Groundwater Impact Assessment for the Proposed New Residential Development on Portion 91 of Farm 304 Matjesfontein, Keurboomstrand, Western Cape

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Prepared for:

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Author's Resume

Divan Stroebel is a SACNASP registered and active member of the Groundwater Division, the Geological Society of South Africa, hydrogeologist and professional geoscientist with more than 18 years of industry experience. He obtained his B.Sc. (Geology) degree in 2005 and his B.Sc. Honours (Geology) degree in 2006 from Stellenbosch University. From 2007, he worked throughout Africa as an exploration geologist in base metal, iron ore and gold exploration. In 2009 he joined a hydrogeological consultancy and completed additional groundwater modules at the Institute for Groundwater Studies (IGS), University of Free State. These modules included Aquifer Mechanics, Groundwater Chemistry, Groundwater Geophysics, Groundwater Modelling and Groundwater Management.

He was employed by mining giant, Rio Tinto in 2010 in Guinea as a Geologist, after which he was the Superintendent Geologist at Goldfields' Kloof mine from 2012. He joined AEON at the Nelson Mandela University (NMU) in 2014 as Associate Research Manager for the Karoo Shale Gas Research Programme- focused on Karoo hydrogeology.

Divan's technical experience includes all aspects of mineral exploration, extraction and reserve management as well as hydrogeological assessments (basic, environmental management plan, permits and licensing, legal query, impact assessments, integrated waste water management plans and external audits), aquifer characterisation, groundwater supply development, groundwater and surface water characterisation and monitoring as well as water quality assessments.

Divan is very active in the hydrogeological community and has attended, presented at and co-organised numerous water-research workshops and conferences. In June 2016, he was appointed as a visiting researcher at Queen's University, Belfast. In China (2017), he successfully completed an international training programme on the Sustainable Development of Water Resources in Arid Regions for Developing Countries.

During his time at AEON, Divan researched the Groundwater Hydrochemistry and Aquifer Connectivity Baseline of the Eastern Cape Karoo. In anticipation of the controversial hydraulic fracturing planned for the Eastern Cape, he has obtained unique experience in the determination of salinity, aquifer yields and groundwater levels of the Karoo's scarce groundwater resources and has published an article in a special publication by the Geological Society of London on fractured aquifers on the topic. https://sp.lyellcollection.org/content/479/1/129

Divan is the founder and owner of DHS Groundwater Consulting Services and leads the team as principal hydrogeologist, overseeing all projects from inception to completion.

Declaration of Consultants Independence

I consider myself bound to the rules and ethics of the South African Council for Natural Scientific Professions (SACNASP);

• At the time of conducting the study and compiling this report I did not have any interest, hidden or otherwise, in the proposed development that this study has reference to, except for financial compensation for work done in a professional capacity;

• Work performed for this study was done in an objective manner. Even if this study results in views and findings that are not favourable to the client/applicant, I will not be affected in any manner by the outcome of any environmental process of which this report may form a part, other than being members of the general public;

• I declare that there are no circumstances that may compromise my objectivity in performing this specialist investigation. I do not necessarily object to or endorse any proposed developments, but aim to present facts, findings and recommendations based on relevant professional experience and scientific data;

• I do not have any influence over decisions made by the governing authorities;

• I undertake to disclose 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 a competent authority to such a relevant authority and the applicant;

• I have the necessary qualifications and guidance from professional experts in conducting specialist reports relevant to this application, including knowledge of the relevant Act, regulations and any guidelines that have relevance to the proposed activity;

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• All the particulars furnished by me in this document are true and correct.

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Executive Summary

DHS Groundwater Consulting Services (Pty) Ltd. was appointed by Familie Roux Eiendomme (Pty) Ltd to conduct a groundwater impact assessment prior to the proposed development on Portion 91 of Farm 304 Matjesfontein, Keurboomstrand, Western Cape. The primary objective of this assessment is to evaluate the potential impact of the development on groundwater resources, particularly in relation to the construction and operation of an onsite wastewater treatment plant (WWTP) and the irrigation of gardens with treated effluent.

Objectives of the Assessment

- Conduct a geohydrological characterization of groundwater in the vicinity of the site.
- Assess groundwater use through a hydrocensus within a 1 km radius of the site.
- Identify and propose mitigation measures for potential negative impacts.
- Recommend a groundwater monitoring program as part of an environmental management plan.

This report serves as a specialist geohydrological assessment, focusing on the overall geohydrological characteristics of the site, the potential impacts of the development, and the necessary mitigation measures.

Key Findings

- The site is underlain by a low-yielding, intergranular aquifer consisting of shallow, unconsolidated formations, making it highly vulnerable to contamination.
- Groundwater was encountered at shallow depths (1.95m and 2.3m below ground level) in geotechnical test pits, confirming the need for careful contamination management.
- A hydrocensus identified three boreholes, a spring, and a groundwater spike within a 3 km radius, with groundwater users present at MG01 and MF01.
- Groundwater quality is moderate, with electrical conductivity (EC) values ranging from 150 to 370 mS/m; however, samples from MG01 and MF01 exceed drinking water standards due to elevated chloride (Cl), sodium (Na), manganese (Mn), iron (Fe), and turbidity levels.
- Based on national-scale DRASTIC data, the aquifer vulnerability is classified as "moderate," but localized conditions (high permeability and proximity to contamination sources) increase the rating to "high."
- The Aquifer System Management Index and Groundwater Quality Management Index confirm a high-risk classification for the site.

Risk Assessment and Potential Impacts

A Source-Pathway-Receptor model was used to evaluate contamination risks:

- Sources: Potential contamination sources include chemical spills during construction, leakage from the WWTP and associated pipelines, and improper handling of hazardous materials.

- Pathway: The shallow intergranular aquifer facilitates rapid contaminant migration, increasing the risk to groundwater quality.
- Receptors: The shallow aquifer, deeper aquifers, nearby groundwater users (MG01 borehole and MF01 spring), and the broader environment.
- Impact Classification: The overall risk of groundwater contamination is classified as minor-negative, but effective mitigation measures can reduce it to negligible-negative.

Groundwater Recharge and Flooding Risks

- Groundwater recharge occurs regionally rather than being site-specific, meaning the development is unlikely to significantly affect it.
- The sandy subsurface has high permeability, reducing the likelihood of groundwater mounding and flooding.
- Proper stormwater management, including permeable pavements, retention ponds, and controlled drainage, will be essential to mitigate local hydrological changes.

Recommendations

1. Mitigation Measures: Implement strict environmental management practices to prevent contamination and ensure compliance with relevant regulations.
2. Monitoring Network Installation: Establish a monitoring network before construction begins to track groundwater quality and detect contamination early.
3. Piezometer Installation: Install at least four monitoring piezometers for regular groundwater assessment.
4. Regular Monitoring: Conduct monthly sampling of groundwater and treated effluent, with laboratory analysis by an accredited SANAS facility.
5. Rapid Response Plan: Develop a contingency plan to address contamination incidents promptly.

Conclusion

With the recommended mitigation strategies, monitoring framework, and proactive management measures in place, the potential negative impacts on groundwater quality, recharge, and flooding can be reduced to negligible levels. This will ensure the protection of groundwater resources, safeguard water users, and uphold environmental sustainability throughout the construction and operational phases of the development.

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List of Abbreviations

Term	Definition
%	Percentage
CDT	Constant Discharge Test
CFU	Colony Forming Unit
DEA	Department of Environmental Affairs
DRO	Diesel Range Organics
DWAF	Department of Water Affairs & Forestry
DWS	Department of Water & Sanitation
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMP	Environmental Management Program
EWR	Ecological Water Requirement
GA	General Authorisation
GMA	Groundwater Management Area
GMU	Groundwater Management Unit
GQM	Groundwater Quality Management
GRDM	Groundwater Resource Directed Measures
GRO	Gasoline Range Organics
GRU	Groundwater Resource Unit
Ha	Hectare
K	Hydraulic Conductivity
km	Kilometre
km^2	Square Kilometre
l/h	litres/hour
l/s	litres/second
LDPE	Low density polyethylene
M	meter
m/d	Meters per day
m^3	Cubic Meters

Term	Definition
m^3/a	Cubic Meters/annum
$m^3/ha/a$	Cubic Meters/hectare/annum
mamsl	meters above mean sea level
mbcl	meters below casing level
mbgl	meters below ground level
ML/d	Mega Litre/day
mm/a	Millimetres/annum
Mm^3/a	Million Cubic Meters/annum
mS/m	Millisiemens per meter
NEMA	National Environmental Management Act
NGA	National Groundwater Archive
nm	not measured
NTU	Nephelometric Turbidity Units
NWA	National Water Act
^oC	Degrees Centigrade
SABS	South African Bureau of Standards
SANAS	South African National Accreditation System
SANS	South African National Standards
SWL	Static water level
T	Transmissivity
TMG	Table Mountain Group
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
WARMS	Water Use Authorization & Registration Management System
WRC	Water Research Commission
WULA	Water Use Licence Application

1 Introduction

DHS Groundwater Consulting Services (Pty) Ltd. was appointed by Familie Roux Eiendomme (Pty) Ltd to conduct a groundwater impact assessment prior to the proposed new development on Portion 91 of Farm 304 Matjesfontein, Keurboomstrand, Western Cape. The purpose of this geohydrological assessment is to determine any impact that the development may have on groundwater, which includes the construction and operation of an onsite wastewater treatment plant (WWTP) as well as the irrigation of gardens with treated effluent.

2 Scope of Work

The objective of this assessment is to:

- Complete a geohydrological characterisation of the groundwater in the vicinity of the site;
- Complete an assessment of the groundwater use in the area by means of a hydrocensus, up to a maximum distance of 1 km from the site;
- Propose measures to mitigate identified negative impacts;
- Advise on a monitoring program as part of an environmental management plan;

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

3 Methodology

It must be stated that no intrusive groundwater investigations were done and reporting is thus based on and limited to observations made during the site visit, hydrocensus and the collation of available information. The work completed for the purposes of compiling a geohydrological report comprised the following:

3.1 Desktop Study

Undertake a desk study of existing information available from relevant literature, the National Groundwater Archive (NGA), the Water Use Authorization & Registration Management System (WARMS), the National Water Resources Monitoring (NWRM) Network, the Water Management System (WMS) and published geological and geohydrological maps and reports.

3.2 Site Visit & Hydrocensus

A site visit was conducted to evaluate the geology, geohydrology and potential receptors of possible groundwater impacts. A hydrocensus was carried out within maximum distance of a 1km radius to identify legitimate groundwater users, the groundwater potential and quality.

3.3 Aquifer Vulnerability Assessment

The national scale groundwater vulnerability map, which was developed according to the DRASTIC methodology (DWAF, 2005)[1] and recompiled in 2013 was used to assess the project area in terms of "Aquifer Vulnerability". Aquifer Vulnerability can be defined as *"the likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer".*

3.4 Aquifer Characterisation

The aquifer(s) underlying the project area was classified in accordance with "A South African Aquifer System Management Classification"[2] developed by the Water Research Commission and DWAF.

3.5 Impact Assessment

The methodology used herein is broadly consistent to that described in the Environmental Impact Assessment Regulations[3] in terms of the NEMA[4].

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

- Intensity
- Duration
- Extent
- Probability

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

The "Impact Assessment Methodology" is presented in Chapter 8.

4 Setting

4.1 Site Location

The site is located within the Western Cape in the Bitou Municipality in the town of Keurboomstrand. The site is situated on portion 91 of farm 304, Matjesfontein. (Figure 1).

[1] DWAF, 2005. Groundwater Resources Assessment Project, Phase II (GRAII). Department of Water Affairs and Forestry, Pretoria.

[2] Department of Water Affairs and Forestry & Water Research Commission (1995). A South African Aquifer System Management Classification. WRC Report No. KV77/95.

[3] Environmental Impact Assessment Regulations, 2014 published under Government Notice No. 982 in Government Gazette No. 38282 of 4 December 2014

[4] National Environmental Management Act, 1998 (Act No. 107 of 1998) ("NEMA")

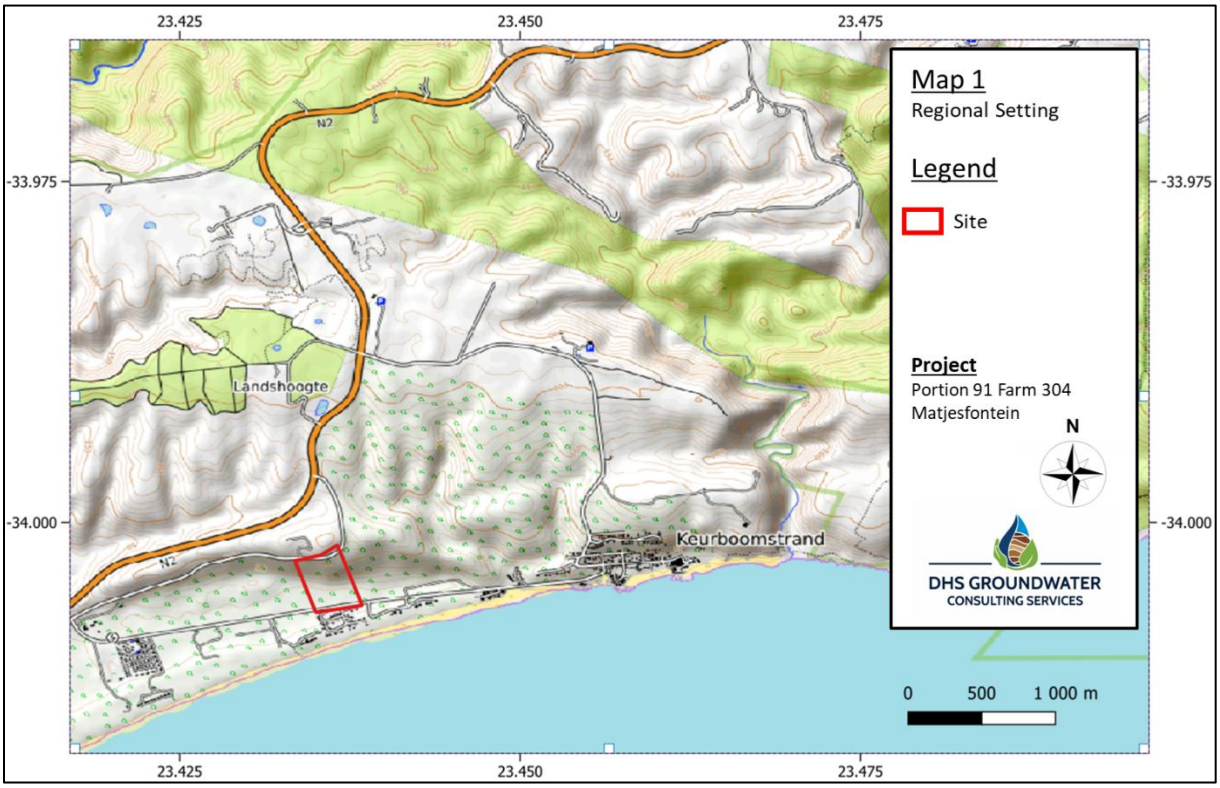


Figure 1. Site locality.

4.2 Topography and Surface Drainage

The site is located in quaternary catchment K60E within the Breede-Olifants Water Management Area (WMA). The northern part of the site has a steep gradient, while the southern part features gently sloping to flat gradients. The site drains from north to south, following the local topographic slopes.

4.3 Climate

The weather is mild without extreme conditions with an average maximum summer temperature of 23.66°C and an average minimum summer temperature of 18°C. The winter months are at an average maximum temperature of 18°C with an average minimum temperature of 12°C . The autumn months of March, April and May receive the lowest average windspeed of 10 km/h while the winter months of June, July and August receive the highest average windspeed of 14.11 km/h.

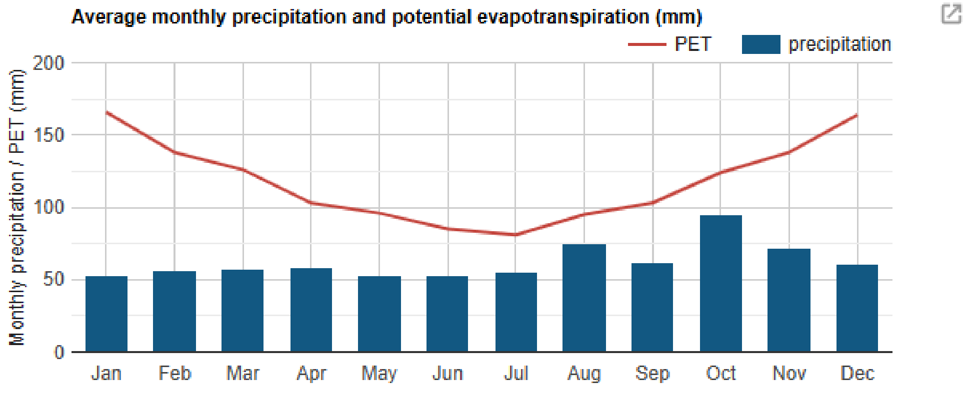
gMeteorological data obtained from SamSam Water Climate Tool[5] is presented in Figure 2. Figures of 751 mm for the mean annual precipitation (MAP) and 1424 mm for the potential evapotranspiration (PET) is reported. The PET exceeds the MAP by an order of magnitude, resulting in a negative moisture index. Rainfall within the study area is bimodal where both summer and winter rainfall occurs, a feature typical of the south-east coastal region of the country.

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

Latitude, longitude: -34.0052, 23.4388

SamSamWater Climate Tool

The average annual rainfall (1970-2000) for this location is 751 mm per year.
Average monthly rainfall and potential evapotranspiration (PET) values are displayed in the chart and table below.



description	PET	precipitation
01 - January	166	53
02 - February	138	56
03 - March	126	57
04 - April	103	59
05 - May	96	53
06 - June	85	53
07 - July	81	55
08 - August	95	75
09 - September	103	62
10 - October	124	95
11 - November	138	72
12 - December	164	61
Total	1,424	751

To copy the data for use in other software: click on the icon in the top-right corner of the table to open in a new tab. There you can select and copy the values.

Close

The data in this tool is sourced from WorldClim v2 and Global Aridity Index and Potential Evapotranspiration (ET0) Climate Database v2 . For questions or remarks on the data, please contact these organisations.

Figure 2. Precipitation and evapotranspiration within the project area.

4.4 Geology

The site is underlain by the Gydo Formation in the north, whilst the Kirkwood Formation is seen to underly the central portion of the site. To the south, the quartenary sands of the Kleinbrak- and Strandveld Fromations are observed.

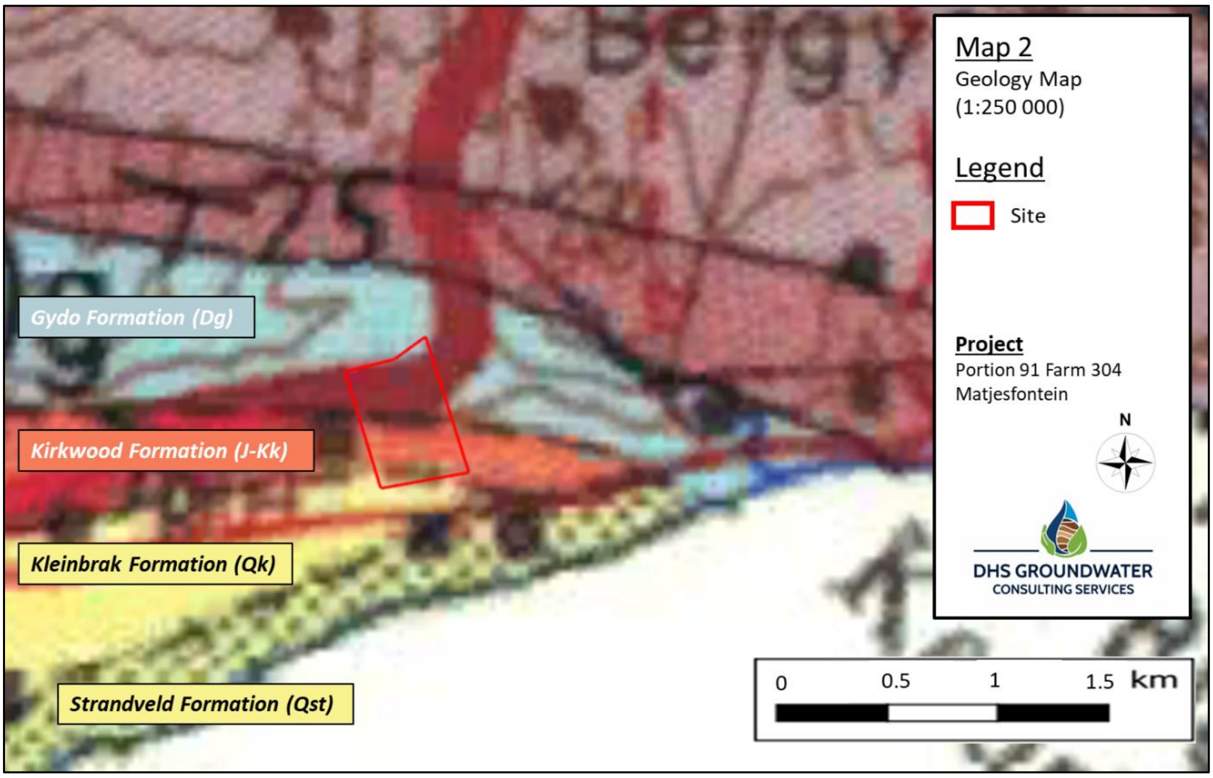


Figure 3. 1:50 000 Geological map.

The Gydo Formation is primarily made up of mudrock and siltstone, and is part of the Bokkeveld Group within the Cape Supergroup. It is covered by the Kirkwood Formation, which consists mainly of variegated silty mudstone and sandstone, along with some grey shale. The Kirkwood Formation belongs to the Uitenhage Group. Above this, the Kirkwood Formation is overlain by Quaternary deposits including sand, sandstone, calcarenite, gravel, and conglomerate from the Kleinbrak Formation, and unconsolidated dunes from the Strandveld Formation. Both the Kleinbrak- and Strandveld Formation form part of the Bredasdorp Group of sediments. The lithostratigraphy is shown in Table 1.

Table 1. Lithostratigraphy of underlying geology.

Supergroup	Group	Formation	Lithology
	Bredasdorp	Strandveld (Qst)	Unconsolidated dunes
		Kleinbrak (Qk)	Sand, sandstone, calcarenite, gravel, conglomerate
	Uitenhage	Kirkwood (J-Kk)	Silty mudstone, sandstone, grey shale
Cape Supergroup	Bokkeveld	Gydo (Dg)	Mudrock, siltstone

4.5 Geohydrology

4.5.1 Desktop Study

4.5.1.1 General Groundwater Understanding

Groundwater refers to water located in the saturation zone, which lies beneath the aeration (or unsaturated) zone. The unsaturated zone functions like a sponge, allowing water to seep down into the saturation zone. The boundary between these two zones is called the water table, as depicted in Figure 8[6].

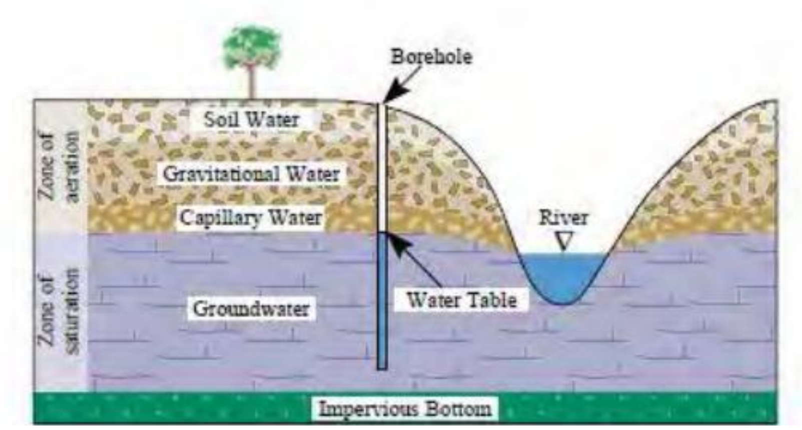


Figure 4. The basic concept of groundwater[6].

An aquifer is a geological formation that holds sufficient water for economical uses, such as domestic consumption[7]. There are two main types of aquifers: porous shallow weathered aquifers and deep fractured rock aquifers. The porous shallow weathered aquifers are made up of individual grain particles like sand, gravel, and silt. In contrast, fractured rock aquifers are geological formations where groundwater flows along fractures, joints, and other discontinuities in the rock[6]. Geology plays a crucial role in groundwater flow, as the type of geological formation determines how groundwater moves[7].

It is important to note that geology and groundwater are in very close relation to each other because the type of geology governs the flow of groundwater[7].

[6] KRUSEMAN, G.P. & DE RIDDER, N.A. 1991. Analysis and Evaluation of Pumping Test Data. Second Edition. International Institute for Land Reclamation and Improvement. Publication 47. Wageningen, the Netherlands.

VAN TONDER, G., BARDENHAGEN, I., RIEMANN, K., VAN BOSCH, J., DZANGA, P. & XU, Y. 2001. Manual on Pumping test analysis in fractured rock aquifers. University of the Free State, Bloemfontein. South Africa.

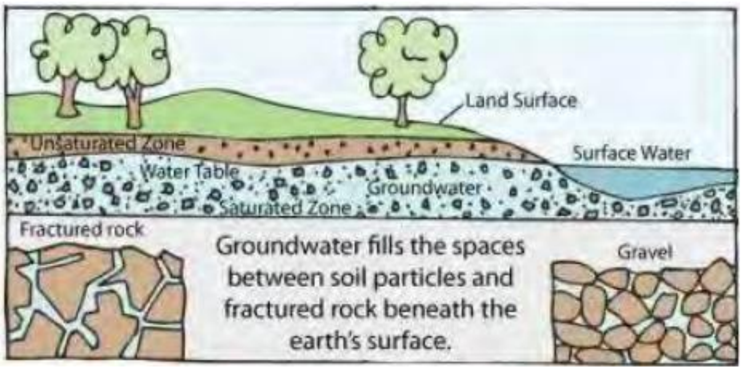


Figure 5. The basic concept of aquifers.

Unless otherwise stated, the published 1:500 000 General Hydrogeological Map[8] and associated explanatory booklet[9] were used as basis to describe the geohydrological conditions.

4.5.1.2 Aquifer Types and Borehole Yields

Groundwater within the project area occurs predominantly within intergranular aquifers with reported yields of 0.5 – 2.0 L/s.

4.5.1.3 Depth to Groundwater

The static groundwater level generally occurs at approximately 50.10m below surface. It must be stated that this is low resolution interpolation and is an average. It is not intended to define water level depths on small scale.

4.5.1.4 Groundwater Recharge and Baseflow

The study area falls within quaternary catchment K60E. The mean annual precipitation and annual recharge figures for the study area is presented in Table 2. Vegter's (1995)[10] recharge and baseflow maps were used to obtain a first estimate of regional recharge and groundwater contribution to rivers and streams (baseflow).

Table 2. Regional Rainfall, Recharge and Baseflow.

Mean Annual Precipitation (mm):	751
Annual Recharge (mm):	75 - 110
Percentage Recharge of MAP:	9.98% - 14.64%
Annual Baseflow (mm):	25 - 50
Percentage Baseflow of MAP:	3.32% - 6.65%

[8] 1:500 000 General Hydrogeological Map, Oudtshoorn 3320 (1998)

[9] MEYER, P S (1999). An explanation of the 1:500 000 General Hydrogeological Map Oudtshoorn 3320. Department of Water Affairs and Forestry, Pretoria.

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

4.5.1.5 Groundwater Quality

Electrical Conductivity (EC) of groundwater in the area is generally between 150 and 370 mS/m[11]. This is considered as a "moderate" water quality with respect to drinking water standards.

4.5.1.6 Aquifer Vulnerability

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

The DRASTIC method takes into account the following factors:

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

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

Aquifer Vulnerability is rated as follows:

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

[11] Murray R, Beker K, Ravenscroft P, Musekiwa, C AND Dennis, R. (2012). A Groundwater Planning Toolkit for the Main Karoo Basin: Identifying and quantifying groundwater development options incorporating the concept of wellfield yields and aquifer firm yields. WRC Report No. 1763/1/11, Pretoria, South Africa.

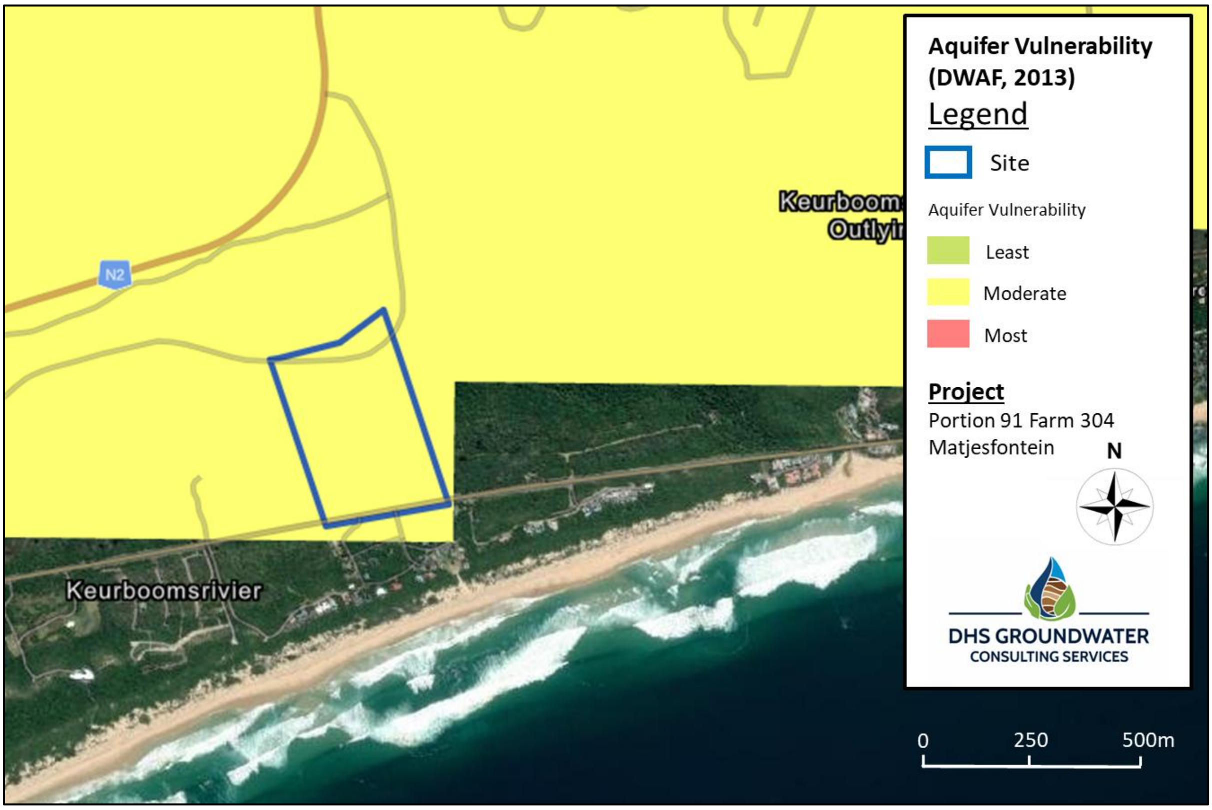


Figure 6. Regional groundwater vulnerability for the study area (DWAF, 2013).

The vulnerability of the aquifers within the project area is rated as "moderate" vulnerable to pollutants. Please note this is a low resolution, regional interpolation of the aquifer vulnerability. A site-specific DRASTIC model is discussed in section 8.2.

5 Site Specific Assessment

5.1 Review of Geotechnical Report – Ref No: 2022\Poise\Report\Geotechnical Report 8.3.2023 Rev0 by Outeniqua Geotechnical Services

Eleven test pits were excavated to a maximum depth of 3 mbgl or to a shallower stoppage due to slope instability or groundwater being intersected.[12].

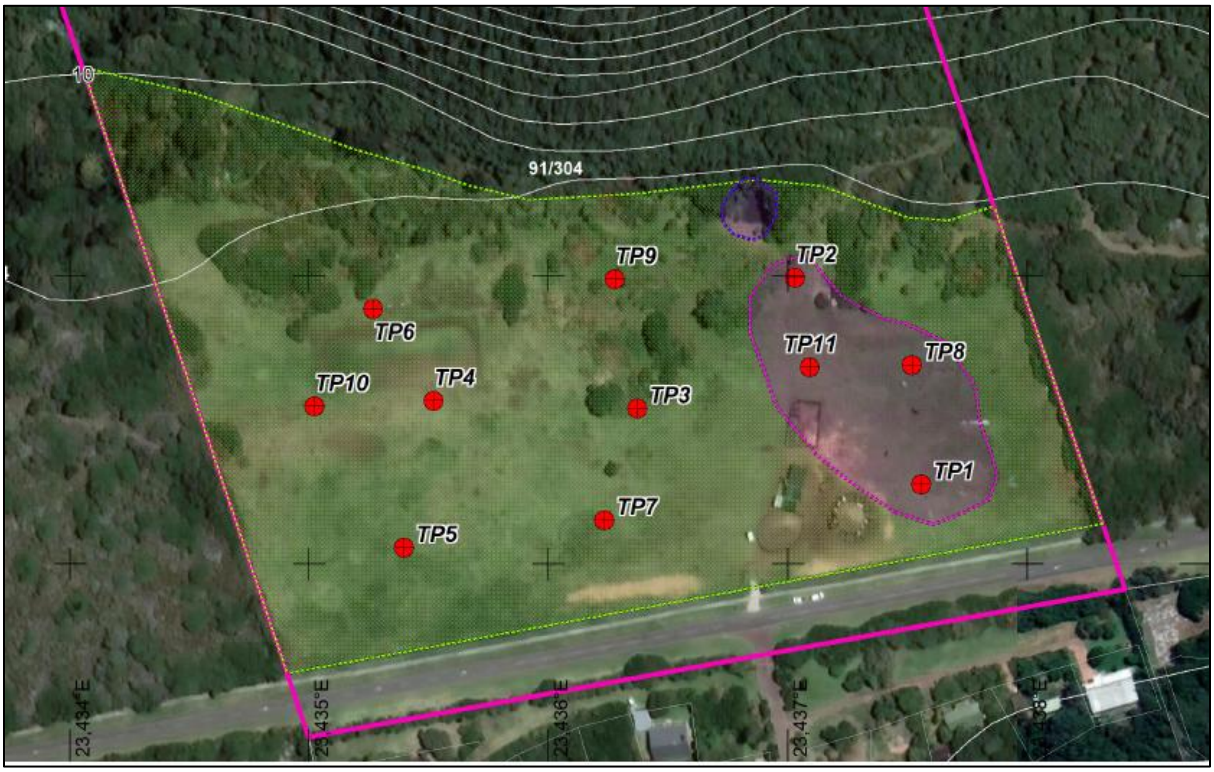


Figure 7. Geotechnical test pit locations.

All test pits were terminated in moist, light yellowish orange, medium dense, intact, transported sand. Above this sand, alternating layers of silty sand and gravelly sand were observed. Groundwater was recorded in TP1 and TP5 at depths of 1.95 mbgl and 2.3 mbgl respectively.

[12] Outeniqua Geotechnical Services. (2023). Geotechnical Report – Proposed New Residential Development on Portion 91 of Matjiesfontein 301, Keurboomstrand, Plettenberg Bay. Ref No: 2022\Poise\Report\Geotechnical Report 8.3.2023 Rev0

5.2 Existing Groundwater Information

The boreholes, well points and spikes as identified from the various databases along with the boreholes identified during the hydrocensus are shown in the below (Figure 8).

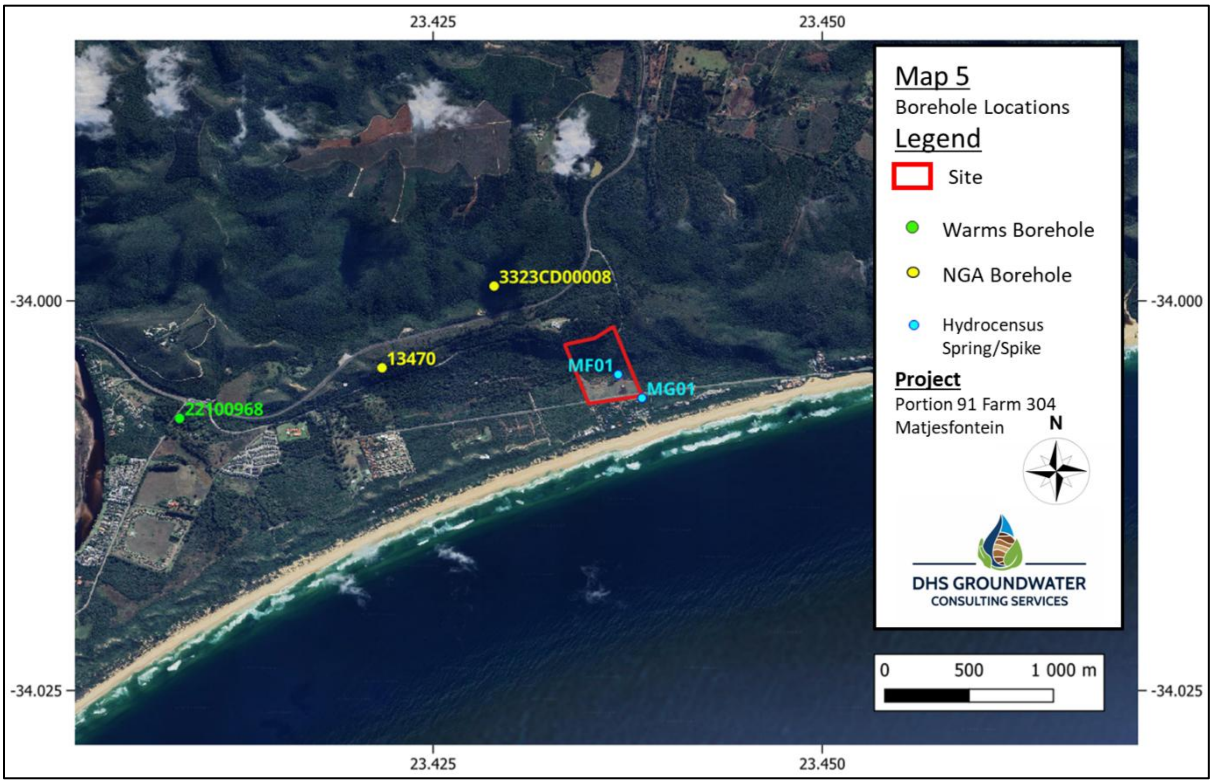


Figure 8. Borehole locations.

5.2.1 National Groundwater Archive

A desktop hydrocensus was carried out within a one-kilometre search radius around the site boundaries. This was done to determine groundwater use in the area. A search of the National Groundwater Archive (NGA), which provides data on borehole positions, groundwater chemistry and yield, when available, was carried out to identify proximal boreholes. These sites are then typically verified in the field and provide background information on the area, should they exist.

A search of the NGA produced zero boreholes within a 1 km radius from the site. The search radius was extended to 3 km and two boreholes were identified. A summary of the borehole data contained in the database is presented in Table 3.

Table 3. Summary of data contained in the NGA.

BH Id	Latitude (°)	Longitude (°)	Water Use	BH Depth (m)	SWL (mbgl)	Yield (L/s)
13470	-34.0043	23.42172	-	61.57	-	-
3323CD00008	-33.99906	23.42892	-	180	-	-

5.2.2 Water Use Authorization & Registration Management System (WARMS)

The WARMS database (updated 20 November 2024) provides (but is not limited to) data on borehole positions, groundwater use and registered abstraction volume. The WARMS indicated there are zero boreholes within the 1 km search area of the site. The search was extended to a 3 km radius which identified one borehole. The identified WARMS site are summarised in Table 4.

Table 4. Summary of data contained in the WARMS.

Register No.	Latitude (°)	Longitude (°)	Water Use	Registered Volume m^3/a
22100968	-34.00754	23.40872	Irrigation	30000

5.3 Hydrocensus

A hydrocensus was conducted on 29 January 2025 to establish groundwater use within the larger project area. The hydrocensus extended to a minimum distance of ~1km from the site boundaries, except where a river or a surface water body exist. The hydrocensus did not extend past such a feature as surface water bodies are usually hydraulically connected to an aquifer, act as a constant-head boundary and a groundwater pollution plume or cone of depression would theoretically not extend past a constant head boundary. Any information pertaining to the abstraction, yield and quality of groundwater was sought.

One spring, onsite, was identified along with a spike on a neighbouring property. Details are shown in below Table 5.

Table 5. Details of boreholes located on neighbouring properties.

BH nr	Coordinates Decimal Degrees (WGS84)	Depth (m)	Estimated Yield (l/s)	EC (mS/m)	Static water level (mbgl)	Equipment	Water Use	Property Owner (Cell nr.)
MG01	S -34.00624 E 23.43842	2	~	290	~	Centrifugal pump	~	Dr Nick Frootko (076 223 0803)
MF01	S -34.00473 E 23.43689	Surface	~	143	~	~	~	Stephan Roux (sroux@world online.co.za)

MG01

MG01

MF01

Figure 9. Photos of hydrocensus sites.

5.4 Groundwater Flow Direction

Groundwater elevations typically follow surface topography, flowing from higher to lower areas, such as springs or valleys. In the described area, the five-meter contours in Figure 10 show inferred groundwater flow directions. The northern part of the site has a steep slope to the south, with the topography flattening further south. Based on this gradient, it is expected that groundwater will flow southward towards the ocean.

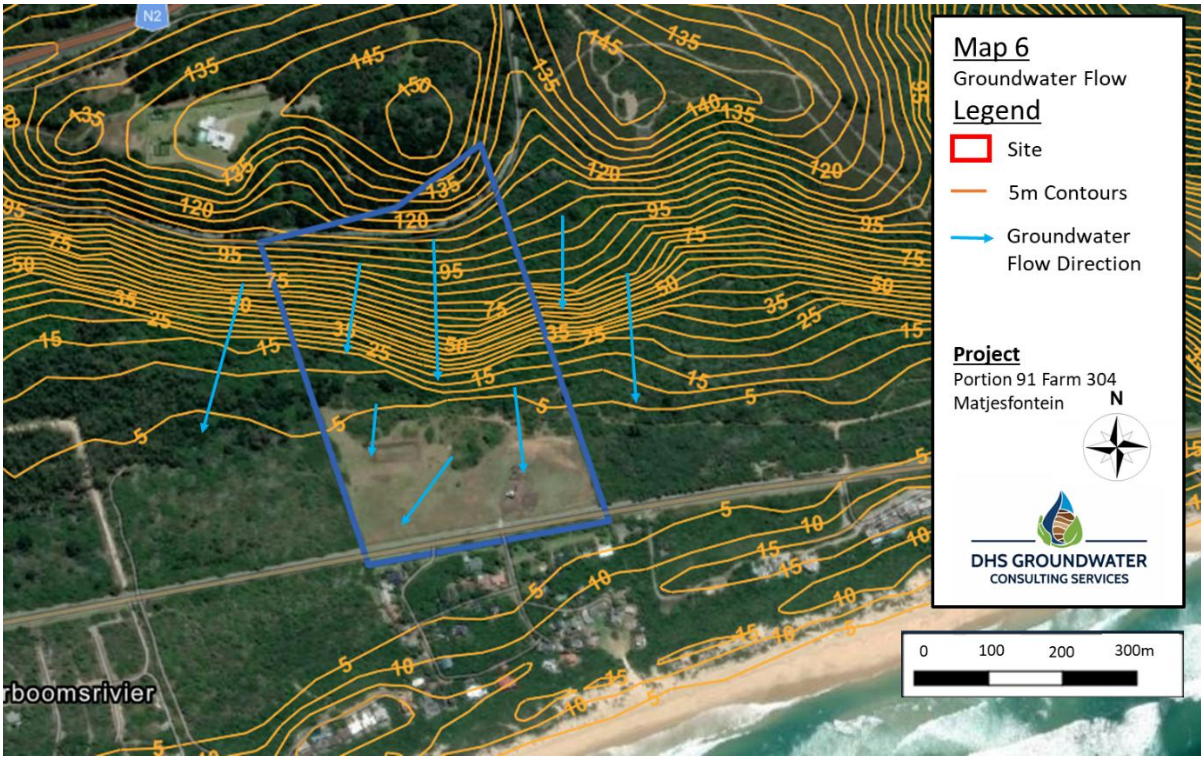


Figure 10. Map with 5m contours showing the inferred groundwater flow direction.

5.5 Groundwater Response Unit

In order to define a more localised area within which groundwater and groundwater users may be affected by potential pollutants, a "Geohydrological Response Unit" (GRU), is delineated. It is defined as a groundwater system that has been delineated or grouped into a single significant water resource based on one or more characteristics that are similar across that unit. Criteria to map a GRU would include:

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

For this study area there are drainage features that enable the definition of a more localised aquifer (i.e., a GRU).

The GRU has been defined as follow:

- The eastern and northern boundaries were defined by topographic highs;
- The western and southern boundary was defined by the topographic lows and the coastal plain.

The mapped GRU covers a total area of 269 ha and is indicated in Figure 11.

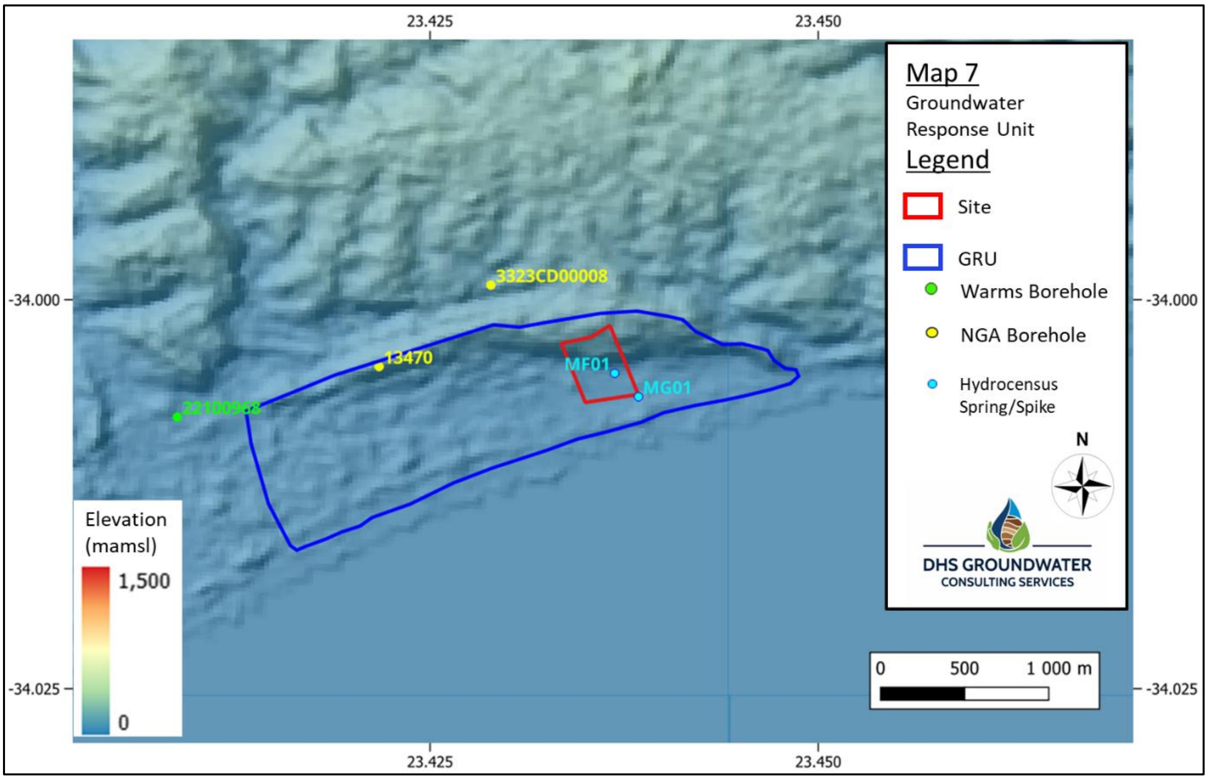


Figure 11. Mapped GRU shown on 30m digital elevation model.

<u>It is important to note that two potential groundwater users were identified within the GRU, along with the onsite spring, from both the DWS databases and during the hydrocensus.</u>

5.6 Groundwater Quality

Groundwater samples were collected for analysis of the major ions and trace elements from the hydrocensus spring MF01, situated within the site perimeter, and spike MG01 which is approximate 30 m south of the site. The laboratory reports are presented in Appendix A.

Water quality results were compared with the SABS drinking water standards (SANS 241-1:2015, edition 2)[13] (Table 6). Water is classified unfit for human consumption if the Standard Limits are exceeded.

[13] SABS drinking water standards (SANS 241-1:2015) Second Edition. SABS Standards Division, March 2015. ISBN 978-0-626-29841-8

Table 6. Water quality results compared to SANS 241-1:2015 (edition 2) drinking water standards.

Sample Nr.	MG01	MF01	Standard Limits
pH	7.21	6.88	5.0 - 9.7
EC	380	167.5	170
TDS	2470	1089	1200
T-Alk	387.6	194.4	~
Cl	1089.02	424.72	300
SO_4	236	85	250
NO_3-N	0.8	0.7	11
NO_2-N	0.003	0.002	0.9
NH_4-N	0.2	0.4	1.5
F	0.85	0.77	1.5
Ca	280.365	70.264	~
Mg	90.33	26.379	~
Na	528.005	317.91	200
K	17.224	3.939	~
Fe	0.46	0.27	0.3
Mn	0.452	0.37	0.1
Cu	0	0	2
Zn	0	0	5
E.Coli (cfu/100ml)	0	0	0
Total Coliform (cfu/100ml)	35	27	10
Turbidity	6.01	1.75	5

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

EC measurements in mS/m, Tubidity in NTU, other parameters in mg/ℓ

Based on Table 6, both water samples, MG01 and MF01, are deemed unfit for human consumption. Both samples contain elevated levels of chloride (Cl), sodium (Na) and manganese (Mn), exceeding the SANS 241:2015 drinking water standards. Additionally, MG01 exhibits elevated electrical conductivity (EC), total dissolved solids (TDS) and iron (Fe).

The water quality is also compared to Department of Water Affairs, 1998 Quality of Domestic Water Supplies[14]. The results are colour coded according to the different classification classes as determined by DWAF (1998) (Table 7 and Table 8)

14 DWS - DEPARTMENT OFWATERAFFAIRS AND FORESTRY 1998. Quality of Domestic Water Supplies. Water Quality, 2nd edn. Department of Water Affairs and Forestry, Pretoria, South Africa, http://www.wrc.org.za

Table 7. DWAF (1998) Quality of Domestic Water Supplies classification scheme.

Quality of Domestic Water Supllies, DWA&F, Second Edition 1998	
Class 0	- **Ideal water quality** - Suitable for lifetime use
Class 1	- **Good water quality** - Suitable for use, rare instances negative effects
Class 2	- **Marginal water quality** - Conditionally acceptable - Negative effects may occur in some sensitive groups
Class 3	- **Poor water quality** - Unsuitable for use without treatment. Chronic effects may occur
Class 4	- **Unacceptable water quality** - Totally unsuitable for use. Acute effects may occur

Table 8. Classified groundwater sample results according to DWAF 1998.

Sample:	MG01	MF01	DWAF (1998) Domestic Water Use Assessment Guide				
			Class 0	Class 1	Class 2	Class 3	Class 4
pH	7.21	6.88	5-9.5	4.5-5 & 9.5-10	4-4.5 & 10-10.5	3-4 & 10.5-11	< 3 & >11
Conductivity (mS/m)	380	167.5	<70	70-150	150-370	370-520	>520
Turbidity (NTU)	6.01	1.75	<0.1	0.1-1	1.0-20	20-50	>50
	Concentration as mg/l						
Hardness (as CaCO3)	1072.05	284.08	<200	200-300	300-600	>600	
Calcium (as Ca)	280.365	70.264	<80	80-150	150-300	>300	
Chloride (as Cl)	1089.02	424.72	<100	100-200	200-600	600-1200	>1200
Copper (as Cu)	0.002	0.002	<1	1-1.3	1.3-2	2.0-15	>15
Fluoride (as F)	0.85	0.77	<0.7	0.7-1.0	1.0-1.5	1.5-3.5	>3.5
Iron (as Fe)	0.46	0.27	<0.5	0.5-1.0	1.0-5.0	5.0-10.0	>10
Magnesium (as Mg)	90.33	26.379	<70	70-100	100-200	200-400	>400
Manganese (as Mn)	0.452	0.37	<0.1	0.1-0.4	0.4-4	4.0-10.0	>10
Nitrate & Nitrite (as N)	0.08	0.07	<6	6.0-10	10.0-20	20-40	>40
Potassium (as K)	17.224	3.939	<25	25-50	50-100	100-500	>500
Sodium (as Na)	528.005	317.91	<100	100-200	200-400	400-1000	>1000
Sulphate (as SO4)	236	85	<200	200-400	400-600	600-1000	>1000

According to the DWAF (1998) guidelines, water from spike MG01 is classified as Class 4, indicating unacceptable water quality due to elevated hardness. Additionally, high levels of sodium (Na) and chloride (Cl) further degrade its quality. Elevated turbidity, calcium (Ca), and manganese (Mn) are also observed. Water from MF01 is classified as Class 2, indicating marginal water quality, due to elevated turbidity, chloride (Cl), and sodium (Na).

To obtain the chemical characterisation of the water, the relative concentrations of the cations and anions were plotted on a Piper Diagram and Stiff Diagrams (Figure 12 and Figure 13).

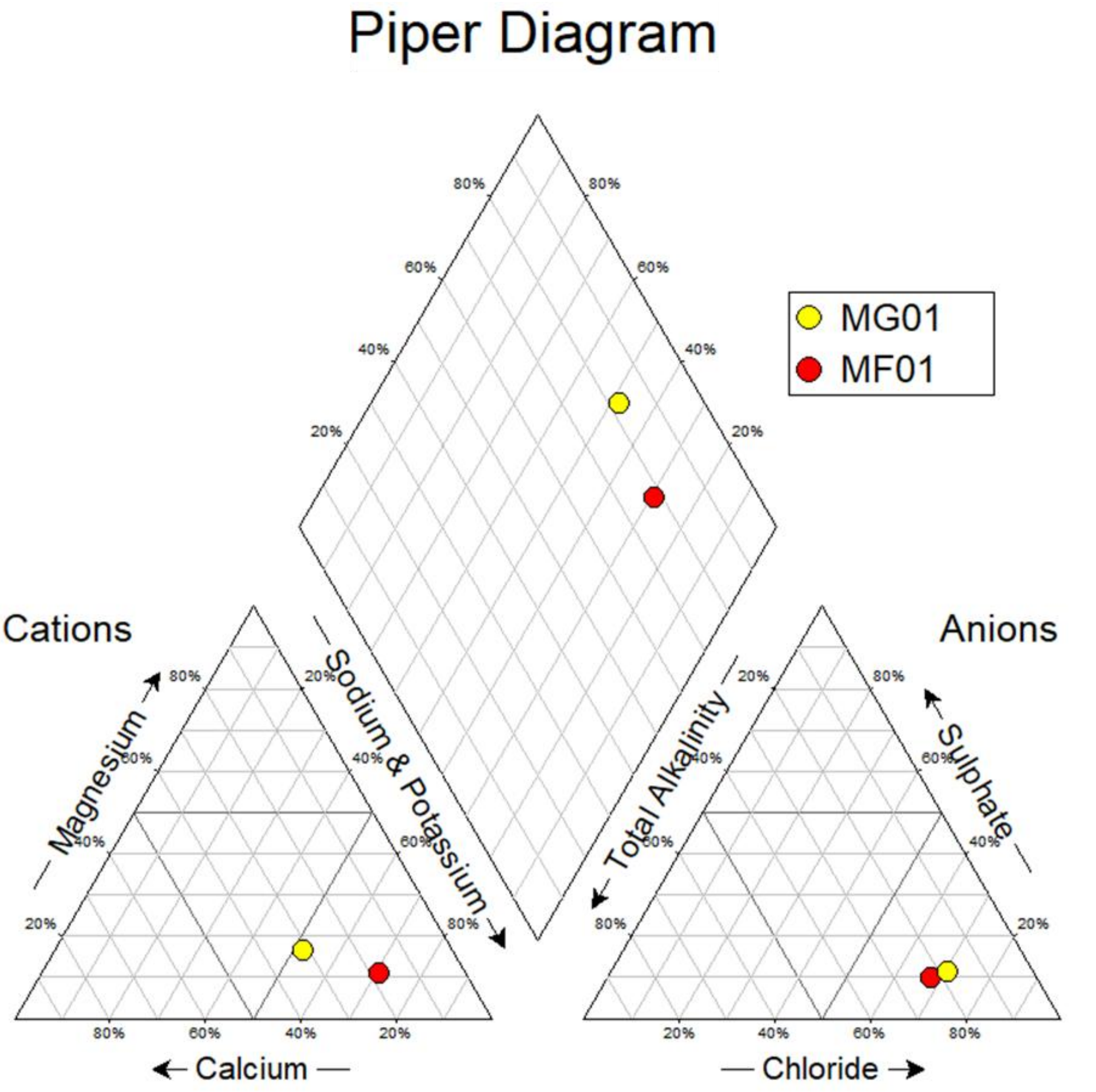


Figure 12. Piper Diagram of hydrocensus samples.

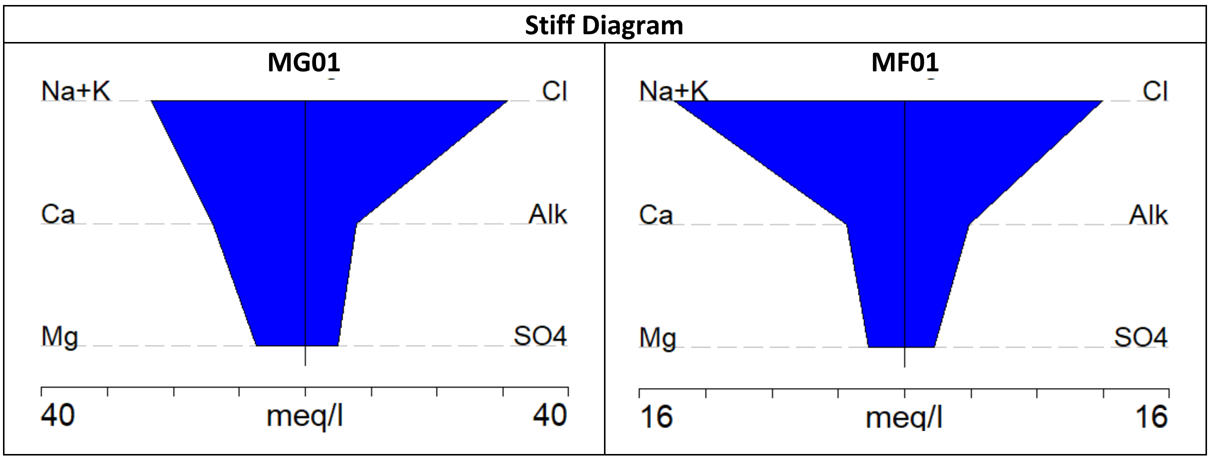


Figure 13. Stiff Diagrams of hydrocensus samples.

Both the Piper Diagram and Stiff Diagrams indicate that MG01 and MF01 exhibit a sodium chloride (Na-Cl) type water composition.

6 Aquifer Classification

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

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

Based on the available information it can be concluded that aquifer system in the study area can be classified as a "Minor Aquifer System". The aquifers are mostly important to maintain baseflow to the ecosystem and seldom produce large quantities of groundwater.

In order to achieve an Aquifer System Management Index and a Groundwater Quality Management Index a point scoring system, as presented in Table 9 and Table 11 below, was used.

Table 9. Ratings for the Aquifer System Management and Second Variable Classifications.

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

The values in Table 9 are naturally subjective, but is based on the aquifer descriptions given previously. The importance of each aquifer should provide guidance on the protection to be assigned to each area.

The level of protection required of a groundwater system depend, amongst other, on the aquifer system classification class and the fractured extent and connectivity of the aquifers. The assumption is that a higher fracture presence results in a higher aquifer connectivity. An aquifer system management index can be derived with the following equation:

Aquifer System Management Index = Aquifer System Management Class x Fracturing

= 4 x 3 = 12

Table 10. Ratings for the Aquifer System Management Index.

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

The ratings for the Aquifer System Management Classification and Second Variable Classification (Fracturing) yield an Aquifer System Management Index of 2 for the study area, indicating that a "low" level of groundwater protection is required in terms of prevailing groundwater flow regime management.

Table 11. 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	4
Minor Aquifer System:	2	
Non-Aquifer System:	0	
Special Aquifer System:	0 - 6	
Aquifer Vulnerability Classification		
Class	Points	Study area
High:	3	
Medium:	2	2
Low:	1	

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

GQM Index = Aquifer System Management x Aquifer Vulnerability

= 4 X 2 = 8

Table 12. GQM index for the study area.

GQM Index	Level of Protection	Study Area
<1	Limited	8
1 - 3	Low Level	
3 - 6	Medium Level	
6 - 10	High Level	
>10	Strictly Non-Degradation	

The ratings for the Aquifer System Management Classification and Aquifer Vulnerability Classification yield a Groundwater Quality Management Index of 8 for the study area, indicating that a "high" level of groundwater protection is required in terms of groundwater quality management.

In terms of DWS's overarching water quality management objectives which is (1) protection of human health and (2) the protection of the environment, the significance of this aquifer classification is that if any potential risk exists, measures must be triggered to limit the risk to the environment. In this instance it would be the (1) protection of the "Major Aquifer", (2) the external groundwater users in the area, and (3) maintain baseflow to the surrounding ecosystems dependent on groundwater.

7 Preliminary Risk Assessment

7.1 Groundwater Contamination

In order to assess the risks associated with the proposed development at the site with specific reference of the operational working of the WWTP, the "Source-Pathway-Receptor" principle was applied as outlined in the G4 Impact Prediction Best Practice Guideline for the Mining Industry (DWA, 2007)[15] . The following preliminary risk assessment is based on the information collected during the desktop study, literature review and fieldwork assessment.

7.1.1 Identified Sources

The sources of groundwater contamination for the development can be grouped into those associated with the construction phase as well as the operational phase.

7.1.1.1 Construction Phase

During the construction phase, several sources of pollution pose risks to both soil and groundwater contamination. These sources include:

- **Hydrocarbons, paint, solvents, cleaners, and other harmful chemicals**: These materials, if not managed properly, can leak or spill onto the ground, contaminating the soil and potentially reaching the groundwater. Improper use, storage, disposal, or spillage of these substances can lead to significant contamination risks.
- **Miscellaneous construction debris and dirt**: Construction debris, if not properly managed or disposed of, can also contribute to soil contamination. If hazardous materials are mixed with general waste, this can increase the risk of harmful substances leaching into the environment.

[15]. 2007. Best Practice Guidelines: Impact Prediction (G4).

- **Improper storage or disposal of solid waste**: If solid waste materials are not stored and disposed of correctly during construction, there is a high chance of soil contamination, which can, in turn, affect groundwater. Waste left on-site or improperly disposed of can release contaminants over time.

- **Contaminants washed into stormwater systems**: If pollutants are spilled on hard surfaces like roads or concrete, they can be washed by rainwater into stormwater systems. From there, they may be discharged into the surrounding environment or directly into local streams, carrying contaminants that can further impact groundwater quality.

7.1.1.2 Operation Phase

Several potential groundwater pollutants may arise from the operation of a Wastewater treatment plant (WWTP), with seepages being one of the primary concerns. These include:

- **Leakages from the sewage pipework system**: If the pipes transporting sewage are not properly maintained or sealed, they can leak untreated or partially treated sewage into the surrounding environment, potentially contaminating groundwater.
- **Leakages from the anaerobic underground raw sewage holding tank**: If there is a failure in the holding tank (such as cracks or faulty seals), raw sewage can seep into the surrounding soil and eventually reach the groundwater, introducing harmful contaminants.
- **Leakages and leachate from the treatment plant**: The wastewater treatment process may generate leachate or other by-products that, if not properly contained, can leak into the ground and contaminate the surrounding soil and groundwater.
- **Irrigation with improperly treated effluent**: If effluent used for irrigation is not properly treated to remove harmful substances, it could contaminate the soil and, eventually, the groundwater. Pollutants such as pathogens, heavy metals, and nutrients may be introduced into the groundwater system.

7.1.2 Pathways

The potential risk pathways at the site are primarily related to the movement of contaminants through different layers of the soil and aquifer system:

- **The weathered soil/vadose zone and the shallow aquifer**: If contaminants leach into the soil and percolate downwards, they can enter the groundwater system. Once in the shallow aquifer, there is a significant risk that these contaminants could spread into the surrounding area, especially if the groundwater is in close proximity to surface water or wells used for drinking or irrigation.
- **The deeper fractured aquifer**: The presence of secondary fractures within the underlying aquifer can act as hydraulic pathways, allowing contaminants to travel deeper. If contaminants make it through the shallow aquifer, they could be transported along these fractures into the deeper aquifer, where the contamination might spread more extensively, affecting larger volumes of groundwater.

7.1.3 Receptor

The receptor of potential contaminants will be the following:

- Shallow and Deeper Aquifer;
- Surrounding environment.

Given the potential for contaminants to affect both the groundwater and the surrounding environment, it is clear that without mitigation plans, the risk of contamination is high.

7.1.4 Recommended Mitigation Plans

To prevent groundwater contamination, it is crucial to properly manage hazardous materials, debris, waste, and stormwater runoff during the construction phase. Implementing strict protocols for handling, storage, and disposal, along with effective spill containment measures, will significantly minimize the risk of pollution. Additionally, regular servicing and maintenance of infrastructure throughout the operational phase are essential to ensure long-term environmental protection.

Monitoring piezometers should be installed to assess at least the shallow aquifer. These piezometers will provide essential data and help track any changes in the shallow aquifer over time. By regularly monitoring the groundwater, it will be easier to identify potential issues such as contamination. This data is crucial for making informed decisions about managing and protecting the groundwater system throughout the development and its operation.

7.2 Groundwater Recharge and Flooding

In addition to groundwater contamination concerns, another key risk is the impact the development could have on groundwater recharge and potential flooding. The alteration of the natural groundwater catchment area—through changes such as increased impermeable surfaces, construction, and modified drainage patterns—can disrupt the natural processes of water infiltration and recharge. This can lead to reduced groundwater replenishment and possibly lower groundwater levels over time. Additionally, such changes could increase the risk of flooding, especially if the development prevents water from naturally flowing or draining in the way it used to. These effects may affect the broader hydrological balance and could have long-term consequences for both surface water and groundwater systems.

7.2.1 Mitigation plans

The developer should carefully design the rain and stormwater drainage systems to balance groundwater recharge and flood prevention. Effective drainage planning will manage surface runoff while promoting natural infiltration, ensuring sufficient water reaches the groundwater while preventing accumulation in undesirable areas that could lead to flooding.

Additionally, installing piezometers—devices used to measure groundwater levels—is essential for ongoing monitoring of the groundwater system. These instruments will provide critical data on groundwater fluctuations, enabling early detection of changes in recharge rates, contamination risks, or potential flooding. Continuous monitoring will help maintain groundwater balance and allow for timely interventions to address any emerging issues.

8 Aquifer Impact Assessment

As outlined in section 7, the primary concern is the potential contamination of groundwater. To assess the vulnerability of the aquifer to pollution, three different assessment methods were employed:

- **Method 1 - Assessment of the reduction of contaminants in the unsaturated zone**: This method focuses on the unsaturated zone and evaluates how easily contaminants may travel from the surface through the soil and unsaturated zone to the water table. It examines the ability of the soil to filter or reduce contaminants before they reach the groundwater.
- **Method 2 - Aquifer vulnerability rating (DRASTIC Index)**: This method uses a rating system based on seven key hydrogeological parameters (such as depth to water, recharge, soil type, etc.) to assess the vulnerability of the aquifer. The DRASTIC Index generates a final vulnerability rating that helps indicate the likelihood of contamination based on the site's conditions.
- **Method 3 - NEMA (2014) Impact Assessment**: This method evaluates the potential risks of groundwater contamination during both the construction and operational phases of the project. Following the criteria established by the National Environmental Management Act (NEMA, 2014), it systematically scores and rates various factors to determine the overall risk to groundwater. Additionally, this assessment considers the potential impacts on groundwater recharge and the risk of flooding, ensuring a comprehensive evaluation of environmental risks.

These three methods collectively provide a comprehensive evaluation of groundwater vulnerability, taking into account the movement of contaminants, the specific characteristics of the aquifer, and the potential environmental impacts throughout the development process. Each method is designed to assess different aspects of the groundwater system, ensuring a thorough understanding of the risks involved.

8.1 Method-1: Assessment of the Reduction of Contaminants in the Unsaturated Zone

Vulnerability in the unsaturated zone refers to how easily contaminants can travel from the surface through soil and rock layers to the water table. This zone acts as the first barrier against groundwater contamination.

At this site, the subsurface consists of silty sand and sand extending to approximately 3 meters below ground level (mbgl). The ability of this layer to reduce contaminants depends on factors such as flow rate, contaminant type, and the soil's capacity to absorb or slow down pollutants. Due to the sandy composition, the unsaturated zone is expected to have high permeability, allowing contaminants to move rapidly with minimal filtration or absorption.

Table 13 evaluates contaminant reduction in an unsaturated zone consisting of mostly silty sand, following the DWAF (1997) Protocol to Manage the Potential of Groundwater Contamination from On-Site Sanitation. A detailed assessment can be found in Appendix A.

The below table summarizes how well the unsaturated zone can filter and reduce contaminants, which is crucial in understanding the potential risks to groundwater contamination.

Table 13. Assessment of the reduction of contaminants in the unsaturated zone.

<table>
<tr><th colspan="2">Unsaturated Zone conditions</th><th>Silty Sand and Sand</th></tr>
<tr><td rowspan="3">Factor affecting reduction</td><td>Rate of flow in unsaturated zone</td><td>Medium to fast 10m/d</td></tr>
<tr><td>Capacity of the media to absorb contaminants</td><td>Minimal</td></tr>
<tr><td>Capacity to create an effective barrier to contaminants</td><td>Medium</td></tr>
<tr><td rowspan="3">Contami nation reductio</td><td>Bacteria and viruses</td><td>High reduction</td></tr>
<tr><td>Nitrates and phosphates</td><td>Minimal reduction</td></tr>
<tr><td>Chlorides</td><td>Minimal reduction</td></tr>
<tr><td colspan="2">Comments</td><td>Good barrier to the movement of biological contaminants, but little reduction in chemical contaminants.</td></tr>
</table>

Table 13 demonstrates that the unsaturated zone effectively reduces the movement of biological contaminants, significantly limiting their potential to reach groundwater. However, it provides minimal resistance to chemical contaminants, allowing them to migrate more easily and increasing the risk of groundwater contamination. This underscores the need for additional protective measures to manage chemical pollutants, particularly in areas with sandy or highly permeable soils where natural filtration is less effective.

8.2 Method-2: Aquifer Vulnerability Rating (DRASTIC Method)

As discussed in section 4.5.1.6, in the DRASTIC method, aquifer vulnerability is determined within hydrogeological settings by evaluating seven parameters denoted by the acronym:

- **D**epth to groundwater – Determined from DWA, GRA2 data, geotechnical test pit profiles,
- **R**echarge – Obtained from DWA, GRA2 data,
- **A**quifer media – Determined from geological maps and geotechnical test pit profiles,
- **S**oil media – Determined from geotechnical test pit profiles,
- **T**opography – Determined by digital elevation data,
- **I**mpact on vadose zone – Determined from geological maps and test pit profiles,
- Hydraulic **C**onductivity – Protocol to Manage the Potential of Groundwater Contamination form on-site Sanitation (DWAF, 1997).

Groundwater vulnerability is assessed by assigning a rating to each relevant parameter based on its influence on contamination risk. These ratings are then weighted according to their significance and summed to determine the DRASTIC Index, which provides an overall measure of groundwater susceptibility to contamination.

A higher DRASTIC Index indicates an increased risk, identifying areas that require enhanced protection and mitigation measures. The results of this assessment, presented in Tables 14 and 15, outline the parameter ratings and calculated vulnerability levels specific to the site. These tables help prioritize areas where targeted management strategies are needed to minimize contamination risks.

Table 14. DRASTIC method: aquifer vulnerability rating for the proposed development.

Parameter	Effect	Rating										Weight	Site rating	Score
		1	2	3	4	5	6	7	8	9	10			
Depth to Water	Increasing depth to water increases time for natural attenuation or remediation of contaminant	> 33m	25 - 33m	17 - 25m		10 - 17m		5 - 10m		2 - 5m	0 - 2m	5	10	50
Recharge	Increasing recharge leads to faster movement of contaminant	0 - 10mm/a	10 - 25mm /a	25 - 37mm/a		37 - 50mm/a	50 - 75mm/a	75 - 110mm/a	110 - 160mm/a	160 - 200mm/a	>200mm/a	4	5	20
Aquifer Media	Increasing porosity increases movement of contaminants		Compact sedimentary rocks with widely spaced fractures	Igneous and/or crystalline metamorphic rocks: fractured	Igneous and/or crystalline metamorphic rocks: fractured and weathered	Compact sedimentary rocks: fractures directly below groundwater level		Compact sedimentary rocks: weathered and fractured	Massive dolomite / limestone. Sand and Gravel		Fractured dolomite / limestone with solution channels	3	8	24
Soil media (Drainage)	Increasing soil drainage decreases time for natural attenuation or remediation		Clay loam and silty clay	Silty clay loam, sandy clay and silty loam	Sandy clay loam and loam	Sandy loam	Sandy loam	Shrinking and/or aggregate clay. Loamy sand	Sand. Shrinking and/or aggregate clay	Sand	Sand	2	9	18
Topography (%Slope)	Increasing slope promotes runoff and decreases downward contaminant movement	> 18		12 - 18		6 - 12				2 - 6	0 - 2	1	10	10
Impact of the Vadose Zone	Increasing vadose zone conductivity decreases time for natural attenuation or remediation of contamination		Mainly compact tillite	Mainly compact tillite and shale. Lava and Intrusives.	Mainly compact tillite, shale and sandstone. Assemblage of compact sedimentary strata, and extrusive and intrusive rocks	Compact sedimentary strata	Compact, dominantly arenaceous strata	Consolidated porous to compact sedimentary strata		Porous unconsolidated to semiconsolidated sedimentary strata	Dolomite, chert, subordinate limestone	5	9	45
Hydraulic **C**onductivity	Increasing vadose zone conductivity decreases time for natural attenuation or remediation of contamination	0.03 - 0.69m	0.69 - 1.35m	1.35 - 2.02m	2.02 - 2.68m	2.68 - 3.34m	3.34 - 10m				>10m	3	6	18
													Final score	**185**

The vulnerability index score (DRASTIC index) for the site is 185. Below is a classification table indicating the class description for the index range.

Table 15. Vulnerability Index Classification

Index range	Class name
<89	Very low
90 – 105	Low
106 – 140	Medium
141 – 186	**High**
187 – 210	Very high
>211	Extremely high

The aquifer's vulnerability to potential pollution sources is classified as "HIGH," indicating a significant risk of contaminants reaching the groundwater table. This suggests that pollutants can easily infiltrate through the soil and unsaturated zone, posing a threat to groundwater quality.

To mitigate this risk, stringent aquifer protection measures are essential. These should include enhanced monitoring, advanced wastewater treatment, secure containment of hazardous materials, and strict management of construction and operational activities. Implementing these safeguards will help prevent contamination and ensure long-term groundwater protection.

8.3 NEMA Impact Assessment

This This assessment method follows the Environmental Impact Assessment (EIA) Regulations and the National Environmental Management Act (NEMA, 2014) to evaluate potential risks to groundwater. The primary concern is the release of contaminated water into the regional hydrological system, which could impact groundwater and aquifers. The assessment considers key factors such as the proximity of contamination sources, pollutant migration potential, and the overall sensitivity of the groundwater system, helping to determine the level of risk posed by the proposed development and guiding mitigation strategies.

In addition to contamination risks, the assessment examines potential impacts on groundwater recharge and flooding. Changes in surface runoff, impervious surfaces, and drainage patterns could disrupt natural recharge processes, leading to reduced groundwater levels. Furthermore, flooding could exacerbate contamination risks and alter groundwater flow. By evaluating these factors together, the assessment provides a comprehensive understanding of the environmental impacts of the development, ensuring that mitigation strategies address all potential risks.

The most significant impacts were individually assessed and graded using a numerical system to determine their overall significance. This process involved an initial evaluation, followed by a reassessment after applying mitigation measures to gauge their effectiveness. A detailed summary of the assessed impacts, mitigation measures, and the significance of each impact—both before and after mitigation—is presented in the tables below. These tables offer a clear overview of potential risks and the steps taken to minimize them, ensuring environmental and groundwater protection. The methodology followed for the NEMA impact assessment is discussed in Appendix C.

Table 16. Impact and risk ratings for the construction phase.

Project Phase	Construction			
Impact	Spillages of diesel, petrol, oil, paints, clears and other harmful chemicals. These substances may potentially percolate into the groundwater and enter the surrounding environment.			
Mitigatability	High		Mitigation exists and will considerably reduce significance of impacts.	
Potential Mitigation	i) Install the sewage and and wastewater infrastructure according to applicable national SANS standards (SANS1200 Part K:Civil Engineering Standard Specifications, SANS10400:The National Building Regulations and Building Standards Act, SANS 1913:Planning, Design, and Construction of Sanitation Systems), DWS Guidelines and adhere to municipal regulations & by-laws. ii) Site to be monitored regularly for contaminant spillages and if detected, contact spillage remediation companies. iiI) Separate, tightly cover and monitor toxic substances to prevent spills and possible site contamination. iv) Cover stockpiles of building materials like cement, sand and other powders. v) Regularly inspect stockpiles for spillages and store away from waterways or drainage areas. vi) Collect any wastewater generated from site activities during construction insettlement tanks then screen, discharge the clean water,and dispose of remaining sludge according to environmental regulations. vii) Install at least three monitoring piezometers into the water table, one upstream and two downstream of site.			
Assessment	**Without mitigation**		**With mitigation**	
Intensity	3	Damage to biophysical and/or social system components	2	Minor damage to biophysical and / or social system components and species. Likely to recover over time. Ecosystem processes not affected.
Duration	3	Medium term: 1-5 years	2	Short term: Less than 1 year
Extent	3	Local Area: Extending across the site and to nearby settlements	2	Limited: Limited to the site and its immediate surroundings
Type	-1	Negative	-1	Negative
Consequence	-9	Slightly detrimental	-6	Slightly detrimental
Probability	4	Probable: Has occurred here or elsewhere and could therefore occur	4	
Significance	-36	Minor - negative	-24	Negligible - negative
Comment on Consequence and Significance	After the implementation of mitigation measures, the significance becomes negligible - negative.			
Cumulative impacts	Since the impact is negligible negative with mitigation, cumulative impacts to groundwater with other projects are not anticipated.			

Table 17. Impact and risk ratings pertaining to potential groundwater contamination during the operational phase.

Project Phase	Operational - Groundwater Contamination			
Impact	i) Leakage from underground sewage holding tank and associated pipework. ii)Leaks and leachate from the wastewater treatment plant. iii) Improperly treated effluent used for irrigation. iv) WWTP failure. All of the aforementioned impacts could percolate into the groundwater.			
Mitigatability	High		Mitigation exists and will considerably reduce significance of impacts.	
Potential Mitigation	i) Ensure the WWTP comply with SANS1200 Part K:Civil Engineering Standard Specifications, NWA, Water Quality Guidelines (DWAF), SANS1913:Planning, Design, and Construction of Sanitation Systems, Wastewater Treatment Plant Design and Operational Guidelines (DWAF, 2008) ii) All areas where potential leachate may occur are to be paved and cemented. iii) Regularly service the WWTP and inspect the integrity and efficacy of the WWTP. iv) Ensure emergency procedures are in place to rapidly repair WWTP should failure occur. v) Set up a comprehensive monitoring system to monitor the effluent quality. vi) Incorporate monitoring network as implemented during the construction phase into operational phase monitoring viii) Install shallow aquifer piezometers in close proximity to the WWTP to be monitored regularly for any leakages. ix) Should a leak be detected or the monitoring piezometers be contaminated, a baseline Phase 1 Contamination Assessment should be undertaken and the site remediated in consultation with a contamination remediation consultant and the Authorities.			
Assessment	**Without mitigation**		**With mitigation**	
Intensity	3	Damage to biophysical and / or social system components and species.	1	Negligible damage to individual components of biophysical and / or social systems.
Duration	3	Medium term: 1-5 years	2	Short term: Less than 1 year
Extent	3	Local Area: Extending across the site and to nearby settlements	2	Limited: Limited to the site and its immediate surroundings
Type	-1	Negative	-1	Negative
Consequence	-9	Slightly detrimental	-5	Negligible
Probability	4	Probable: Has occurred here or elsewhere and could therefore occur	4	
Significance	-36	Minor - negative	-20	Negligible - negative
Comment on Consequence and Significance	After the implementation of mitigation measures, the consequence becomes neglible and the significance, negligible - negative.			
Cumulative impacts	Since the impact is negligible negative with mitigation, cumulative impacts to groundwater with other projects are not anticipated.			

Table 18. Impact and risk ratings pertaining to potential groundwater recharge and potential flooding during the operational phase.

Project Phase	Operational - Groundwater Recharge and Flooding			
Impact	Infrastructure limiting groundwater recharge and/or flooding risk			
Mitigatability	High		Mitigation exists and will considerably reduce significance of impacts.	
Potential Mitigation	i) Permeable pavement and green infrastructure (limit coverage of surface area by infrastructure as far as possible. ii) Rainwater Harvesting iii) Sustainable Urban Drainage Systems (SUDS) iv) Retention and Detention Basins v) Design stormwater drainage systems to handle increased rainfall events by incorporating overflow pathways, sump pumps, and flow control structures. vi) Installation of piezometers to track groundwater level. vii) Inspect and maintain drainage systems, stormwater infrastructure, and mitigation features.			
Assessment	**Without mitigation**		**With mitigation**	
Intensity	3	Damage to biophysical and / or social system components and species.	1	Negligible damage to individual components of biophysical and / or social systems.
Duration	1	Short Term: Less than 1 month	1	Short Term: Less than 1 month
Extent	2	Limited: Limited to the site and its immediate surroundings	1	Very limited: Limited to specific isolated part of the site
Type	-1	Negative	-1	Negative
Consequence	-6	Slightly detrimental	-3	Negligible
Probability	4	Probable: Has occurred here or elsewhere and could therefore occur	4	
Significance	-24	Negligible - negative	-12	Negligible - negative
Comment on Consequence and Significance	After the implementation of mitigation measures, the consequence becomes neglible and the significance ramain as negligible - negative.			
Cumulative impacts	Since the impact is negligible negative with mitigation, cumulative impacts to groundwater with other projects are not anticipated.			

This groundwater risk assessment is based on the data collected during the desktop study and field assessment. While the data provides useful insights, several limitations were identified that need to be taken into account when evaluating the risks:

1. **Lack of Deep Geology Logs:** There are no deep geology logs beyond the depths of the geotechnical boreholes, meaning information regarding the deeper geological strata is limited.
2. **Absence of Aquifer Parameters**: The assessment does not include detailed aquifer parameters, such as permeability, porosity, or aquifer storage capacity, which are important for understanding how water moves through the subsurface and how contaminants may spread.

The impacts on groundwater primarily depend on the shallow geology and, to a lesser extent, on the deeper geology. The shallow water table recorded at depths between 1.95 and 2.30 meters below ground level (mbgl) poses a significant concern. This proximity to the surface increases the likelihood of groundwater contamination from surface activities, particularly from potential contaminants related to the proposed development. However, there is a positive aspect to this shallow water table: it allows for early detection of leaks or contamination, which can help in mitigating the spread of pollutants.

Given the shallow water table, it is critical to implement stringent mitigation measures to prevent any potential groundwater contamination. These measures should be focused on the following:

- **Early detection** of any contaminants or leaks due to the shallow groundwater level.
- **Strict management** of potential contamination sources, such as wastewater treatment and effluent disposal, to ensure that pollutants do not reach the water table.
- **Protecting groundwater recharge** by maintaining the natural flow of water into the aquifers and avoiding excessive impermeable surfaces that may reduce infiltration.
- **Flood prevention measures** to avoid overwhelming the drainage system and ensuring that the natural hydrological system is not disrupted.

Despite the limitations in the available data, the risk of groundwater contamination associated with the proposed development is considered **minor – negative**. However, with the implementation of the appropriate **mitigation strategies**, the significance of this impact can be **reduced to negligible – negative**. It is imperative that these strategies are maintained throughout the construction and operational phases to protect the groundwater and the surrounding environment.

9 Environmental Management & Groundwater Monitoring Program

The primary objective of the proposed mitigation measures, designed to address the identified impacts as identified in Table 16, Table 17 and Table 18, is to ensure the protection and monitoring of local groundwater quality and levels throughout the various phases of the project. These measures are vital to safeguard both the quantity and quality of groundwater resources, thus ensuring the sustainability of this essential resource for all users. The specific goals of these mitigation measures are as follows:

- **To ensure that Schedule 1 water users within the area** have access to groundwater supplies that meet the required standards of quality and quantity, ensuring that the water remains uncontaminated and fit for its intended purposes.
- **To ensure that registered groundwater users within the catchment area** continue to receive an adequate and uncontaminated water supply, safeguarding the long-term viability of the groundwater as a resource for agricultural, industrial, and domestic use.
- **To ensure the availability of groundwater of appropriate quality** to support groundwater-dependent ecosystems, including the baseflow that sustains rivers, streams, and wetlands in the area. These ecosystems rely on a consistent and clean supply of groundwater to thrive, making their protection an essential aspect of sustainable development.

In order to effectively monitor and protect groundwater quality and levels, the installation of piezometers is crucial. It is recommended that three monitoring piezometers be strategically installed within the vicinity of the proposed development. These piezometers should be installed to a depth of 10 meters below ground level (mbgl), with one placed up-gradient of the proposed development (to monitor background groundwater quality) and two placed down-gradient (to track any potential movement of contaminants). Additionally, a fourth piezometer should be placed adjacent to the wastewater treatment plant (WWTP), particularly near the underground sewage storage tank, as this is a critical area for potential contamination. The placement of these piezometers will provide comprehensive coverage for groundwater monitoring across the site, both prior to and after construction.

9.1 Piezometers

9.1.1 Timing of installation

The piezometers should be installed prior to the construction phase in order to establish baseline groundwater quality and levels. This is essential for detecting any early signs of contamination during the construction phase. Monitoring will continue throughout the operational phase to ensure that the groundwater remains uncontaminated and that any potential issues are detected and addressed promptly.

9.1.2 Design and Construction of Piezometers

The piezometers should be appropriately designed and constructed to ensure that they provide reliable and accurate data throughout the project lifespan (see Figure 14).

- The following specifications are recommended for the piezometer installation:
  - **Piezometer Type:** Use PVC piezometers with a maximum depth of 10 meters to capture a broad range of groundwater data. The depth should be sufficient to monitor the water table.
  - **Casing Diameter:** The diameter of the PVC casing should not be less than 110 mm to provide adequate flow of groundwater and to allow for proper monitoring and sampling.
  - **Gravel/Filter Pack:** The hole annulus surrounding the piezometer should be filled with a gravel/filter pack (typically between 2 and 3 mm in diameter). This ensures proper filtration and prevents fine particles from entering the piezometer, which could potentially affect the accuracy of measurements.
  - **Bentonite Seal:** The top 2 meters of the annulus should be filled with a bentonite seal to prevent surface water or other contaminants from entering the piezometer and affecting groundwater readings.
  - **Protection and Marking:** Each piezometer should be equipped with lockable protection to prevent tampering and damage. The piezometers should also be clearly marked and easily identifiable to ensure proper operation and maintenance throughout the development lifecycle.

The construction of the piezometers should be supervised and managed by a qualified geohydrologist to ensure that the installations meet industry standards and are placed in optimal locations for monitoring purposes. The geohydrologist should oversee the entire process, from design to installation, ensuring that the piezometers are constructed in accordance with best practices. No installation should be undertaken without the consultation or supervision of a geohydrologist, as their expertise is critical for the successful monitoring of groundwater quality and levels.

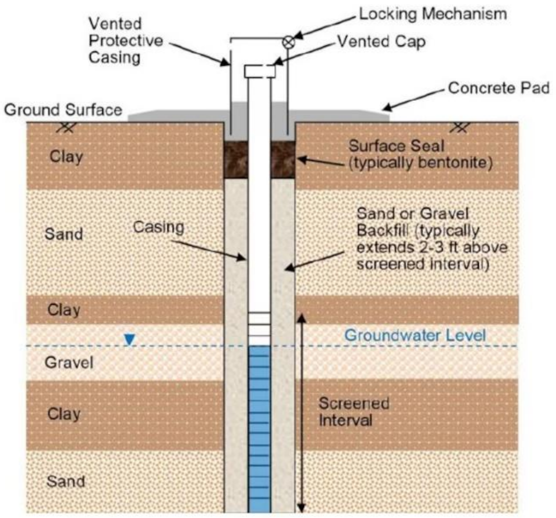


Figure 14. Typical example of a piezometer installation.

9.2 Effluent Quality Monitoring

In addition to monitoring groundwater quality, it is crucial to also monitor the effluent quality from the wastewater treatment plant (WWTP). Regular sampling and analysis of the effluent will help ensure that the treatment processes are effective and that no contaminants are being released into the groundwater system. This will provide additional layers of protection, particularly for areas in close proximity to the WWTP and the underground sewage storage tank.

9.3 Groundwater Monitoring Program

A comprehensive groundwater monitoring program should be developed to outline the specific parameters to be monitored, as well as the frequency of sampling and analysis. Table 19 below presents a proposed list of parameters and recommended monitoring frequencies that should be included in the program. It is essential that this data be captured in an appropriate electronic database, which will facilitate easy retrieval and submission to the relevant authorities as required by regulations. Additionally, the data should be reviewed by a geohydrologist on a quarterly basis to ensure that no contamination is occurring and that groundwater quality remains within acceptable limits.

9.4 Sampling Standards

Groundwater sampling should be conducted in accordance with the SANS 5667-11:2015 standard, which outlines the procedures for groundwater sampling, including the use of proper equipment, handling protocols, and analytical methods. Following these standards ensures that the data collected is accurate, reliable, and consistent, allowing for effective monitoring and timely intervention if necessary.

By implementing these mitigation measures and ensuring regular, systematic monitoring, the risk of groundwater contamination can be significantly reduced, and the long-term sustainability of local water resources can be maintained. The early detection capabilities afforded by the piezometer network will provide valuable insights into groundwater quality, allowing for proactive management and timely corrective actions if any issues are identified. The comprehensive monitoring program, in conjunction with the oversight of qualified professionals, will help ensure that both the development and the surrounding environment are adequately protected throughout the project lifecycle. The proposed monitoring is presented in Table 19.

Table 19. Proposed Monitoring Requirements.

Class	Parameter	Frequency	Motivation
Physical	Static groundwater levels	Monthly	Groundwater recharge, flooding risk, temporal variation
Chemical	Faecal Coliforms, COD, pH, Ammonia as Nitrogen, Nitrate/Nitrite as Nitrogen, Chlorine as free Chlorine, EC, Orthophosphate as phosphorous, Fluoride, Soap oil or grease, Major ions and trace elements.	Monthly	Changes in chemical and microbial composition may indicate areas of groundwater contamination and be used as an early warning system to implement management/remedial actions.

9.5 Additional Mitigation Measures

In addition to installing piezometers and monitoring groundwater quality and levels, the following management and mitigation measures are recommended:

a. Waste Containment and Infrastructure

- Use synthetic/geotextile liners and impermeable surfaces approved by the Department of Water and Sanitation (DWS) in areas where sewage and associated waste are handled.
- Construct all sewer lines and pipes to ensure leak-proof systems that prevent contamination.
- Ensure that sewage holding tanks and accommodation facilities are properly managed to prevent overflow and spillage.

b. Inspection, Maintenance, and Leak Prevention

- Conduct regular inspections and upgrades of pipes and associated infrastructure to maintain system integrity.
- Install leak monitoring devices in the sewage system to enable early detection and proactive groundwater contamination prevention.
- Keep the facility clean and well-maintained at all times to reduce the risk of pollution.

c. Waste Management and Disposal

- Dispose of all waste at registered landfill sites; on-site dumping and disposal in surrounding areas are strictly prohibited.
- Sludge and waste must not be disposed of on-site due to the shallow groundwater table, which increases the risk of contamination.
- Properly clean up and dispose of spills or sludge at a registered landfill site to prevent environmental hazards.
- Ensure that all waste-handling surfaces are impermeable to prevent leaks and seepage.

d. Stormwater and Runoff Management

- Implement an effective stormwater management system to prevent runoff from coming into contact with waste.
- Divert and control stormwater to reduce contamination risks.
- By implementing these measures, the risk of groundwater contamination, infrastructure failure, and regulatory non-compliance can be significantly reduced.
- Implement green infrastructure and permeable surfaces to enhance infiltration, reduce runoff through rainwater harvesting and SUDS, and manage excess water using retention and detention basins. Design stormwater drainage systems to handle heavy rainfall with overflow pathways, sump pumps, and flow controls. Install piezometers for groundwater monitoring and conduct regular inspections and maintenance of drainage systems to ensure long-term effectiveness.

10 Post Closure Management Plan

With respect to groundwater and geology predicted potential impacts, the following remediation measures must be considered when the facility suspends all activities and the facility closes.

- Upon completion of activities, the site must be rehabilitated through appropriate landscaping, levelling, topsoil dressing, and land preparation. Alien plant species must be eradicated, and vegetation must be established as required by the Environmental Control Officer.
- Piezometers must be securely sealed to prevent damage and to avoid debris accumulation.
- All temporary infrastructure and construction structures must be completely removed from the site.
- Rehabilitation structures must be regularly inspected for debris accumulation, blockages, instability, and erosion. Any identified issues must be promptly addressed with remedial and maintenance actions.
- Topsoil backfilling must only be conducted when the soil is dry and should not take place immediately after rainfall events.
- Whenever possible, topsoil should be reused in situ during construction or replaced immediately after construction in a given area is completed.
- Topsoil must be returned to the same location from which it was originally stripped.
- The developer must monitor the regrowth of invasive plant species for a period of one (1) year.
- All disturbed areas must be re-vegetated using indigenous plant species suitable for the local environment.

11 Discussion

According to the Department of Water and Sanitation (DWAF), the site is underlain by a low-yielding, intergranular aquifer that predominantly consists of shallow, unconsolidated formations. These shallow aquifers are typically more vulnerable to contamination due to their composition and proximity to the surface. This is supported by the geotechnical investigation, where groundwater was intersected at relatively shallow depths in two geotechnical test pits, TP1 and TP5, at depths of 1.95 meters and 2.3 meters below ground level (mbgl), respectively. These test pits encountered silty sand and sand layers, which are indicative of the aquifer's permeable nature and further reinforce the likelihood of groundwater presence within these shallow formations.

As part of the hydrocensus, three boreholes, a spring, and a groundwater spike were identified within a reasonable radius of the site, specifically within a 1 km radius and up to 3 km, or within the defined Groundwater Response Unit. These findings, combined with data from various Department of Water and Sanitation (DWS) databases, provide a broader context for understanding groundwater flow dynamics in the region. Based on the national electrical conductivity map of South Africa, groundwater within this area exhibits moderate water quality, with electrical conductivity values ranging from 150 to 370 mS/m. The chemistry of the MG01 and MF01 water samples, taken during the hydrocensus, reflects similar characteristics, with electrical conductivity (EC) values of 380 mS/m and 167.50 mS/m, respectively. However, both samples are unfit for human consumption based on the SANS 241:2015 drinking water standards. Both samples exhibit elevated levels of chloride (Cl), sodium (Na), and manganese (Mn), exceeding the acceptable limits. Additionally, MG01 shows elevated electrical conductivity (EC), total dissolved solids (TDS), and iron (Fe). According to the DWAF (1998) guidelines, water from MG01 is classified as unacceptable (Class 4) due to high hardness, with further quality degradation from elevated sodium (Na) and chloride (Cl). Elevated turbidity, calcium (Ca), and manganese (Mn) are also present. Meanwhile, MF01 is classified as marginal water quality (Class 2) due to elevated turbidity, chloride (Cl), and sodium (Na).

The vulnerability of the aquifer at this site is initially categorized as "moderate" based on national-scale DRASTIC data, a commonly used index for assessing groundwater vulnerability to contamination. However, when considering localized factors such as the permeability of the shallow unconsolidated formations, the presence of contamination sources, and the aquifer's close proximity to human activity, the vulnerability rating increases to "high." This localized, high vulnerability is further corroborated by the Aquifer System Management Index and the Groundwater Quality Management Index, both of which also indicate a high-risk classification for this site. Given that the intergranular aquifer consists primarily of shallow, unconsolidated material, it is particularly sensitive to contamination and requires stringent protective measures to mitigate potential risks.

To assess the potential impacts from the proposed development, both during the construction and operational phases, the Source-Pathway-Receptor model was applied. This model is a widely used framework that helps assess how contaminants could migrate from their source to the receptor through various pathways. In this case, potential contamination sources include spillage of toxic chemicals during construction, improper handling and storage of hazardous materials, and leakages from the wastewater treatment plant (WWTP) and associated pipework. The underlying aquifer, consisting of both shallow and deeper aquifers, is of concern because it serves as both a pathway for contaminants and a receptor for these pollutants. Given the shallow depth of the water table, contaminants are more likely to migrate rapidly into the groundwater system, with the shallow aquifer being the primary concern due to its vulnerability and accessibility.

The primary receptors of contamination are the shallow aquifer, with the deeper aquifer being a secondary receptor. Identified groundwater users at site MG01, along with a nearby spring (MF01), are also considered receptors of potential contamination. In addition to these, the surrounding environment may be affected if contaminants reach the surface or move laterally into adjacent areas. However, due to the localized nature of the site and the protective characteristics of the surrounding terrain, it is expected that any contamination will be largely confined to the immediate area of the development.

Based on this assessment, the risk of groundwater contamination during both the construction and operational phases of the development is classified as minor-negative. While this risk is relatively low, special attention must be paid to the shallow aquifer due to its proximity to potential contamination sources. The presence of a shallow water table offers a positive aspect: it facilitates early detection of any leaks or contamination through the use of piezometers, which can monitor changes in groundwater levels and quality. This early detection system allows for proactive management and remediation. However, it is essential that rigorous mitigation measures are implemented, including the proper containment of potential contaminants, use of spill containment systems, and regular inspections of infrastructure to prevent leakage. **By enforcing these mitigation strategies, the risk to the aquifer can be reduced to negligible-negative**. Furthermore, it is crucial to establish a regular monitoring program to assess groundwater quality throughout the life of the development, ensuring that contamination is detected early and addressed promptly.

In addition to concerns regarding potential contamination, the development also poses risks to the natural groundwater recharge process and may exacerbate the potential for flooding. The subsurface in this area primarily consists of sand, which has high permeability and is less likely to cause groundwater mounding and flooding. Additionally, groundwater recharge occurs over a broad region rather than being site-specific. It is thus not anticipated to significantly diminish the natural recharge of the aquifer. However, it is still important to consider the potential for changes to the local hydrology due to the alteration of land surfaces and drainage patterns. Modifications to the site, such as the construction of impervious surfaces or changes in runoff flow, could disrupt the natural groundwater recharge and increase the risk of localized flooding.

To mitigate these risks, appropriate stormwater management measures should be implemented to manage runoff effectively and maintain groundwater recharge. This includes the use of permeable pavements, retention ponds, and managed drainage systems that ensure water infiltrates into the ground rather than being directed away from the site. **By adopting these strategies, the risk of flooding can be minimized, with a goal of reducing it to negligible-negative.**

In conclusion, while the development poses a potential risk to both groundwater quality and natural hydrological processes, the implementation of stringent mitigation measures—such as early detection systems, regular monitoring, and appropriate stormwater management—can significantly reduce these risks. By carefully managing the construction and operational phases and addressing the identified vulnerabilities, the impacts of the development on the groundwater system can be minimized, preserving the integrity of both the aquifer and the surrounding environment.

12 Conclusion & recommendations

The following recommendations are made to ensure the protection of groundwater resources to mitigate the potential risks of contamination, recharge and flooding during both the construction and operational phases of the development:

- **Mitigation Measures:** Implement and strictly adhere to prescribed mitigation measures to minimize environmental impact and ensure compliance with relevant regulations.
- **Monitoring Network Installation:** It is strongly recommended that the monitoring network be installed prior to the commencement of the proposed development. This will ensure that data is available to monitor groundwater quality and levels from the outset and allow for early detection of any potential issues during the construction phase. This network will also be essential for monitoring during the operational phase to ensure continuous assessment of groundwater quality and levels and to detect any contamination, recharge and flooding risks promptly.
- **Piezometer Installation:** At least four monitoring piezometers should be installed to effectively detect any potential contaminants and enable monitoring of groundwater quality and levels over time.
- **Regular Monitoring:** To track changes in groundwater quality, water levels and chemical parameters should be recorded monthly from each of the installed piezometers. Additionally, effluent quality should also be regularly tested to assess the potential impact of the wastewater treatment plant (WWTP).
    - **Laboratory Testing:** All groundwater and effluent samples should be sent to an accredited SANAS laboratory for analysis. Sample collection, handling, and transport should strictly adhere to laboratory standards to ensure the accuracy and integrity of the results.
- **Rapid Response Plan:** A rapid response plan should be developed in the event that any contamination is detected during the monitoring process. This plan should include clear procedures for identifying the source of contamination, containing the issue, and mitigating any potential environmental impacts. It should also outline specific actions to address contamination quickly and effectively, reducing the risk of groundwater or environmental degradation.

Conclusion:
By implementing the recommended monitoring network and mitigation measures outlined above, the risk of groundwater contamination during both the construction and operational phases can be reduced to negligible - negative. This will ensure that groundwater quality is continuously protected and that any potential issues are addressed promptly, safeguarding the health and sustainability of the surrounding ecosystem and water users.

13 References

1:50 000 Geological Map (George 3322CD). Council for Geoscience, 2008.

1:500 000 General Hydrogeological Map, Port Elizabeth 3324 (1998)

Department of Water Affairs and Forestry & Water Research Commission (1995). A South African Aquifer System Management Classification. WRC Report No. KV77/95.

Department of Water Affairs and Forestry, 1996. South African Water Quality Guidelines (second edition). Volume 1: Domestic Use.

Department of Water Affairs and Forestry, 2003. Protocol to Manage the Potential of Groundwater Contamination from on site Sanitation, National Sanitation Co-ordination Office, Directorate of Geohydrology, Edition 2, 2003.

DWA (Department of Water Affairs). (2005.). Groundwater Resource Assessment II

DWAF, 2005. Groundwater Resources Assessment Project, Phase II (GRAII). Department of Water Affairs and Forestry, Pretoria.

Environmental Impact Assessment Regulations, 2014 published under Government Notice No. 982 in Government Gazette No. 38282 of 4 December 2014.

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

https://crudata.uea.ac.uk/cru/data/hrg/ - CRU CL 2.0 data-set comprises monthly grids of observed mean climate from 1961-1990, and covering the global land surface at a 10 minute spatial resolution for up to 14 observed and computed agroclimatic parameters.

https://dffeportal.environment.gov.za/ Protected Areas Register (PAR).

https://wazimap.co.za/ Census Data.

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

MEYER, P S (1999). An explanation of the 1:500 000 General Hydrogeological Map Oudtshoorn 3320. Department of Water Affairs and Forestry, Pretoria.

National Environmental Management Act, 1998 (Act No. 107 of 1998) (“NEMA”)

SABS drinking water standards (SANS 241-1:2015) Second Edition. SABS Standards Division, March 2015. ISBN 978-0-626-29841-8

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

14 Appendix

14.1 Appendix A: Groundwater chemistry results of hydrocensus

GTL GEOSCIENCE TESTING LABORATORY (PTY)LTD
CIVIL ENGINEERING MATERIALS LABORATORY
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CLIENT :	DHS Groundwater Consulting	**PROJECT:**	Plettenberg Baai
		JOB CARD :	TET2606
		DATE SAMPLED :	29.01.2025
		DATE DELIVERED:	30.01.2025
DATE TESTED:	31.01.2025	**DATE COMPLETED:**	07.02.2025
		DATE REPORTED:	10.02.2025
ATT :	Divan	**SAMPLED BY:**	Client
		SAMPLING PROCEDURE:	N/A

LABORATORY ANALYTICAL REPORT

Parameter	Units	Method Reference / Method No	Limits SANS 241:2015	SANS 241 RISK CLASS	Sample No: WL8984 Sample ID: MG01	Sample No: WL8985 Sample ID: MF01
Electrical Conductivity	mS/m	SANS 7888	≤ 170	Aesthetic	380.00	167.50
pH @ 25 °C	pH units	SANS 5011:2005	≥ 5 and ≤ 9.7	Operational	7.21	6.88
Turbidity	NTU	APHA 2130	Operational ≤ 1 Aesthetic ≤ 5	Operational ≤ 1 Aesthetic ≤ 5	6.01	1.75
Colour *	Pt-Co Units	Hach 8025	≤ 15	Aesthetic	1	<5
Sodium *	mg/l Na	SANS 11885	≤ 200	Aesthetic	528.005	317.910
Calcium *	mg/l Ca	SANS 11885	n/a	n/a	280.365	70.264
Magnesium *	mg/l Mg	SANS 11885	n/a	n/a	90.330	26.379
Potassium *	mg/l K	SANS 11885	n/a	n/a	17.224	3.939
Iron *	mg/l Fe	SANS 11885	Chronic Health ≤2 Aesthetic ≤ 0.3	Chronic Health ≤2 Aesthetic ≤ 0.3	0.460	0.270
Manganese *(s)	mg/l Mn	ALM 31	Chronic Health ≤ 0.4 Aesthetic ≤ 0.1	Chronic Health ≤ 0.4 Aesthetic ≤ 0.1	0.452	0.370
Total Alkalinity	mg/l CaCO3	APHA 2023	n/a	n/a	387.60	194.40
Chloride	mg/l Cl	APHA 4500-Cl	≤ 300	Aesthetic	1089.02	424.72
Ammonia as N	mg/l NH_3-N	USEPA Method 10031	≤ 1.5	Aesthetic	0..2	<0.4
Nitrate as N	mg/l NO_3-N	USEPA Method 10020	≤ 11	Acute Health	0.8	0.7
Nitrite as N *	mg/l NO_2-N	Hach 10019	≤ 0.9	Acute Health	0.003	0.002
Combined Nitrate plus Nitrite*	Ratio	SANS 5210	≤ 1.0	Acute Health	0.08	0.07
Flouride as F	mg/l F	USEPA Method 10225	≤ 1.5	Chronic Health	0.85	0.77
Sulphate as SO_4^{2-}	mg/l SO_4^{-2}	USEPA Method 8051	Acute Health ≤ 500 Aesthetic ≤ 250	Acute Health ≤ 500 Aesthetic ≤ 250	236	85
Total Dissolved Solids	mg/l TDS	SANS 5213	≤ 1200	Aesthetic	2470	1089
Copper *	mg/l Cu	SANS 11885	≤ 2	Chronic Health	<0.002	<0.002
Zinc *	mg/l Zn	SANS 11885	≤ 5	Aesthetic	0.069	0.0498
E. coli *	count/100ml	IDEXX	N/D	Acute Health	ND	ND
Total Coliforms *	count/100ml	IDEXX	≤ 10	Operational	35	27
Heterotrophic Plate Count	count/ml	IDEXX	≤ 1000	Operational	>2420	>2420
Total Hardness *	mg equiv. $CaCO_3$/L	APHA 2340-B	n/a	Operational	1072.05	284.08

Remarks: The above test results are pertinent only to the samples as per conditions received and tested at the laboratory. This report shall not be reproduced, except in full, without the

2. The highlighted result is an intrepretation of the direct comparison between the quoted specification and the single test sample result obtained.

3. The results met/not met is based on an aproximate of 95% level of confidence with reference to ISO/IEC 98-4

Name: Aviwe Nontenja

Position: Technical Signatory

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14.2 Appendix B: Assessment of the reduction of contaminants in the unsaturated zone

Table 20. Assessment of the reduction of contaminants in the unsaturated zone

Unsaturated zone conditions	Factor affecting reduction			Contaminant reduction			Comments
	Rate of flow in unsaturated zone	Capacity of the media to absorb contaminants	Capacity to create an effective barrier to contaminants	bacteria and viruses	nitrates and phosphates	chlorides	
clay	very slow <10mm/d	high	high	very high reduction	high reduction	high reduction	Very good barrier to the movement of contaminants. May have problems with water retention in pit.
massive shales	very slow <10mm/d	high	high	very high reduction	high reduction	high reduction	Very good barrier to the movement of contaminants. May have problems with water retention in pit.
solid granites	very slow <10mm/d	minimal	high	high reduction	high reduction	high reduction	Good barrier to the movement of contaminants. Horizontal flow may be more relevant than vertical flow.
silt	slow 10-100mm/d	medium	high	high reduction	some reduction	minimal reduction	Good barrier to the movement of biological contaminants, but little reduction in chemical contaminants.
sandy loam	slow 10-100mm/d	medium	high	high reduction	some reduction	minimal reduction n	Good barrier to the movement of biological contaminants, but little reduction in chemical contaminants.
bedded shales	slow 10-100mm/d	high	high	very high reduction	some reduction	minimal reduction	Good barrier to the movement of biological contaminants, but little reduction in chemical contaminants.
weathered or fractured granites	slow to medium 0.01-10m/d	minimal to medium	minimal to low	high reduction	minimal reduction	minimal reduction	Fair barrier to the movement of biological contaminants, but little reduction in chemical contaminants.
fractured or weathered sandstones	medium 0.1-10m/d	medium	medium	high reduction	minimal reduction	minimal reduction	Fair barrier to the movement of biological contaminants, but little reduction in chemical contaminants.
cavernous limestones/ calcretes	medium 1-100m/d	medium	medium	high reduction	some reduction	minimal reduction	Good barrier to the movement of biological contaminants, but little reduction in chemical contaminants.
fine sand	medium 0.1-10m/d	minimal	high	high reduction	minimal reduction	minimal reduction	Good barrier to the movement of biological contaminants, but little reduction in chemical contaminants.
coarse sand and gravels	fast 10-1000m/d	minimal	low	some reduction	minimal reduction	minimal reduction	Poor barrier to the movement of contaminants.

Note: light shading = minimal risk of contamination medium shading = low risk of contamination dark shading = higher risk of contamination

14.3 Appendix C: NEMA Impact Assessment Methodology

The assessment of the predicted significance of impacts for a proposed development is by its nature, inherently uncertain – environmental assessment is thus an imprecise science. To deal with such uncertainty in a comparable manner, a standardised and internationally recognised methodology has been developed. This methodology will be applied in this study to assess the significance of the potential environmental impacts of the proposed development.

For each predicted impact, certain criteria are applied to establish the likely **significance** of the impact, firstly in the case of no mitigation being applied and then with the most effective mitigation measure(s) in place.

These criteria include the **intensity** (size or degree scale), which also includes the **type** of impact, being either a positive or negative impact; the **duration** (temporal scale); and the **extent** (spatial scale). For each predicted impact, the specialist applies professional judgement in ascribing a numerical rating for each of these criteria respectively as per Table 21, Table 22 and Table 23 below. These numerical ratings are used in an equation whereby the **consequence** of the impact can be calculated. Consequence is calculated as follows:

Consequence = type x (intensity + duration + extent)

Depending on the numerical result, the impact's consequence would be defined as either extremely, highly, moderately or slightly detrimental; or neutral; or slightly, moderately, highly or extremely beneficial. These categories are provided in Table 25.

To calculate the significance of an impact, the **probability** (or likelihood) of that impact occurring is also taken into account. The most suitable numerical rating for probability is selected from Table 24 below and applied with the consequence as per the equation below:

Significance = consequence x probability

Depending on the numerical result, the impact would fall into a significance category as negligible, minor, moderate or major, and the type would be either positive or negative. These categories are provided in Table 26.

Once the significance of an impact occurring without mitigation has been calculated, the specialist must also apply their professional judgement to assign ratings for the same impact after the proposed mitigation has been implemented.

The tables on the following pages show the scales used to classify the above variables, and define each of the rating categories.

Table 21. Definition of Intensity ratings.

Rating	Criteria	
	Negative impacts (Type of impact = -1)	**Positive impacts** (Type of impact = +1)
7	Irreparable damage to biophysical and / or social systems. Irreplaceable loss of species.	Noticeable, on-going benefits to which have improved the quality and extent of biophysical and / or social systems, including formal protection.
6	Irreparable damage to biophysical and / or social systems and the contravention of legislated standards.	Great improvement to ecosystem processes and services.
5	Very serious impacts and irreparable damage to components of biophysical and / or social systems.	On-going and widespread positive benefits to biophysical and / or social systems.
4	On-going damage to biophysical and / or social system components and species.	Average to intense positive benefits for biophysical and / or social systems.
3	Damage to biophysical and / or social system components and species.	Average, on-going positive benefits for biophysical and / or social systems.
2	Minor damage to biophysical and / or social system components and species. Likely to recover over time. Ecosystem processes not affected.	Low positive impacts on biophysical and / or social systems.
1	Negligible damage to individual components of biophysical and / or social systems.	Some low-level benefits to degraded biophysical and / or social systems.

NOTE: Where applicable, the intensity of the impact is related to a relevant standard or threshold, or is based on specialist knowledge and understanding of that particular field.

Table 22. Definition of Duration ratings.

Rating	Criteria
7	**Permanent:** The impact will remain long after the life of the project
6	**Beyond project life**: The impact will remain for some time after the life of the project
5	**Project Life:** The impact will cease after the operational life span of the project
4	**Long term**: 6-15 years
3	**Medium term:** 1-5 years
2	**Short term:** Less than 1 year
1	**Immediate**: Less than 1 month

Table 23. Definition of Extent ratings.

Rating	Criteria
7	**International:** The effect will occur across international borders
6	**National:** Will affect the entire country
5	**Province/ Region:** Will affect the entire province or region
4	**Municipal Area:** Will affect the whole municipal area
3	**Local:** Extending across the site and to nearby settlements
2	**Limited:** Limited to the site and its immediate surroundings
1	**Very limited:** Limited to specific isolated parts of the site

Table 24. Definition of Probability ratings.

Rating	Criteria
7	**Certain/ Definite:** There are sound scientific reasons to expect that the impact will definitely occur
6	**Almost certain/Highly probable:** It is most likely that the impact will occur
5	**Likely:** The impact may occur
4	**Probable:** Has occurred here or elsewhere and could therefore occur
3	**Unlikely:** Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur
2	**Rare/ improbable:** Conceivable, but only in extreme circumstances and/ or has not happened during lifetime of the project but has happened elsewhere. The possibility of the impact manifesting is very low as a result of design, historic experience or implementation of adequate mitigation measures
1	**Highly unlikely/None:** Expected never to happen.

Table 25. Application of Consequence ratings.

Range		Significance rating
-21	-18	Extremely detrimental
-17	-14	Highly detrimental
-13	-10	Moderately detrimental
-9	-6	Slightly detrimental
-5	5	Negligible
6	9	Slightly beneficial
10	13	Moderately beneficial
14	17	Highly beneficial
18	21	Extremely beneficial

Table 26. Application of Significance ratings.

Range		Significance rating
-147	-109	Major - negative
-108	-73	Moderate - negative
-72	-36	Minor - negative
-35	-1	Negligible - negative
0	0	Neutral
1	35	Negligible - positive
36	72	Minor - positive
73	108	Moderate - positive
109	147	Major - positive

Despite attempts at providing a completely objective and impartial assessment of the environmental implications of development activities, environmental assessment processes can never escape the subjectivity inherent in attempting to define significance. The determination of the significance of an impact depends on both the context (spatial scale and temporal duration) and intensity of that impact. Since the rationalisation of context and intensity will ultimately be prejudiced by the observer, there can be no wholly objective measure by which to judge the components of significance, let alone how they are integrated into a single comparable measure.