ENERTRAG South Africa (Pty) Ltd

Green Hydrogen and Ammonia Facility, Mpumalanga

Geohydrological Impact Study

04 May 2023

SHANGONI AquiScience

A division of Shangoni Management Services Pty Ltd

Project:	Geohydrological Impact Assessment for the Green Hydrogen and Ammonia Facility, Mpumalanga
Client:	ENERTRAG South Africa
Site/Farm:	Hartebeestkuil 185IS, portion 3, Komati Power Station 56IS and various portions of farms Dunbar 189IS, Weltevreden 193IS, Wilmansrust 47IS, Bultfontein 187IS, Geluk 26IS and Wilmansrust 47IS
Location:	Hendrina, Mpumalanga
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I, Ockert F. Scholtz declare that

General declaration:

- I act as the independent specialist in this application.
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant.
- I declare that there are no circumstances that may compromise my objectivity in performing such work.
- I have expertise in conducting the specialist report relevant to this application.
- I have no, and will not engage in, conflicting interests in the undertaking of the activity.
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority.

Signature of the specialist: Ockert F. Scholtz, *Pr.Sci.Nat*

Shangoni AquiScience, a division of Shangoni Management Services (Pty) Ltd

Name of company:

04 May 2023

Date:

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1. INTRODUCTION

Shangoni AquiScience, a division of Shangoni Management Services (Pty) Ltd, was appointed by to complete an assessment of the geohydrology at the proposed Hendrina Renewable Energy Complex, located near to the town of Hendrina in Mpumalanga.

ENERTRAG South Africa (hereafter “ENERTRAG SA”) is a subsidiary of the German-based ENERTRAG AG, a hydrogen and renewable energy developer founded in 1992. ENERTRAG AG has an established track-record of renewable energy projects around the world, comprising over 100 wind turbines with an installed capacity of over 760MW, and over 500 employees. Current Projects are in Germany, United Kingdom, France, Poland, Bulgaria and Belarus.

ENERTRAG SA was established in 2017, with the intention to investigate and develop renewable energy projects in South Africa. The transition from coal-based energy supply to renewables in the Country is inevitable, as coal resources are depleted, coal-based power stations reach the end of their economic life and considering international obligations and commitments to reduced emissions. The Project development area is blanketed with numerous coal prospecting and mining rights. Coal mining and energy derived from coal mining is the likely alternative to the Project. ENERTRAG SA are developing renewable energy projects to contribute to the Just Transition that promises to decarbonise South Africa's energy sector and aims to:

- replace coal-based electricity with renewable electricity; and
- decarbonise different sectors of the economy through the replacement of fossil-based hydrogen and ammonia with green hydrogen and ammonia.

ENERTRAG SA proposes to develop the Hendrina Renewable Energy Complex, the complex comprises of five separate projects. The projects are:

- Hendrina North Wind Energy Facility (up to 200MW) over 3600ha;
- Hendrina South Wind Energy Facility (up to 200MW) over 2900ha;
- Hendrina North Grid Infrastructure (up to 275kV) – 15km;
- Hendrina South Grid Infrastructure (up to 275kV) – 16km; and
- **Green Hydrogen and Ammonia Facility (up to 25ha).**

Each of these projects are being assessed, as part of the Complex development, and involve the undertaking of Listed Activities identified in the Environmental Impact Assessment (EIA) Regulations, 2014 (as amended) and as such require an Environmental Authorisation in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA) before being undertaken.

This report pertains specifically to the Geohydrological Impact Assessment for the Green Hydrogen and Ammonia Facility (“the Project”).

2. BACKGROUND

ENERTRAG AG developed its first green hydrogen facility, Hybridkraftwerk, in Germany which is powered by wind energy. The Hybridkraftwerk was commissioned in October 2011 and produces 94 tons of hydrogen per year.

"Green" hydrogen and ammonia production differs from traditional production technologies in that the process relies exclusively on renewable resources (renewable energy) and for input air and water (feedstock), to produce commercially usable green hydrogen and ammonia. The only solid waste stream is the production of brine from the water treatment plant. Ammonia spillages may occur however these will be accidental and mitigation measures will be developed and implemented, including amongst others suitable containment related to storage and emergency response measures.

A gaseous 'waste' (oxygen) is generated from the electrolyses process. Another source of gaseous 'wastes' is from the Air Separation Unit. This is where nitrogen is removed from the air and the other natural gases as expelled back to the environment.

Traditional hydrogen and ammonia are produced thought the burning of fossil fuels (coal or natural gas) to provide the required energy needed for their production. This method of production results in 'brown' hydrogen as fossil fuels are used and therefore carbon forms an integral part of such traditional hydrogen production.

Commercially, hydrogen is used as a fuel for transport in hydrogen fuel cells. Alternatively, hydrogen is used for welding and in the production of other chemicals such as methanol and hydrochloric acid and also has other commercial uses like the filling of balloons. It is also a primary input to the production of ammonia. Ammonia in turn is primarily used in the production of ammonium nitrate (fertiliser) and is also used as refrigerant gas and the manufacture of plastics, explosives, textiles, pesticides and other chemicals. Ammonia can also be used as a stable 'carrier' of hydrogen, allowing hydrogen to be readily stored and transported. A simplified flow process diagram is shown in Figure 1 and Figure 2.

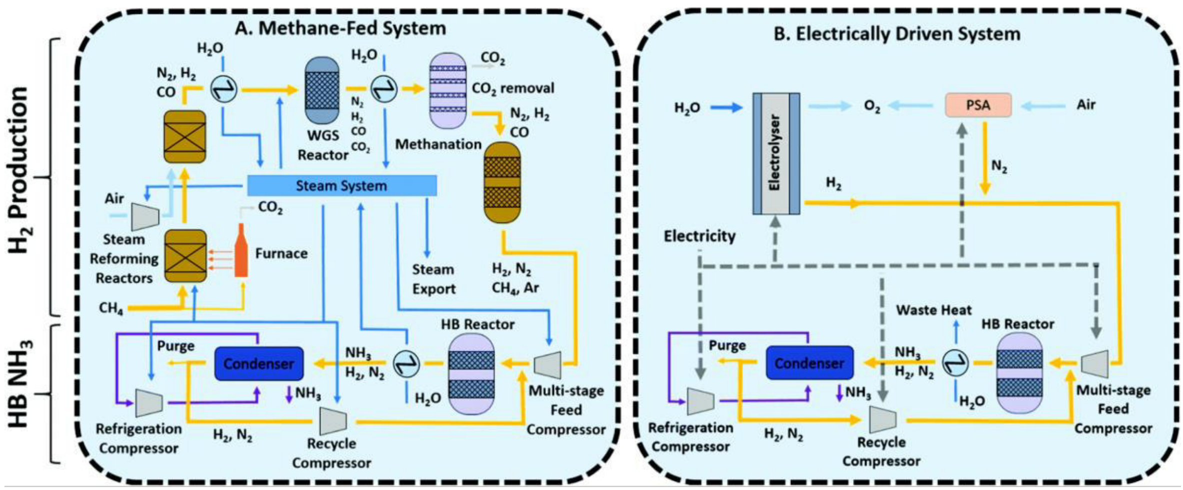

Figure 1: Simplified process flow diagram- traditional ammonia vs green ammonia production.

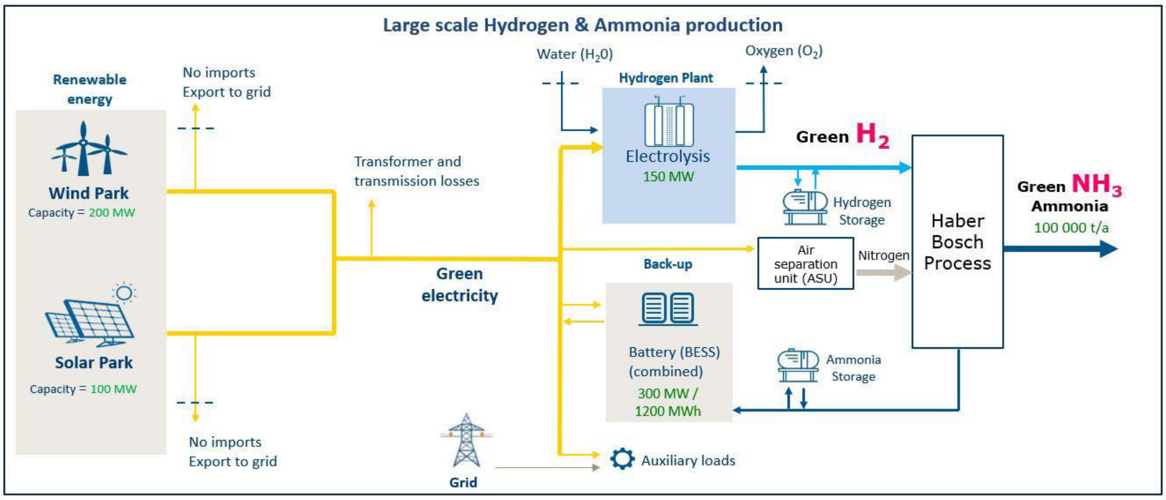

Figure 2: Simplified green hydrogen and ammonia production life cycle example.

2. PROJECT DESCRIPTION

ENERTRAG SA, is proposing the development of up to 150MW green hydrogen and ammonia facility ('Facility'). The Project is located 17 km west of Hendrina, in the Steve Tshwete Local Municipality, of the Nkangala District Municipality, Mpumalanga Province. The Facility will encompass approximately 25 hectares of land (three alternative locations being assessed), and the affected land parcels are shown in Table 1.

Table 1: Farm Portions affected by the Project Alternatives

Parent Farm	Farm No	Portion No
Facility Alternative Site 1		
Dunbar	189IS	3
Facility Alternative Site 2		
Dunbar	189IS	3
Weltevreden	193IS	18
Facility Alternative Site 3		
Weltevreden	193IS	14
Weltevreden	193IS	15
Associated pipelines and powerlines may affect portions of the following land parcels:		
Bultfontein	187IS	1
Bultfontein	187IS	2
Bultfontein	187IS	3
Bultfontein	187IS	4
Bultfontein	187IS	6
Bultfontein	187IS	10

Parent Farm	Farm No	Portion No
Bultfontein	187IS	14
Dunbar	189IS	0
Dunbar	189IS	1
Dunbar	189IS	2
Dunbar	189IS	4
Dunbar	189IS	5
Dunbar	189IS	6
Dunbar	189IS	7
Geluk	26IS	6
Geluk	26IS	7
Hartebeestkuil	185IS	3
Komati Power Station	56IS	0
Wilmansrust	47IS	1
Wilmansrust	47IS	3
Wilmansrust	47IS	9

The production, storage and transport of hydrogen and ammonia is an industry undergoing in-depth research and developments. Consequently, technological solutions are constantly being improved and changing. Thus, the below Facility description is based on available technological solutions, however, the underlying fundamentals will remain.

The facility comprises the following components as summarised in Table 2, where the footprint and capacities are presented. These parameters on based on the assumption that an up to 150MW electrolyser is installed (maximum). These components are detailed further below, but comprise the following general components:

- Water treatment.
- Electrolyser.
- Air separator.
- Ammonia processing unit.
- Liquid air energy system (LAES) for nitrogen storage.
- Feedstock and product storage.
- Utilities.
- Gantry and loading bay.

Table 2: Facility Components

No.	Component	Footprint (Ha)	Storage Capacity (m^3 / tons)	Maximum Throughput (m^3 / tpa)	Conversion	Note
1	Water Reservoir	2	6 800 / 6 800	800 / 800	Density of water taken as 1 000 kg/m3	Process and utilities water
2	Water Treatment Unit	1.5	N/A	192 000 / 192 000	Density of water taken as 1 000 kg/m3	Process and utilities water
3	Electrolyser Unit	1	N/A	(1 239 157 – 301 932 367) / 20 000	Density of hydrogen can be 16.14kg/m3 at 200 barg and 25 °C or 0.06624 kg/m3 at 0 barg and 90 °C depending on the operating conditions of the unit.	Hydrogen Output Oxygen Output
4	Air Separation Unit	0.5	N/A	92 905 405 / 110 000	The density of air taken as 1.184 kg/m3	Air Input
5	Ammonia Processing Unit	2	N/A	149 253 / 100 000	The density of liquid ammonia taken 670 kg/m3 at -33 °C at 1 atm	Ammonia Output
6	Liquid Air Storage System (LAES)	1	3 983/ 3 505	460 227 / 405 000	The density of liquid nitrogen taken 880 kg/m3 at -33 °C at 1 atm	Nitrogen Storage
7	Liquid Ammonia Storage Tank	2	2 273/ 1 523	261 194 / 175 000	The density of liquid ammonia taken as 670 kg/m3 at -196 °C at 1 atm	
8	Hydrogen and Oxygen Storage Tank Farm	12	59 566/ 800	5 576 208 / 90 000	A density of 16.14kg/m^3 for hydrogen at 200 barg and 25 °C. Oxygen density estimated at liquid boiling point and 1 atmosphere pressure, totalling 1141 kg/m^3.	Hydrogen and Oxygen storage (combined tank farm), i.e. feedstock storage
9	Ancillary infrastructure	3	n/a	n/a	n/a	Includes temporary and permanent laydown areas, parking, offices and other related infrastructure.
	Total Footprint	**25**				

Associated infrastructure further include:

- Electrical infrastructure required for power supply to the facility.
- Temporary and permanent laydown areas required for temporary storage and assembly of components and materials.
- Access road/s to the site and internal roads between project components, with a width of up to up to 6m wide respectively.
- Fencing and lighting.
- Lightning protection.
- Telecommunication infrastructure.
- Stormwater channels.
- Water pipelines
- Offices.
- Operational control centre.
- Operation and Maintenance Area / Warehouse / workshop.
- Ablution facilities.
- A gate house.
- Control centre, offices, warehouses.
- Security building.

The three alternative Project locations being investigated for the development of the proposed Project include:

Site Alternative 1 is located on Portion 3 of the Farm Dunbar 189IS, at the site of an old abandoned farmyard and has three powerline options from the associated Hendrina North and South Wind Energy Facilities ("WEF") as follows (also refer to Figure 3):

- Powerline option 1 is up to 2 km in length, to the Hendrina North WEF substation Option 1 on Portion 1 of the Farm Dunbar 189IS;
- Powerline option 2 is up to 7 km in length, to the Hendrina North WEF substation Option 2 on Portion 3 of the Farm Hartebeestkuil 185IS;
- Powerline option 3 is up to 1.5 km in length, to the Hendrina South WEF substation on Portion 3 of the Farm Dunbar 189IS.

water supply to the Site:

- constructing a new pipeline (up to 16km) from the Komati Power Station.

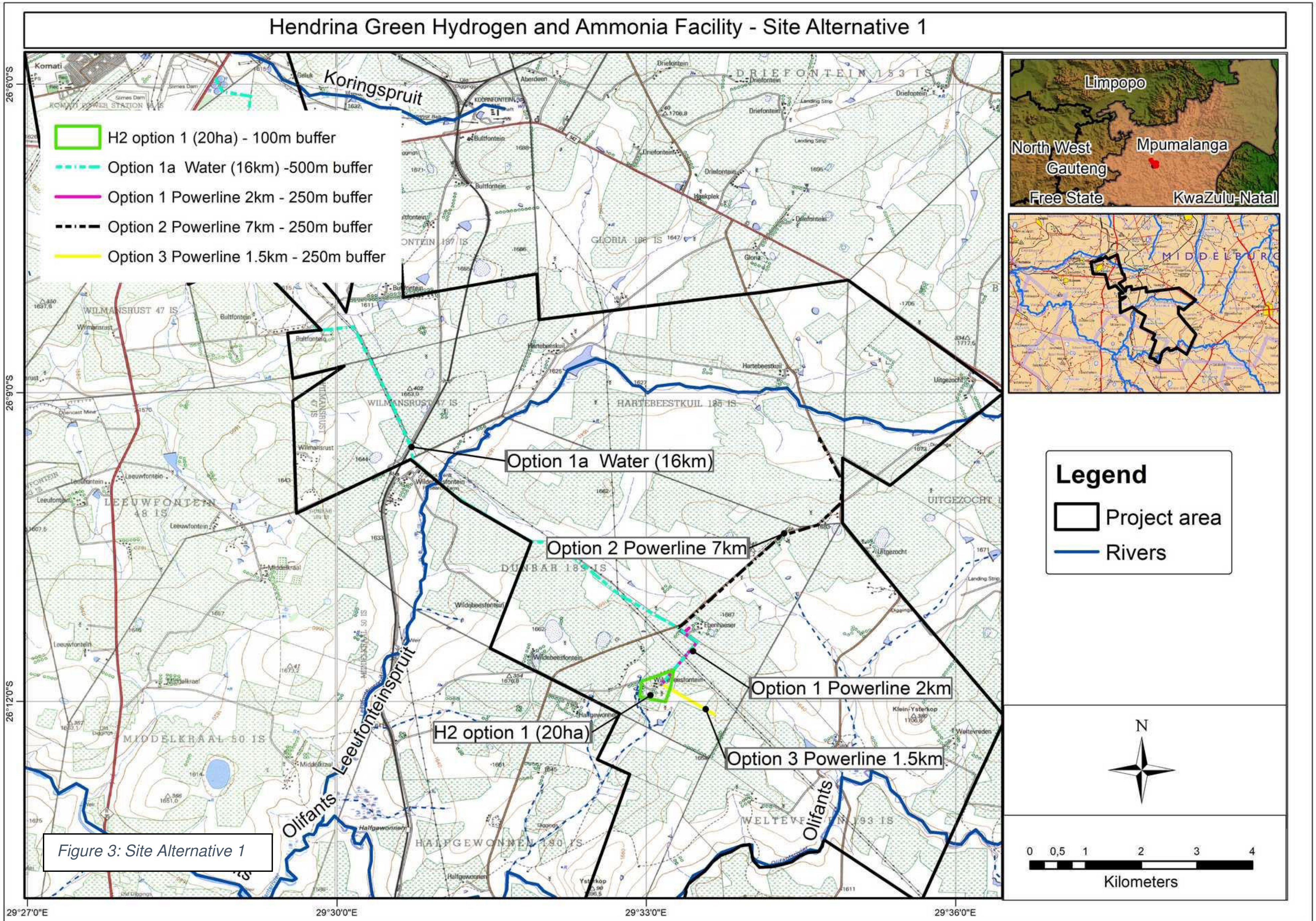

Figure 3: Site Alternative 1

Site Alternative 2 is located on Portion 3 of the Farm Dunbar 189IS and Portion 18 of the Farm Weltevreden 193IS, adjacent to the proposed Hendrina South WEF substation and has three powerline options from the associated wind farms as follows (also refer to Figure 4):

- Powerline option 1 is up to 3km in length to the Hendrina North WEF Option 1 substation on Portion 1 of the Farm Dunbar 189IS;
- Powerline option 2 is up to 8km in length to the Hendrina North WEF substation Option 2 on Portion 3 of the Farm Hartebeestkuil 185IS;
- Powerline option 3 is up to 0.5km in length to the Hendrina South WEF substation on Portion 3 of the Farm Dunbar 189IS;

water supply to the Site:

- constructing a new pipeline (up to 16km) from the Komati Power Station.

Site Alternative 3 is located on Portions 14 and 15 of the Farm Weltevreden 193IS and has three powerline options from the associated wind farms as follows (also refer to Figure 5):

- Powerline option 1 is up to 5 km in length to the Hendrina North WEF Option 1 substation on Portion 1 of the Farm Dunbar 189IS;
- Powerline option 2 is up to 5 km in length to the Hendrina North WEF substation Option 2 on Portion 3 of the Farm Hartebeestkuil 185IS;
- Powerline option 3 is up to 7 km in length to the Hendrina South WEF substation on Portion 3 of the Farm Dunbar 189IS.

water supply to the Site:

- constructing a new pipeline (up to 16km) from the Komati Power Station

Hendrina Green Hydrogen and Ammonia Facility - Site Alternative 2

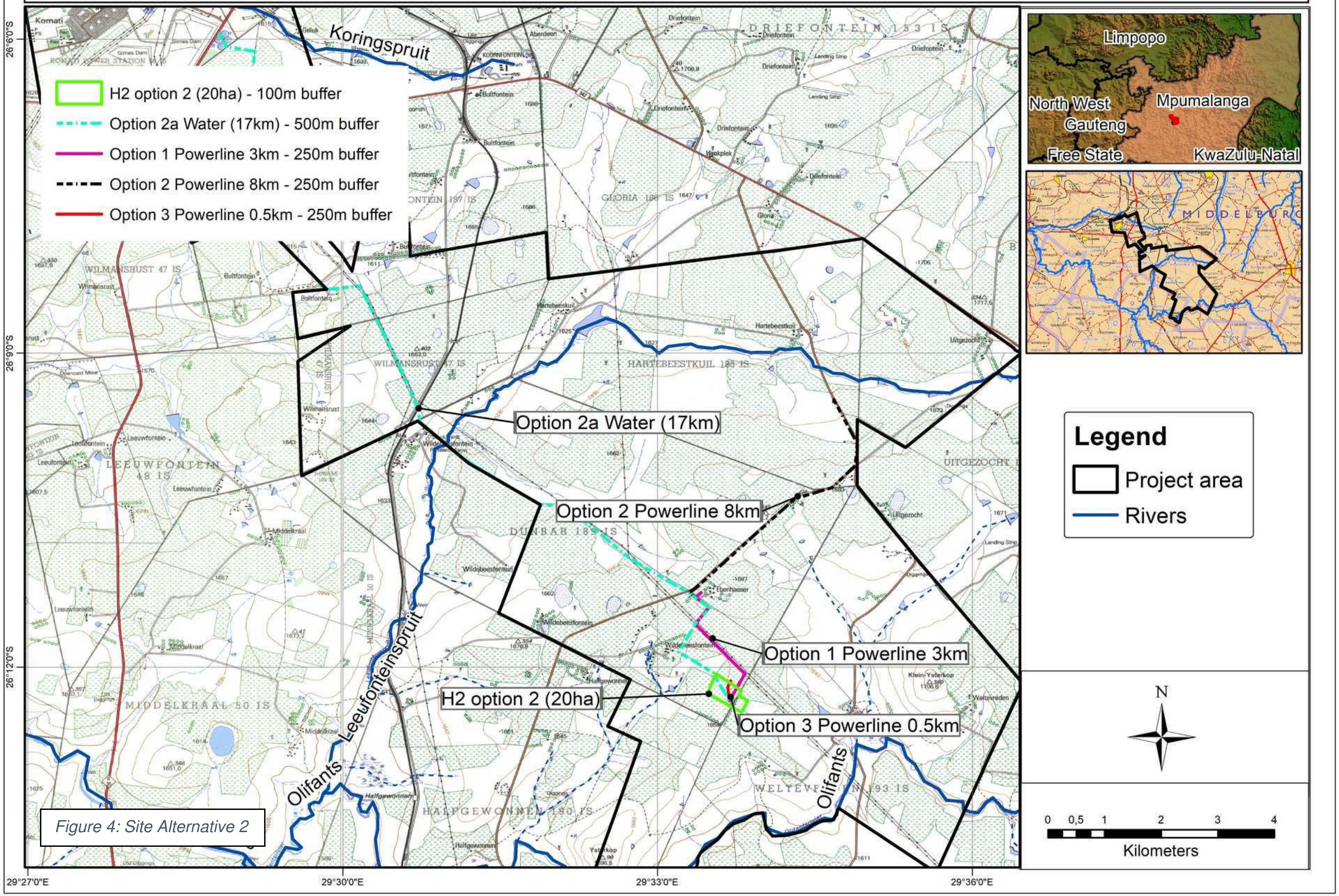

Figure 4: Site Alternative 2

Hendrina Green Hydrogen and Ammonia Facility - Site Alternative 3

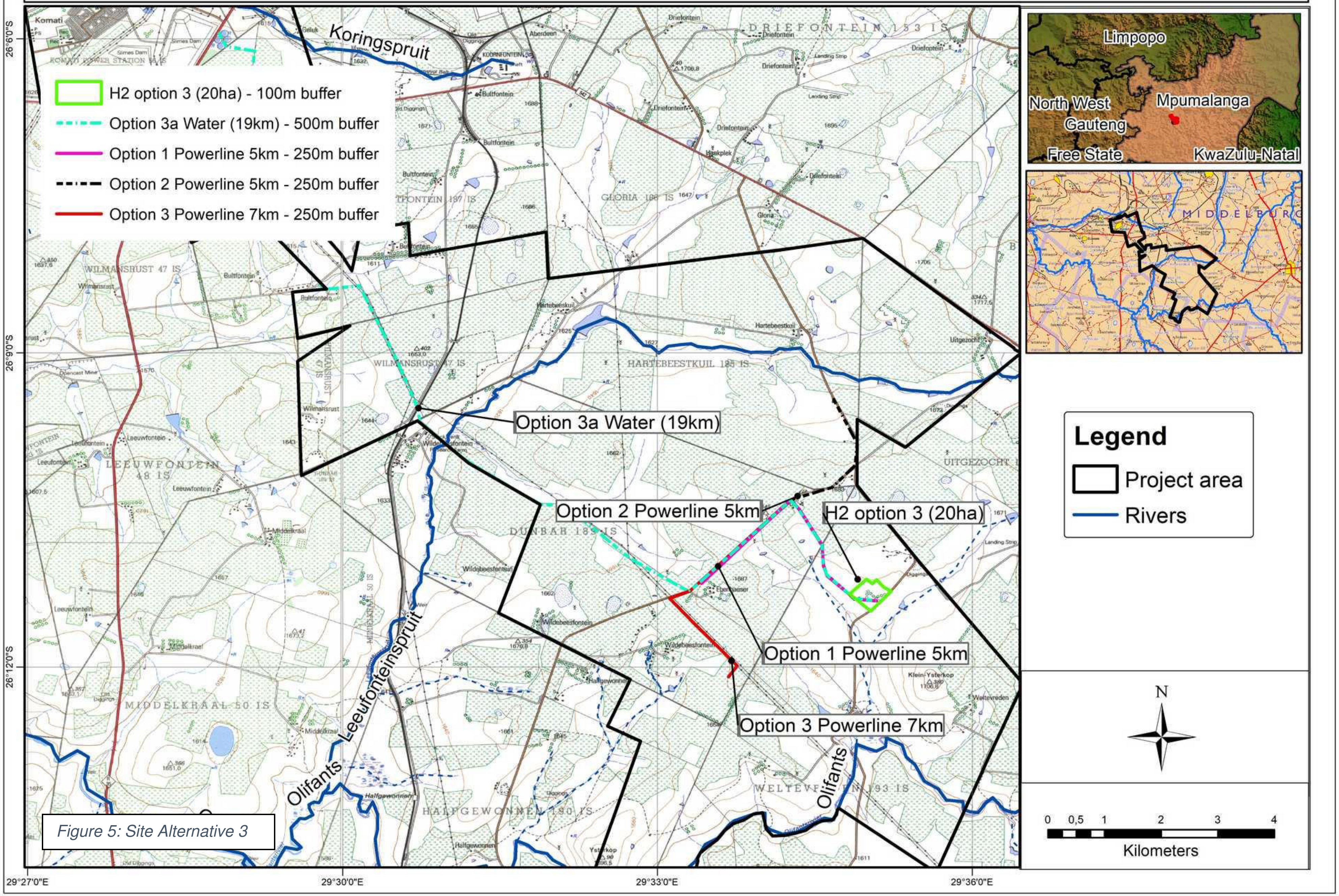

Figure 5: Site Alternative 3

2. SCOPE OF WORK AND OBJECTIVES

The aims of the project were to i) determine baseline geohydrological conditions; ii) assess probable water related impacts; and iii) to propose management plans and monitoring protocols to pro-actively manage all future potential water related impacts related to the Green Hydrogen and Ammonia facility.

The focus areas required to assess the geohydrological conditions were:

- Description of baseline environmental conditions.
- Determination of baseline (*status quo*) geohydrology of the area, which included a desktop study of the groundwater conditions and relevant environmental factors.
- Development of a conceptual model based on current geohydrological conditions.
- Risk assessment of the geohydrological impact resulting from the operations. This includes the description of possible negative groundwater related impacts during construction and operation.
- Recommendations on a groundwater management framework and monitoring programme.

To meet the aims and objectives for the current project, the following phases were completed:

Phase 1 - Fieldwork

- An initial site visit and hydrocensus to assess ground- and surface water utilisation and baseline ground- and surface water properties.

Phase 2 – Reporting and Impact Assessment

- Baseline description of geohydrology for the study area.
- Combine and interpret available topographical, geohydrological and related information.
- Assessment of potential sources of pollution.
- Development of a conceptual geohydrological model for the project areas.
- Identify impacts and rate them in a risk assessment.
- Recommendation of a suitable monitoring programme.

2.1 Desk Study

A desk study was conducted to gather all relevant environmental information, including topographical, hydrological and geohydrological data. Data/information was also gathered from previous relevant studies conducted for the area as well as data published in the public domain.

The aquifer classification system that was used to classify South African aquifers is the National Aquifer Classification System developed by Parsons (1995). This system has a certain amount of flexibility and can be linked to second classifications such as a vulnerability or usage classification. This aquifer classification system can also be used as a planning tool to guide the management of groundwater issues.

2.1.1 Aquifer classification

The South African Aquifer System Management Classification is presented by five major classes as defined in Table 1:

Table 3: Aquifer classification scheme (Parsons, 1995)

Aquifer system	Defined by Parsons (1995)	Defined by DWA minimum requirements (DWAF, 1998)
Sole source aquifer	An aquifer that is used to supply 50% or more of domestic water for a given area, and for which there are no reasonable alternative sources should the aquifer become depleted or impacted upon. Aquifer yields and natural water quality are immaterial.	An aquifer, which is used to supply 50% or more of urban domestic water for a given area for which there are no reasonably available alternative sources should this aquifer be impacted upon or depleted.
Major aquifer	Highly permeable formations, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good.	High yielding aquifer (5-20 l/s) of acceptable water quality.
Minor aquifer	These can be fractured or potentially fractured rocks that do not have a high primary hydraulic conductivity, or other formations of variable hydraulic conductivity. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are both important for local supplies and in supplying base flow for rivers.	Moderately yielding aquifer (1-5 l/s) of acceptable quality or high yielding aquifer (5-20 l/s) of poor-quality water.
Non-aquifer	These are formations with negligible hydraulic conductivity that are generally regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer unusable. However, groundwater flow through such rocks does occur, although imperceptible, and needs to be considered when assessing risk associated with persistent pollutants.	Insignificantly yielding aquifer (< 1 l/s) of good quality water or moderately yielding aquifer (1-5 l/s) of poor quality or aquifer which will never be utilised for water supply and which will not contaminate other aquifers.
Special aquifer	An aquifer designated as such by the Minister of Water Affairs, after due process.	

2.1.2 Aquifer vulnerability

Groundwater plays an important role in supplying water to many regions of Southern Africa due to its low annual average precipitation of 460 mm, which is well below the world average of 860 mm. The quality of groundwater resources in South Africa has therefore received considerable focus and attention on the need for a proactive approach to protect these sources from contamination (Lynch *et.*

al., 1994). Groundwater protection needs to be prioritised based upon the susceptibility of an aquifer towards pollution. This can be done in two ways, namely i) pollution risk assessments and ii) aquifer vulnerability. Pollution risk assessments consider the characteristics of a specific pollutant, including source and loading while aquifer vulnerability considers the characteristics of the aquifer itself or parts of the aquifer in terms of its sensitivity to being adversely affected by a contaminant should it be released.

The DRASTIC model concept developed for the USA (Aller *et. al*., 1987) is well suited for producing a groundwater vulnerability evaluation for South African aquifers. The DRASTIC evaluates the intrinsic vulnerability (*IV*) of an aquifer by considering factors including **D**epth to water table, natural **R**echarge rates, **A**quifer media, **S**oil media, **T**opographic aspect, **I**mpact of vadose zone media, and hydraulic **C**onductivity. Different ratings are assigned to each factor and then summed together with respective constant weights to obtain a numerical value to quantify the vulnerability:

$$\text{DRASTIC Index } (IV) = DrDw + RrRw + ArAw + SrSw + TrTw + IrIw + CrCw$$

Where *D*, *R*, *A*, *S*, *T*, *I*, and *C* are the parameters, *r* is the rating value, and *w* the constant weight assigned to each parameter (Lynch *et al*, 1994). The scores associated with the vulnerability of South African aquifers are shown in Table 4.

Table 4: South African National Groundwater Vulnerability Index to Pollution (Lynch et al, 1994)

Score	Vulnerability
50-87	Least susceptible
87 - 109	Moderate susceptible
109 - 226	Most susceptible

The concept of DRASTIC in vulnerability assessments is based on:

- A contaminant is introduced at the surface of the earth or just below it.
- A contaminant is flushed into the groundwater by precipitation.
- A contaminant has the mobility of water.
- The area evaluated is 0.4 km^2 or larger.

The weighting for each parameter is constant. The minimum value for the DRASTIC index that one can calculate (assuming all seven factors were used in the calculation) is therefore 24 with the maximum value being 226. The higher the DRASTIC index the greater the vulnerability and possibility of the aquifer to become polluted if a pollutant is introduced at the surface or just below it.

2.2 Hydrocensus

A hydrocensus was performed on and around the study area to identify groundwater users, groundwater potential and baseline data. The survey was conducted during August 2021.

During the hydrocensus, all available details of boreholes and borehole-owners were collected and recorded. Where possible, information was collected on water use, water levels and yields of boreholes, etc. This information was used to assess the potential risk posed by the proposed activities on the groundwater regime and users thereof. The following parameters, where possible, were captured:

- XYZ Coordinates
- Existing equipment
- Current use
- Future use
- Yield
- Drill depth
- Static/dynamic water level
- Water quality
- Photograph

3. ENVIRONMENTAL SETTING

The study area is in the Eastern Highveld region of Mpumalanga, characterised by gently undulating plains with wide to narrowly incised valleys, such as the Olifants River valley. Typically, this landscape is associated with surface water features such as rivers, streams, wetlands and pans.

3.1 Topography and drainage

The topography is slightly undulating. Surface elevations range from 1589 meters above mean sea level ("mamsl") at the drainage lines to 1710 mamsl on the north-western border of the project area. This indicates a generally flat and shallow sloped area dipping down towards the Olifants River to the south, Leeuwfontein Spruit to the west, and Koringspruit to the north-west. The topographical contour lines in Figure 6 show that surface water drainage will occur towards these drainage lines. The topography is usually a good first indication of the groundwater flow directions, and often hydraulic heads in a semi-confined aquifer mimics surface flow.

The Olifants River is the main receiving surface water body of the catchment. Several tributaries consisting of perennial and nonperennial streams bisect the project area and eventually connects to the two main streams (Leeuwfonteinspruit and Koringspruit) that drain into the Olifants River. The Olifants River runs in a western direction along the southern boundary of the project area.

The Hendrina Green Hydrogen and Ammonia Project falls within the Upper Olifants of the Olifants Water Management Area and within the B11A quaternary drainage regions but the project area also include B11B catchment (Figure 7).

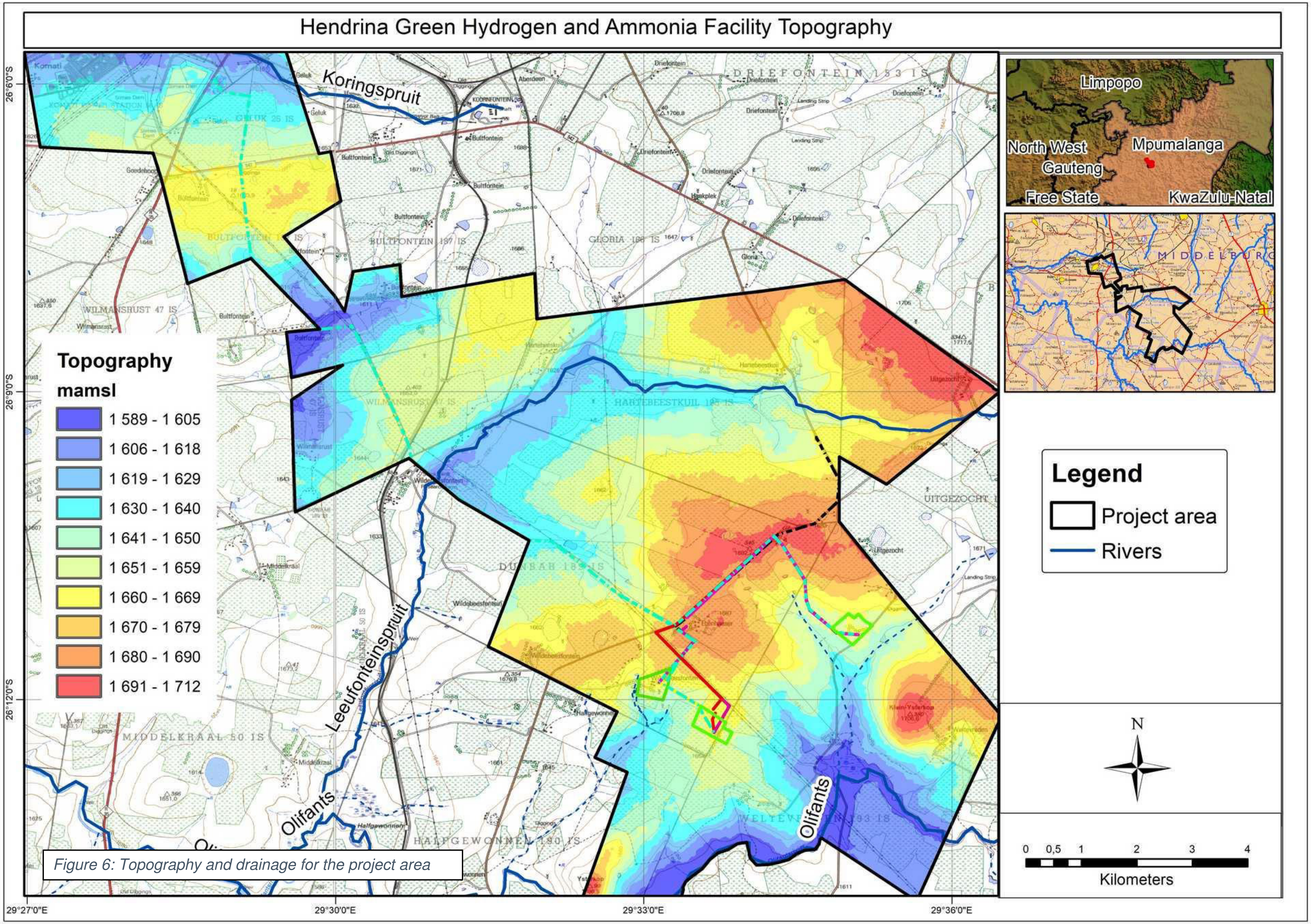

Figure 6: Topography and drainage for the project area

Hendrina Green Hydrogen and Ammonia Facility Quaternary Catchments

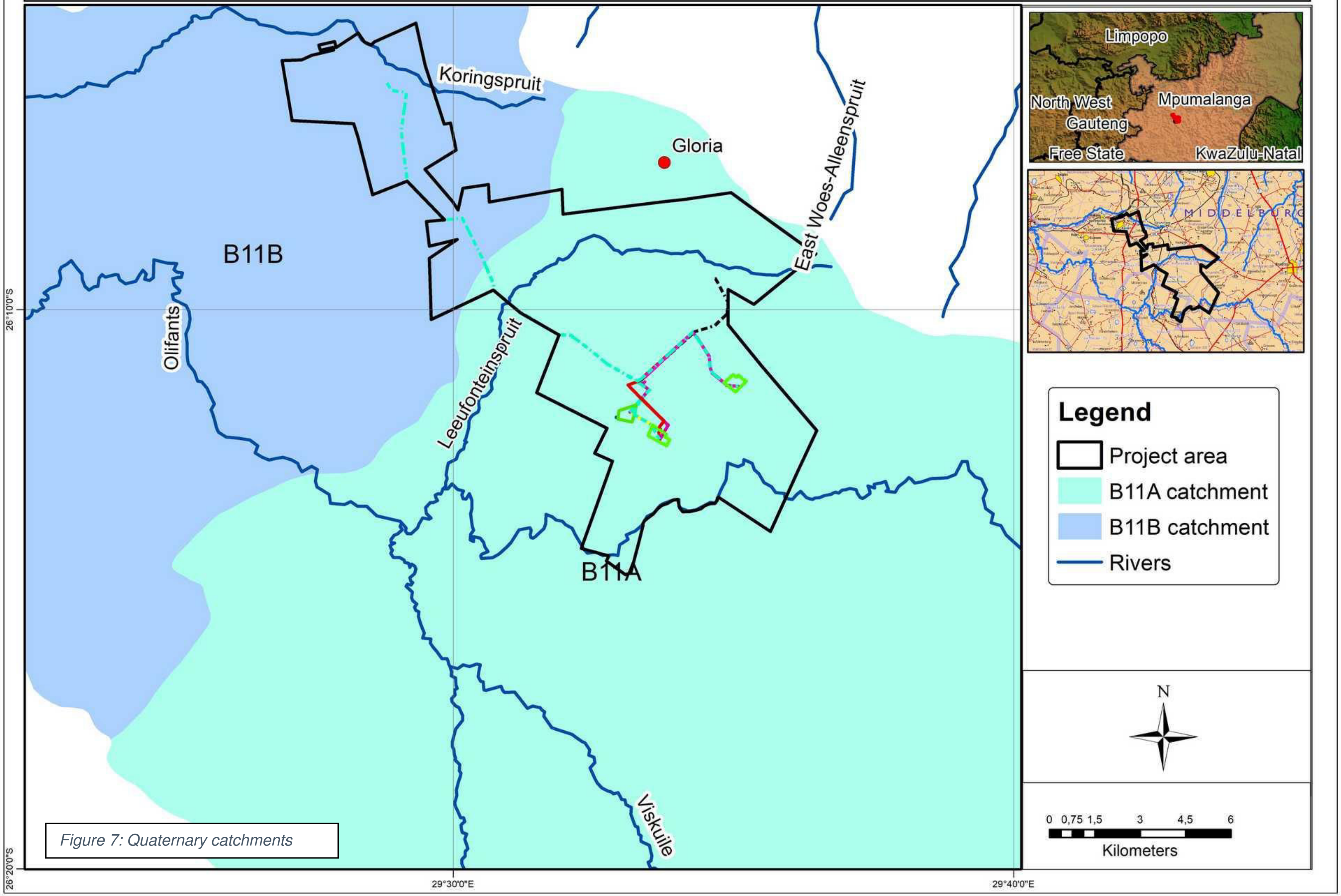

Figure 7: Quaternary catchments

Additional information pertaining to water management for the B11A and B11B quaternary catchments are shown in Table 5 (GRDM, 2010).

The status of the ecosystem function being classified as a B (B11A) and C (B11B) is an indication of the natural and relatively unaffected to slightly affected status of the catchment habitats and biota. Categories B and C are defined as:

B Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.

C Moderately modified. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.

Table 5: Quaternary catchment information (WR90, WR2021)

Attribute/Catchment	B11A	B11B
Quaternary catchment area (km^2)	954.4	435.3
Mean annual rainfall (mm/a)	699	687
Mean annual runoff (mm/a)	39	36
Baseflow (mm/a)	7	7
Mean annual evaporation (mm/a)	1550	1550
Total groundwater use (Mm^3/a)	≥0.0515	≥0.2034
Ecoregion	Highveld	Highveld
Present Eco Status Category	B	C
Recharge (mm/a)	42	51.11
Exploitation potential (Mm^3/a)	10	5
Vegetation type	Moist Sandy Highveld Grassland	Moist Sandy Highveld Grassland
Soil	SaClLm	SaClLm
Groundwater General Authorization $m^3/ha/a$	75	75

Livestock use is by far the greatest groundwater user in the B11A catchment, making up more than 80% of the total usage (Table 6), while mining use outweighs the other groundwater uses considerably; more than 55% is used by mining in catchment B11B, which is followed by livestock. According to WR90 data (GRDM, 2010), groundwater of up to 5-10 Mm^3/a can be exploited in the catchments.

Table 6: Total groundwater use in the B11A quaternary catchment (GRDM, 2010)

Type of use	Value (Mm^3/a)	
	B11A	B11B
Total use	0.0515	0.2034
Rural use	0.001	0.041
Municipal use	0	0
Irrigational use	0	0

Type of use	Value (Mm^3/a)	
	B11A	B11B
Livestock use	0.0435	0.0489
Mining use	0	0.1135
Industry use	0.007	0
Aquatic ecosystem use	0	0

3.2 Climate

Average Precipitation ("MAP") for the area is between 600 – 800 mm with an overall average of between 680 mm to 714 mm (Table 7). MAP is relatively uniform across most of this unit area but increases significantly in the extreme southeast. Rainfall occurs mainly in the summer months from October to March, almost exclusively as showers and thunderstorms with the highest rainfall occurring in November, December and January. The winter months are typically dry; however, periodic thunder showers do occur.

Table 7: Average Rainfall recorded for Meteorological Stations 0479369W, 0479225 and 0478726W (WR2012)

Month	Ave Rainfall (mm)		
Station	**0479369W (1950-2009)**	**0479225W (1920-1974)**	**0478726W (1987-2004)**
January	123	118	125
February	83	83	102
March	76	77	75
April	41	52	30
May	12	17	13
June	6	8	7
July	4	8	1
August	9	8	7
September	23	24	14
October	85	70	85
November	125	115	105
December	127	102	134
Sum of avg.	**714**	**680**	**698**

3.3 Groundwater recharge calculations

Recharge is defined as the addition of water to the saturated zone, either by the downward percolation of precipitation or surface water and/ or the lateral migration of groundwater from adjacent aquifers. The main source of recharge into the shallow primary aquifers is direct rainfall recharge that infiltrates the aquifer through the overlying unsaturated zone. Recharge to the deep Karoo aquifer is limited to vertical seepage from the shallow Karoo aquifer through permeable fracture systems that link the two aquifers hydraulically. Due to the heterogeneous nature of such fracture systems, it is assumed to be highly variable and some aquifers may be connected while others may be not.

Groundwater recharge was estimated using the RECHARGE programme (van Tonder and Xu, 2000), which uses qualified guesses as guided by various schematic maps. The following recharge values as in Table 8 were calculated from the RECHARGE software programme.

Table 8: Recharge values inferred for the study area (RECHARGE; van Tonder and Xu, 2000)

Method/reference	Recharge (%)	Recharge (mm/a)
Geology[1]	3.00	22.41
Vegter[2]	4.86	36.30
Acru[3]	4.55	34.0
Harmonic mean	**3.95**	**29.53**

Notes: *Recharge per annum were calculated using a MAP figure of 700 mm.*

[1] Sandstone/shale/mudstone = 80%; hard rock 20%; soil cover <0.5% = 20%, soil cover >0.5% = 80%

[2] Vegter 1995

[3] Agricultural Catchments Research Unit

According to the various sources used, the recharge of the study area varies between 3% and 4.86% with an average (harmonic mean) recharge of 3.95% of MAP. This is, however, suspected to be a slight overestimation. In general, recharge into the Karoo sandstones is relatively low with various factors controlling the recharge but typically range between 0.5 and 3% of MAP.

4. PREVAILING GEOHYDROLOGICAL CONDITIONS

A variety of anthropogenic activities affect groundwater flow and chemistry, the extent of which can only be quantified if the baseline conditions are known. The purpose of this section is, therefore, to describe the baseline environment to such an extent that it can be used as information in the quantification of any future impacts on the groundwater regime related to the proposed project.

The current physical, hydrochemical and hydrogeochemical properties of the aquifers in the region are explained in the following sections.

4.1 Geology

4.1.1 Regional geology

The 2628 East Rand 1:250 000 geological map showing the regional geology is shown in Figure 8.

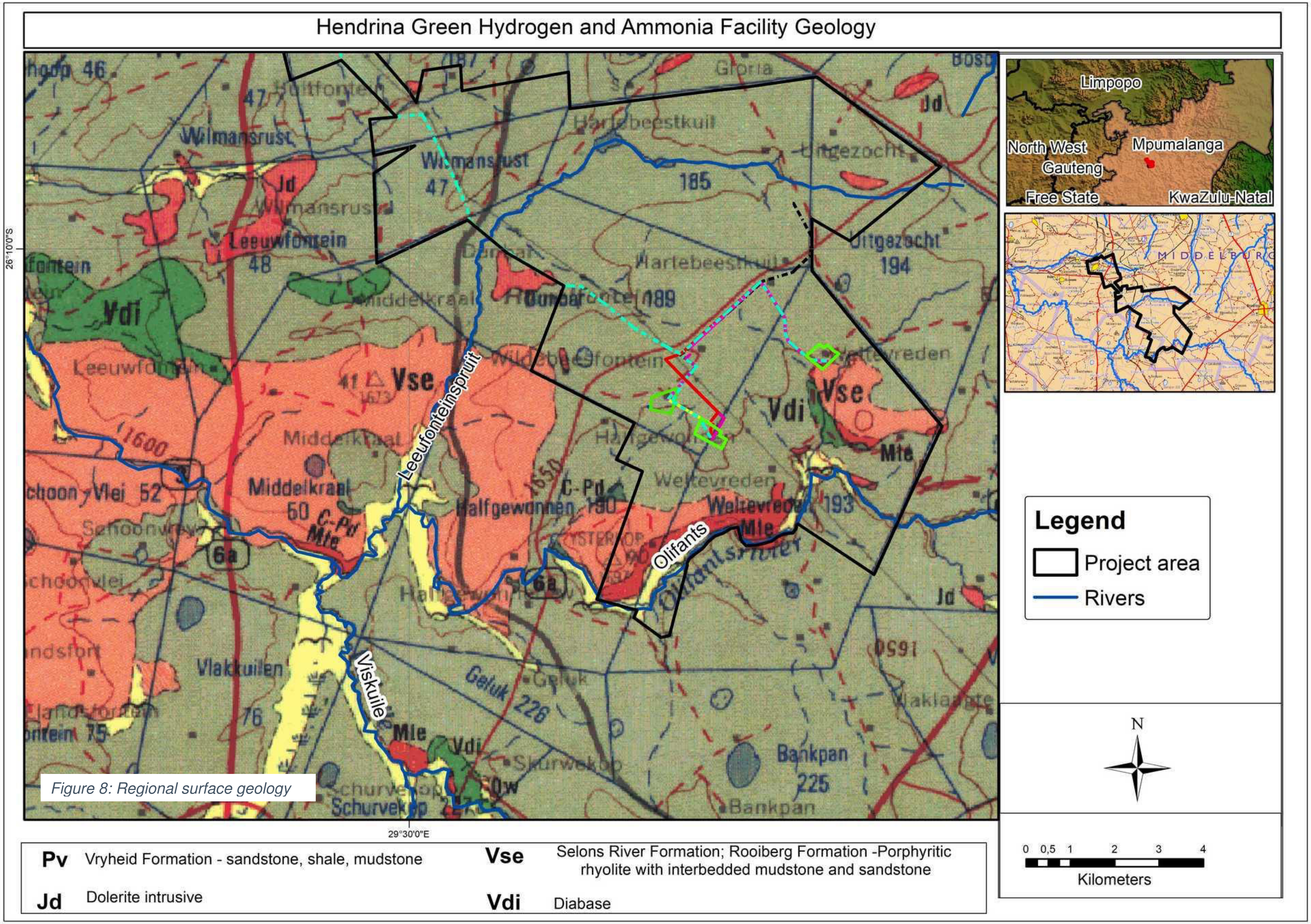

Figure 8: Regional surface geology

The regional geology is mainly covered by sandstone and shale, with interbedded coal of the Karoo aged Vryheid Formation (Pv). Vaalium aged Selons River rhyolite (Vse), diabase (Vdi) as well as some small Dwyka tillite, sandstone, mudstone and shale outcrops (C-Pd) are indicated. Alluvial deposits are indicated along sections of the Olifants River and Leeuwfonteinspruit. These are river deposits and will have a relatively high transmissivity and storage capacity. Depending on the interconnection with the underlying hard rock aquifers, the alluvial material can contribute substantially to the recharge of underlying aquifers.

The geological map shows little indication of geological structures such as dykes or other anomalies within the project area.

4.1.2 Dykes, sills and faults

Abundant dolerite intrusions are present in the Ecca sediments. These intrusions comprise sills, which vary from being concordant to transgressive in structure, and feeder dykes. The sills usually precede the dykes, with the latter being emplaced during a later period of tensional forces within the earth's crust. Although these structures serve as aquitards and tend to compartmentalise the Karoo aquifers, the contact zones with the pre-existing geological formations also serve as groundwater conduits.

Tectonically, the Karoo sediments are practically undisturbed. No dykes or sills are visible on the 1: 250 000 geological map (2628) within the study area.

4.2 Hydrogeology

4.2.1 Unsaturated zone (vadose zone)

The characteristics of vadose zone vulnerability dominating factors are closely related to the migration and transformation mechanisms of contaminants in the vadose zone, which directly affect the state of the contaminants percolating to the groundwater. The permeability and thickness of the unsaturated zone are some of the main factors determining the infiltration rate, the amount of runoff and consequently the effective recharge percentage of rainfall to the aquifer. The type of material forming the unsaturated zone as well as the permeability and texture will significantly influence the mass transport of surface contamination to the underlying aquifer(s). Factors like ion exchange, retardation, biodegradation and dispersion all play a role in the unsaturated zone.

The thickness of the unsaturated zone was determined by subtracting the undisturbed static water levels in the study area from the topography. Water level measurements showed that the depth to water level, and thus the unsaturated zone, generally varies between 3 and 15 m below ground level.

4.2.2 Saturated zone

4.2.2.1 Weathered horizon

The weathered zone hosts the unconfined to semi-confined shallow weathered aquifer or hydro-stratigraphic zone. The zone is on average 15 – 20 m thick and water levels are often shallow (few meters below ground level). Due to direct rainfall recharge and dynamic groundwater flow through the unconfined aquifer in weathered sediments, the water quality is generally good, but also vulnerable to pollution. A weathered water bearing horizon is defined as groundwater saturated strata which possesses a secondary porosity associated with weathering of rock strata. The weathered water bearing horizon may or may not be hydraulically connected with the regional fractured water bearing horizon, depending on the presence, thickness and weathering of confining layers (typically horizontal sills or shale layers). Water intersections in the weathered aquifer are mostly above or at the interface of fresh bedrock where less permeable layers of weathering products and capillary forces limit the vertical percolation of water and promote lateral water movement. Groundwater daylights as springs (contact springs) where the flow path is obstructed by impermeable layers or where the surface topography cuts into the groundwater level at e.g. drainage lines (free draining springs).

The weathered horizon is typically not regarded as good aquifers but suitable for household supply, with yields ranging between 0.1 and 1.0 l/s but typically less than 0.5 l/s. Where the weathered aquifer does become significant is from a pollution transport perspective.

4.2.2.2 Fractured horizon

A fractured water bearing horizon is defined as a groundwater saturated stratum displaying secondary porosity due to fracturing. Fractured horizons are common in sandstone and shale host rock of the Karoo sequence. The permeability within fresh matrix rocks (sandstone and shale) is extremely low and the matrix is not expected to allow any significant groundwater flow. Therefore, groundwater flow in the sedimentary rocks is expected only along weathered zones and fractures.

The fractured horizon is confined but may be semi-confining at places of extreme weathering. The aquifer depth extends from a depth of ±20-100 mbs with limited yields at depth, indicating the absence of major water bearing fractures and low permeability at depth. The aquifer can be regarded as heterogeneous having a moderate fracture network formed in the consolidated and mostly impervious matrix because of depositional stresses. Movement of groundwater is mostly restricted to fracture flow.

The fractured rock aquifer is a more reliable source of groundwater compared to the weathered zone aquifer. Typical characteristics of the fractured flow aquifer include:

- They are present as either confined or semi-confined aquifers. In the former instance, the aquifer is overlain by sediments or rock of a confining nature, thus limiting direct recharge from rainfall.
- Natural Karoo aquifers in the study area typically have a low hydraulic conductivity but are known to be highly heterogeneous with yields ranging from 0.5 up to 5 l/s (the latter only when large scale fractures are intersected).
- Higher yields are typically associated with higher hydraulic conductivities along contact zones with intrusive rocks.
- The contact zones of dolerite dykes with the host rock provide preferential flow pathways, while the dolerite itself is rather impermeable or semi-permeable (hydraulic conductivity of 0.00086 m/d or 1×10^{-8} m/s). This setting promotes groundwater flow along, but not across dykes or sills.
- Depending on the residence time of water in the aquifer, groundwater quality is good to moderate.

- Recharge from rainfall is generally low and averages between 0.5 to 3% of the annual rainfall.
- Characteristics of the aquifer vary greatly over short distances.
- Contaminant transport through fracture flow aquifers is comparatively fast.
- There is hardly any attenuation of pollutants in fractures.

4.2.2.3 Dwyka horizon

The succession of sedimentary rocks generally overly the well-consolidated glacial tillites of the Dwyka Group, but in places the Ecca Group rocks rest directly on the felsites and granites of the pre-Karoo basement rocks. The permeability of fresh tillite is generally and widely regarded as very low. The Dwyka tillite may form a separate aquifer but because of its negligible aquifer forming properties it is generally discussed as one with the Ecca aquifer. The aquifer permeability of the Dwyka tillite is estimated to be between 0.0002 and 0.015 m/d. Due to its low hydraulic conductivity, the Dwyka tillite where present, forms a hydraulic barrier between the overlying activities and the basal floor.

4.2.2.4 Pre-Karoo aquifer

The pre-Karoo rocks, consisting mainly of felsites of the Bushveld Igneous Complex, are present below the Dwyka group tillites/diamictite. At places, the Ecca Group rocks do rest directly on the felsites and granites of the pre-Karoo Basement rocks.

Groundwater is mostly present in very small and low yielding fractures. The pre-Karoo is considered not to be a reliable source of groundwater given its great depth, compactness of the host rock and inability to fracture, inferior quality associated with felsites and granites (mostly fluoride), and low recharge because of the overlying impermeable Dwyka tillite. However, reliable sources of groundwater may be encountered on bedding plane fractures or lithological contact zones.

4.2.3 Hydraulic conductivity

No aquifer hydraulic testing was done as part of this project. However, previous work and experience from doing hydraulic testing within similar Karoo environments show that the primary aquifers of the Vryheid Formation have a very low permeability with hydraulic conductivities generally ranging between $1x10^{-5}$ to $1x10^{-2}$ m/d. Preferential flow paths or fractures created in the secondary aquifer created by dolerite intrusions within the host rock display hydraulic conductivities orders of magnitude greater.

4.3 Hydrocensus

Several boreholes, surface water resources, which included dams and rivers, and fountains were surveyed during the hydrocensus. The survey was conducted between the 2nd and 26th of August 2021. A total of 44 boreholes, 2 fountains, 16 dams and 3 rivers were surveyed during the census.

Details captured during the survey are presented in Table 9 and a map showing the relative positions of the surveyed localities in Figure 9.

Table 9: Hydrocensus information

Field ID	Coordinates			Water level (mbs)	Hydraulic head (mamsl)	Pump type	Application/ Description	Owner	Sample Taken Y/N	BH Condition
	y	x	Z (mamsl)							
Boreholes										
APBH 01	-26.088590	29.554100	1675	19.31	1653.77	Submersible	Water Supply	Anton Pelser	N	Good
APBH 02	-26.088560	29.554280	1675	5.09	1656.14	Not Equipped	Not in use		Y	Poor
APBH 03	-26.088820	29.560290	1682	32.44	1638.77	Not Equipped	Not in use		Y	Good
APBH 04	-26.188690	29.558490	1690	7.00	1620.78	Windpump	Not in use		N	Good
APBH 05	-26.211770	29.572710	1631	4.10	1639	Not Equipped	Not in use		Y	Good
APBH 06	-26.200080	29.553430	1650	3.19	1706.27	Not Equipped	Not in use		Y	Good
APBH 07	-26.201520	29.553900	1644	1.20	1713	Windpump	Not in use		N	Moderate
APBH 08	-26.197290	29.548520	1659	4.63	1707.18	Not Equipped	Not in use		Y	Good
APBH 10	-26.198450	29.543860	1669	4.62	1680.3	Windpump	Not in use		N	Good
APBH 11	-26.201690	29.539960	1657	20.44	1663.21	Not Equipped	Not in use		Y	Good
APBH 12	-26.201370	29.539860	1659	23.89	1613.03	Not Equipped	Not in use		Y	Moderate
APBH 13	-26.200630	29.540430	1657	0.00	1603.24	Submersible	Water Supply		Y	Good
APBH 14	-26.207110	29.530470	1663	48.24	1619.58	Not Equipped	Not in use		Y	Good
APBH 15	-26.191180	29.534570	1666	42.40	1628.8	Not Equipped	Not in use		Y	Good
APBH 16	-26.187330	29.536920	1668	8.84	1640	Windpump	Stock Water		Y	Good
APBH 17	-26.185440	29.551480	1666	15.05	1653	Windpump	Stock Water		Y	Good
APBH 18	-26.185560	29.551420	1666	12.55	1645.14	Not Equipped	Not in use		Y	Moderate
WDKBH 01	-26.117490	29.478630	1666	12.23	1606.84	Not Equipped	Not in use	W.A De Klerk	N	Good
WDKBH 02	-26.117050	29.479110	1666	9.86	1637.92	Submersible	Water Supply		Y	Good

Field ID	Coordinates			Water level (mbs)	Hydraulic head (mamsl)	Pump type	Application/ Description	Owner	Sample Taken Y/N	BH Condition
	y	x	Z (mamsl)							
WDKBH 03	-26.106360	29.478980	1643	4.23	1649.08	Not Equipped	Not in use		Y	Good
Boreholes continued										
WDKBH 04	-26.128570	29.495290	1632	11.22	1642.75	Submersible	Water Supply	W.A De Klerk	Y	Good
WDKBH 05	-26.125850	29.496390	1639	obstructed	1647.26	Windpump	Not in use		N	Poor
WDKBH 06	-26.146480	29.618890	1710	3.73	1648.18	Windpump	Not in use		N	Poor
WDKBH 07	-26.155900	29.617470	1713	obstructed	1657	Windpump	Stock Water		Y	Good
WDKBH 08	-26.141440	29.611760	1709	1.82	1635.67	Not Equipped	Not in use		Y	Good
TBBH 01	-26.156120	29.599890	1680	0	1608.77	Not Equipped	Not in use	Jan Breedt	Y	Good
TBBH 02	-26.159740	29.579150	1664	0.79	1653.77	Not Equipped	Not in use		Y	Good
HDB BH 01	-26.083869	29.482094	1627	13.97	1656.14	Submersible	Water Supply	Hannes de Beer	Y	Good
HDB BH 02	-26.082939	29.484146	1629	25.76	1638.77	Submersible	Not in use		Y	Good
HDB BH 03	-26.082689	29.484882	1631	11.42	1620.78	Not Equipped	Not in use		Y	Good
DVW BH 01	-26.149036	29.543877	1632	3.20	1639	Windpump	Stock Water	Dirk van Woudenberg	N	Good
DVW BH 02	-26.154987	29.541359	1640	obstructed	1706.27	Windpump	Stock Water		Y	Good
DVW BH 03	-26.157640	29.553894	1653	obstructed	1713	Windpump	Stock Water		Y	Good
DVW BH 04	-26.166764	29.549706	1663	17.86	1707.18	Windpump	Stock Water		Y	Good
DVW BH 05	-26.159587	29.518753	1628	21.16	1680.3	Windpump	Stock Water		Y	Good
DVW BH 06	-26.149108	29.529382	1647	9.08	1663.21	Windpump	Not in use		N	Good
DVW BH 07	-26.143155	29.533758	1657	7.92	1613.03	Not Equipped	Not in use		Y	Good
DVW BH 08	-26.142565	29.537046	1650	7.25	1603.24	Submersible	Water Supply		Y	Good
DVW BH 09	-26.140084	29.538192	1652	4.74	1619.58	Submersible	Water Supply	Anton Pelser	Y	Good
DVW BH 10	-26.147509	29.572679	1659	10.82	1628.8	Windpump	Stock Water		Y	Good

Field ID	Coordinates			Water level (mbs)	Hydraulic head (mamsl)	Pump type	Application/ Description	Owner	Sample Taken Y/N	BH Condition
	y	x	Z (mamsl)							
APWELL 01	-26.200660	29.540380	1657	0.00 (shallow well)	1640	-	Not in use	Anton Pelser	Y	-
HD BH 01	-26.266020	29.599270	1644	8.33	1653	Windpump	Not in use	Hennie Davel	Y	Good
HD BH 02	-26.217090	29.614970	1632	23.23	1645.14	Submersible	Water Supply		Y	Good
BP BH 01	-26.122950	29.515720	1663	12.75	1650.25	Not equipped	Not in use	Mike	Y	Good
BP BH 02	-26.135110	29.509500	1621	1.64	1619.36	Not equipped	Not in use		Y	Good
BP BH 03	-26.135070	29.509620	1621	No access	-	Submersible	Domestic & Livestock		N	Good
Surface water/dams										
APSW 01	-26.194270	29.566600	-	N/A	N/A	N/A	Domestic	Anton Pelser	Y	N/A
APSW 03	-26.207880	29.577580	-	N/A	N/A	N/A	Livestock		Y	N/A
APSW 04	-26.203310	29.552350	-	N/A	N/A	N/A	Livestock		Y	N/A
APSW 05	-26.197690	29.548530	-	N/A	N/A	N/A	Livestock		Y	N/A
APSW 06	-26.190700	29.533960	-	N/A	N/A	N/A	Livestock		Y	N/A
APSW 07	-26.175020	29.537130	-	N/A	N/A	N/A	Livestock		Y	N/A
APSW 08	-26.183540	29.539500	-	N/A	N/A	N/A	Livestock		Y	N/A
APSW 09	-26.190550	29.578790	-	N/A	N/A	N/A	Livestock		Y	N/A
WDKSW 01	-26.126820	29.495780	-	N/A	N/A	N/A	Livestock	W.A De Klerk	Y	N/A
WDKSW 02	-26.181860	29.567080	-	N/A	N/A	N/A	Livestock		Y	N/A
TBSW 01	-26.160190	29.569950	-	N/A	N/A	N/A	Livestock	Jan Breedt	Y	N/A
TBSW 02	-26.157100	29.593150	-	N/A	N/A	N/A	Livestock		Y	N/A

Field ID	Coordinates			Water level (mbs)	Hydraulic head (mamsl)	Pump type	Application/ Description	Owner	Sample Taken Y/N	BH Condition
	y	x	Z (mamsl)							
HDB SW 01	-26.083479	29.483097	-	N/A	N/A	N/A	Livestock	Hannes de Beer	Y	N/A
DVW SW 01	-26.150803	29.550089		N/A	N/A	N/A	Livestock	Dirk van Woudenberg	Y	N/A
HD SW 01	-26.208150	29.601840	-	N/A	N/A	N/A	Livestock	Hennie Dafel	Y	N/A
BP SW 01	-26.135380	29.508990	-	N/A	N/A	N/A	Livestock	Mike		
BP SW 02	-26.132540	29.514130	-	N/A	N/A	N/A	Domestic & livestock			
Surface water/rivers/streams										
ESKOM SW 01	-26.094686	29.482551	-	N/A	N/A	N/A	Koringspruit	-	Y	N/A
APSW 02	-26.213810	29.580680	-	N/A	N/A	N/A	Olifants River	-	Y	N/A
HD SW 03	-26.217980	29.591890	-	N/A	N/A	N/A	Olifants River	-	Y	N/A
Fountain										
WDRFO 01	-26.125130	29.497930	1645	0	1645	N/A	Livestock	-	sampled at WDKSW01	N/A
TBFO 01	-26.149850	29.605290	1709	0	1709	N/A	Domestic	-	Y	N/A

N/A not applicable

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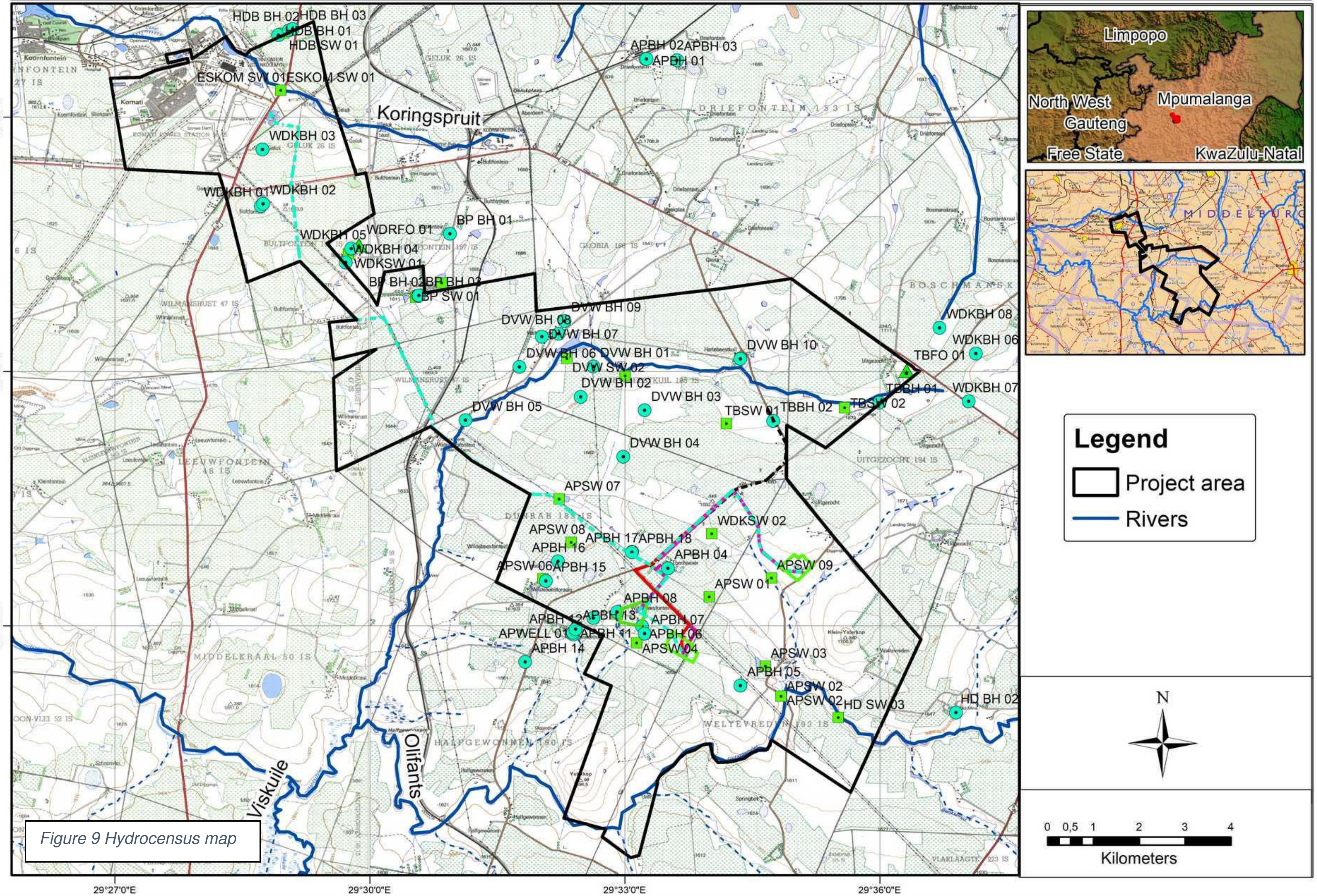

Figure 9 Hydrocensus map

4.3.1 Water levels

Water levels measured range between 0.79- and 48.24 meters below surface ("mbs"). One borehole, APBH13 was measured as artesian. The deeper water levels present dynamic water levels, which were affected by pumping at time of the survey. The average water level is 13.17 mbs.

The majority of boreholes and dams are utilised for livestock watering purposes while some also function as domestic sources.

Figures 10 and 11 show linear regressions between the hydraulic heads of the aquifers and topography. A fair correlation of 0.73 was achieved for the all hydraulic heads calculated and the topography. Some water levels are, however, suspected to be dynamic heads, that is either artesian or influenced by pumping (or recovering). These dynamic heads were subsequently removed and a better correlation of 0.97 was achieved. It can therefore be assumed with relative confidence that the natural groundwater flow mimics surface water flow directions and that certain water levels recorded are indeed dynamic heads affected by groundwater abstraction.

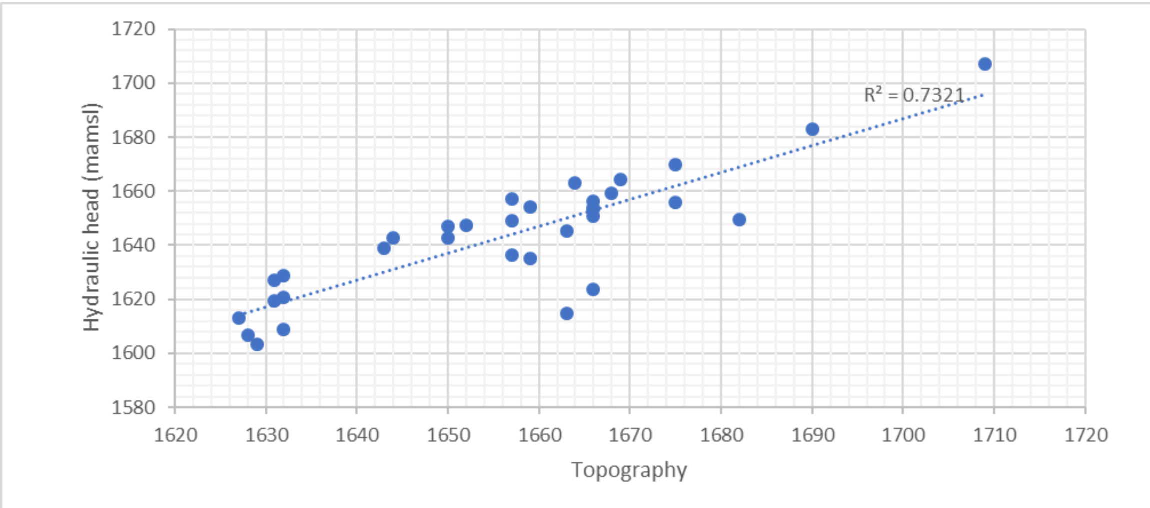

Figure 10: Linear regression between topography and hydraulic heads

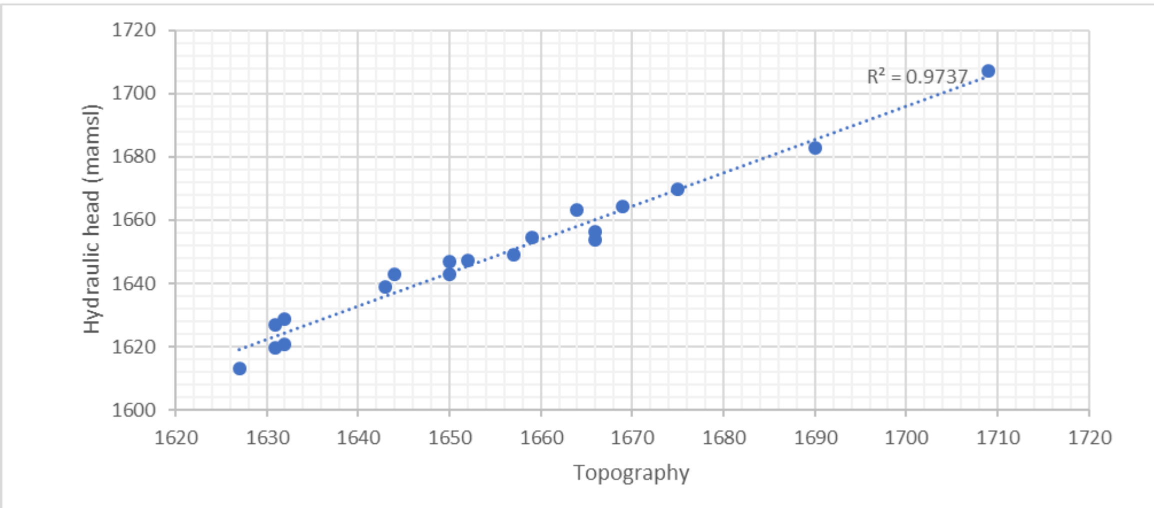

Figure 11: Linear regression between topography and hydraulic heads with suspected dynamic levels removed

4.3.2 Water Quality

During the hydrocensus, samples were taken from surveyed localities and analysed for chemical quality. Of the 65 surveyed points, only 41 were analysed. This included 25 privately owned boreholes, one fountain, 13 farm dams and three river samples – two from the Olifants River and one from the Koringspruit to the north. The hydrochemical data of the sampled localities are presented in tables 10 to 14.

An Expanded Durov for groundwater and Stiff diagrams for surface water can be viewed in figures 12 and 13.

4.3.3 Groundwater quality

Based on the groundwater quality data of hydrocensus boreholes displayed in tables 10 to 12, the following:

- Groundwater is generally circum-neutral to slightly alkaline and non-saline.
- EC and TDS are generally in the low ranges and mineralisation of major cations and anions are also low.
- In most boreholes nitrate (NO_3), ammonium (NH_4) and phosphate (PO_4) are low to undetected and well within SANS241 guidelines.
- Three (3) groundwater sources, APBH18 (refer to Table 10), DVW BH 07 and DVW BH 08 (refer to Table 11) recorded NO_3 levels exceeding the SANS 241: 2015 guidelines.
- Trace metal concentrations are generally low to undetected and well within the standards for drinking water.
- Fluoride (F) levels were mostly recorded as undetected.

4.3.4 Water quality of surface water

Based on the data displayed in tables 13 and 14, the following:

- The chemical profiles of the surface water can be described as circum-neutral, non-saline and moderately soft to moderately hard.
- TDS levels are relatively low ranging between 97 mg/l and 271 mg/l with very little mineralisation.
- Sulphate (SO_4), the indicator mineral mostly used to indicate coal-mining related contamination is generally low although some domination of it in terms ion equivalency is evident in some samples, especially recorded in the Koringspruit (*ESKOM SW01*).
- Trace metals recorded in low to relatively raised levels (especially in APSW01). Farm dam APSW01 recorded a circum-neutral pH, but Fe, Al and Mn are raised and exceed domestic standards (*used as reference guideline only*). This dam also recorded relatively raised levels of NH_4 and PO_4.
- F levels recorded in relatively raised levels in some boreholes. Fluoride (F) of 2.21 was recorded in APSW08, which exceeds the domestic standards (*not a suggestion of use or compliance objective – used as reference guideline only*).

Table 10: Water quality of hydrocensus boreholes sampled between 02 August and 26 August 2021

Locality / Guideline Parameter	Unit	**SANS 241:2015**	AP BH 05	AP BH 06	AP BH 08	AP BH 11	AP BH 12	AP BH 13	AP WELL 01	AP BH 14	AP BH 15	AP BH 16	AP BH 17
pH	-	≥ 5 and ≤ 9.7	7.13	6.96	6.95	6.84	7.02	6.59	6.43	6.54	6.87	6.91	6.66
EC	mS/m	≤ 170	39.9	26.4	15.8	29.8	29.1	13.2	14.2	6.67	21.3	24.1	53.8
TDS	mg/l	≤ 1200	201	132	73.0	147	144	63.7	67.3	34.8	101	113	271
Calcium (Ca)	mg/l	-	17.3	23.3	9.56	27.2	16.9	5.39	5.76	5.08	12.0	20.3	50.8
Magnesium (Mg)	mg/l	-	14.0	7.86	5.07	10.2	10.6	4.10	4.14	1.03	7.72	7.21	14.0
Sodium (Na)	mg/l	≤ 200	24.5	14.6	8.86	13.2	23.1	6.45	6.75	3.94	7.45	11.2	23.8
Potassium (K)	mg/l	-	7.71	2.93	3.57	3.31	2.68	3.20	3.31	2.75	3.77	3.63	4.58
Alkalinity	mg/l	-	50.4	123	68.0	136	127	17.4	16.0	19.6	46.0	109	149
Chloride (Cl)	mg/l	≤ 300	32.6	3.86	2.98	7.28	8.45	7.64	7.98	1.26	7.47	4.10	47.1
Sulphate (SO_4)	mg/l	≤ 500	74.4	2.77	1.45	3.73	2.51	1.34	1.14	4.21	1.15	1.48	19.7
Nitrate as N (NO_3-N)	mg/l	≤ 11	<0.35	0.62	<0.35	<0.35	0.70	5.67	6.47	1.03	7.50	<0.35	4.77
Ammonium as N (NH_4-N)	mg/l	≤ 1.5	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	0.47	<0.45	<0.45
Phosphate as P (PO_4)	mg/l	-	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Fluoride (F)	mg/l	≤ 1.5	<0.09	<0.09	<0.09	<0.09	0.30	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09
Aluminium (Al)	mg/l	≤ 0.30	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.15	<0.01	<0.01	<0.01
Iron (Fe)	mg/l	≤ 2	0.01	0.12	0.66	0.01	<0.01	<0.01	<0.01	0.06	<0.01	0.09	<0.01
Manganese (Mn)	mg/l	≤ 0.4	<0.01	0.13	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01
Total Hardness	mg $CaCO_3$/l	-	101	90.5	44.7	110	85.8	30.3	31.4	16.9	61.8	80.4	184

Values highlighted in red text exceed the SANS 241: 2105 standards.

Table 11: Water quality of hydrocensus boreholes sampled between 02 August and 26 August 2021

Locality / Guideline Parameter	Unit	SANS 241:2015	AP BH 18	WDK BH 02	WDK BH 03	WDK BH 04	TB FO 01	TB BH 01	TB BH 02	DVW BH 02	DVW BH 03	DVW BH 04	DVW BH 05
pH	-	≥ 5 and ≤ 9.7	6.77	7.42	7.31	7.36	7.36	7.81	7.32	7.48	7.23	7.86	7.75
EC	mS/m	≤ 170	75.1	31.7	29.9	35.0	31.9	45.5	75.6	52.8	28.9	29.0	41.2
TDS	mg/l	≤ 1200	380	158	148	171	171	247	397	263	138	151	204
Calcium (Ca)	mg/l	-	34.5	25.2	20.2	25.1	21.6	14.9	34.4	18.9	20.8	17.1	12.9
Magnesium (Mg)	mg/l	-	18.9	11.3	12.9	14.1	11.2	8.12	27.1	11.0	9.90	10.2	7.36
Sodium (Na)	mg/l	≤ 200	64.8	13.6	13.0	16.2	17.6	71.5	59.4	61.1	9.68	26.0	56.4
Potassium (K)	mg/l	-	8.99	10.4	4.78	3.35	5.02	2.32	3.23	4.26	3.28	3.69	2.66
Alkalinity	mg/l	-	56.6	143	123	122	86.4	206	88.4	141	70.4	141	170
Chloride (Cl)	mg/l	≤ 300	155	8.98	7.13	16.4	22.2	19.3	62.4	49.8	15.1	5.99	15.8
Sulphate (SO_4)	mg/l	≤ 500	4.96	3.16	2.54	14.6	6.47	5.97	96.5	31.9	9.80	3.01	5.95
Nitrate as N (NO_3-N)	mg/l	≤ 11	**13.1**	<0.35	2.95	1.90	7.86	<0.35	**13.8**	<0.35	6.16	<0.35	<0.35
Ammonium as N (NH_4-N)	mg/l	≤ 1.5	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45
Phosphate as P (PO_4)	mg/l	-	0.22	<0.03	<0.03	<0.03	0.07	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Fluoride (F)	mg/l	≤ 1.5	<0.09	<0.09	<0.09	<0.09	<0.09	0.81	0.21	0.21	<0.09	0.75	0.70
Aluminium (Al)	mg/l	≤ 0.30	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
Iron (Fe)	mg/l	≤ 2	<0.01	<0.01	0.30	<0.01	<0.01	0.55	<0.01	0.67	0.01	<0.01	0.13
Manganese (Mn)	mg/l	≤ 0.4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.16	<0.01	<0.01	<0.01
Total Hardness	mg $CaCO_3$/l	-	164	110	104	121	99.9	70.6	197	92.4	92.7	84.6	62.5

Values highlighted in red text exceed the SANS 241: 2105 standards.

Table 12: Water quality of hydrocensus boreholes sampled between 02 August and 26 August 2021

Locality / Guideline Parameter	Unit	**SANS 241:2015**	DVW BH 07	DVW BH 08	DVW BH 09	DVW BH 10
pH	-	≥ 5 and ≤ 9.7	7.15	6.91	7.01	7.26
EC	mS/m	≤ 170	55.5	41.3	25.4	21.4
TDS	mg/l	≤ 1200	283	198	126	106
Calcium (Ca)	mg/l	-	31.1	19.9	18.0	12.7
Magnesium (Mg)	mg/l	-	19.7	15.0	7.67	7.74
Sodium (Na)	mg/l	≤ 200	22.1	18.7	12.5	16.6
Potassium (K)	mg/l	-	6.47	5.69	5.25	2.76
Alkalinity	mg/l	-	31.0	19.2	80.8	90.4
Chloride (Cl)	mg/l	≤ 300	66.3	70.7	9.96	10.4
Sulphate (SO_4)	mg/l	≤ 500	10.7	2.04	2.30	1.37
Nitrate as N (NO_3-N)	mg/l	≤ 11	**24.2**	**12.4**	4.96	<0.35
Ammonium as N (NH_4-N)	mg/l	≤ 1.5	<0.45	<0.45	<0.45	<0.45
Phosphate as P (PO_4)	mg/l	-	0.28	<0.03	0.04	<0.03
Fluoride (F)	mg/l	≤ 1.5	<0.09	<0.09	<0.09	<0.09
Aluminium (Al)	mg/l	≤ 0.30	<0.01	<0.01	<0.01	<0.01
Iron (Fe)	mg/l	≤ 2	<0.01	<0.01	<0.01	<0.01
Manganese (Mn)	mg/l	≤ 0.4	<0.01	<0.01	<0.01	<0.01
Total Hardness	mg $CaCO_3$/l	-	159	111	76.5	63.6

Values highlighted in red text exceed the SANS 241: 2105 standards.

Table 13: Water quality of surface water sampled between 02 August and 26 August 2021

Locality / Guideline Parameter	Unit	SANS 241:2015	AP SW 01	AP SW 02	AP SW 03	AP SW 07	AP SW 08	AP SW 09	TB SW 01	TB SW 02	WDK SW 01	WDK SW 02
pH	-	≥ 5 and ≤ 9.7	6.49	6.80	7.43	6.81	6.89	6.80	7.30	7.64	8.44	7.57
EC	mS/m	≤ 170	37.7	53.0	33.4	42.2	28.8	19.2	52.4	70.8	50.0	29.3
TDS	mg/l	≤ 1200	178	271	164	214	136	97.4	267	349	260	145
Calcium (Ca)	mg/l	-	11.3	29.6	21.3	16.0	13.2	8.16	21.3	28.5	23.1	15.3
Magnesium (Mg)	mg/l	-	6.75	20.1	13.7	10.8	9.36	6.12	21.1	33.3	34.2	11.0
Sodium (Na)	mg/l	≤ 200	6.68	38.0	16.1	36.4	11.2	11.8	17.3	48.8	21.1	14.8
Potassium (K)	mg/l	-	27.5	4.87	6.84	12.4	16.4	6.16	26.6	15.6	3.89	8.22
Alkalinity	mg/l	-	72.8	156	119	68.6	61.0	18.2	168	240	178	66.0
Chloride (Cl)	mg/l	≤ 300	32.9	39.9	15.4	44.5	33.2	17.8	39.1	68.6	30.3	23.7
Sulphate (SO_4)	mg/l	≤ 500	26.0	44.8	19.0	51.4	12.6	35.8	11.1	8.97	35.3	30.8
Nitrate as N (NO_3-N)	mg/l	≤ 11	0.46	<0.35	<0.35	<0.35	<0.35	<0.35	4.72	<0.35	1.11	<0.35
Ammonium as N (NH_4-N)	mg/l	≤ 1.5	**8.61**	<0.45	<0.45	<0.45	0.56	<0.45	6.30	<0.45	<0.45	<0.45
Phosphate as P (PO_4)	mg/l	-	0.86	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Fluoride (F)	mg/l	≤ 1.5	1.17	0.34	0.75	1.15	**2.12**	0.45	0.27	1.01	0.21	0.68
Aluminium (Al)	mg/l	≤ 0.30	**1.51**	<0.01	<0.01	0.19	0.10	0.04	0.50	<0.01	0.08	0.29
Iron (Fe)	mg/l	≤ 2	**3.34**	0.01	<0.01	0.28	0.48	0.10	0.26	0.01	0.06	0.19
Manganese (Mn)	mg/l	≤ 0.4	**1.20**	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Total Hardness	mg $CaCO_3$/l	-	56.0	157	110	84.2	71.5	45.6	140	208	199	83.4

Values highlighted in red text exceed the SANS 241: 2105 standards

Evaluation according to domestic standards is not a suggestion of use but is used as reference guideline only.

Table 14: Water quality of surface water sampled on 09 February 2021

Locality / Guideline	Unit	**SANS 241:2015**	AP SW 03	AP SW 04	River samples	ESKOM SW 01	AP SW 02
Parameter							
pH	-	≥ 5 and ≤ 9.7	7.43	6.85		7.62	6.80
EC	mS/m	≤ 170	33.4	26.6		46.2	53.0
TDS	mg/l	≤ 1200	164	134		247	271
Calcium (Ca)	mg/l	-	21.3	9.77		25.9	29.6
Magnesium (Mg)	mg/l	-	13.7	7.51		15.3	20.1
Sodium (Na)	mg/l	≤ 200	16.1	16.8		29.8	38.0
Potassium (K)	mg/l	-	6.84	8.24		4.10	4.87
Alkalinity	mg/l	-	119	20.4		43.0	156
Chloride (Cl)	mg/l	≤ 300	15.4	16.9		28.1	39.9
Sulphate (SO_4)	mg/l	≤ 500	19.0	60.8		118	44.8
Nitrate as N (NO_3-N)	mg/l	≤ 11	<0.35	<0.35		<0.35	<0.35
Ammonium as N (NH_4-N)	mg/l	≤ 1.5	<0.45	<0.45		<0.45	<0.45
Phosphate as P (PO_4)	mg/l	-	<0.03	<0.03		<0.03	<0.03
Fluoride (F)	mg/l	≤ 1.5	0.75	0.70		0.21	0.34
Aluminium (Al)	mg/l	≤ 0.30	<0.01	0.31		<0.01	<0.01
Iron (Fe)	mg/l	≤ 2	<0.01	0.51		<0.01	0.01
Manganese (Mn)	mg/l	≤ 0.4	<0.01	<0.01		<0.01	<0.01
Total Hardness	mg $CaCO_3$/l	-	110	55.3		128	157

Values highlighted in red text exceed the SANS 241: 2105 standards

Evaluation according to domestic standards is not a suggestion of use but is used as reference guideline only.

4.3.5 Hydrogeochemical profiles

The Durov Diagram in Figure 13 shows that most boreholes plot in fields 1, 2 or 3 of the diagram. These groundwater types are typical of fresh, recently recharged water with Ca, Mg or Na dominated ions. They are dominated by bi-carbonate alkalinity (HCO_3) and Ca, Mg and/or Na cations.

Two groundwaters sampled from boreholes APBH05 and TBBH02 plot in Field 5. This type is typical of groundwater that is usually a mix of different types – either clean water from fields 1 and 2 that has undergone SO_4 and NaCl mixing/contamination or old stagnant NaCl dominated water that has mixed with clean water. Three boreholes' samples, APBH02, DVWBH08 and DVWBH07 plot in Field 8 which is typical of groundwater that is also a mix of different types – either clean water from fields 1 and 2 that has undergone SO_4, but especially Cl mixing/contamination or old stagnant NaCl dominated water that has mixed with water richer in Mg. The SO_4 enrichment in these groundwaters may be an indication of groundwater affected by mining or other anthropogenic activities.

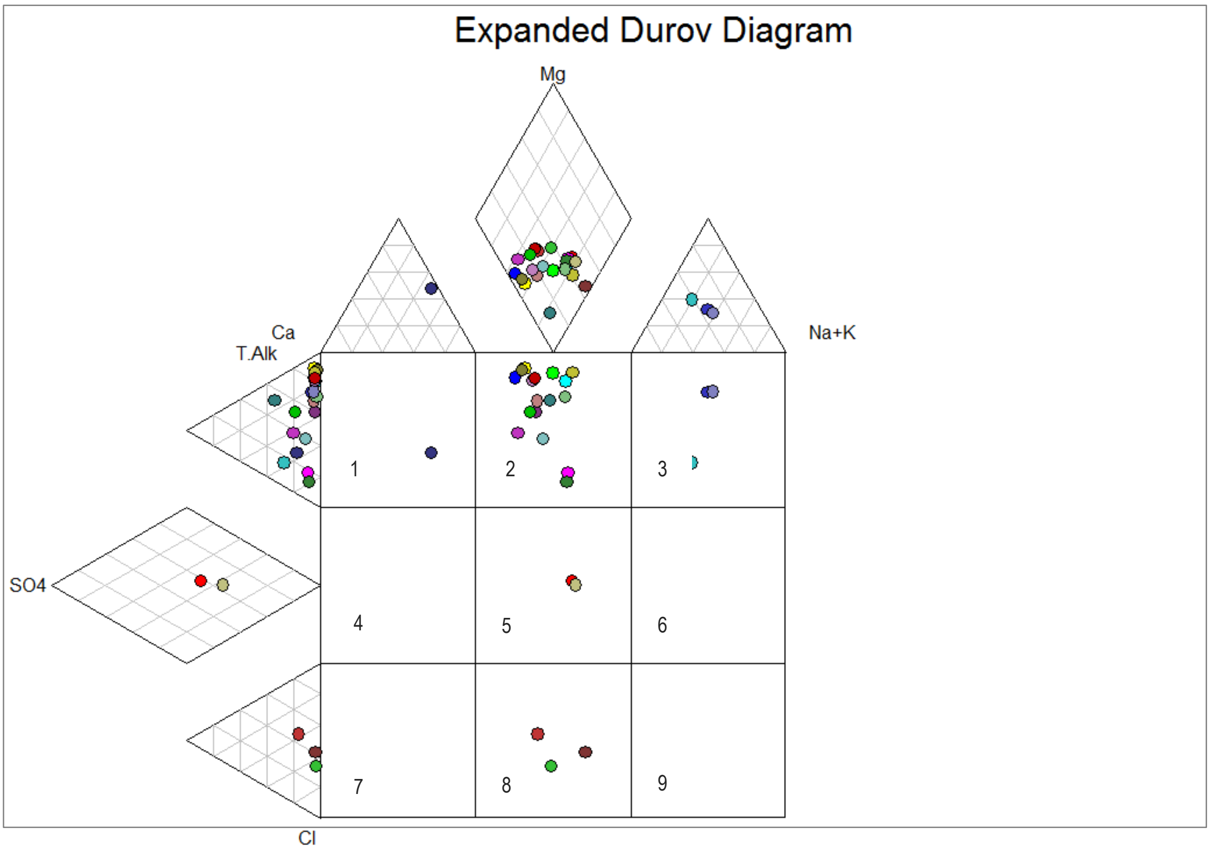

Figure 12: Expanded Durov diagram showing relative ratios in meq/l

Most of the surface water profiles are dominated by the Mg cation and HCO_3^- anion, which are indicative of unaffected water. Farm dam waters from APSW01, APSW04, APSW07 and APSW09 have dominating Cl and / or SO_4 anions and Na and /or Mg dominating cations, which indicate affected water or representing evaporation signatures. The Koringspruit sample *Eskom SW01* has a distinct SO_4 character and is possibly affected by the Komati Power Station and Ash dams (Figure 14).

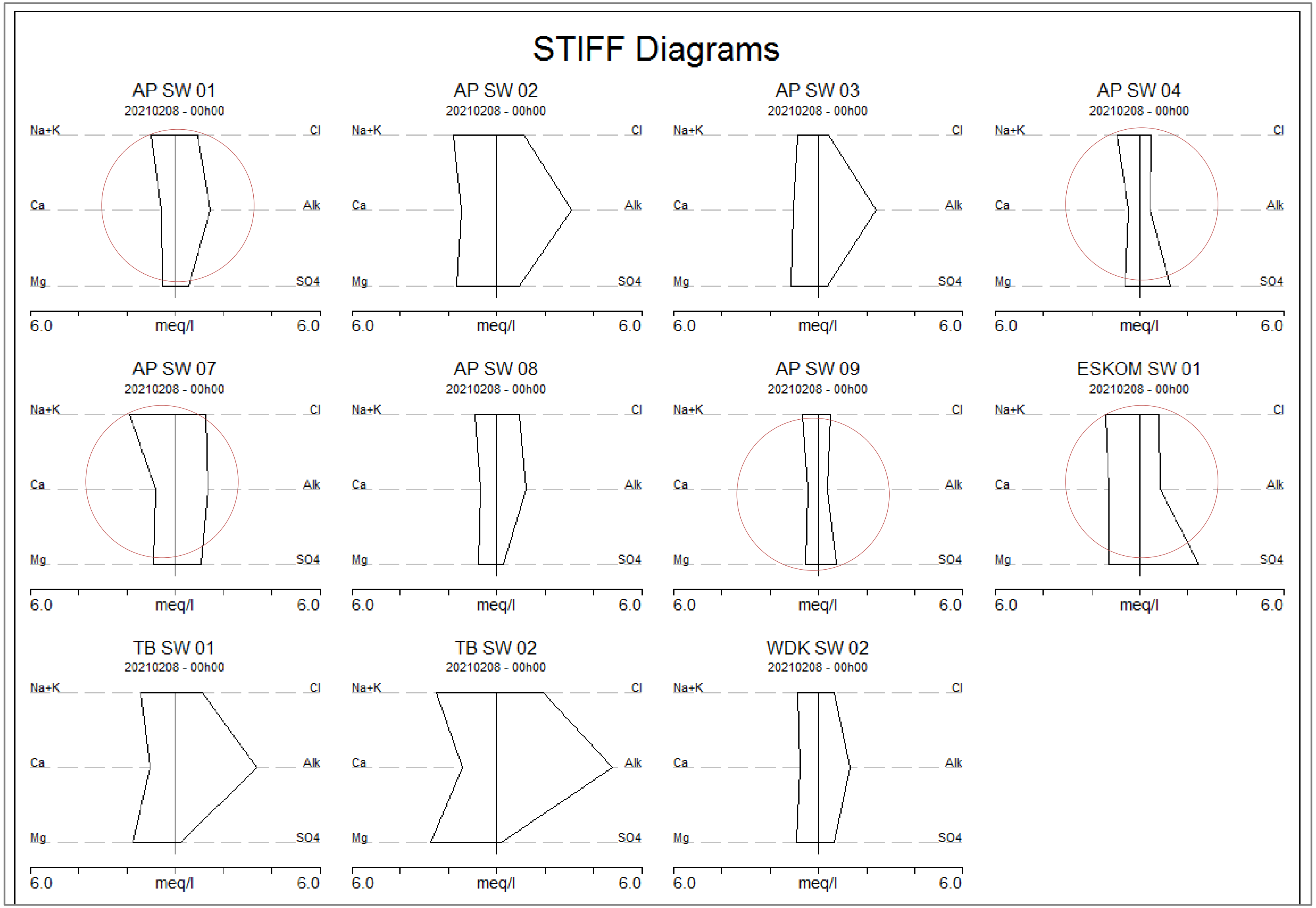

Figure 13: Stiff Diagrams for surface water based on meq/l

5. AQUIFER CHARACTERISATION

5.1 Aquifer vulnerability

Table 15 summarizes the aquifer classification vulnerability scores for the aquifer/s in vicinity of the project area. The final DRASTIC score of 99 indicates that the regional fractured aquifer has a medium susceptibility to pollution and a medium level of aquifer protection is therefore required (Refer to Section 2.1.2 for the methodology used).

Table 15: DRASTIC vulnerability scores (fractured aquifer)

Factor	Range/Type	Weight	Rating	Total
D	5 - 15 m	5	7	35
R	5 - 10 mm	4	3	12
A	Fractured	3	6	18
S	clay loam/silty loam	2	2	4
T	0-2%	1	10	10
I	Karoo (northern)	5	4	20
C	-	3	-	-
DRASTIC SCORE = 99				

5.2 Aquifer classification

The Department of Water and Sanitation ("DWS"), has characterised South African aquifers based on the rock formations in which they occur together with its capacity to transmit water to boreholes drilled into specific formations. The water bearing properties of rock formations in South Africa can be classified into four classes defined as:

1. **Class A - Intergranular**
   - Aquifers associated either with loose and unconsolidated formations such as sands and gravels or with rock that has weathered to only partially consolidated material.
2. **Class B - Fractured**
   - Aquifers associated with hard and compact rock formations in which fractures, fissures and/or joints occur that are capable of both storing and transmitting water in useful quantities.
3. **Class C - Karst**
   - Aquifers associated with carbonate rocks such as limestone and dolomite in which groundwater is predominantly stored in and transmitted through cavities that can develop in these rocks.
4. **Class D - Intergranular and fractured**
   - Aquifers that represent a combination of Class A and B aquifer types. This is a common characteristic of South African aquifers. Substantial quantities of water are stored in

the intergranular voids of weathered rock but can only be tapped via fractures penetrated by boreholes drilled into the fractured aquifer.

Each of these classes is further subdivided into groups relating to the capacity of an aquifer to transmit water to boreholes, typically measured in l/s. The groups therefore represent various ranges of borehole yields.

According to the 1: 25 000 hydrogeological map (2526) for Johannesburg (map not shown) the study area is predominantly located in a d2 aquifer class region; the porphyritc rhyolite (Selons River Formation) being slightly more favourable compared to the Vryheid Formation sandstone and shale, but only constitute a very small area to the south. The groundwater yield potential is classed as low on the basis that most of the boreholes on record in vicinity of the study area produce between 0.1 and 0.5 l/s, although larger yields (up to 5 l/s) can be obtained in weathered or fractured aquifers associated with dolerite intrusions. Such intrusions may be present, although they are not shown on the geological map.

The different modes of undisturbed/natural groundwater occurrences associated with the study area include:

- Joints and fractures occurring in contact zones related to the heating and cooling of country rock, caused by the intrusion of dykes and sills;
- Along sedimentary or sedimentary / igneous rock contacts. A contact may either be open, weathered or fractured due to movement along the contact, or fractured due to heating and subsequent cooling related to large extrusive or intrusive events; and
- Minor groundwater occurrences are often encountered in association with coal seams.

According to the regional aquifer classification map of South Africa, the surrounding Karoo aquifer has been identified as a minor aquifer with good groundwater quality (<300 mg/l TDS), a medium vulnerability and a medium susceptibility towards contamination. Based on the ‘undisturbed’ underlying hydrogeology of the project area the aquifers can classified according to Parsons (1995) and system as follows:

i) Weathered unconfined aquifer
   a. <u>Minor aquifer</u>
ii) Fractured confined or semi-confined aquifer in the Vryheid & Selons River Formation
   a. <u>Minor aquifer</u>

The occurrences and classification of the respective undisturbed aquifer types underlying the wider study area are shown in Table 16 below.

Table 16: Principal groundwater occurrences and classification according to the Parsons (Parsons, 1995) classification system for undisturbed aquifers

Aquifer	Type	Lithology	Groundwater occurrence	Depth (m)	Probable yield (l/s)	Classification
Shallow weathered	Unconfined	Semi consolidated material	Weathered rock	~3~20	0.1	**Minor aquifer**
Intergranular and/ or Fractured	Confined/ semi-confined	Ecca Group: Vryheid Formation shale/sandstone	Seepage water between host rock particles Discontinuities – fractures, fissures, joints	~20 ~ 100	0.1 – 0.5*	**Minor aquifer**

* Larger yields of up to 5 l/s are possible in weathered and/or fractured zones associated with dolerite dyke intrusive bodies

5.3 Aquifer protection classification

In order to achieve the Groundwater Quality Management Index a point scoring system as presented in tables 17 and 18 was used for the naturally occurring undisturbed aquifers in the wider study area.

The occurring aquifer, in terms of the above definitions, is classified as a minor aquifer system. The vulnerability, or the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer is classified as medium. The level of groundwater protection based on the Groundwater Quality Management Classification is shown in Table 19.

Table 17: Ratings for the Aquifer System Management and Second Variable Classifications

Aquifer System Management Classification		
Class	**Points**	**Study Area**
Sole Source Aquifer System	6	
Major Aquifer System	4	
Minor Aquifer System	2	2
Non-Aquifer System	0	
Special Aquifer System	0-6	
Second Variable Classification (fractured)		
High	3	
Medium	2	2
Low	1	

Table 18: Ratings for the Groundwater Quality Management (GQM) Classification System

Aquifer System Management Classification		
Class	**Points**	**Study Area**
Sole Source Aquifer System	6	
Major Aquifer System	4	

Minor Aquifer System	2	2
Non-Aquifer System	0	
Special Aquifer System	0-6	
Aquifer Vulnerability Classification		
High	3	
Medium	2	2
Low	1	

GQM Index = Aquifer System Management x Aquifer Vulnerability:

2 X 2 = 4

Table 19: GQM index for the study area

GQM Index	Level of Protection	Study Area
<1	Limited	
1-3	Low level	
3-6	**Medium level**	**4**
6-10	High level	
>10	Strictly non-degradation	

The ratings for the Aquifer System Management Classification and Aquifer Vulnerability Classification yield a GQM index of 4 for the study area, indicating that **medium level groundwater protection** is required to adhere to DWS's water quality objectives. Reasonable and sound groundwater protection measures are recommended to ensure that no cumulative pollution affects the aquifer, during short- and long-term. DWS's water quality management objectives are to protect human health and the environment. Therefore, the significance of this aquifer classification is that if any potential risk exists, measures must be taken to limit the risk to the environment, which in this case is:

- The protection of the underlying weathered and fractured aquifers; and
- Olifants River, Leeuwfonteinspruit and Koringspruit.

5.4 Groundwater elevation and gradients

The groundwater elevations (hydraulic heads) were calculated by subtracting static water levels from the topography. The data as shown in Table 20 show that the hydraulic heads vary between 1585 to 1696 mamsl with the highest hydraulic head and lowest head corresponding to higher and lower lying surface elevations.

Table 20: Calculated hydraulic heads for hydrocensus and monitoring boreholes

Site ID	Y	X	Z (mamsl)	Water Level (mbgl)	Measured Head (mamsl)
MBH 01B	-2900845	52843	1639	1.50	1637.5
MBH 01A	-2900837	52823	1640	3.00	1637
MBH 02	-2900578	52922	1648	1.64	1646.36
MBH 05	-2902359	53210	1595	2.51	1592.49
MBH 07	-2899887	53017	1663	42.41	1620.59
HGM 03	-2900922	53983	1611	10.30	1600.7
HGM 08	-2900110	50215	1586	0.84	1585.16
MBH 08	-2899306	53981	1656	21.60	1634.4
HG 03	-2898935	54362	1669	2.41	1666.59
HG 04	-2899117	55316	1650	2.41	1647.59
HGM 11	-2899292	53967	1657	23.06	1633.94
HGM 12	-2899257	53959	1659	22.89	1636.11
2629AD00187	-2908069	48526	1602	7.01	1594.99
2629BC00006	-2907496	57406	1640	6.1	1633.9
2629BC00091	-2906285	61574	1648	7.01	1640.99
2629BC00153	-2905680	52446	1637	15	1622
2629BA00008	-2901935	52434	1608	11.58	1596.42
2629BA00062	-2901246	57212	1639	7.92	1631.08
2629BA00076	-2900529	62712	1649	8.23	1640.77
2629BA00056	-2895706	64208	1707	10.97	1696.03
2629BA00066	-2894887	59826	1693	12.19	1680.81
2629BA00073	-2893917	55911	1643	3.96	1639.04
2629BA00061	-2893775	51155	1657	5.18	1651.82

5.5 Groundwater sources and sinks

Depending on the prevailing gradient between groundwater in the shallow aquifer and the surface water stage in a river, groundwater will discharge into surface waters or vice versa. Groundwater sources are predominantly from rainfall recharge at an average of between 0.5 to 3% and discharges as baseflow into wetlands, rivers and streams, but this occurrence is mostly between the weathered aquifer and the natural surface water system. The main groundwater sources in the wider area of interest are:

- direct rainfall recharge of the shallow weathered aquifer with vertical leakage to the fractured aquifer;
- potential leakage from surface water courses and unlined dams; and
- regional groundwater inflow.

The main groundwater sinks in the model domain are:

- groundwater seepage towards surface waters;

- regional groundwater outflow; and
- shallow interflow and groundwater fed pans, wetlands and natural drainage systems.

The main sources and sinks for the relevant catchment areas are shown below in Table 21.

Table 21: Recharge (sources) and baseflow (sinks) figures for the catchment area

Quaternary	Area	MAP	Recharge		Baseflow	
catchment	Km²	mm/a	mm/a	Mm³/a	mm/a	Mm³/a
B11A	954.4	699	42	40.1	7	6.68
B11B	435.3	687	51.11	22.25	7	3.04

5.6 Conceptual model

The first step in any modelling exercise is the development of a conceptual geohydrological model. This is an idealisation of the real world that summarises the current understanding of site conditions and how the groundwater flow system works. It includes all the important features of the flow system, while incorporating simplifying assumptions. The conceptual model relies heavily on the information gathered during the field investigation phase.

The geology in any geohydrological setting forms the basis for groundwater flow and aquifer development. The geohydrology in the study area is no exception and will conform thereto.

A conceptual model was developed based on the review of available data and the information gathered during the field investigations. The model is a simplified representation of the geohydrological conditions and processes taking place in the study area and forms the cornerstone for understanding and describing the geohydrological environment and its behaviour. It describes the simplifying assumptions necessary to represent the real-world system in a numerical model.

5.6.1 Local geology

The geology governs the aquifer formation through the weathering and fracturing processes.

5.6.2 Geohydrology

Three distinct undisturbed saturated groundwater regions are potentially underlying the study area, and include:

i. Perched aquifer, mostly associated within wetlands (unconfirmed);
ii. Weathered aquifer; and
iii. Fractured aquifer.

Groundwater flow directions largely correlate with surface flow. It tends to follow relatively similar gradients and flow patterns compared to surface topography. Based on first principles, groundwater flow patterns are largely towards the major drainage systems, being the Olifants River and Leeuwfonteinspruit. Groundwater leaves the aquifer as discharge contributing to flow within the bases of these systems (groundwater contribution baseflow). A good correlation of 0.97 was achieved between static hydraulic heads and surface elevation. Groundwater flows from higher lying ground towards lower lying springs or valleys including surface water drainages (Olifants River and Leeuwfonteinspruit), where it 'daylights' or accumulates in the alluvial and hill wash deposits.

The groundwater levels within the weathered and fractured aquifer are relatively shallow being of semi-confined to confined nature. Ferricrete underly the study area at certain places (unconfirmed) and acts as a confining aquiclude or aquitard (in places) that separate the weathered aquifer from the fractured aquifer resulting in piezometric heads to form, some of which may be artesian (Figure 14). Sills are generally confined to specific horizons and will also act as a largely impermeable barrier for groundwater movement.

Several wetlands occur within the study area, which is largely disconnected from the fractured aquifer. Only the weathered and/ or perched aquifer is hydraulically connected to the wetlands.

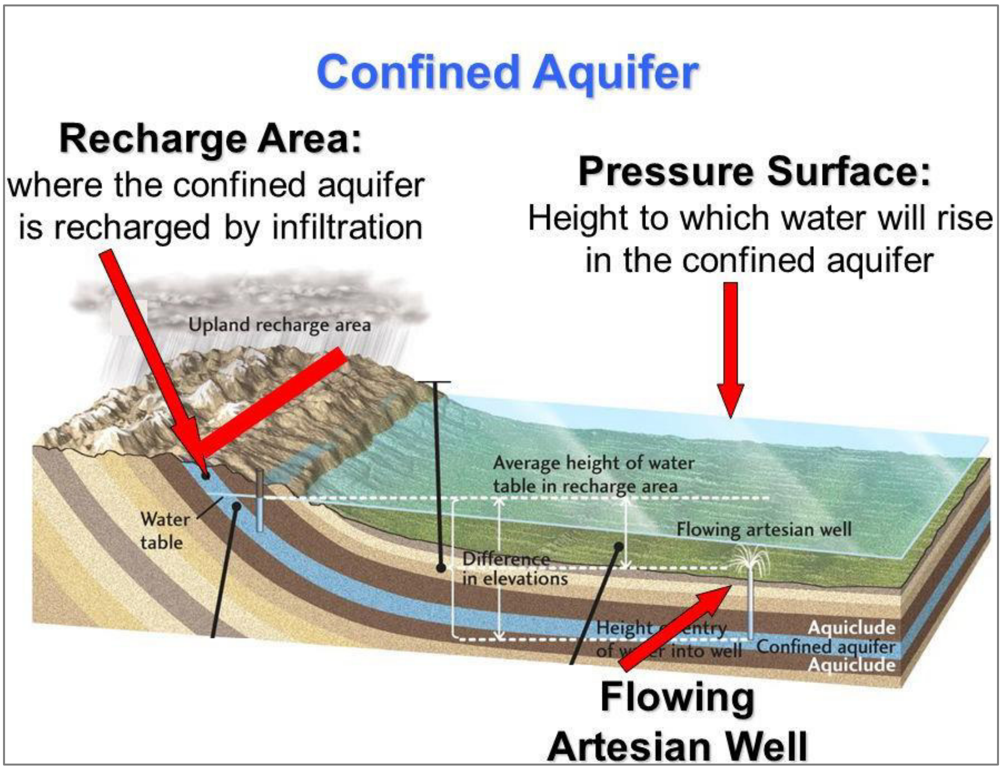

Figure 14: Confined aquifer pressure surface

5.6.3 Recharge

Groundwater recharge represents infiltration of rainwater through the overlying geology into the aquifer. There are several processes occurring at surface that contribute to the amount of recharge to groundwater from rainfall. Figure 15 presents a simplified water balance for illustrative purposes. Precipitation (P) that falls on the land surface enters various pathways of the hydrologic cycle. Some water can be temporarily stored on the land surface in wetlands, perched aquifers and water puddles

(∆SW), some will be evaporated directly from surface (ET) or from wetlands, perched aquifers and puddles (ETW). Some water will drain across the land surface to stream channels (run-off, RO) and some water will infiltrate through porous surface soil and seep into the ground. Water is stored in the vadose (unsaturated) zone from where it can be accessed by vegetation via the roots and used by the plants (transpired). Water infiltrating the soil/rock matrix reaching the water table is called groundwater recharge (RCH) and contributes to groundwater storage (∆SGW).

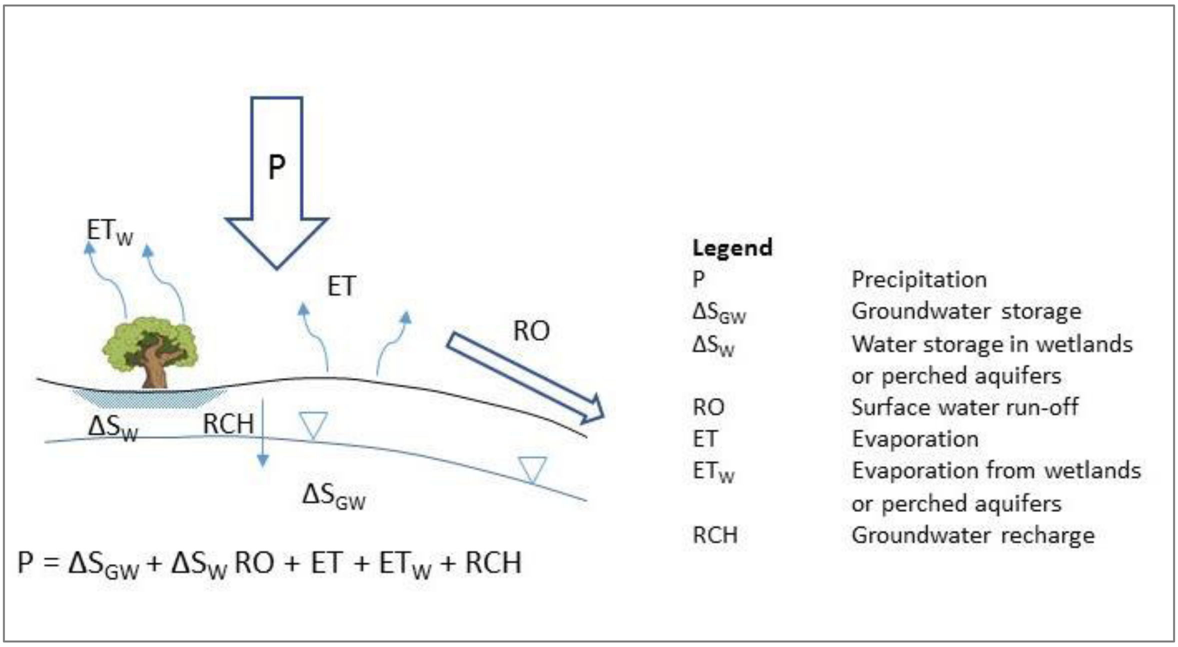

Figure 15: Surface processes related to precipitation and groundwater recharge

The collection of direct field measurements for groundwater recharge was not included in the field investigation. The percentage recharge to the 'undisturbed' Karoo aquifers is expected to be in the order of 0.5 – 3% of the annual rainfall. Recharge in this Karoo aquifer system is therefore highly variable and different recharge figures can be found from one area to the next. This is due to variations in the composition of the overlying and weathered sediments and heterogeneity of the competent and fractured sandstone matrices.

The following mechanisms are expected to contribute to groundwater recharge in the study area:

- Direct infiltration of rainfall through the overlying unconsolidated material and the weathered matrix.
- Significantly higher recharge compared to ambient is expected through the alluvial wash material.

5.6.4 Hydraulic properties

The Karoo aquifer underlying the study area is not a well-developed aquifer. While the sandstone/shale matrix contain considerable volumes of water due to intergranular spaces present and possess a relatively large porosity, the absence of connectedness between the pores, known as effective porosity, is very low. The consequence is that a hydraulic conductivity within the matrix is very low and groundwater flow therefore tend to be restricted to fractures. Previous work and experience from doing hydraulic testing within the Karoo aquifers show that the primary aquifers of the Vryheid Formation have very low permeabilities with hydraulic conductivities generally ranging between $1x10^{-5}$ to $1x10^{-2}$. Preferential flow paths or fractures created in the secondary aquifer created by dolerite intrusions within the host rock display hydraulic conductivities orders of magnitude greater.

6. GEOHYDROLOGICAL IMPACTS

The assessment of impacts and mitigation evaluates the likely extent and significance of the potential impacts on identified receptors and resources against defined assessment criteria, to develop and describe measures that will be taken to avoid, minimise or compensate for any adverse environmental impacts, to enhance positive impacts, and to report the significance of residual impacts that occur following mitigation.

The key objectives of the risk assessment methodology are to identify any additional potential environmental issues and associated impacts likely to arise from the proposed project, and to propose a significance ranking. Issues / aspects will be reviewed and ranked against a series of significance criteria to identify and record interactions between activities and aspects, and resources and receptors to provide a detailed discussion of impacts. The assessment considers direct, indirect, secondary as well as cumulative impacts.

A standard risk assessment methodology is used for the ranking of the identified environmental impacts pre-and post-mitigation (i.e. residual impact). The significance of environmental aspects is determined and ranked by considering the criteria presented in Table 22.

Table 22: Impact Assessment Criteria and Scoring System

CRITERIA	SCORE 1	SCORE 2	SCORE 3	SCORE 4	SCORE 5
Impact Extent (E) The geographical extent of the impact on a given environmental receptor	Site: Site only	Local: Inside activity area	Regional: Outside activity area	National: National scope or level	International: Across borders or boundaries
Impact Duration (D) The length of permanence of the impact on the environmental receptor	Immediate: On impact	Short term: 0-5 years	Medium term: 5-15 years	Long term: Project life	Permanent: Indefinite
Impact Reversibility (R) The ability of the environmental receptor to rehabilitate or restore after the activity has caused environmental change	Reversible: Recovery without rehabilitation		Recoverable: Recovery with rehabilitation		Irreversible: Not possible despite action

CRITERIA	SCORE 1	SCORE 2	SCORE 3	SCORE 4	SCORE 5
Impact Magnitude (M) The degree of alteration of the affected environmental receptor	Very low: No impact on processes	Low: Slight impact on processes	Medium: Processes continue but in a modified way	High: Processes temporarily cease	Very High: Permanent cessation of processes
Probability of Occurrence (P) The likelihood of an impact occurring in the absence of pertinent environmental management measures or mitigation	Improbable	Low Probability	Probable	Highly Probability	Definite
Significance (S) is determined by combining the above criteria in the following formula:	$[S = (E + D + R + M) \times P]$ $Significance = (Extent + Duration + Reversibility + Magnitude) \times Probability$				
IMPACT SIGNIFICANCE RATING					
Total Score	**4 to 15**	**16 to 30**	**31 to 60**	**61 to 80**	**81 to 100**
Environmental Significance Rating (Negative (-))	**Very low**	**Low**	**Moderate**	**High**	**Very High**
Environmental Significance Rating (Positive (+))	**Very low**	**Low**	**Moderate**	**High**	**Very High**

6.1 Impact assessment for the risks posed by Green Hydrogen and Ammonia Facility

6.1.1 Construction phase

Regarding **groundwater quantity** during the construction phase, a temporary water supply for construction will need to be installed. Should existing or new boreholes be used or required, this must comprise of over-ground water pipelines and tanks to the construction camp. In addition, over abstraction of groundwater can result in aquifer depletion and loss of resource for farmers.

Another impact on groundwater quantity could potentially relate to an increase in recharge due to topsoil and vegetation clearance but will be counteracted by lowered recharge on compacted surfaces.

The impacts on **groundwater quality** during the construction phase are primarily related to the management of materials, wastes and spills and unauthorised disposal of contaminated substances. Contamination of groundwater may also arise due to incorrect handling and disposal of waste materials. The risks associated therewith is considered low.

Operation of earth moving equipment and machinery within the project site presents a risk of petrochemical spillages. Equipment and machinery require fuels, lubricants and hydraulic fluids to operate. Should a machine malfunction occur, and a spill result, it could lead to groundwater contamination.

Except for the lesser oil and diesel spills and sewage from generated from construction campsites there are no activities expected that could impact on regional groundwater quality. This phase should thus cause very little additional impacts.

Risks related to groundwater quality and quantity are potentially expected during the construction phases of development. These impacts are primarily related to minor hydrocarbon or other spills, potable water sourcing, clearance of vegetation and soil compaction.

Impact ratings associated with groundwater during the construction phase are displayed in tables 23 and 24.

Table 23: Impact assessment on groundwater quantity during construction phases of the Green Hydrogen and Ammonia Facility

Aspect affected	Activity	Phase	Pre-mitigation[1] Significance	Mitigation	Post mitigation[2] Significance
Groundwater quantity	Water use	Construction	Low (24)	Management measures: • The design, construction and maintenance of all infrastructure related to construction phases of the Project must ensure that the quantity of the groundwater that feeds sensitive receptors (groundwater abstractions and groundwater dependant terrestrial ecosystems) downstream from any infrastructure does not significantly change and the development does not act as a preferential pathway to groundwater flow. Action plans: • Identified boreholes should be subjected to pump tests overseen by a professional geohydrologist. • Boreholes should not be pumped more than its sustainable use allows as recommended by the geohydrologist.	Vert low (12)

[1] Pre-Mitigation significance $S = (E + D + R + M) \times P]$: $24 = (2 + 2 + 1 + 3) \times 3]$

[2] Post-Mitigation significance $S = (E + D + R + M) \times P]$: $12 = (2 + 1 + 1 + 2) \times 2]$

Table 24: Impact assessment on groundwater quality during construction phases of the Green Hydrogen and Ammonia Facility

Aspect affected	Activity	Phase	Pre-mitigation[1] Significance	Mitigation	Post mitigation[2] Significance
Groundwater quality	Soil clearing and construction of infrastructure	Construction	Low (16)	Management measures: • The design, construction and maintenance of all infrastructure must ensure that the quality of the groundwater that feeds sensitive receptors (groundwater abstractions and groundwater dependant terrestrial ecosystems) downstream from any infrastructure does not significantly change and the development does not act as a preferential pathway to groundwater flow. Action plans: • Contain spillage, excavate and dispose of soil if required. Utilisation of spill kits and/or excavation of affected soil with subsequent disposal at an accredited disposal site is crucial. • Uncontrolled discharges from the construction camp/s should not be permitted. • All vehicles must be properly maintained and serviced so that no oil leaks occur on site. • Diesel fuel storage tanks should be above ground on an impermeable concreted surface in a bunded area in accordance to SANS 10131: Above-ground storage tanks for petroleum products.	Very low (12)

[1] Pre-Mitigation significance $S = (E + D + R + M) \times P]$: $16 = (2 + 2 + 1 + 3) \times 2]$

[2] Post-Mitigation significance $S = (E + D + R + M) \times P]$: $12 = (2 + 1 + 1 + 2) \times 2]$

6.1.2 Operational phase

Potential risks associated with the Green Hydrogen and Ammonia Facility during the operational phases include risks from a groundwater quality and quantity perspective. These risks are mainly associated with waste disposal and water sourcing activities.

A reliable source of water is needed to produce commercially usable green hydrogen and ammonia. Highly pure RO water is needed for hydrogen production and an environmental concern would be production, storage and disposal of the brine waste. The long-term availability and sustainability of water (both quantity and quality) is a critical issue for hydrogen production through water electrolysis. A variety of water sources are being investigated for the broader development, and include the following options:

A. Komati Power Station (technical preferred option): Bulk water infrastructure from the Usuthu Water Scheme currently feeding the surrounding coal mines and power stations (specifically Eskom Komati Power Station) may be utilised for construction and operational water. Initial water results indicate good quality supply in sufficient quantities is available. This option is the preferred water sourcing for the development due to excess water being available at the Power Station's water reservoirs.
   - Little or no impacts are associated with this option.

B. Groundwater: Various boreholes may be utilised across the project site for extraction of construction and operational water requirements. The volumes will be dependent on the available groundwater and the quality thereof, which has not yet been determined. Large quantities of water are needed for the project and one option is to utilise groundwater from a multitude of scattered boreholes or from wellfields designed for this purpose. A groundwater quantity impact is mainly associated with this option.
   - Over abstraction of groundwater can result in aquifer depletion and loss of resource for farmers that rely on groundwater as sole source of water for farming and domestic purposes.
   - If groundwater needs to be treated with RO, the remaining brine could result in groundwater pollution if not adequately contained.

C. Purified wastewater: Wastewater from nearby commercial or mining facilities could be sourced to provide the facility with water. This would depend on availability of suitable quality wastewater and agreements with the respective entities involved. It is possible that water may be sourced from existing surrounding mining operations that are experiencing or anticipating mine water decant from their operations. A groundwater quality impact is mainly associated with this option.
   - Water source is at this stage unknown but is expected to be sourced from coal mines in the area, which is typical of a poor quality being acidic with solubilised heavy metals and saline. Leakage or bursting pipes transporting this water or mine-water storage can result in groundwater contamination.

Ammonia spillages may also occur although these are expected to be accidental and mitigation measures will be developed and implemented, including amongst others suitable containment related to storage and emergency response measures.

Impact ratings associated with groundwater during the operational phase are displayed in tables 25 to 30.

Table 25: Impact assessment on groundwater quantity during operational phases of the Green Hydrogen and Ammonia Facility

Water sourced from Usuthu Water Scheme -

Aspect affected	Activity	Phase	Pre-mitigation[1] Significance	Mitigation	Post mitigation[2] Significance
Groundwater quantity	Water feed from Usuthu Water Scheme	Operational	Very low (4)	Excess water is available at the Komati Power Station. This option is preferred from a groundwater quantity perspective and little or no impact is expected from a quantity perspective.	Very low (4)

[1] Pre-Mitigation significance $S = (E + D + R + M) \times P]$: $4 = (1 + 1 + 1 + 1) \times 1]$

[2] Post-Mitigation significance $S = (E + D + R + M) \times P]$: $4 = (1 + 1 + 1 + 1) \times 1]$

Table 26: Impact assessment on groundwater quality during operational phases of the Green Hydrogen and Ammonia Facility

Water sourced from Usuthu Water Scheme -

Aspect affected	Activity	Phase	Pre-mitigation[1] Significance	Mitigation	Post mitigation[2] Significance
Groundwater quality	Water feed from Usuthu Water Scheme	Operational	Very low (4)	Excess water of good quality is available at the Komati Power Station. This option is preferred from a groundwater quality perspective and little or no impact is expected from a quality perspective	Very low (4)

[1] Pre-Mitigation significance $S = (E + D + R + M) \times P]$: $4 = (1 + 1 + 1 + 1) \times 1]$

[2] Post-Mitigation significance $S = (E + D + R + M) \times P]$: $4 = (1 + 1 + 1 + 1) \times 1]$

Table 27: Impact assessment on groundwater quantity during operational phases of the Green Hydrogen and Ammonia Facility Groundwater abstraction -

Aspect affected	Activity	Phase	Pre-mitigation[1] Significance	Mitigation	Post mitigation[2] Significance
Groundwater quantity	Groundwater abstraction for production purposes	Operational	Moderate (44)	Management measures: • The design, construction and maintenance of all infrastructure must ensure that the quantity of the groundwater that feeds sensitive receptors (groundwater abstractions and groundwater dependant terrestrial ecosystems) downstream from any infrastructure does not significantly change and the development does not act as a preferential pathway to groundwater flow. Action plans: • Identified boreholes should be subjected to pump tests overseen by a professional geohydrologist. • Boreholes should not be pumped more than its sustainable use allows as recommended by the geohydrologist.	Low (18)

[1] Pre-Mitigation significance $S = (E + D + R + M) \times P]$: $44 = (3 + 2 + 3 + 3) \times 4]$

[2] Post-Mitigation significance $S = (E + D + R + M) \times P]$: $18 = (2 + 1 + 1 + 2) \times 3]$

Table 28: Impact assessment on groundwater quality during operational phases of the Green Hydrogen and Ammonia Facility

Groundwater abstraction -

Aspect affected	Activity	Phase	Pre-mitigation[1] Significance	Mitigation	Post mitigation[2] Significance
Groundwater quality	Groundwater abstraction for production purposes	Operational	Low (16)	Management measures: • Prevent groundwater pollution from brine seepages or spillages. Action plans: • Contain brine in fit for use holding facilities and remove from site as frequently as possible.	Very low (12)

[1] Pre-Mitigation significance $S = (E + D + R + M) \times P]$: $16 = (2 + 2 + 1 + 3) \times 2]$

[2] Post-Mitigation significance $S = (E + D + R + M) \times P]$: $12 = (2 + 1 + 1 + 2) \times 2]$

Table 29: Impact assessment on groundwater quantity during operational phases of the Green Hydrogen and Ammonia Facility

Use of purified wastewater from mining -

Aspect affected	Activity	Phase	Pre-mitigation[1] Significance	Mitigation	Post mitigation[2] Significance
Groundwater quantity	Use of purified wastewater from nearby mining	Operational	Very low (4)	Management measures: • Reduce the impact on groundwater quantity Action plans: • No impact on local or regional groundwater quantity is foreseen and therefore no action plans related to groundwater quantity is applicable.	Very low (4)

[1] Pre-Mitigation significance $S = (E + D + R + M) \times P]$: $4 = (1 + 1 + 1 + 1) \times 1]$

[2] Post-Mitigation significance $S = (E + D + R + M) \times P]$: $4 = (1 + 1 + 1 + 1) \times 1]$

Table 30: Impact assessment on groundwater quality during operational phases of the Green Hydrogen and Ammonia Facility

Use of purified wastewater from mining -

Aspect affected	Activity	Phase	Pre-mitigation[1] Significance	Mitigation	Post mitigation[2] Significance
Groundwater quality	Use of purified wastewater from nearby mining	Operational	High (64)	Management measures: • The design, construction and maintenance of all infrastructure must ensure that the quality of the groundwater that feeds sensitive receptors (groundwater abstractions and groundwater dependant terrestrial ecosystems) downstream from any infrastructure does not significantly change and the development does not act as a preferential pathway to groundwater flow. • Contain brine in fit-for-purpose facilities and prevent seepage, spills and groundwater contamination. Action plans: • Pipes and tanks should be regularly inspected for leaks, leaks should be repaired upon detection. • All facilities constructed to contain brine should be constructed according to water balance so as not to allow overflow of the facilities. • Brine must be contained on the sites in facilities constructed for this specific purpose. • Brine facilities should be lined to limit seepage and a leak detection system must be installed. • A minimum freeboard of 0.8 meters be maintained for brine ponds facilities above the expected maximum water level. • Runoff water may not be discharged to a watercourse and/or the environment unless it complies with the quality requirements. • Liquid brine must not be discharged into the natural environment. • Where feasible or practical, liquid brine can be made into a solid through several available technologies such as, settlement tanks, cooling water circuits, and forced crystallization. • Dispose solid salt at a licenced fit for purpose hazardous waste facility or sell to third parties depending on its chemical make-up.	Low (18)

[1] Pre-Mitigation significance $S = (E + D + R + M) \times P]$: $64 = (3 + 4 + 5 + 4) \times 4]$

[2] Post-Mitigation significance $S = (E + D + R + M) \times P]$: $18 = (2 + 1 + 1 + 2) \times 3]$

6.1.3 Decommissioning phase

Oil spills and the risk of hydrocarbon pollution are regarded as the only risk on groundwater quality during this phase, but it is expected to be minor with no substantial risks on the regional groundwater quality. Spills are likely to be minor and quickly reversible if managed in an environmentally effective and safe manner.

No Groundwater quantity impacts are expected during the decommissioning of the Green Hydrogen and ammonia facility.

6.2 Cumulative impacts

There are numerous activities within or surrounding the area of interest that are or can potentially impact on ground- and surface water resources. These activities include Hendrina Renewable Energy Complex, Komati Power Station with ash dams and various other infrastructure and coal mines. Sulphate (SO_4) and other salts from the power station infrastructure, and acid mine drainage and subsequent salts (especially SO_4) and trace metal mineralisation from the coal mines, are typical contaminants of concern. However, no cumulative impacts are expected on the groundwater environment from the Green Hydrogen and Ammonia Facility during any of the phases discussed in this report.

7. GROUNDWATER MONITORING SYSTEM

7.1 Groundwater monitoring network

7.1.1 Source plume, impact and background monitoring

Prior to the design of any monitoring programme, the current understanding of the groundwater system must be understood in terms of i) flow dynamics and behaviour, ii) potential sources of groundwater and related surface water impacts; iii) receptors that may be affected by impacts to groundwater and surface water; and iv) the pathways that could potentially connect them. No risk exists if an impact source is not linked to a potential receptor.

A deterioration in groundwater quality is the most significant risk associated with the activity.

The source-pathway-receiver model provides a conceptual portrayal of the mode through which contaminants act and the potential harm they may inflict on a receiving water body and/or organism. The conceptual model is used to develop management action plans and reclamation alternatives that are directed towards mitigating potentially harmful effects caused by the contaminants of concern. Refer to the conceptual site model discussion under Section 8.6 for a more detailed discussion on interaction between potential sources of contamination and receptors that could be affected using the source – pathway – receptor methodology.

7.1.2 System response monitoring network

A Water Management Plan is required to ensure that the proposed Renewable Energy Complex does not impact negatively on groundwater levels and quality to unacceptable levels. It will also serve as early warning systems to implement mitigation measures at early stages to reduce cumulative impacts. To ensure that the groundwater environment is protected, monitoring of water quality and levels are required on an on-going basis.

Monitoring is required for the following purposes:

1. To detect the actual impact on groundwater quality timeously.
2. To assess whether the mitigation measures given in Section 6 are effective, supporting the update of mitigation measures where necessary.
3. Models can be updated and refined based on new information to support adaptive management measures. Model confidence levels can be increased, and groundwater impacts be predicted with more accuracy. With updated and high confidence predictions, the Developer can act in a pre-emptive manner, thus reducing risks, rather than acting retrospectively when monitoring data reveals a problem.
4. To interrogate unknowns identified in this report, in which various field investigations can be carried out to test and improve the conceptual hydrogeological understanding of the aquifer system.

Monitoring in general should follow the risk-based approach to define or characterise the risks that the operations and associated infrastructure may pose on the receiving environment.

Risk assessments involve the understanding of the generation of a hazard, the probability that the hazard will occur, and the consequences should it occur, i.e. understanding the complete cause and effect cycle. The most basic risk assessment methodology is based on defining and understanding the three basic components of the risk, i.e. the source of the risk (source term), the pathway along which the risk propagates, and finally the target that experiences the risk (receptor). The risk assessment approach is aimed at describing and defining the relationship between cause and effect.

The main objective in positioning monitoring boreholes is to intercept groundwater i) upgradient from the source (background); ii) at the source; iii) moving away/downgradient from the source; and iv) interception at selected intervals towards a final receptor.

7.2 Monitoring recommendations

No specific regular monitoring requirements can at this stage be recommended until a definite water source has been confirmed. Regardless, the baseline water quality and water levels as discussed in this report prior to development should provide a qualitative and quantitative baseline. Should any potential impact on a groundwater supply feature be suspected then an investigation should be launched, and appropriate remediation measure(s) must be identified by the developer if such impact is indeed proved to be significant.

8. CONCLUSION AND RECOMMENDATIONS

Shangoni AquiScience, a division of Shangoni Management Services (Pty) Ltd, was appointed by ENERTRAG to complete an assessment of the geohydrology at the proposed Hendrina Renewable Energy Complex, located near to the town of Hendrina in Mpumalanga. ENERTRAG intends to develop and commission a wind energy facility with associated grid infrastructure in the Hendrina area. This geohydrological assessment included a hydrocensus of groundwater users in the area with the aim of determining the potential for groundwater, as well as risk to nearby users.

A field visit was conducted between the 2nd and 26th of August 2021 during which baseline geohydrological information was gathered and water samples were submitted for analysis.

The hydrocensus revealed that the farmers make use of a large number of boreholes (wind pumps and submersible pumps) that they mainly used for livestock watering and domestic use. This, in terms of groundwater volumes are minimal. The yield of the area is estimated as 0.1 – 0.5 l/s, however larger yields can be obtained when intersecting large water bearing fractures.

The proposed area is suitable for groundwater exploration and development due to the Ecca Formation of the Karoo Supergroup being host to a large number of Karoo age dolerite intrusions. Although not prevalent on the 1:250 000 geological map, more in-detail surveys would be required to locate such intrusions. Should the drilling of boreholes be considered as option, it is recommended that geophysical surveys be undertaken prior to the identification of drill targets. If water is encountered, the boreholes must be pump tested to determine sustainable abstraction yields.

Groundwater quality in the area is classified as very good (average EC of 40 mS/m), as confirmed by the extensive hydrocensus and groundwater quality analysis. Some occasional outliers of especially nitrogen (as nitrate-nitrogen) were, however, recorded. No substantial cumulative impacts are expected and risks towards the groundwater environment are expected to be minimal to negligible.

No specific routine monitoring requirements can at this stage be recommended for the project until a water source has been confirmed. Regardless, the baseline water quality and water levels as discussed in this report prior to development should provide a qualitative and quantitative baseline. Should an impact on a groundwater supply feature be identified as significant then appropriate remediation measure(s) must be identified by developer.

Based on the findings of the geohydrological assessment, no fatal flaws have been identified that may limit the application. It is the opinion of the specialist that it may proceed on condition that all mitigation measures as outlined and discussed in this report are adhered to.

From a geohydrological perspective, and the three alternatives considered, there is no preference when considering geohydrological impacts.

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APPENDIX A

Laboratory Certificates

YANKA LABORATORIES

(Pty) Ltd.

Registration No. 2012/113891/07 VAT No. 4380263659

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Shangoni Management Services
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Job No: **E50514 - W21_3152**
Report Reference: **ER_SHA_2021-08-23_06766_001**
Enquiries: **Rita Botha**
Date: **2021/08/23**
RitaB@yanka.co.za
Job Reference: **W21/3152 - Advice Note 2108W289**

Job Description: **41 x Routine Analysis**

Project: **AS-CAB-ENE WATER SAMPLES**

TEST RESULTS FOR Shangoni AS-CAB-ENE Water - 19 August 2021

This report contains results pertaining only to the water/dust samples analysed.

For Standards referenced, and methods base, please see http://www.yanka.co.za/TestsAndStandards.htm

Please contact us if you have any queries concerning the information contained herein. Thank you for your support.

Electronically approved

ANALYSED WITHIN 19 August 2021 - 2021/08/23

RITA BOTHA (Technical Signatory)
ENVIRONMENTAL SERVICES

SANAS Certificate obtainable from the address below
http://www.yanka.co.za/Services.htm

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ANALYSTS

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YANKA LABORATORIES

CHEMISTRY TEST RESULTS

LABORATORY NUMBER			SpShangoni 1	SpShangoni 2	SpShangoni 3	SpShangoni 4	SpShangoni 5	SpShangoni 6	SpShangoni 7	SpShangoni 8	SpShangoni 9
SAMPLE DESCRIPTION			AP SW 01	AP SW 02	AP SW 03	AP BH 05	AP BH 06	AP SW 04	AP BH 08	AP BH 11	AP BH 12
SAMPLE NUMBER			E50514-001	E50514-002	E50514-003	E50514-004	E50514-005	E50514-006	E50514-007	E50514-008	E50514-009
SAMPLED		Test Method **	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00
Remarks			Clear	Clear	Clear	Clear	Rusty	Rusty	Rusty	Blackish	Clear
Total Alkalinity (pH>4.5)	mg $CaCO_3$/L	YE010Alk	72.8	156	119	50.4	123	20.4	68.0	136	127
Bicarbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	72.8	156	119	50.4	123	20.4	68.0	136	127
Carbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M Alkalinity (8.3>pH>4.5)	mg $CaCO_3$/L	YE010Alk	72.8	156	119	50.4	123	20.4	68.0	136	127
P Alkalinity (pH>8.3)	mg $CaCO_3$/L	YE010Alk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Conductivity (Laboratory)	mS/m	YE020CON	37.7	53.0	33.4	39.9	26.4	26.6	15.8	29.8	29.1
pH (Laboratory)		YE030pH	6.49	6.80	7.43	7.13	6.96	6.85	6.95	6.84	7.02
Total Hardness	mg $CaCO_3$/L	YE061H	56.0	157	110	101	90.5	55.3	44.7	110	85.8
Calcium Hardness	mg $CaCO_3$/L	YE061H	28.2	73.9	53.2	43.2	58.2	24.4	23.9	67.8	42.2
Magnesium Hardness	mg $CaCO_3$/L	YE061H	27.8	82.8	56.4	57.7	32.4	30.9	20.9	42.1	43.6
Total Dissolved Solids (TDS)	mg/L	Calculation	178	271	164	201	132	134	73.0	147	144
Temperature	°C	Thermometer	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
Ammonia and Ammonium	mg N/L	YE070AK	8.61	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45
Calcium	mg Ca/L	YE060ICP	11.3	29.6	21.3	17.3	23.3	9.77	9.56	27.2	16.9
Chloride	mg Cl/L	YE070AK	32.9	39.9	15.4	32.6	3.86	16.9	2.98	7.28	8.45
Magnesium	mg Mg/L	YE060ICP	6.75	20.1	13.7	14.0	7.86	7.51	5.07	10.2	10.6
Nitrate and Nitrite (TON)	mg N/L	YE070AK	0.46	<0.35	<0.35	<0.35	0.62	<0.35	<0.35	<0.35	0.70
Ortho Phosphate	mg P/L	YE070AK	0.86	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Potassium	mg K/L	YE060ICP	27.5	4.87	6.84	7.71	2.93	8.24	3.57	3.31	2.68
Sodium	mg Na/L	YE060ICP	6.68	38.0	16.1	24.5	14.6	16.8	8.86	13.2	23.1
Silicon	mg Si/L	YE060ICP	4.47	0.97	<0.1	4.81	10.4	1.72	18.3	14.5	10.9
Sulphate	mg SO_4/L	YE070AK	26.0	44.8	19.0	74.4	2.77	60.8	1.45	3.73	2.51
Total Aluminium	mg Al/L	YE060ICP									
Aluminium	mg Al/L	YE060ICP	1.51	<0.01	<0.01	<0.01	<0.01	0.31	<0.01	<0.01	<0.01
Fluoride	mg F/L	YE070AK	1.17	0.34	0.75	<0.09	<0.09	0.70	<0.09	<0.09	0.30
Total Iron	mg Fe/L	YE060ICP									
Iron	mg Fe/L	YE060ICP	3.34	0.01	<0.01	0.01	0.12	0.51	0.66	0.01	<0.01
Manganese	mg Mn/L	YE060ICP	1.20	<0.01	<0.01	<0.01	0.13	<0.01	<0.01	<0.01	<0.01
Langelier Index (indicative, not SANS)		Calculation	-2.09	-1.05	-0.66	-1.43	-1.07	-2.32	-1.69	-1.08	-1.14
pHs (indicative, not SANS)		Calculation	8.58	7.85	8.09	8.56	8.03	9.17	8.64	7.92	8.16
Sodium Absorption Ratio (indicative)		Calculation	0.39	1.32	0.67	1.06	0.67	0.98	0.57	0.55	1.08
TDS to EC Ratio (indicative, not SANS)		Calculation	4.72	5.12	4.92	5.03	5.00	5.03	4.62	4.92	4.94
Corrosion Ratio (indicative, not SANS)		Calculation	1.46	0.87	0.45	2.59	0.10	3.89	0.13	0.17	0.20
Ryznar Index (indicative, not SANS)		Calculation	10.67	8.91	8.75	9.98	9.09	11.49	10.33	9.00	9.29
Anion Sum			3.11	5.21	3.26	3.49	2.67	2.19	1.48	3.01	2.90
Cation Sum			3.13	4.93	3.08	3.30	2.54	2.12	1.41	2.87	2.80
Difference			0.02	-0.28	-0.17	-0.19	-0.13	-0.08	-0.06	-0.14	-0.10
% Difference			0.24%	-2.75%	-2.73%	-2.86%	-2.52%	-1.77%	-2.17%	-2.31%	-1.75%

Methods adapted to accommodate local laboratory conditions. SM refers to the Standard Methods for the Examination of Water and Wastewater.

Unless analysis is indicated as "Total", tests are performed on filtered samples as per ISO 11885.

Ion balance is not used as QC check where pH<3.5.

**** Methods Starting with YE are accredited, and based on ISO, SANS, and/or other national or international standards,**

YANKA LABORATORIES

CHEMISTRY TEST RESULTS

LABORATORY NUMBER			SpShangoni 10	SpShangoni 11	SpShangoni 12	SpShangoni 13	SpShangoni 14	SpShangoni 15	SpShangoni 16	SpShangoni 17	SpShangoni 18
SAMPLE DESCRIPTION			AP BH 13	AP WELL 01	AP BH 14	AP BH 15	AP SW 06	AP BH 16	AP SW 07	AP SW 08	AP BH 17
SAMPLE NUMBER			E50514-010	E50514-011	E50514-012	E50514-013	E50514-014	E50514-015	E50514-016	E50514-017	E50514-018
SAMPLED		Test Method **	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00
Remarks			Clear	Black	Clear	Clear	Clear	Clear	Rusty	Rusty	Clear
Total Alkalinity (pH>4.5)	mg $CaCO_3$/L	YE010Alk	17.4	16.0	19.6	46.0	124	109	68.6	61.0	149
Bicarbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	17.4	16.0	19.6	46.0	124	109	68.6	61.0	149
Carbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M Alkalinity (8.3>pH>4.5)	mg $CaCO_3$/L	YE010Alk	17.4	16.0	19.6	46.0	124	109	68.6	61.0	149
P Alkalinity (pH>8.3)	mg $CaCO_3$/L	YE010Alk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Conductivity (Laboratory)	mS/m	YE020CON	13.2	14.2	6.67	21.3	35.6	24.1	42.2	28.8	53.8
pH (Laboratory)		YE030pH	6.59	6.43	6.54	6.87	6.80	6.91	6.81	6.89	6.66
Total Hardness	mg $CaCO_3$/L	YE061H	30.3	31.4	16.9	61.8	130	80.4	84.2	71.5	184
Calcium Hardness	mg $CaCO_3$/L	YE061H	13.5	14.4	12.7	30.0	58.7	50.7	40.0	33.0	127
Magnesium Hardness	mg $CaCO_3$/L	YE061H	16.9	17.0	4.24	31.8	71.7	29.7	44.3	38.5	57.7
Total Dissolved Solids (TDS)	mg/L	Calculation	63.7	67.3	34.8	101	170	113	214	136	271
Temperature	°C	Thermometer	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
Ammonia and Ammonium	mg N/L	YE070AK	<0.45	<0.45	<0.45	0.47	0.65	<0.45	<0.45	0.56	<0.45
Calcium	mg Ca/L	YE060ICP	5.39	5.76	5.08	12.0	23.5	20.3	16.0	13.2	50.8
Chloride	mg Cl/L	YE070AK	7.64	7.98	1.26	7.47	31.3	4.10	44.5	33.2	47.1
Magnesium	mg Mg/L	YE060ICP	4.10	4.14	1.03	7.72	17.4	7.21	10.8	9.36	14.0
Nitrate and Nitrite (TON)	mg N/L	YE070AK	5.67	6.47	1.03	7.50	<0.35	<0.35	<0.35	<0.35	4.77
Ortho Phosphate	mg P/L	YE070AK	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Potassium	mg K/L	YE060ICP	3.20	3.31	2.75	3.77	6.29	3.63	12.4	16.4	4.58
Sodium	mg Na/L	YE060ICP	6.45	6.75	3.94	7.45	11.3	11.2	36.4	11.2	23.8
Silicon	mg Si/L	YE060ICP	16.0	16.0	10.6	27.5	0.68	20.1	0.20	3.00	15.4
Sulphate	mg SO_4/L	YE070AK	1.34	1.14	4.21	1.15	4.16	1.48	51.4	12.6	19.7
Total Aluminium	mg Al/L	YE060ICP									
Aluminium	mg Al/L	YE060ICP	0.02	<0.01	0.15	<0.01	<0.01	<0.01	0.19	0.10	<0.01
Fluoride	mg F/L	YE070AK	<0.09	<0.09	<0.09	<0.09	0.65	<0.09	1.15	2.12	<0.09
Total Iron	mg Fe/L	YE060ICP									
Iron	mg Fe/L	YE060ICP	<0.01	<0.01	0.06	<0.01	0.05	0.09	0.28	0.48	<0.01
Manganese	mg Mn/L	YE060ICP	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01
Langelier Index (indicative, not SANS)		Calculation	-2.88	-3.04	-2.87	-1.85	-1.23	-1.22	-1.65	-1.68	-0.98
pHs (indicative, not SANS)		Calculation	9.47	9.47	9.41	8.72	8.03	8.13	8.46	8.57	7.64
Sodium Absorption Ratio (indicative)		Calculation	0.51	0.52	0.42	0.41	0.43	0.54	1.72	0.57	0.76
TDS to EC Ratio (indicative, not SANS)		Calculation	4.83	4.74	5.22	4.74	4.77	4.71	5.08	4.72	5.03
Corrosion Ratio (indicative, not SANS)		Calculation	1.28	1.44	0.29	0.47	0.73	0.11	2.22	1.64	0.96
Ryznar Index (indicative, not SANS)		Calculation	12.34	12.52	12.29	10.58	9.26	9.35	10.11	10.26	8.61
Anion Sum			1.00	1.03	0.59	1.69	3.50	2.33	3.77	2.54	5.08
Cation Sum			0.98	1.01	0.60	1.70	3.33	2.20	3.63	2.42	4.86
Difference			-0.02	-0.02	0.01	0.00	-0.17	-0.13	-0.14	-0.12	-0.22
% Difference			-1.20%	-1.11%	1.03%	0.12%	-2.47%	-2.79%	-1.92%	-2.38%	-2.19%

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YANKA LABORATORIES

CHEMISTRY TEST RESULTS

LABORATORY NUMBER			SpShangoni 19	SpShangoni 20	SpShangoni 21	SpShangoni 22	SpShangoni 23	SpShangoni 24	SpShangoni 25	SpShangoni 26	SpShangoni 27
SAMPLE DESCRIPTION			AP BH 18	AP SW 09	ESKOM SW 01	WDK BH 02	WDK BH 03	WDK BH 04	WDK SW 01	WDK SW 02	TB FO 01
SAMPLE NUMBER			E50514-019	E50514-020	E50514-021	E50514-022	E50514-023	E50514-024	E50514-025	E50514-026	E50514-027
SAMPLED		Test Method **	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00
Remarks			Clear	Clear	Clear	Clear	Clear	Rusty	Clear	Clear	Clear
Total Alkalinity (pH>4.5)	mg $CaCO_3$/L	YE010Alk	56.6	18.2	43.0	143	123	122	178	66.0	86.4
Bicarbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	56.6	18.2	43.0	143	123	122	110	66.0	86.4
Carbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	0.00	0.00	0.00	0.00	0.00	0.00	67.6	0.00	0.00
M Alkalinity (8.3>pH>4.5)	mg $CaCO_3$/L	YE010Alk	56.6	18.2	43.0	143	123	122	144	66.0	86.4
P Alkalinity (pH>8.3)	mg $CaCO_3$/L	YE010Alk	0.00	0.00	0.00	0.00	0.00	0.00	33.8	0.00	0.00
Conductivity (Laboratory)	mS/m	YE020CON	75.1	19.2	46.2	31.7	29.9	35.0	50.0	29.3	31.9
pH (Laboratory)		YE030pH	6.77	6.80	7.62	7.42	7.31	7.36	8.44	7.57	7.36
Total Hardness	mg $CaCO_3$/L	YE061H	164	45.6	128	110	104	121	199	83.4	99.9
Calcium Hardness	mg $CaCO_3$/L	YE061H	86.1	20.4	64.7	62.9	50.4	62.7	57.7	38.2	53.9
Magnesium Hardness	mg $CaCO_3$/L	YE061H	77.8	25.2	63.0	46.6	53.1	58.1	141	45.2	46.0
Total Dissolved Solids (TDS)	mg/L	Calculation	380	97.4	247	158	148	171	260	145	171
Temperature	°C	Thermometer	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
Ammonia and Ammonium	mg N/L	YE070AK	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45
Calcium	mg Ca/L	YE060ICP	34.5	8.16	25.9	25.2	20.2	25.1	23.1	15.3	21.6
Chloride	mg Cl/L	YE070AK	155	17.8	28.1	8.98	7.13	16.4	30.3	23.7	22.2
Magnesium	mg Mg/L	YE060ICP	18.9	6.12	15.3	11.3	12.9	14.1	34.2	11.0	11.2
Nitrate and Nitrite (TON)	mg N/L	YE070AK	13.1	<0.35	<0.35	<0.35	2.95	1.90	1.11	<0.35	7.86
Ortho Phosphate	mg P/L	YE070AK	0.22	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.07
Potassium	mg K/L	YE060ICP	8.99	6.16	4.10	10.4	4.78	3.35	3.89	8.22	5.02
Sodium	mg Na/L	YE060ICP	64.8	11.8	29.8	13.6	13.0	16.2	21.1	14.8	17.6
Silicon	mg Si/L	YE060ICP	22.0	0.75	5.21	25.1	20.5	19.8	4.61	0.32	21.3
Sulphate	mg SO_4/L	YE070AK	4.96	35.8	118	3.16	2.54	14.6	35.3	30.8	6.47
Total Aluminium	mg Al/L	YE060ICP									
Aluminium	mg Al/L	YE060ICP	<0.01	0.04	<0.01	<0.01	<0.01	<0.01	0.08	0.29	<0.01
Fluoride	mg F/L	YE070AK	<0.09	0.45	0.21	<0.09	<0.09	<0.09	0.21	0.68	<0.09
Total Iron	mg Fe/L	YE060ICP									
Iron	mg Fe/L	YE060ICP	<0.01	0.10	<0.01	<0.01	0.30	<0.01	0.06	0.19	<0.01
Manganese	mg Mn/L	YE060ICP	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Langelier Index (indicative, not SANS)		Calculation	-1.46	-2.48	-0.84	-0.52	-0.78	-0.65	0.54	-0.91	-0.86
pHs (indicative, not SANS)		Calculation	8.23	9.28	8.46	7.94	8.09	8.01	7.90	8.48	8.22
Sodium Absorption Ratio (indicative)		Calculation	2.19	0.76	1.14	0.56	0.55	0.64	0.65	0.70	0.76
TDS to EC Ratio (indicative, not SANS)		Calculation	5.06	5.07	5.35	5.00	4.94	4.90	5.20	4.93	5.36
Corrosion Ratio (indicative, not SANS)		Calculation	7.77	3.78	3.27	0.19	0.17	0.44	0.58	1.26	0.76
Ryznar Index (indicative, not SANS)		Calculation	9.70	11.77	9.29	8.45	8.88	8.66	7.36	9.39	9.08
Anion Sum			6.62	1.64	4.13	3.18	2.93	3.35	5.25	2.67	3.07
Cation Sum			6.35	1.60	3.97	3.06	2.79	3.22	5.03	2.58	2.90
Difference			-0.27	-0.04	-0.16	-0.12	-0.14	-0.13	-0.22	-0.10	-0.16
% Difference			-2.11%	-1.34%	-1.99%	-1.94%	-2.42%	-1.95%	-2.11%	-1.86%	-2.69%

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YANKA LABORATORIES

CHEMISTRY TEST RESULTS

LABORATORY NUMBER			SpShangoni 28	SpShangoni 29	SpShangoni 30	SpShangoni 31	SpShangoni 32	SpShangoni 33	SpShangoni 34	SpShangoni 35	SpShangoni 36
SAMPLE DESCRIPTION			TB BH 01	TB BH 02	TB SW 01	TB SW 02	DVW BH 02	DVW BH 03	DVW BH 04	DVW SW 01	DVW SW 02
SAMPLE NUMBER			E50514-028	E50514-029	E50514-030	E50514-031	E50514-032	E50514-033	E50514-034	E50514-035	E50514-036
SAMPLED		Test Method **	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00
Remarks			Black	Clear	Brownish	Clear	Clear	Clear	Clear	Brownish	Clear
Total Alkalinity (pH>4.5)	mg $CaCO_3$/L	YE010Alk	206	88.4	168	240	141	70.4	141	142	106
Bicarbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	206	88.4	168	240	141	70.4	141	142	106
Carbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M Alkalinity (8.3>pH>4.5)	mg $CaCO_3$/L	YE010Alk	206	88.4	168	240	141	70.4	141	142	106
P Alkalinity (pH>8.3)	mg $CaCO_3$/L	YE010Alk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Conductivity (Laboratory)	mS/m	YE020CON	45.5	75.6	52.4	70.8	52.8	28.9	29.0	47.0	37.3
pH (Laboratory)		YE030pH	7.81	7.32	7.30	7.64	7.48	7.23	7.86	7.64	7.60
Total Hardness	mg $CaCO_3$/L	YE061H	70.6	197	140	208	92.4	92.7	84.6	128	104
Calcium Hardness	mg $CaCO_3$/L	YE061H	37.2	85.9	53.3	71.2	47.2	51.9	42.7	54.4	45.2
Magnesium Hardness	mg $CaCO_3$/L	YE061H	33.4	112	86.9	137	45.2	40.8	41.9	73.7	58.9
Total Dissolved Solids (TDS)	mg/L	Calculation	247	397	267	349	263	138	151	227	176
Temperature	°C	Thermometer	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
Ammonia and Ammonium	mg N/L	YE070AK	<0.45	<0.45	6.30	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45
Calcium	mg Ca/L	YE060ICP	14.9	34.4	21.3	28.5	18.9	20.8	17.1	21.8	18.1
Chloride	mg Cl/L	YE070AK	19.3	62.4	39.1	68.6	49.8	15.1	5.99	49.5	35.7
Magnesium	mg Mg/L	YE060ICP	8.12	27.1	21.1	33.3	11.0	9.90	10.2	17.9	14.3
Nitrate and Nitrite (TON)	mg N/L	YE070AK	<0.35	13.8	4.72	<0.35	<0.35	6.16	<0.35	<0.35	<0.35
Ortho Phosphate	mg P/L	YE070AK	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Potassium	mg K/L	YE060ICP	2.32	3.23	26.6	15.6	4.26	3.28	3.69	14.8	9.04
Sodium	mg Na/L	YE060ICP	71.5	59.4	17.3	48.8	61.1	9.68	26.0	29.0	22.0
Silicon	mg Si/L	YE060ICP	6.97	11.7	27.2	<0.1	7.56	11.2	10.7	0.42	<0.1
Sulphate	mg SO_4/L	YE070AK	5.97	96.5	11.1	8.97	31.9	9.80	3.01	7.23	11.8
Total Aluminium	mg Al/L	YE060ICP			14.5						
Aluminium	mg Al/L	YE060ICP	<0.01	<0.01	0.50	<0.01	<0.01	<0.01	<0.01	0.22	<0.01
Fluoride	mg F/L	YE070AK	0.81	0.21	0.27	1.01	0.21	<0.09	0.75	1.12	1.05
Total Iron	mg Fe/L	YE060ICP			6.39						
Iron	mg Fe/L	YE060ICP	0.55	<0.01	0.26	0.01	0.67	0.01	<0.01	0.28	<0.01
Manganese	mg Mn/L	YE060ICP	<0.01	<0.01	0.01	<0.01	0.16	<0.01	<0.01	<0.01	<0.01
Langelier Index (indicative, not SANS)		Calculation	-0.22	-0.73	-0.66	-0.06	-0.61	-1.09	-0.25	-0.38	-0.61
pHs (indicative, not SANS)		Calculation	8.03	8.05	7.96	7.70	8.09	8.32	8.11	8.02	8.21
Sodium Absorption Ratio (indicative)		Calculation	3.69	1.83	0.63	1.46	2.76	0.44	1.23	1.11	0.93
TDS to EC Ratio (indicative, not SANS)		Calculation	5.43	5.26	5.10	4.93	4.97	4.78	5.21	4.83	4.71
Corrosion Ratio (indicative, not SANS)		Calculation	0.28	2.56	0.69	0.83	1.11	0.68	0.13	1.01	1.01
Ryznar Index (indicative, not SANS)		Calculation	8.25	8.77	8.62	7.75	8.70	9.40	8.36	8.40	8.82
Anion Sum			4.84	6.56	5.06	7.00	4.92	2.48	3.09	4.46	3.44
Cation Sum			4.62	6.64	4.78	6.72	4.67	2.37	2.93	4.26	3.28
Difference			-0.22	0.09	-0.28	-0.28	-0.25	-0.11	-0.16	-0.20	-0.16
% Difference			-2.32%	0.65%	-2.84%	-2.02%	-2.63%	-2.33%	-2.62%	-2.32%	-2.32%

Methods adapted to accommodate local laboratory conditions. SM refers to the Stanc
Unless analysis is indicated as "Total", tests are performed on filtered samples as per
Ion balance is not used as QC check where pH<3.5.

**** Methods Starting with YE are accredited, and based on ISO, SANS, and/or otl**

YANKA LABORATORIES
CHEMISTRY TEST RESULTS

LABORATORY NUMBER			SpShangoni 37	SpShangoni 38	SpShangoni 39	SpShangoni 40	SpShangoni 41
SAMPLE DESCRIPTION			DVW BH 05	DVW BH 07	DVW BH 08	DVW BH 09	DVW BH 10
SAMPLE NUMBER			E50514-037	E50514-038	E50514-039	E50514-040	E50514-041
SAMPLED		Test Method **	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00	2021/08/02 00:00
Remarks			Clear	Clear	Clear	Clear	Clear
Total Alkalinity (pH>4.5)	mg $CaCO_3$/L	YE010Alk	170	31.0	19.2	80.8	90.4
Bicarbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	170	31.0	19.2	80.8	90.4
Carbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	0.00	0.00	0.00	0.00	0.00
M Alkalinity (8.3>pH>4.5)	mg $CaCO_3$/L	YE010Alk	170	31.0	19.2	80.8	90.4
P Alkalinity (pH>8.3)	mg $CaCO_3$/L	YE010Alk	0.00	0.00	0.00	0.00	0.00
Conductivity (Laboratory)	mS/m	YE020CON	41.2	55.5	41.3	25.4	21.4
pH (Laboratory)		YE030pH	7.75	7.15	6.91	7.01	7.26
Total Hardness	mg $CaCO_3$/L	YE061H	62.5	159	111	76.5	63.6
Calcium Hardness	mg $CaCO_3$/L	YE061H	32.2	77.7	49.7	44.9	31.7
Magnesium Hardness	mg $CaCO_3$/L	YE061H	30.3	81.1	61.8	31.6	31.9
Total Dissolved Solids (TDS)	mg/L	Calculation	204	283	198	126	106
Temperature	°C	Thermometer	21.0	21.0	21.0	21.0	21.0
Ammonia and Ammonium	mg N/L	YE070AK	<0.45	<0.45	<0.45	<0.45	<0.45
Calcium	mg Ca/L	YE060ICP	12.9	31.1	19.9	18.0	12.7
Chloride	mg Cl/L	YE070AK	15.8	66.3	70.7	9.96	10.4
Magnesium	mg Mg/L	YE060ICP	7.36	19.7	15.0	7.67	7.74
Nitrate and Nitrite (TON)	mg N/L	YE070AK	<0.35	24.2	12.4	4.96	<0.35
Ortho Phosphate	mg P/L	YE070AK	<0.03	0.28	<0.03	0.04	<0.03
Potassium	mg K/L	YE060ICP	2.66	6.47	5.69	5.25	2.76
Sodium	mg Na/L	YE060ICP	56.4	22.1	18.7	12.5	16.6
Silicon	mg Si/L	YE060ICP	8.46	18.9	13.0	19.5	18.5
Sulphate	mg SO_4/L	YE070AK	5.95	10.7	2.04	2.30	1.37
Total Aluminium	mg Al/L	YE060ICP					
Aluminium	mg Al/L	YE060ICP	0.02	<0.01	<0.01	<0.01	<0.01
Fluoride	mg F/L	YE070AK	0.70	<0.09	<0.09	<0.09	<0.09
Total Iron	mg Fe/L	YE060ICP					
Iron	mg Fe/L	YE060ICP	0.13	<0.01	<0.01	<0.01	<0.01
Manganese	mg Mn/L	YE060ICP	<0.01	<0.01	<0.01	<0.01	<0.01
Langelier Index (indicative, not SANS)		Calculation	-0.41	-1.37	-2.00	-1.31	-1.15
pHs (indicative, not SANS)		Calculation	8.16	8.52	8.91	8.32	8.41
Sodium Absorption Ratio (indicative)		Calculation	3.09	0.76	0.77	0.62	0.90
TDS to EC Ratio (indicative, not SANS)		Calculation	4.96	5.10	4.81	4.97	4.94
Corrosion Ratio (indicative, not SANS)		Calculation	0.28	6.21	10.44	0.36	0.33
Ryznar Index (indicative, not SANS)		Calculation	8.58	9.90	10.90	9.62	9.56
Anion Sum			4.02	4.49	3.33	2.31	2.13
Cation Sum			3.79	4.32	3.20	2.22	2.07
Difference			-0.23	-0.17	-0.13	-0.09	-0.06
% Difference			-2.98%	-1.89%	-1.97%	-1.98%	-1.45%

Methods adapted to accommodate local laboratory conditions. SM refers to the Stanc

Unless analysis is indicated as "Total", tests are performed on filtered samples as per

Ion balance is not used as QC check where pH<3.5.

**** Methods Starting with YE are accredited, and based on ISO, SANS, and/or otl**

APPENDIX B

CV of Specialist

SHANGONI Management Services (Pty) Ltd

Stewards | Problem Solvers | Team Players

Celebrating more than 20 years of providing a sustainable and exemplary service that influences decisions affecting the environment

Block C8, Block@Nature, 472 Botterklapper Str, The Willows, 0081

Tel +27 (12) 807-7036 | www.shangoni.co.za | info@shangoni.co.za

Curriculum Vitae for Ockie Scholtz

Overview and Profile

Ockie is a qualified geohydrologist (M.Sc) with 17 years' experience in mining and non-mining related water resource management and contaminated land investigations. He also holds a MSc (cum laude) degree in Botany during which, in collaboration with the Department of Geology of the University of the Free State, valuable insights and experience regarding the disciplines of geochemistry, pollution and contaminated land investigations were gained.

He is currently employed as the Principal Hydrogeologist and Head of Shangoni AquiScience, a division of Shangoni Management Services. This role allows him to be actively involved in all aspects of hydrogeological and contaminated land investigations within the mining, industrial and farming sectors. His areas of expertise range from operational and closure ground- and surface water impact assessments, numerical flow and groundwater contaminant transport modelling, geophysical investigations and borehole siting, drilling supervision, aquifer testing, geochemical characterisation of mine waste and classification (mining and non-mining), contaminated land investigations and auditing of mining related environmental performances and water use licences.

During his professional career, Ockie has gained extensive industry experience regarding hydrogeology, geochemistry and aquatic sciences, which have resulted in the development of a good understanding regarding the fundamentals of hydrogeology, contaminated land and water resource management.

Education and Skills

M.Sc. Geohydrology – University of the Free State	2011
M.Sc. Botany (Cum Laude) – University of the Free State	2006
B.Sc. Hons. Botany – University of the Free State	2004
B.Sc. Zoology – University of the Free State	2003

Professional Affiliations

Registered as Professional Natural Scientist with the South African Council for Natural Scientific Professions (SACNASP) in the fields of Water Resources Science, Botanical Science and Ecological Science.

Work and Project Experience

Company: **Shangoni Management Services**

Position: Principal Environmental Consultant (Geohydrology)

Years with company: 11 Years

Experience in field: 17 Years

Key responsibilities:

Consulting services in all aspects of geohydrology are provided to mining and non-mining clients. Services include:

- 2- and 3-dimensional numerical modelling for groundwater flow and mass transport, hydrogeological risk and impacts assessments forming part of EMPR investigations, geophysical investigations for monitoring and water supply, management plans and monitoring of surface and groundwater.
- contaminated land (soil, water, plants) and geochemical investigations including classification and characterisation of all mining and non-mining related wastes as per the relevant South African regulations.

Clients:

- Coal mining sector:
  - Anglo Coal (Landau Colliery, Goedehoop Colliery, Kromdraai Colliery, Leslie Colliery, Greenside Colliery, Kleinkopje Colliery, Tumelo Colliery, Navigation Colliery, Goedehoop Colliery, New Vaal Colliery)
  - Ngululu Resources
  - Canyon Coal
  - Glencore
  - Kibo Mining (Tanzania)
  - African Exploration Mining and Finance Corporation (Vlakfontein Colliery)
  - African Rainbow Minerals
  - Black Minerals Resources
  - Thungela Resources Limited

- Gold mining sector:
  - Pan African Resources, Evander Gold Mine, Kusasalethu Mine
  - Pamodzi Mine

- Platinum mining sector:
  - Mototolo Platinum Mine
  - Pilanesberg Platinum Mine (PPM)

- Manganese mining sector:
  - Kudumane Manganese Resources
  - South32 Metalloys

- Chrome mining sector:
  - Bushveld Chrome Resources

- Diamond mining sector:
  - Petra Diamond Group (Cullinan Mine, Koffiefontein Mine, Helam Mine, Sedibeng Mine, Williamson Mine)
  - De Beers Group (Kimberly Diamond Mine, Venetia Mine, Orapa Diamond Mine)
  - DMI Minerals
  - Ekapa Group

- Iron Ore Mines:
  - Thabazimbi Iron Ore
  - Sishen Iron Ore
  - Aquilla Iron Ore

- Andalusite mining sector:
  - Imerys Annesley Mine, Havercroft Mine, Rhino Andalusite

- Chrome mining sector:
  - Samancor Chrome

- Lime mining sector:
  - PPC
  - AfriSam

- Non-mining clients:
  - Enertrag (Renewables)
  - Vuka Africa Holdings (civil engineers)
  - Globeleq (Vivo and Boshoff solar farms)
  - Afgri Poultry (Daybreak Farms)
  - Chubby Chick
  - Rainbow Chickens
  - Ukupha Chickens
  - Era Bricks

- RMB Private Bank
- Brazen Algar
- PRASA
- Eskom
- Pioneer Industrial Park
- Oilkol
- PE Chemicals
- Dense Media Separation (DMS)
- University of Pretoria
- NWK Liquid Fertiliser

Declaration of Content

I, the undersigned, certify that this CV correctly describe my qualifications and my professional work experience.

Ockie Scholtz

EAPASA: 2020/100

Pr.Sci.Nat: 400220/09

Date: 03 March 2023