place on the same property, and close to other solar development there will be cumulative impacts (however limited due to the project type). Figure 6-3 shows the sub-catchments associated with this project, boreholes identified as part of the hydrocensus, and other solar development within a 30km radius of the project.

The cumulative impacts from a groundwater perspective are limited in that only a few boreholes will be used to supplement the water use at the site (small-scale local use) and that no dedicated groundwater pollution sources will be created (i.e., landfills, oil or fuel storage areas, mining, wellfields to provide water to a town etc.). Moreover, the other proposed solar developments are situated in different drainage areas, rendering the likely impact associated with this project zero. Any geohydrological risk for this project will be confined to the delineated sub-catchments (worst case) and only local impacts around boreholes being used for the development (refer to Section 6.2). The operational phase risk table includes cumulative risk about the site, and activities thereon.

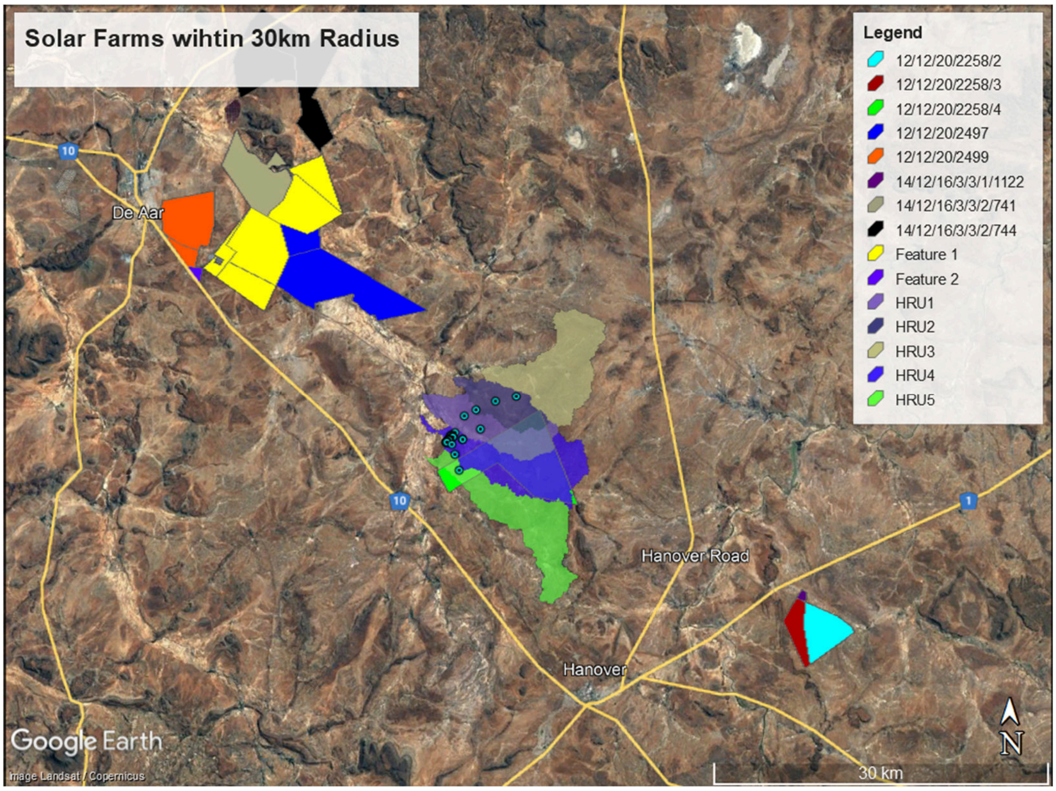


Figure 6-3: Other solar farms within a 30km radius & sub-catchments associated with this project

Table 6-8: Construction (preparation and development) phase risk

			Pre- Mitigation								Post Mitigation							
Component Being Impacted On	**Activity Which May Cause the Impact**	**Activity**	**Duration (D)**	**Extent (E)**	**Potential for impact on irreplaceable resources (I)**	**Severity (S)**	**Consequence (C)**	**Probability (P)**	**Significance**	**Recommended Mitigation Measures**	**Duration (D)**	**Extent (E)**	**Potential for impact on irreplaceable resources (I)**	**Severity (S)**	**Consequence (C)**	**Probability (P)**	**Significance**	**Confidence**
Vadose zone soils	Disturbing vadose zone during excavations activities, contractor laydown areas. Excavations associated with the borrow pits for road-building material may subject the surroundings to temporary sedimentation during storm events. There is a potential for some erosion if there are storm events. Hydrocarbon/oil spillages onto soils have the potential to contaminate the soils.	Earthworks and PV array assemblage. MTS and transmission line construction	Short-term (2)	Site (2)	Yes (1)	Medium (-2)	Slightly detrimental (-7 to -12) (-10)	Definite (2)	Low (-20)	• Only excavate / clear areas applicable to the project area. • Keep the site clean of all general and domestic wastes. • All development footprint areas to remain as small as possible and vegetation clearing to be limited to what is essential. • Retain as much indigenous vegetation as possible / re-vegetate. • Have fuel/oil spill clean-up kits on site. • Exposed soils are to be protected using a suitable covering or sandbags or berms to control erosion.	Short-term (2)	Site (2)	Yes (1)	Low (1)	Negligible (0 to -6) (-5)	Definite (2)	Negligible (0 to -12) (-10)	Medium
Primary Surface Water Receivers – > Non-perennial streams	Erosion and sedimentation of watercourses due to unforeseen circumstances (i.e., bad weather). Alteration of natural drainage lines may lead to ponding or increased runoff patterns (i.e., may cause stagnant water levels or increase erosion). Installation of road culverts or pylons for transmission lines may cause temporary sedimentation after storm events.	Earthworks and PV array assemblage. MTS and transmission line construction	Short-term (2)	Site (2)	Yes (1)	Medium (-2)	Slightly detrimental (-7 to -12) (-10)	Definite (2)	Low (-20)	• Cover soil stockpiles with a temporary liner to prevent contamination (where required and visually determined). • Ensure box culverts are used for any dedicated stream crossings. Box culverts should be sized to accommodate at least 1:100y flood events.	Short-term (2)	Site (2)	Yes (1)	Low (1)	Negligible (0 to -6) (-5)	Definite (2)	Negligible (0 to -12) (-10)	Medium

Component Being Impacted On	Activity Which May Cause the Impact	Activity	Pre- Mitigation							Recommended Mitigation Measures	Post Mitigation							Confidence
			Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance		Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance	
Regional groundwater table	Oil/fuel spillages may enter the regional groundwater table if prolonged percolation via the vadose zone takes place	Earthworks and PV array assemblage. MTS and transmission line construction	Short-term (2)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-5)	Improbable (0)	Negligible (0 to -12) (0 - ZERO)	No mitigation is possible. Impact projected to be zero.								Medium
Groundwater users	Poor quality seepage from oil/fuel spills during the construction phase, at any point in the project area, may impact the shallow groundwater table. Groundwater boreholes are generally situated within and downstream of the development areas, hence are potential receptors to pollution.	Earthworks and PV array assemblage. MTS and transmission line construction	Short-term (2)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-5)	Probable (1)	Negligible (0 to -12) (-10)	• Do not overproduce from boreholes used as part of the project. 8 hours of pumping per day is recommended. • Ensure routine water quality monitoring is undertaken. • Conduct multi-borehole water level logging, to ensure that no cumulative dewatering impacts are taking place for boreholes which may be in the same contact zones.	Short-term (2)	Site (2)	Yes (1)	Low (1)	Negligible (0 to -6) (-5)	Improbable (0)	Negligible (0 to -12) (0 - ZERO)	Medium

Table 6-9: Operational phase risk

Component Being Impacted On	Activity Which May Cause the Impact	Activity	Pre- Mitigation: Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance	Recommended Mitigation Measures	Post Mitigation: Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance	Confidence
Vadose zone soils	***Soil quality*** Fuel or oil leakages from tractors/vehicles entering the site may also cause soil quality degradation.	The net result of the development and activities at the site. MTS and transmission line construction	Short-term (2)	Site (2)	Yes (1)	Low (-1)	Negligible (0 to -6) (-5)	Definite (2)	Negligible (0 to -12) (-10)	• Ensure all vehicles entering the site are parked in designated areas, with drip trays, and that vehicles are in good order (i.e., don't let an observed leaking vehicle enter the site or service it on-site).	Short-term (2)	Site (2)	Yes (1)	Low (-1)	Negligible (0 to -6) (-5)	Improbable (0)	Negligible (0 to -12) (0)	Medium
Primary Surface Water Receivers - > Non-perennial streams	***Runoff and sedimentation*** Sedimentation of the non-perennial streams if storm events take place and insufficient vegetation cover is present. This is likely only to take place during severe storm events (i.e., 1:2 to 1:100y events). Accidental rainfall will likely not cause sedimentation.	The net result of the development and activities at the site. MTS and transmission line construction	Short-term (2)	Site (2)	Yes (1)	Low (-1)	Negligible (0 to -6) (-5)	Definite (2)	Negligible (0 to -12) (-10)	• Re-vegetate areas where erosion is noted or where vegetation is required to reduce stormwater peak flows.	Short-term (2)	Site (2)	Yes (1)	Low (-1)	Negligible (0 to -6) (-5)	Improbable (0)	Negligible (0 to -12) (0)	Medium
	Impact on water quality Hydrocarbon spills from vehicles accessing the site, or leakages from sub-stations transformers.	The net result of the development and activities at the site. MTS and transmission line construction.	Short-term (2)	Site (2)	Yes (1)	Low (-1)	Negligible (0 to -6) (-5)	Definite (2)	Negligible (0 to -12) (-10)	• Ensure all vehicles entering the site are parked in designated areas, with drip trays, and that vehicles are in good order (i.e., don't let an observed leaking vehicle enter the site or service it on-site). • Regular inspections (monthly) and maintenance of sub-stations.	Short-term (2)	Site (2)	Yes (1)	Low (-1)	Negligible (0 to -6) (-5)	Improbable (0)	Negligible (0 to -12) (0)	Medium
Regional groundwater table	Oil/fuel spillages may enter the regional groundwater table if prolonged percolation via the vadose zone takes place	Earthworks and PV array assemblage. MTS and transmission line construction	Short-term (2)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-5)	Improbable (0)	Negligible (0 to -12) (0 - ZERO)	• No mitigation is possible. Impact projected to be zero.								Medium

Component Being Impacted On	Activity Which May Cause the Impact	Activity	Pre- Mitigation							Recommended Mitigation Measures	Post Mitigation							Confidence
			Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance		Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance	
Groundwater users	Poor quality seepage from oil/fuel spills during the construction phase, at any point in the project area, may impact the shallow groundwater table. Groundwater boreholes are generally situated within and downstream of the development areas, hence are potential receptors to pollution.	Earthworks and PV array assemblage. MTS and transmission line construction	Short-term (2)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-5)	Probable (1)	Negligible (0 to -12) (-10)	• Do not overproduce from boreholes used as part of the project. 8 hours of pumping per day is recommended. • Ensure routine water quality monitoring is undertaken. • Conduct multi-borehole water level logging, to ensure that no cumulative dewatering impacts are taking place for boreholes which may be in the same contact zones.	Short-term (2)	Site (2)	Yes (1)	Low (1)	Negligible (0 to -6) (-5)	Improbable (0)	Negligible (0 to -12) (0 - ZERO)	Medium
Cumulative Impact	The effects on the groundwater regime and surface water bodies fed by groundwater, as a result of the activities at the site, and other solar facilities within a 30km radius. There may be an impact on the Brak River (about 6km downstream of the site) if PU is not decreased by 2050 to limits that the sub-catchments can handle (refer to the water balance section). Sustainable production rates now can be overproduction rates in future, and should therefore be adjusted accordingly nearing the 2050 mark. The imp[act on groundwater recharge as a result of the PV arrays is deemed zero, as a result of the stormwater philosophy that will be implemented (refer to the recharge section of the report).	PV arrays and groundwater abstraction. MTS and transmission line construction	Short-term (2)	Site (2)	Yes (1)	Medium (-2)	Slightly detrimental (-7 to -12) (-10)	Definite (2)	Low (-20)	Decrease the abstraction rates nearing the 2050 mark. Ensure that only the required water is pumped from the boreholes, even if the proposed sustainable yields are greater than what is required. Because the water is available, does not mean that it should be abstracted if not going to be used.	Short-term (2)	Site (2)	Yes (1)	Low (1)	Negligible (0 to -6) (-5)	Improbable (0)	Negligible (0 to -12) (0 - ZERO)	Medium

7 GROUNDWATER MONITORING

The monitoring network is based on the principles of a monitoring network design as described by (DWAF, 2007). The methodological approach that the monitoring plan follows is represented in Figure 7-1, below.

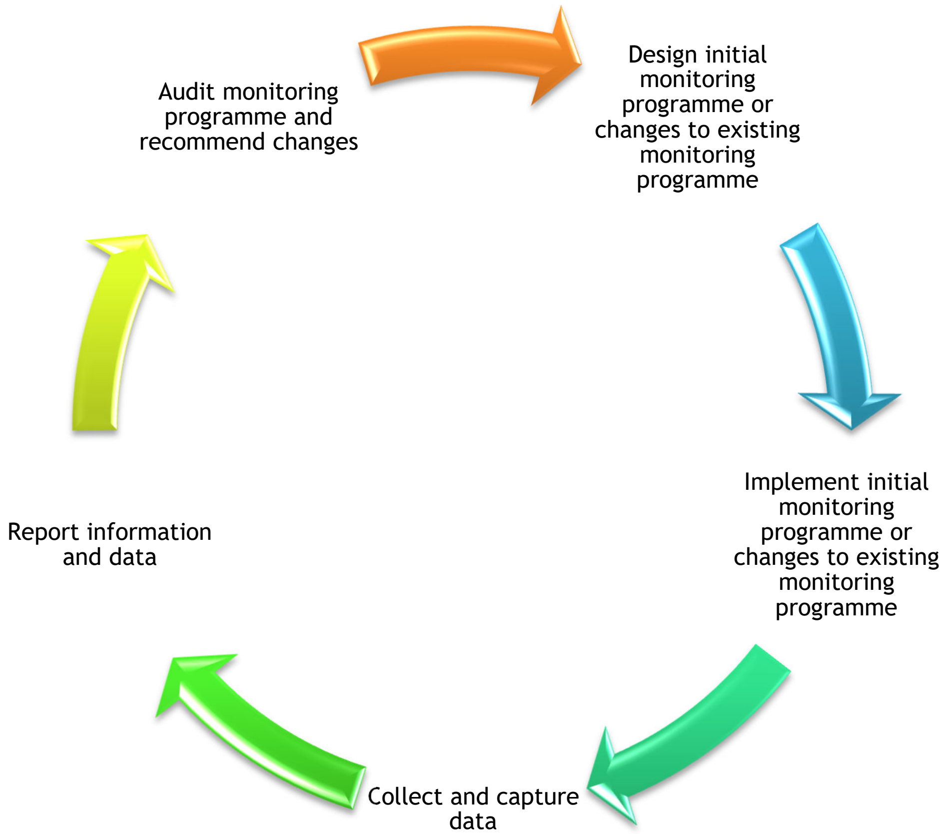


Figure 7-1: Monitoring Process

7.1 Establishment of the monitoring network

Currently, no groundwater (GW) monitoring is taking place. It is proposed that a proper monitoring programme be implemented to monitor both the water quality and quantity at the site. The monitoring programme is divided into two phases:

- Phase 1: Monitoring during any expansion, construction or decommissioning activities (temporary monitoring); and
- Phase 2: Monitoring after development expansion (long term or for a period after the activity).

7.1.1 Phase 1 monitoring

During the construction phase, it is recommended that all vehicles are in good working order when entering the site (i.e., visual observations of any leakages that may emanate from the vehicle accessing the site) and parked in designated areas with drip trays.

As part of Phase 1 monitoring, visual observations (i.e., monthly inspections and inspections shortly after rainfall events) of the banks associated with the non-perennial streams and rivers and the general conditions of the areas cleared, should be adequate to determine if there is any sediment runoff taking place or erosion.

7.1.2 Phase 2 monitoring

From the risk assessment undertaken, it is anticipated that soils downstream of the proposed development, boreholes which fall within and downstream of the proposed development areas and the non-perennial streams (feeding into temporary livestock watering dams) are the receivers of any sediment runoff or poor-quality seepage/runoff from the site.

Monitoring the groundwater quality and quantity at the boreholes identified for future groundwater use (borehole 13, solar BH1 and solar BH2, solar BH5, Windmill BH4 and Windmill BH5) should be sufficient to determine the impact on the local aquifer system. Moreover, if any additional boreholes are drilled for this project (as per Section 4.3) these boreholes should be added to routine groundwater monitoring.

As part of the monitoring efforts, an annual hydrocensus of all known groundwater boreholes, springs, and new boreholes, is recommended. During the hydrocensus water levels and water quality should be evaluated, as well as complaints by landowners about declining yields which may relate to the project.

7.2 Monitoring duration and responsibility

Permanent monitoring at the frequencies specified below is recommended (refer to Table 7-1). It is proposed that the applicant be responsible for Phase 1 and Phase 2 monitoring or appoint a service provider who can assist with the specialised groundwater monitoring.

7.3 Proposed monitoring localities

The proposed monitoring type, frequencies and constituents are listed in Table 7-1.

Table 7-1: Proposed monitoring points, frequencies, and sample analyses

Site Type	Frequency	Type	Field Measurements	Laboratory Analyses
Groundwater boreholes for abstraction: • Solar BH3 in area PV1. • Borehole 4 (BH4) in area PV3. • Borehole 5 (BH5) in area PV3. • Borehole 13 (BH13) in area PV1. • Solar BH1 in area PV2. • Solar BH2 in area PV2.	Monthly	• Field assessment (monthly). • Lab samples (annual).	• pH. • Electrical Conductivity (EC) / Total Dissolved Solids (TDS). • Temp. • Groundwater Level.	• pH. • EC/TDS. • COD. • Turbidity. • Major cations and anions (Ca, Mg, Na, K, Cl, NO_3, SO_4, PO_4, F). • Microbes (E. coli, total coliforms and standard plate count)
Hydrocensus of springs, boreholes and new boreholes within the project area	Annual	• Field visual assessment	• pH. • Electrical Conductivity (EC) / Total Dissolved Solids (TDS). • Temp. • Groundwater Level.	• pH, EC, TDS, Ca, Mg, Na, K, Cl, F, NO_3. SO_4, Fe, Mn, Al

8 CONCLUSIONS

Based on the findings of the investigation, the following conclusion is drawn:

- The study area is predominantly underlain by sedimentary rocks of the Beaufort Group, which forms part of the Karoo Supergroup. Occurrences of dolerite sills and dykes are well known to occur in the project area, and the contacts between the intrusive rock and the host rock are generally targeted for groundwater development.
- Based on the groundwater data collected, it is confirmed that three (3) aquifers exist in the area:

    a. Unconfined aquifers associated with paleo drainage as well as flood plains of non-perennial river systems (about 5 to 10m thick) – not associated with the study area but closer to the Brak River;

    b. A shallower semi-unconfined aquifer system associated with weathered Beaufort sediments; and

    c. A deeper confined intergranular and fractured aquifer network is associated with the older Beaufort and Ecca sediments, of the Karoo Group.

- The aquifer underlying the development areas can be regarded as a moderate-yielding aquifer, with reported yields ranging from 0.5 to 2 l/sec. From available literature data, the weathered zone for the area is estimated to be in the order of 10m thick, followed by a subsequent thicker fractured aquifer zone. Based on available groundwater levels for the study area, the groundwater table is placed in the order of 5 mbgl, when considering a regional-scale water table. Groundwater is found within the bedding planes in shale or interbedded sandstone and jointed and fractured contact zoned between sedimentary rocks and dolerite dyke. As such, where these structures daylight in low-laying topographical areas, springs will be produced fed by the groundwater within the contacts. The groundwater table mimics the topography and groundwater flows from high-lying areas (water divides) to low-lying areas.
- Surface water streams in the area are non-perennial. Hence, groundwater is the main source of water for inhabitants who reside in the project area. As part of this assessment, a hydrocensus was undertaken, and 28 boreholes were identified in the study area, of which 13 are used for livestock watering and 6 for domestic use.

- The end client desires to use groundwater to supplement the construction and operational water required for the project. The following boreholes were yield tested, and based on 8hr recommended abstraction, the following yields are attained (refer to Table 8-1). Smaller-size pumps (as indicated below) can be installed if 24hr pumping is required. This is however not advised, as the boreholes may be overpumped, decreasing the borehole life and increasing the probability of pump failure. As part of the pump testing and data gathered, the following boreholes can be considered as additional water sources. Though these boreholes have not been pump tested, indicative yields based on field observations, local hydrogeology and pump test data for nearby boreholes are presented:
    - **Borehole BH14 in Phase 1**
        - Expected yield 6 l/sec for 8 hours/day (172.8 m^3/day)
        - No interference on nearby BH13 was anticipated.
    - **Solar BH4 in Phase 1**
        - Expected yield 0.5 l/sec for 8 hours/day (14.4 m^3/day).

Table 8-1: Sustainable yields for tested boreholes

BH ID		BH 13 (PV1)	Solar BH1 (PV2)	Solar BH2 (PV2)	BH 4 (PV3)	BH 5 (PV3)	Solar BH5 (PV1)
Q Sustain	l/sec	6.64	0.45	0.21	6.58	5.11	0.23
Rec Pump Time	Hours	8.00	8.00	8.00	8.00	8.00	8.00
Q Sustain Total	m^3/day	191.23	12.96	6.05	189.50	147.17	6.62
Q Sustain Total	m^3/month	5736.96	388.80	181.44	5685.12	4415.04	198.72
Q Sustain	l/sec	3.83	0.26	0.12	3.80	2.95	0.13
Rec Pump Time	Hours	24.00	24.00	24.00	24.00	24.00	24.00
Q Sustain Total	m^3/day	330.91	22.46	10.37	328.32	254.88	11.23
Q Sustain Total	m^3/month	9927.36	673.92	311.04	9849.60	7646.40	336.96

- Several groundwater borehole positions were sited, via the application of magnetic geophysical methods, within the Phase 1, Phase 2 and Phase 3 areas. The proposed drilling targets are available in Section 4.3.2).
- Groundwater quality for the region, based on field-gathered data, can be considered hard water. The high dissolved salt content will likely cause scaling in piping exposed to heat, or in utensils used to boil water. High EC indicates a high salt load, which could result in scaling on solar panels if applied and left to evaporate. For cleaning purposes, the water would need to be wiped from the panels before it is allowed to evaporate. Otherwise, water softeners or deionisation plants will be required.

- The projected rainfall decrease for the area as a result of climate change is estimated to decrease by as much as 150mm, reducing the total rainfall to about 170 mm/yr by 2050. It should be noted that the projected changes in the annual average number of extreme rainfall days throughout the district over the period 2021-2050 under the RCP 8.5 scenario suggest either a decrease or increase in rainfall events. It is anticipated that under the scenarios put forth, the groundwater resources in the project area may become completely replenished in the event of 1:50 and 1:100-year storm events that occur in the project area. As a climate change scenario, the 170mm annual rainfall for the area is used.
    a. Based on the groundwater availability in all sub-catchments for the current setting it is estimated that there is enough groundwater available on a sub-catchment level to sustain the proposed 8-hour abstraction from the designated boreholes and the sub-catchments they fall in.
    b. It should be noted that dust suppression will also take place at all phases of the project. Dust suppression will likely be very high, and the water not used as part of the construction phase estimate (presented in Section 5.4.2.) will be allocated to dust suppression. The demand will depend on the frequency of spraying events for dust suppression. It is recommended that environmentally safe binding liquids be considered to decrease water use volumes. As long as dust suppression and operational water use volumes taken from groundwater resources in the sub-catchments are within the surplus estimates, the impact on the groundwater reserve will likely be minimum.
- The risk assessment for both the construction and post-construction phases of the project is considered marginal, with mostly reversible and manageable impacts. The largest risk about geohydrology is the proposed groundwater abstraction activities. As groundwater is a very important resource for locals in the area, care should be taken not to overproduce from boreholes chosen for this project; and there is a limited impact on existing livestock/domestic watering already implemented. The risk of poor-quality seepage via the vadose zone and impacts on groundwater water quality is predicted to be marginal, and will only be a problem if the developing contractor allows leaking vehicles onto the site, or cause deliberate environmental harm.

8.1 Identification of any areas that should be avoided

No dedicated buffer areas are recommended, other than staying out of pre-identified high ecological importance areas as identified per the EIA screening assessment.

8.2 Mitigation measures for inclusion in the EMPr and EIA

The following mitigation measures can be implemented as part of the EMPr to further reduce the risk of flooding on site and contribution to stormwater generation potential:

- During the construction phase, it is recommended that sandbags and temporary berms be used, to manage stormwater runoff (if storms do occur). It is recommended that the construction phase take place during the winter months, with a decreased probability of storm events. Temporary stormwater systems should be sufficient to manage the stormwater at the site during the construction phase.
- Ensure that all vehicles entering the site (construction and servicing) are not leaking fuel or oils, which can lead to soil and water contamination. Have spill kits on site.
- Do not overproduce from existing or proposed boreholes and ensure that water level monitoring of boreholes within a 1.5km radius of the pumping borehole is undertaken. If a decline in water levels is noted in all boreholes, as a result of pumping, the abstraction rate should be lowered to prevent aquifer depletion.

8.3 Reasoned opinion on whether the activity should be authorized

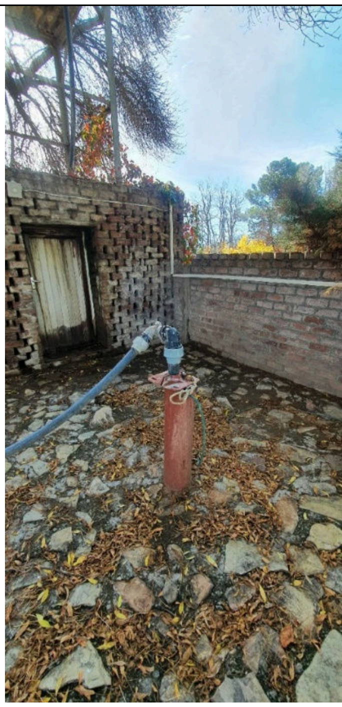
This assessment cannot find any grounds or identify high geohydrological risk to not proceed with the authorisation and the proposed developments. This is grounded on the assumption that the proposed mitigation measures (Sections 6 & 7), EMPr and EIA recommendations are implemented during the construction and operational phase of the development.

9 BIBLIOGRAPHY

Aquiworx, 2015. *Aquiworx Software Integrated Information,* s.l.: s.n.
ARC, 2006. *Lan Types of South Africa,* s.l.: Pretoria: Agricultural Reserach Council.
Bailey, A. & Pitman, W., 2015. *Water Resources of South Africa 2012 Study (WR2012): Executive Summary Version 1. WRC Report No. K5/2143/1.,* Gezina, South Africa: Water Research Commission Report: s.n.
Botha, J. et al., 1998. *Karoo Aquifers: Their Geology, Geometry and Physical Properties,* s.l.: WRC Report No: 457/1/98.
CSIR, 2019. *'Green Book | Adapting South African Settlements to Climate Change'. Green Book | Adapting South African Settlements to Climate Change. 2019.,* s.l.: s.n.
DEA, 2019. *South African National Land-Cover (SANLC) 2018,* South Africa: DEA on 1st October 2019.
DMEA, 1998. *3024 Colesberg - 1:250 000 Geological map Series,* s.l.: DMEA.
DWA, 2012. *Aquifer Classification of South Africa map,* s.l.: Hydrological Services - Groundwater Information..
DWAF, 2006. *Groundwater Resource Assessment II,* s.l.: s.n.
DWAF, 2007. *Best Practice Guidelines – G3: Water Monitoring Systems,* s.l.: DWS.
DWAF, 2007. *Best Practice Guidelines – G3: Water Monitoring Systems,* s.l.: DWAF.
DWAF, 2008. *Best Practice Guidelines: Impact Prediction (G4),* s.l.: DWS.
DWS, 2016. *New Water Management Areas,* South Africa: Government Gazette No. 40279.
EcoLeges, 2022. *5. Estimated Water Demand_Henri,* s.l.: s.n.
GRIP, 2016. *Groundwater Resource Information Project* , s.l.: s.n.
Kottek, M. et al., 2006. *World Map of the Köppen-Geiger climate classification updated. Meteorol. Z.15, 259-263. doi:10.1127/0941-2948/2006/0130.* s.l.:s.n.
Lourens, P., 2013. *The relationship between South African geology and geohydrology,* s.l.: IGS, University of the Free State, Bloemfontein. Masters Dissertation..
Meteoblue, 2021. *Climate Data.* s.l.:https://www.meteoblue.com.
Meyer, P.S., Chetty, T., Jonk, F., 2002. *2924 Bloemfontein - 1:500 000 Hydrological Map Series of the Republic of South Africa,* s.l.: s.n.
NGA, 2022. *National Groundwater Archive.* [Online]
Available at: https://www3.dwa.gov.za/NGANet/Security/WebLoginForm.aspx
Parsons, R., 1995. *A South African Aquifer System Management Classification,* s.l.: Water Research Commission Report No. KV 7795.
Parsons, R. & Wentzel, J., 2007. *Groundwater Resource Directed Measures Manual, WRC Report No TT 299/07,* s.l.: DWAF.
SADAC GIP, 2021. *SADC Groundwater Information Portal,* s.l.: s.n.
Van Deventer, H. S.-A. L. M. N. P. C. S. A. C. N. G. M. J. N. L. M. O. D. S. P. S. E. &. S. K., 2018. *NBA2018 National Wetland Map 5.* s.l.:s.n.
Vegter, J., 1995. *An explanation of a set of National Groundwater Maps. Water Research Commission. Report No TT 74/95..* s.l.:s.n.
Woodford, A. V. T. G. T. A. T. G. R. P. G. M. O. R. V. D. a. E. C., 2013. *Karoo Groundwater Atlas Volume 2,* s.l.: Karoo Groundwater Expert Group (KGEG).
WRC, 2015. *http://www.waterresourceswr2012.co.za/resource-centre/.* [Online].

APPENDIX A: PHOTOGRAPHIC LOG

Client Name: Ecoleges Environmental Consultants	Site Location: De Aar	Project No. 22-0401

Photo No. 1	**Date:** 23 May 2022
Direction Photo Taken: N/A	
Description Farmhouse windmill pumping to small water storage dam. Water Level: 3 mbcl Collar: 0.3 m	 Lat: -30.859824 Lon: 24.304545 Elevation: 1317 mamsl
Photo No. 2	**Date:** 23 May 2022
Direction Photo Taken: N/A	
Description Farmhouse Borehole 1 Pumps to a water storage tank for domestic use. Water Level: 3.79 mbcl Collar: 0.69 m	 Lat: -30.86006 Lon: 24.304732 Elevation: 1317 mamsl

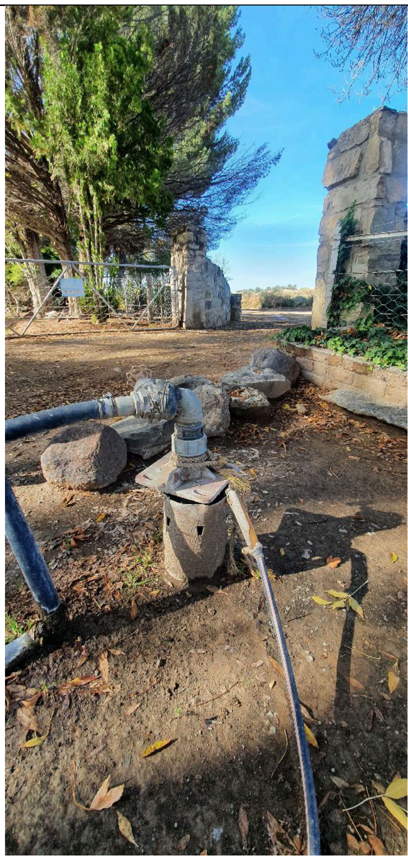
<table>
<tr><td>Photo No.
3</td><td>Date:
23 May 2022</td><td rowspan="3">
Lat: -30.860176 Lon: 24.304801 Elevation: 1319 mamsl</td></tr>
<tr><td colspan="2">Direction Photo Taken:
N/A</td></tr>
<tr><td colspan="2">Description
Farmhouse Borehole 2 Pumps to a water storage tank for domestic use.
Water Level: 3.03 mbcl
Collar: 0.255 m</td></tr>
<tr><td>Photo No.
4</td><td>Date:
23 May 2022</td><td rowspan="3">
Lat: -30.859783 Lon: 24.30565Elevation: 1319 mamsl</td></tr>
<tr><td colspan="2">Direction Photo Taken:
N/A</td></tr>
<tr><td colspan="2">Description
Farmhouse borehole 3 Not Used (backup)
Water Level: 2.68 mbcl
Collar: 0.44 m</td></tr>
</table>

Photo No.	Date:	
5	23 May 2022	 Lat: -30.859707 Lon: 24.305267 Elevation: 1319 mamsl
Direction Photo Taken: N/A		
Description Farmhouse Borehole 4 pumps to the water storage tank for domestic use. Water Level: 2.47 mbcl Collar: 0.43 m		
Photo No.	**Date:**	
6	23 May 2022	 Lat: -30.861158 Lon: 24.302765 Elevation: 1318 mamsl
Direction Photo Taken: N/A		
Description Community Borehole 1 pumps to a water storage tank used by farm workers. Water Level: 4.57 mbcl Collar: 0.2 m		

<table>
<tr><td>Photo No.

7</td><td>Date:

23 May 2022</td><td rowspan="3">
Lat: -30.861823 Lon: 24.302079 Elevation: 1319 mamsl</td></tr>
<tr><td colspan="2">Direction Photo Taken:

N/A</td></tr>
<tr><td colspan="2">Description

Livestock Borehole 1 (Solar Pump) Used for livestock watering

Water Level: 3.195 mbcl

Collar: 0.2 m</td></tr>
<tr><td>Photo No.

8</td><td>Date:

23 May 2022</td><td rowspan="3">
Lat: -30.861699 Lon: 24.302989 Elevation: 1320 mamsl</td></tr>
<tr><td colspan="2">Direction Photo Taken:

N/A</td></tr>
<tr><td colspan="2">Description

Livestock Borehole 2 Used for livestock watering

Water Level: 4.34 mbcl
Collar: 0.46 m</td></tr>
</table>

<table>
<tr><td>Photo No.

9</td><td>Date:

23 May 2022</td><td rowspan="3">
Lat: -30.861712 Lon: 24.303115 Elevation: 1320 mamsl</td></tr>
<tr><td colspan="2">Direction Photo Taken:

N/A</td></tr>
<tr><td colspan="2">Description

Livestock Borehole 3 Not Used (backup)

Water Level: 4.36 mbcl

Collar: 0.2 m</td></tr>
<tr><td>Photo No.

10</td><td>Date:

23 May 2022</td><td rowspan="3">
Lat: -30.860281 Lon: 24.30396 Elevation: 1320 mamsl</td></tr>
<tr><td colspan="2">Direction Photo Taken:

N/A</td></tr>
<tr><td colspan="2">Description

Community Borehole 2 Not Used (backup)

Water Level: 2.31 mbcl

Collar: 0.2 m</td></tr>
</table>

Photo No. 11	Date: 23 May 2022	 Lat: -30.86006 Lon: 24.304732 Elevation: 1317 mamsl
Direction Photo Taken: N/A		
Description Farmhouse Borehole 1 Pumps to a water storage tank for domestic use. Water Level: 3.195 mbcl Collar: 0.2 m		
Photo No. 12	**Date:** 23 May 2022	 Lat: -30.851277 Lon: 24.334566 Elevation: 1333 mamsl
Direction Photo Taken: N/A		
Description Solar Borehole 1 (BH1) Used for livestock watering. pH = 6, EC = 600 uS/cm, Temp = 12.7 Water Level: 4.28 mbcl Collar: 0 m		

Photo No.	Date:	
13	23 May 2022	 Lat: -30.828809 Lon: 24.348689 Elevation: 1332 mamsl
Direction Photo Taken: N/A		
Description Windmill 1 (BH4) Used for livestock watering. pH = 6.3, EC = 650 uS/cm, Temp = 9.6. Auto logger installed at 12m. Water Level: 4.15 mbcl Collar: 0.2 m		

Photo No.	Date:	
14	23 May 2022	 Lat: -30.824873Lon: 24.368173 Elevation: 1350 mamsl
Direction Photo Taken: N/A		
Description Windmill 2 (BH5) No access for water level measurement. pH = 6.4, EC = 530 uS/cm, Tep = 7.3		

<table>
<tr><td>Photo No.

15</td><td>Date:

23 May 2022</td><td rowspan="3">
Lat: -30.835772 Lon: 24.330404 Elevation: 1333 mamsl</td></tr>
<tr><td colspan="2">Direction Photo Taken:

N/A</td></tr>
<tr><td colspan="2">Description

Windmill 3 No access for WL or Quality</td></tr>
<tr><td>Photo No.

16</td><td>Date:

23 May 2022</td><td rowspan="3">
Lat: -30.840681 Lon: 24.319462 Elevation: 1321 mamsl</td></tr>
<tr><td colspan="2">Direction Photo Taken:

N/A</td></tr>
<tr><td colspan="2">Description

Solar Borehole 2 (BH2) Used for livestock watering.

pH = 6.5, EC = 740 uS/cm, Temp = 18.3. Auto Logger installed at 20m.

Water Level: 11 mbcl

Collar: 0.28 m</td></tr>
</table>

Photo No. 17	Date: 23 May 2022	 Lat: -30.857577 Lon: 24.30863 Elevation: 1321 mamsl
Direction Photo Taken: N/A		
Description Solar Borehole 3 Used for domestic and livestock Water Level: 5.62 mbcl Collar: 0.44 m		
Photo No. 18	**Date:** 23 May 2022	 Lat: -30.857645 Lon: 24.308698 Elevation: 1321 mamsl
Direction Photo Taken: N/A		
Description Solar Borehole 3.2 (Backup) Not used (Backup) Water Level: 4.78 mbcl Collar: 0.47 m		

Photo No. **19**

Date: 23 May 2022

Direction Photo Taken: N/A

Description

Windmill 4 No access for WL or Quality

Lat: -30.8636 Lon: 24.307778 Elevation: 1321 mamsl

Photo No. **20**

Date: 23 May 2022

Direction Photo Taken: N/A

Description

Solar Borehole 4 Used for livestock watering

Water Level: 12.265 mbcl

Collar: 0.25 m

Lat: -30.871571 Lon: 24.310588 Elevation: 1330 mamsl

Photo No. **21**

Date: 23 May 2022

Direction Photo Taken: N/A

Description

Solar Borehole 5 Used for livestock watering.

pH = 6.8, EC = 810 uS/cm, Temp = 16.8. Water Level: 16.6 mbcl

Collar: 0 m

Lat: -30.88434 Lon: 24.31464 Elevation: 1335 mamsl

<table>
<tr><td>Photo No.
22</td><td>Date:
23 May 2022</td><td rowspan="3">
Lat: -30.859654 Lon: 24.317973 Elevation: 1321 mamsl</td></tr>
<tr><td colspan="2">Direction Photo Taken:
N/A</td></tr>
<tr><td colspan="2">Description
Borehole 13 was Not used. Near Phase 1. Can be used if required. Pump tested.
Pump installed @ 24mbgl, depth of hole 28m.
pH = 6.9, EC = 670 uS/cm, Temp = 19.9
Water Level: 3.725 mbcl
Collar: 0.56 m</td></tr>
<tr><td>Photo No.
23</td><td>Date:
23 May 2022</td><td rowspan="3">
Lat: -30.859271 Lon: 24.317607 Elevation: 1322 mamsl</td></tr>
<tr><td colspan="2">Direction Photo Taken:
N/A</td></tr>
<tr><td colspan="2">Description
Borehole 14 Not Used. Near Phase 1. Can be used if required.
Water Level: 3.77 mbcl
Collar: 0.515 m</td></tr>
</table>

<table>
<tr><td>Photo No.
24</td><td>Date:
23 May 2022</td><td rowspan="3">
Lat: -30.856677 Lon: 24.306986 Elevation: 1318 mamsl</td></tr>
<tr><td colspan="2">Direction Photo Taken:
N/A</td></tr>
<tr><td colspan="2">Description
Solar Borehole 6 Used for livestock watering
Water Level: 6.52 mbcl
Collar: 0.43 m</td></tr>
<tr><td>Photo No.
25</td><td>Date:
23 May 2022</td><td rowspan="3">
Lat: -30.856589 Lon: 24.306435 Elevation: 1316 mamsl</td></tr>
<tr><td colspan="2">Direction Photo Taken:
N/A</td></tr>
<tr><td colspan="2">Description
Borehole Dam Backup 1 Not Used (backup)
Water Level: 4.75 mbcl
Collar: 0.2 m</td></tr>
<tr><td>Photo No.
26</td><td>Date:
23 May 2022</td><td rowspan="3">
Lat: -30.856959 Lon: 24.307939 Elevation: 1320 mamsl</td></tr>
<tr><td colspan="2">Direction Photo Taken:
N/A</td></tr>
<tr><td colspan="2">Description
Solar Borehole 7 Used for livestock watering
Water Level: 5.51 mbcl
Collar: 0.34 m</td></tr>
</table>

<table>
<tr><td>Photo No.
27</td><td>Date:
23 May 2022</td><td rowspan="3">
Lat: -30.856031 Lon: 24.307938 Elevation: 1319 mamsl</td></tr>
<tr><td colspan="2">Direction Photo Taken:
N/A</td></tr>
<tr><td colspan="2">Description
Field Borehole 1 Not Used (backup)
Water Level: 4.45 mbcl
Collar: 0.26 m</td></tr>
<tr><td>Photo No.
28</td><td>Date:
23 May 2022</td><td rowspan="3">
Lat: -30.854071 Lon: 24.31068 Elevation: 1317 mamsl</td></tr>
<tr><td colspan="2">Direction Photo Taken:
N/A</td></tr>
<tr><td colspan="2">Description
Old Windmill 1 No access for WL or Quality</td></tr>
</table>

APPENDIX B: GEOPHYSICAL INVESTIGATION

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

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

1. Survey orientation and spacing length

Five (5) Mag profiles were completed. The Mag traverse varied from approximately 200 m in length. Mag readings were taken at 5 m intervals. Moreover, each spacing was recorded with a handheld GPS.

2. Potential inference

Mag lines were shifted and oriented to best avoid and compensate for the interference sources identified in the project area (i.e., power lines and fences).

3. Data analyses

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

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

4. Results

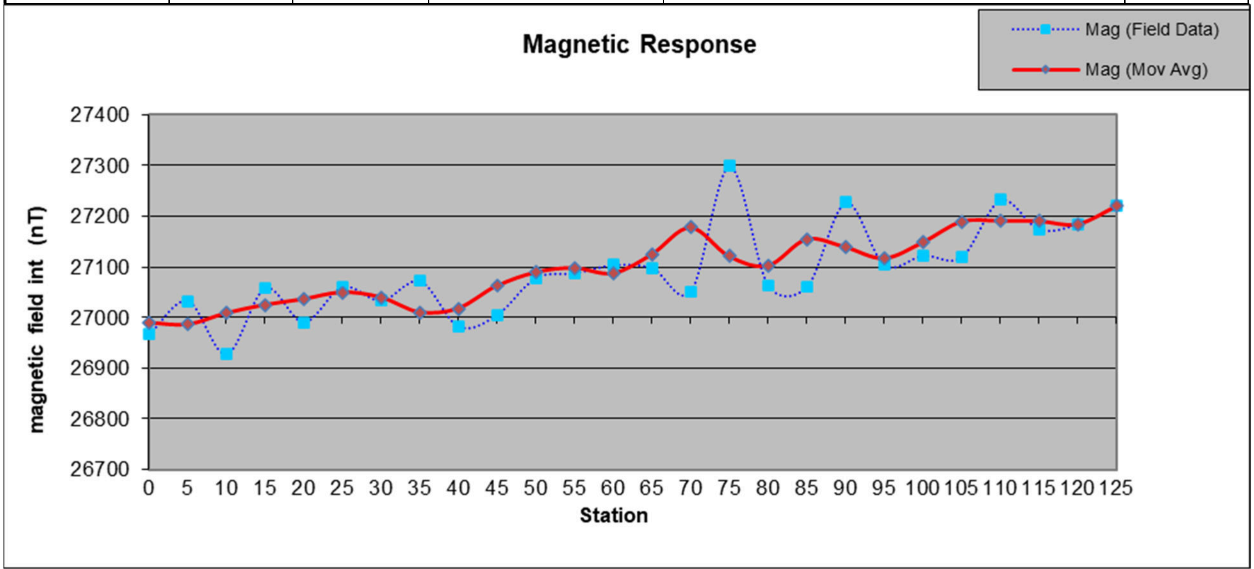
The magnetic response (magnetic field strength measured in nano Tesla [nT]) graphs from the survey lines are shown below. In the graphs, the horizontal axis represents the position along the survey line, while the vertical axis represents the magnetic field strength. The following drilling positions can be considered for future water supply:

Target ID	Latitude (WGS84)	Longitude (WGS84)	Elevation (mamsl)	Proposed Depth
T1	-30.851	24.35747	1382.89	60m-80m
T2	-30.8514	24.35786	1383.474	60m-80m
T3	-30.8858	24.31503	1370.921	60m-80m
T4	-30.8858	24.31503	1370.874	60m-80m

MAGNETIC LINE 1

Project:	De Aar	Traverse Number:	T1
Project Number:	22-0401	Traverse Direction:	SW
Survey Area:	De Aar	Station Spacing:	5m
Date of Survey:	May 2022	Operator:	HB

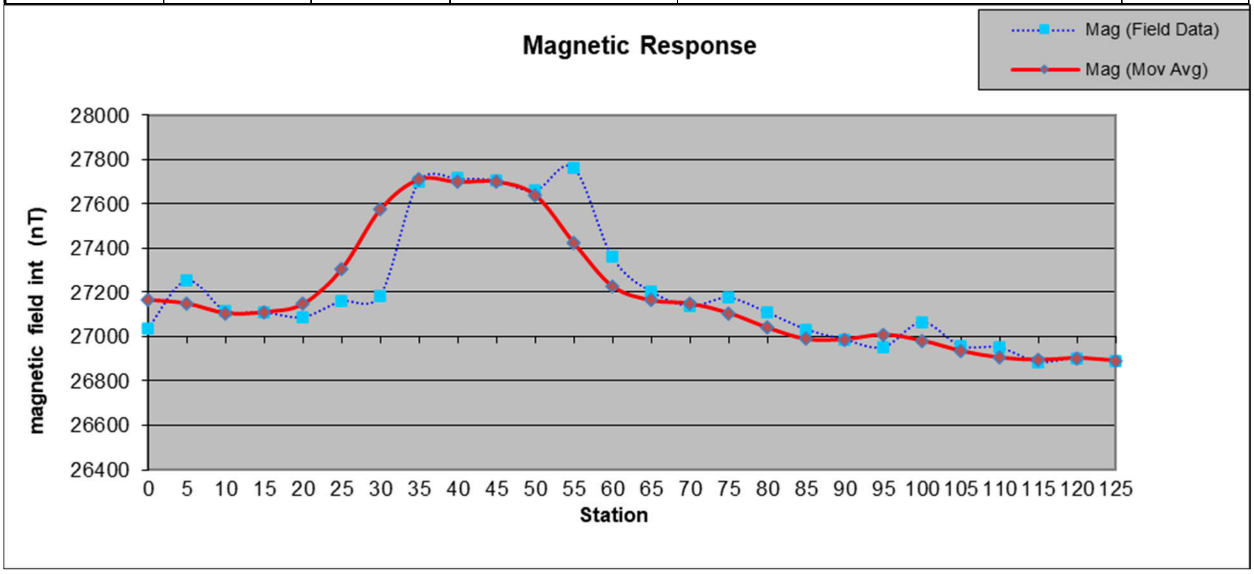
Station	Station Coordinates		Mag		Comments
Station	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)	
0	-30.8329	24.3405	26966.3	26989.35	
5	-30.8330	24.3405	27032.2	26985.7	
10	-30.8330	24.3404	26926.7	27007.825	
15	-30.8330	24.3404	27057.2	27024.45	
20	-30.8330	24.3403	26990.2	27035.775	
25	-30.8330	24.3403	27060.2	27049.325	
30	-30.8331	24.3402	27032.5	27039.55	
35	-30.8331	24.3402	27072.1	27010.025	
40	-30.8331	24.3401	26981.5	27017.525	
45	-30.8331	24.3401	27005	27062.55	
50	-30.8331	24.3400	27078.6	27089.625	
55	-30.8331	24.3400	27088	27098.425	
60	-30.8332	24.3399	27103.9	27087.85	
65	-30.8332	24.3399	27097.9	27125	
70	-30.8332	24.3399	27051.7	27178	
75	-30.8332	24.3398	27298.7	27121.25	
80	-30.8333	24.3397	27062.9	27102.725	
85	-30.8333	24.3397	27060.5	27154.65	
90	-30.8333	24.3396	27227	27139.475	
95	-30.8333	24.3396	27104.1	27117.375	
100	-30.8334	24.3396	27122.7	27148.675	
105	-30.8334	24.3395	27120	27189.625	
110	-30.8334	24.3395	27232	27191.4	
115	-30.8335	24.3394	27174.5	27190.925	
120	-30.8335	24.3394	27184.6	27184.6	
125	-30.8336	24.3393	27220	27220	



MAGNETIC LINE 2

Project:	De Aar	Traverse Number:	T2
Project Number:	22-0401	Traverse Direction:	NE
Survey Area:	De Aar	Station Spacing:	5m
Date of Survey:	May 2022	Operator:	HB

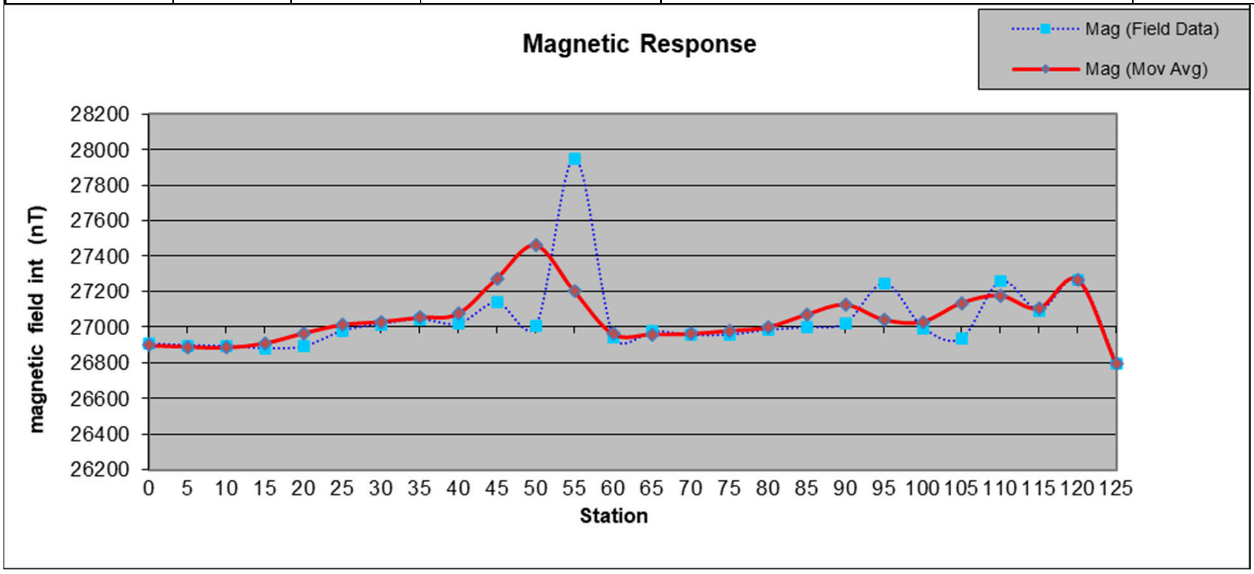
Station	Station Coordinates		Mag		Comments
Station	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)	
0	-30.8338	24.3396	27036.2	27164.825	
5	-30.8338	24.3396	27253.8	27148.675	
10	-30.8337	24.3397	27115.5	27105.475	
15	-30.8337	24.3397	27109.9	27110.475	
20	-30.8336	24.3398	27086.6	27146.975	
25	-30.8336	24.3398	27158.8	27307.025	
30	-30.8335	24.3398	27183.7	27575.6	
35	-30.8335	24.3399	27701.9	27709.6	
40	-30.8334	24.3399	27714.9	27697.525	
45	-30.8334	24.3400	27706.7	27698.625	
50	-30.8334	24.3400	27661.8	27637.575	
55	-30.8334	24.3400	27764.2	27421.95	
60	-30.8333	24.3401	27360.1	27225.95	
65	-30.8333	24.3401	27203.4	27162.9	
70	-30.8333	24.3402	27136.9	27148.425	
75	-30.8332	24.3402	27174.4	27105.6	
80	-30.8332	24.3402	27108	27039.475	
85	-30.8331	24.3403	27032	26988.8	
90	-30.8331	24.3403	26985.9	26988.1	
95	-30.8330	24.3403	26951.4	27008.925	
100	-30.8330	24.3404	27063.7	26981.825	
105	-30.8330	24.3404	26956.9	26935.225	
110	-30.8329	24.3404	26949.8	26905.475	
115	-30.8329	24.3404	26884.4	26895.725	
120	-30.8328	24.3404	26903.3	26903.3	
125	-30.8327	24.3405	26891.9	26891.9	



MAGNETIC LINE 3

Project:	De Aar	Traverse Number:	T1
Project Number:	22-0401	Traverse Direction:	N
Survey Area:	De Aar	Station Spacing:	5m
Date of Survey:	May 2022	Operator:	HB

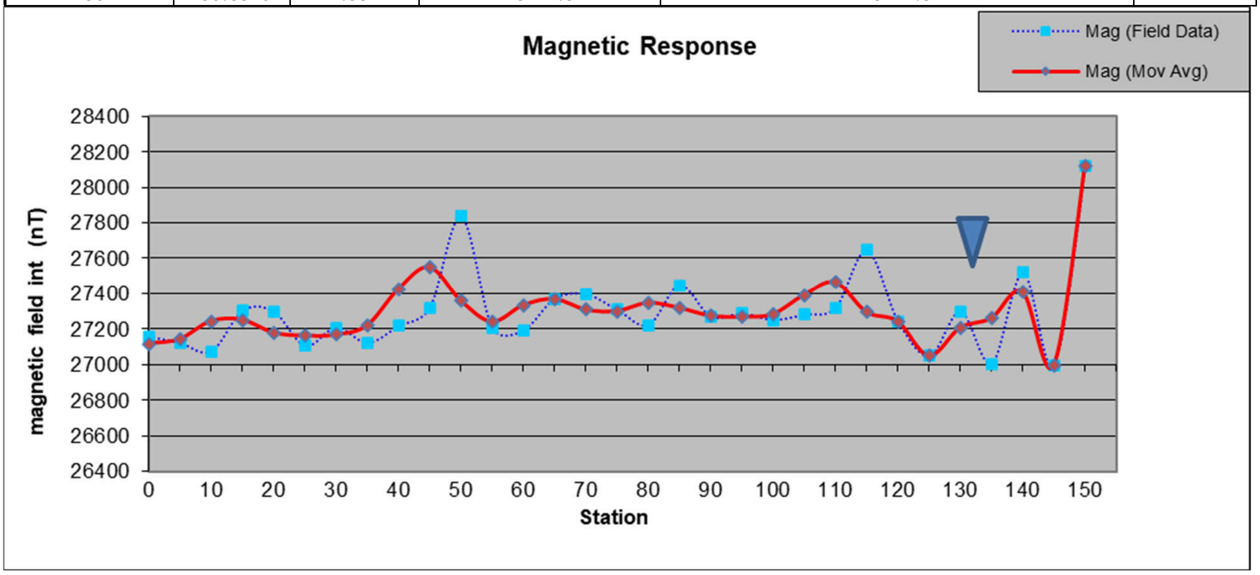
Station	Station Coordinates		Mag		Comments
Station	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)	
0	-30.8515	24.3574	26905.8	26896.875	pw line
5	-30.8515	24.3574	26895.7	26888.725	
10	-30.8514	24.3574	26890.3	26884.225	
15	-30.8514	24.3574	26878.6	26908.475	pw line
20	-30.8513	24.3574	26889.4	26964.5	Dol Outcrop
25	-30.8513	24.3574	26976.5	27012.275	
30	-30.8512	24.3574	27015.6	27028.875	
35	-30.8512	24.3574	27041.4	27053.075	
40	-30.8511	24.3574	27017.1	27074.2	
45	-30.8511	24.3575	27136.7	27274.35	
50	-30.8510	24.3575	27006.3	27460.925	@ Target
55	-30.8510	24.3575	27948.1	27201.275	
60	-30.8510	24.3575	26941.2	26960.825	
65	-30.8509	24.3575	26974.6	26958.825	
70	-30.8509	24.3576	26952.9	26961.275	
75	-30.8508	24.3576	26954.9	26978.925	
80	-30.8508	24.3576	26982.4	26998.55	
85	-30.8507	24.3576	26996	27069.65	
90	-30.8506	24.3576	27019.8	27124.875	
95	-30.8506	24.3577	27243	27041.325	
100	-30.8506	24.3577	26993.7	27029.725	
105	-30.8506	24.3578	26934.9	27134.125	
110	-30.8505	24.3578	27255.4	27175.975	
115	-30.8505	24.3578	27090.8	27104.05	
120	-30.8504	24.3578	27266.9	27266.9	
125	-30.8504	24.3579	26791.6	26791.6	



MAGNETIC LINE 4

Project:	De Aar	Traverse Number:	T1
Project Number:	22-0401	Traverse Direction:	S
Survey Area:	De Aar	Station Spacing:	5m
Date of Survey:	May 2022	Operator:	HB

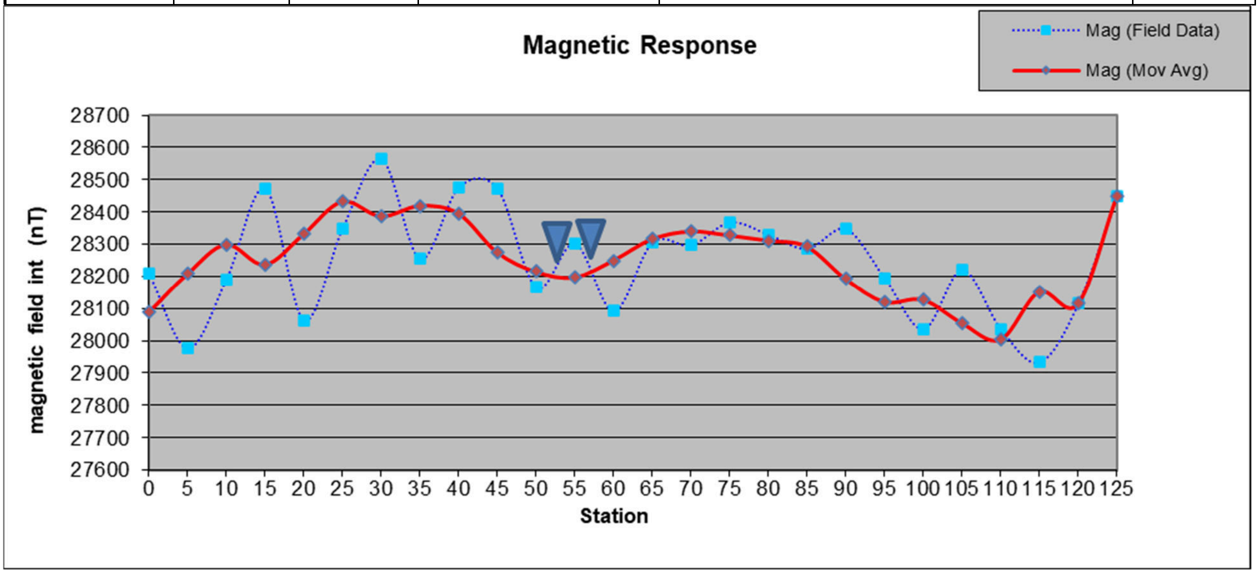
Station	Station Coordinates		Mag		Comments
Station	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)	
0	-30.8505	24.3589	27156.1	27117.225	
5	-30.8506	24.3589	27119.9	27142.125	
10	-30.8506	24.3589	27073	27243.75	
15	-30.8506	24.3588	27302.6	27250.25	
20	-30.8507	24.3588	27296.8	27178.575	
25	-30.8507	24.3588	27104.8	27160.575	
30	-30.8507	24.3587	27207.9	27166.925	
35	-30.8508	24.3587	27121.7	27218.775	
40	-30.8508	24.3586	27216.4	27423.35	
45	-30.8509	24.3586	27320.6	27549.175	
50	-30.8509	24.3586	27835.8	27359.25	
55	-30.8509	24.3585	27204.5	27239.85	
60	-30.8510	24.3585	27192.2	27332.175	
65	-30.8510	24.3584	27370.5	27367.25	
70	-30.8510	24.3584	27395.5	27308	
75	-30.8511	24.3583	27307.5	27299.325	
80	-30.8511	24.3583	27221.5	27345.9	
85	-30.8511	24.3583	27446.8	27317.725	
90	-30.8512	24.3582	27268.5	27273.375	
95	-30.8512	24.3582	27287.1	27267.2	
100	-30.8512	24.3582	27250.8	27282.475	
105	-30.8513	24.3581	27280.1	27390.85	
110	-30.8513	24.3580	27318.9	27462.825	
115	-30.8513	24.3580	27645.5	27293.975	
120	-30.8514	24.3579	27241.4	27241.4	
125	-30.8514	24.3579	27047.6	27047.6	
130	-30.8514	24.3579	27296.7	27205.6	A target
135	-30.8515	24.3578	27003.1	27259.35	
140	-30.8515	24.3578	27519.5	27407.9	
145	-30.8515	24.3578	26995.3	26995.3	
150	-30.8516	24.3577	28121.5	28121.5	



MAGNETIC LINE 5

Project:	De Aar	Traverse Number:	T1
Project Number:	22-0401	Traverse Direction:	SW
Survey Area:	De Aar	Station Spacing:	5m
Date of Survey:	May 2022	Operator:	HB

Station	Station Coordinates		Mag		Comments
Station	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)	
0	-30.8854	24.3154	28208.2	28088.475	
5	-30.8854	24.3154	27977.2	28207.95	
10	-30.8855	24.3153	28191.3	28299.8	
15	-30.8855	24.3153	28472	28237.225	
20	-30.8856	24.3153	28063.9	28331.425	
25	-30.8856	24.3152	28349.1	28432.65	
30	-30.8857	24.3152	28563.6	28387.05	
35	-30.8857	24.3152	28254.3	28419.425	
40	-30.8857	24.3151	28476	28395.925	
45	-30.8858	24.3151	28471.4	28275.75	
50	-30.8858	24.3150	28164.9	28215.175	@Target 1
55	-30.8858	24.3150	28301.8	28197.875	@Target 2
60	-30.8858	24.3150	28092.2	28249.825	
65	-30.8858	24.3149	28305.3	28316.425	
70	-30.8859	24.3149	28296.5	28340.175	
75	-30.8859	24.3149	28367.4	28327.9	
80	-30.8859	24.3148	28329.4	28311.75	
85	-30.8859	24.3147	28285.4	28293.35	
90	-30.8860	24.3147	28346.8	28193	
95	-30.8860	24.3147	28194.4	28121.725	
100	-30.8860	24.3146	28036.4	28127.975	
105	-30.8860	24.3145	28219.7	28056.4	
110	-30.8861	24.3145	28036.1	28004.7	
115	-30.8861	24.3144	27933.7	28152.925	
120	-30.8861	24.3144	28115.3	28115.3	
125	-30.8861	24.3143	28447.4	28447.4	
130	-30.8861	24.3143	28517.4	28311.075	
135	-30.8861	24.3142	28237.9	28242.4	
140	-30.8861	24.3142	28251.1	28271.675	
145	-30.8861	24.3141	28229.5	28255.6	
150	-30.8861	24.3140	28376.6	28111.325	
155	-30.8861	24.3140	28039.7	21703.15	
160	-30.8861	24.3139	27989.3	15443.725	
165	-30.8861	24.3139	2794.3	21746.85	
170	-30.8861	24.3138	28197	27946.25	
175	-30.8861	24.3138	27799.1	27799.1	
180	-30.8861	24.3137	27989.8	27989.8	



APPENDIX C: LABORATORY CERTIFICATES

TALBOT
A Level 1 B-BBEE company

[004621/22], [2022/06/13]

Certificate of Analysis

Project details

Customer Details

Customer reference:	DE AAR SOLAR PHASE 1, 2 & 3 (22-0401)
Order number:	22-0401
Company name:	GCS (PTY) LTD DURBAN
Contact address:	P O BOX 819, GILLITS, 3603
Contact person:	HENDRIK BOTHA
Additional customer information:	CLIENT: ECOLEGES ENVIRONMENTAL CONSULTANTS

Sampling Details

Sampled by:	CUSTOMER
Sampled date:	2022/05/26

Sample Details

Sample type(s):	GROUNDWATER SAMPLES
Date received:	2022/05/31
Delivered by:	COURIER SERVICE
Sample condition:	COMPOSITE SAMPLE MADE
Temperature at sample receipt (°C):	14.7

Report Details

Testing commenced:	2022/05/31
Testing completed:	2022/06/10
Report date:	2022/06/13
Our reference:	004621/22

Talbot Laboratories (Pty) Ltd Reg: 2016/334237/07
P.O Box 22598 Pietermaritzburg 3203 South Africa
+27 (0) 33 346 1444 www.talbot.co.za

Analytical Results

Methods	Determinands	Units	014686/22 DE AAR: F. HOUSE GW (TREATED) 26.05.2022	014687/22 DE AAR: F. HOUSE GW 26.05.2022
Chemical				
85	Dissolved Calcium	mg Ca/ℓ	1.37	81
85	Potassium	mg K/ℓ	0.35	3.62
85	Dissolved Magnesium	mg Mg/ℓ	<0.63	34
84	Sodium	mg Na/ℓ	223	54
94	Dissolved Aluminium*	µg Al/ℓ	<10	19
94	Dissolved Iron*	µg Fe/ℓ	22	17
94	Dissolved Manganese*	µg Mn/ℓ	<5	<5
10	Total Alkalinity	mg $CaCO_3$/ℓ	301	303
10	Bicarbonate Alkalinity	mg $CaCO_3$/ℓ	301	303
16G	Chloride	mg Cl/ℓ	28	35
2A	Electrical Conductivity at 25°C	mS/m	85.2	76.6
18G	Fluoride	mg F/ℓ	0.90	1.02
65Gc	Nitrate	mg N/ℓ	5.07	4.95
1	pH at 25°C	pH units	7.0	6.8
67G	Sulphate	mg SO_4/ℓ	55.6	64.0
41	Total Dissolved Solids at 180°C	mg/ℓ	464	452

Methods	Determinands	Units	014688/22 DE AAR: SOLAR BOREHOLE 5 25.05.2022	014689/22 DE AAR: SOLAR BOREHOLE 1 24.05.2022
Chemical				
85	Dissolved Calcium	mg Ca/ℓ	94	87
85	Potassium	mg K/ℓ	2.38	2.13
85	Dissolved Magnesium	mg Mg/ℓ	37	33
84	Sodium	mg Na/ℓ	57	48
94	Dissolved Aluminium*	µg Al/ℓ	18	18
94	Dissolved Iron*	µg Fe/ℓ	21	44
94	Dissolved Manganese*	µg Mn/ℓ	<5	<5
10	Total Alkalinity	mg $CaCO_3$/ℓ	331	299
10	Bicarbonate Alkalinity	mg $CaCO_3$/ℓ	331	299
16G	Chloride	mg Cl/ℓ	42	30
2A	Electrical Conductivity at 25°C	mS/m	82.7	74.4
18G	Fluoride	mg F/ℓ	0.76	1.22
65Gc	Nitrate	mg N/ℓ	9.71	7.33
1	pH at 25°C	pH units	6.7	6.7

Methods	Determinands	Units	014688/22 DE AAR: SOLAR BOREHOLE 5 25.05.2022	014689/22 DE AAR: SOLAR BOREHOLE 1 24.05.2022
67G	Sulphate	mg SO_4/ℓ	61.4	52.7
41	Total Dissolved Solids at 180°C	mg/ℓ	466	416
Methods	**Determinands**	**Units**	**014690/22 DE AAR: WINDMILL 1 BOREHOLE 4 24.05.2022**	**014691/22 DE AAR: WINDMILL 2 BOREHOLE 2 24.05.2022**
Chemical				
85	Dissolved Calcium	mg Ca/ℓ	78	55
85	Potassium	mg K/ℓ	2.02	1.44
85	Dissolved Magnesium	mg Mg/ℓ	29	24
84	Sodium	mg Na/ℓ	48	50
94	Dissolved Aluminium*	µg Al/ℓ	64	<10
94	Dissolved Iron*	µg Fe/ℓ	149	17
94	Dissolved Manganese*	µg Mn/ℓ	<5	<5
10	Total Alkalinity	mg $CaCO_3$/ℓ	283	251
10	Bicarbonate Alkalinity	mg $CaCO_3$/ℓ	283	251
16G	Chloride	mg Cl/ℓ	25	19.0
2A	Electrical Conductivity at 25°C	mS/m	71.2	59.7
18G	Fluoride	mg F/ℓ	0.92	0.97
65Gc	Nitrate	mg N/ℓ	5.03	4.73
1	pH at 25°C	pH units	7.0	7.1
67G	Sulphate	mg SO_4/ℓ	51.0	31.7
41	Total Dissolved Solids at 180°C	mg/ℓ	386	304
Methods	**Determinands**	**Units**	**014692/22 DE AAR: SOLAR BOREHOLE 2 24.05.2022**	**014693/22 DE AAR: BOREHOLE 13 25.05.2022**
Chemical				
85	Dissolved Calcium	mg Ca/ℓ	95	89
85	Potassium	mg K/ℓ	1.94	1.84
85	Dissolved Magnesium	mg Mg/ℓ	45	28
84	Sodium	mg Na/ℓ	34	58
94	Dissolved Aluminium*	µg Al/ℓ	<10	31
94	Dissolved Iron*	µg Fe/ℓ	11	23
94	Dissolved Manganese*	µg Mn/ℓ	<5	<5
10	Total Alkalinity	mg $CaCO_3$/ℓ	305	313
10	Bicarbonate Alkalinity	mg $CaCO_3$/ℓ	305	313
16G	Chloride	mg Cl/ℓ	33	34
2A	Electrical Conductivity at 25°C	mS/m	79.3	75.5

Methods	Determinands	Units	014692/22	014693/22
			DE AAR: SOLAR BOREHOLE 2 24.05.2022	DE AAR: BOREHOLE 13 25.05.2022
18G	Fluoride	mg F/ℓ	0.66	0.49
65Gc	Nitrate	mg N/ℓ	6.75	<0.25
1	pH at 25°C	pH units	6.9	6.9
67G	Sulphate	mg SO_4/ℓ	80.7	<2.5
41	Total Dissolved Solids at 180°C	mg/ℓ	474	402

Refer to the "Notes" section at the end of this report for further explanations.

Specific Observations

None

Quality Assurance

Technical signatories

Inorganic Chemistry: [illegible]

Notes to this report

Limitations

This report shall not be reproduced except in full without prior written approval of the laboratory.
Results in this report relate only to the samples as taken, and the condition received by the laboratory.
Any opinions and interpretations expressed herein are outside the scope of SANAS accreditation.
The decision rule applicable to this laboratory is available on request.
Sample preparation may require filtration, dilution, digestion or similar. Final results are reported accordingly.
Where the laboratory has undertaken the sampling, the location of sampling and sampling plan are available on request. Talbot Laboratories is guided by the National Standards SANS 5667-3:2006 Part 3 Guidance on the Preservation and Handling of Water Samples; SANS 5667-1:2008 Part 1 Guidance on the Design of Sampling Programmes and Sampling Techniques and SANS 5667-2:1991 Part 2: Guidance on Sampling Techniques.
Customers to contact Talbot Laboratories for further information.

Uncertainty of measurement

Talbot Laboratories' Uncertainty of Measurement (UoM) values are:

- Identified for relevant tests.
- Calculated as a percentage of the respective results.
- Applicable to total, dissolved and acid soluble metals for ICP element analyses.
- Available upon request.

Analysis explanatory notes

Tests may be marked as follows:

^	Tests conducted at our Port Elizabeth satellite laboratory.
*	Tests not included in our Schedule of Accreditation and therefore that are not SANAS accredited.
#	Tests that have been sub-contracted to a peer laboratory.
NR	Not required -shown, for example, where the schedule of analysis varied between samples.
σ	Field sampling point on-site results.
a	Testing has deviated from Method.

*********************End of Report*********************

APPENDIX D: RISK ASSESSMENT RATING

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

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

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

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

Table 9-1 provides a summary of the criteria used to assess the significance of the potential impacts identified. An explanation of these impact criteria is provided in Table 9-2.

The net consequence is established by the following equation:

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

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

Table 9-1: Proposed Criteria and Rating Scales to be used in the Assessment of the Potential Impacts

Criteria	Rating Scales	Notes
Nature	Positive (+)	An evaluation of the effect of the impact related to the proposed development.
	Negative (-)	
Extent	Footprint (1)	The impact only affects the area in which the proposed activity will occur.
	Site (2)	The impact will affect only the development area.
	Local (3)	The impact affects the development area and adjacent properties.
	Regional (4)	The effect of the impact extends beyond municipal boundaries.
	National (5)	The effect of the impact extends beyond more than 2 regional/ provincial boundaries.
	International (6)	The effect of the impact extends beyond country borders.
Duration	Temporary (1)	The duration of the activity associated with the impact will last 0-6 months.
	Short-term (2)	The duration of the activity associated with the impact will last 6-18 months.
	Medium-term (3)	The duration of the activity associated with the impact will last 18 months-5 or years.
	Long-term (4)	The duration of the activity associated with the impact will last more than 5 years.
Severity	Low (1)	Where the impact affects the environment in such a way that natural, cultural and social functions and processes are minimally affected.
	Moderate (2)	Where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way; and valued, important, sensitive, or vulnerable systems or communities are negatively affected.
	High (3)	Where natural, cultural, or social functions and processes are altered to the extent that the natural process will temporarily or permanently cease; and valued, important, sensitive, or vulnerable systems or communities are substantially affected.
Potential for impact on irreplaceable resources	No (0)	No irreplaceable resources will be impacted.
	Yes (1)	Irreplaceable resources will be impacted.
Consequence	Extremely detrimental (-25 to -33)	

Criteria	Rating Scales	Notes
	Highly detrimental (-19 to -24)	A combination of extent, duration, intensity, and the potential for impact on irreplaceable resources.
	Moderately detrimental (-13 to -18)	
	Slightly detrimental (-7 to -12)	
	Negligible (-6 to 0)	
	Slightly beneficial (0 to 6)	
	Moderately beneficial (13 to 18)	
	Highly beneficial (19 to 24)	
	Extremely beneficial (25 to 33)	
Probability (the likelihood of the impact occurring)	Improbable (0)	It is highly unlikely or less than 50 % likely that an impact will occur.
	Probable (1)	It is between 50 and 70 % certain that the impact will occur.
	Definite (2)	It is more than 75 % certain that the impact will occur, or the impact will occur.
Significance	Very high – negative (-49 to -66)	A function of Consequence and Probability.
	High – negative (-37 to -48)	
	Moderate – negative (-25 to -36)	
	Low – negative (-13 to -24)	
	Very low (0 to -12)	
	Low – positive (0 to 12)	
	Moderate – positive (13 to 24)	
	High-positive (37 to 48)	
	Very high – positive (49 to 66)	

Table 9-2: Explanation of Assessment Criteria

Criteria	Explanation
Nature	This is an evaluation of the type of effect the construction, operation, and management of the proposed development would have on the affected environment. Will the impact of change on the environment be positive, negative, or neutral?
Extent or Scale	This refers to the spatial scale at which the impact will occur. The extent of the impact is described as footprint (affecting only the footprint of the development), site (limited to the site), and regional (limited to the immediate surroundings and closest towns to the site). The extent of scale refers to the actual physical footprint of the impact, not to the spatial significance. It is acknowledged that some impacts, even though they may be of a small extent, are of very high importance, e.g., impacts on species of very restricted range. To avoid "double counting, specialists have been requested to indicate spatial significance under "intensity" or "impact on irreplaceable resources" but not under "extent" as well.
Duration	The lifespan of the impact is indicated as temporary, short, medium, and long term.

Criteria	Explanation
Severity	This is a relative evaluation within the context of all the activities and the other impacts within the framework of the project. Does the activity destroy the impacted environment, alter its functioning, or render it slightly altered?
Impact on irreplaceable resources	This refers to the potential for an environmental resource to be replaced, should it be impacted. A resource could be replaced by natural processes (e.g., by natural colonization from surrounding areas), through artificial means (e.g., by reseeding disturbed areas or replanting rescued species) or by providing a substitute resource, in certain cases. In natural systems, providing substitute resources is usually not possible, but in social systems, substitutes are often possible (e.g., by constructing new social facilities for those that are lost). Should it not be possible to replace a resource, the resource is essentially irreplaceable e.g., red data species that are restricted to a particular site or habitat to a very limited extent.
Consequence	The consequence of the potential impacts is a summation of the above criteria, namely the extent, duration, intensity, and impact on irreplaceable resources.
Probability of occurrence	The probability of the impact occurring is based on the professional experience of the specialist with environments of a similar nature to the site and/or with similar projects. It is important to distinguish between the probability of the impact occurring and the probability that the activity causing a potential impact will occur. Probability is defined as the probability of the impact occurring, not as the probability of the activities that may result in the impact.
Significance	Impact significance is defined to be a combination of the consequence (as described below) and the probability of the impact occurring. The relationship between consequence and probability highlights that the risk (or impact significance) must be evaluated in terms of the seriousness (consequence) of the impact, weighted by the probability of the impact occurring. In simple terms, if the consequence and probability of an impact are high, then the impact will have a high significance. The significance defines the level to which the impact will influence the proposed development and/or environment. It determines whether mitigation measures need to be identified and implemented and whether the impact is important for decision-making.
Degree of confidence in predictions	Specialists and the EIR team were required to indicate the degree of confidence (low, medium, or high) that there is in the predictions made for each impact, based on the available information and their level of knowledge and expertise. The degree of confidence is not taken into account in the determination of consequence or probability.
Mitigation measures	Mitigation measures are designed to reduce the consequence or probability of an impact or to reduce both consequence and probability. The significance of impacts has been assessed both with mitigation and without mitigation.

APPENDIX E: DISCLAIMER

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

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

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

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

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

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

PROJECT TITLE

The development of three Solar Photovoltaic (PV) facilities and associated infrastructure (Phases 1, 2 and 3) between De Aar & Hanover, Emthanjeni Local Municipality, Pixley Ka Seme District Municipality, Northern Cape Province, South Africa Geohydrological Assessment Report

SPECIALIST INFORMATION

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

DECLARATION BY THE SPECIALIST

I, _Hendrik Botha, declare that –

- I act as the independent specialist in this application.
- I will perform the work relating to the application objectively, even if this results in views and findings that are not favourable to the applicant.
- I declare that there are no circumstances that may compromise my objectivity in performing such work.
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity.
- I will comply with the Act, Regulations and all other applicable legislation.
- I have no, and will not engage in, conflicting interests in the undertaking of the activity.
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken concerning the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority.
- all the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 24F of the Act.

31/01/2023
4:33:03
Pr.Sci.Nat (400139/17)

Signature of the Specialist

GCS

Name of Company:

31 January 2023

Date

CV OF SPECIALIST

Hendrik Botha

Technical Director

LinkedIn:

PROFILE

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

Professional Affiliations:

SACNASP Professional Natural Scientist (400139/17)

Areas of Expertise:

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

CORE SKILLS

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

DETAILS

Qualifications

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

Membership

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

Languages

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

Projects undertaken in

- South Africa
- Nigeria
- Namibia
- Liberia

SCAN ME
PROJECT RECORD

Page 1 of 8