MVW Geohydrologist
Independent Consulting and
Geohydrological Expertise

GEOHYDROLOGICAL ASSESSMENT

GEOHYDROLOGICAL INVESTIGATION AND HYDRO-CENSUS FOR OUTSPAN 1960, BLOEMFONTEIN DISTRICT, FREE STATE

NOVEMBER 2019

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Declaration

I, Morné van Wyk, appointed by OVK Bedryf (Edms.) Bpk., act as an independent professional and have the necessary Geohydrological expertise to conduct such assessments. I declare that there are no circumstances that may compromise my objectivity, results or findings in preforming geohydrological assessments and that all information in this assessment is correct.

I state that I have no vested interest in this project other than remuneration for geohydrological work performed.

Abbreviations:

MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
mbgl	Meters below ground level
SWL	Static Water Level
WR	Water Resources

Table of Contents

1. Introduction

A geohydrological assessment was required for the development of the following:

- an agricultural related sales area with a maximum footprint of 1 000 m2,
- an agricultural related storage area with a maximum footprint of 2 000 m2,
- a workshop with a maximum footprint of 500 m2,
- an outside exhibition area with a maximum footprint of 200 m2,
- offices with a maximum footprint of 2 000 m2,
- a public garage, including a convenience store with a maximum footprint of 200 m2.

It is planned that the public garage will store approximately 120 000 L of dangerous goods in the form of 40 000 L (2×40 000 L tanks) of diesel and 40 000 L of petrol. These tanks will be located underground. It is planned that the garage will operate from 6am to 6pm initially. In future, the applicant would like the garage to be open 24 hours a day.

Due to the storage of petrochemical substances underground a geohydrological study was required to determine the potential impacts the proposed development of a garage would have on the current groundwater system.

The assessment includes gathering information through previous work done in the area and a desktop study as well as gathering information on groundwater resources through a comprehensive hydro census of the surrounding area.

A recommendation will be made concerning the protection of the groundwater resource and any mitigation if it is required.

2. Geographical Setting

2.1. Topography and Drainage

The regional topography indicates that the study area is situated in the lowest lying area which all slopes towards the North-West. All the directions show a gentle slope of between 1 – 1.5 m/ 100 m (Figure 1).

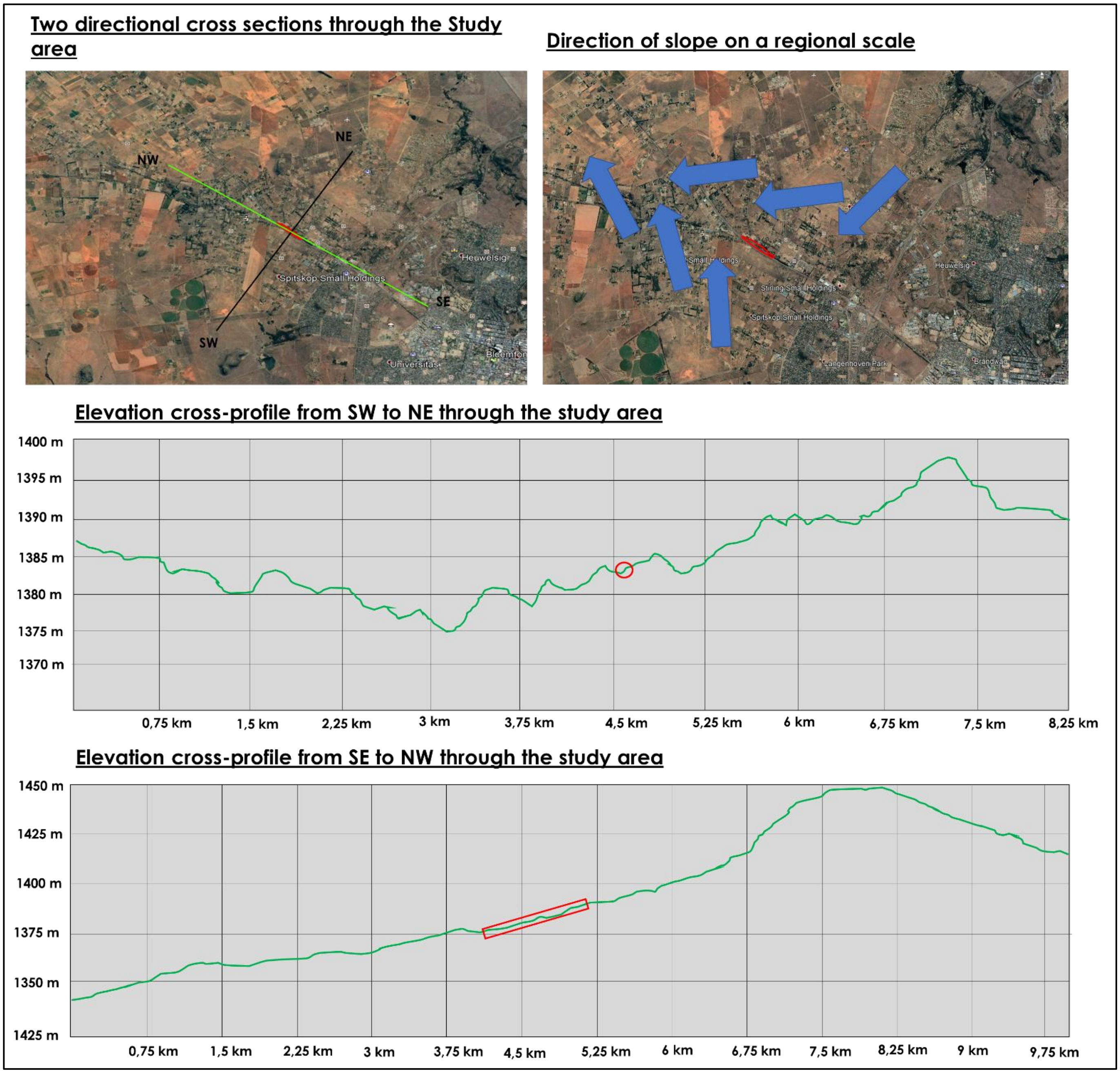


Figure 1:Topography and drainage for the area surrounding the study area.

The slope on site is very gentle around 1,2 m/100 m with the same flow direction as that of the regional topography (Figure 2). The study area is situated adjacent the raised R64 Highway which will channel the surface runoff towards the site (light blue arrows).

Figure 2: Blue arrows indicating general drainage direction. Light blue arrows indicate present flow direction on-site.

2.2. Climate

According to the Köppen-Geiger Climate Classification (Figure 3), the whole of Bloemfontein, including the study area falls within the "Arid, Steppe, Cold (BSk)" defining the region as a semi-arid cold climate.

Cold semi-arid climates (type "BSk") tend to be located in elevated portions of temperate zones, typically bordering a humid continental climate or a Mediterranean climate. They are typically found in continental interiors some distance from large bodies of water. Cold semi-arid climates usually feature warm to hot dry summers, though their summers are typically not quite as hot as those of hot semi-arid climates. Unlike hot semi-arid climates, areas with cold semi-arid climates tend to have cold winters. These areas usually see some snowfall during the winter, though snowfall is much lower than at locations at similar latitudes with more humid climates. Areas featuring cold semi-arid climates tend to have higher elevations than areas with hot semi-arid climates and tend to feature major temperature swings between day and night, sometimes by as much as 20 °C or more in that time frame. These large diurnal temperature variations are seldom seen in hot semi-arid climates. Cold semi-arid climates at higher latitudes tend to have dry winters and wetter summers, while cold semi-arid climates at lower latitudes tend to have precipitation patterns more akin to subtropical climates, with dry summers, relatively wet winters, and even wetter springs and autumns (Peel, M. C, 2007).

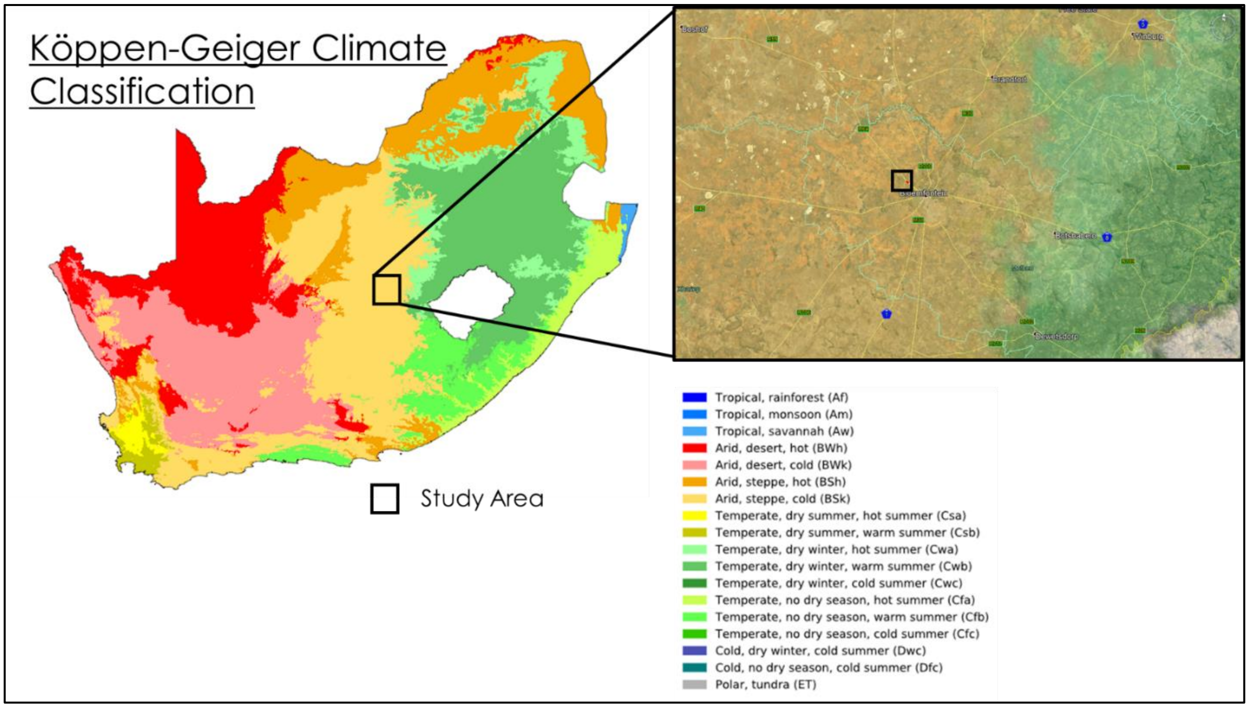


Figure 3: Koppen-Geiger Climate Classification for the study area

Statistical data of rainfall for South Africa (Figure 4), indicate that the study area's Mean Annual Precipitation ("**MAP**") of around 400 mm/a of rain.

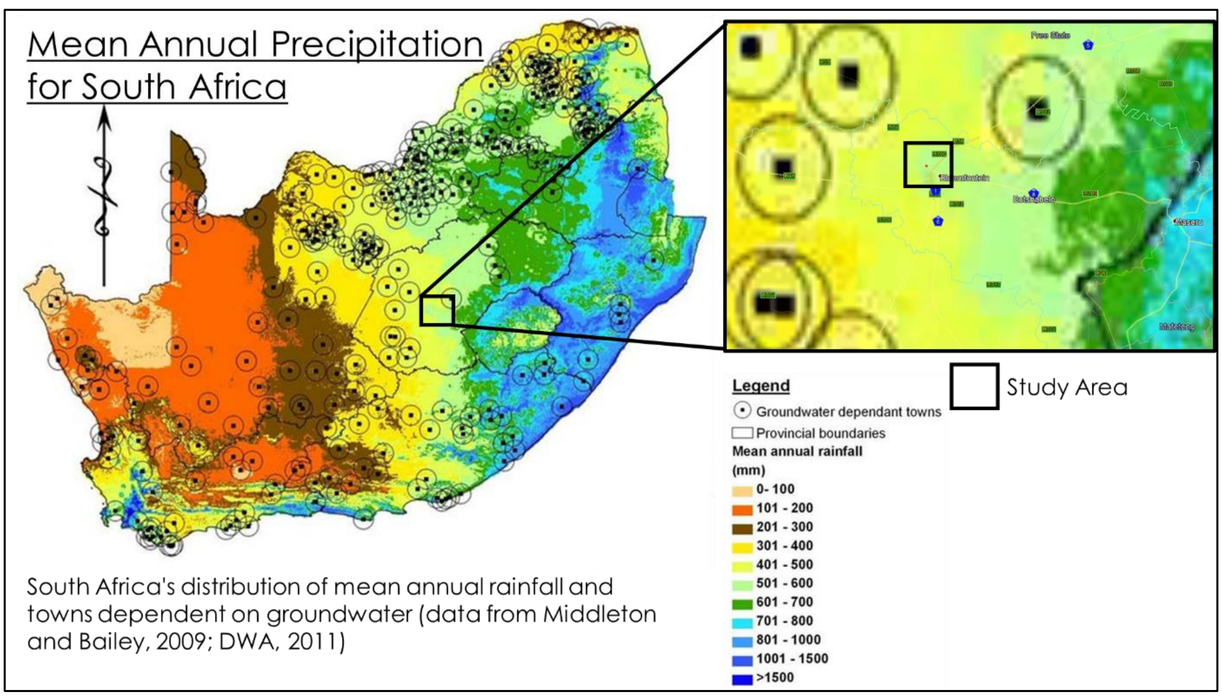


Figure 4: Mean Annual Rainfall for South Africa (K. Robey, 2014)

According to the maps compiled by the Water Resources ("**WR**") of South Africa 2005, the Mean Annual Evaporation A-pan ("**MAE**") (Figure 5) for the study area is around 2200 – 2600 mm/a. The WR also indicates that the Mean Annual Runoff ("**MAR**") for the study area is between 10 -20 mm/a.

In conclusion the study area is a semi-arid, cold region were the MAE exceeds the MAP and 10 -20 mm of rainfall calculates to MAR.

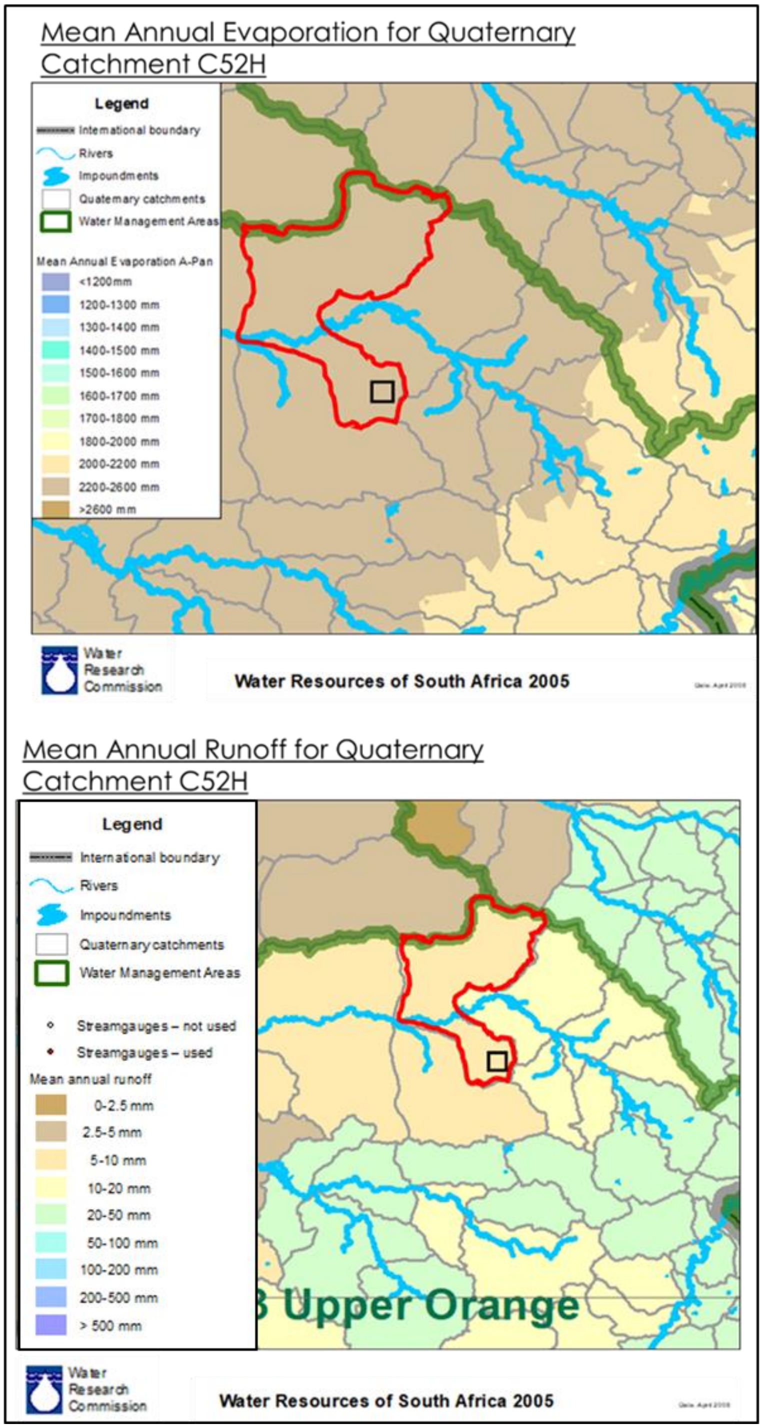


Figure 5:Mean Annual Evaporation and - Runoff for the study area

3. Scope of Work

The development proposes to erect a filling station on Outspan 1960. This requires a geohydrological assessment to be conducted before the construction process begins.

The geohydrological work included the following:

- Desktop Study
- Siting and drilling of a monitoring borehole downstream from the proposed filling station.
- A hydro-census including the adjacent landowners and further downstream of the site.
- Identifying monitoring boreholes during the hydro-census to sample regularly during the operational phase.
- Taking samples of the identified monitoring boreholes to establish a base line environment (1 upstream, 1 on-site and 2 downstream).
- Geohydrological analysis of the groundwater conditions on site.
- Formulation of the expected impacts the development will have on the environment.

4. Methodology

4.1. Desk Study

The desktop study included gathering information on the site and surrounding area. The applicant provided detailed layout plans on the proposed site and from these an on-site, downstream, monitoring borehole location was selected.

From water-, topographical- and geological maps it was determine that the flow of groundwater for the study area should be in a North-West direction. It was also determined that the aquifer itself is most probably deep-seated in nature (+50 m) and that the aquifer should be located on the contact between the host rock and dolerite intrusions (sills).

Adjacent and downstream landowners were contacted, and information was gathered on their boreholes and the possibility of monitoring these boreholes.

4.2. Hydro-Census

The following data was collected during the hydro-census surrounding the proposed site:

Table 1: Data collected during the hydro census

OVK Outspan Hydro Census							
	Coordinates						
BH Name	**E**	**S**	**Casing Height**	**Water Level**	**Depth**	**Pump Y/N**	**Comments**
BH 1	29.06857	26.14051	0 cm	33.06	Unknown	Y	SWL 30 years ago 20 m
BH 2	29.06871	26.14072	5 cm	34.18	70 m	Y	
BH 3	29.06883	26.14145	5 cm	35.8	Unknown	Y	Used for cattle and drinking water
BH 4	29.06915	26.14274	10 cm	Collapsed	Unknow	N	Rock thrown down hole
BH 5	29.07002	26.14287	0 cm	31.34	115 m	Y	Relatively strong
BH 6	29.06982	26.14378	20 cm	31.91	70 m	N	
BH 7 Downstream	29.06982	26.13669	- 30 cm	27.68	90 m	Y	Relatively strong
BH 8 Downstream	29.06557	26.13656	- 100 cm	27.46	80 m	Y	Relatively strong

BH Upstream	29.07309	26.14465	To be determined	35.38 (6 days after drilling)	90 m	N	Blow yield 3000 L/hr
BH On-Site	29.06982	26.14154	To be determined	40.45 (6 days after drilling)	61 m	N	Infiltrating water – not aquifer.

The information gathered on and around the site lead to the following conclusion. The aquifer of exploitable water is deep-seated between 90 – 110 meters below ground level ("**mbgl**"). All the boreholes examined in the area shows a static water level ("**SWL**") of between 30 and 24 mbgl and is a combination of hydrostatic pressure from below and infiltration water from the surface (Figure 6).

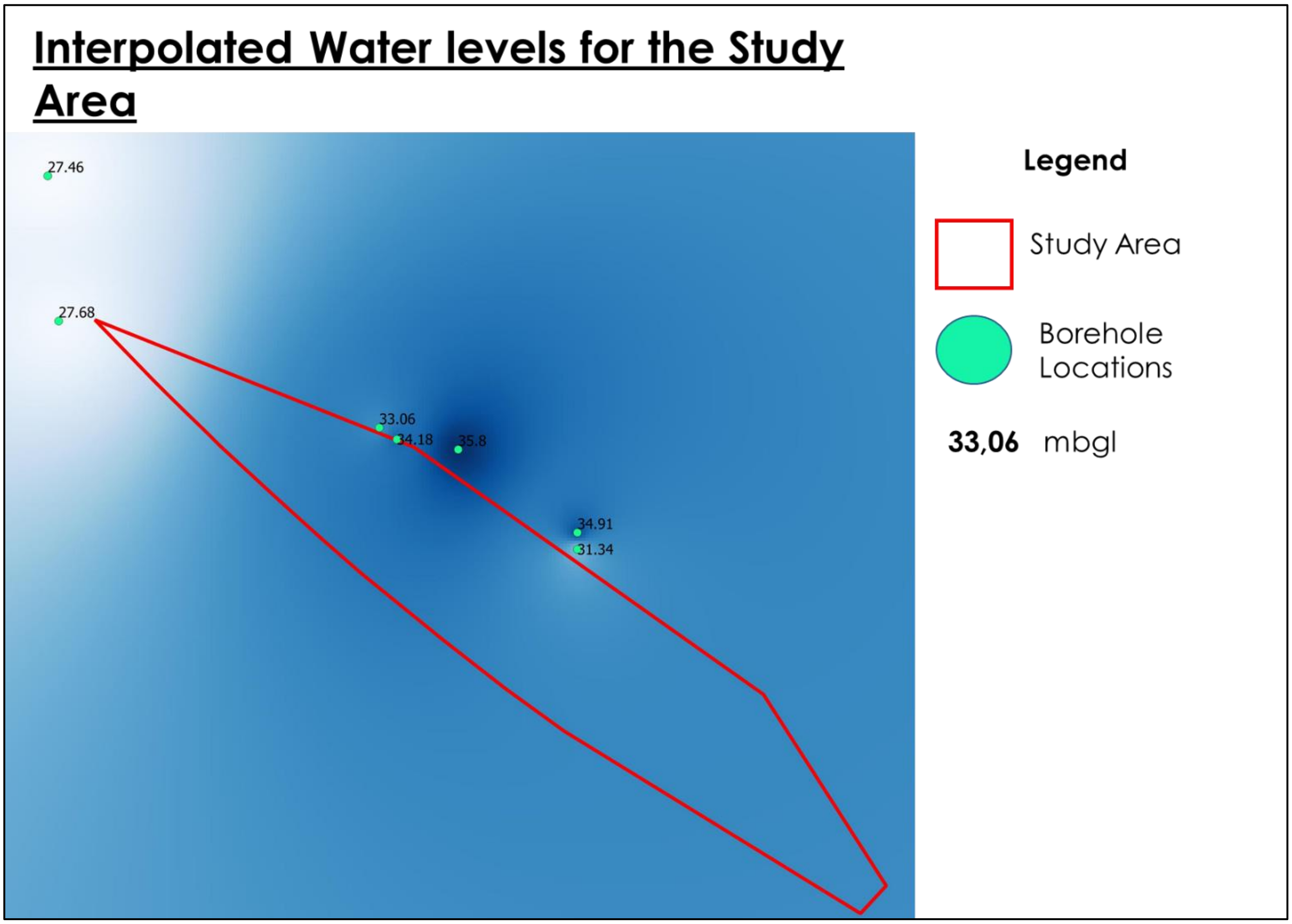
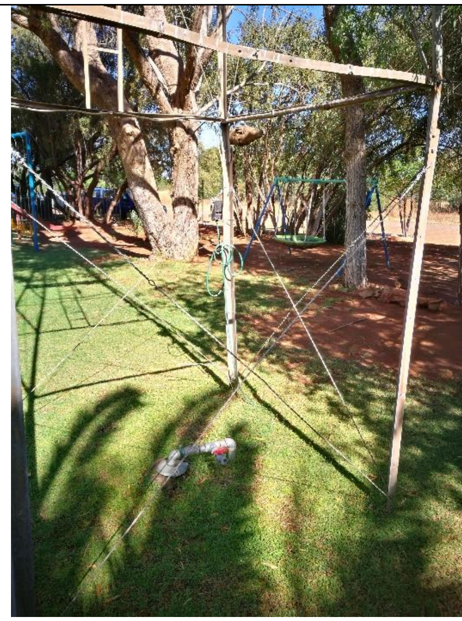
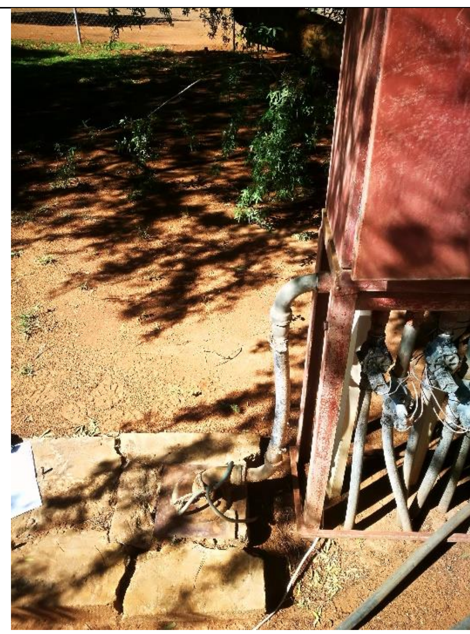


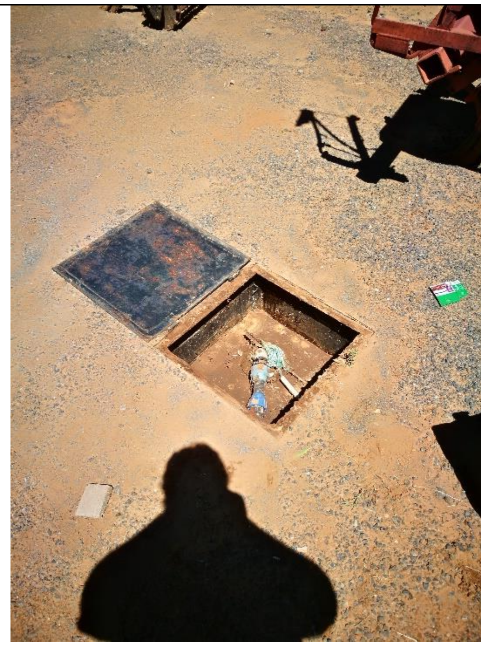
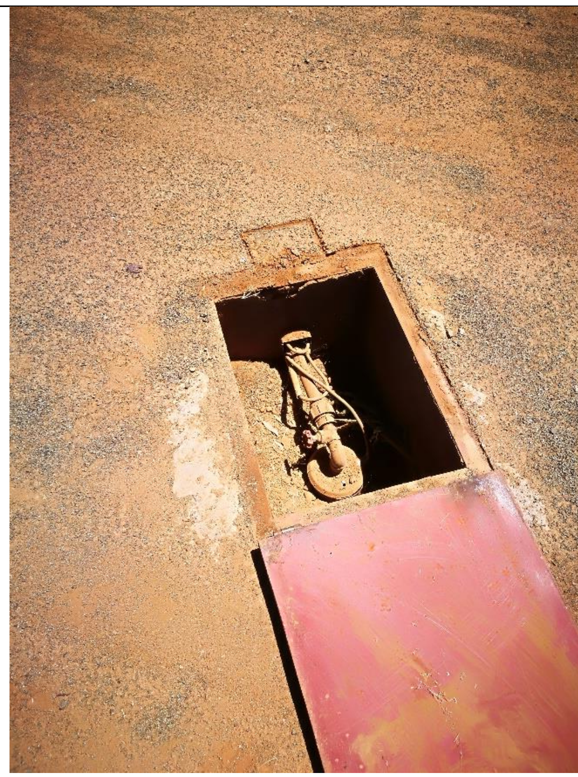
Figure 6: Interpolated water levels using data from the hydro census.

Most of the boreholes which were examined was equipped with pumps which were actively being used. The boreholes themselves weren't classified as being strong boreholes and would only deliver a sustainable yield of 3000 L/hr. The borehole in the area are primarily used for domestic and agricultural purposes.

Table 2:Hydro census data and photographs.

OVK Hydro Census Photographs		
Property	**BH Name**	**Picture**
1672 Erfenis	BH 1	
1672 Erfenis	BH 2	

3/1791 Avoca	BH 3	
2/179 Avoca	BH 4	Collapsed
1894 Gardenia	BH 5	
1894 Gardenia	BH 6	

Skietwinkel	BH 7 Downstream	
Skietwinkel	BH 8 Downstream	
1960 Outspan	BH Upstream	

1960 Outspan	BH On-Site		

4.3. Geo-physical survey and results

No commissioned geo-physical survey took place, only the foreman of the drilling company did a quick walk on site with his magnetometer and indicated were the anomalies were. The monitoring borehole on site was selected downstream from the proposed storage tanks were an anomaly was detected.

4.4. Drilling and siting of boreholes

The only parameters set for the drilling of the monitoring borehole on site was that it should be downstream form the petrol storage tanks, and it must not be deeper than 80 mbgl, to avoid penetrating into the aquifer and creating a preferred pathway for pollutants.

The borehole was drilled at the following location: S 29.06982 and E 26.14154; and to a depth of 61 mbgl. It also had a SWL of 40.45 mbgl, 5 days after the drilling of the borehole ceased.

The analysis of the geology indicates that water would have been found occurring naturally at around 30 mbgl, but it is estimated due to drought, development and use of the aquifer, that amount of water at this depth is significantly reduced. This is why there are numerous dry water strikes on the contact between layers and within the numerous fractures in the shales.

Table 3: Geological log of the new monitoring borehole.

New monitoring borehole geological log.
Casing Depth: 38 mbgl
Borehole diameter: 165 mm

Meters Below Ground Level	New monitoring borehole	Geology	Comments/chip sample description	Analysis
0 - 11		Light red muddy sand	Coarse-fine	
11 - 19		Brown sand	Very fine	
19 - 25		Light red sand	Fine	
25 - 26		Light red sand	Fine more silica	
Contact				
26 - 30		Light brown-red sand alternating with light brown sand	Very fine-muddy	Dry Strike-no water
Contact				
30-61		Alternating light grey shale	Coarse fine	No water Strikes-Infiltrating water- Multiple fractures in shale

4.5. Aquifer Testing

No aquifer testing took place since the borehole was drilled for monitoring purposes and not into the aquifer itself. From the hydro census it was determine that the aquifer itself yields around 3000 – 4000L /hour and it situated between 90 and 110 mbgl. As a result of infiltrating water through the first 30 m of sand (refer to chapter 4.4), the SWL in the area is between 30 – 34 mbgl.

4.6. Sampling and chemical analysis

For the proposed project, 4 boreholes were identified and selected during the hydro census to be used as monitoring boreholes for water quality assessment. These included the following BH 7 Skiet, BH 8 Skiet, On Site BH and Upstream BH (Please refer to Table 1 for location).

The following background water quality results are as follows:

Table 4: Chemical analysis for the 4 selected monitoring boreholes (red indicates exceedance of SANS for drinking water**)**

Chemical result for the monitoring boreholes sampled						
Parameters	**Units**	**SANS for Drinking water 2005**	**BH 7 Skiet**	**BH 8 Skiet**	**On Site BH**	**Upstream BH**

pH	pH Units	5.5 - 9.7	7.22	7.59	7.33	7.6
Electrical Conductivity	mS/m	<170	74.6	71.1	58.7	91.5
Calcium as Ca	mg/L	<150	57.3	42.9	39.5	48.2
Magnesium as Mg	mg/L	<70	10.5	11.7	16.3	19.7
Sodium as Na	mg/L	<200	75.8	83.0	51.5	92.7
Potassium as K	mg/L	<50	1.22	1.01	4.28	6.27
P-Alkalinity	mg/L	Not assigned	0	0	0	0
M-Alkalinity	mg/L	Not assigned	221	228	169.9	201.7
Fluoride as F	mg/L	<1.5	0.41	0.6	1.82	0.83
Chloride as Cl	mg/L	<300	40.2	26.7	62.5	150.5
Nitrate as N	mg/L	<11	0.95	0.81	1.15	0.79
Sulphate as SO_4	mg/L	<500	37.9	34.8	42.9	29.0
Calcium Hardness	mg/L	<375	143	107	99	120
Magnesium Hardness	mg/L	<287	43	48	67	81
Total Hardness as $CaCO_3$	mg/L	<662	186	155	166	201
Total Dissolved Solids	mg/L	<1200	449	433	394	552
Aluminium as Al	mg/L	<0.3	<0.020	<0.020	0.033	<0.020
Arsenic as As	mg/L	<0.010	<0.020	<0.020	<0.020	<0.020
Barium as Ba	mg/L	<0.7	0.113	0.187	0.053	0.044
Cadmium as Cd	mg/L	Not assigned	<0.003	<0.003	<0.003	<0.003
Cobalt as Co	mg/L	Not assigned	<0.020	0.003	0.003	<0.002
Chromium as Cr	mg/L	<0.050	<0.020	0.004	0.004	<0.002
Copper as Cu	mg/L	<2	0.008	0.004	0.009	0.005
Iron as Fe	mg/L	<0.3	<0.020	<0.020	0.120	0.032

Manganese as Mn	mg/L	<0.1	<0.020	<0.020	0.05	0.021
Nickel as Ni	mg/L	Not assigned	<0.020	<0.020	<0.020	<0.020
Lead as Pb	mg/L	<0.010	<0.015	<0.015	<0.015	<0.015
Selenium as Se	mg/L	<0.04	<0.020	<0.020	<0.020	<0.020
Vanadium as V	mg/L	<0.200	<0.010	<0.010	<0.010	<0.010
Zinc as Zn	mg/L	<5	<0.020	<0.020	<0.020	<0.020

All the chemical parameters tested for are below the threshold limit as prescribed by the South African National Standard for Drinking Water 2005 (SANS 2005), with the exception of the On Site BH's Aluminium and Fluoride concentrations which marginally exceeds the threshold limits (refer to table 4). The On Site borehole was sampled a week after it was drilled and the marginal exceedance of Fluoride and Aluminium can be attributed to the installation of the metal casing. Also, drilling will release stored minerals from the geology which will require time to settled in the water, which accounts for the marginally high Fluoride concentrations.

The chemical concentration values given in Table 4 can be used in the future as a quality comparison when monitoring and sampling takes place.

4.7. Groundwater recharge calculations

No physical calculation of recharge was done for the area due to a lack of specific data and that no pump test was conducted. Instead the Water Resources of South Africa (2005) maps were used to determine recharge (Figure 7). The maps indicated that the annual recharge for this aquifer is between 5 – 10 mm/a.

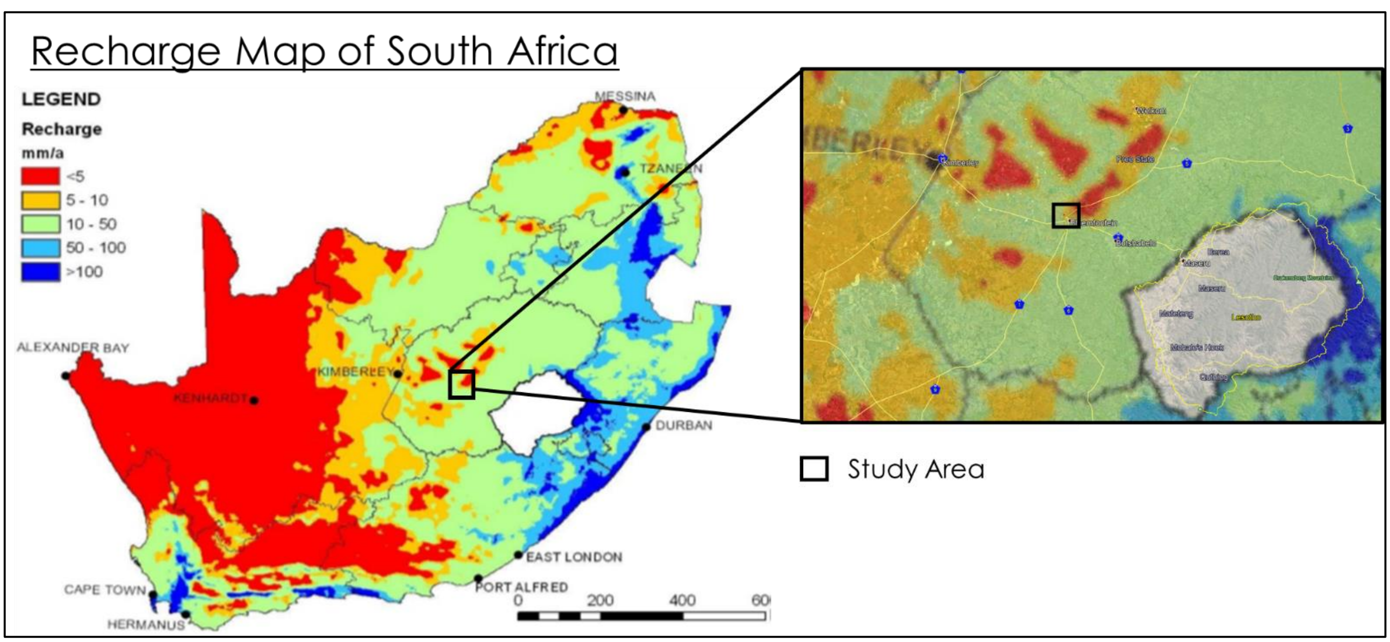


Figure 7: Water resources map indicating recharge for the study area.

4.8. Groundwater Modelling

No ground water modelling was conducted as the monitoring borehole is not situated in the aquifer and would require more boreholes for a detailed study and model. However, chapter 7 shows a conceptual model which was constructed to give a general idea of groundwater conditions.

4.9. Groundwater availability assessment

It would be difficult to determine the amount of water available for use through means of abstraction, as the site currently on has one borehole that partially penetrates the aquifer. From the hydro census it is clear that, around 3000 -4000 L/hour is pumped from the aquifer by the adjacent landowners for domestic use and cattle watering. It would then be safe to assume that any borehole on site should be able to sufficiently supply around 3000 L/hour. Note that this is only an estimate and any borehole water use for industrial purposes, will have to undergo a pump test to confirm the correct yield over a period of time.

5. Prevailing groundwater Conditions

5.1. Geology

5.1.1. Regional Geology

The regional geology classifies the area as containing the Karoo Supergroup which is further subdivided into the Beaufort Group and Adelaide Sub – Group (Figure 8).

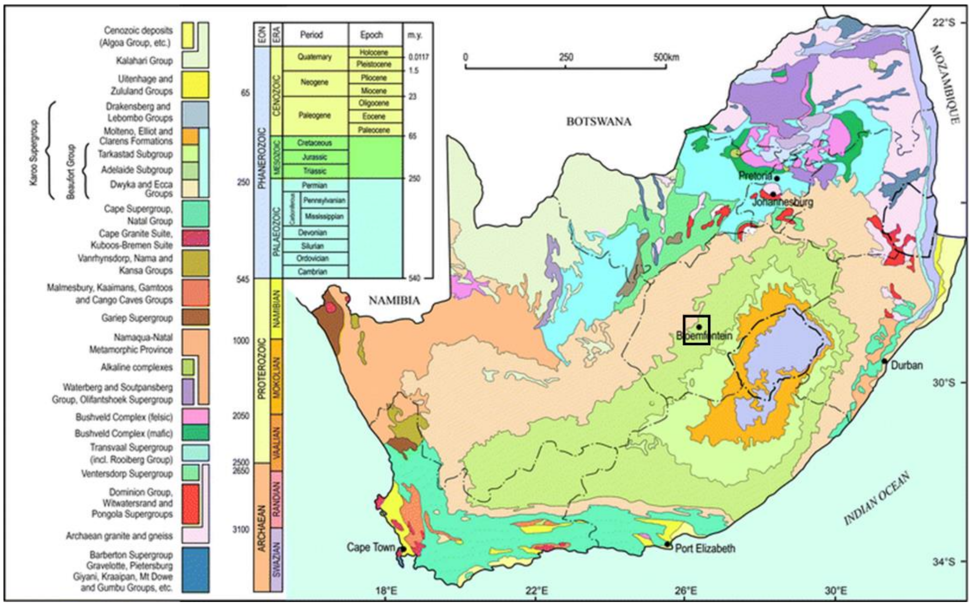


Figure 8: Geological groups of South Africa

5.1.2. Local Geology

According to Figure 9, the study area consists of geological unit K_3l of the Adelaide Sub-Group, consisting of mainly sandstones, shales and mudstone. In this case the geological log of the borehole indicates that the geology is mostly grey shales. The upper part (0 - 30 mbgl) consists of Kalahari Group sands characterized in the study area as alternating layers of light brown - red to red sands.

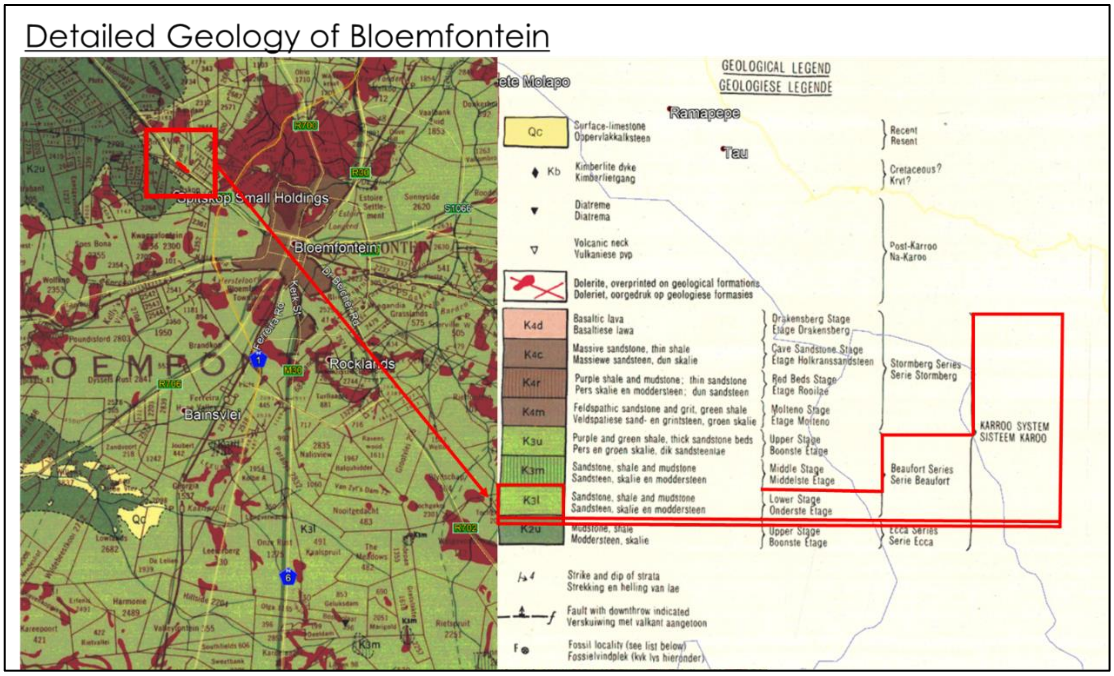


Figure 9: Local and study area's geological composition.

5.2. Hydrogeology

5.2.1. Unsaturated Zone

The unsaturated zone stretches from the surface to the contact between the red sand and grey shale around 30 mbgl. The unsaturated zone contains alternating layers of red and brown sand with various degrees of silica content. This unsaturated zone has high permeability and a low water retention capability where water infiltrates unhindered to the partially impermeable shale zone.

5.2.2. Saturated Zone

The saturated zone starts from the shale contact at 30 mbgl up until it reaches the dolerite - shale contact of the aquifer. Note that this contact was not reached when the drilling of the monitoring borehole was conducted but the on-site upstream drilling for a water borehole confirmed this contact. The saturated zone consists mainly of highly fractured shale layers up until the contact with the dolerite sill.

5.2.3. Hydraulic Conductivity

Hydraulic conductivity could not be determined as there was no pump test conducted and not enough information was available during the hydro census to conduct such calculations. However, research was done by Domenico and Schwartz (1990) for values of hydraulic conductivity on various geological and soil layers and are as follows:

Unconsolidated Sedimentary Materials	
Material	**Hydraulic Conductivity (m/sec)**
Gravel	3×10^{-4} to 3×10^{-2}
Coarse sand	9×10^{-7} to 6×10^{-3}
Medium sand	9×10^{-7} to 5×10^{-4}
Fine sand	2×10^{-7} to 2×10^{-4}
Silt, loess	1×10^{-9} to 2×10^{-5}
Till	1×10^{-12} to 2×10^{-6}
Clay	1×10^{-11} to 4.7×10^{-9}
Unweathered marine clay	8×10^{-13} to 2×10^{-9}

Figure 10: Hydraulic conductivity range for selected sedimentary rocks

The first 30 mbgl, as determined by drilling of the new monitoring borehole on site, consisted of mainly red sand with a high silica content. Using Figure 10 the sand can be classified as being of medium coarseness with a hydraulic conductivity of between 0.78 m – 432 m/day.

On the other hand, the shale will have a lower hydraulic conductivity due to finer materials and less void spaces. Figure 10 indicates a hydraulic conductivity for shale between 0.0009 m – 17 m/day.

5.3. Groundwater levels

From the hydro census it is clear that the SWL for the area is between 30 – 34 mbgl and around 27 mbgl further downstream around 300 m North West. Keep in mind that the SWL is not representative of the aquifer water level and is merely infiltrating water from the surface raising the water level.

5.4. Groundwater potential contaminants

Potential pollution to the groundwater might occur from the following:

Table 5: Properties and their potential pollution sources.

Potential Contaminants that can occur at Outspan 1960		
Pollution source	**Type of Pollutants**	**Explanation**
Construction works on 1672 Erfenis	Heavy Metals, Oil & Grease and Hydraulic fluids	Numerous activities such as welding involving the use of oil & grease and hydraulic fluid for the equipment can enter the groundwater during a rainfall event. It must be mentioned that

		this is highly unlikely as activities take place on thick concrete slabs which are situated under roof.
Horse stables on 3/1791 and 2/1791 Avoca	Higher concentrations of Total Plate Count, Total Coliforms and E.coli.	Faecal matter from horse around the stables were noticed and it is possible for micro biological constituents to enter the groundwater during a rainfall event.
Traffic associated pollutants from the R64 road	Oil, hydraulic fluids, vehicle debris and petroleum products.	The R64 is a busy double lane road and it's not uncommon for vehicles to break down alongside the road. Here oil, hydraulic fluids and petroleum products can leak from the vehicles and enter the groundwater during rainfall events.
Proposed filling station on Outspan2/1960	Petroleum products, soap, oil and grease.	It is possible for pollutants such as petroleum products to leak from the underground tanks and enter the groundwater through infiltration and during rainfall events. Spillages of petroleum, oil and grease may occur at the workshop and may enter the groundwater through runoff during a rainfall event.

5.5. Groundwater quality

From the chemical analysis done on the 4 selected boreholes, it can be concluded that the groundwater is of good quality, suitable for domestic use and drinking water. It must be mentioned that during the hydro census, a couple of neighbours mentioned that they intersected a sulphur (SO_4) bank, caused by the, now dewatered wetland, situated upstream, …. . They also mentioned, that with constant abstraction the levels of sulphur decreased to such as point that the sulphur was negligible in the groundwater.

6. Aquifer Characterization

6.1. Groundwater vulnerability

The Council of Geoscience (2011) compiled a groundwater vulnerability map (Figure 11) using the DRASTIC model. According to this model the study area's aquifer is classified a being moderately vulnerable taking into account factors such as Depth to water table, Recharge, Aquifer media, Soil media, Topography, Impact of the vadose zone and Conductivity (Hydraulic).

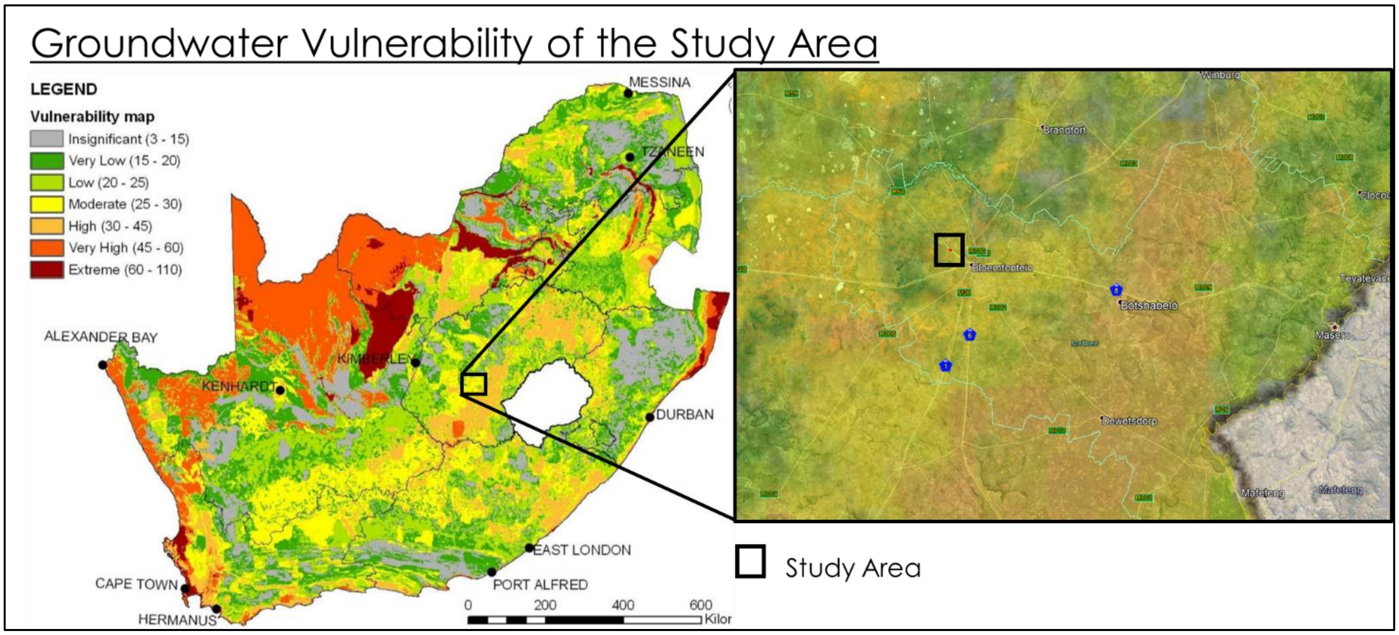


Figure 11: Vulnerability index of aquifers in South Africa.

6.2. Aquifer classification

According to the aquifer classification map of South Africa (2012) the study area's aquifer is classified as being a minor aquifer (Figure 12). Most of the water in and around Bloemfontein uses municipal water supplied by surface water dams. The specific area around the study area mostly relies on groundwater resources from this minor aquifer which supplies around 3000 L/day. This aquifer is classified as minor but abstraction from this aquifer should be monitored as historic data, eyewitness accounts and the fact that several fractures in the shales were dry, show a decrease in water levels.

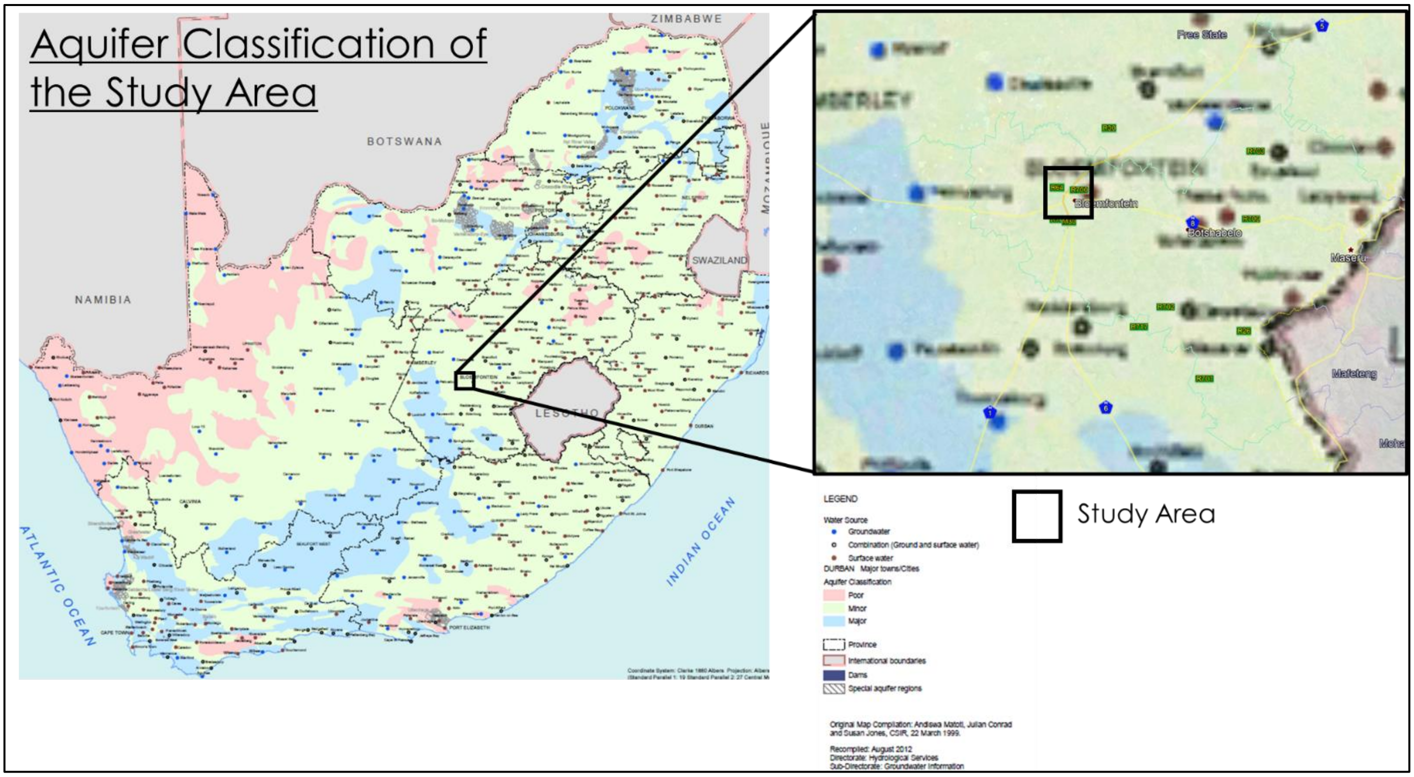


Figure 12: Aquifer classification of South Africa

6.3. Aquifer Protection Classification

The study area consists of a minor aquifer classified as "These can be fractured or potentially fractured rocks which do not have a high primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important both for local supplies and in supplying base flow for rivers".

Due to this aquifer being utilized by neighbors in the area surrounding, at the study area and the aquifer itself being classified a minor, it is recommended that this aquifer receive some protection in the form of monitoring the water levels, abstraction rates and quality of water. This will ensure the availability of water and protection from over abstraction of the aquifer through sustainable and environmentally friendly methods.

7. Groundwater Modelling

No software modelling was not preformed due to a lack of data and not a requirement as part of this study. However, a conceptual model is provided below in Figure 13.

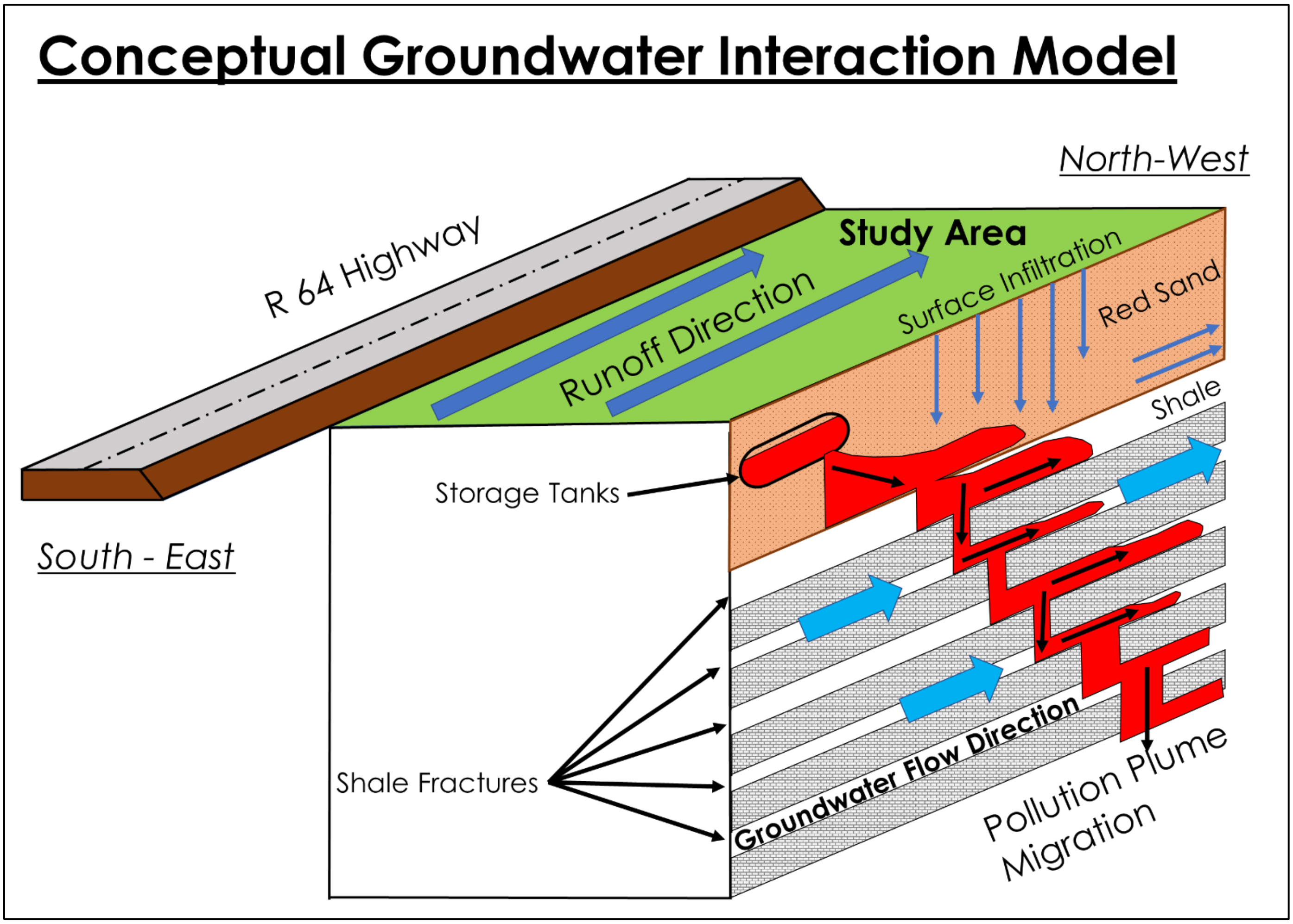


Figure 13: Outspan Conceptual Model

8. Geohydrological Impacts

8.1. Impact Assessment Methodology

The main objective of the impact assessment process will be to assess and quantify the potential impacts that were identified by the specialists during their investigations.

The concept of "significance" is at the core of impact identification, evaluation and decision-making, and can be differentiated into impact magnitude and impact significance. Impact magnitude is the measurable change (i.e. intensity, duration and likelihood), while impact significance is the value placed on the change by different affected parties (i.e. level of acceptability) (DEAT, 2002).

The environmental significance assessment methodology is based on the following determination:

Environmental Significance = Overall Consequence x Overall Likelihood

Determination of Consequence

Consequence analysis is a mixture of quantitative and qualitative information and the outcome can be positive or negative. Several factors can be used to determine consequence. For the purpose of determining the environmental significance in terms of consequence, the following factors were chosen: **Severity/Intensity, Duration and Extent/Spatial Scale**. Each factor is assigned a rating of 1 to 5, as described below.

Determination of Severity

Severity relates to the nature of the event, aspect or impact to the environment and describes how severe the aspects will impact on the biophysical and socio-economic environment.

Type of criteria	Rating				
	1	2	3	4	5
Quantitative	0-20%	21-40%	41-60%	61-80%	81-100%
Qualitative	Insignificant / Non-harmful	Small / Potentially harmful	Significant / Harmful	Great / Very harmful	Disastrous Extremely harmful
Social / Community response	Acceptable / I&AP satisfied	Slightly tolerable / Possible objections	Intolerable / Sporadic complaints	Unacceptable / Widespread complaints	Totally unacceptable / Possible legal action
Irreversibility	Very low cost to mitigate /	Low cost to mitigate	Substantial cost to	High cost to mitigate	Prohibitive cost to

Type of criteria	Rating				
	1	**2**	**3**	**4**	**5**
	High potential to mitigate impacts to level of insignificance / Easily reversible		mitigate / Potential to mitigate impacts / Potential to reverse impact		mitigate / Little or no mechanism to mitigate impact Irreversible
Biophysical (Air quality, water quantity and quality, waste production, fauna and flora)	Insignificant change / deterioration or disturbance	Moderate change / deterioration or disturbance	Significant change / deterioration or disturbance	Very significant change / deterioration or disturbance	Disastrous change / deterioration or disturbance

Determination of Duration

Duration refers to the amount of time that the environment will be affected by the event, risk or impact, if no intervention.

Rating	**Description**
1: Low	One month
2: Low-Moderate	Between 1 and 3 months (Quarter)
3: Moderate	3 months to 1 year
4: Moderate-High	1 to 10 years
5: High	More than 10 years

Determination of Extent/Spatial Scale

Extent refers to the spatial influence of an impact. It will be: a) limited to the site and its immediate surroundings; b) extending to the surrounding local area, c) regional (will have an impact on the region) c) national (will have an impact on a national scale); or d) or international (impact across international borders).

Rating	**Description**
1: Low	Immediate, fully contained area
2: Low-Moderate	Surrounding area
3: Moderate	Regional
4: Moderate-High	National
5: High	International

Determination of Overall Consequence

Overall consequence is determined by adding the factors determined above and summarised below, and then dividing the sum by 3.

Consequence	Rating
Severity	Example 4
Duration	Example 2
Extent	Example 4
SUBTOTAL	10
TOTAL CONSEQUENCE:(Subtotal divided by 3)	3.3

Determination of Likelihood

The determination of likelihood is a combination of **Frequency** and **Probability**. Each factor is assigned a rating of 1 to 5, as described below.

Determination of Frequency

Frequency refers to how often the specific activity, related to the event, aspect or impact, is undertaken.

Rating	**Description**
1: Low	Once a year or once during operation
2: Low-Moderate	Once / more in 6 Months

3: Moderate	Once / more a Month
4: Moderate-High	Once / more a Week
5: High	Daily

Determination of Probability

Probability refers to how often the activity/event or aspect has an impact on the environment.

Rating	Description
1: Low	Almost never / almost impossible
2: Low-Moderate	Very seldom / highly unlikely
3: Moderate	Infrequent / unlikely / seldom
4: Moderate-High	Often / regularly / likely / possible
5: High	Daily / highly likely / definitely

Determination of Overall Likelihood

Overall likelihood is calculated by adding the factors determined above and summarised below, and then dividing the sum by 2.

Likelihood	Rating
Frequency	Example 4
Probability	Example 2
SUBTOTAL	6
TOTAL LIKELIHOOD (Subtotal divided by 2)	3

Determination of Overall Environmental Significance

Quantitative description or magnitude of Environmental Significance

The multiplication of overall consequence with overall likelihood will provide the environmental significance, which is a number that will then fall into a range of LOW, LOW-MEDIUM, MEDIUM, MEDIUM, MEDIUM-HIGH or HIGH, as shown in the table below.

Significance or Risk	Low	Low-Moderate	Moderate	Moderate-High	High

Overall Consequence X Overall Likelihood	1 - 4.9	5 - 9.9	10 - 14.9	15 – 19.9	20 - 25

Qualitative description or magnitude of Environmental Significance

This description is qualitative and is an indication of the nature or magnitude of the Environmental Significance. It also guides the prioritisations and decision-making process associated with this event, aspect or impact.

Significance	**Low**	**Low-Moderate**	**Moderate**	**Moderate-High**	**High**
Impact Magnitude	Impact is of very low order and therefore likely to have very little real effect. Acceptable.	Impact is of low order and therefore likely to have little real effect. Acceptable.	Impact is real, and potentially substantial in relation to other impacts. Can pose a risk to I&AP.	Impact is real and substantial in relation to other impacts. Poses a risk to the I&AP. Unacceptable.	Impact is of the highest order possible. Unacceptable. Fatal flaw.
Action Required	Maintain current management measures. Where possible improve.	Maintain current management measures. Implement monitoring and evaluate to determine potential increase in risk. Where possible improve.	Implement monitoring. Investigate mitigation measures and improve management measures to reduce risk, where possible.	Improve management measures to reduce risk.	Implement significant mitigation measures or implement alternatives.

8.2. Construction phase

8.2.1. Impacts on Groundwater Quantity

Impacts on Groundwater Quantity								
	Outspan 1960							
Potential Impact Description:	Over abstraction of boreholes in the area for water use in construction activities may detrimentally affect the quantity of water available in the future or for other groundwater users.							
Duration of Impact:	Construction phase							
	Construction phase							
	Severity	Duration	Extent	Consequence	Probability	Frequency	Likelihood	Significance
Without Mitigation	No Impact							
With Mitigation								
Mitigation Measures	No water will be abstracted from the aquifer during the construction phase							
Can the Impact be Reversed	Yes							
Will impact cause irreplaceable loss to resource	No							
Cumulative Impacts	None							

8.2.2. Impacts on Groundwater Quality

Impacts on Groundwater Quality	
	Outspan 1960

Potential Impact Description:	During the construction phase the use of hazardous substances may be spilled and end up on open soil which will infiltrate to the groundwater during rainfall events. The proposed petroleum tanks underground may also develop crack or holes, during the installation of them underground, which will leak the petroleum substances into the groundwater.							
Duration of Impact:	Construction phase							
	Construction phase							
	Severity	Duration	Extent	Consequence	Probability	Frequency	Likelihood	Significance
Without Mitigation	4	3	3	3	4	2	3	10
With Mitigation	2	1	1	1	2	2	2	2,5
Mitigation Measures	Ensure that all spillages of hazardous and petrochemical substances are immediately removed using spill kits. Maintain vehicles in proper working condition to minimize leaking substances from the equipment and ensuring that repairs are done in a designated lined area.							
Can the Impact be Reversed	Yes							
Will impact cause irreplaceable loss to resource	No							
Cumulative Impacts	Activities of the neighbours such as metal works and horse stables may additionally affect the quality of water.							

8.2.3. Groundwater Management during the Construction phase

The following groundwater management and mitigation measure can be applied to ensure minimal impacts on the environment during the construction phase:

- Ensure that personnel on site are informed of the risks associated with groundwater contamination
- Construction personnel receive proper training in identifying, mitigating and removing of the hazardous substances.

- All vehicles requiring repairs or not in use, will use drips trays to ensure that no hazardous substances accidentally contaminate the soil and infiltrates to the groundwater during rainfall events.
- All repairs and storage of equipment will either be done in a properly lined area or workshop.
- Contaminated soils will be collected and disposed of correctly.

8.3. Operational phase

8.3.1. Impacts on Groundwater Quantity

Impacts on Groundwater Quantity								
	Outspan 1960							
Potential Impact Description:	The applicant indicated that borehole water will be used from a new drilled borehole on site for industrial use at the workshop and in the office as well as for the gardens. Over abstraction may either deprive neighbouring groundwater users of water or may completely dewater the aquifer.							
Duration of Impact:	Operational phase							
	Operational phase							
	Severity	Duration	Extent	Consequence	Probability	Frequency	Likelihood	Significance
Without Mitigation	4	4	3	3,5	4	5	4,5	16,5
With Mitigation	2	1	1	1	1	2	1,5	2
Mitigation Measures	Ensure that the abstraction borehole has been tested and the correct yield of the aquifer is established. Installation of a flow meter to ensure that no over abstraction takes place.							
Can the Impact be Reversed	Yes, if the aquifer hasn't been depleted and has collapsed.							
Will impact cause irreplaceable loss to resource	No, if proper abstraction methods are followed							
Cumulative Impacts	If neighbouring groundwater users also simultaneously over abstract water, the minor aquifer will quickly become depleted.							

8.3.2. Impacts on Groundwater Quality

Impacts on Groundwater Quality								
	Outspan 1960							
Potential Impact Description:	During the operational phase the underground petroleum tanks may weaken and start to leak its substances which will reach the groundwater. The inability to remove spillages of hazardous substances on site, will infiltrate into the soil during rainfall events and reach the groundwater.							
Duration of Impact:	Operational phase							
	Operational phase							
	Severity	Duration	Extent	Consequence	Probability	Frequency	Likelihood	Significance
Without Mitigation	4	3	3	3	4	2	3	10
With Mitigation	2	1	1	1	2	2	2	2,5
Mitigation Measures	Constant monitoring of water quality to ensure that water quality remains the same. Monitoring of petroleum tanks underground to ensure that there are no leaks. Maintain proper housekeeping practices through keeping the workshop areas clean and immediate removal of any hazardous spillages on site.							
Can the Impact be Reversed	Yes							
Will impact cause irreplaceable loss to resource	No							
Cumulative Impacts	A cumulative impact to groundwater quality may occur if the surrounding areas also start with activities which may pollute the groundwater.							

8.3.3. Groundwater Management

The following groundwater management and mitigation measure can be applied to ensure minimal impacts on the environment during the operational phase:

- Ensure that no over abstraction of the aquifer takes place through installing flowmeters and keeping to recommended yield volumes.
- Regular monitoring of selected borehole for water quality.
- Ensure that all spillages are cleaned up immediately and disposed of correctly.
- All stormwater running off the site must be contained and kept separate from clean runoff.

9. Groundwater monitoring system

9.1. Groundwater monitoring network

9.1.1. Source, plume, impact and background monitoring

As of yet there is still no pollution plume to delineate but will require more boreholes downstream, if future conditions dictate that such as study must be done. For the background monitoring the boreholes selected to be sampled during the hydro census is sufficient and the applicant must maintain these water quality values as close as possible.

9.1.2. System response monitoring network

If hydrocarbons or Volatile Organic Compounds are found in the monitoring boreholes on site, an action plan to remediate the impact must be implemented. This will include locating the source of hydrocarbon leaks, repairing the tanks and physically removing the pollution plume by pumping the water out of the boreholes (slow dewatering).

If hydrocarbons are found further downstream and in the monitoring boreholes on site, a larger remediation process will need to be followed. This will include removing the underground tanks and the polluted soil around it as well as active dewatering to remove the contaminated water from the groundwater.

9.1.3. Monitoring frequency

It is recommended that water samples be taken at quarterly intervals each year.

9.2. Monitoring parameters

The following parameters should be monitored for:

Table 6: Chemical parameters to be tested for.

Groundwater Quality Testing	
Parameters	**Thresholds**
Total Suspended Solids	25 mg/L
Total Dissolved Solids	1200 mg/L
Electrical Conductivity	170 mg/L
pH	5.5 – 9.7
Chloride as Cl	300 mg/L
Nitrate as NO_3	11 mg/L
Fluoride	1.5 mg/L
Calcium	300 mg/L
Magnesium	100 mg/L
Sodium	200 mg/L

Calcium Hardness	750 mg $CaCO_3$/L
Magnesium Hardness	410 mg $CaCO_3$/L
Petroleum Present Testing	
Volatile Organic Compounds	0.01 mg/L
Total Hydrocarbons	2 mg/L
Sulphate as SO_4	500 mg/L
Lead as Pb	0.01 mg/L
Iron as Fe	2000 mg/L
Arsenic as As	0.01 mg/L
Dissolved Oxygen	1 – 20 mg/L
Oil and Grease	0.2 mg/L

9.3. Monitoring boreholes

Table 7: Details on sampling and location of monitoring boreholes

Boreholes to be monitored						
		Coordinates				
BH Name	**Purpose**	**S**	**E**	**Water Level**	**Depth**	**Water Sample taken of:**
On-site BH	Close proximity underground storage tank monitoring of groundwater at 30 mbgl and not the aquifer.	29.06982	26.14154	40.45	61	Infiltrating water from 30 -61 mbgl
Upstream BH	Monitoring of standard background values for the groundwater.	29.07309	26.14465	35.38	90	Infiltrating water between 30 -61 mbgl
BH 7 (Downstream 1)	Monitoring water quality to check for any pollution plume migration	29.06982	26.13669	27.68	90	Deep sample at 80 mbgl
BH 8 (Downstream 2)	Monitoring water quality to check for any pollution plume migration	29.06557	26.13656	27.46	80	Deep sample at 70 mbgl

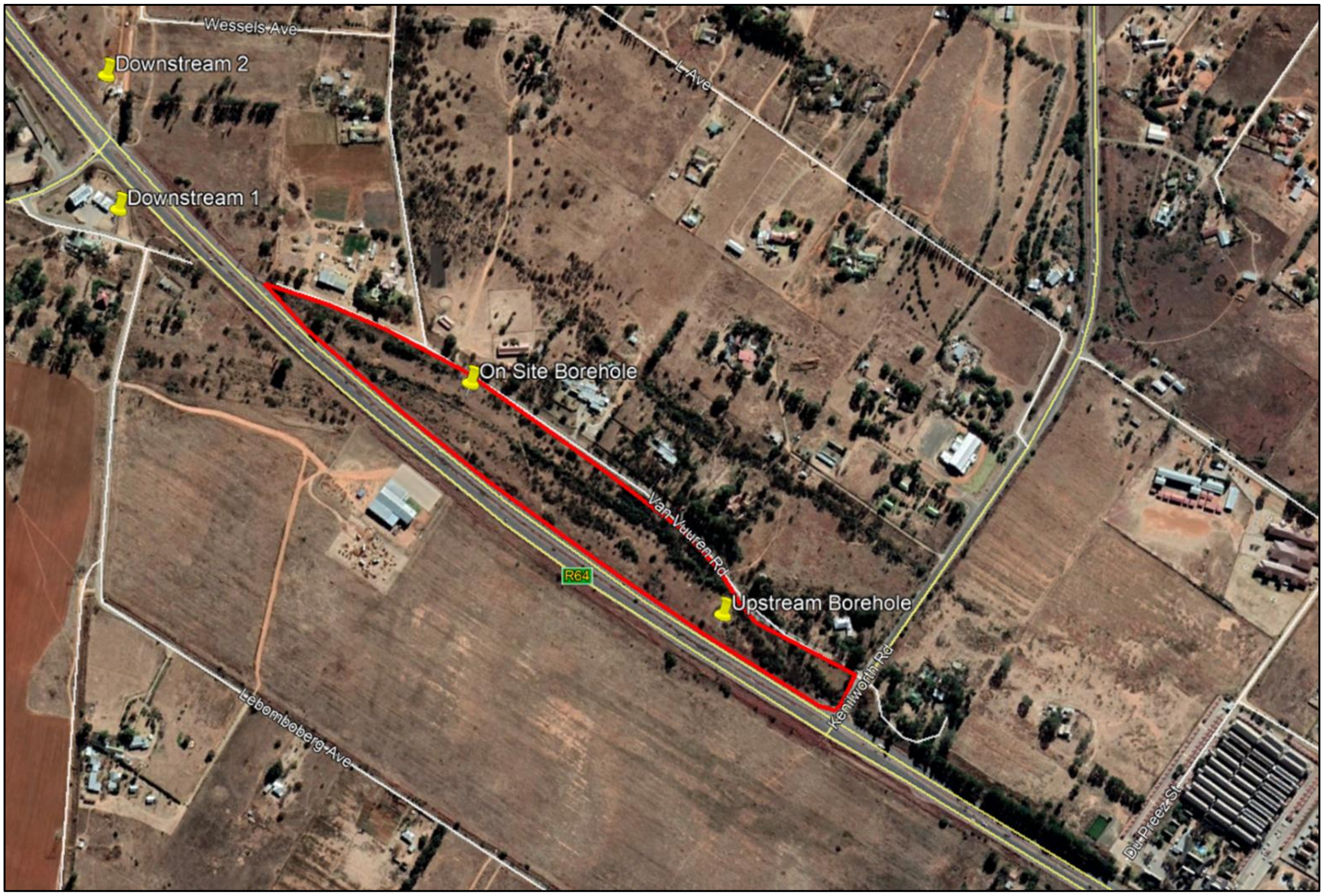


Figure 14: Location study area and proximity of the monitoring boreholes.

10. Groundwater Environmental Management Program

10.1. Current Groundwater conditions

For the proposed site and neighbouring areas, the water level fluctuates between 30 – 34 mbgl depending on the amount of infiltrating water during rainfall events. Although the water level is relatively shallow the aquifer is only reached around 90 mbgl. The water underground moves from an East and South East direction towards a West and North West direction around 2 m/day for the upper infiltrating water.

The groundwater quality, as determined by chemical analysis, is of good quality and suitable for drinking purposes.

10.2. Predicted impacts of facility

Numerous studies and fieldwork show that nearly all filling stations cause some form of environmental contamination from negligible impacts to high risk impacts. With that being said, the level of contamination all depends on the preventative measure that will be implemented and mitigation measures that will be executed during the lifetime of operation.

It is predicted that petrochemical substances will enter the groundwater, but no conclusion can be made about the severity of contamination at this point in time.

10.3. Mitigation Measures

As described in chapter 8 the following mitigation measures will need to be implemented to minimize environmental contamination:

- Proper stormwater controls need to be implemented alongside the separation of clean and dirty water and the correct disposal thereof.
- Any spills of petrochemical and hazardous substances need to be immediately removed using spill kits.
- Ensure that the underground storage tanks have sufficient lining of either plastics, concrete, clay or a combination of the mentioned material.
- Regular monitoring of the storage tanks to swiftly identify and correct any leaks found in the tanks.
- Systematically monitoring of the on-site and downstream borehole water quality to identify if a pollution plume has manifested from the underground storage tanks or from surface contamination entering the groundwater system.
- If the environmental impact caused by the leaking of underground storage tanks are significantly high, it is recommended that the tanks be completely removed alongside the contaminated soils and that on-site boreholes be dewatered constantly to remove any contaminates from the groundwater.

11. Conclusion

The aquifer beneath the study area is classified as being a minor aquifer (3000 L/hour) but will require some form of monitoring/protection as neighbouring groundwater users in the area rely heavily on this aquifer for cattle watering and domestic use.

The first 30 mbgl consists of mainly red sand which has high permeability and is estimated that contaminates can spread as fast as 2 m/ day if it comes in contact with the groundwater. It is thus recommended that special precautions need to be taken to prevent surface contamination (spillages and runoff) from infiltrating into the permeable sand and end up in the groundwater.

It is recommended that any form of contamination found during quarterly water sample analysis be treat with swift remedial action to avoid the creation of a pollution plume which will affect downstream groundwater users. If contaminates are found downstream at a depth of around 70 mbgl serious mitigation measures will need to be implemented as the pollution plume has reached the aquifer.

In conclusion the aquifer system in the area is not specifically important on a large scale and also the aquifer is situated very deep at 90 mbgl making it difficult for contaminates to reach that depth. However, on local scale the aquifer is being utilized for important activities and strict monitoring and mitigation measures will determine whether the groundwater quality changes.

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