Hydrological Impact Assessment on the Farm Melkhoutrivier 492, Malgas.

Prepared by

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Executive Summary

Creo Design (Pty) Ltd was tasked with the assessment of the hydrology of a small catchment area and springs in a valley where two recently enlarged instream dams occur. The assessment area is situated approximately 7.5 km south-southeast of Malgas near Witsand in the Western Cape Province. The area under investigation is located on the remainder of portion 1 of the farm Melkhoutrivier 492 in the Swellendam District. The farm borders the Breede River to the south and lies within Quaternary catchment H70H and forms part of the Breede-Gouritz Water Management Area. The dams under investigation are located on the northern part of the farm in a small valley that leads down to the Breede River.

The topography of the region ranges from relatively low relief to rolling hills with the major topographical features being well-incised river valleys occupied by almost exclusively non-perennial streams. These numerus drainage systems are tributary streams feeding the Breede River, the only true perineal river in the area. Remnants of an expansive marine terrace occupies the property from just above the southern limit of the watershed of the valley investigated (just below the foot of the mountain) to the cliff above the river edge. The region has a predominantly Mediterranean climate, characterized by hot, dry summers and mild, wet winters. It is a winter rainfall area, with the average rainfall being approximately 465 mm per annum and the maximum mean occurring in August (52.8 mm) and the minimum mean in December (21.6 mm).

The substrate geology of the area under investigation comprises of shale and sandstone of the Table Mountain Group and the Bokkeveld Group. The valley at the springs and dam sites are underlain by thick Ceres Subgroup shale units, part of the Bokkeveld Group, with much thinner interbedded feldspathic arenite and wacke sandstone layers. At the portion of the valley where the spring system occur a prominent sandstone layer can be seen outcropping over the entire width of the valley and dipping at a low angle (15 - 18˚) to the north-east.

The ground water vulnerability of the area was assessed using the DRASTIC method. After assessing all the parameters of the DRASTIC method, the overall groundwater vulnerability for the area is determined to be low to moderate.

The Hydrological Surveys performed by Creo at the valley with the two instream dams and springs determined: 1) the surface area of the catchment feeding the two instream dams; 2) the discharge into the two instream dams and 3) the flow released by the springs just upstream of the dams.

The estimation of the catchment area was done using the GIS software QGIS. Through the use of a Digital Elevation Model (DEM) and the geospatial data analysis platform WhiteboxTools for QGIS, the watershed boundary was established and the catchment surface area that feeds

the dams were estimated. The total estimated surface area of the catchment is 947 321.71 m^2 (94.7 ha).

The discharge into the two instream dams were determined by a discharge calculation method that makes use of rainfall data. The method used is the Rational Method, which uses an empirical linear equation to compute the peak runoff rate from a selected period of uniform rainfall intensity. Using the determined catchment area and historic rainfall records, the following was determined:

1) The discharge rates:
   - Peak discharge during the maximum rainfall recorded is = 23.02 L s^{-1}.
   - Discharge during and shortly after average rainfall periods is = 3.55 L s^{-1}.

2) The discharge volumes per rainfall event:
   - Peak discharge volume during the maximum rainfall episode was = 497.2 m^3
   - Discharge volume during and shortly after average rainfall episodes is = 76.7 m^3

The spring system, some 84 m up valley from the upper inflow of the two instream dams, is in actual fact a series of springs emanating where groundwater from the Bokkeveld Group sandstone aquifer daylights at the lowest point where the sandstone has been truncated by erosion in the valley floor. This exposure of the aquifer led to the establishment of springs at the point of outcrop on the valley floor. This type of spring system is referred to as a contact spring and is formed where relatively permeable rocks overlie rocks of low permeability.

For spring discharge survey, a high gradient section of the valley was selected, and measurements were done by filling a container with a known volume and recording the time to fill the container. This process was repeated a few times and by doing so an average cumulative flow from the springs was determined.

The discharge measurements taken for the total spring system on 24 October 2022 was 0.206 L s^{-1} or 742.2L h^{-1}. Due to the relative low rainfall experienced during the last 12 months in this region one can safely assume that this discharge value represents the low end of the discharge scale for this spring system. The discharge from the springs equates to 17. 8 m^3 per day or 534.0 m^3 per month which exceeds even the maximum rainfall discharge figure per month.

The pan feature on the southern edge and just outside the watershed is outside the drainage area feeding the dams and no geological connection was found to exists between the pan and the spring and it can therefore be assumed that the pans have if any, very little influence on discharge to the springs or any other discharge into the dams and valley as such.

Requirements of a Specialist Report

Appendix 6 of Government Notice NEMA EIA Regulations.

Reg	Requirements	Included (Yes/No)	Report Reference
1	A Specialist report prepared in terms of these Regulations must contain		
a	Details of the independent Specialist who prepared the report; and,	Yes	Page v
	The expertise of that specialist to compile a specialist report including a curriculum vitae.	Yes	Page vi
b	A declaration that the specialist is independent in a form as may be specified by the competent authority	Yes	Page vii
c	An indication of the scope of, and the purpose for which, the report was prepared	Yes	Page 1
d	The date and season of the site investigation and the relevance of the season to the outcome of the assessment	Yes	Page 18
e	A description of the methodology adopted in preparing the report or carrying out the specialised process; the specific identified sensitivity of the site related to the activity and its associated structures and infrastructure	Yes	Page 1
f	An identification of any areas to be avoided, including buffers	N/A	
g	A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers	Yes	Page 13, 17
h	A description of any assumptions made and any uncertainties or gaps in knowledge; a description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives on the environment; and the assessment of all alternatives	Yes	Page 11-24
i	Any mitigation measures/ conditions for inclusion in the WULA or EA conditions	Yes	Page 24
j	Any requirements for inclusion in the MMP	Yes	Page 24
k	Any monitoring requirements for inclusion	Yes	Page 24
l	A reasoned opinion as to whether the proposed activity or portions thereof should be authorised; and	Yes	Page 23, 24
	If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the WULA and EA	Yes	Page 24
m	A description of any consultation process that was undertaken during the course of preparing the specialist report	N/A	

n	A summary and copies of any comments received during any consultation process and where applicable all responses thereto	N/A	
o	Any other information requested by the competent authority	N/A	

Independence & Conditions

Creo Design (Pty) Ltd ("Creo") is an independent entity with no interest in the activity other than fair remuneration for services rendered. Remunerations for services are not linked to approval by decision making authorities and Creo have no interest in secondary or downstream development because of these services. There are no circumstances that compromise the objectivity of this report. The findings, results, observations, and recommendations given in this report are based on the author's best scientific and professional knowledge and available information. Creo reserve the right to modify aspects of this report, including the recommendations if new information become available which may have a significant impact on the findings of this report.

Relevant Qualifications & Experience of the Authors

Dr Johan Hattingh

Dr Johan Hattingh holds a BSc. (Hons.) degree in Geology from the University of Stellenbosch (Sedimentology) as well as a MSc and PhD in Geology from the University of Port Elizabeth with fluvial sedimentology and hydrology as focus.

Work experience includes:

- 9 years in the environmental geology division of the Council for Geoscience in Port Elizabeth.
- 2 years as sedimentologist and exploration geologist at Trans Hex Group, Richtersveld.
- 24 years as managing director of Creo consulting amongst others on sedimentological and hydrological related work.

Main hydrological experience:

- Basic Assessment Studies
    - Proposed slimes dam establishment on south bank of the Orange River, Richtersveld.
    - Proposed cemetery development Upington, Malmsbury and Springbok
    - Dam site selection in the Lower Orange River
- Specialist studies
    - N3 rerouting hydrology and geohydrology assessment
    - Perdevlei, Strand development impact assessment
    - Specialist reports to mining licence applications
    - Eskom nuclear site at Thyspunt hydrology and geohydrology assessment
    - Bredasdorp Feed lot hydrology and geohydrology assessment

Dr Hattingh is a registered Professional Geological Scientists at SACNASP (South African Council for Natural Scientific Professions) as required in terms of Section 18(1)(a) of the Natural Scientific Professions Act, 2003, since 1993.

Mr. Riaan Zeeman

Mr. Riaan Zeeman holds a BSc. (Hons.) degree in Geology from the University of Stellenbosch (Sedimentology) with fluvial sedimentology as focus.

Work experience includes:

- 4 years as geologist at Creo Design focusing on exploration and assisting in the writing of CPR`s and specialist study reports along with related consultation work.

Declaration of Independence

I Johan Hattingh, declare that I:

- Am the lead author of this report
- am a geologist specialising in sedimentology, hydrology and groundwater
- am assigned as independent Specialist Consultant to this project;
- regard the information contained in this report as it relates to my specialist input/study to be true and correct, and
- do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed in terms of the NEMA, the Environmental Impact Assessment Regulations, 2014, as amended, and any specific environmental management Act;
- have and will not have no vested interest in the proposed activity proceeding;
- have disclosed, to the applicant, EAP and competent authority, any material information that have or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document required in terms of the NEMA, the Environmental Impact Assessment Regulations, 2014 and any specific environmental management Act;
- have no and will not engage in conflicting interests in the undertaking of the activity;
- disclaim responsibility for any changes that may have occurred after the time of the site visit and the time that the report was written;
- assumed that the information in this report is the most recent available information;
- undertake to disclose to the client and the competent authority any material, information that have or may have the potential to influence the decision of the competent authority required in terms of the Environmental Impact Assessment Regulations 2017; and,
- will provide the client and competent authority with access to all information at my disposal, regarding this project, whether favourable or not.

Signature of the specialist:

Dr Johan Hattingh
Creo Design (Pty) Ltd
3 November 2022

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Glossary For Geohydrological- And Geological Terms

Term	Definition
Aquifer	A geological formation that contains enough water to be used for economical uses such as domestic use etc.
Aquiclude	An impermeable geological unit that is incapable of transmitting water. Thus, cannot transmit nor store water.
Catchment	A catchment is an area of land where rain water is collected by the natural landscape.
Discharge	Discharge is the volumetric flow rate of water that is transported through a given cross-sectional area.
Fracture aquifer	A geological formation in which the groundwater moves through joints, faults, and cracks in solid rock. Most South African aquifers are fractured aquifers.
Fault	A planar fracture in a volume of rock, across which there has been significant displacement along the fracture plane.
Groundwater recharge	Groundwater recharge is the process by which surface water moves through the process of percolation/drainage into the saturated zone. This process takes place within the vadose zone.
Hydraulic conductivity (K)	The volume of water that will move through a porous medium in a unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.
mamsl	Meters above mean sea level.
mbgl	Meters below ground level.
Permeability	The ease with which water can flow through a geological formation.
Porosity (n)	A measure of the storage capacity of a geological formation.
Saturated zone	Zone of subsurface that is completely saturated with water.
Sedimentary rock	Rocks that are formed by the accumulation or deposition of small particles (sediments).
Spring	A spring is a point of exit at which groundwater from an aquifer flows out on top of Earth's crust and becomes surface water.
SWL	Static water level. It is the level of water in a well under normal, undisturbed, no-pumping conditions. Thus, the level of groundwater before pumping.
Vadose zone	Unsaturated zone of subsurface that is not saturate with water and determines the vulnerability of groundwater to pollution or contamination generated on the surface.
Vulnerability	The likelihood of groundwater to be contaminated.
Watershed	A watershed is an area of land that drains or “sheds” water into a specific waterbody or direction.
Water table	Dividing line between the saturated- and unsaturated zone in the subsurface in unconfined aquifers. Thus, the level of water in the saturated zone in unconfined aquifers.

List Of Acronyms and Abbreviations

DEM	-	Digital Elevation Model
GIS	-	Geographic Information System
$L\ h^{-1}$	-	Litres per hour
$L\ s^{-1}$	-	Litres per second
MAP	-	Mean Annual Precipitation
mm/a	-	Millimetres per annum
$mm\ h^{-1}$	-	Millimetres per hour
$m^3\ s^{-1}$	-	Cubic metres per second
NASA	-	National Aeronautics and Space Administration
NEMA	-	National Environmental Management Act, 1998 (Act No. 107 of 1998)
SACNASP	-	South African Council for Natural Scientific Professions
SANS 241	-	South African National Standards
WULA	-	Water Use Licence Application

1. Introduction

This report has been prepared for JPB Construction and Civils and documents the results of a hydrological assessment undertaken by Creo Design (Pty) Ltd ("Creo") on Portion 1 of the farm Melkhoutrivier 492 some 7 km south-southeast of Malgas in the Western Cape Province of South Arica. The assessment entails the determination of the prevailing hydrological conditions in the catchment area upstream of two instream dams. The storage capacity of these dams was recently increased.

The objective of this investigation is to report on the catchment area size feeding the two instream dams, estimates of discharge into the two instream dams from the drainage area and to survey the flow released by the springs just upstream of the dams. In addition, the potential contribution of the small pans on the western edge of the catchment area to the groundwater resource and ultimately the springs had to be assessed.

1.1. Scope of the Assessment

The tasks performed during this assessment were as follow:

- Perform a desktop study of the area under investigation for the purpose of establishing a basic appreciation of the study site and its immediate surrounding areas as well as the geological, hydrological & geohydrological setting of the area.
- Do a GIS based estimation of the catchment area feeding the dams.
- Determine the catchment discharge.
- Conduct a site visit to survey the area and to locate the spring and measure its flow.
- Compile an inclusive hydrological report covering all aspects that might influence the hydrological parameters of the study site.

2. Methodology

The hydrological assessment consists of the following:

1. Desktop Study that investigates the geographical setting of the area, the climate, and the drainage basin substrate geology.
2. Groundwater vulnerability classification of the area.
3. Determination of the dam catchment area and catchment discharge.
4. A site visit on 24 October 2022 to investigate the area and to determine the location and flow rate of the spring feeding the stream and dams.

Detail descriptions of the methods employed, and execution of these studies are discussed in sections 4 and 5 of this report.

3. Desktop Study

3.1. Location of Area

The assessment aera is situated approximately 7.5 km south-southeast of Malgas near Witsand in the Western Cape Province of South Arica. The area under investigation is located on the remainder of portion 1 of the farm Melkhoutrivier 492 in the Swellendam District. The farm is located on a southwest to northeast slope ranging from steep in the southwest to gentle in the northeast. The highest point on the farm, at the southernmost boundary is 415 m above mean sea level (mamsl) with the lowest point, the north-eastern boundary, being 5 mamsl.

The farm is located on the southern flank of the Breede River Valley and lies within Quaternary catchment H70H and forms part of the Breede-Gouritz Water Management Area (Figures 1 and 2).

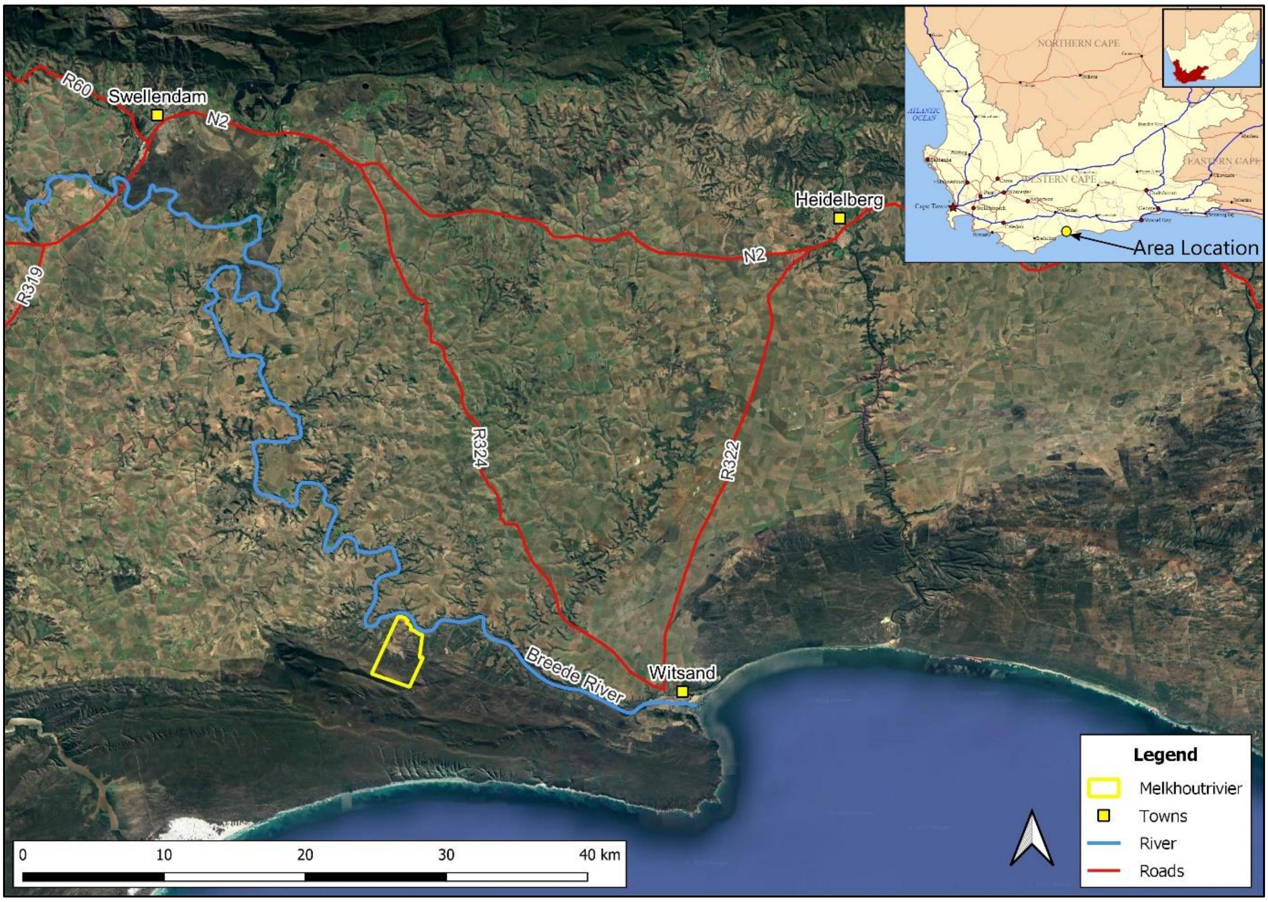

Figure 1: Map showing the location of the farm.

Two instream dams occur in a prominent north-northeast trending valley in the central northern part of the farm (Figures 3 & 4). The original construction date of the two dams is unknown but the existence of the dams is evident in excavations at these sites on aerial photos of 1967. At about 2020 these dams were enlarged to their present state.

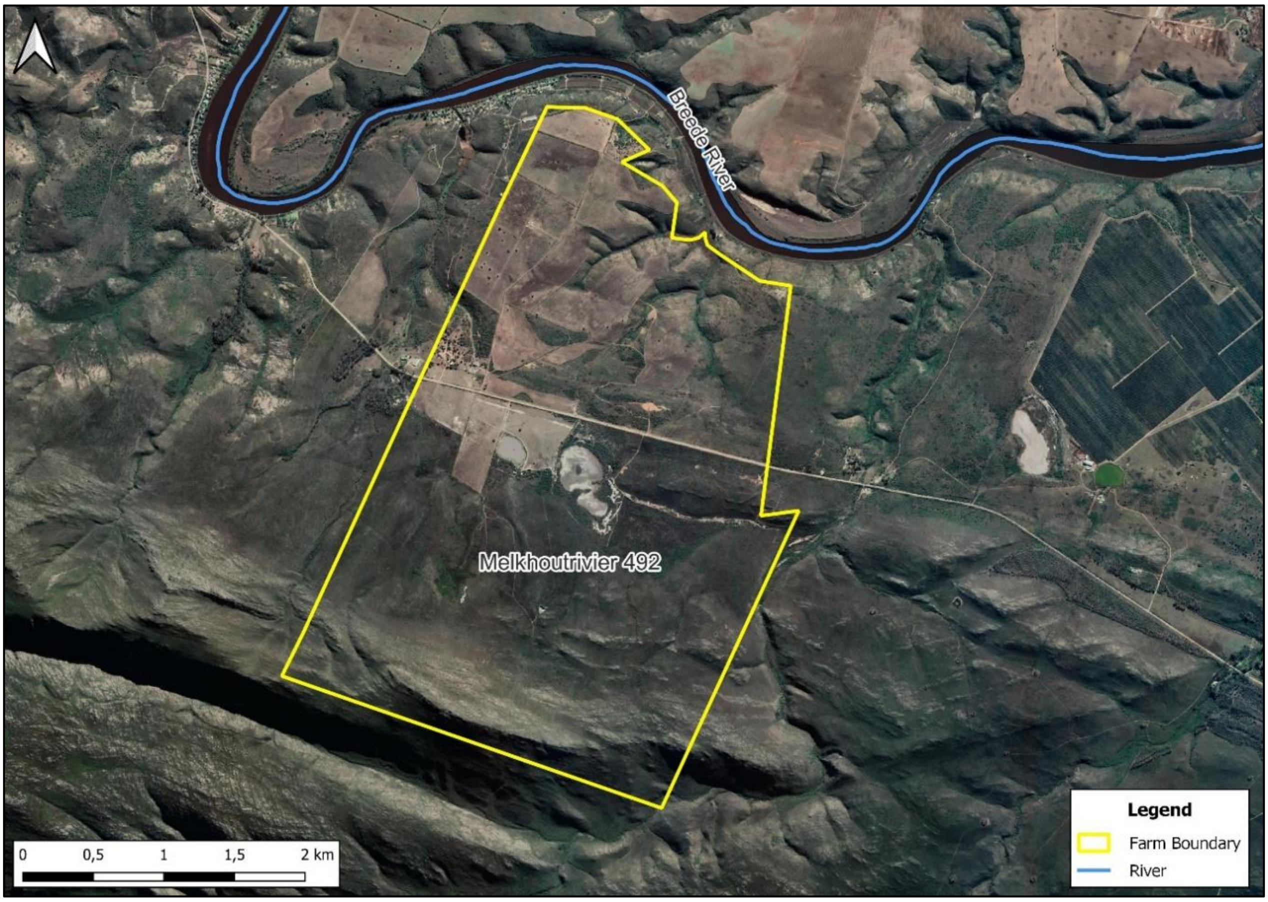

Figure 2: Map indicating the extend of the farm and its position relative to the Breede River.

Figure 3: The smaller, first dam (upper dam) within the stream. Looking upstream (to the south-southwest).

Figure 4: The larger, second dam (lower dam) within the stream looking south.

The dams are located on the northern part of the farm in a small valley that leads down to the Breede River. The location of the smaller upper dam (Figure 3) is defined by the coordinates 34° 21' 38" S, 20° 37' 43" E and the larger lower dam (Figure 4) can be found at 34° 21' 33" S, 20° 37' 45" E. Figures 10 and 13 indicate the location of the dams.

3.2. Climate

The region has a predominantly Mediterranean climate, characterized by hot, dry summers and mild, wet winters. The average annual maximum and minimum temperatures is 25^{0}C and 11.6^{0}C respectively (Figure 5).

The summer months of December, January and February are hot and dry, while the winter months of June, July and August are cold and rainy. The area is located in a winter rainfall region; however, rainfall occurs throughout the year with the wetter months being March to November. The average rainfall is approximately 465 mm per annum with the maximum mean occurring in August (52.8 mm) and the minimum mean in December (21.6 mm) (Figure 6).

The highest recorded rainfall during a single calendar month was 252.1 mm experienced during February 1942 and the lowest recorded rainfall during a calendar month was 2.0 mm experienced during February 1926.

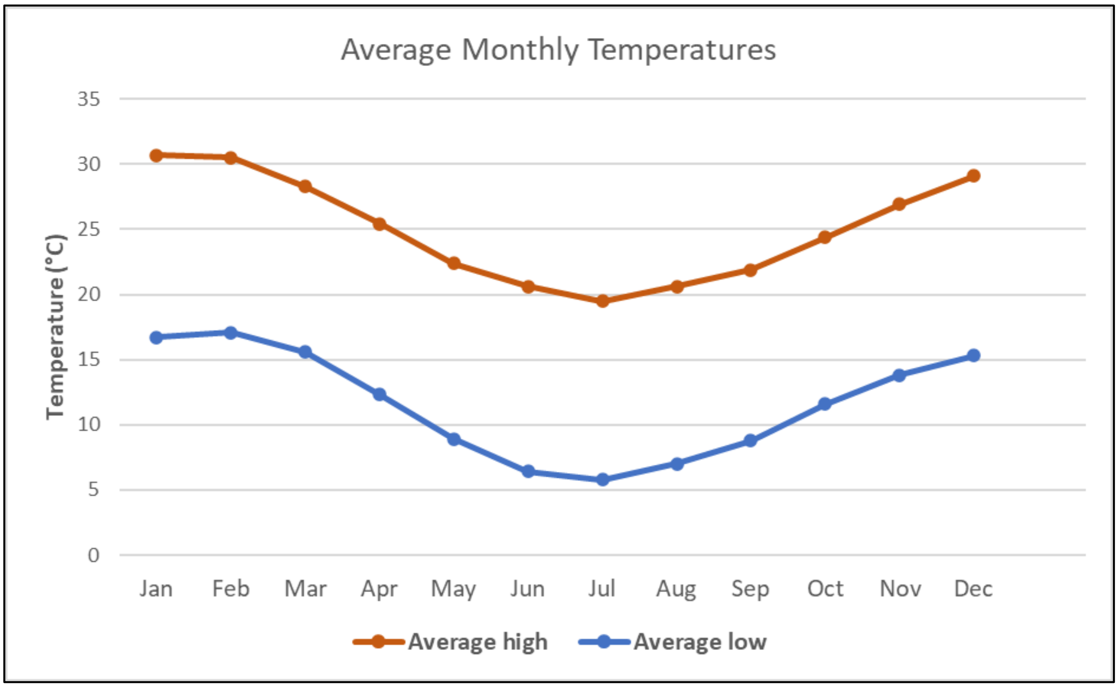

Figure 5: The average monthly maximum and minimum temperatures of the area.

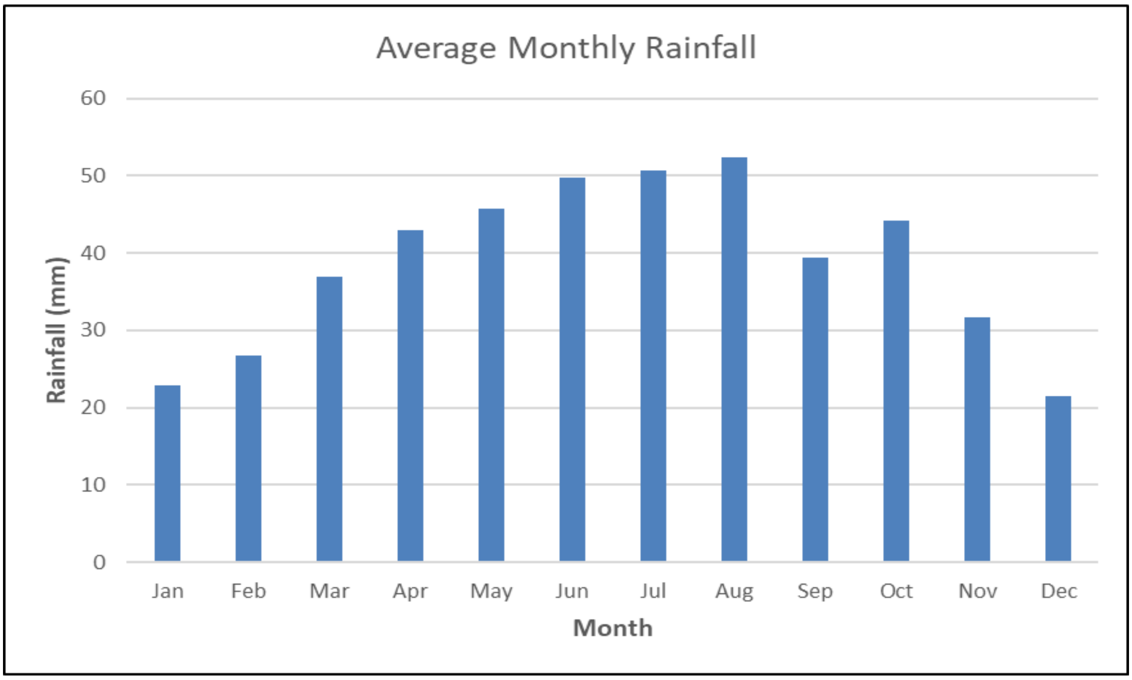

Figure 6: The average monthly rainfall recorded in the area.

3.3. Topography and Drainage

The topography of the region ranges from relatively low relief to rolling hills with the major topographical features being Potberg on the southern portion of the farm and well-incised river valleys occupied by almost exclusively non-perennial streams. These numerus drainage systems are tributary streams feeding the Breede River.

The only true perineal river is the Breede River a major drainage system that occur here as an incised bedrock controlled meandering river at its lower reaches just above the Breede River estuary. At this location the river is well within the tidal prism of the estuary and experiencing a strong tidal influence of the estuary. Here, the south-east flowing meandering Breede River reaches the ocean at Witsand, some 20 km down valley from the assessment area (Figure 7).

To the south and southwest of the farm the area becomes mountainous. Remnants of an expansive marine terrace occupies the rest of the property from just above the southern limit of the watershed of the valley investigated (just below the foot of the mountain) to the cliff above the river edge. Marine gravel strewn over this gently sloping surface bears testimony of the origin of this surface, today being well incised by numerous younger streams (Figure 7).

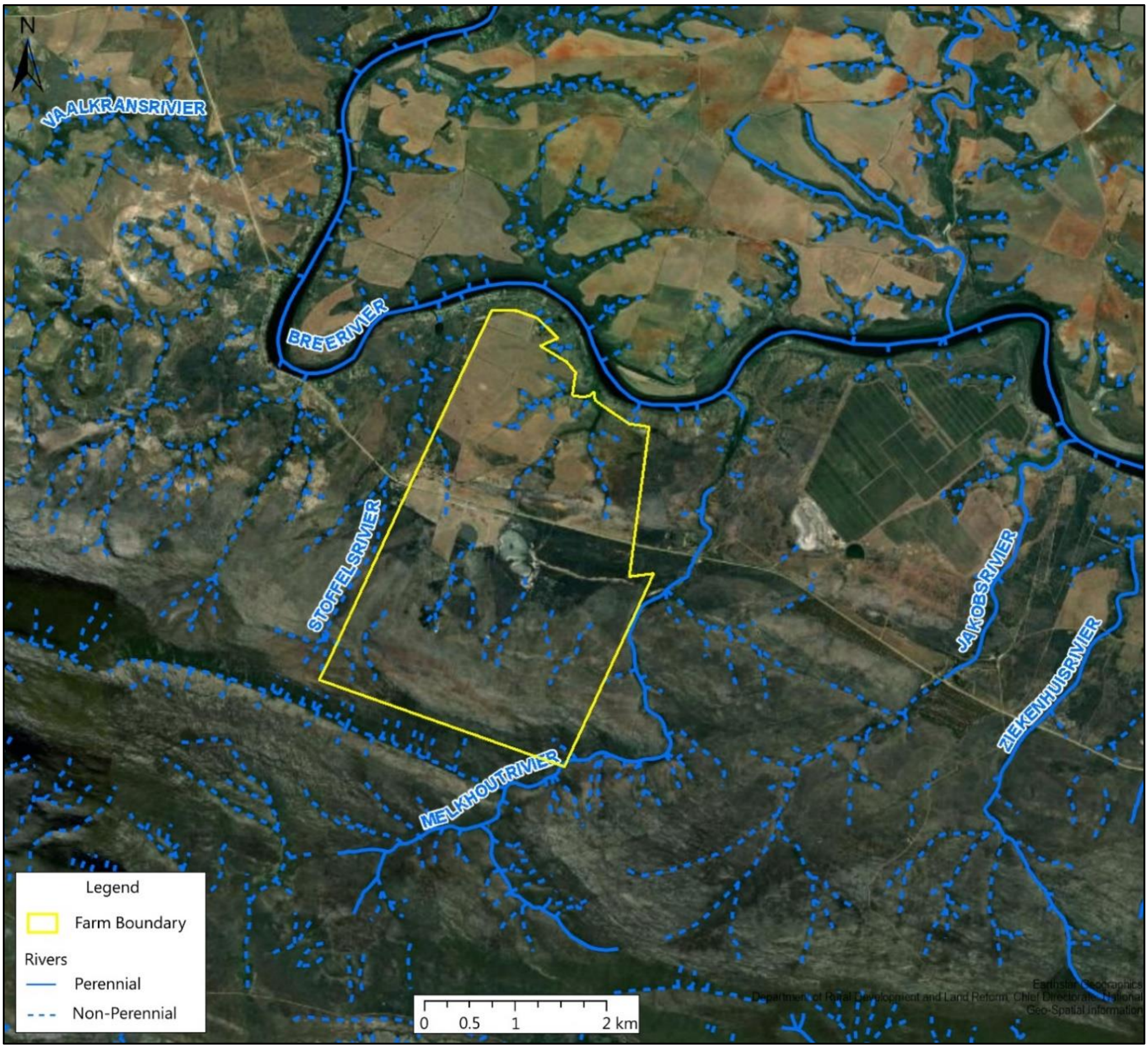

Figure 7: Drainage patterns of the area.

3.4. Geology

3.4.1. Regional Geology

The regional geology of the area under investigation comprises of the Palaeozoic aged Cape Supergroup. The succession of sandstone, shale and minor conglomerate were deposited between ~500 Ma and ~330 Ma and unconfromably overlies a Precambrian-Cambrian basement. Regionally the Cape Supergroup is overlaid by Cenozoic sediments of the Bredasdorp Group. Generally, the Cape Supergroup is overlain by Quaternary aged semi- to unconsolidated sediments.

The Cape Supergroup in the region comprise of the Table Mountain Group and the Bokkeveld Group. The older Table Mountain group is sandstone dominated with minor shale and is overlain by the Bokkeveld Group consisting of shale and sandstone. The Witteberg Group overlies the Bokkeveld Group and consist of sandstone and mudrock, however, it only outcrops in small areas to the north of the investigated area (Thamm & Johnson, 2006).

3.4.2. Local Geology

The geology underlying the property under investigation comprise of rocks of the Table Mountain Group and Bokkeveld Group. Outcropping in the southern portion of the farm is the Nardouw Subgroup of the Table Mountain Group (Figure 8). The Nardouw Subgroup mainly consists of white, coarse-grained to fine-grained, thick-bedded pebbly quartz arenite, thin bedded feldspathic and ferruginous sandstone, with subordinate shale and siltstone (Thamm & Johnson, 2006).

In the northern portion of the farm rocks of the Nardouw Subgroup is overlain by the Ceres Subgroup of the Bokkeveld Group (Figure 8). The Ceres Subgroup mainly consists of Mudrock, shale, siltstone, feldspathic arenite and wacke (Thamm & Johnson, 2006). The arenite and wacke units occur as well-defined sandstone layers (good aquifer) interbedded in mudstone and shale units (aquicludes).

A NE-SW trending fault occurs in the area just south-east of the farm. Large scale faults also occur further to the south and north-west of the assessment area.

The substrate rock at the springs and dam sites consists of thick Ceres Subgroup shale units with much thinner interbedded feldspathic arenite and wacke sandstone layers with regularly spaced joint sets as main structural feature. At the portion of the valley where the spring system occur a prominent sandstone layer can be seen outcropping over the entire width of the valley and dipping at a low angle (15 - 18˚) to the north-east. At the springs water is released at the base of the sandstone layer right where this truncated sandstone outcrops at the valley floor. This results in a series of closely spaced springs all along the base of the sandstone layer.

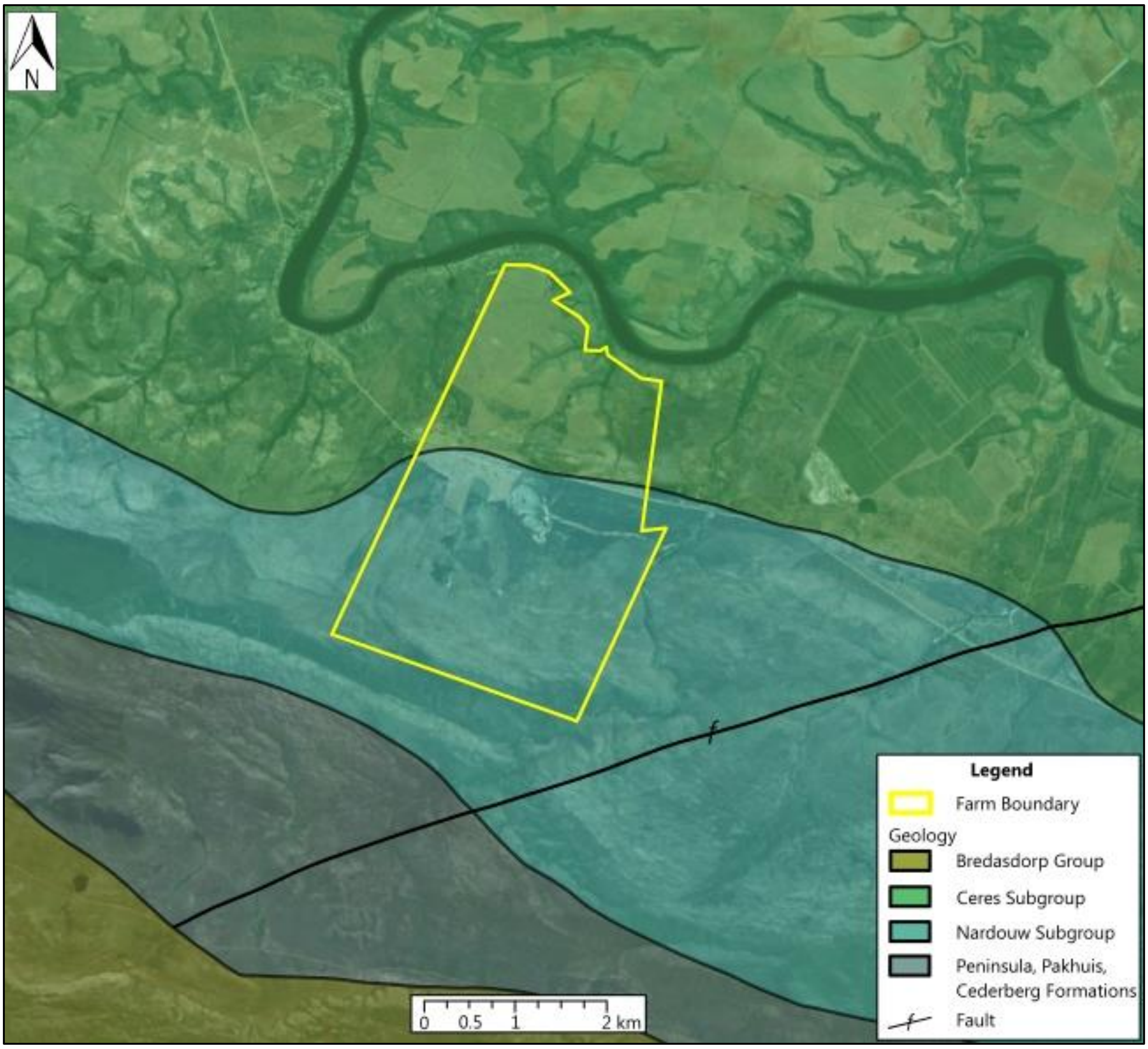

Figure 8: Geological map of the area.

4. Groundwater Vulnerability

The vulnerability of groundwater is a relative, non-measurable, dimensionless property and is based on the concept that certain land areas are more vulnerable to groundwater contamination than others (Musekiwa & Majola, 2011).

The DRASTIC method has been identified as the most appropriate method for groundwater vulnerability determination since the method is for regional applications, thus evaluating the pollution potential of large areas (Musekiwa & Majola, 2011).

The name DRASTIC is an acronym and is derived from the seven parameters required for its use:

D - Depth to water table
R - Recharge (net)
A - Aquifer media
S - Soil media
T - Topography (Slope
I - Impact of the vadose zone
C - Conductivity (Hydraulic)

4.1. Depth To Water Table

The depth to the groundwater table is the depth of the water table below ground level and thus the relative distance that a potential contaminant travels to reach the saturated zone (Musekiwa & Majola, 2011). The shallower the groundwater table, the shorter the flow path for the contaminate to reach the aquifer, thus increasing the vulnerability of the groundwater.

The regional groundwater table in the area is >30 mbgl., indicating that groundwater pollution probability with respect to the depth of the groundwater table is very low. However, as can be seen at the valley that forms part of this study valley incision has breached the groundwater table by exposing an aquifer. This bears testimony of the proximity of the very shallow water table in the valleys.

4.2. Net Recharge

The net recharge is the annual rate at which the groundwater recharge and is dependent on factors such as annual precipitation, evaporation, evapotranspiration, air temperature, humidity, solar radiation as well as wind frequency and speed. The higher the recharge rate the more vulnerable is the groundwater (Musekiwa & Majola, 2011).

The recharge rate in the area is 10 – 50 mm/a, thus, indicating that groundwater pollution probability with respect to recharge rate of the groundwater table is low.

4.3. Aquifer Media

The type of aquifer plays an important role in groundwater vulnerability with respect to the geohydrological composition of the aquifer. Therefore, the more fractured and weathered an aquifer, the higher the permeability of the rock which the aquifer consists of, thus increasing the vulnerability of contaminants to contaminate groundwater (Musekiwa & Majola, 2011).

The aquifer present in the area is classified as a fractured and weathered and intergranular aquifer. These fractures and weathered rock create preferential flow paths for groundwater which enables contaminants to infiltrate into the groundwater table.

4.4. Soil Media

The soil composition determines the rate of recharge and contaminant transport, for example a composition of high clay content lessen the potential for groundwater contamination due to low permeability, whereas sandy soils have a much higher permeability, therefore a higher vulnerability (Musekiwa & Majola, 2011).

The soil in the area is classified as sand to loamy sand which has a very high permeability, therefore may result in a high vulnerability.

4.5. Topography (Slope)

In areas of gentle slope there is a greater chance of the pollution infiltrating the aquifer as opposed to areas of steep slope where the pollutant is more likely to run off and not infiltrate (Musekiwa & Majola, 2011).

The slope in the area is between 2^0 - 18^0 indicating the vulnerability in relation to slope varies throughout the area.

4.6. Impact of the Vadose Zone

The type of the vadose zone media affects the vulnerability of groundwater. This parameter involved the consideration of the properties of the aquifer including the geology, soil porosity, the permeability and the depth to water levels (Musekiwa & Majola, 2011).

The geology consists of Table Mountain Group sandstone and quartzite and Bokkeveld Group sandstone and shale. The areas consisting of Bokkeveld shale has a low vulnerability, because of the impermeability of the shale, whereas the Table Mountain sandstone has a higher vulnerability because its higher permeability.

4.7. Hydraulic Conductivity

The hydraulic conductivity of an aquifer is a measure of the aquifer's ability to transport water when a hydraulic gradient is present. The hydraulic conductivity therefore controls the velocity of groundwater and contaminants that are transported via groundwater. A high hydraulic conductivity increases the vulnerability of groundwater to become contaminated (Musekiwa & Majola, 2011).

The geology and type of aquifer therefore determines the hydraulic conductivity, which in this case is a fractured and weathered and intergranular aquifer, thus the hydraulic conductivity is low to moderate, therefore decreasing the groundwater vulnerability (Musekiwa & Majola, 2011).

4.8. Groundwater Vulnerability Conclusion

When assessing all the parameters of the DRASTIC method an overall groundwater vulnerability for an area can be derived. For the area under investigation the overall groundwater vulnerability is low to moderate as indicated in the vulnerability map in figure 9.

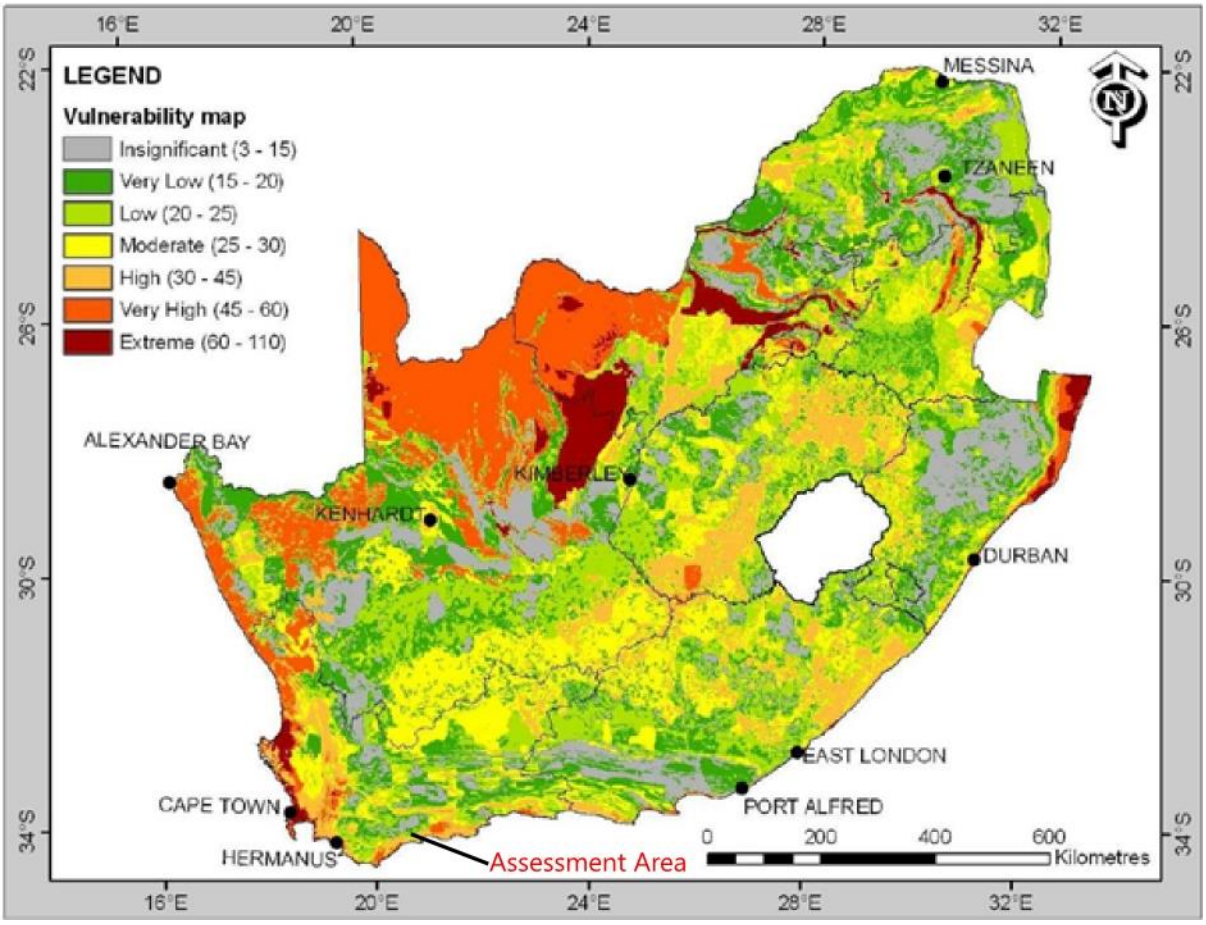

Figure 9: The overall groundwater vulnerability map of South Africa.

5. Hydrological Surveys

The hydrological surveys performed by Creo at the valley with the two instream dams and springs had to determine:

1) the surface area of the catchment feeding the two instream dams at Portion 1 of the Farm Melkhoudsfontein 492, Malgas.
2) the rainfall related discharge into the two instream dams
3) the flow released by the springs just upstream of the dams.

5.1. Estimation Of Catchment Area Surface

The estimation of the catchment area was done using the GIS software QGIS. A Digital Elevation Model (DEM) of the area was obtained from NASA Earthdata and was used as reference for the elevation of the area. Using the DEM and the geospatial data analysis platform WhiteboxTools for QGIS, the watershed boundary was established and the catchment surface area that feeds the dams were estimated. The total estimated surface area of the catchment is 947 321.71 m^2 (94.7 ha). Figure 10 indicates the watershed and extend of the catchment area. Figure 11 demonstrate a 3D image of the catchment area looking up valley in a southerly direction.

5.2. Discharge Received by The Instream Dams

In the absence of flow gauges in the stream feeding the dams a discharge calculation method had to be used that makes use of rainfall data. The two universal runoff computation methods generally used to compute runoff rates and volumes for small catchment areas using rainfall data are:

a) the Rational Method and;
b) the associated Modified Rational Method.

A general description of each method is provided below.

5.2.1. Rational Method

The Rational Method uses an empirical linear equation to compute the peak runoff rate from a selected period of uniform rainfall intensity. Originally developed more than 100 years ago, it continues to be useful in estimating runoff from simple, relatively small drainage areas.

Use of the Rational Method is limited to small drainage areas less than 100 ha with generally uniform surface cover and topography. It is important to note that the Rational Method can be used only to compute peak runoff rates. Since it is not based on a total storm duration, but rather a period of rain that produces the peak runoff rate, the method cannot compute runoff volumes unless the user assumes a total storm duration.

The Rational equation is the simplest method to determine peak discharge from drainage basin runoff and is the most common method used for small catchment areas.

Rational Equation: $Q=ciA$

This calculation allows you to use a variety of units.

The Rational method runoff coefficient (c) is a function of the soil type and drainage basin slope (Thompson, 2006) (LMNO Engineering, Research, and Software, Ltd., 2022).

The Rainfall intensity (i) is typically found from Intensity/Duration/Frequency curves for rainfall events in the geographical region of interest. The duration is usually equivalent to the time of concentration of the drainage area.

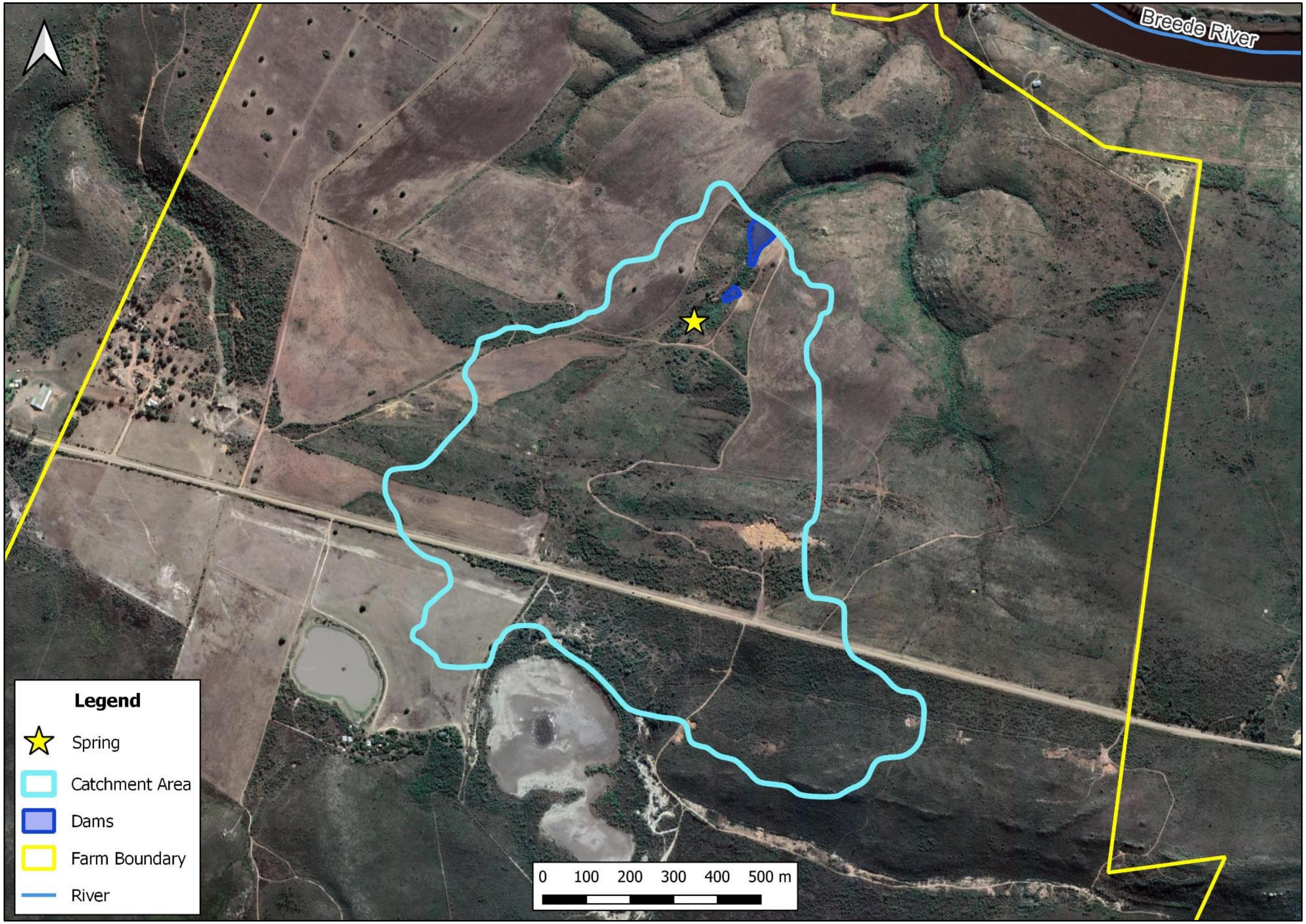

Figure 10: Map indicating the extend of the catchment area feeding the dams. Note the locations of the spring and the dams.

Figure 11: A 3D map of the catchment area looking to the south. Note the vertical exaggeration is x 1.5.

5.2.2. Modified Rational Method

The Modified Rational Method is a somewhat recent adaptation of the Rational Method that can be used to not only compute peak runoff rates, but also to estimate runoff volumes and hydrographs. This method uses the same input data and coefficients as the Rational Method along with the further assumption that, for the selected storm frequency, the duration of peak-producing rainfall is also the entire storm duration. Since, theoretically, there are an infinite number of rainfall intensities and associated durations with the same frequency or probability, the Modified Rational Method requires that several of these events be analysed in the method to determine the most severe.

5.2.3. Calculation Of Peak Discharge

The Rational Equation:

Qp = C I A

requires the following SI Units (metric): L s^{-1}, mm hr^{-1}, and hectares (ha) units where:
Q = Peak discharge, m^3 s^{-1}
c = Rational method runoff coefficient
i = Rainfall intensity, mm/hour
A = Drainage area, hectare

One of the parameters in the Rational Method equation (Q = CiA) is the runoff coefficient, C. The other parameters are A, the area of a catchment; i, the rainfall intensity for a storm of specified recurrence interval and duration equal to the catchment time of concentration; and Q, the peak water runoff rate due to a storm of intensity i, on a watershed of area, A, and with runoff coefficient, C. The shape of the catchment area also influences the discharge duration where a relatively round catchment area as seen in this particular case results in short-lived but intense flood episodes.

The major factors affecting the rational method runoff coefficient value for a catchment are the land use, the soil type and the slope of the watershed. The physical interpretation of the runoff coefficient for a catchment is the fraction of rainfall on that catchment that becomes water runoff. Thus, the runoff coefficient must have a value between zero and one.

Land Use: Surfaces that are relatively impervious like rocky outcrop and paved roads have runoff coefficients approaching one. Surfaces with vegetation to intercept surface runoff and those that allow infiltration of rainfall have lower runoff coefficients.

Slope: A catchment area with a greater slope will have more storm water runoff and thus a higher runoff coefficient than an area with a lower slope.

Soil Type: Soils that have a high clay content don't allow very much infiltration and thus have relatively high runoff coefficients, while soils with high sand content have higher infiltration rates and low runoff coefficients.

Therefor:

- The Runoff Coefficient in this case has been taken at 0.25.
- Catchment area = 947 321.71 m^2 (94.7 ha)
- The maximum rainfall recorded in the area was 252.1 mm in one calendar month. The average monthly rainfall is 38.75 mm per month.

The discharge rates

- Peak discharge during the maximum rainfall recorded is = 23.02 $L\ s^{-1}$.
- Discharge during and shortly after average rainfall periods is = 3.55 $L\ s^{-1}$.

The discharge volumes per rainfall event

- Peak discharge volume during the maximum rainfall episode was = 497.2 m^3
- Discharge volume during and shortly after average rainfall episodes (>6 mm per episode) is at a minimum = 76.7 m^3

5.3. Cumulative Spring Discharge

The spring system, some 84 m up valley from the upper inflow of the two instream dams, is in actual fact a series of springs originating where groundwater from the Bokkeveld Group sandstone aquifer daylights at the lowest point where the sandstone has been truncated by erosion in the valley floor. This exposure of the aquifer led to the establishment of springs at the point of outcrop on the valley floor (Figures 12 & 13).

This type of spring system is referred to as a ***contact spring*** and is formed where relatively permeable rocks overlie rocks of low permeability. A lithological contact such as this is usually marked by a line of springs. Such springs are usually associated with perched aquifers in mountainous or areas of significant topographical variation.

Since groundwater outflow occur along the width of the valley at the point this aquifer intersects the land surface, any measurements at the springs itself was found to be impractical. For this reason, a high gradient section of the valley was selected, and measurement was done by filling a container with a known volume and measuring the time to fill the container. This process was repeated a few times and by doing so an average cumulative flow from the springs was determined.

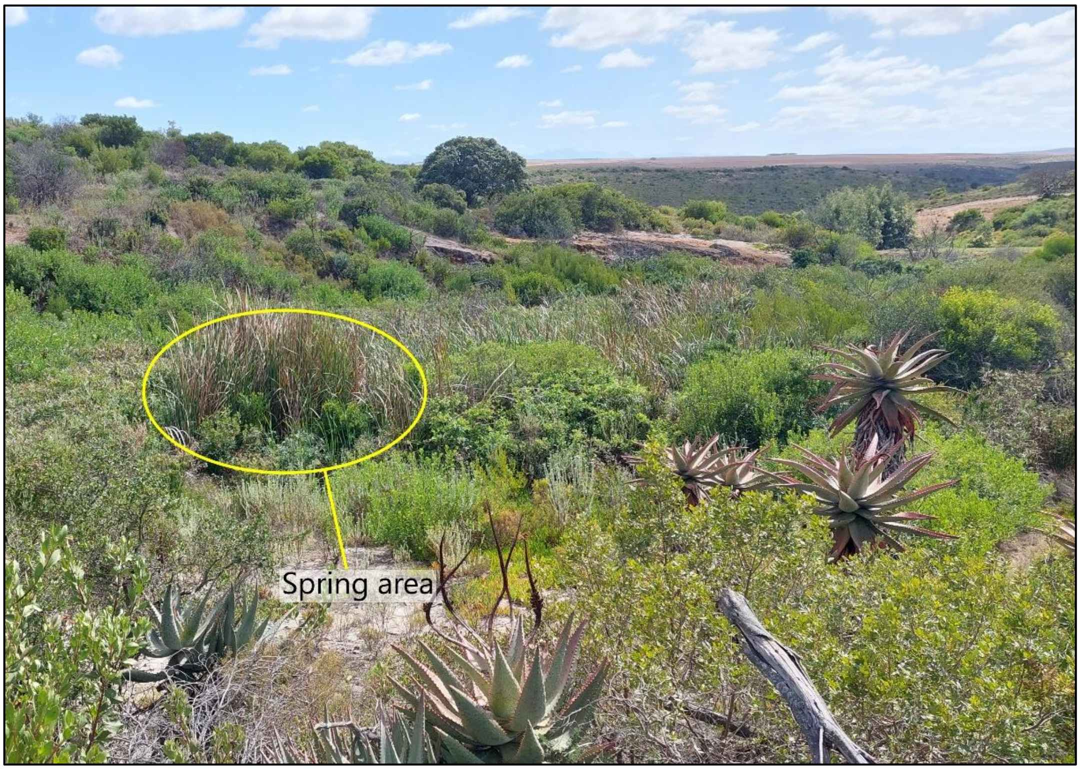

Figure 12: Down valley view showing the location of the spring in the foreground and the dams in the background.

Figure 13: Satellite image indicating the location of the spring in relation to the dams. The red dots indicate the locations of the overflow/outflow of the dams.

The discharge measurements taken for the total spring system on 24 October 2022 was 0.206 L s^{-1} or 742.2 L h^{-1}. Due to the relative low rainfall experienced during the last 12 months in this region one can safely assume that this discharge value represents the low end of the discharge scale for this spring system.

The discharge from the springs equates to 17. 8 m^3 per day or 534.0 m^3 per month which exceeds even the maximum rainfall discharge figure per month.

The coordinates defining the location of the spring are 34° 21' 40" S, 20° 37' 39" E. The coordinates of the outflow/overflow of the dams as indicated in figure 13 are defined as: no.1: 34° 21' 37" S, 20° 37' 43" E and no.2: 34° 21' 32" S, 20° 37' 46" E (Figure 14).

The pan feature on the southern edge of and just outside the watershed (Figure 10) is outside the drainage area of the dams and no geological connection exists between the pan and the spring. It can therefore be assumed with a great deal of confidence that the pans have no influence on the spring or and other discharge into the dams and valley as such.

Figure 14: The outflow/overflow of the larger (lower dam). The flow measurements were taken at this location. Figure 13 indicate the location of this outflow/overflow (red dot no.2).

6. Hydrological and Geohydrological Impact Assessment

Table 1: Hydrological Impact Assessment.

Planning, Design and Construction phase	**Site Layout**		**No-Go Alternative**
	Before Mitigation	**After Mitigation**	
POTENTIAL HYDROLOGICAL AND GEOLOGICAL IMPACTS:			
Nature of impact: Over exploitation of the resource by extracting more water than the base flow rate. Inflow of effluent and chemicals that have the potential to change the quality of the surface- and groundwater.	**Activity:** The discharge from rainfall in the catchment area and flow from the springs have a finite contribution in terms of discharge volume. Over exploitation may cause termination of flow in the valley below the dams. Sandstone outcrop in the study area can create a potential impact where a preferential path can be created where the potential leachate from livestock and game manure as well as pollutants from vehicles can pollute the surface- and groundwater by changing the quality of the water.		Over exploitation will deprive the downstream users of water. Definite pollution of surface- and groundwater may cause water to be unfit for use for downstream users.
Magnitude:	6	4	-
Duration:	4	2	-
Extent:	2	2	-
Irreplaceable:	3	2	-
Reversibility:	3	1	-
Probability:	3	3	-
Total SP:	54	33	-
Significance rating:	M	L	-
Cumulative impact:	-	-	-
Proposed Mitigation:	• Monitoring of water resources to prevent over exploitation and avoid surface- and groundwater contamination, through means of prevention when detected early enough. • Avoid spillages in the immediate vicinity of the water resources • Any waste generated should be disposed of accordingly in registered waste (landfill) sites and not dumped on site or the surrounding area. • Stormwater and runoff should be diverted and managed to not come in contact with any waste generated on site.		N/A

<table>
<tr><th rowspan="2">Planning, Design and Construction phase</th><th colspan="2">Site Layout</th><th rowspan="2">No-Go Alternative</th></tr>
<tr><th>Before Mitigation</th><th>After Mitigation</th></tr>
<tr><td colspan="4">POTENTIAL HYDROLOGICAL AND GEOLOGICAL IMPACTS:</td></tr>
<tr><td>Nature of impact:
Over exploitation of the resource by extracting more water than the base flow rate.
Inflow of effluent and chemicals that have the potential to change the quality of the surface- and groundwater.</td><td colspan="2">Activity:
Taking the site-specific properties such as:
• Recharge (average);
• Rainfall (average rainfall MAP: 350 - 400 mm);
• Temperature (average annual temperature of 18.30°C);
• Topography and drainage (Westward drainage – towards topographical depression – Breede River);
• Water table (shallow water table of 0 - 30 mbgl. – swl);
• Fractured weathered aquifer (very high permeability);
• Groundwater vulnerability (Insignificant to very low), and,
• Groundwater quality (good quality with respect to EC Values).</td><td>Over exploitation will deprive the downstream users of water.

Definite pollution of surface- and groundwater may cause water to be unfit for use for downstream users.</td></tr>
<tr><td>Magnitude:</td><td>4</td><td>4</td><td>-</td></tr>
<tr><td>Duration:</td><td>4</td><td>3</td><td>-</td></tr>
<tr><td>Extent:</td><td>2</td><td>2</td><td>-</td></tr>
<tr><td>Irreplaceable:</td><td>2</td><td>2</td><td>-</td></tr>
<tr><td>Reversibility:</td><td>2</td><td>2</td><td>-</td></tr>
<tr><td>Probability:</td><td>2</td><td>1</td><td>-</td></tr>
<tr><td>Total SP:</td><td>28</td><td>13</td><td>-</td></tr>
<tr><td>Significance rating:</td><td>L</td><td>L</td><td>-</td></tr>
<tr><td>Cumulative impact:</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Proposed Mitigation:</td><td colspan="2">• Monitoring of water resources to prevent over exploitation and avoid surface- and groundwater contamination, through means of prevention when detected early enough.
• Avoid spillages in the immediate vicinity of the water resources
• Any waste generated should be disposed of accordingly in registered waste (landfill) sites and not dumped on site or the surrounding area.
• Stormwater and runoff should be diverted and managed to not come in contact with any waste generated on site.</td><td>N/A</td></tr>
</table>

The scales to be used to assess these variables and to define the rating categories are tabulated in the tables below:

6.1. Impact assessment methodology

For each potential impact, the EXTENT (spatial scale), MAGNITUDE, DURATION (time scale), PROBABILITY of occurrence, IRREPLACEABLE loss of resources and the REVERSIBILITY of potential impacts must be assessed by the specialist by using the results of their specialist studies. The assessment of the above criteria will be used to determine the significance of each impact, with and without the implementation of the proposed mitigation measures. The scales to be used to assess these variables and to define the rating categories are tabulated in Table 2 & Table 3 below.

Table 2: Evaluation components, ranking scales, and descriptions (criteria).

Evaluation component	Ranking scale and description (criteria)
MAGNITUDE of NEGATIVE IMPACT (at the indicated spatial scale)	10 - Very high: Bio-physical and/or social functions and/or processes might be severely altered. 8 - High: Bio-physical and/or social functions and/or processes might be considerably altered. 6 - Medium: Bio-physical and/or social functions and/or processes might be notably altered. 4 - Low: Bio-physical and/or social functions and/or processes might be slightly altered. 2 - Very Low: Bio-physical and/or social functions and/or processes might be negligibly altered. 0 - Zero: Bio-physical and/or social functions and/or processes
MAGNITUDE of POSITIVE IMPACT (at the indicated spatial scale)	10 - Very high (positive): Bio-physical and/or social functions and/or processes might be substantially enhanced. 8 - High (positive): Bio-physical and/or social functions and/or processes might be considerably enhanced. 6 - Medium (positive): Bio-physical and/or social functions and/or processes might be notably enhanced. 4 - Low (positive): Bio-physical and/or social functions and/or processes might be slightly enhanced. 2 - Very Low (positive): Bio-physical and/or social functions and/or processes might be negligibly enhanced. 0 - Zero (positive): Bio-physical and/or social functions and/or processes will remain unaltered.
DURATION	5 - Permanent 4 - Long term: Impact ceases after operational phase/life of the activity > 60 years. 3 - Medium term: Impact might occur during the operational phase/life of the activity – 60 years. 2 - Short term: Impact might occur during the construction phase - < 3 years. 1 – Immediate

EXTENT (or spatial scale/influence of impact)	5 - International: Beyond National boundaries. 4 - National: Beyond Provincial boundaries and within National boundaries. 3 - Regional: Beyond 5 km of the proposed development and within Provincial boundaries. 2 - Local: Within 5 km of the proposed development. 1 - Site-specific: On site or within 100 m of the site boundary. 0 – None
IRREPLACEABLE loss of resources	5 – Definite loss of irreplaceable resources. 4 – High potential for loss of irreplaceable resources. 3 – Moderate potential for loss of irreplaceable resources. 2 – Low potential for loss of irreplaceable resources. 1 – Very low potential for loss of irreplaceable resources. 0 – None
REVERSIBILITY of impact	5 – Impact cannot be reversed. 4 – Low potential that impact might be reversed. 3 – Moderate potential that impact might be reversed. 2 – High potential that impact might be reversed. 1 – Impact will be reversible. 0 – No impact.
PROBABILITY (of occurrence)	5 - Definite: >95% chance of the potential impact occurring. 4 - High probability: 75% - 95% chance of the potential impact occurring. 3 - Medium probability: 25% - 75% chance of the potential impact occurring 2 - Low probability: 5% - 25% chance of the potential impact occurring. 1 - Improbable: <5% chance of the potential impact occurring.
Evaluation component	**Ranking scale and description (criteria)**
CUMULATIVE impacts	High: The activity is one of several similar pasts, present or future activities in the same geographical area, and might contribute to a very significant combined impact on the natural, cultural, and/or socio-economic resources of local, regional, or national concern. Medium: The activity is one of a few similar pasts, present or future activities in the same geographical area, and might have a combined impact of moderate significance on the natural, cultural, and/or socio-economic resources of local, regional, or national concern. Low: The activity is localised and might have a negligible cumulative impact. None: No cumulative impact on the environment.

Once the evaluation components have been ranked for each potential impact, the significance of each potential impact will be assessed (or calculated) using the following formula:

- SP (Significance Points) = (Magnitude + Duration + Extent + Irreplaceable + Reversibility) x Probability.

The maximum value is 150 SP (significance points). The unmitigated and mitigated scenarios for each potential environmental impact should be rated as per Table below.

Table 3: Definition of significance ratings (positive and negative).

Significance Points	Environmental Significance	Description
125 – 150	**Very high (VH)**	An impact of very high significance will mean that the project cannot proceed, and that impacts are irreversible, regardless of available mitigation options.
100– 124	**High (H)**	An impact of high significance which could influence a decision about whether or not to proceed with the proposed project, regardless of available mitigation options.
75 – 99	**Medium-high (MH)**	If left unmanaged, an impact of medium-high significance could influence a decision about whether or not to proceed with a proposed project. Mitigation options should be relooked.
40 – 74	**Medium (M)**	If left unmanaged, an impact of moderate significance could influence a decision about whether or not to proceed with a proposed project.
<40	**Low (L)**	An impact of low is likely to contribute to positive decisions about whether or not to proceed with the project. It will have little real effect and is unlikely to have an influence on project design or alternative motivation.
+	**Positive impact (+)**	A positive impact is likely to result in a positive consequence/effect and is likely to contribute to positive decisions about whether or not to proceed with the project.

7. Conclusion

Taking all the different aspects and their limitations that were investigated during the hydrological impact assessment into account the following conclusions can be made.

The catchment area that forms the subject of this study is very small covering 94.7 ha in total. It constitutes a fraction of the larger Breede River catchment area covering some 12 384 km^2, as a rather insignificant tributary.

Rainfall in this area is relatively low at an average of 465 mm per annum resulting in low discharge volumes, however, due to the impermeable Bokkeveld shale substrate covering most of the drainage area not much rainfall is required to allow for surface runoff. As little as 6 mm of rain over just a few hours result in flow into the non-perennial stream and beyond causing frequent flow episodes in the stream during above average rainfall events. The total discharge remains low due to a combination of low and infrequent rainfall episodes and small catchment area with an average discharge of <80 m^3 during normal rainfall episodes and up to just below 500 m^3 during intense flood episodes.

The spring system is a unique phenomenon in this particular environment and the perennial, but seasonally fluctuating discharge being a significant contributor to the overall discharge in the drainage system under consideration. The discharge from the spring system even during a below average rain period exceeds that of a maximum flood event in the drainage system at some 534 m^3 per month.

8. Recommendations

The following recommendations should be adhered to in terms of mitigation measures:

- Monitoring the overflow of the dams should be done on a regular basis to ensure that a constant base flow is maintained;
- The flow should be recorded and a base flow of at least 10 m^3 per day should be allowed through the overflow of the lower dam into the downstream section of this tributary;
- Surface water quality should be monitored to ensure that surface water contamination does not take place;
- The water monitoring plan should be revised on a regular basis to incorporate the changes in the water flow regime;
- Regular inspections should be undertaken of any access roads and stormwater management systems for signs of erosion and sedimentation;
- Regularly inspect all vehicles used in the catchment area for leaks to prevent ingress of hydrocarbons into topsoil;
- If any spills occur, they should be immediately cleaned up;
- Utmost care must be taken to ensure the runoff water does not pollute the watercourses.

9. References

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