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Groundwater Reserve Determination Study in the Mhlathuze Catchment

High Level Assessment

INSTITUTE FOR GROUNDWATER STUDIES

March 26, 2009

Authored by: Ingrid Dennis and Rainier Dennis

Groundwater Reserve Determination for the Mhlathuze Water Management Area

Project numbers: WP9437/1 and 2008-214

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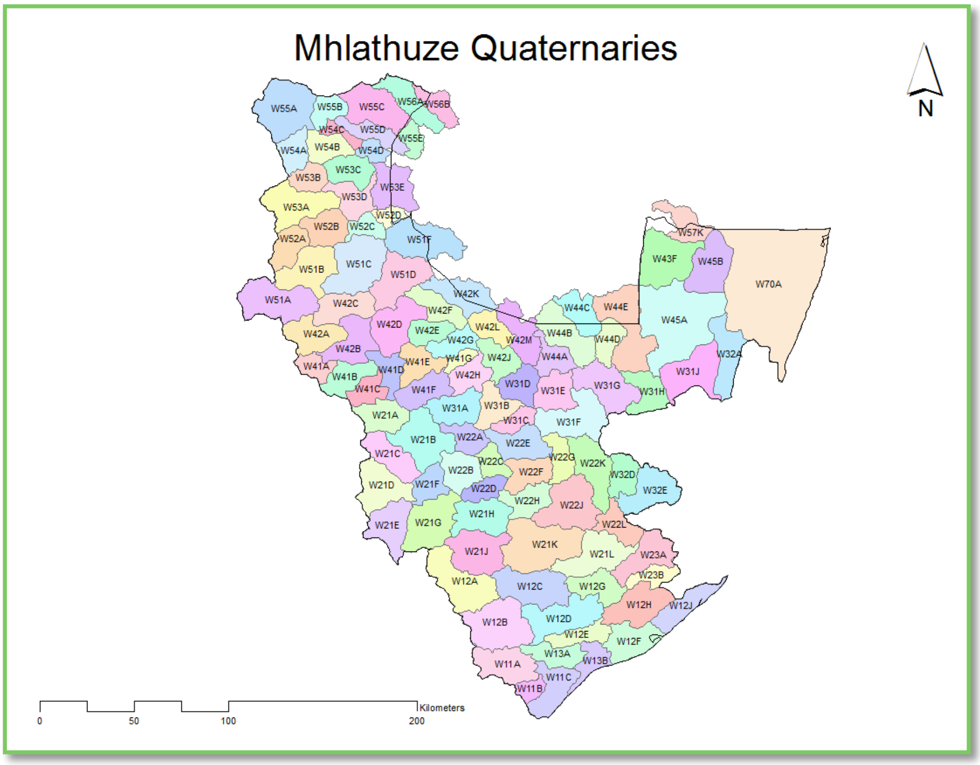
EXECUTIVE SUMMARY

Introduction

The Usutu to Mhlathuze Water Management Area lies predominantly within KwaZulu-Natal, with the northern part in the Mpumulanga province. It borders on Swaziland and Mozambique in the north, as well as on the Inkomati, Upper Vaal and Thukela Water Management Areas. The WMA is also referred to as the 'W' Hydrological Drainage Region (Midgeley et al., 1994).

The main rivers in the water management area are the Usutu, Pongola, Mkuze, Mfolozi and Mhlathuze Rivers, which drain adjoining catchments and all flow in a general eastward direction. The Usutu River has several parallel tributaries in South Africa, which all flow together in Swaziland. The Pongola River catchment falls mainly within South Africa, and also drains the south-eastern corner of Swaziland. On the eastern side of Swaziland, the Usutu River forms the border between South Africa and Swaziland, and then between South Africa and Mozambique before flowing together with the Pongola River (on the South African/Mozambican border) to form the Maputo River in Mozambique, where it discharges into Maputo Bay. The Mkuze River drains via the Mkuze swamps into Lake St Lucia, the largest natural lake in South Africa, and then via the St Lucia estuary to the Indian Ocean. The Mfolozi and Mhlatuze Rivers discharge directly into the ocean. An endoreic area with no significant surface drainage exists in the vicinity of Lake Sibayi and Kosi Bay in the north-east of the water management area.

Parsons and Associates are completing a comprehensive groundwater Reserve determination for the St Lucia area and therefore these catchments will not be included in this investigation.



The catchment experiences a wide range of climatic conditions. The climate in the region varies from cool near the western escarpment to sub-tropical along the coast. Summers are generally hot with temperatures often exceeding 35oC. Winters are cold, particularly in the west and north, where temperatures fall below freezing and frost occurs regularly. Along the coast, conditions are generally more temperate.

Rainfall varies significantly throughout the catchment and exhibits a strong correlation with relief. Rainfall is strongly seasonal, with in excess of 80% occurring as thunderstorms during the period from October to March. The peak rainfall months are December to February in the inland areas, and November to March at the coast. Rainfall ranges from as high as 1500 mm per year to the east of the escarpment and near the coast, to about 600 mm per year in the north-central area near the Lebombo mountains. Potential evaporation varies between 1 300 and 1 500 mm per year.

This very extensive WMA is some 45 000 km² in total. Of this, some 6000 km² comprises the Zululand Coastal Plain. Elevation in the area varies from sea level in the east to an average of some 100 m over the width of the Zululand Coastal Plain, inland of which the meridionally-trending Lebombo range rises to some 700 m, inland, and falls abruptly to only some 250 m in the similarly trending 'Lowveld' further inland, where it rises progressively to a maximum elevation of some 1700 m on the Great Escarpment on the north-western boundary of the WMA. Physiographically, the inland portion of the WMA comprises a number of low-standing, generally east or south-east trending catchments of the major rivers that are separated by elevated interfluve ridges.

Distinctly different vegetation types occur over the water management area - from savannah grassland in the north-west, to dense coastal and swamp forests in the east. A huge amount of the natural vegetation has been destroyed due to farming and forestry. However, Ngongoni veld is still found in the upper less developed areas, and coastal forest and thorn veld in the coastal and more developed areas. Both these veld types are more than 70% transformed from their natural state. Important afromontane natural forests are found along the southern fringes of the WMA.

The agricultural sector in the WMA is well-developed. The major activities are crop farming, cattle farming, game farming, sugar plantations and forestry. The importance of the manufacturing sector can be attributed to the railway infrastructure, the harbour at Richards Bay (incorporating the world's largest coal export terminal), power supplies, and water. Key industries are pulp and paper manufacturing and aluminium smelting. Timber and sugar are critical raw materials. The relatively high contribution of the transport sector can be attributed to the shipment of coal across the WMA from the Mpumalanga Highveld, as well as the transport of timber.

There are several nature reserves in the area, among which are Hluhluwe (famous for the black rhinoceros), Mfolozi, Mkuze, St Lucia, Sodwana and Itala. The St Lucia Estuary was recently proclaimed a World Heritage Site.

The foundations of KwaZulu-Natal comprise two distinct geological units; the Kaapvaal Craton and the Natal Metamorphic Province. After formation, the Kaapvaal Craton was uplifted and exposed to the atmosphere. This resulted in weathering, erosion and transport of sediment into shallow basins. Both the Pongola Supergroup and the similar gold-rich Witwatersrand rocks were deposited in these early basins. The lower part of the Pongola Supergroup (Nsuze Group) is a succession of basalt, sandstone and minor limestone. Old gold workings can be seen at Denny Dalton, between Vryheid and Melmoth. Vein gold is also mined near the Swaziland border. In northern KwaZulu-Natal and Swaziland, the Pongola Supergroup was intruded by granite. As these intrusions cooled, the surrounding rock was metamorphosed.

Approximately 1000 million years ago, subduction and collision along the southern margin of the Kaapvaal Craton produced the rocks of the Natal Metamorphic Province. The rocks were heated and deformed into a mountain range many thousands of kilometres long. The first sedimentary sequence deposited on the new basement was the Cambrian to Ordovician Natal Group (490 million years ago).

The Dwyka Group forms the lowermost and oldest deposit in the Karoo Supergroup basin. The shales of Pietermaritzburg Formation (Ecca Group) follow. Overlying the shale is a thick sequence dominated by light grey sandstones, called the Vryheid Formation.

Dramatic outpourings of lava spread across much of Gondwana about 180 million years ago heralded the start of the Gondwana breakup. Crystallisation of magma within fractures formed dolerite sills and dykes. The final volcanic event produced rhyolite lava, which now forms the Lebombo mountains. These volcanic events were followed by uplift and faulting that eventually separated Africa and Antarctica.

The first deposits (Zululand Group) formed in the newly opened Indian Ocean were silt- and sandstone of Cretaceous age (145-65 million years ago). A series of large coast-parallel dune complexes developed along most of the KwaZulu-Natal coastline. In most areas, deep weathering of old dunes has produced dark red coloured sand called the Berea Red Sand.

The western or inland portion of the WMA and its limited portion south of the southern end of the Zululand Coastal Plain at Mtunzini, that involves the catchments of the smaller Mlalazi and Matikulu Rivers, comprises 'hard rock' secondary porosity aquifers of the 'weathered and fractured' and 'fractured' classes. Faults, joints, and intrusive Karoo dolerite sheet and dyke contacts particularly in the Karoo sedimentary and volcanic rocks, in the regional 'hard-rocks', are zones of significant groundwater presence. Of the 'hard-rocks', the deeply weathered granite and granite-gneiss rocks, and the rocks of the Vryheid Formation, as well as those of the Natal Group in the southern portion of the region, are generally the best groundwater aquifers, the Dwyka Tillite Formation, where present, is the poorest.

By contrast, the aquifers of the Zululand Coastal Plain portion of the WMA are of the primary porosity or intergranular type.

Springs and seepages, although their flows are very markedly seasonally affected are extensively exploited as a domestic water supply source in the rural residential and agricultural 'hard-rock' portion of the WMA. On the Zululand Coastal Plain, the deep aquifer is exploited by appropriately installed fully cased and basally screened boreholes, while the shallow aquifer is exploited by the local population as a source of domestic water supply by shallow unlined open wells, shallow concrete ring-supported open wells, and more recently shallow hand pump-equipped screened tube wells, the latter two well forms were installed by relevant Governmental authorities. A very few deep (20 to 25 m) screen-well boreholes have been installed in a few places within the southern portion of the WMA to exploit the primary porosity aquifer present in the near-coastal portions of the WMA, represented by sandy alluvium beneath the beds of the larger rivers.

Groundwater quality in the WMA is variable, being best in the higher rainfall portions and poorest in the lower rainfall portions, as in the major river basins of the interior and in the 'rain shadow' or 'Lowveld' area immediately inland of the Lebombo range.

Project Objectives

The primary objective of the study is to calculate the Groundwater Reserve for the study area with a satisfactory associated confidence level. Issues to be addressed during this investigation include:

- ✓ The rapid population growth and the need for development through economic activities lead to greater water demand and increased pollution of available resources. As the consumption user demands of industrial and urban development rises, so will the proper functions of the freshwater resources within the study area be threatened.
- ✓ The Mhlathuze River is the principle source of water people living in this area. The river reach has been extensively modified, especially from the Goedertrouw Dam eastwards.
- ✓ The water resources of the catchment are over-allocated and the current estimated water requirements exceed the system yield.
- ✓ There is very little or no reticulated water supply for some of the informal settlements on the outskirts of some of the urban areas. For example, people living within the Madlebe Tribal Area to the south of Ngwelezane, are supplied with untreated water from boreholes and springs.
- ✓ Agriculture consumes a substantial proportion of capacity for irrigation.
- ✓ Run-off is reduced by afforestation.

✓ A certain amount of water is required to maintain the status of the environmental systems (rivers, lakes and estuaries). The most important systems are the wetland systems on the coastal plain, and the natural vegetation.

✓ The scarcity of water is also exacerbated by pollution of the surface and groundwater resources. Typical pollutants of freshwater aquatic ecosystems include industrial effluents, mining, domestic and commercial sewage, agriculture run-off and litter.

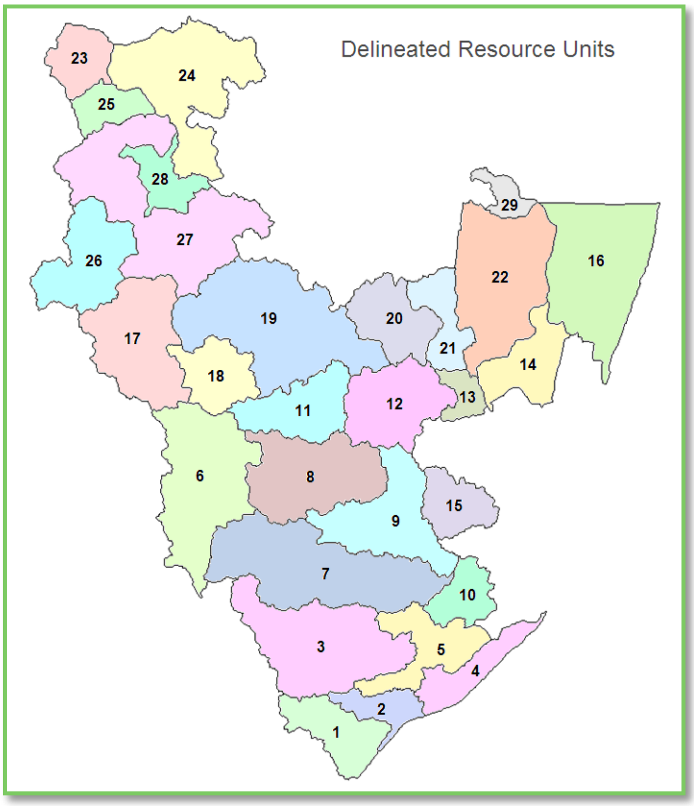
A secondary objective is training. The aim of this is to ensure the transfer of technical skills to historically disadvantaged individuals.

Delineation of Resource Units

Due to the size of the study area, it is not feasible to determine a Groundwater Reserve for the entire. Therefore the study area is divided into smaller sub-regions, called Resource Units (RU). There are over a hundred quaternary catchments within the WMA, making delineation a complex process. The first step in the delineation process was to divide the study area into six sub-catchments. Each area is then divided into smaller resource units. Other aspects taken into consideration are:

- Geology
- Climate
- Recharge
- Surface water and groundwater stresses

The delineated resource units are shown in the Figure below.



Classification and the Reserve

The results of the classification and the Reserve are summarised in the Table below. Please note that allocation = recharge – basic human needs – baseflow – current use.

Resource Unit	Classification		Recharge			Reserve			Allocation	
	Present Status Category	Resource Category	Total Area km²	Effective Area km²	Recharge Mm³/a	Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
MRU-1	B/C	Good/Fair	954.1	914.1	65.982	33.380	0.106	51%	19.902	12.594
MRU-2	B/C	Good/Fair	498.2	427.0	36.339	19.750	0.142	55%	11.219	5.228
MRU-3	B	Good	2418.6	2341.0	181.474	42.540	0.162	24%	132.613	6.159
MRU-4	C/D	Fair	731.1	727.7	63.178	39.580	0.185	63%	21.500	1.912
MRU-5	C/D	Fair	1059.6	1028.7	58.502	26.920	0.211	46%	27.623	3.749
MRU-6	C	Good/Fair	2417.5	2391.0	122.491	20.240	0.381	17%	90.162	11.707
MRU-7	B	Good	2855.8	2457.0	129.948	21.770	0.226	17%	102.881	5.071
MRU-8	C	Good/Fair	1900.3	1791.0	103.694	20.630	0.148	20%	70.129	12.787
MRU-9	B	Good	1665.8	1358.8	64.924	12.790	0.331	20%	51.227	0.575
MRU-10	B/C	Good/Fair	606.5	603.1	22.129	11.630	0.095	53%	8.879	1.525
MRU-11	C	Good/Fair	1140.2	1126.3	57.853	13.670	0.031	24%	41.475	2.677
MRU-12	B	Good	1437.3	1437.3	51.131	3.300	0.039	7%	42.391	5.400
MRU-13	B/C	Good/Fair	322.6	291.8	11.506	1.020	0.001	9%	9.226	1.259
MRU-14	C	Good/Fair	970.0	859.0	31.008	6.960	0.023	23%	19.524	4.501
MRU-15	B	Good	723.1	477.1	26.042	2.260	0.090	9%	23.208	0.483
MRU-16	C	Good/Fair	2589.0	1916.0	156.863	57.735	0.091	37%	65.857	33.179
MRU-17	B	Good	1901.0	1860.4	178.254	65.310	0.019	37%	110.837	2.088
MRU-18	B	Good	884.6	884.6	66.498	26.980	0.030	41%	34.945	4.542
MRU-19	B	Good	3247.0	2666.0	224.301	89.734	0.181	40%	125.755	8.631
MRU-20	C	Good/Fair	1036.8	973.4	26.846	1.231	0.057	5%	16.398	9.160
MRU-21	C	Good/Fair	711.4	550.4	29.514	0.751	0.000	3%	23.363	5.400
MRU-22	C	Good/Fair	2428.9	2390.5	48.354	3.030	0.196	7%	27.324	17.804
MRU-23	D	Fair	688.7	688.7	41.674	3.427	0.016	8%	19.573	18.658
MRU-24	C	Good/Fair	2434.5	2434.5	195.502	130.012	0.495	67%	49.706	15.289
MRU-25	C/D	Fair	533.0	533.0	36.268	4.340	0.002	12%	24.166	7.760
MRU-26	B/C	Good/Fair	1409.9	1409.9	95.851	14.975	0.005	16%	75.420	5.450
MRU-27	C	Good/Fair	3212.2	3172.6	233.433	48.318	0.369	21%	164.612	20.134
MRU-28	B	Good	611.8	611.8	46.303	9.071	0.050	20%	35.429	1.753
MRU-29	B	Good	301.0	205.2	11.808	0.933	0.007	8%	10.380	0.488

Resource Quality Objectives

Guidelines for Resource Quality Objectives were provided for the following:

- ✓ Borehole management
- ✓ Wetlands and estuaries
- ✓ Springs
- ✓ Basic human needs, strategic use and international obligations
- ✓ Protected areas
- ✓ Contaminated sites

Recommendations

Based on the results of this study the project team would like to make the following recommendations:

- According to the definition of a comprehension Reserve (Parsons and Wentzel, 2005):

‘*Comprehensive GRDM determinations aim to produce high confidence results and are based on site-specific data collected by a team of specialists; used for all compulsory licensing exercises, as well as for individual licence applications that could have a large impact in any catchment, or a relatively small impact in ecologically important and sensitive catchments. It should take less than two years to complete. Due to lack of long-term geohydrological data sets, GRDM assessments will only rarely be done at this level*.’

Although the project team aimed to achieve the highest confidence in the results of this GRDM investigation, the size of the WMA is too large to allow aquifer testing to obtain aquifer parameters and although more than one hydrocensus was conducted and numerous boreholes were sampled and chemistry analysed it is impossible to sample and test all the boreholes in the study area. It is however strongly recommended that comprehensive Reserve determinations be carried out on the resource units that are stressed and have a poor classification. These determinations must included extensive field work including drilling of boreholes and aquifer testing.

- Groundwater related data issues must be addressed. Project team members spent weeks trying to obtain data from various sources. The merging of the data into a single database for the project took much longer than expected due to the incompatibility and lack of structure of some of the various databases. Currently there are numerous databases for example WARMS, GRIP and NGDB/NGA. These need to be merged into a single database. Once this is complete the gaps in the data must be identified and addressed. This will provide an indication of where monitoring should take place.

- Numerical groundwater flow models were used to try and quantify the groundwater contribution to baseflow. However the results were discarded due to the scale of the models and the lack of aquifer parameters.

- Groundwater use in the study area is a concern. Because of the uncertainty in groundwater use, a stochastic analysis was applied assuming a normal distribution for the groundwater use. The stochastic analysis yielded a range of values with a specified confidence rather than a single value for the stress index. Resource Units with a wide range stress index should be targeted to obtain more accurate groundwater use data which will refine the stress index range.

- The formation of groundwater user associations must be encouraged. As already mentioned groundwater use information is a concern. Users of groundwater must therefore be encouraged to take responsibility for the resource by means of monitoring groundwater use, water levels and quality.

- National maps such as landcover must be updated. The land cover shown on these maps differs drastically from what was delineated from Google Earth.

- Numerous municipalities in the WMA were contacted for information. It became clear from these contact sessions that there is a lack of capacity and knowledge. A strategy must be developed and implemented to ensure local government has the skills to manage the groundwater resources.

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List of Abbreviations and Acronyms

BHN	Basic Human Needs
BHNR	Basic Human Needs Reserve
CMA	Catchment Management Agency
CRD	Cumulative Rainfall Departure
DSS	Decision Support System
DWAF	Department of Water Affairs and Forestry
EARTH	Extended Model for Aquifer Recharge and Soil Moisture Transport through the Saturated Hardrock
EC	Electrical Conductivity
EIS	Ecological Importance and Sensitivity
EMC	Ecological Management Category
ER	Ecological Reserve
EWR	Ecological Water Requirements
GMU	Groundwater Management Unit
GRDM	Groundwater Resource Directed Measures
GRU	Groundwater Resource Unit
HDI	Historically Disadvantaged Individual
ICM	Integrated Catchment Management
IFR	Instream Flow Requirements
IWRM	Integrated Water Resource Management
K	Hydraulic Conductivity
KZN	KwaZulu-Natal
MAP	Mean Annual Precipitation
MAR	Mean Annual Run-off
MLF	Maintenance Low Flow
MSL	Mean Sea Level

NGDB	National Groundwater Database
NWA	National Water Act (Act 36 of 1998)
NWRS	National Water Resource Strategy
PES	Present Ecological State
PESC	Present Ecological State Category
QRU	Quality Resource Unit
RDM	Resource Directed Measures
RQO	Resource Quality Objectives
RU	Resource Unit
S	Storativity
T	Transmissivity
TDS	Total Dissolved Solids
WMA	Water Management Area

UNITS OF MEASUREMENT

A	annum
cm	centimetre
d	day
ha	hectare
km^2	square kilometre
l	litre
l/cap ·d	litres per person per day
m	metre
Ma	million years
m^2	square metre
m^3	cubic metre
mamsl	metres above mean sea level
mbgl	metres below ground level
mbs	metres below sea level
MCM	million cubic metre
mg	milligram
mm	millimetre
mS	milliSiemen
s	second

The catchment of Forests . . .

1. Introduction

1.1 Preamble

The Mhlathuze River has its origin in the vicinity of the town of Babanango. The Mhlathuze River flows to the south-west of Empangeni and Ngwelezane and to the south of Felixton, and connects with the Indian Ocean via the Mhlathuze Estuary just south of Richards Bay. The river is approximately 170 km long. The water resources of the coastal zone of the Mhlathuze River are the most heavily utilised in the Richards Bay area. The port of Richards Bay was constructed in the estuary, and a new mouth dredged south of the previous estuary mouth. The catchment falls within the Usutu to Mhlathuze Water Management Area (WMA). The main river systems in this WMA include:

- Usutu
- Pongola
- Sibaya
- Mkuze
- Umfolozi
- Mhlathuze

The study area, however, is not water rich, since the major rivers are relatively short, have high gradients, and show strong, seasonal variations in flow. There is a strong hydraulic link between the surface and subsurface, to the extent that in some areas the distinction becomes very vague. The rich mosaic of wetlands, seepage pans and hygrophilous grasslands that occur in this area testifies to this strong connection. This can especially be seen along the coast.

The Department of Water Affairs and Forestry have requested a Groundwater Reserve determination for the Mhlathuze River catchments. Although the focus of this investigation will be the nine quaternary catchments of the Mhlathuze, the whole WMA will be investigated. The Mhlathuze River urgently requires compulsory licensing, due to stressed conditions and water quality problems.

The WMA is also referred to as the 'W' Hydrological Drainage Region (Midgeley *et al.*, 1994). The quaternary catchments within the WMA are shown in **Figure 1**.

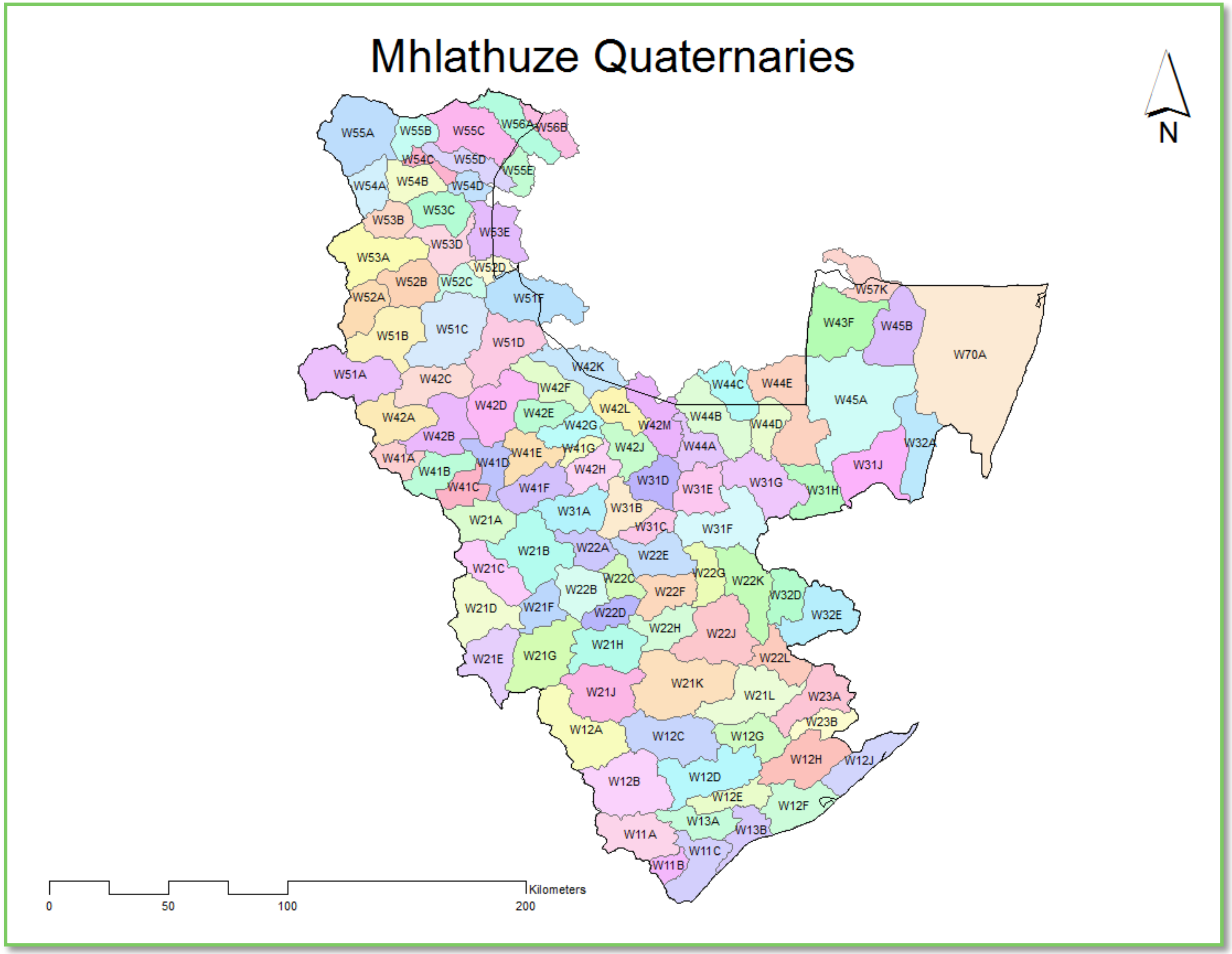


Figure 1: Quaternary Catchments included in the study area

1.2 Project Objectives

Detailed determinations aim to produce high-confidence results, are based on site-specific data collected by specialists, and are used for all compulsory licensing exercises, as well as for individual license applications that could have a large impact on any catchment, or a relatively small impact on ecologically important and sensitive catchments. The primary objective of the study is to calculate the Groundwater Reserve for the study area with a satisfactory associated confidence level. Issues to be addressed during this investigation include:

- The rapid population growth and the need for development through economic activities lead to greater water demand and increased pollution of available resources. As the consumption user demands of industrial and urban development rises, so will the proper functions of the freshwater resources within the study area be threatened.

PHOTO 1: FORESTRY IN THE AREA

- The Mhlathuze River is the principle source of water people living in this area. The river reach has been extensively modified, especially from the Goedertrouw Dam eastwards.
- The water resources of the catchment are over-allocated and the current estimated water requirements exceed the system yield.
- There is very little or no reticulated water supply for some of the informal settlements on the outskirts of some of the urban areas. For example, people living within the Madlebe Tribal Area to the south of Ngwelezane, are supplied with untreated water from boreholes and springs.
- Agriculture consumes a substantial proportion of capacity for irrigation.
- Run-off is reduced by afforestation (**Photo 1**).
- A certain amount of water is required to maintain the status of the environmental systems (rivers, lakes and estuaries). The most important systems are the wetland systems on the coastal plain, and the natural vegetation.
- The scarcity of water is also exacerbated by pollution of the surface and groundwater resources. Typical pollutants of freshwater aquatic ecosystems include industrial effluents, mining (**Photo 2**), domestic and commercial sewage, agriculture run-off and litter.

- Alien vegetation consumes large quantities of water within the study area.

A secondary objective is training. The aim of this is to ensure the transfer of technical skills to historically disadvantaged individuals. The project team also involved regional DWAF officials in the Groundwater Reserve determination. The training component of the investigation is discussed in a separate document.

PHOTO 2: MINE WITHIN THE STUDY AREA

1.3 Levels of Reserve Determinations

Ideally, all water resources in South Africa should be assessed to the same degree, and the results of the assessment should be of high confidence. However, the country does not have the manpower or financial resources to carry out Groundwater Resource Directed Measures (GRDM) assessments countrywide in the short term. To overcome this problem, different levels of GRDM assessments are used.

Four levels of GRDM determination are recognised, with each expected to yield a greater level of confidence in the results. The following general features characterise the differences between the four levels (taken from Parsons and Wentzel, 2007):

- Desktop: these determinations are created by means of readily available data and information; usually the first step in any GRDM process and a useful planning tool.
- Rapid: includes a short field trip to assess present state; typically used to assess individual licence applications with low impact in unstressed catchments and/or catchments of low ecological importance and sensitivity; should take less than two weeks to complete.
- Intermediate: these determinations yield results of medium confidence; require field investigations by experienced specialists and should take about two months (but <6 months) to complete; used to assess individual licences for moderate impacts in relatively stressed catchments.
- Comprehensive: comprehensive GRDM determinations aim to produce high confidence results and are based on site-specific data collected by a team of specialists; used for all compulsory licensing exercises, as well as for individual licence applications that could have a large impact in any catchment, or a relatively small impact on ecologically important and sensitive catchments. It should take less than two years to complete. Due to

the lack of long-term geohydrological data sets, GRDM assessments will only rarely be done at this level.

The main difference between intermediate and comprehensive assessments is the nature and extent of data used. As far as possible, comprehensive assessments have been conducted throughout the study area. However, where there are data shortages, intermediate assessments had to be conducted.

2. Groundwater Resource Directed Measures

2.1 Groundwater Resource Directed Measures Steps (summarised from Parsons and Wentzel, 2007)

The objective of Resource Directed Measures (RDM) is to facilitate the proactive protection (for use) of the country's water resources, in line with sustainability principles. The National Water Act (NWA) recognises the need to develop and use the country's water resources to grow. RDM hence strives to ensure that the water resources are afforded a level of protection that will ensure a sustainable level of development for the future. To this end, RDM comprises three main interrelated components, namely:

- Classification
- Reserve
- Resource Quality Objectives

Six steps are included in the GRDM methodology in this document:

1. Description of study area: This phase is probably the longest in the GRDM determination process, as it entails the collection of data and information on which the GRDM assessment is based. The collected information is then analysed and a conceptual understanding of the geohydrology of the study area developed.

2. Delineation of units: Based on the description of the study area, areas of similar character are demarcated. Resource units are areas of similar physical or ecological properties that are grouped or typed to simplify the Reserve determination process. For intermediate and comprehensive GRDM assessments, a more detailed delineation may be required and could be based on factors such as geology, topography, groundwater dependence and use.

3. Resource Classification: The key outcome of this phase is to define the water resource category for each groundwater resource unit (natural, good, fair, poor). The difference between reference conditions and present status is used to assess the sustainability of current groundwater use and the stress status of the groundwater resource. A single present status category is assigned to each groundwater response unit, which in turn is used to determine the water resource category of each unit.

4. Quantification of the Reserve: The only right to water in the NWA is water for basic human needs and for aquatic ecosystems. Basic human needs include water for cooking, drinking and personal hygiene, currently set at 25 l/d.

5. Setting Resource Quality Objectives: These are clear goals that balance the need to protect and sustain a water resource with the need to develop and use

it. The objectives will tell managers how much water is needed to keep a water resource healthy, what the quality of the water should be and what the condition of the animals and plants should be. The outcome from this phase is a list of goals – either numeric or descriptive – that can be used to set aquifer management criteria.

6. Review: DWAF (1999) proposed that each assessment of the groundwater allocation of a significant water resource be reviewed by a panel of experts prior to setting the Reserve.

2.2 Delineation of Resource Units

A three-tier system of delineation is used. By definition, quaternary catchments are used as the primary delineation of water resource units in RDM assessments. Secondary delineation takes into account surface water, when it is necessary to delineate zones of similar ecology within the study area. Groundwater resource units specifically relate to geohydrological characteristics, but may coincide with other significant water resource units or ecoregions, or parts thereof.

No formal methodology exists for delineating groundwater resource units beyond the second level of delineation. Until formal tools are available for this, expert judgement and local knowledge will be required. In the case of this investigation, tertiary delineation will be conducted in areas where groundwater is highly impacted. Unique classification and resource quality objectives must be determined and assigned to protect the groundwater resource.

Three criteria are recognised for potential use as the basis for delineation, namely physical, management, and functional criteria. It is necessary to specify which criteria or characteristics were used in the delineation process, and motivate why these were considered the most appropriate.

- Typically, delineation based on physical criteria would consider one or more of the following:
  - Geology
  - Climate
  - Topography and geomorphology
  - Recharge
  - Groundwater levels and flow directions
  - Temporal hydrostatic response patterns
  - Groundwater quality

- Groundwater use (and stress)
- Groundwater-dependent ecosystems.

- Management criteria: The outcome of a GRDM assessment and aquifer management goals are key components of the National Water Resource Strategy. In some cases, it may be difficult to manage an aquifer on the basis of physical delineation considerations, and it may be more practical and meaningful to use management criteria for delineation. Examples could include property, water user association, catchment management, water management and political boundaries.

- Functional criteria: It may be useful to type areas in terms of the role groundwater plays in sustaining the environment. The purpose of this sort of typing is to identify components within the study area that play a unique role in the hydrological and ecological functioning of a water resource.

In this Assessment . . .

As already mentioned, there are 88 quaternary catchments within the WMA, making delineation a complex process. In addition, as the surface water Reserve has already been completed for the WMA, the groundwater Reserve must take these results into account, and the surface water RUs must therefore also be taken into account, with groundwater. The first step in the delineation process was to divide the study area into four sub-catchments, namely the Upper Thukela, Buffalo, Mooi/Sundays and Lower Thukela catchments. Each area is then divided into smaller resource units. Other aspects taken into consideration are:

- Geology
- Climate
- Recharge
- Surface water and groundwater stresses

"Hot spots" were identified during the classification process. A hot spot can be defined as an area within a RU that is severely stressed.

2.3 Classification

The overall objective of classifying a water resource is to define its water resource class (in terms of natural, good, fair and poor) and its management class (in terms of excellent, good and fair), as explicated in **Figure 2**. The management class is set to ensure both long-term protection and management of groundwater resources, as well as to promote the development and use of the resource. The management class is also used to define the level at which the Reserve and RQOs must be set.

Classification of groundwater resources will occur at two levels, namely a regional scale for each resource unit, and a local scale where problem areas might occur and more rigorous constraints (classification and RQOs) might be necessary. The reason for including two scales for classification and RQOs is that groundwater-related problems (contamination and over-abstraction) are usually localised and do not affect the whole area for which the Reserve is calculated. This process also allows the RQOs to be site-specific and more accurate.

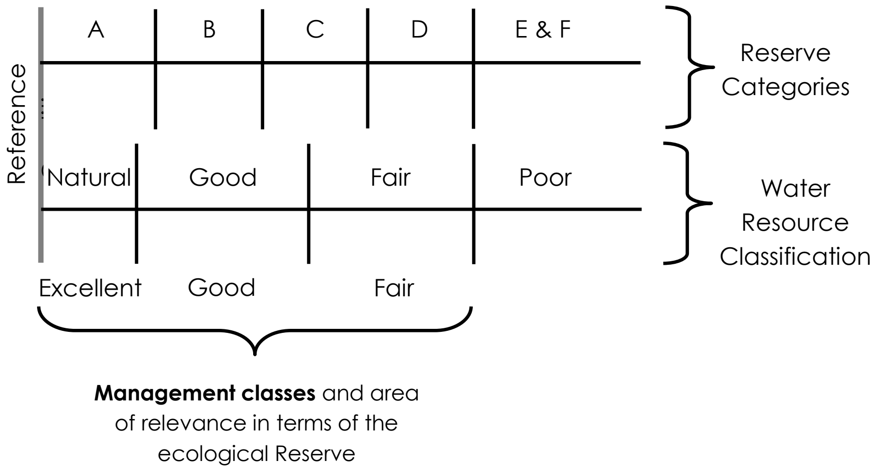


FIGURE 2: RELATIONSHIP BETWEEN VARIOUS CLASSIFICATION SYSTEMS (PARSONS AND WENTZEL, 2007)

In terms of the overall groundwater categorisation process, and in order to be able to determine the class of a water resource, reference conditions need to be identified and present status assessed. A single present status category is assigned to each groundwater resource unit, which is then used to assign a water resource category to each unit.

Reference conditions refer to the natural or ambient state of the groundwater system, while present status (also referred to as present ecological status category or PESC) relates to the current state of the groundwater system. A significant difference between reference conditions and present state implies that a resource is in a degraded state, and is hence assigned a lower category.

Once a single present status category is assigned to each resource unit, then the groundwater resource category can be determined using **Table 1**. It must be remembered that the desired status of the resource and management class is not addressed here, but rather in public participation and catchment visioning processes.

Table 1: Relationship between present status category, desired status category and management class (Parsons and Wentzel, 2007)

<table>
<tr><th>Present Status Category</th><th>Water Resource Category</th><th>Desired Status * Category</th><th>Management * Class</th></tr>
<tr><td>A – unmodified natural</td><td>Natural</td><td>A – Highly sensitive systems, negligible risk allowed</td><td>Excellent</td></tr>
<tr><td>B – largely natural</td><td rowspan="2">Good</td><td>B – Sensitive systems, small risk allowed</td><td rowspan="2">Good</td></tr>
<tr><td>C – moderately modified</td><td>C – Moderately sensitive systems, moderate risk allowed</td></tr>
<tr><td>D – largely modified</td><td>Fair</td><td>D – Resilient systems, large risk allowed</td><td>Fair</td></tr>
<tr><td>E – seriously modified</td><td rowspan="2">Poor</td><td></td><td></td></tr>
<tr><td>F – critically modified</td><td></td><td></td></tr>
</table>

Note: *only considered during public participation and catchment visioning processes

In this Assessment . . .

Defining Quantitative Stress

To provide a quantitative means of defining stress, a groundwater stress index was developed by dividing the volume of groundwater abstracted from a groundwater unit by the estimated recharge to that unit. The PESC is then calculated as:

PRESENT STATUS CATEGORY	DESCRIPTION	STRESS INDEX (abstraction / recharge)
A	Unstressed or slightly stressed	< 0.05
B		0.05–0.20
C	Moderately stressed	0.20–0.40
D		0.40–0.65
E	Highly stressed	0.65–0.95
F	Critically stressed	> 0.95

Abstraction takes into account all groundwater use including aquatic ecosystems and basic human needs.

- ***Calculating Basic Human Needs***

  The 2001 census data were used, with an annual growth rate of 1.5%. The groundwater dependence from the population in the study area is an estimated 20%. The basic human need contribution to the water balance becomes negligible when a large study area is considered, but remains an important component to quantify according to the water law. When the area diminishes e.g. the extent of a village, the BHN component represents a significant amount of the water balance. The reason for this is that, in the Reserve, a uniform population distribution is assumed for the study area, which results in a low population density over a large extent. In the case of a village, the population total is known and the area is small, resulting in a dense population distribution.
- ***Calculating Aquactic Ecosystem Use (Groundwater Contribution to Baseflow)***

  Groundwater contribution to baseflow was estimated through the baseflow separation technique proposed by Herold. The Herold method is used in the GRDM Assessment Software to determine the groundwater contribution to flow in a river. Vegter used the Herold method to separate monthly river flows into a surface run-off component and a groundwater contribution. The Herold method can be explained as follows:

$$Qi = QGi + Qsi$$

where: Qi = total flow during month i

QGi = groundwater contribution

QSi = surface run-off

The assumption is that all flow below a certain value (called GGMAX) is groundwater flow, hence:

QSi = Qi – GGMAX (for Qi > QGMAX)

or QSi = 0 (for Qi ≤ QGMAX)

and hence QGi = Qi – Qsi

The value of GGMAX is adjusted each month according to the surface run-off during the preceding month, and is assumed to decay with time, hence

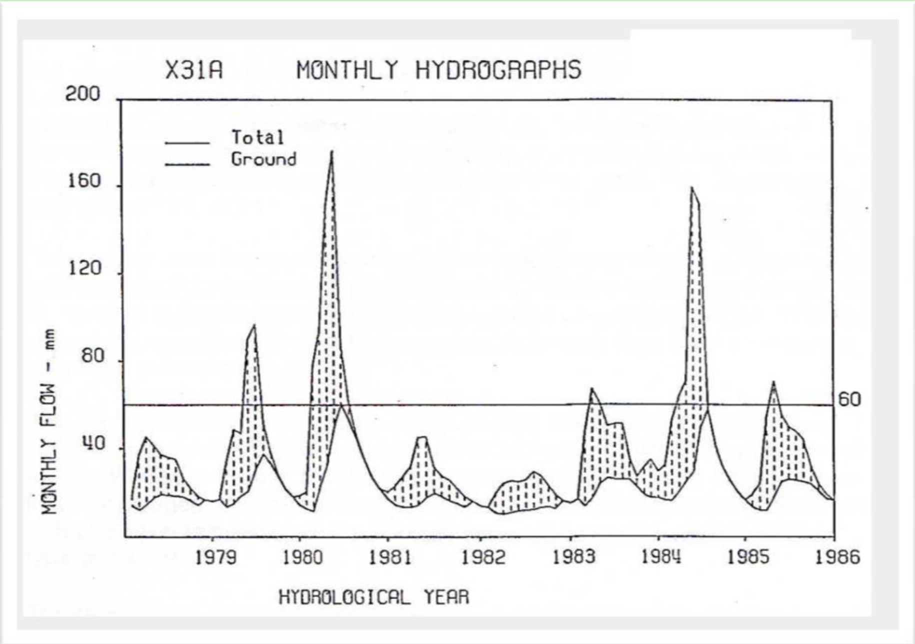
$$GGMAX_i = DECAY.GGMAY_{i-1} + PG.QS_{i-1}/100$$

where: subscripts *i* and *i-1* refer to the current and preceding month.

DECAY = groundwater decay factor (0 < DECAY < 1)

PG = groundwater growth factor (0 < PG > 1)

An added constraint is that *GGMAX* may not fall below a specified value, *QGMAX*. Calibration of this model is achieved by selecting an appropriate value of *DECAY*, *PG* and *QGMAX*, so that a realistic division between surface run-off and groundwater is obtained, as shown in below:



Monthly flow data are required for the separation process. Naturalised monthly flow data for each quaternary catchment can be obtained from WR2005, while flow data can be downloaded from the DWAF website (www.dwaf.gov.za).

The method was included in the GRDM Assessment Software, and is easy to use. However, fitting the separation curve is subjective, and the user has to determine the most appropriate fit when attempting to quantify the groundwater contribution to river flow. When conducting the separation, the following should be borne in mind:

- ✓ Groundwater will contribute very little to the flow in those rivers with a low baseflow index, ephemeral or strongly seasonal rivers. Consequently, the modelled groundwater contribution to flow should be small.
- ✓ Given that annual groundwater level fluctuations in a catchment are small in relation to the length or width of the catchment (and consequently that the hydraulic gradient varies very little), it is conceptualised that the groundwater contribution to flow in a river remains fairly constant. It is hence not possible that the groundwater contribution to flow will vary by orders of magnitude, as suggested by conventional approaches to baseflow separation.

The groundwater contribution to baseflow values were validated by:

- ✓ Comparing them to Pitman's baseflow values
- ✓ Comparing them to Hughes's baseflow values
- ✓ Comparing them to Van Tonder's baseflow values
- ✓ Performing simple models to confirm results

- ***Calculating Groundwater Use***

  When considering the water balance equation used in the groundwater Reserve determination process, the groundwater use component is singled out as the parameter with the highest uncertainty. This is mainly due to unregistered groundwater use. During a Hydrocensus, most of the production boreholes are locked, and there is no accurate record of abstraction rates.

  The approach adopted for this study was to compare the abstraction rates available from hydrocensus data with the WARMS database and the existing use figures available in the GRDM software package. It was evident from the available data that the WARMS database does not reflect all the groundwater use in the area and that the existing groundwater use figure in the GRDM software is also too small.

  An estimation was made of how much of the study area is under irrigation and plantations. The ratio between surface and groundwater use in each of the identified resource units was used to calculate the percentage of irrigation dependent on groundwater. It was evident from a comparison of aerial photos and existing land use maps that the land use in terms of irrigation is much higher than indicated on the maps.

Crop water use was determined using the BEWAP crop water model. BEWAP is a water balance model for irrigation based upon profile available water capacity crop need. BEWAP was developed by the Department of Soil Sciences at the University of the Free State. Simulations were run for various crop types and an average use was included in the groundwater use calculations.

The average tree density was estimated for both natural and planted forests, with an average groundwater use of 10 l/tree/day. The Table below shows typical water use of selected tree types associated with high groundwater use.

Tree Type	Daily Water Use (l)
Blue Gum (Eucalyptus family)	100
Citrus Trees	20 - 50
Eucalyptus	25
Oak	25
Pine	25
Wattle	50

Forestry has a major impact on the water use in an area. A monitoring programme from SAEON (South African Environmental Observation Network) begun in 1938, showed the following trends:

- ✓ The onset of streamflow reductions was evident at ~5 years.
- ✓ Streamflow is strongly associated with plantation age.
- ✓ Peak streamflow reduction occurs at ~15 years.
- ✓ A rule of thumb is 30-40 mm streamflow reduction per 10% of catchment planted, at peak water use.

Furthermore, clearing invasive trees along rivers, during relatively low-flow conditions, typically results in streamflow increases of 8 000 to 12 000 litres/ha per day in the winter rainfall region, and up to 34 000 litres/ha per day in the summer rainfall region, regardless of location and species. It is therefore critical to include water use bt trees in the Reserve determination, especially in areas where forestry is dominant.

Due to the uncertainty associated with the calculation of the groundwater use, a stochastic approach was applied in the Reserve calculation. A normal distribution curve with a specified standard deviation was applied to the groundwater use to account for the uncertainty in that component. The result is a range of the Reserve with a specified confidence rather than a single value.

- ***Calculating Recharge***

  Numerous methods were used to calculate groundwater recharge, including:

  - ✓ **Chloride Mass Balance**

    Aquifer systems are mainly recharged via preferential pathways such as fractures, dykes, bedding planes and highly weathered zones. The recharge from rainfall was estimated using the Chloride Mass Balance (CMB) method, and is expressed as a percentage of the Mean Annual Precipitation (MAP). The method is based on the following equation:

$$\%\,Recharge = \frac{Chloride\ concentration\ in\ rainfall}{Chloride\ concentration\ in\ groundwater} * 100$$

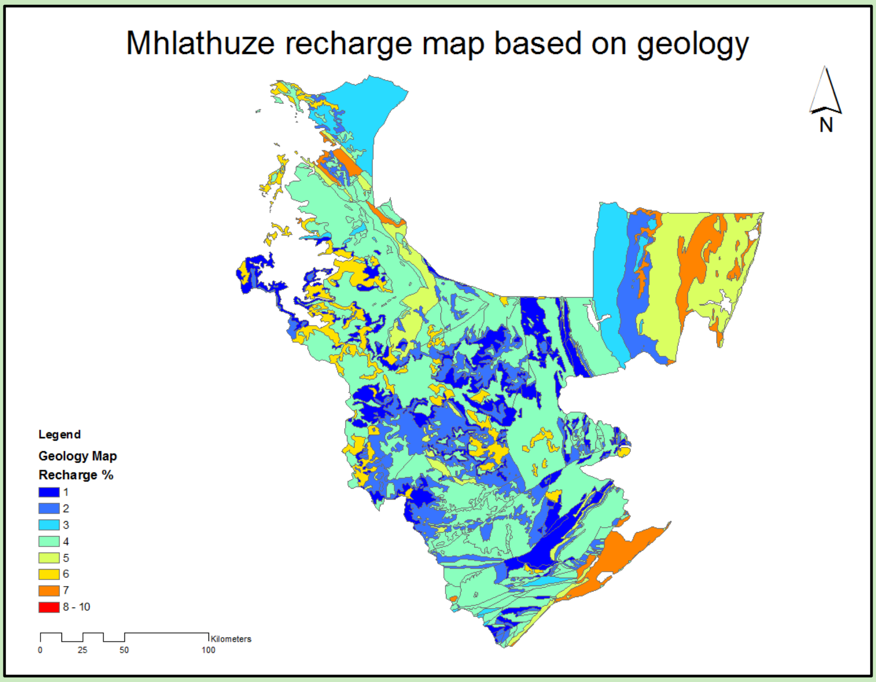
    The assumptions necessary for the successful application of the chloride method are as follows (Van Tonder & Xu, 2001):

    - There is no source of chloride in the soil water or groundwater other than precipitation.
    - Chloride is conservative in the system.
    - Steady state conditions are maintained with respect to long-term precipitation and chloride concentration in that precipitation, and in the case of the unsaturated zone.
    - A piston flow regime, which is defined as downward vertical diffuse flow of soil moisture, is assumed. However this assumption may be invalidated if the flow through the unsaturated zone is along preferred pathways.

    The CMB method is the only analytical method that could be applied to the recharge calculation due to the lack of time series monitoring data across the study area. Ecca formations are known for their high chloride values, which will result in a lower recharge estimation than the actual value. Previous studies have shown that a dilution factor of 2.0 is sufficient to correct the CMB method in Ecca-rich areas.

  - ✓ **Geology Recharge Estimate**

    Various recharge percentages are associated with specific lithogies. The individual resource units were delineated on the basis of the underlying lithology, and a recharge estimate was made using the associated recharge of the identified lithologies proportional to their area. The recharge map of the Thukela, based on the geology, is shown below.



- ✓ **Qualified Guess**

  A qualified guess on recharge per resource unit was made taking into account the Landcover and soil types (Van Tonder, 2001). Although not an analytical approach, the method could be applied as a first attempt in the recharge estimation when little data are available. The qualified guess is presented in this document for comparison purposes.

Defining Quality Stress

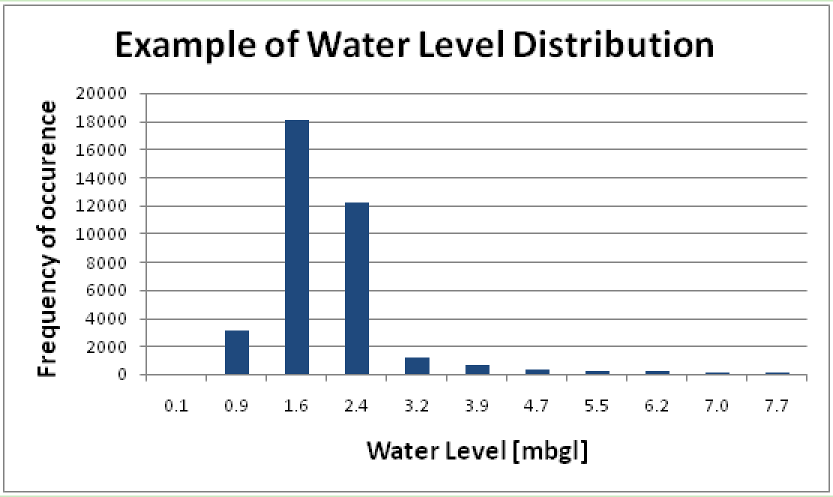
- ***Aquifer Vulnerability and Land Use***

  The aquifer vulnerability assessment technique relies on readily available information for a study area. Utilising the hydrogeological setting, inferences are made regarding the soil's geochemical nature and potential for contaminants to migrate from the soil surface to the groundwater table. The term hydrogeological setting refers to a composite description of all the major geologic and hydrologic factors. These types of analyses apply to areas on the order of 0.5 km^2 and more (Delleur, 1999).

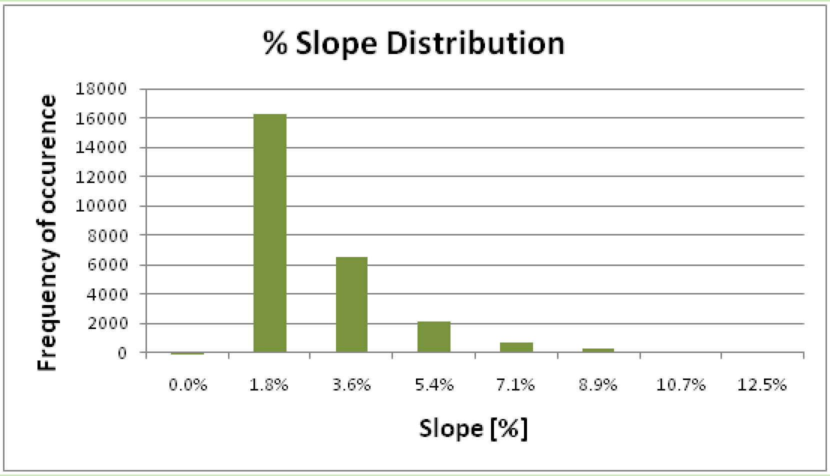
  The DRASTIC method is classified as an overlay technique and provides a simple and straightforward means of assessing the susceptibility of certain areas to contaminants. The acronym DRASTIC refers to the seven factors utilised in the rating system — depth to groundwater, recharge rate (net), aquifer media, soil media, topography, impact on vadose zone, and hydraulic conductivity.

Each of these is assigned a value based on a rating. These factors are adjusted by a weighting factor and summed to calculate the pollution potential or DRASTIC index (Delleur, 1999). The aquifer vulnerability for this study was calculated using the SAGDT (South African Groundwater Decision Tool), which utilises a modified DRASTIC approach, based on a fuzzy logic rule set. Hydraulic conductivies are seldom available, and hence the method of SAGDT aquifer vulnerability calculation is reduced to only the following parameters:

- ✓ Groundwater Level [mbgl] - The water levels across the area are presented as a histogram, and the bin with the highest frequency is chosen as a representative water level. An example is shown in the figure below. When more than one dominant water level exists, the shallower level is used to obtain a conservative vulnerability estimate.



- ✓ Slope of the area [%] – Random elevation samples taken over the area are used to produce a distribution of representative slopes over the area. An example is shown in the figure below. When more than one dominant slope exists, the smaller one is used to obtain a conservative vulnerability estimate.
- ✓ Recharge [%] – The recharge percentage is the calculated value from all existing recharge data.
- ✓ Soil Media – Soil media information is obtained from soil covers available for the area.
- ✓ Aquifer Media – Aquifer media are associated with geology in the area, and can also be confirmed by borehole logs available for some of the boreholes.
- ✓ Vadose Zone – The Vadose zone types for most of the country are available and associated with the soils and geology in the area.



The calculated aquifer vulnerability is expressed as a percentage rather than the traditional DRASTIC index. Note that the aquifer vulnerability is determined from natural parameters that are not likely to change with time. The only parameter that is prone to change is the water levels, but due to the large aerial extent, these should not have an influence if water levels were to change drastically in a specific area.

The land use is defined as a low, moderate or high impact, according to the table below:

EXPECTED IMPACT	LAND USE
Low impact	natural veld industrial area – (not chemical) pastures rural area – farms abattoirs irrigation – limited chemicals kraals rural area – low density
Moderate impact	sewage works – small (less than 1 Mℓ/d) spills – hazardous waste site – small industrial area – food processing irrigation – chemicals rural area – high density feedlots sewage works – medium waste site – medium (between 1 and 20 Mℓ/d)
High impact	industrial area – chemical mine dumps urban area waste site – large sewage works – large (greater than 20 Mℓ/d) underground storage tanks industrial area – metal processing power generation waste site – hazardous

The land use and vulnerability are combined to assign categories as follows:

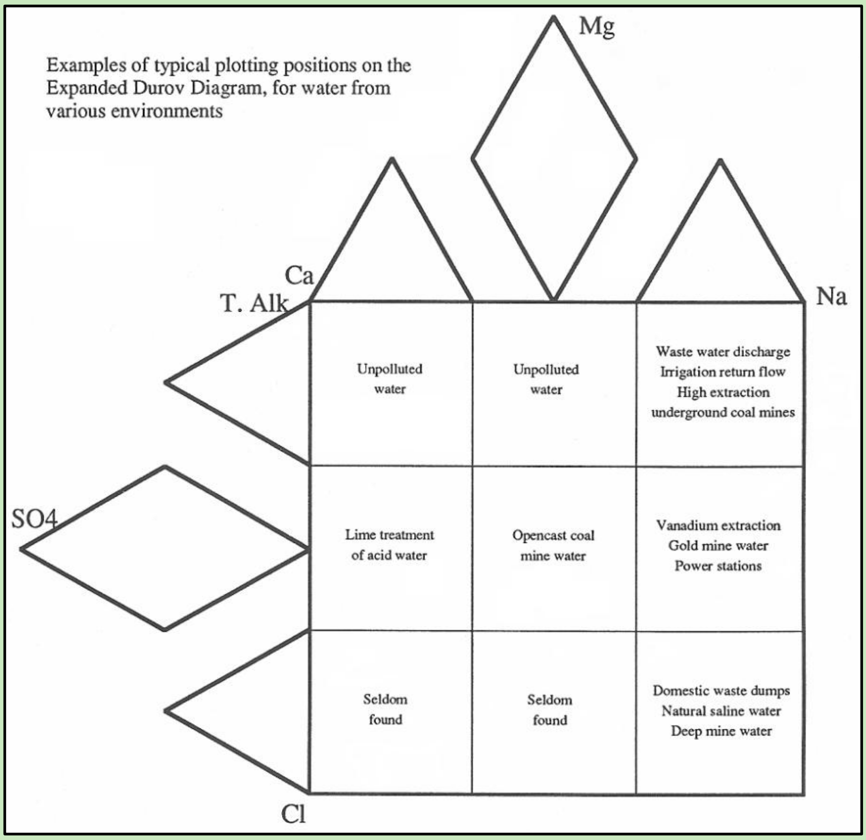
LAND USE	VULNERABILITY				
	20	40	60	80	100
Low	A	A	B	B	C
Medium	B	B	C	C	D
High	C	C	D	D	E

- ***Groundwater quality***

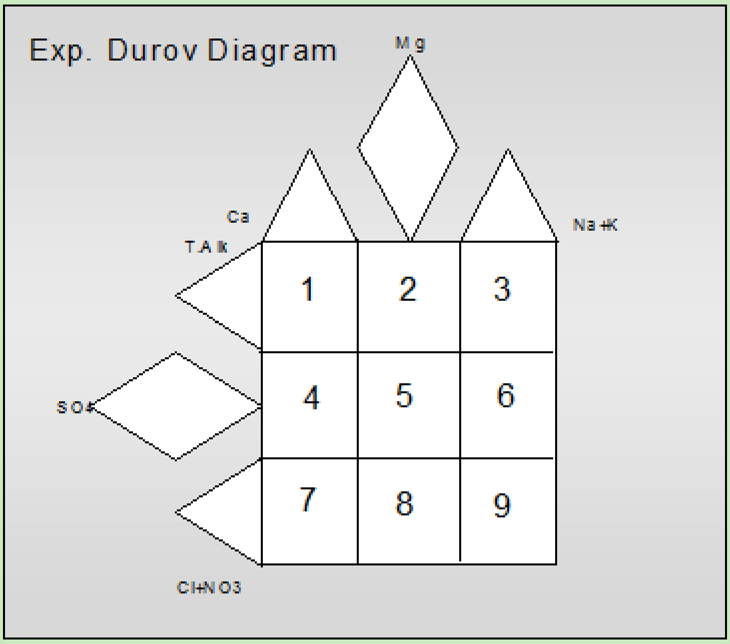
With the available hydrocensus data and chemical analysis done during the Reserve determination at selected sites, enough information is available to produce expanded Durov diagrams of selected boreholes. The expanded Durov diagrams allow the plotting of eight chemical parameters for a single water sample. Either surface or groundwater chemistries may be plotted. The procedure is as follows:

- ✓ Calculate concentrations for Ca, Mg, Na, K, Cl, SO4, NO3, T.Alk in units of milli-equivalents per litre.
- ✓ Calculate relative percentages for the cations and anions.
- ✓ Plot the percentages cations in the top triangle (see figure below).
- ✓ Plot the percentages anions in the bottom triangle (see Figure below).
- ✓ Project the two points to the central block on the diagram and make a mark where the two projections cross.

A very general interpretation is given in the figure below.

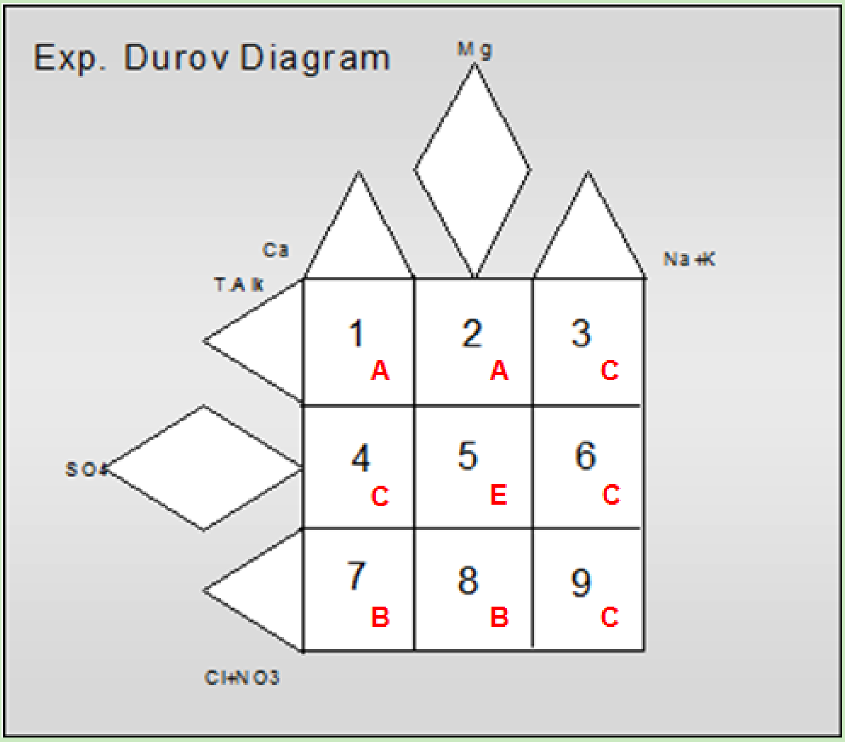


A more detailed description of each field is summarised below, with reference to the figure below.



1. Fresh, very clean recently recharged groundwater with HCO_3^- and CO_3 dominated ions.
2. Field 2 represents fresh, clean, relatively young groundwater that has started to undergo Mg ion exchange, often found in dolomitic terrain.
3. This field indicates fresh, clean, relatively young groundwater that has undergone Na ion exchange (sometimes in Na-rich granites or other felsic rocks), or because of contamination effects from a source rich in Na.
4. Fresh, recently recharged groundwater with HCO_3^- and CO_3 dominated ions, which has been in contact with a source of SO_4 contamination, or moved through SO_4 enriched bedrock.
5. Groundwater that is usually a mix of different types – either clean water from Fields 1 and 2 that has undergone SO_4 and NaCl mixing / contamination, or old, stagnant NaCl dominated water that has mixed with clean water.
6. Groundwater from Field 5 that has been in contact with a source rich in Na, or old, stagnant NaCl dominated water that resides in Na-rich host rock / material.
7. Water rarely plots in this field, which indicates an NO_3 or Cl enrichment, or dissolution.
8. Groundwater that is usually a mix of different types - either clean water from Fields 1 and 2 that has undergone SO_4, but especially Cl mixing / contamination, or old, stagnant NaCl dominated water that has mixed with water richer in Mg.
9. Very old, stagnant water that has reached the end of the geohydrological cycle (deserts, salty pans, etc.); or water that has moved a long time and / or distance through the aquifer and has undergone significant ion exchange.

For the purpose of this Reserve study, the expanded Durov fields were related to the classification system as presented at the beginning of this section. The relation between the Durov fields and the present status classification system is shown in the figure below.



The available TDS (Total Dissolved Solids) values are also displayed in the resource units to give an indication of possible pollution. The boreholes rated against the TDS drinking standards are also displayed on the expanded Durov diagrams for each resource unit, to highlight the dominating constituents.

2.4 Reserve

The groundwater component of the Reserve is the part of the groundwater resource that sustains basic human needs and aquatic ecosystems. Groundwater can only be allocated to users and potential users once the volume of groundwater that contributes to sustaining the Reserve has been quantified and RQOs met. To be able to quantify the groundwater component of the Reserve, the following equation has to be solved:

$$GW_{allocate} = (Re + GW_{in} - GW_{out}) - BHN - GW_{Bf}$$

where:

$GW_{allocate}$	=	groundwater allocation
Re	=	recharge
GW_{in}	=	groundwater inflow
GW_{out}	=	groundwater outflow
BHN	=	basic human needs
GW_{Bf}	=	groundwater contribution to baseflow

2.5 Resource Quality Objectives

The purpose of the Resource Quality Objectives is to establish clear goals relating to the quality of the relevant water resource. When setting Resource Quality Objectives (RQOs), a balance must be found between the need to protect and sustain water resources on the one hand, and the need to develop and use them on the other. Resource quality may relate to critical flows, groundwater levels and quality that must be maintained. RQOs are considered powerful tools for implementing groundwater protection for sustainable use. At present, no formal guidelines exist with respect to setting RQOs.

2.6 Assumptions related to GRDM

Understanding the role of groundwater in sustaining the environment is still in its infancy. To be able to undertake GRDM assessments and quantify the volume of groundwater required to meet Classification requirements and sustain the Reserve, a number of assumptions are made:

- Groundwater systems are generally resilient and can normally recover from most perturbations. However, it is accepted that groundwater contamination can persist over decades and centuries.

- Groundwater resources can be developed and used up to a point without significantly impacting the ability of groundwater resources to sustain the Reserve or meet the RQOs.
- The ability of a geohydrological system to satisfy basic human needs, RQOs and the ecological Reserve is not impacted if regional groundwater levels do not decline significantly over the long term, and ambient groundwater quality remains within natural limits.
- The sustainable rate at which groundwater can be abstracted is a function of the average long-term annual recharge, while the volume of groundwater held in storage acts as a buffer during dry periods.
- It is assumed that recharge and groundwater abstraction are distributed relatively evenly throughout significant water resources.
- The validity of each GRDM assessment will be reviewed at least every five years using monitored data from the study area.
- The GRDM assessment will be carried out by persons qualified and experienced in the field of groundwater hydrology who, in turn, will collaborate with other specialist hydrologists and ecologists. The GRDM assessment will also be subject to formal review.

2.7 Sources of Information

The following sources of information were accessed during this study:

- Numerous reports documented in the reference list of this report.
- Data from the following databases/institutions were obtained and included in the study:
  - National Groundwater Archive (NGA)/National Groundwater Database (NGDB)
  - Groundwater Resource Information Project (GRIP) from DWAF, Durban
  - Field investigations (hydrocensus data)
  - Geohydrological reports reports obtained from consultants and DWAF officials
  - WARMS database from DWAF, Durban
  - Local monitoring data from DWAF, Durban
  - Local and regional municipalities

3. Summary of Surface Water Reserve

3.1 Preamble

IWR Environmental was responsible for the surface water Reserve in the Mhlathuze River Catchment. It is important to note that the surface water Reserve has only been cconducted for the Mhlathuze River and none of the others within the WMA. This Chapter contains extracts of the reports generated by IWR Environmental in 2000. The results obtained from the various specialist meetings convened are summarised below.

3.2 River Classification and Importance

The Mhlathuze River within the study area runs from the Goedertrouw Dam to the Mhlathuze Estuary, a total length of approximately 180 km (**Figure 3**). The river has been extensively modified through the construction of the Goedertrouw Dam and the Mhlathuze Weir, canalisation downstream of the Mhlathuze Weir, various types of direct utilisation such as vegetation removal and sand winning and the extensive colonisation of exotic plant species. The river downstream of the Goedertrouw Dam reveals extensive change from a wide sand bed dominated channel with depositional features to a narrow single thread channel with extensive vegetation encroachment. The river is the main water source for the Richards Bay area, as well as for farming in the greater area. These impacts have resulted in extensive changes in the habitat integrity, ecological status and hydrology of the river. While the river has low to moderate social importance, it has moderate to very high ecological importance, which justifies the need for the application of an Ecological Reserve. The PES is documented in **Table 2**.

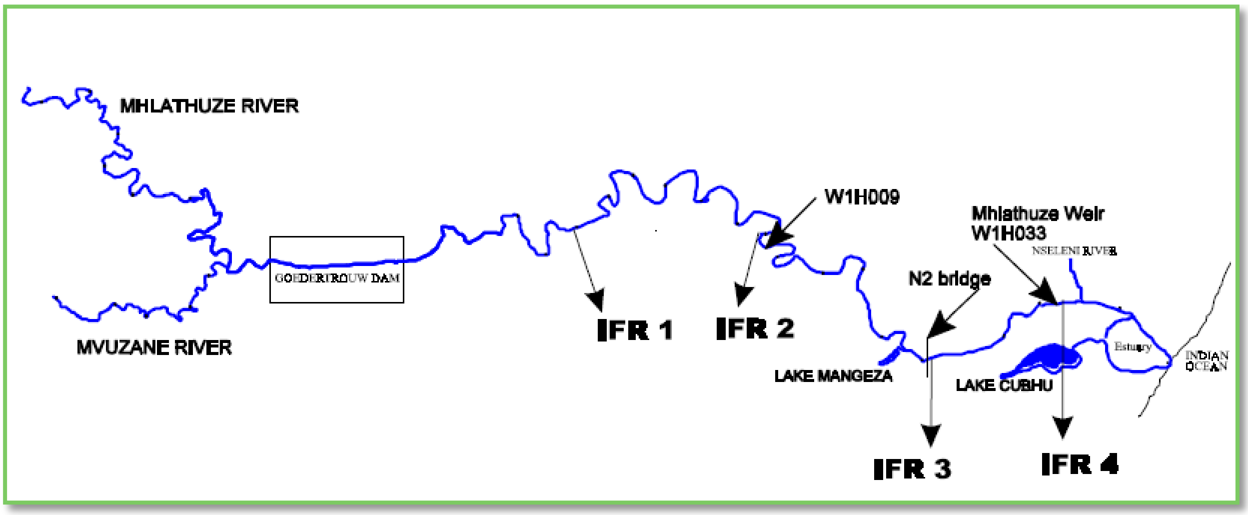


FIGURE 3: MAP OF STUDY AREA SHOWING IFR SITES

Table 2: PES, importance and technical AEMC of the various river reaches

River reach	PES		Importance		AEMC	
	Instream	Riparian	Ecological	Social	Instream	Riparian
Goedertrouw Dam to Mfule Confluence	C/D	E	Moderate	Moderate	C/D	D
Mfule Confluence to Mhlathuze Weir	C/B	D	High	Moderate	B	C/D
Mhlathuze Weir to Estuary	E	E	Very high	Low	not applicable – must function only as conduit between river and estuary	

AEMC = Attainable Ecological Management Class

3.3 Inflow Stream Requirements

Four IFR sites were selected to characterise the study area (**Figure 3**). Time constraints dictated that only two, (IFRs 1 and 3) the ones in which the specialists expressed the highest confidence, could be considered in detail. The results from these sites were subsequently extrapolated to the other two sites, using hydrological and other techniques, with a range of checks. The annual total volume of flow required for the different IFR flow types (or building blocks) is summarised in Table 3.

Table 3: IFR results

	IFR 1		IFR 3	
	x 10^6 m^3	% OF MAR	x 10^6 m^3	% OF MAR
Maintenance low flows	38.1	20.6	58.1	18.6
Maintenance high flows	17.6	9.6	23.6	7.6
Total	**55.7**	**30.2**	**81.7**	**26.2**
Drought low flows	11.6	6.3	20.7	6.6
Drought high flows	2.29	0	3.9	1.2
Total	**13.89**	**6.31**	**24.6**	**7.8**

3.4 Estuary Classification

The Mhlathuze Estuary has been primarily impacted by the construction of the harbour, the opening of the estuary mouth and the construction of the Goedertrouw Dam with the associated changes in the morphology (to an estuarine embayment), salinity gradient, sediment regime, freshwater inflow and responses in its instream and littoral biota. The present ecological state of its various components rate from moderate to high, which have been impacted to various degrees. The reference state was considered to be that of an estuarine embayment, and its ecological importance was considered to be very high (national level), largely due to its uniqueness as an open mouth system and water quality characteristics. It is a prime habitat for numerous red data species (fish and birds), and has high species/taxon richness, particularly with respect to its instream biota. It also has a high Botanical Importance Rating due to its extensive mangrove populations and the presence of an important Zostera population. The present ecological state of the Mhlathuze Estuary is presented in **Table 4**.

TABLE 4: PES FOR THE MHLATHUZE ESTUARY

Component	Rating	Rationale
Physical • embayment • estuary channel	C/D	• morphology of the estuary considerably changed with respect to natural configuration • however, mouth is stable
Water quality	B/C	• some chemical and biological contamination • otherwise typical of nutrient poor systems along this coastline
Vegetation	C	• reduced freshwater input and loss of reeds
Zooplankton	D	• tidal exchange is too high to permit the development of communities
Zoobenthos	C/D	• marine dominated, did not fully investigate estuary channel
Macrocrustacea	C	• some rare species as well as economically important species present
Fish	C	• high significance as a permanently open estuary • high number of endemics and Red Data species
Birds	E	• too little information for a proper assessment
Overall score	**C/D**	• although some components showed that the estuary is fulfilling an important role in habitat provision, the estuary is still considered to be largely modified due to the considerable change due to the harbour development

3.5 Estuary Freshwater Requirements

For many estuaries, the monthly baseflow requirements determined are usually set to maintain an open mouth for certain periods during the year. However, in the case of the Mhlathuze, this was not the major rationale for setting baseflow requirements, as tidal exchange rather than baseflow is the primary mechanism for maintaining an open mouth. For this reason, baseflows were set in order to maintain a reasonable salinity gradient. Flow rates of between 0.1 and 0.3 m^3/s were thought to be sufficient to maintain an adequate salinity gradient in the upper estuary.

4. Description of the Study Area

4.1 Location

The Usutu to Mhlathuze Water Management Area lies predominantly within KwaZulu-Natal, with the northern part in the Mpumulanga province. It borders on Swaziland and Mozambique in the north, as well as on the Inkomati, Upper Vaal and Thukela Water Management Areas.

The main rivers in the water management area are the Usutu, Pongola, Mkuze, Mfolozi and Mhlathuze Rivers, which drain adjoining catchments and all flow in a general eastward direction. The Usutu River has several parallel tributaries in South Africa, which all flow together in Swaziland. The Pongola River catchment falls mainly within South Africa, and also drains the south-eastern corner of Swaziland. On the eastern side of Swaziland, the Usutu River forms the border between South Africa and Swaziland, and then between South Africa and Mozambique before flowing together with the Pongola River (on the South African/Mozambican border) to form the Maputo River in Mozambique, where it discharges into Maputo Bay. The Mkuze River drains via the Mkuze swamps into Lake St Lucia, the largest natural lake in South Africa, and then via the St Lucia estuary to the Indian Ocean. The Mfolozi and Mhlatuze Rivers discharge directly into the ocean. An endoreic area with no significant surface drainage exists in the vicinity of Lake Sibayi and Kosi Bay in the north-east of the water management area.

Parsons and Associates are completing a comprehensive groundwater Reserve determination for the St Lucia area and therefore these catchments will not be included in this investigation.

4.2 Main Towns

There are numerous towns within the WMA. The main towns include:

Photo 3: Chrissiesmeer
(Source: www. blogspace.mweb.co.za)

- Chrissiesmeer (Lake Chrissie) is a small town situated in a wetland area of Mpumalanga. This small town is the centre South Africa's largest lake district (**Photo 3**), with some 270 lakes and wetlands located within a 20 km radius.
- Lothair is a picturesque small town situated some 40 kilometres to the east of Ermelo. The town is situated close to the Swaziland border and its economy is derived solely from forestry. Lothair's saw mills are

the basis of a thriving community in this town. The town is situated in the heart of Mpumalanga's wetlands.

- Amsterdam is situated in close proximity to the border between Swaziland and South Africa. This community is predominantly based on sheep farming.
- Piet Retief is situated in south-eastern corner of Mpumalanga. It is surrounded by plantations of Bluegum, Pine and Wattle trees.
- Vryheid is a coal mining and cattle ranching town.
- Umfolozi is the heart of the Zulu Kingdom and the home of the White Rhino.
- Pongola is a small town situated in northern KwaZulu-Natal Province, South Africa, only 10 kilometres from the Swaziland border. Pongola has 50 km² of sugarcane and subtropical fruit plantations surrounding it. Pongola is situated at foothills of the majestic Lebombo Mountains.
- Melmoth is a little town just 90 km from the coastal town of Mtunzini. The Ntingwe Tea Plantations (**Photo 4**), which produce tea solely for export, are found in the vicinity of this town.

PHOTO 4: TEA PLANTATION

(Source: www.sa-venues.com)

- Eshowe "A City Set on a Hill" is surrounded by natural forests, sugar plantations and orchards.
- Amatikulu is situated on the north coast, with the Indian Ocean as its eastern boundary. In the vicinity are the Amatikulu and Nyoni River estuaries, fine coastal lowland forest and some unspoilt climax grassland.
- Richards Bay boasts the country's largest harbour and some of its most magnificent wetland scenery.
- Empangeni is situated in the hilly country side of the Uthungulu District, just 15 kilometres from Richards Bay.
- Mkuze is a small Elephant Coast trade and transport centre. It is also the name of one of the Elephant Coast waterways that meanders across the study area, eventually feeding into the St Lucia wetlands.

4.3 Rivers and Dams

Even though the study area will to be discussed in more detail in the following sections, a short summary of the main catchments is provided here:

- **Mtunzini and Matikulu catchment (W11 and W13):** These two small coastal catchments are characterised by high rainfall, large areas of dryland sugar cane (357 km^2), limited amounts of irrigation (13 km^2), and afforestation (59 km^2). There are only farm dams within the area. There are two towns in the catchment, Eshowe and Mtunzini. Mtunzini is supplied from groundwater, with limited reliability.

- **Mhlathuze catchment (W12):** The Mhlathuze catchment is the economic hub of the Usutu to Mhlathuze WMA, with a large number of industries and the world's largest coal export terminal. The water requirements of the Mhlathuze catchment are substantial, with all user sectors (mining, industrial, irrigation and domestic) having large water requirements. The area under irrigation is estimated at 131 km^2, while there are also large areas of afforestation (576 km^2) and dryland sugarcane (268 km^2). The water resources of the Mhlathuze catchment are well developed with the large Goedertrouw Dam.

- **Mfolozi catchment (W21 - W23):** The Mfolozi catchment consists mostly of communal land, which is used for stock farming, although there is a significant amount of irrigation (72 km^2), forestry (435 km^2) and dryland sugarcane (65 km^2) in the catchment. Richards Bay Minerals occur in this catchment. The Klipfontein Dam is the only major dam in the catchment. The water quality of the Klipfontein Dam is poor due to urban return flows into the dam.

- **Mkuze/Hluhluwe catchment (W31, W32 and W70):** The Mkuze catchment is characterised by large-scale irrigation (76 km^2) and afforestation (392 km^2), while domestic requirements, mostly rural, are also significant. The water resource available to irrigators is limited, however, with the only significant dam in the catchment being the Hluhluwe Dam. The ecologically sensitive Lake St Lucia (which is a World Heritage site) is situated in the catchment. The water quality in the Mkuze River sub-catchment is poor due to coal mining activities and irrigation return flows.

- **Pongola catchment (W41 – W45):** There is a large amount of irrigation in the middle of the Pongola catchment, with an estimated irrigated area of 199 km^2 upstream of the Pongolapoort Dam. There are also large areas under afforestation in the upper reaches of the Pongola catchment, with an estimated area of 480 km^2, which has reduced the assurance of supply to irrigators over the years. The Pongolapoort Dam is one of the largest in South Africa. The Bivane Dam, situated on the Bivane River, upstream of the Pongolapoort Dam, was recently constructed to improve the levels of assurance to existing irrigators. The water quality upstream of the Pongolapoort Dam is poor due to irrigation return flows.

- **Usutu catchment (W51 - W57):** The Usutu catchment is characterised by large transfers from the catchment for cooling purposes at power stations. Four large dams in the Usutu support these transfers. The only significant in-basin use is afforestation, with an estimated area of 1930 km^2. Irrigation is limited with an area of only 27 km^2. The water quality of the Usutu catchment is excellent. However, there are large coal reserves in the catchment and the potential for deterioration is huge.

The major dams and lakes within the study area are listed in **Table 5**, and shown in **Figure 4**.

TABLE 5: MAJOR DAMS AND LAKES WITHIN CATCHMENT (SOURCE TLOU & MATJI (PTY) LTD, 2004)

Dam Name	Catchment	Live Storage Capacity (10^6 m^3)
Goedertrouw	W12B	304
Lake Cubu	W12F	6.5
Lake Nsezi	W12H	2.9
Lake Msingazi	W12J	38
Lake Nhlabane	W12J	39.7
Lake Sokhule	W12J	2.2
Bloemveld	W21A	2.3
Grootfontein	W21A	1.1
Klipfontein	W21A	19.0
Sokhulu	W23C	4
Boulder	W31A	1.5
Kraskop	W31B	2.1
Mhlabinyati	W31H	2.6
River Side	W32B	1.2
Silver Sands	W32C	3
Silver Sands No. 2	W32C	2.5
Hluhluwe	W32E	25
Pongolapoort	W44E	2 445
Heyshope	W51B	453
Morgenstond	W53A	101
Jericho	W53B	60
CJ van Rooyen	W54A	3.7
Westoe	W54B	61
Burgers	W55C	1.4

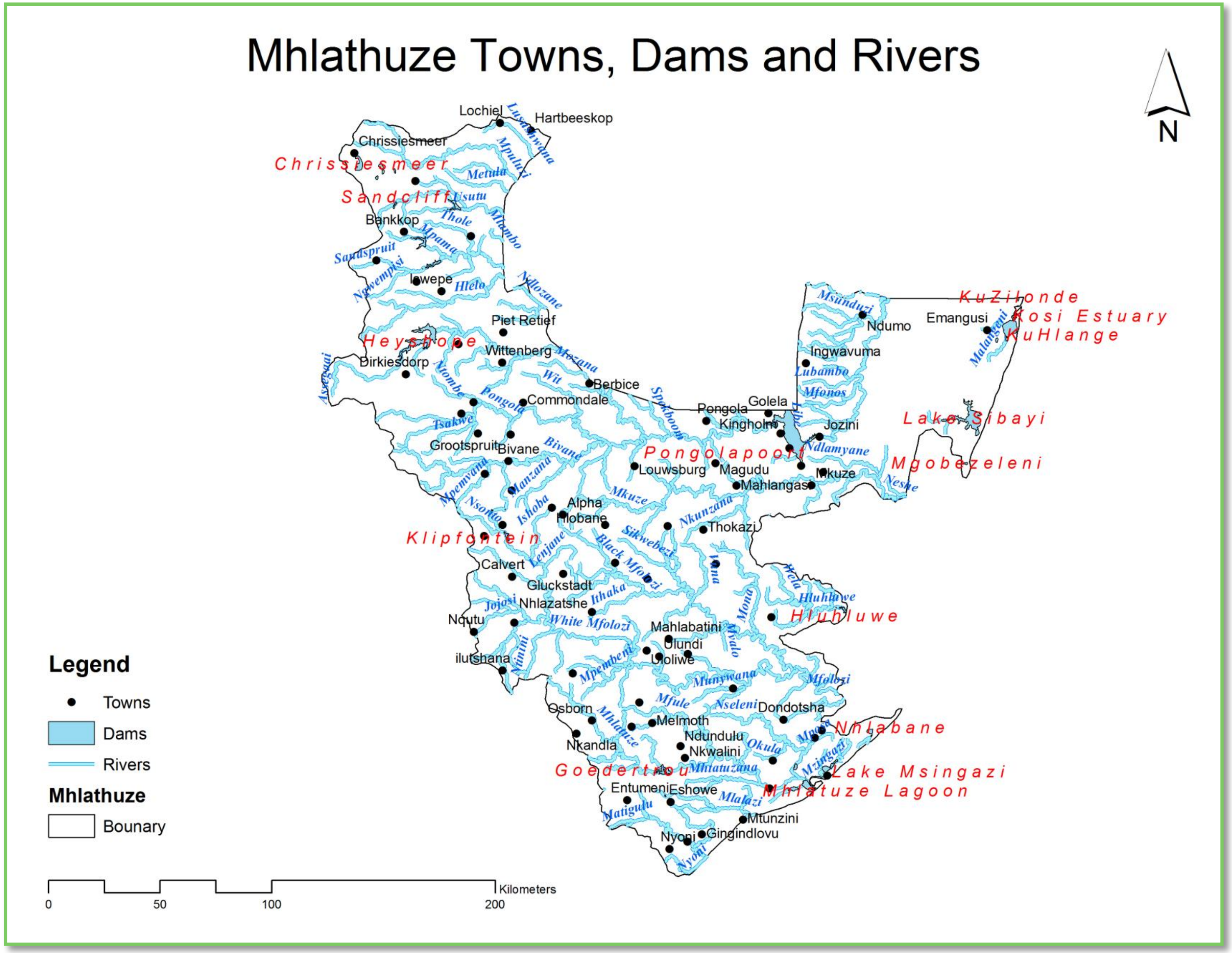


Figure 4: Main towns, rivers and dams within the study area

4.3 Climate

The catchment experiences a wide range of climatic conditions. The climate in the region varies from cool near the western escarpment to sub-tropical along the coast. Summers are generally hot with temperatures often exceeding 35°C. Winters are cold, particularly in the west and north, where temperatures fall below freezing and frost occurs regularly. Along the coast, conditions are generally more temperate.

Photo 5: Thunderstorm
(Source: www.panoramio.com)

Rainfall varies significantly throughout the catchment and exhibits a strong correlation with relief. Rainfall is strongly seasonal, with in excess of 80% occurring as thunderstorms during the period from October to March. The peak rainfall months are December to February in the inland areas, and November to March at the coast. Rainfall ranges from as high as 1 500 mm per year to the east of the escarpment and near the coast, to about 600 mm per year in the north-central area near the Lebombo mountains. Potential evaporation varies between 1 300 and 1 500 mm per year.

4.4 Topography

This very extensive WMA is some 45 000 km² in total. Of this, some 6000 km² comprises the Zululand Coastal Plain. Elevation in the area varies from sea level in the east to an average of some 100 m over the width of the Zululand Coastal Plain, inland of which the meridionally-trending Lebombo range (Photo 6) rises to some 700 m, inland, and falls abruptly to only some 250 m in the similarly trending 'Lowveld' further inland, where it rises progressively to a maximum elevation of some 1700 m on the Great Escarpment on the north-western boundary of the WMA. Physiographically, the inland portion of the WMA comprises a number of low-standing, generally east or south-east trending basins of the major rivers that are separated by elevated interfluve ridges. The coastal portion of the area in the south, and the inland portion of the area west of the Zululand Coastal Plain, are generally characterised by a

Photo 6: Typical topography in western parts of WMA
(Source: www.panoramio.com)

steep and strongly dissected topography. **Figure 5** shows the steep slopes in the middle and upper sections of the WMA.

4.5 Natural vegetation

Distinctly different vegetation types occur over the water management area - from savannah grassland in the north-west, to dense coastal and swamp forests in the east. A huge amount of the natural vegetation has been destroyed due to farming and forestry. However, Ngongoni veld is still found in the upper less developed areas, and coastal forest and thorn veld in the coastal and more developed areas. Both these veld types are more than 70% transformed from their natural state. Important afromontane natural forests are found along the southern fringes of the WMA. The Acocks veld types are shown in **Figure 6**.

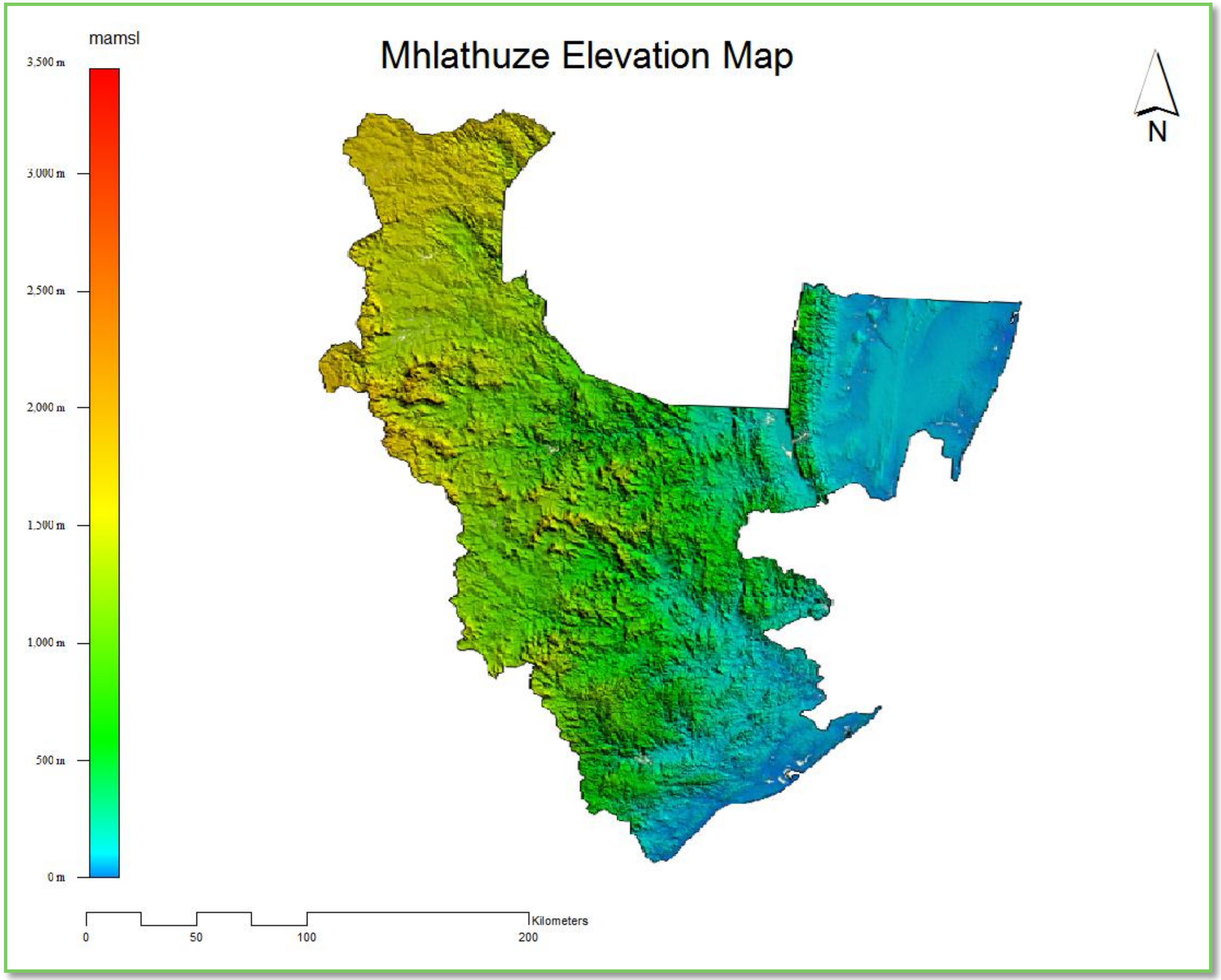


Figure 5: Topography of the WMA

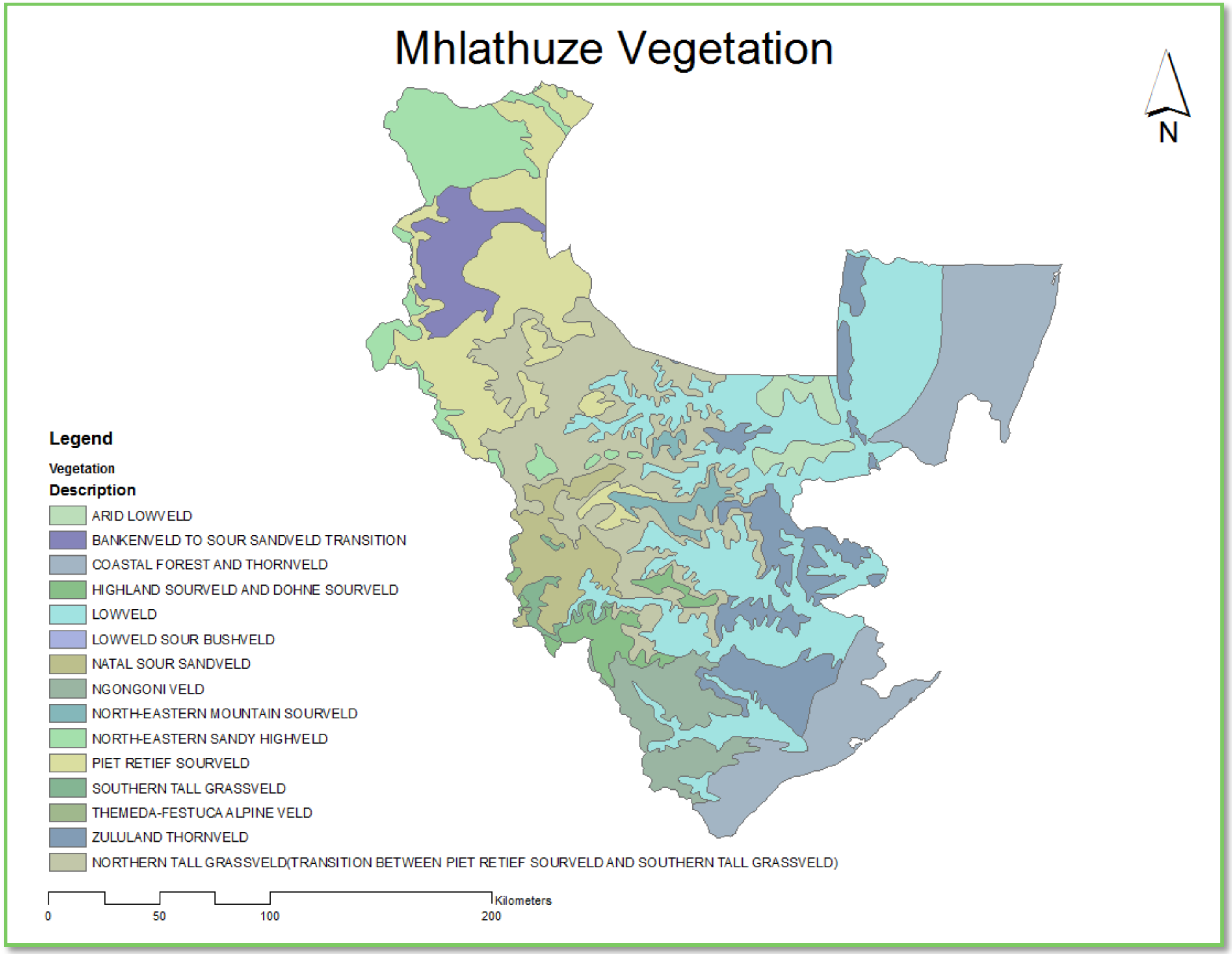


Figure 6: Vegetation within the WMA

4.6 Land Use

The Usutu to Mhlathuze WMA is one of the smaller contributors to the South African economy in terms of Gross Domestic Product (GDP), with a contribution of only 1.94 percent. The most important sectors in terms of contribution to GDP are:

- manufacturing and mining (35.5%)
- agriculture (15.2%)
- transport (12.5%)
- other (36.8%)

The agricultural sector in the WMA is well-developed. The major activities are crop farming, cattle farming, game farming, sugar plantations and forestry. The sugar cane industry (**Photo 7**) has an increasing number of small cane growers.

PHOTO 7: SUGARCANE PLANTATIONS

The importance of the manufacturing sector can be attributed to the railway infrastructure, the harbour at Richards Bay (incorporating the world's largest coal export terminal), power supplies, and water. Key industries are pulp and paper manufacturing and aluminium smelting. Timber and sugar are critical raw materials. The relatively high contribution of the transport sector can be attributed to the shipment of coal across the WMA from the Mpumalanga Highveld, as well as the transport of timber.

There are several nature reserves in the area, among which are Hluhluwe (famous for the black rhinoceros), Mfolozi, Mkuze, St Lucia, Sodwana and Itala. The St Lucia Estuary was recently proclaimed a World Heritage Site.

Urban development accounted for about 2% of the catchment Landcover, and this comprised mainly residential, industrial and commercial development associated with Richards Bay near the coast as well as Empangeni further inland.

4.7 Soils

The soil is a complex mixture of eroded rock, mineral nutrients, decaying organic matter, water, air and billions of organisms, most of which are microscopic decomposers. To see the soils characteristics of the study area, refer to **Figure 7**.

The average size of the spaces or pores in a soil determines soil permeability, i.e. the rate at which water and air move from the upper to lower soil layers. Soil permeability is also influenced by soil structure: how soil particles are organised and clumped together. Soils vary in clay (very fine particles), silt (fine particles), sand (medium size particles), and gravel (course to very course particles) content. The proportion of the different sizes and types of mineral particles determines the soil texture. Loam soils comprised of roughly equal mixtures of clay, sand silt and humus, are the best soils for growing most crops.

4.8 Geology (summarised from geology.ukzn.co.za)

The foundations of KwaZulu-Natal comprise two distinct geological units; the Kaapvaal Craton and the Natal Metamorphic Province. These form separate continental blocks that have influenced the geological history, scenery and economic potential of the region. North of the great Tugela River lies the most ancient crustal block in southern Africa, the Archaean Kaapvaal Craton (3000 million years old). It was formed when when the Earth's basaltic crust was intruded by granite. The basalts are 3500 million years old and are preserved as greenstone fragments within the granite. Granite can be seen in the valley between Melmoth and Vryheid, and at quarries inland of Richards Bay. Basalt of the Nondweni Greenstone Belt south of Vryheid preserves ancient 'pillow structures' (**Photo 8**).

Photo 8: Pillow Lava, White Umfolozi River
(Source: www. geology.ukzn.co.za)

After formation, the Kaapvaal Craton was uplifted and exposed to the atmosphere. This resulted in weathering, erosion and transport of sediment into shallow basins. Both the Pongola Supergroup and the similar gold-rich Witwatersrand rocks were deposited in these early basins. The lower part of the Pongola Supergroup (Nsuze

Group) is a succession of basalt, sandstone and minor limestone. North of the Tugela Fault, the Pongola Supergroup rocks are gently dipping and relatively unaltered. Near the Tugela Fault, these rocks are folded and deformed during collision of the basement. Some limestone units in the Nsuzi Group contain stromatolites - fossils of 2900 million year old-algal colonies which thrived in a shallow, warm ocean. Overlying the Nsuze Group is a thick succession of sedimentary rocks called the Mozaan Group, which contains gold-bearing conglomerate. Old gold workings can be seen at Denny Dalton, between Vryheid and Melmoth. Vein gold is also mined near the Swaziland border. In northern KwaZulu-Natal and Swaziland, the Pongola Supergroup was intruded by granite. As these intrusions cooled, the surrounding rock was metamorphosed.

PHOTO 9: MHLATHUZE VALLEY
(Source: www. geology.ukzn.co.za)

Approximately 1000 million years ago, subduction and collision along the southern margin of the Kaapvaal Craton produced the rocks of the Natal Metamorphic Province. The rocks were heated and deformed into a mountain range many thousands of kilometres long. Once plate collision with the Kaapvaal Craton had ceased, a long period of erosion exposed the deep mountain roots of granite and gneiss. The granite is quarried for dimension stone at a number of localities (**Photo 9**).

The first sedimentary sequence deposited on the new basement was the Cambrian to Ordovician Natal Group (490 million years ago). Structures preserved in these sandstones indicate that the sediments were transported and deposited by rivers that drained highlands to the north-east. Close to their source, in northern KZN, deep valleys were infilled with thick accumulations of boulders and pebbles. Further south, the sediment is finer-grained and forms resistant sandstone cliffs.

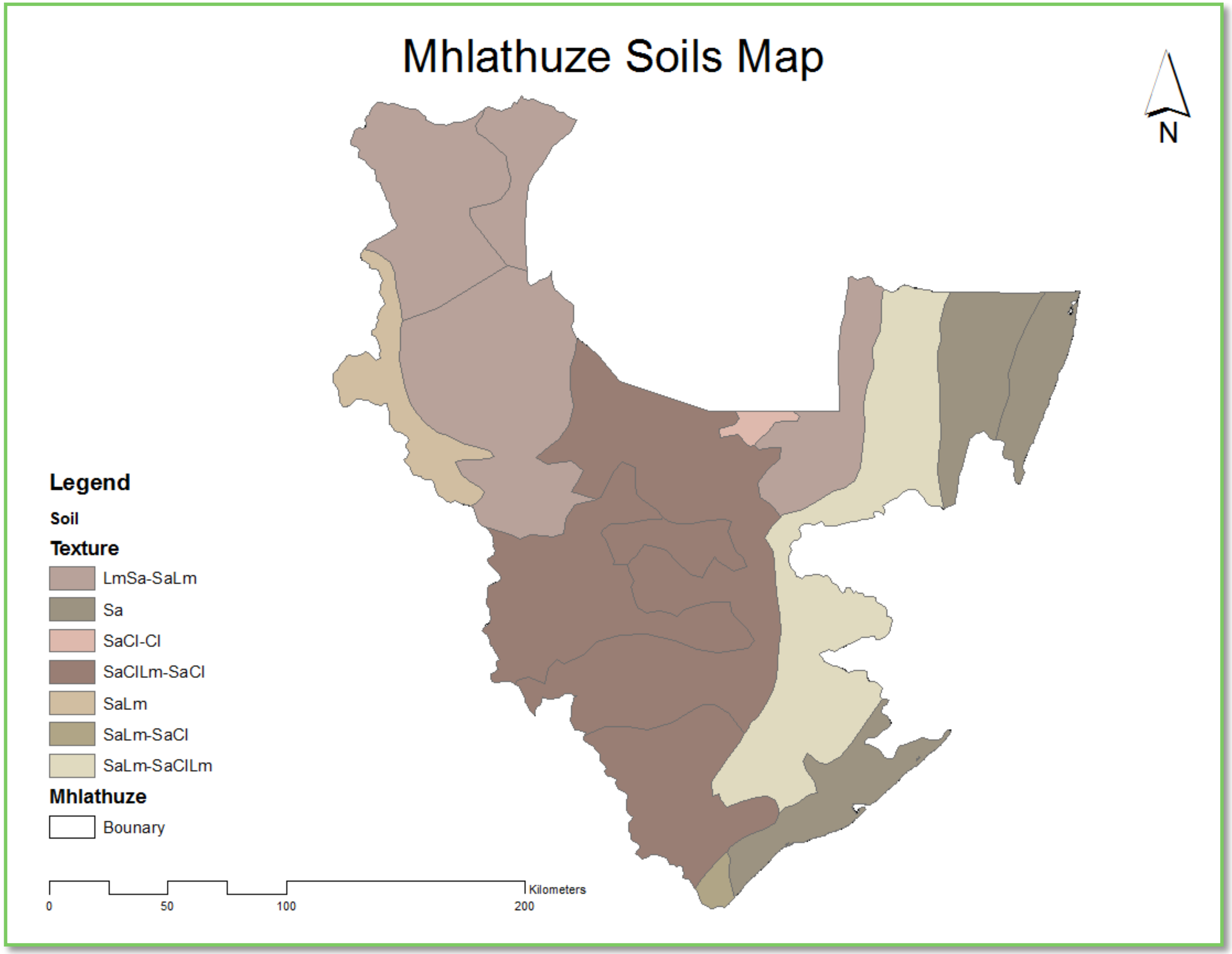


Figure 7: Soils within the Study Area

The Dwyka Group (**Photo 10**) forms the lowermost and oldest deposit in the Karoo Supergroup basin. The group consists mainly of diamictite (tillite), which is generally massive with little jointing, but may be stratified in places. Subordinate rock types are conglomerate, sandstone, rhythmite and mudrock (both with and without dropstones). The Dwyka diamictite and shale have very low hydraulic conductivities [~ 10^{-11} to 10^{-12} m/s], and virtually no primary voids. The Dwyka Group constitutes a very low-yielding fractured aquifer, and water is confined within narrow discontinuities like jointing and fracturing. They therefore tend to form aquitards rather than aquifers. Since the Dwyka sediments were mainly deposited under marine conditions, the water in these aquifers tends to be saline.

PHOTO 10: DWYKA TILLITE
(Source: www. geology.ukzn.co.za)

As Gondwana moved north towards the equator, thick clay and silt beds were laid down in a large sea that occupied the Karoo basin. These sediments now form shales (**Photo 11**) of the Pietermaritzburg Formation (Ecca Group). The shales are easily weathered and often pesent slope stability problems. Overlying the shale is a thick sequence dominated by light grey sandstones, called the Vryheid Formation. These sandstones were deposited along ancient sandy shorelines, behind which lay vast swamplands with numerous Glossopteris plants. Vegetation buried in the swamps eventually formed coal, which is mined in the Vryheid area. Since the shales are very dense, they are often overlooked as significant sources of groundwater. The deltaic sandstones represent a facies of the Ecca sediments, in which one would expect to find high-yielding boreholes. Unfortunately the permeabilities of these sandstones are also usually very low.

PHOTO 11: ECCA SHALE
(Source: www. geology.ukzn.co.za)

Dramatic outpourings of lava spread across much of Gondwana about 180 million years ago heralded the start of the Gondwana breakup. Remnants of these once extensive lavas now form the Lesotho highlands and Lebombo mountains (**Photo 12**). Crystallisation of magma within these fractures formed dolerite sills and dykes. Sills are horizontal intrusions of igneous rock. Dolerite sills are common throughout inland KZN in sedimentary rocks of the Karoo Supergroup. The final volcanic event produced rhyolite lava, which now forms the Lebombo mountains. These volcanic events were followed by uplift and faulting that eventually separated Africa and Antarctica.

PHOTO 12: LEBOMBO MOUNTAIN SOUTH OF JOZINI
(Source: www. geology.ukzn.co.za)

Evidence for this rifting is seen by the numerous faults concentrated along coastal KwaZulu-Natal (**Figure 8**). The largest of these - the Tugela Fault, has exploited the weakness between the Kaapvaal Craton and Natal Metamorphic Province.

The first deposits (Zululand Group) formed in the newly opened Indian Ocean were silt- and sandstone of Cretaceous age (145-65 million years ago). During this time, huge snail-like animals up to a metre in size, called ammonites, thrived in the warm ocean. Their shells are common in almost all exposures of Cretaceous rocks, such as along the shorelines surrounding Lake St Lucia.

During the Cenozoic, seal evels began to fall from the high levels experienced during the Cretaceous. A series of large coast-parallel dune complexes developed along most of the KwaZulu-Natal coastline. In most areas, deep weathering of old dunes has produced dark red coloured sand called the Berea Red Sand. In more recent times, fluctuations in the sea level have continued to shape the KwaZulu-Natal coastline.

Recent coastal dunes contain economic concentrations of minerals such as ilmenite, rutile and zircon, which are mined near Richards Bay. The ilmenite and rutile is smelted to produce titanium metal and white pigments (mostly for paint). The zircon is used for glazing on tiles and pottery, and as a metal alloy. During the last glacial period, approximately 18 000 years ago, the Earth was much colder and the sea level was more than 100 metres below the present level. The coastline at that time would have been far out to sea and many of the larger rivers cut deep valleys along the coast. As the Earth warmed and the sea level rose, the valleys were filled with unconsolidated estuarine muds and shelly sands. See **Figure 9** for the geology of study area.

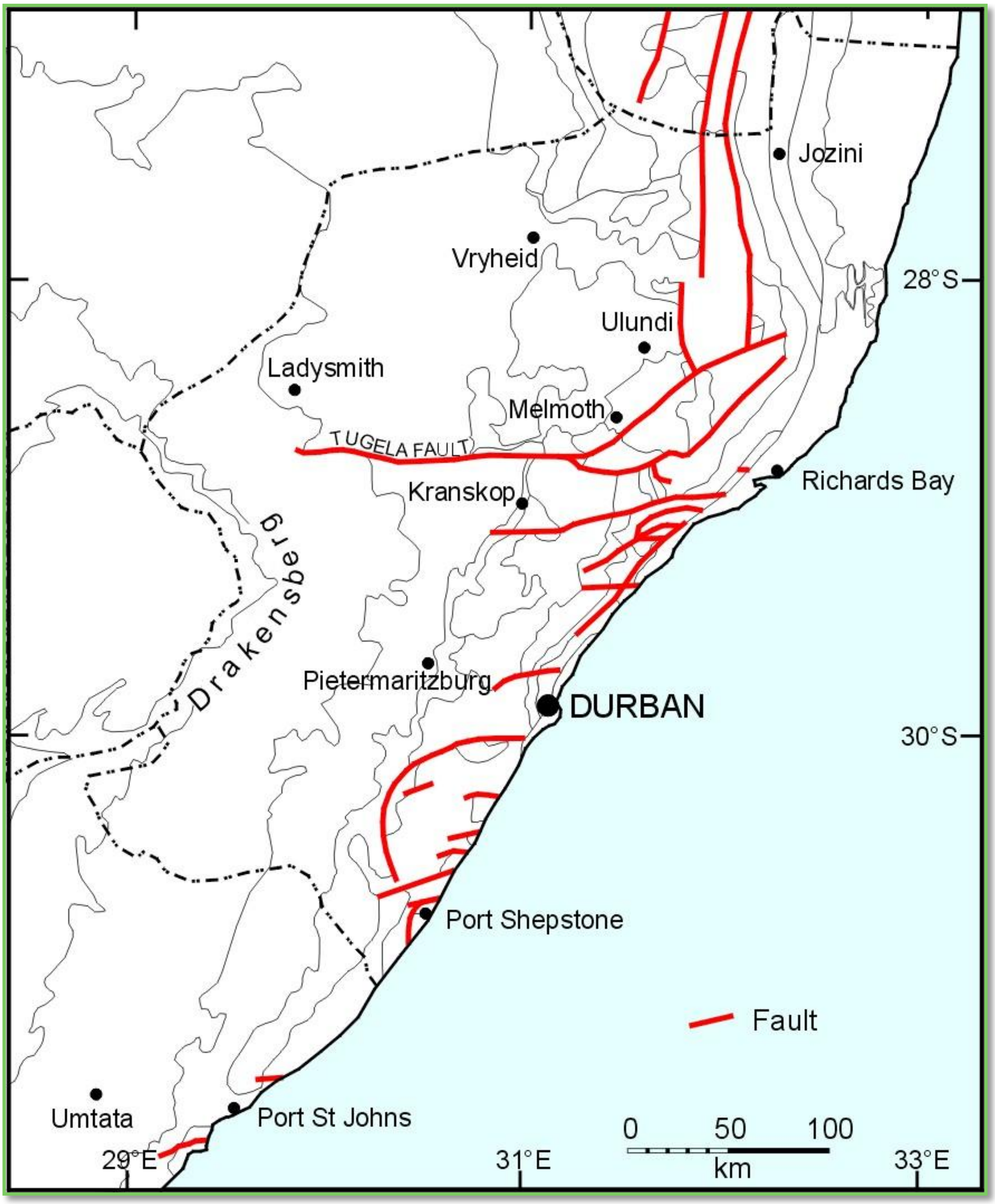


FIGURE 8: MAJOR FAULTS WITHIN STUDY AREA (SOURCE: WWW. GEOLOGY.UKZN.CO.ZA)

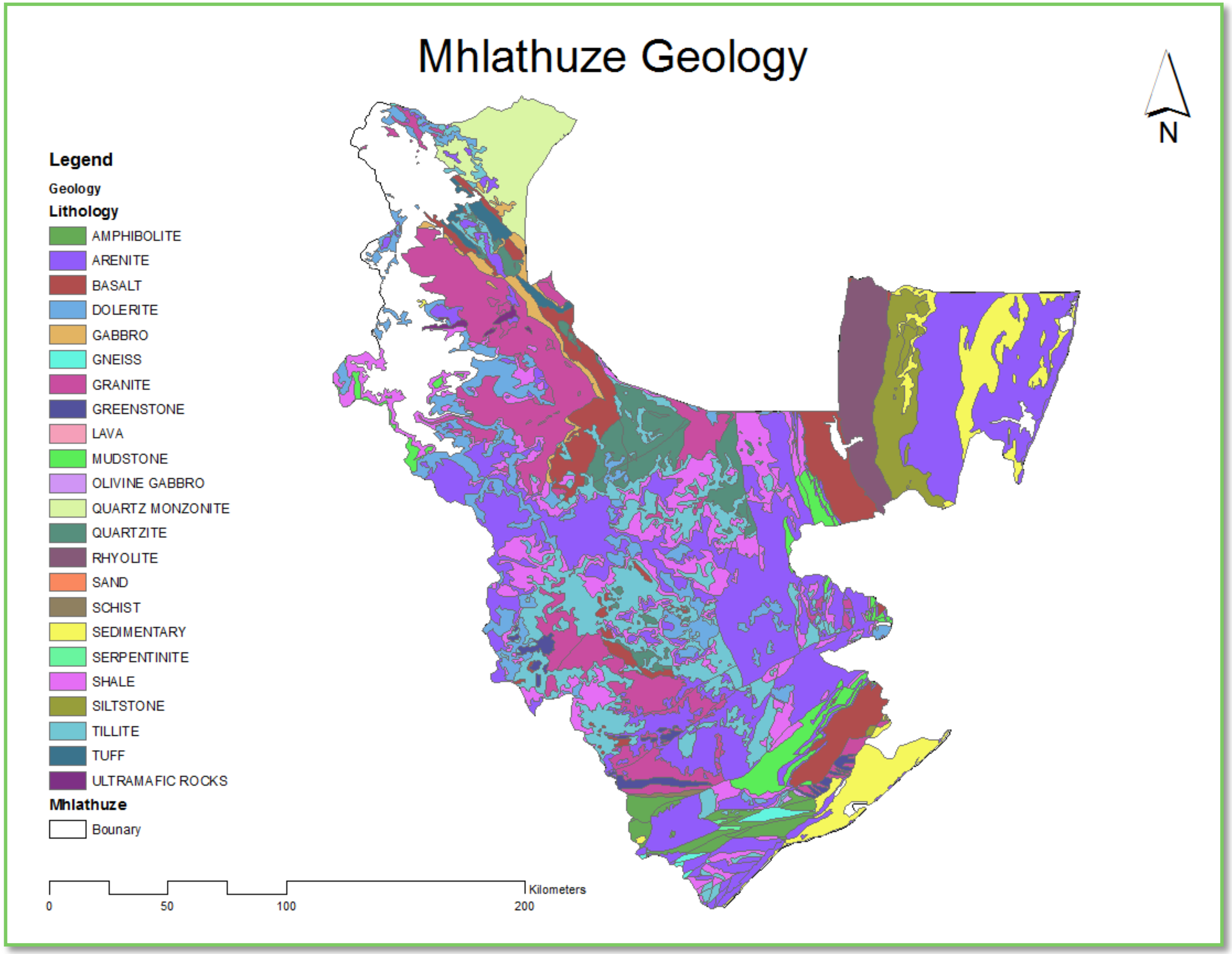


FIGURE 9: GEOLOGY

4.9 Geohydrology

Please note: most information documented here is summarised from Tlou & Matji (Pty) Ltd (2004).

The western or inland portion of the WMA and its limited portion south of the southern end of the Zululand Coastal Plain at Mtunzini, that involves the catchments of the smaller Mlalalazi and Matikulu Rivers, comprises 'hard rock' secondary porosity aquifers of the 'weathered and fractured' and 'fractured' classes. Faults, joints, and intrusive Karoo dolerite sheet and dyke contacts particularly in the Karoo sedimentary and volcanic rocks, in the regional 'hard-rocks', are zones of significant groundwater presence. Of the 'hard-rocks', the deeply weathered granite and granite-gneiss rocks, and the rocks of the Vryheid Formation, as well as those of the Natal Group in the southern portion of the region, are generally the best groundwater aquifers, the Dwyka Tillite Formation, where present, is the poorest.

By contrast, the aquifers of the Zululand Coastal Plain portion of the WMA are of the primary porosity or intergranular type. The Cretaceous siltstones that underlie the coastal plain at depth are an extremely poor groundwater aquifer, such minimal groundwater as may be found to occur is also generally highly saline. Two primary porosity aquifers underlie portions of the coastal plain. Immediately overlying the Cretaceous sediments, but subject to variable thickness and erratic areal distribution, are the karst-weathered shelly coquina and calcarenites, which constitute the 'deep' coastal plain aquifer, which generally occurs at a depth of about 30 to 40 m below levels over the coastal plain. Where present, the sandy lower portion of the overlying Kosi Bay Formation can contribute materially to this aquifer. By contrast, the 'shallow' coastal plain aquifer comprises a saturated fine sand at the base of the surficial Kwambonambi Formation, which occurs at 1 to 6 m below ground level, which is perched on the surface of the much less permeable and more clayey Kosi Bay and Port Durnford Formations, the latter where this ordinarily deeply occurring formation occurs at shallow depth. This shallow aquifer is of extensive occurrence over the higher rainfall (800mm+) eastern and southern portions of the coastal plain, where seepage is the source of the numerous lakes, pans, streams and shallow peat swamps that characterise the surface of the coastal plain. It is not present over the western drier portions of the coastal plain. The nature of the hydraulic continuity between the 'deep' and 'shallow' aquifers is uncertain. In the hard-rock western portion of the WMA, groundwater abstraction is entirely by 60 to 120 m deep 'normal' rotary-percussion drilled 'hard-rock' boreholes in the secondary porosity aquifers that are present.

Springs and seepages, although their flows are very markedly seasonally affected are extensively exploited as a domestic water supply source in the rural residential and agricultural 'hard-rock' portion of the WMA. On the Zululand Coastal Plain, the deep aquifer is exploited by appropriately installed fully cased and basally screened boreholes, while the shallow aquifer is exploited by the local population as a source of domestic water supply by shallow unlined open wells, shallow concrete ring-supported open wells, and more recently shallow hand pump-equipped screened tube wells, the latter two well forms were installed by relevant Governmental authorities. A very few deep (20 to 25 m) screen-well boreholes have been installed in a few places within the southern portion of the WMA to exploit the primary porosity aquifer present in the near-coastal portions of the WMA, represented by sandy alluvium beneath the beds of the larger rivers.

A good, spatially distributed data set of groundwater level measurements is available for the study area (**Figure 10**). Groundwater yields from 'hard-rock' boreholes in the WMA are generally low and ordinarily in the range 0.15 to 0.65 l/s, although higher yields in the order of 2.5 l/s can be obtained from boreholes located in geohydrologically favourable situations. Median depth to the water table in the western 'hard-rock' portion of the WMA is about 20m. Yields from cased and screened boreholes installed into the 'deep aquifer' of the Zululand Coastal Plain, where present, are generally high, in the order of 15 to 25 l/s, the aquifer also has high storativity and transmissivity values. By contrast, yields from the 'shallow aquifer' on the coastal plain are generally low, in the order of 0.3 l/s, due to the low transmissivity of the fine sand that comprises this aquifer. Occasionally, higher yields are obtained. Deep large-diameter screen-well boreholes installed into sandy alluvium in the lower coastal portions of rivers in the south of the WMA can have high yields, depending on the sand size of the alluvium involved and thus its transmissivity. Such screen-well boreholes installed into coarse and medium grain-sized sand in such situations can have yields of up to about 25 l/s, and even more in some situations.

Groundwater quality in the WMA is variable, being best in the higher rainfall portions and poorest in the lower rainfall portions, as in the major river basins of the interior and in the 'rain shadow' or 'Lowveld' area immediately inland of the Lebombo range. In the higher rainfall portions of the WMA, the groundwater generally has a TDS of 200 mg/l or less. In the lower rainfall portions, however, as in the Lebombo 'Lowveld', underlain by the Letaba Basalt and Vryheid Formations to the south, TDS are much higher and generally in the order of 600mg/l, it being much higher in places locally (up to 700mg/l). The quality of the groundwater in both the 'deep' and 'shallow' aquifers of the Zululand Coastal Plain is generally very good, with a TDS value of 200mg/l or less.

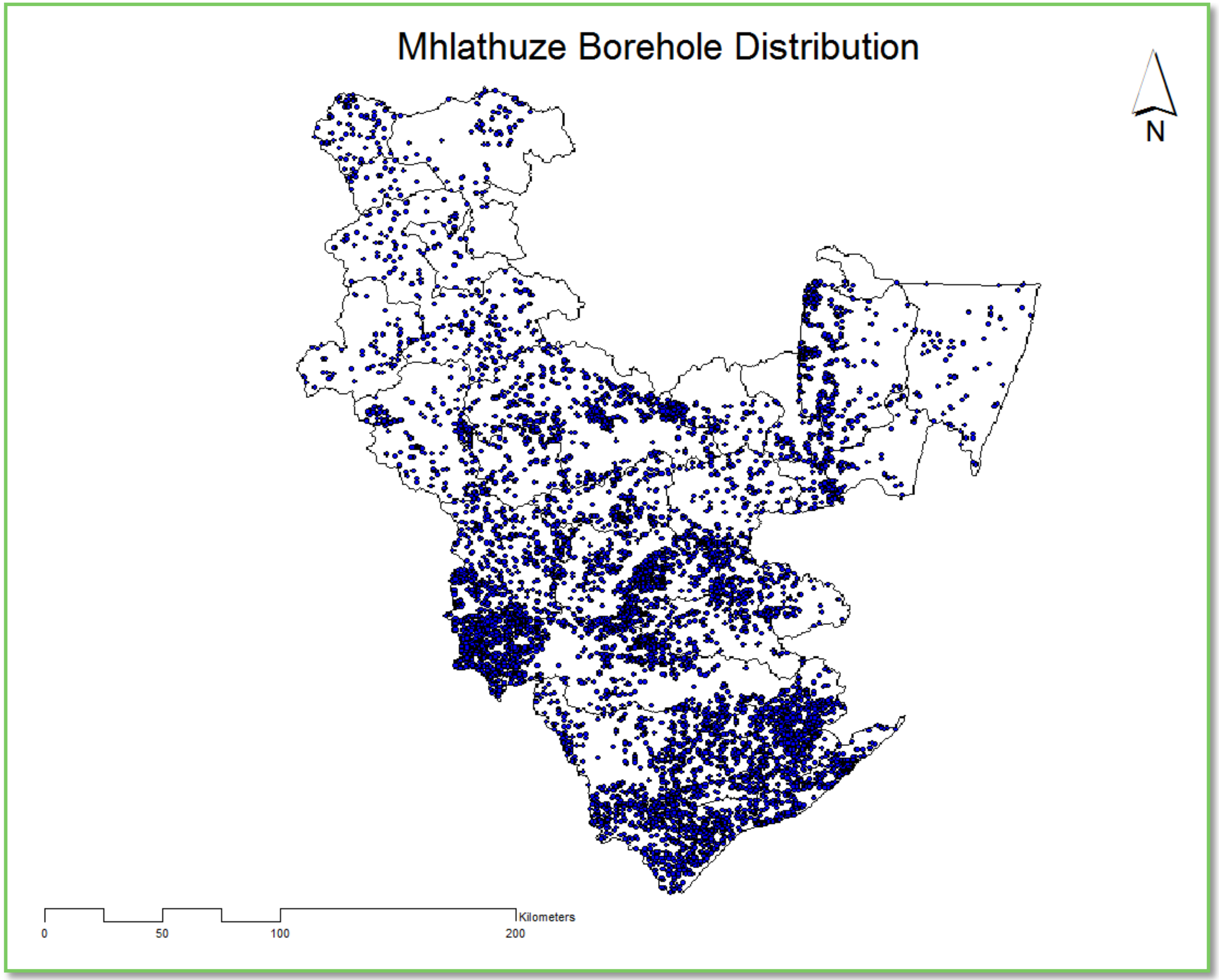


Figure 10: Distribution of boreholes within the WMA

5. Delineation of Resource Units

5.1 Introduction

Due to the size of the study area, it is not feasible to determine a Groundwater Reserve for the entire. Therefore the study area is divided into smaller sub-regions, called Resource Units (RU). Resource units are areas of similar physical or ecological properties that are grouped or typed to simplify the Reserve determination process. A 'groundwater resource unit' (or 'groundwater unit') 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. Other components of the water cycle, such as wetlands and rivers, must also be considered at this stage, to assess possible interdependency and promote the integrated water resource management vision of the NWA.

5.2 Delineation Process

There are over a hundred quaternary catchments within the WMA, making delineation a complex process. The first step in the delineation process was to divide the study area into six sub-catchments, as seen in **Figure 11**. Each area is then divided into smaller resource units. Other aspects taken into consideration are:

- Geology
- Climate
- Recharge
- Surface water and groundwater stresses

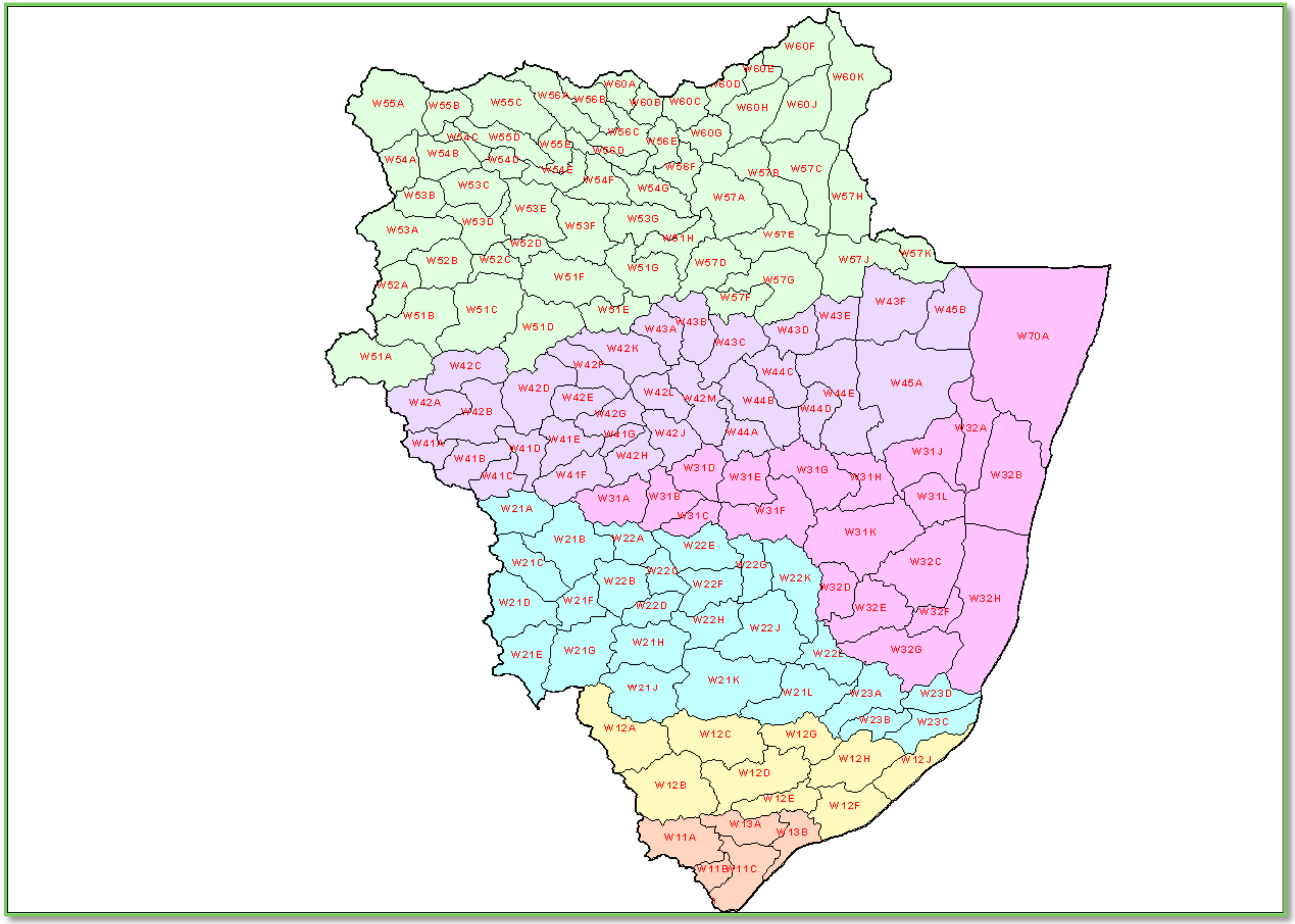


Figure 11: Sub-catchments of the WMA

5.3 Mtunzini and Matikulu catchment (W11 and W13)

This catchment consists of the following quaternary catchments:

- W11A, W11B and W11C
- W13A and W13B

The delineation process is discussed in **Table 6**.

TABLE 6: RESOURCE UNITS IN THE MTUNZINI AND MATIKULU CATCHMENT

Resource Units	Catchment	Characteristics
RU1	W11A, W11B and W11C	Matikulu catchment Recharge 14 mm/a Geology • Karoo • Natal Metamorphic Berea
RU2	W13A and W13B	Mtunzini catchment Recharge 48 mm/a Geology • Karoo • Natal Metamorphic • Berea

5.4 Mhlathuze catchment (W12)

This catchment consists of the following quaternary catchments:

- W12A, W12B, W12C, W12D, W12E, W12F, W12H and W12J

The delineation process is discussed in **Table 7**.

TABLE 7: RESOURCE UNITS IN THE MHLATHUZE CATCHMENT

Resource Units	Catchment	Characteristics

RU3	W12A, W12B, W12C and W12D	Tributaries of Mhlathuze River
		Recharge 14 mm/a
		Geology
		• Karoo
		  o Dwyka
		  o Ecca
		• Natal Metamorphic

RU4	W12F and W12J	Mzingazi River Recharge 48 mm/a Geology • Quaternary
RU5	W12E, W12G and W12H	Mhlathuze River Recharge 48 mm/a Geology • Karoo • Natal Metamorphic • Quaternary

5.5 Mfolozi catchment (W21 - W23)

This catchment consists of the following quaternary catchments:

- W21A, W21B, W21C, W21D, W21E, W21F, W21G, W21H, W21J, W21K and W21L
- W22A, W22B, W22C, W22D, W22E, W22F, W22G, W22H, W22J, W22K and W22L
- W23A, W23B, W23C and W23D

The delineation process is discussed in **Table 8**.

TABLE 8: RESOURCE UNITS IN THE MFOLOZI CATCHMENT

Resource Units	Catchment	Characteristics
RU6	W21A, W21B, W21C, W21D, W21E and W21F	Tributaries of the White Mfolozi River Recharge 42 - 43 mm/a Geology • Karoo o Ecca o Dwyka
RU7	W21G, W21H, W21J, W21K and W21L	White Mfolozi River Recharge 42 - 43 mm/a Geology • Karoo o Dwyka o Ecca • Pongola • Natal
RU8	W22A, W22B, W22C, W22D, W22E, W22F and W22G	Black Mfolozi River Recharge 41 - 43 mm/a Geology • Karoo o Dwyka o Ecca • Dolerite
RU9	W22H, W22J, W22K and W22L	Black and White Mfolozi Rivers join to form Mfolozi River Recharge 42 mm/a Geology • Karoo o Dwyka o Ecca • Dolerite
RU10	W23A andW23B, (Part of St Lucia W23C and W23D)	Mfolozi River Recharge 42 – 48 mm/a Geology • Lebombo • Zululand • Quaternary

5.6 Mkuze/Hluhluwe catchment (W31, W32 and W70)

This catchment consists of the following quaternary catchments:

- W31A, W31B, W31C, W31D, W31E, W31F, W31G, W31H, W31J, W31K and W31L

- W32A, W32B, W32C, W32D, W32E, W32F, W32G and W32H
- W70A

The delineation process is discussed in **Table 9**.

TABLE 9: RESOURCE UNITS IN THE MKUZE/HLUHLUWE CATCHMENT

Resource Units	Catchment	Characteristics
RU11	W31A, W31B, W31C and W31D	Head waters of Mkuze River Recharge 43 mm/a Geology • Karoo o Ecca o Dwyka • Dolerite
RU12	W31E, W31F and W31G	Mkuze River Recharge 41 mm/a Geology • Karoo o Ecca o Dwyka • Pongola
RU13	W31H (Part of St Lucia W31L and W31K)	Mkuze River Recharge 40 mm/a Geology • Lebombo
RU14	W31J and W32A	Mouth of Mkuze River Recharge 39 - 43 mm/a Geology • Lebombo • Zululand • Berea • Quaternary
RU15	W32D and W32E	Catchment of Hluhluwe River Recharge 41 mm/a Geology • Karoo o Ecca o Dwyka • Dolerite • Lebombo • Natal
RU16	W70A	Kosi Bay Recharge 12 mm/a Geology • Quaternary • Berea

5.7 Pongola catchment (W41 – W45)

This catchment consists of the following quaternary catchments:

- W41A, W41B, W41C, W41D, W41E, W41F and W41G
- W42A, W42B, W42C, W42D, W42E, W42F, W42G, W42H, W42J, W42K, W42L and W42M
- W43A, W43B, W43C, W43D, W43E and W43F
- W44A, W44B, W44C, W44D and W44E
- W45A and W45B

The delineation process is discussed in **Table 10**.

Table 10: Resource units in the Pongola catchment

Resource Units	Catchment	Characteristics

RU17	W41A, W41B, W41C, W42A, W42B and W42C	Head waters of Pongola River
		Recharge 44 mm/a
		Geology
		• Karoo
		  o Beaufort
		  o Ecca
		  o Dwyka
		• Dolerite
		• Natal Metamorphic

RU18	W41D, W41E and W41F	Bivane and Manzana tributaries of Pongola River
		Recharge 14 mm/a
		Geology
		• Karoo
		  o Ecca
		  o Dwyka
		• Dolerite
		• Natal Metamorphic
		• Pongola

RU19	W42D, W42E, W42F, W42G, W42H, W42J, W42K, W42L, W42M, W43A, W43B, W43C and W44A	Pongola River
		Recharge 42 mm/a
		Geology
		• Karoo
		  o Ecca
		  o Dwyka
		• Dolerite
		• Pongola

RU20	W44B, W44C and W44D	Pongola River
		Recharge 41 mm/a
		Geology
		• Karoo
		  o Ecca
		  o Dolerite

RU21	W44E	Pongola River Recharge 41 mm/a Geology • Lebombo
RU22	W43F, W45A and W45B	Pongola River flows into Mozambique Recharge 39 - 41 mm/a Geology

		• Lebombo • Zululand • Berea • Quaternary

5.8 Usutu catchment (W51 - W57)

This catchment consists of the following quaternary catchments:

- W51A, W51B, W51C, W51D, W51E, W51F, W51G and W51H
- W52A, W52B, W52C and W52D
- W53A, W53B, W53C, W53D, W53E, W53F and W53G
- W54A, W54B, W54C, W54D, W54E, W54F and W54G
- W55A, W55B, W55C, W55D and W55E
- W56A, W56B, W56C, W56D, W56E and W56F
- W57A, W57B, W57C, W57D, W57E, W57F, W57G, W57H, W57J and W57K

The delineation process is discussed in **Table 11**.

TABLE 11: RESOURCE UNITS IN THE USUTU CATCHMENT

Resource Units	Catchment	Characteristics
RU23	W55A	Chrissiesmeer Recharge 13 mm/a Geology • Karoo ○ Ecca • Dolerite
RU24	W53E, W54C, W54D, W55B, W55C, W55D, W55E, W56A and W56B	Tributaries to the Usutu Recharge 35 - 36 mm/a Geology • Natal Metamorphic • Pongola
RU25	W54A and W54B	Tributaries to the Usutu Recharge 13 - 14 mm/a Geology • Karoo ○ Ecca

RU26	W51A, W51B and W52A	Tributaries to the Usutu
		Recharge 14 mm/a
		Geology
		• Karoo
		  ○ Ecca
		  ○ Beaufort
		• Dolerite

RU27	W51C, W51D, W51E, W51F, W52B, W53A, W53B and W53C	Tributaries to the Usutu Recharge 14 mm/a Geology • Natal Metamorphic • Pongola
RU28	W52C and W52D	Tributaries to the Usutu

		Recharge 14 mm/a Geology • Pongola
RU29	W57K	Usutu River Mouth Recharge 41 mm/a Geology • Zululand

6. Classification and the Reserve for RU1

6.1 Location

The location of the RU is shown in **Figure 12**. The main towns in the area include Entumeni, Nyoni, Amatikulu and Gingindlovu. The RU includes quaternary catchments W11A, W11B and W11C. The RU encompasses numerous protected areas, including the Amatikulu Park, Dlinza Forest, Entumeni Park, Longhurst Park, Arcadia Park and Rocky Ridge Park.

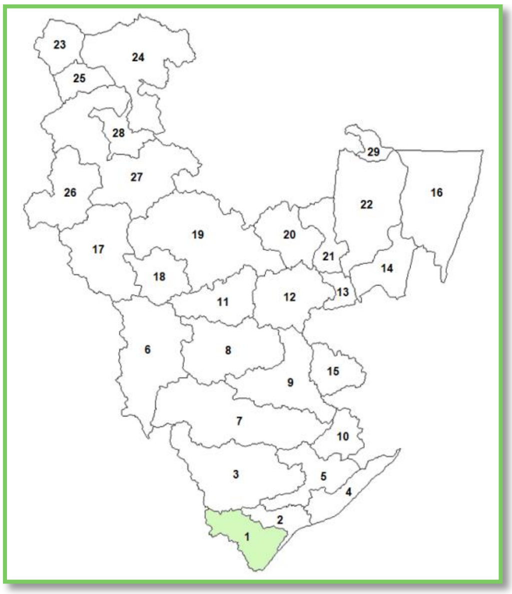


FIGURE 12: LOCATION

6.2 Climate

The area is cooler and drier than the coastal belt, with a rainfall of 750 to 1 300 mm per year. Mean daily temperatures in January are around 22°C with a maximum of about 28°C. July mean temperatures are around 14°C with minima as low as 7°C.

PHOTO 13: NATURAL VEGETATION

(Source: www.panoramio.com)

6.3 Vegetation (taken from environment.gov.za)

The vegetation is an open Sweet Thorn *Acacia karroo* savanna or scrub, with Ngongoni Bristlegrass *Aristida junciformis* almost entirely dominant (**Photo 13**). At well preserved sites, other species include Redgrass *Themeda triandra,* Hairy Tridentgrass *Tristachya leucothrix, Speargrass Heteropogon contortus, Trachypogon spicatus, Diheteropogon amplectens, Eulalia villosa, Alloteropsis semialata, Sporobolus africanus and Monocymbium ceresiiforme.* Forbs such as Natal Vernonia *Vernonia natalensis,* Wild Verbena *Pentanisia prunelloides,* Rasp Thistlethorn *Berkheya setifera, Thunbergia atriplicifolia and Tephrosia macropoda* are abundantly present.

In numerous lower altitude valleys, Valley Thicket occurs. In more sheltered valleys or on slopes, well-developed forests are present. For this reason, Acocks classified this as a forest type. The Coast-Hinterland Bushveld, by contrast, occupies the more exposed, upland hilltops and ridges.

6.4 Demography and Land use

Apart from some light industry, the area is largely dependent on agriculture, primarily sugarcane, timber and cattle. According to the 2001 census data, there are 51240 people living in the RU. There are also numerous game parks within the area. The Landcover within the RU is shown in **Figure 13**.

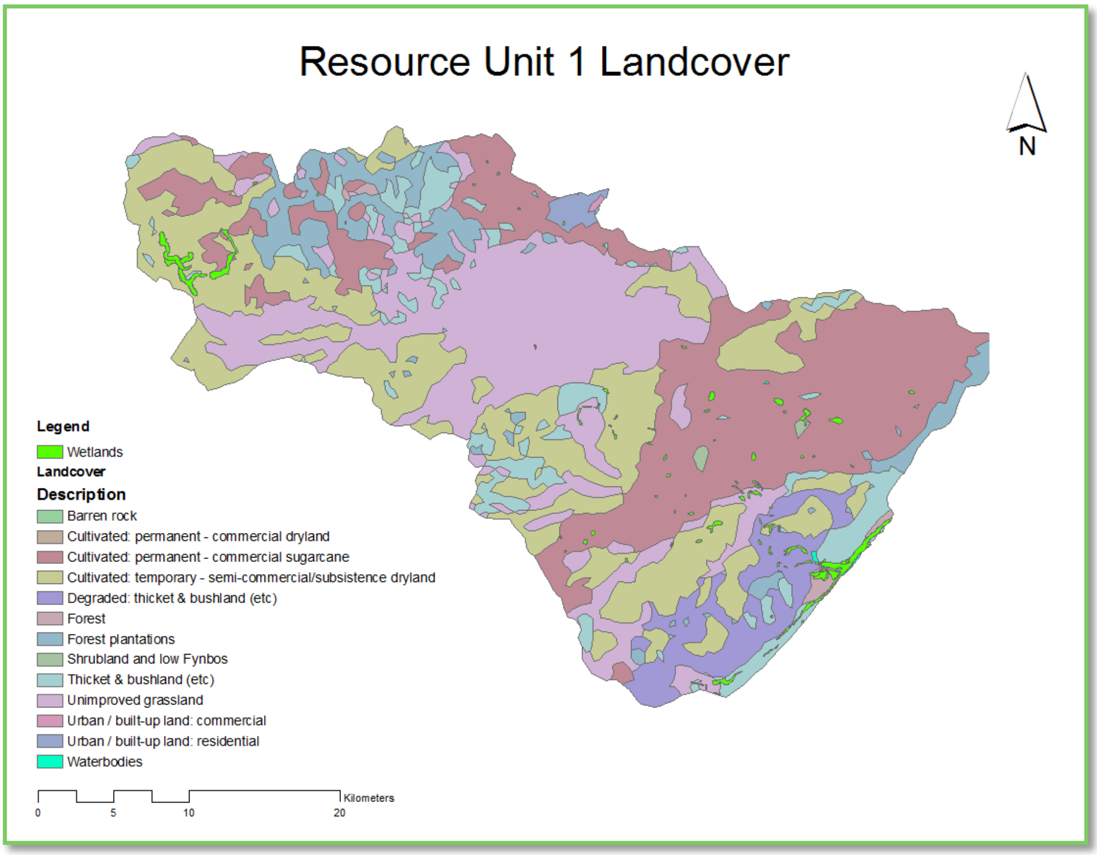


FIGURE 13: LANDCOVER

6.5 Surface water and Wetlands

The Matigulu River runs through this RU. The river mouth is also located within the RU (**Photo 14**). The wetlands in the study area are shown in **Figure 13**.

PHOTO 14: RIVER MOUTH
(Source: www.panoramio.com)

6.6 Soils (taken from environment.gov.za)

Soils are weakly developed, with shallow topsoils underlain by a lithocutanic B horizon. Where soil development has proceeded further, red or black clays may characterise the subsoil.

6.7 Geohydrology

Groundwater levels

It is clear at groundwater levels follow the topography, as seen in Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 14**. The most probable depth to groundwater level in the RU is 8.4 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

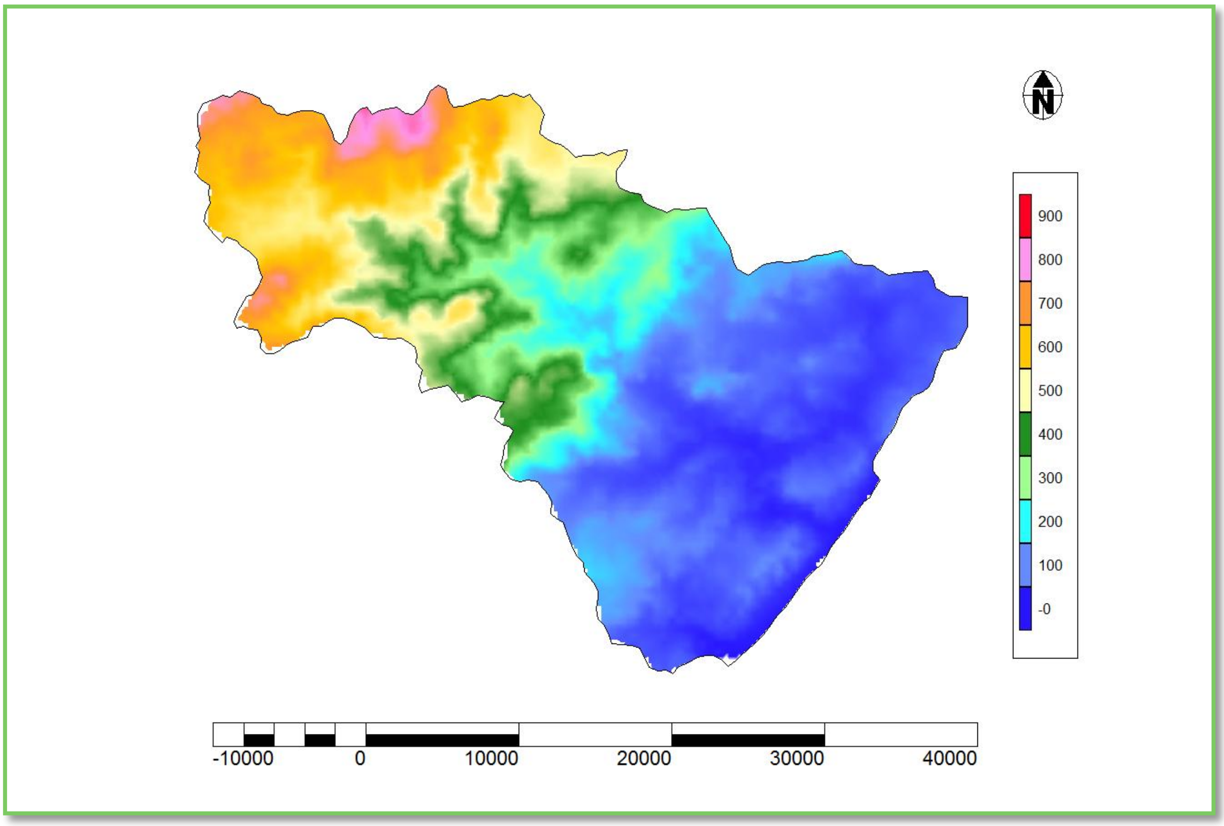


FIGURE 14: GROUNDWATER LEVELS IN RU1

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 12**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 12: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
1027.465	62.017	84.121	65.982	6.4%	6.4%	4.4%	3.3%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 13**.

TABLE 13: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
58926	11785	0.106

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 14** is highlighted in red.

TABLE 14: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm^3/a	Hughes Mm^3/a	Shultz Mm^3/a	Pitman Mm^3/a	vTonder Mm^3/a	MIN Mm^3/a	MAX Mm^3/a	Herold Mm^3/a
31.545	87.601	46.186	30.624	45.308	11.267	84.121	33.380

Groundwater use

The groundwater use in the catchment is documented in **Table 15**.

TABLE 15: GROUNDWATER USE

Groundwater Use							
GRDM Mm^3/a	WARMS Mm^3/a	Hydrocensus Mm^3/a	MIN Mm^3/a	MAX Mm^3/a	Forrest Mm^3/a	Crops Mm^3/a	TOTAL Mm^3/a
0.730	0.275	0.361	0.275	1.443	8.964	3.736	12.594

Groundwater quality

The TDS values for the RU are shown in Figure 15. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines, with the exception of two boreholes. These areas should be treated as hot spots rather than applying a poor classification to the whole resource unit. Treatment of the hot spot areas will be addressed under Resource Quality Objectives in Section 35.

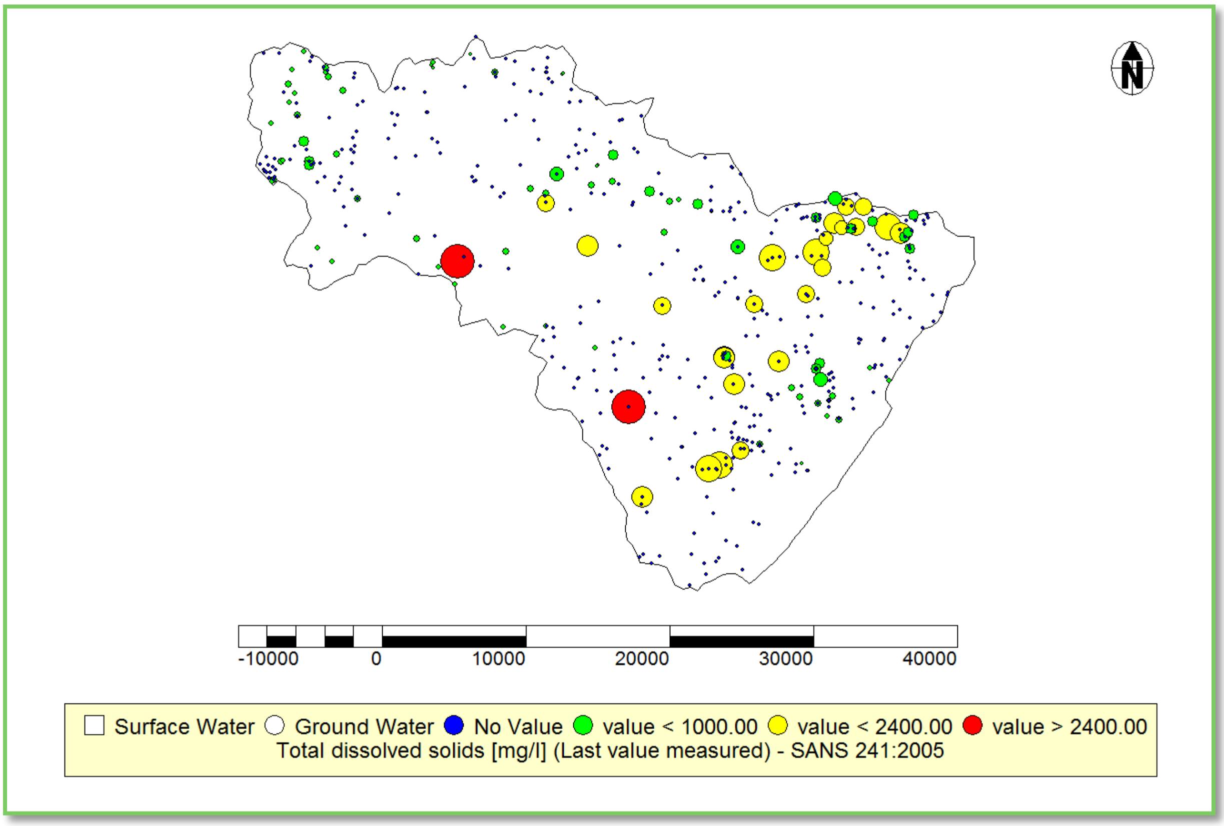


FIGURE 15: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in Table 16. The slope histogram is documented in Appendix D.

TABLE 16: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
8.4	6.4%	0.7	SaClLm-SaCl , SaLm-SaCl , Sa	Weathered/Fractured	Natal	62%

6.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 19.2%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled by assigning a normal distribution curve with a standard deviation of 1.259 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in Figure 16. It is clear from the results that the stress index will vary between 14% and 24%, with a certainty of 98.95%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

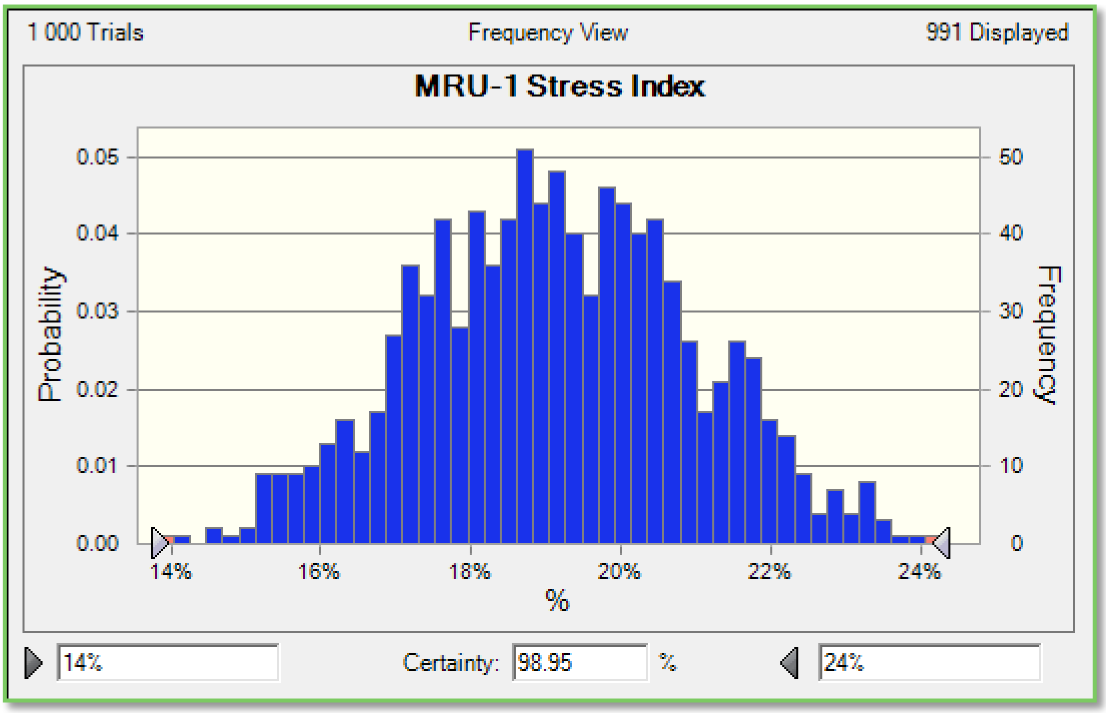


FIGURE 16: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 17**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. There are a number of boreholes with TDS values in the area that are high, even though they are still allowable. The most of the boreholes plot as C's on the expanded Durov diagram, therefore the contamination category is set as a C.

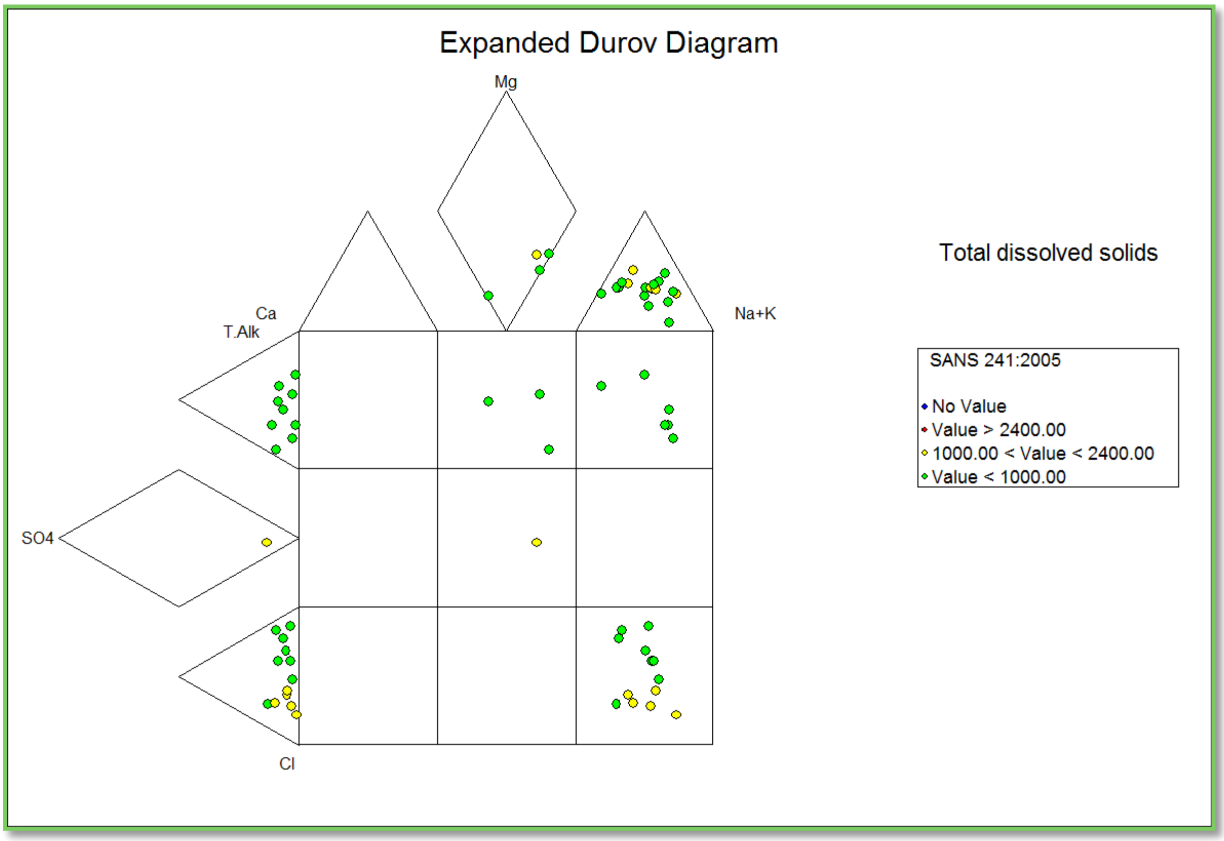


Figure 17: Expanded Durov diagram for RU

As documented, the vulnerability is 62%. The impact of potential contamination, according to Section 2.2, is low.

Final category

The final category for the RU is summarised in **Table 17**.

Table 17: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	B	Good
Groundwater contamination	C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	**B/C**	**Good/Fair**

6.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 18**.

Table 18: Reserve

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
33.380	0.106	51%	19.902	12.594

7. Classification and the Reserve for RU2

7.1 Location

The main towns located in the RU are Mtunzini and Eshowe. The area includes quaternary catchments W13A and W13B. The location of the RU is shown in **Figure 18**. The protected areas included in the RU are: Port Dunford, Ongoyi and Umlalazi.

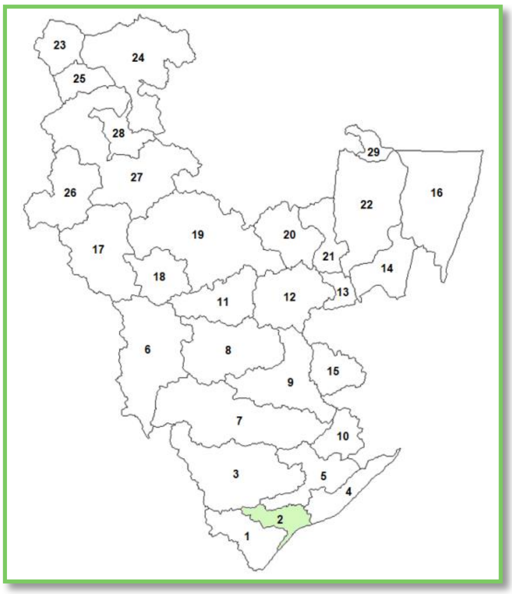


FIGURE 18: LOCATION

7.2 Climate

The area is cooler and drier than the coastal belt, with a rainfall of 750 to 1 300 mm per year. Mean daily temperatures in January are around 22°C with a maximum of about 28°C. July mean temperatures are around 14°C with minima as low as 7°C.

7.3 Vegetation (taken from environment.gov.za)

The vegetation is an open Sweet Thorn *Acacia karroo* savanna or scrub, with Ngongoni Bristlegrass *Aristida junciformis* almost entirely dominant. At well preserved sites, other species include Redgrass *Themeda triandra,* Hairy Tridentgrass *Tristachya leucothrix, Speargrass Heteropogon contortus, Trachypogon spicatus, Diheteropogon amplectens, Eulalia villosa, Alloteropsis semialata, Sporobolus africanus and Monocymbium ceresiiforme*. Forbs such as Natal Vernonia *Vernonia natalensis,* Wild Verbena *Pentanisia prunelloides,* Rasp Thistlethorn *Berkheya setifera, Thunbergia atriplicifolia and Tephrosia macropoda* are abundantly present.

7.4 Demography and Land use

The area is largely dependent on agriculture, primarily sugarcane, timber and cattle. According to the 2001 census data, there are 68430 people living in the RU. There are also numerous game parks within the area. The Landcover within the RU is shown in **Figure 19**.

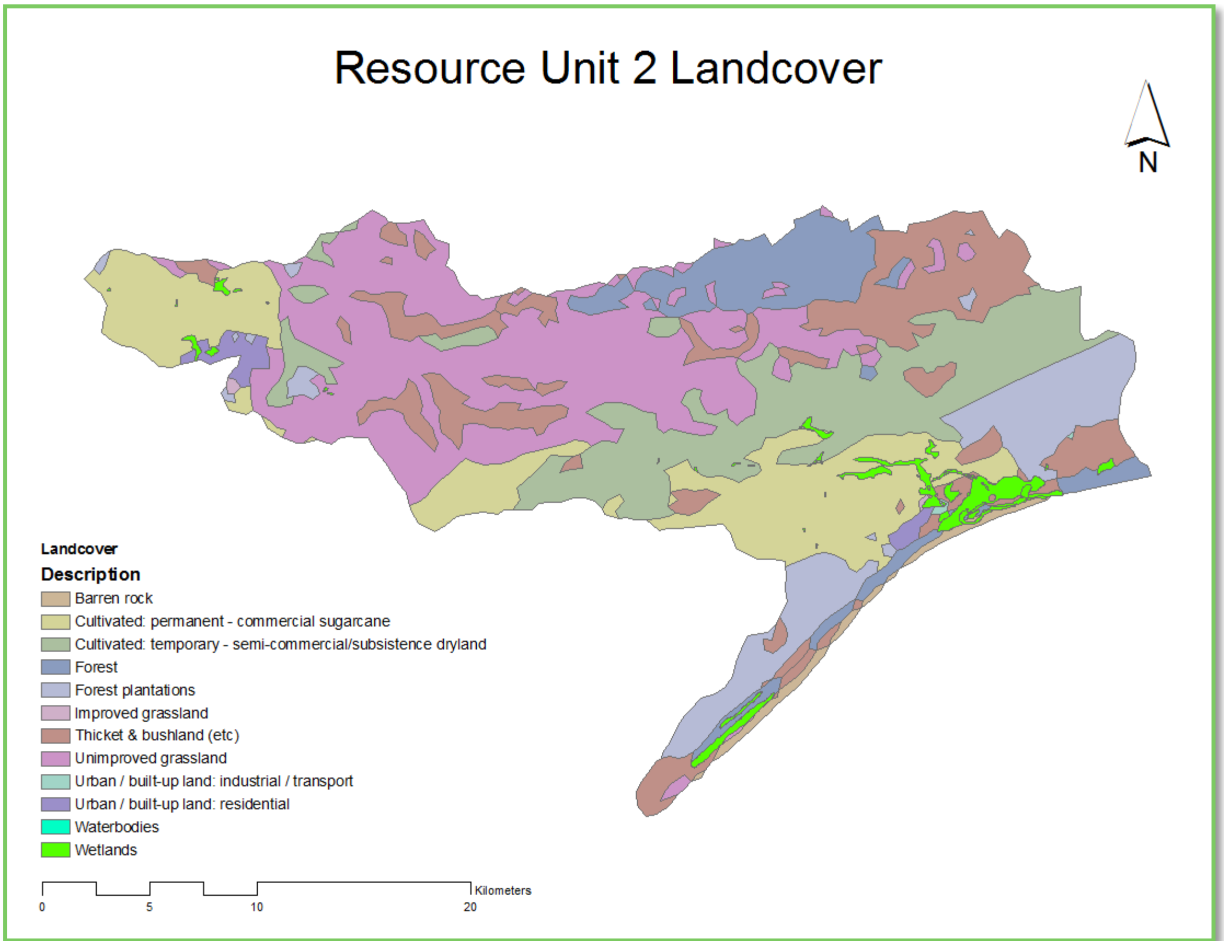


FIGURE 19: LANDCOVER

7.5 Surface water and Wetlands

PHOTO 15: MALALAZI RIVER MOUTH

The Malalazi River runs through this RU. The river mouth is also located within the RU (**Photo 15**). The wetlands in the study area are shown in **Figure 19**.

7.6 Soils (taken from environment.gov.za)

Soils are weakly developed, with shallow topsoils underlain by a lithocutanic B horizon. Where soil development has proceeded further, red or black clays may characterise the subsoil.

7.7 Geohydrology

Groundwater levels

It is clear the groundwater levels follow the topography, as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 20**. The most probable depth to groundwater level in the RU is 6.9 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

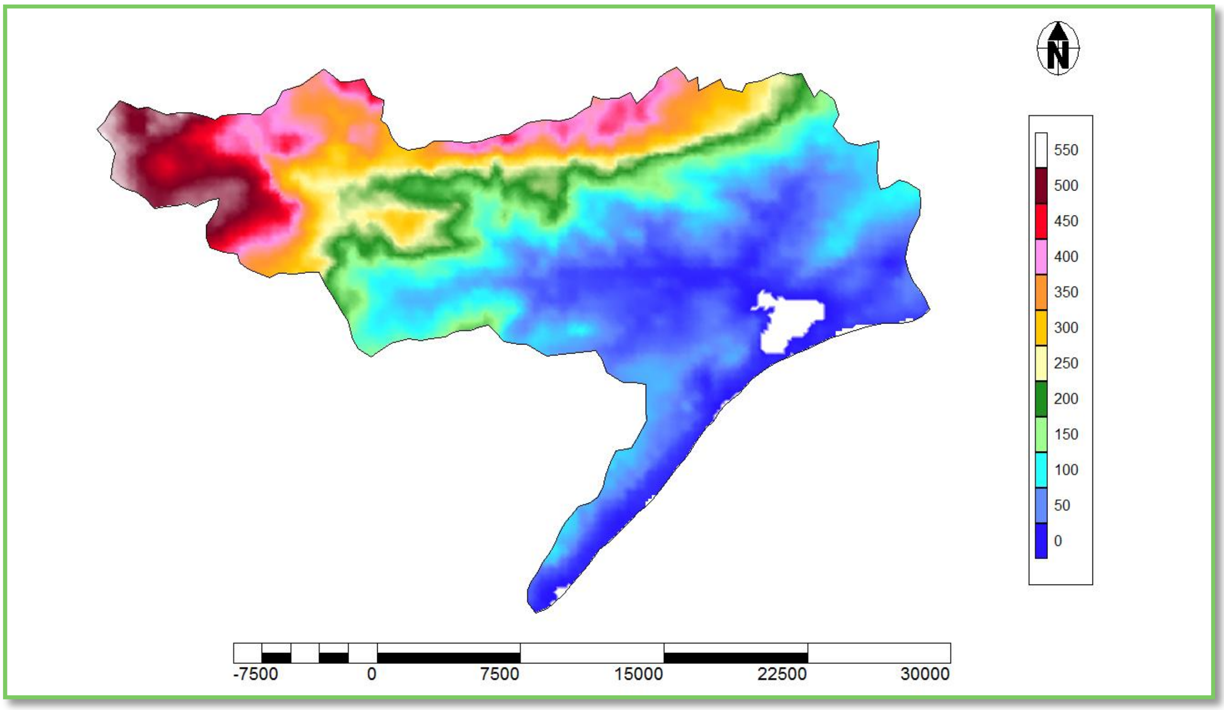


FIGURE 20: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 19**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

Table 19: Recharge values

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
600.596	32.383	57.240	36.339	6.1%	6.1%	11.0%	3.2%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 20**.

Table 20: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
78695	15739	0.142

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 21** is highlighted in red.

Table 21: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
14.144	59.587	27.037	18.653	28.270	3.536	57.240	19.750

Groundwater use

The groundwater use in the catchment is documented in **Table 22**.

Table 22: Groundwater use

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
0.710	0.168	0.126	0.126	0.710	2.583	2.786	5.228

Groundwater quality

The TDS values for the RU are shown in **Figure 21**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines, with the exception of a couple of boreholes whose values are high but still allowable.

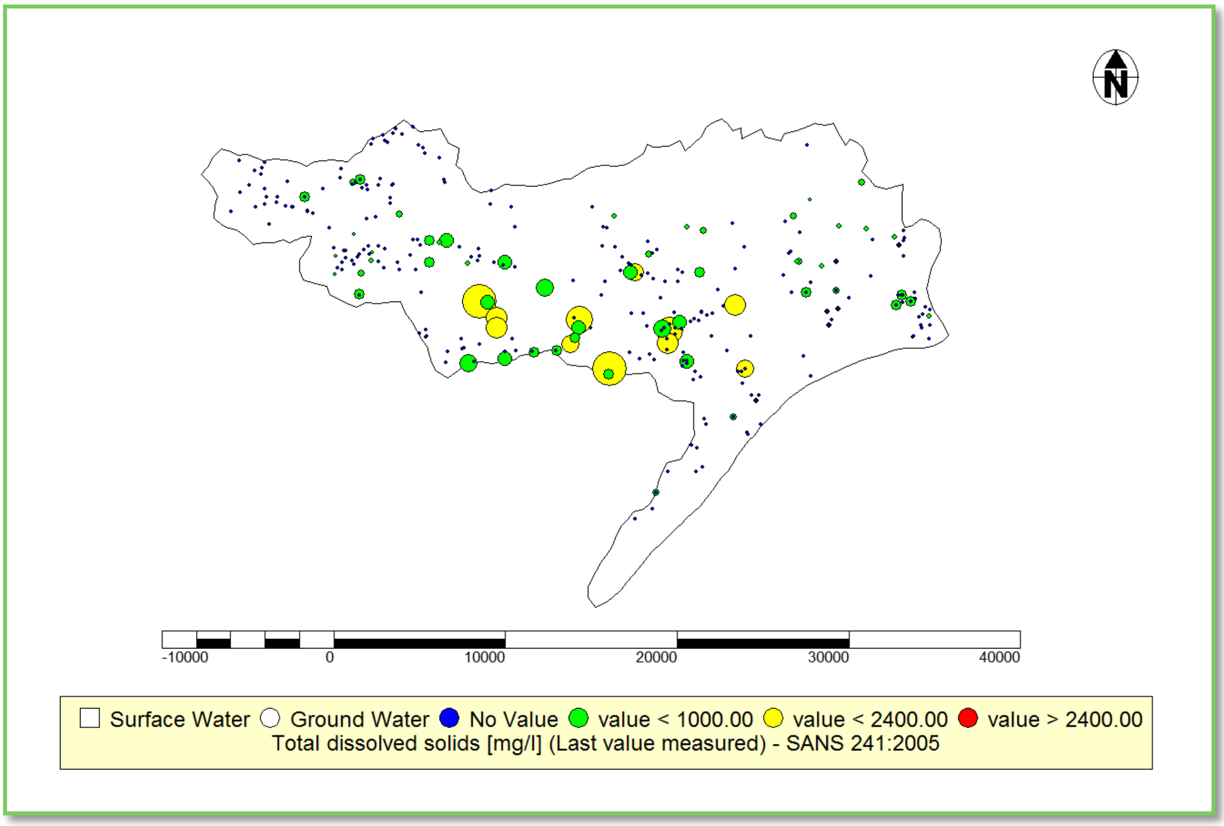


FIGURE 21: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 23**. The slope histogram is documented in Appendix D.

TABLE 23: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
6.9	6.1%	0.6	SaClLm-SaCl , Sa	Weathered/Fractured	Natal	63%

7.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 14.8%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled by assigning a normal distribution curve with a standard deviation of 1.259 Mm^3/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in **Figure 22**. It is clear from the results that the stress index will vary between 11% and 19%, with a certainty of 99.41%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

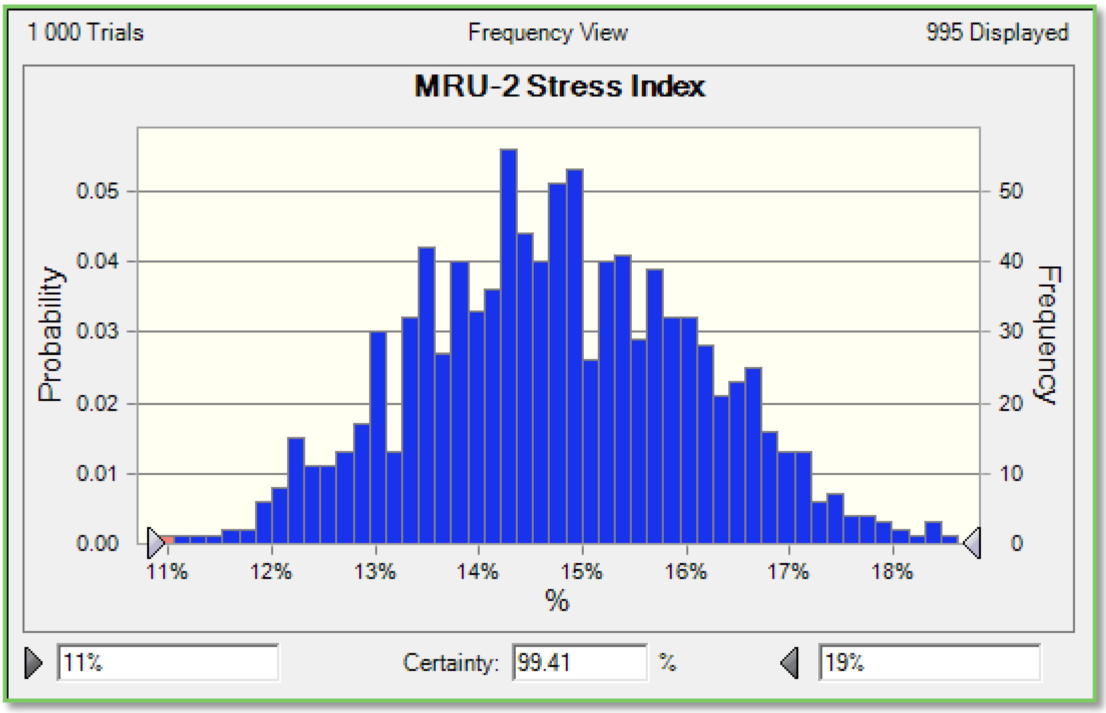


FIGURE 22: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 23**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. It is apparent that the contamination category, according to the explanation, is C.

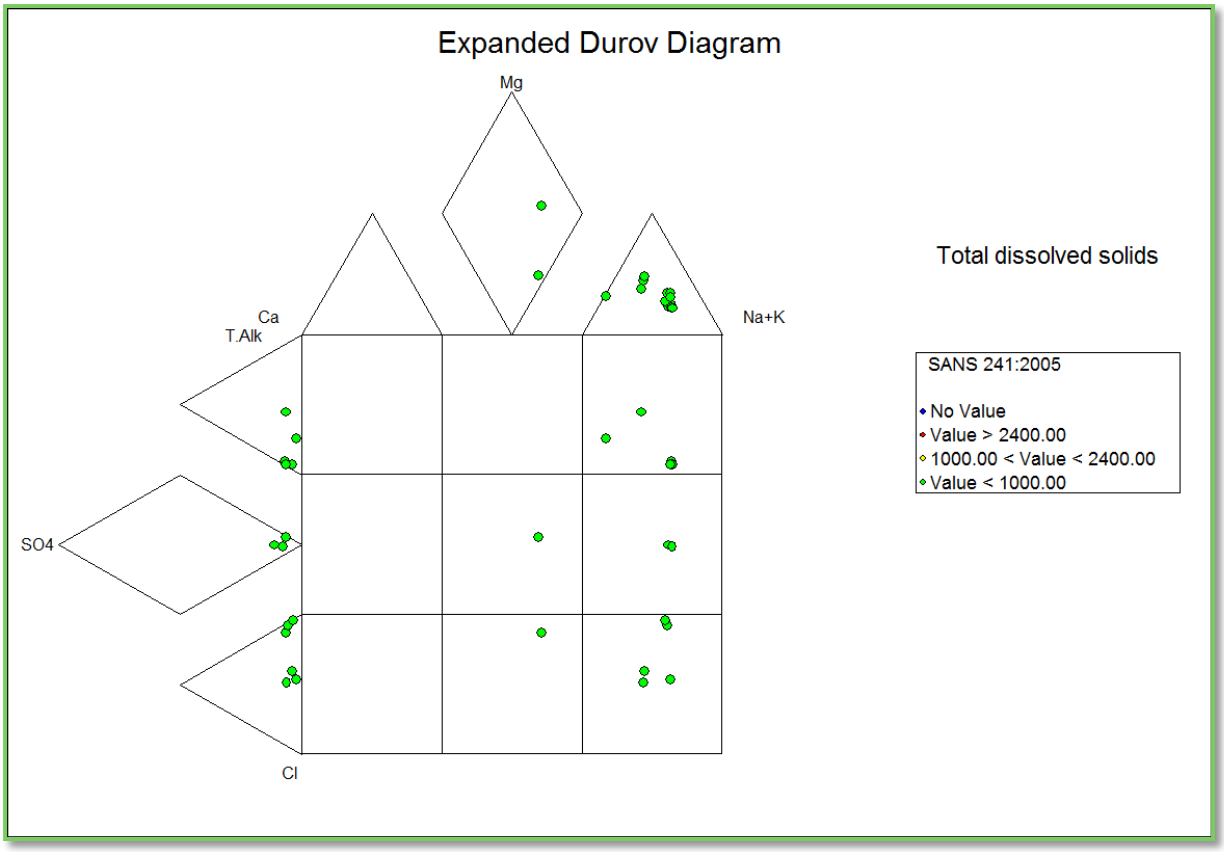


FIGURE 23: EXPANDED DUROV DIAGRAM

As documented, the vulnerability is 63%. The impact of potential contamination, according to Section 2.2, is low.

Final category

The final category for the RU is summarised in **Table 24**.

TABLE 24: CATEGORY FOR RU

Impact	Present status category	Water resource category
Groundwater usage	B	Good
Groundwater contamination	C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	**B/C**	**Good/Fair**

7.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 25**.

TABLE 25: RESERVE

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
19.750	0.142	55%	11.219	5.228

8. Classification and the Reserve for RU3

8.6 Location

The main town included in the study area are: Osborn, Melmoth, Randalhurst Ndundulu and Nkwalini. The quaternary catchments making up the RU include W12A, W12B, W12C and W12D. The location of the RU is shown in **Figure 24**. Protected areas include Mooiplaas, Matshenezimpisi and Nkandla.

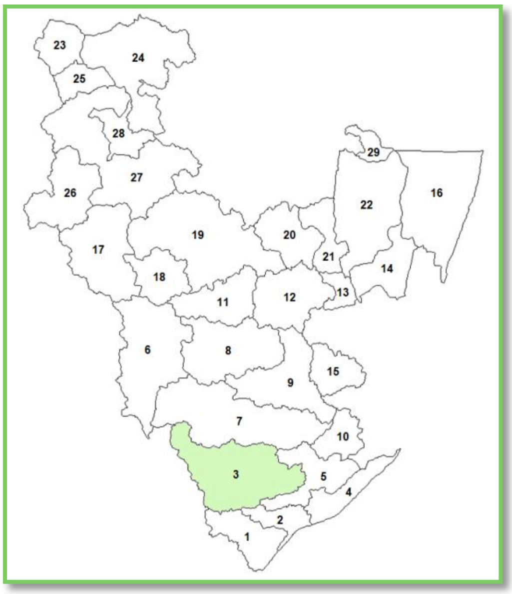


FIGURE 24: LOCATION

8.7 Climate

The area is cooler and drier than the coastal belt, with a rainfall of 750 to 1 300 mm per year. Mean daily temperatures in January are around 22°C with a maximum of about 28°C. July mean temperatures are around 14°C with minima as low as 7°C.

PHOTO 16: WATTLE PLANTATION

(Source: www.panoramio.com)

8.8 Vegetation (taken from environment.gov.za)

The vegetation is an open Sweet Thorn *Acacia karroo* savanna or scrub, with Ngongoni Bristlegrass *Aristida junciformis* almost entirely dominant. At well preserved sites other species include Redgrass *Themeda* *triandra,* Hairy Tridentgrass *Tristachya leucothrix, Speargrass Heteropogon contortus, Trachypogon spicatus, Diheteropogon amplectens, Eulalia villosa, Alloteropsis semialata, Sporobolus africanus and Monocymbium ceresiiforme*. Forbs such as Natal Vernonia *Vernonia natalensis,* Wild Verbena *Pentanisia prunelloides,* Rasp Thistlethorn *Berkheya setifera, Thunbergia atriplicifolia and Tephrosia macropoda* are abundantly present.

In numerous lower altitude valleys, Valley Thicket occurs. In more sheltered valleys or on slopes, well-developed forests are present. For this reason, Acocks classified this as a forest type. The Coast-Hinterland Bushveld, by contrast, occupies the more exposed upland hilltops and ridges.

8.9 Demography and Land use

Apart from some light industry and some mining, the area is largely dependent on agriculture, primarily sugarcane, timber (**Photo 16**) and cattle. Citrus and avocado pears also play a significant role, with markets both locally and overseas. The area is also filled with animals and extraordinary bird types. According to the 2001 census data, there are 78365 people living in the RU. The land use within the RU is shown in **Figure 25**.

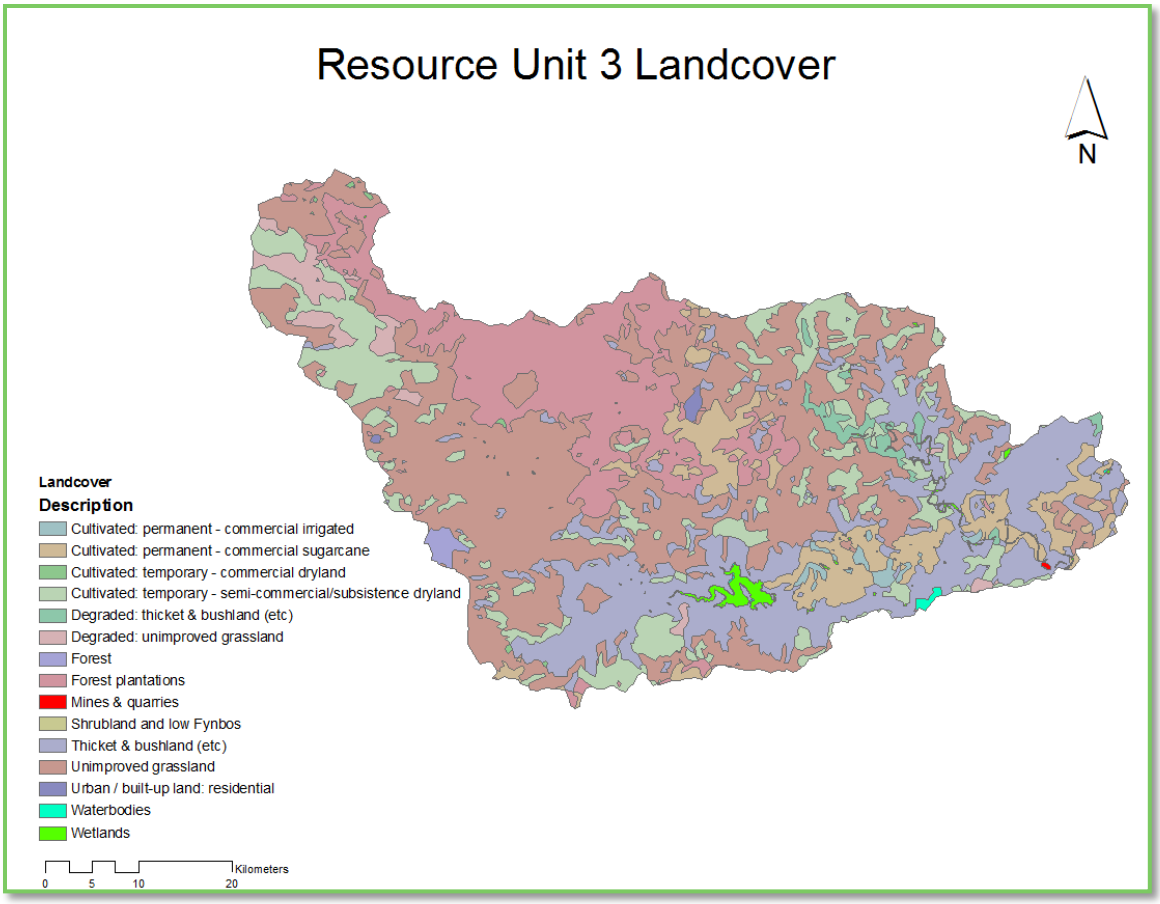


FIGURE 25: LANDCOVER

8.10 Surface water and Wetlands

The Mhlathuze and Mfule are the main rivers in the area. The wetlands in the study area are shown in **Figure 25**. The Goedertrou Dam is located within the RU (**Photo 17**).

PHOTO 17: GOEDERTROU DAM
(Source: www.panoramio.com)

8.11 Soils (taken from environment.gov.za)

Soils are weakly developed, with shallow topsoils underlain by a lithocutanic B horizon. Where soil development has proceeded further, red or black clays may characterise the subsoil.

8.12 Geohydrology

Groundwater levels

It is clear the groundwater levels follow the topography, as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 26**. The most probable depth to groundwater level in the RU is 19.1 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal, due to prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

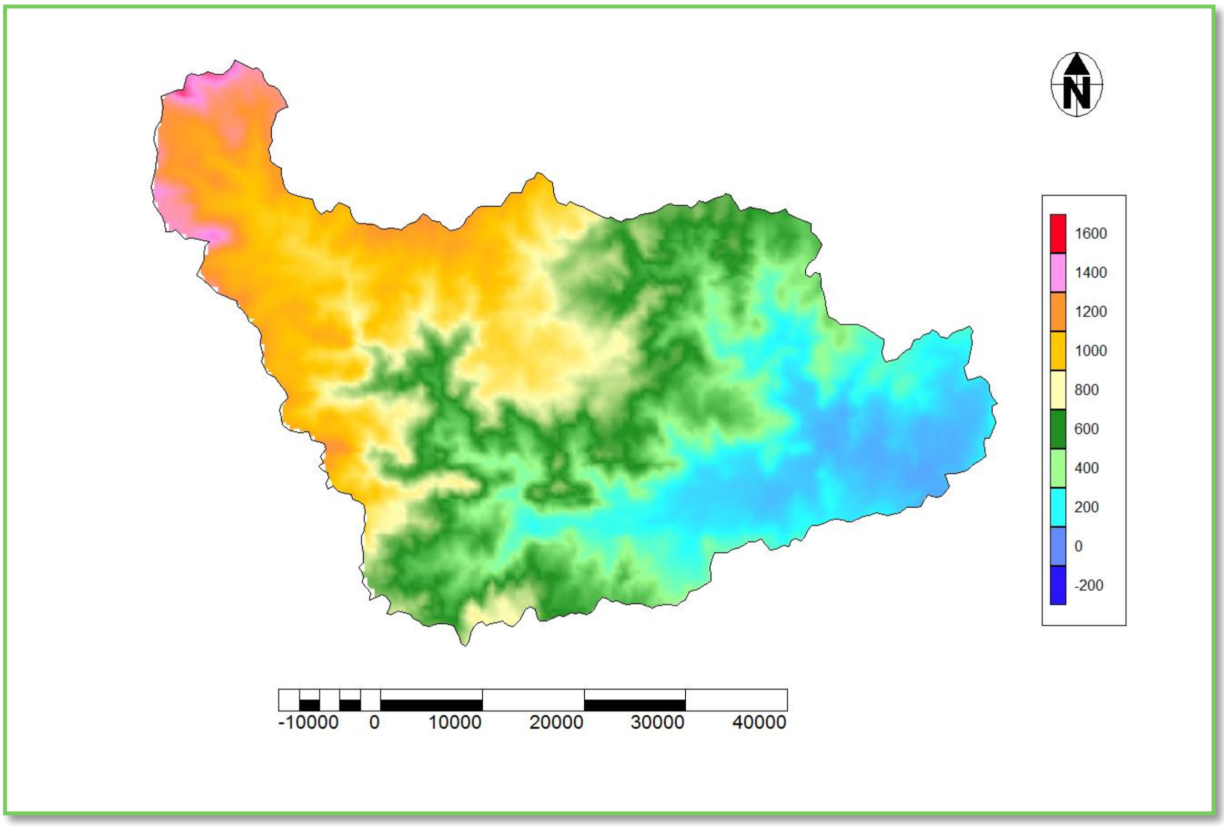


FIGURE 26: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 26**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 26: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
2123.554	107.331	174.276	181.474	8.5%	8.5%	3.9%	3.0%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 27**.

TABLE 27: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
90120	18024	0.162

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 21** is highlighted in red.

TABLE 28: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
65.728	105.666	84.921	43.456	67.646	26.546	174.276	42.540

Groundwater use

The groundwater use in the catchment is documented in **Table 29**.

TABLE 29: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
1.710	0.079	0.347	0.079	1.710	6.120	0.202	6.159

Groundwater quality

The TDS values for the RU are shown in **Figure 27**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines, with the exception of five boreholes. These areas should be treated as hot spots rather than applying a poor classification to the whole resource unit. Treatment of the hot spot areas will be addressed under Resource Quality Objectives in Section 35.

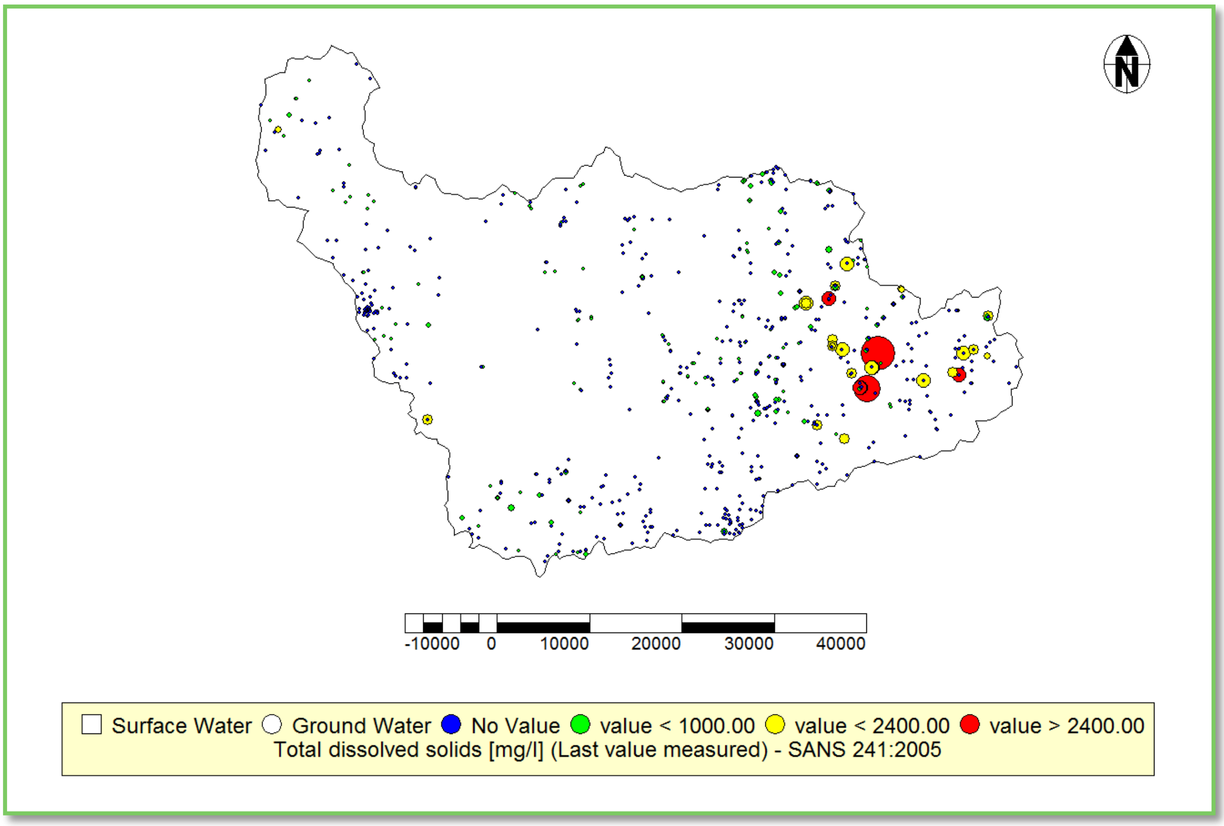


FIGURE 27: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 30**. The slope histogram is documented in Appendix D.

TABLE 30: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
19.1	8.5%	1.8	SaClLm-SaCl, SaLm-SaCl	Weathered/Fractured	Natal	55%

8.13 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 3.5%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled by assigning a normal distribution curve with a standard deviation of 0.616 Mm³/a to the groundwater use estimate, to account for the associated uncertainty. The stochastic results are shown in **Figure 28**. It is clear from the results that the stress index will vary between 3% and 4%, with a certainty of 99.34%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

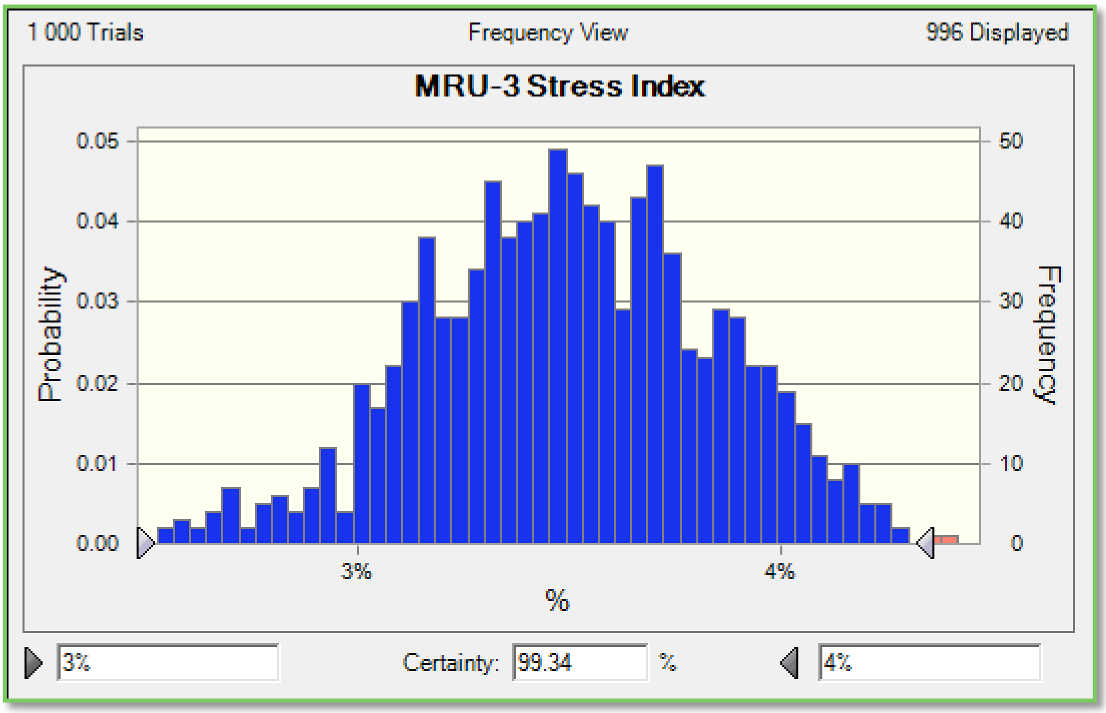


FIGURE 28: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 29**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. It is apparent that the contamination category, according to the explanation, is C.

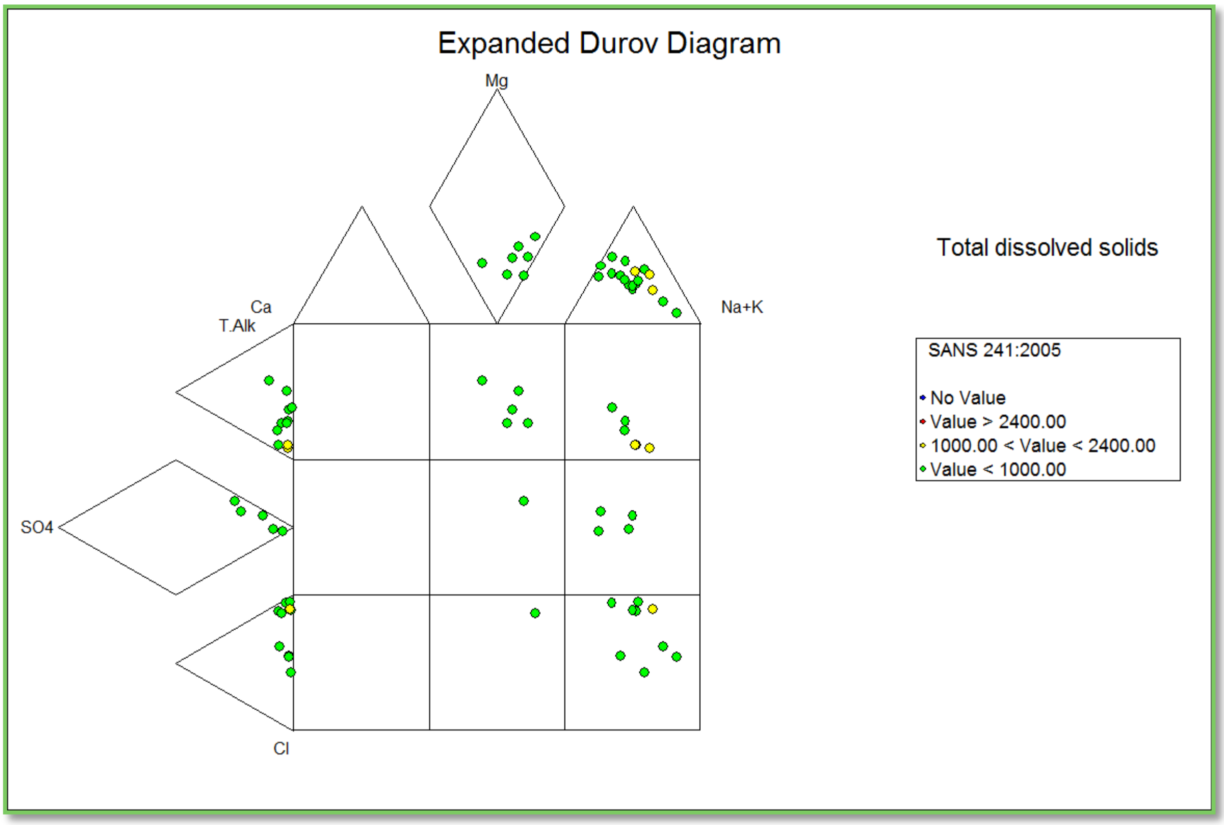


Figure 29: Expanded Durov diagram

As documented, the vulnerability is 55%. The impact of potential contamination according to Section 2.2, is low to medium because of all the agriculture and forestry in the area.

Final category

The final category for the RU is summarised in **Table 31**.

Table 31: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	A	Natural
Groundwater contamination	C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	**B**	**Good**

8.14 The Reserve

The groundwater Reserve for the RU is summarised in **Table 32**.

Table 32: Reserve

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
42.540	0.162	24%	132.613	6.159

9. Classification and the Reserve for RU4

9.1 Location

The economic hub of Richards Bay is the main town in this RU. Another town in the area is Felixton, known for its mills. Quaternary catchments W12F and W12J are included in the RU shown in **Figure 30**. A section of Port Dunford is included as a protected area.

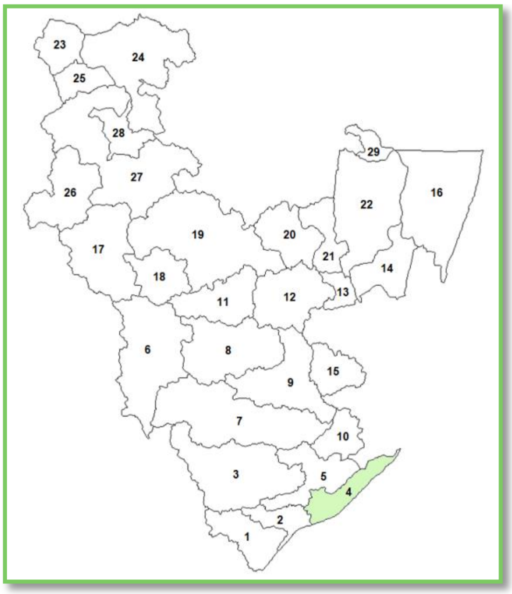


FIGURE 30: LOCATION

9.2 Climate

The climate is humid, with only one or two months of very little or no rain. The rainfall exceeds 1000 mm per year. Mean annual temperatures for January are around 25°C and those in July around 17°C.

9.3 Vegetation (taken from environment.gov.za)

Towards the coast there are forest patches characterised by a large number of species of woody lianas. Much closer to the seashore, evergreen thicket occurs on littoral dunes. On the seaward, side the canopy exhibits the typical clipped appearance of wind-pruning as a result of constant exposure to salt-laden easterly winds.

Sand Forests occur in the study area. Sand Forest is distinctive in the preponderance of deciduous to semi-deciduous elements, especially in the canopy. They form dense, almost impenetrable stands, up to 25 m tall. Lianas, palms and Natal Wild Banana *Strelitzia nicolai* are abundant.

9.4 Demography and Land use

The total population in the area is 89350 (2001 census data). Forestry and sugarcane are the main agricultural activities. The Felixton Cane Mill (**Photo 18**) crushes 2.1 million tons of cane and produces 220000 tons of sugar per year. There are also paper mills located in the RU. The Richards Bay landfill site is situated close to Alton, near the old sewage works, and excees capacity. The aluminium industry was established in the industrial area of Richards Bay in the 1970s. Richards Bay has the largest manufacturer of South African-made earth moving and handling equipment. Other industries such as brick making, fertilizers and chemicals are located within the Richards Bay industrial area. Sixty-five million tons of coal are exported annually through the port of Richards Bay. Three major producers of industrial, medical and household gases have plants located in Richards Bay. The titanium mining operations are located to the north of Richards Bay (**Photo 19**) in the coastal sands, producing about 1.5 million tons of export product per annum. Extensive sand mining occurs in the RU. The Landcover for the RU is shown in **Figure 31**.

PHOTO 18: CANE MILL

PHOTO 19: MINING NORTH OF RICHARDS BAY

9.5 Surface water and Wetlands

The Mhlathuze and Mzingazi River's estuaries occur in the RU. There are important wetlands in the RU are shown in **Figure 31**.

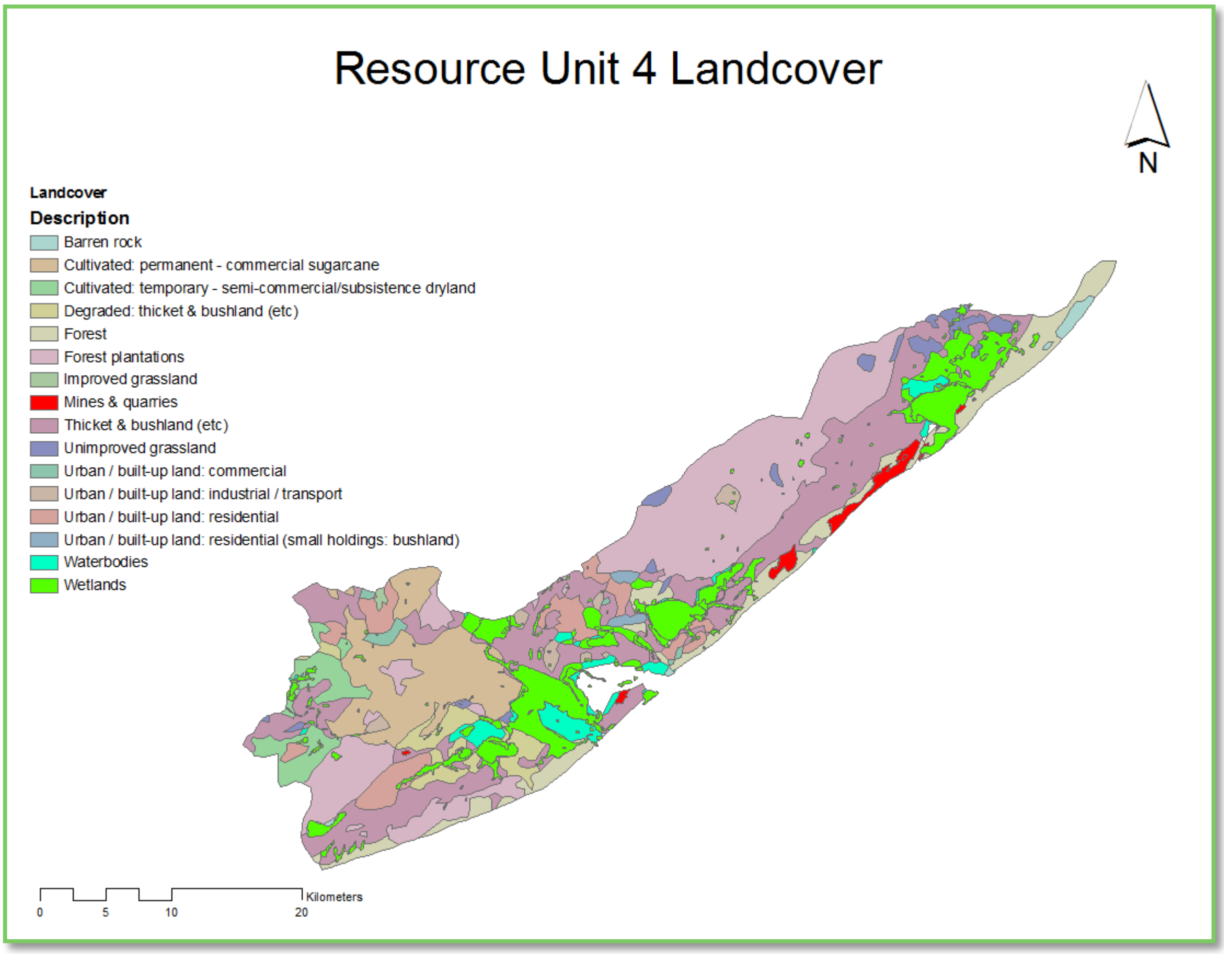


FIGURE 31: LANDCOVER

9.6 Soils (taken from environment.gov.za)

Sandy soils of Quaternary aeolian and marine origin.

9.7 Geohydrology

Groundwater levels

It is clear that the groundwater levels follow the topography, as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 32**. The most probable depth to groundwater level in the RU is 5.4 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

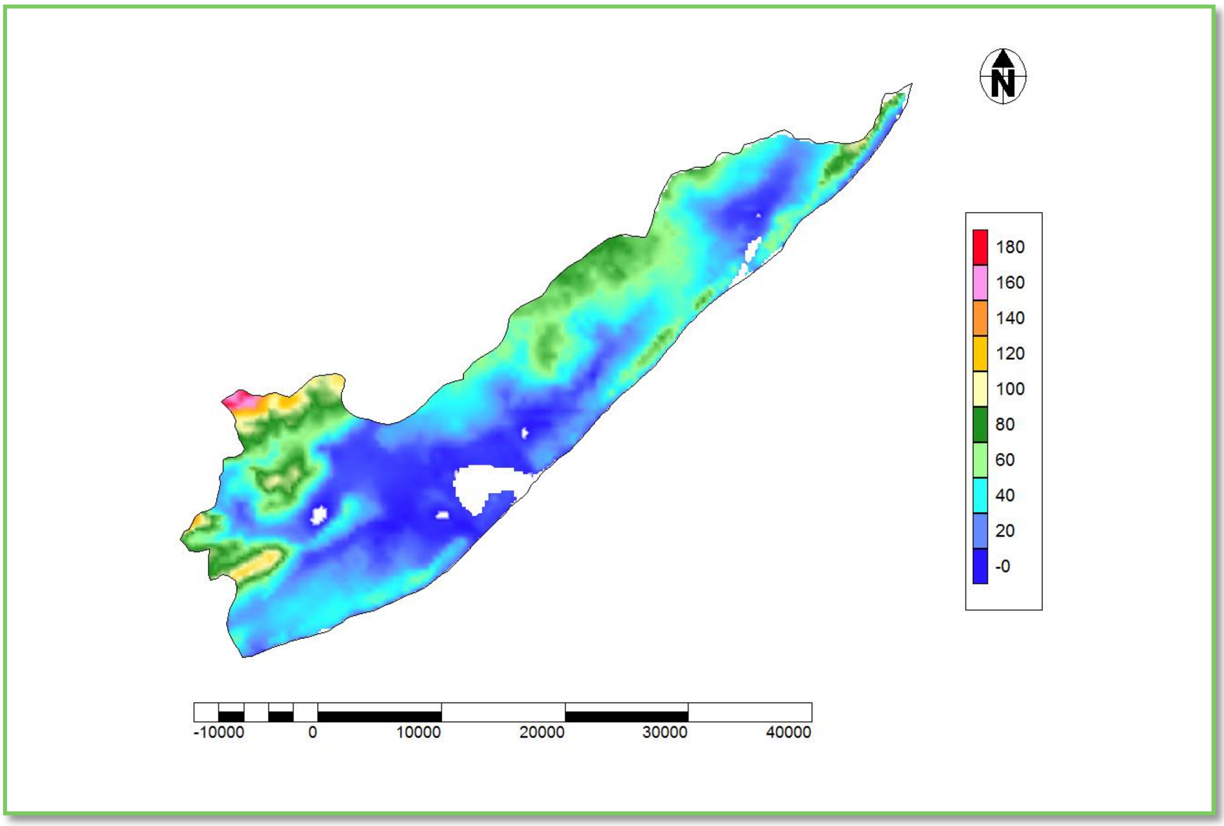


FIGURE 32: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 33**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 33: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
937.803	69.455	101.482	63.178	6.7%	6.7%	9.5%	6.4%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 34**.

TABLE 34: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
102753	20551	0.185

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 35** is highlighted in red.

TABLE 35: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
37.366	94.042	69.395	39.064	58.337	13.291	101.482	39.580

Groundwater use

The groundwater use in the catchment is documented in **Table 36**.

TABLE 36: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
0.440	0.329	0.002	0.002	0.440	1.944	0.153	1.912

Groundwater quality

The TDS values for the RU are shown in **Figure 33**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines, with the exception of one borehole. This area should be treated as a hot spot rather than applying a poor classification to the whole resource unit. Treatment of the hot spot areas will be addressed under Resource Quality Objectives in Section 35. In addition it is known that the shallow aquifers in the vicinity of Richards Bay are polluted and therefore the whole of Richards Bay must be treated as a hot spot.

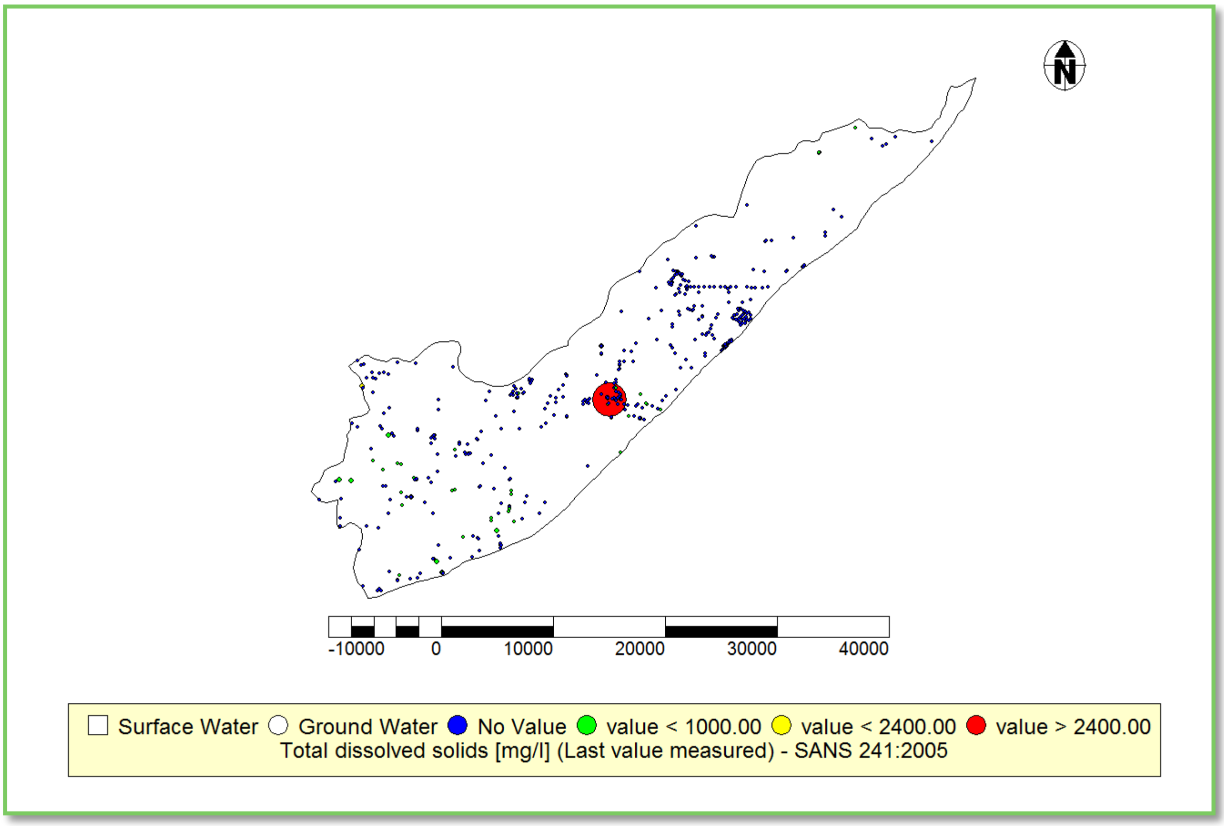


FIGURE 33: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 37**. The slope histogram is documented in Appendix D.

TABLE 37: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
5.4	6.7%	0.4	Sa	Weathered/Fractured	Natal	66%

9.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 3.3%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled by assigning a normal distribution curve with a standard deviation of 0.191 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in **Figure 34**. It is clear from the results that the stress index will vary between 2% and 4%, with a certainty of 99.51%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

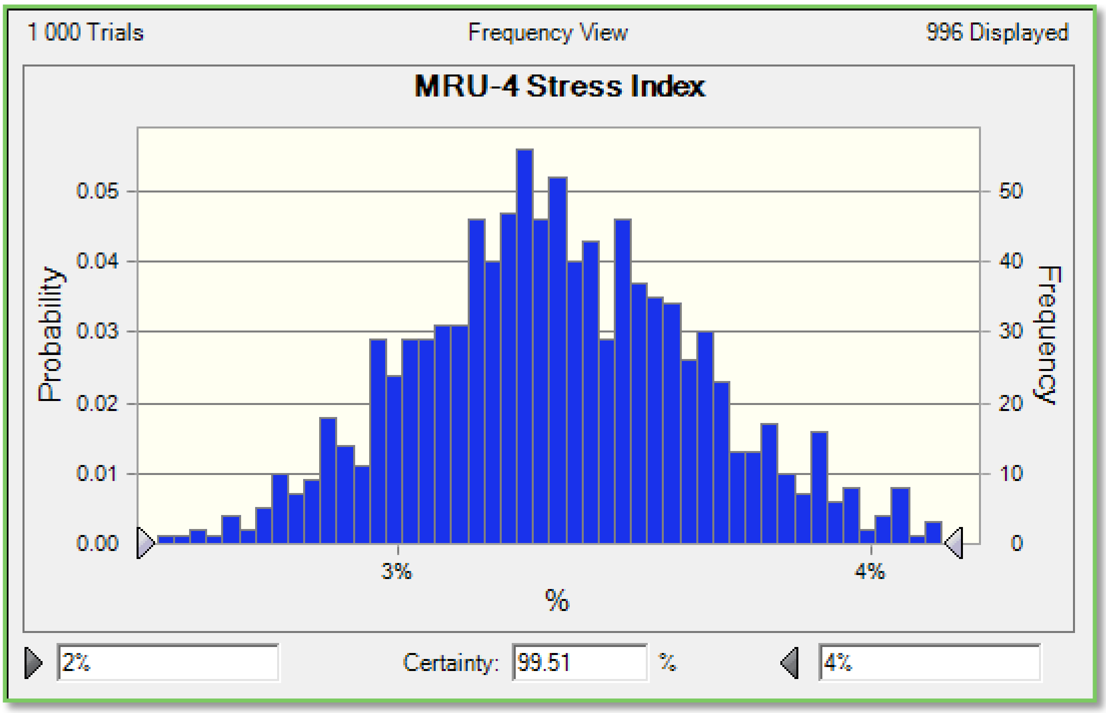


FIGURE 34: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 35**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. It is apparent that the contamination category, according to the explanation, is C.

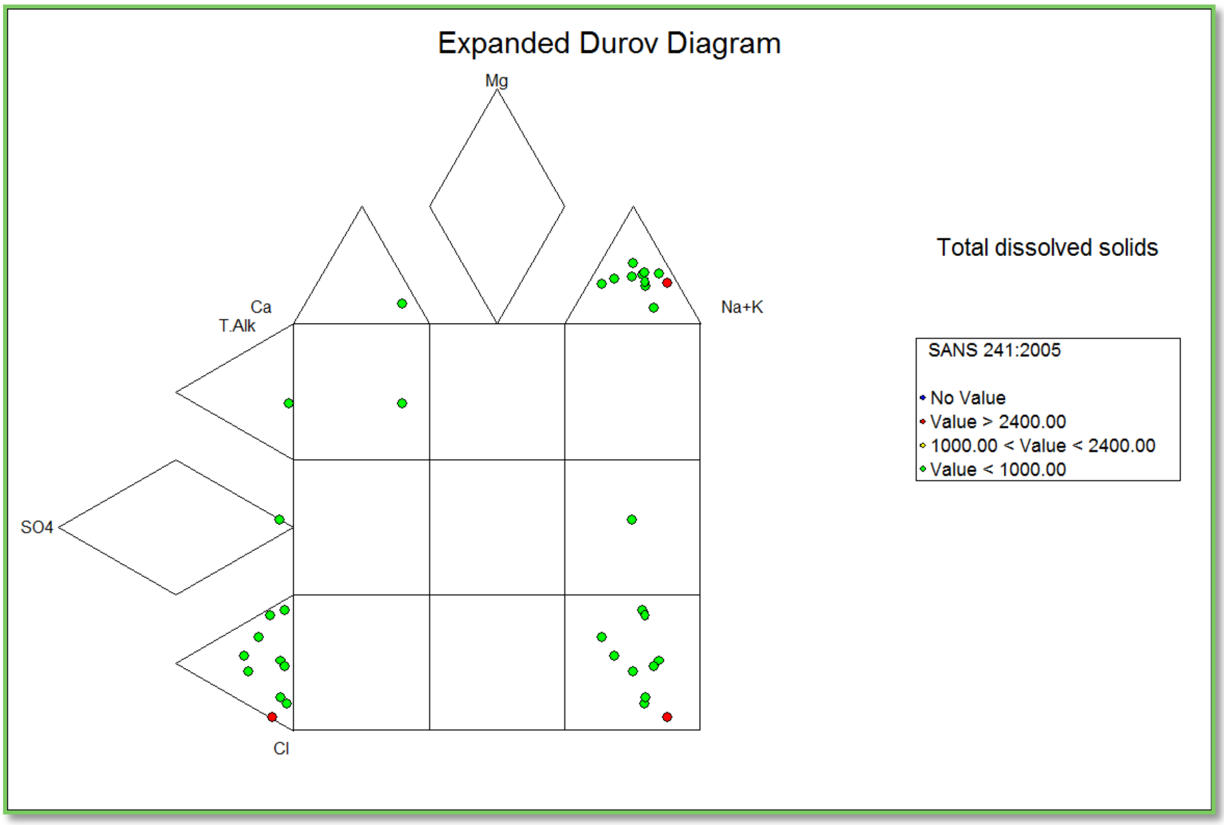


Figure 35: Expanded Durov diagram

As documented, the vulnerability is 66%. The impact of potential contamination, according to Section 2.2, is high due to the mining, urbanisation and industries in the RU.

Final category

The final category for the RU is summarised in **Table 38**.

Table 38: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	B	Good
Groundwater contamination	C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	D	Fair
FINAL	**C/D**	**Fair**

9.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 39**.

Table 39: Reserve

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
39.580	0.185	63%	21.500	1.912

10. Classification and the Reserve for RU5

10.1 Location

The location of the RU is shown in **Figure 36**. The towns included in this unit are Empangeni, Mposa and Kwa Mbonambi. Empangeni is situated in attractive hilly country side, overlooking a flat coastal plain, 90 to 150 metres above sea level, with panoramic views of Richards Bay. The following quaternary catchments are also included in the RU: W12E, W12G and W12H. The protected areas include sections of Ongoyi and Mfazi Parks.

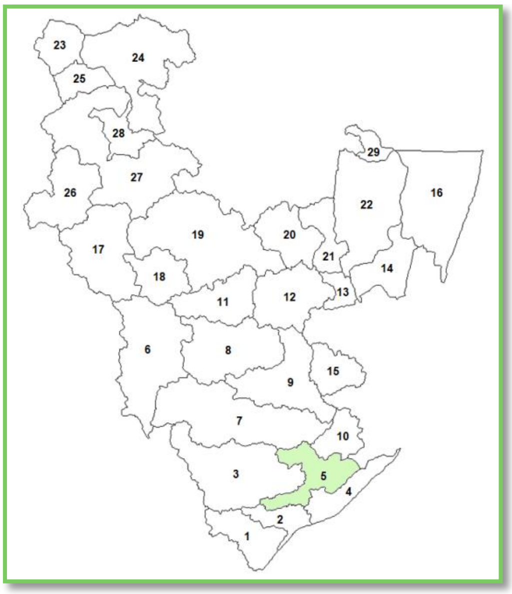


FIGURE 36: LOCATION

10.2 Climate

Inland, the area is cooler and drier than the coastal belt, with a rainfall of 750 to 1300 mm per year. Mean daily temperatures in January are around 22°C, with a maximum of about 28°C. July mean temperatures are around 14°C, with minima as low as 7°C.

Towards the coast, the climate is humid, with only one or two months of very little or no rain. The rainfall exceeds 1000 mm per year. Mean annual temperatures for January are around 25°C, and those in July around 17°C.

10.3 Vegetation (taken from environment.gov.za)

To the west of the study area the vegetation is an open Sweet Thorn Acacia karroo savanna or scrub, with Ngongoni Bristlegrass Aristida junciformis almost entirely dominant. Valley thicket is also present. The flora has transitional Tongoland-

Pondoland and Afromontane affinities. The closed canopy is up to 6 m in height and woody evergreen species are dominant, rather than succulent trees or shrubs.

Towards the coast, there are forest patches characterised by a large number of species of woody lianas. Much closer to the seashore, evergreen thicket occurs on littoral dunes. On the seaward side, the canopy exhibits the typical clipped appearance of wind-pruning as a result of constant exposure to salt-laden easterly winds.

10.4 Demography and Land use

The total population of the study area is approximately 102020 (2001 census data). Land use includes sugarcane and forest plantations (**Figure 37**). There are many industries and some mines in the vicinity of Empangeni, including building making works, a Titanium plant (**Photo 20**). The solid waste disposal sites in Empangeni and Richards Bay are, however, reaching capacity, and a regional landfill site near Empangeni is being investigated. A gas pipeline runs from Secunda to Durban via Empangeni.

PHOTO 20: TITANIUM PLANT

10.5 Surface water and Wetlands

The main rivers in the area are the Mhlathuze, Mhtatuzana and Nseleni Rivers. The wetlands in the study area are shown in **Figure 37**.

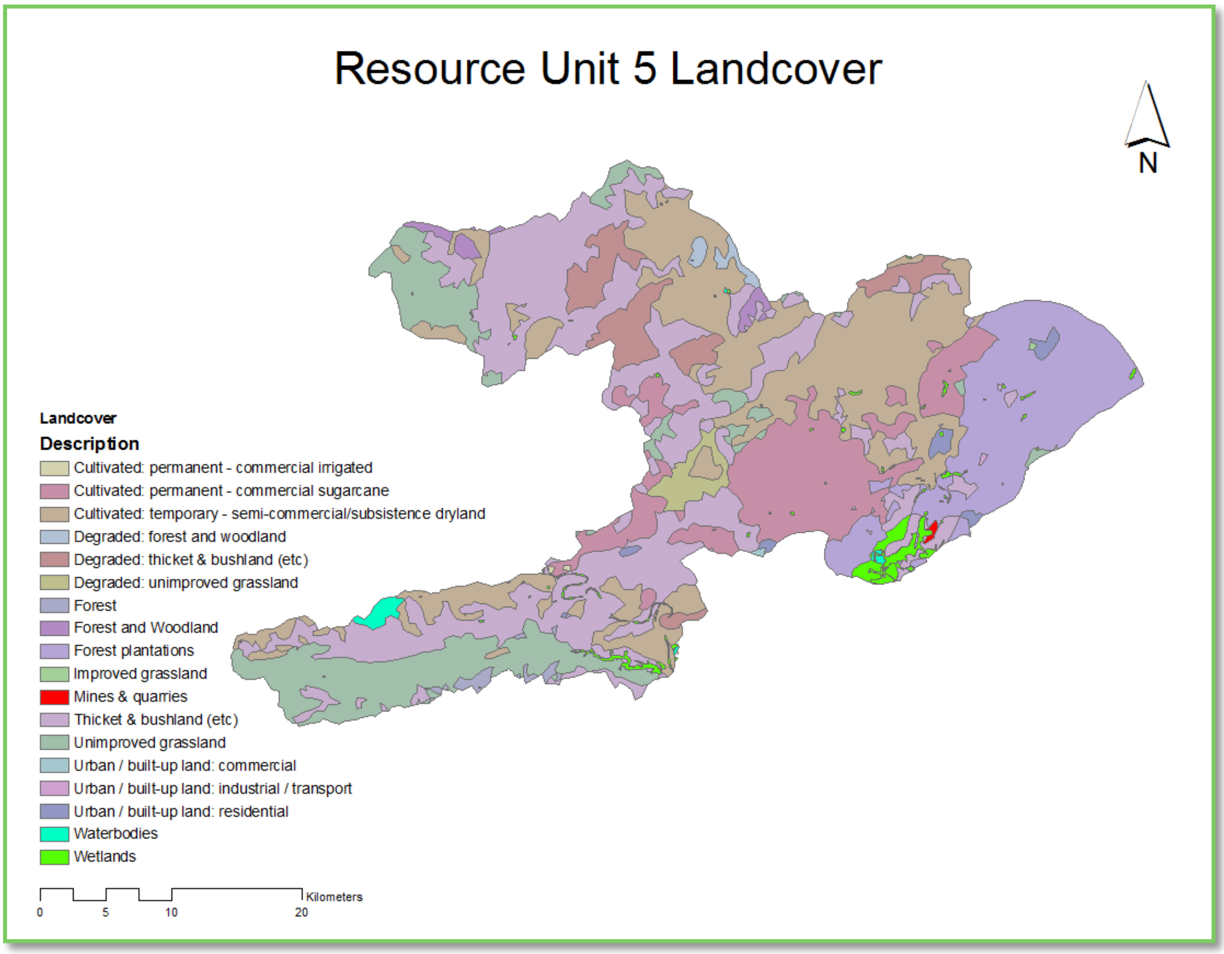


FIGURE 37: LANDCOVER

10.6 Soils (taken from environment.gov.za)

Inland soils are weakly developed, with shallow topsoils underlain by a lithocutanic B horizon. Where soil development has proceeded further, red or black clays may characterise the subsoil. Towards the coast, the soils are sandy being of Quaternary aeolian and marine origin.

10.7 Geohydrology

Groundwater levels

It is clear that the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 38**. The most probable depth to groundwater level in the RU is 8.4 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

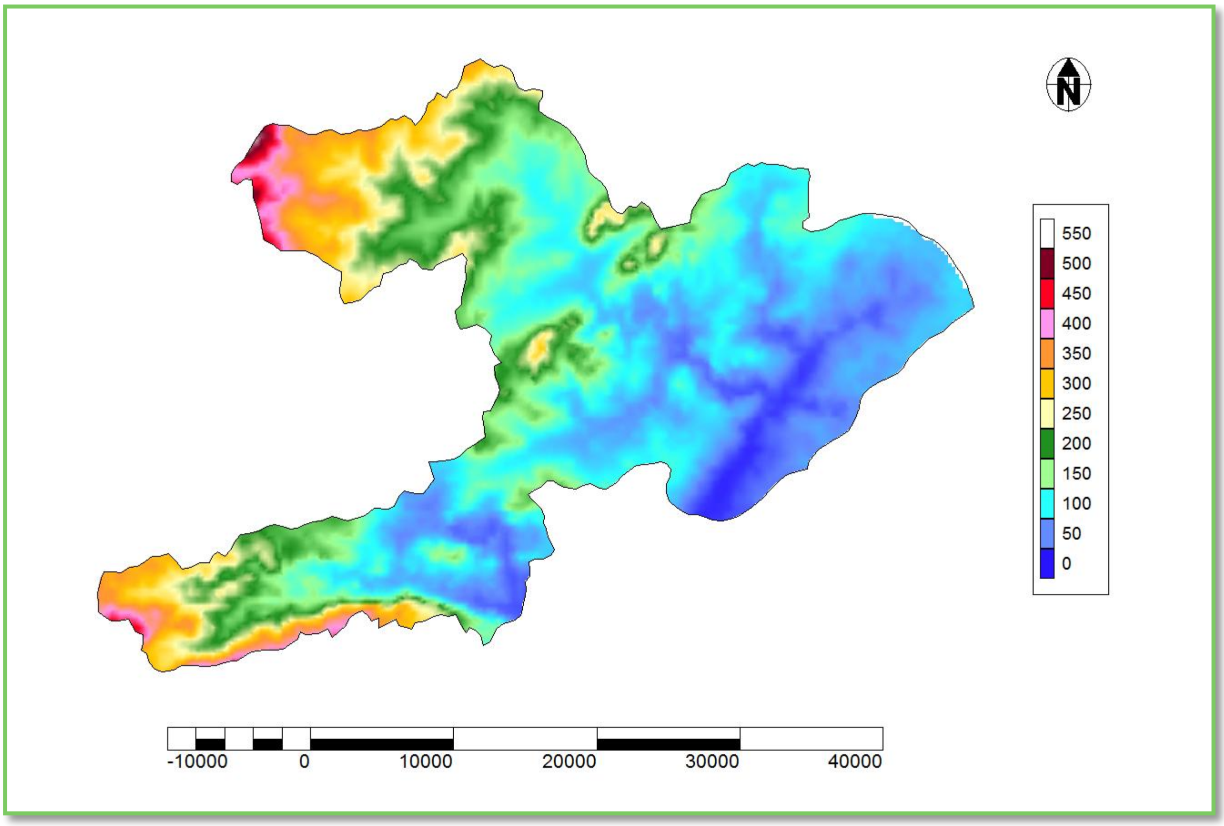


FIGURE 38: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 40**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 40: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
1034.836	59.758	90.775	58.502	5.7%	5.7%	17.3%	3.5%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 41**.

TABLE 41: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
117323	23465	0.211

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 42** is highlighted in red.

TABLE 42: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
29.782	68.718	47.421	25.295	39.907	8.599	90.775	26.920

Groundwater use

The groundwater use in the catchment is documented in **Table 43**.

TABLE 43: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
0.980	0.360	0.006	0.006	0.980	3.708	0.252	3.749

Groundwater quality

The TDS values for the RU are shown in **Figure 39**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. There are numerous boreholes in the RU that exceed the drinking quality guidelines. These areas should be treated as hot spots rather than applying a poor classification to the whole resource unit. Treatment of the hot spot areas will be addressed under Resource Quality Objectives in Section 35.

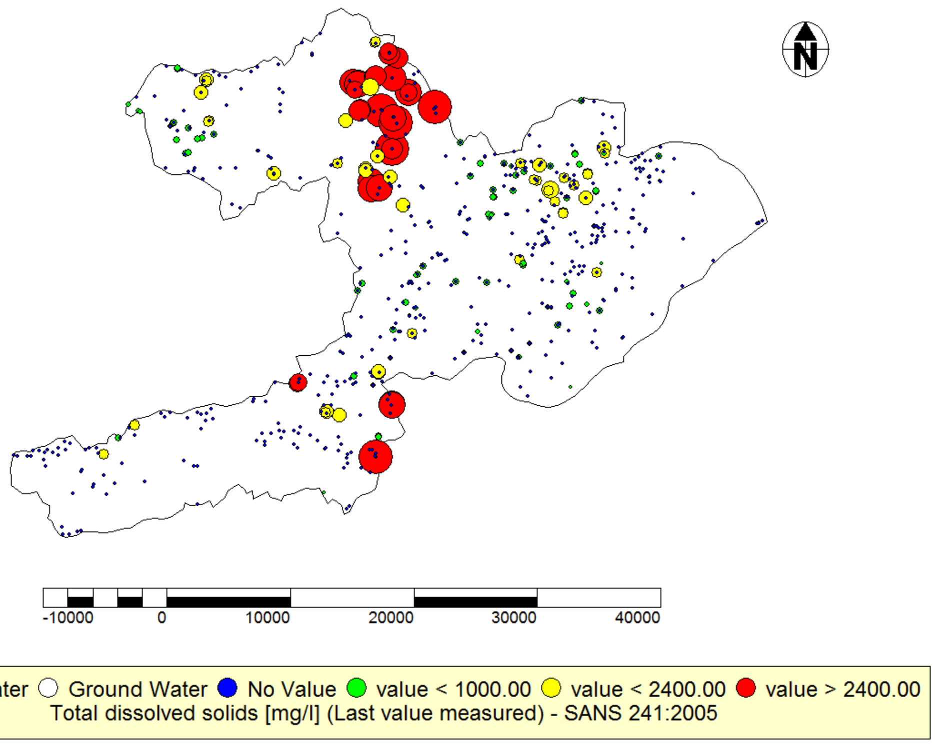


FIGURE 39: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 44**. The slope histogram is documented in Appendix D.

TABLE 44: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
8.4	5.7%	0.6	SaLm-SaCl, Sa	Weathered/Fractured	Natal	61%

10.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 6.8%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 0.375 Mm^3/a to the groundwater use estimate, to account for the associated uncertainty. The stochastic results are shown in **Figure 40**. It is clear from the results that the stress index will vary between 5% and 8%, with a certainty of 99.01%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

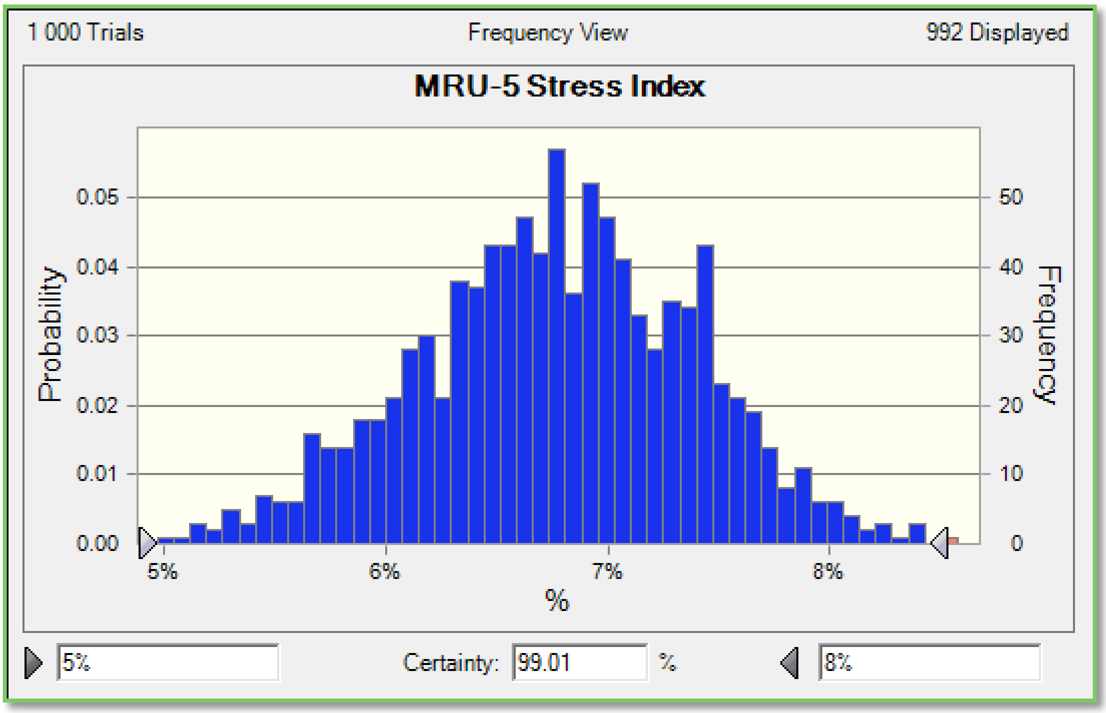


FIGURE 40: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 41**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. It is apparent that the contamination category, according to the explanation, is C.

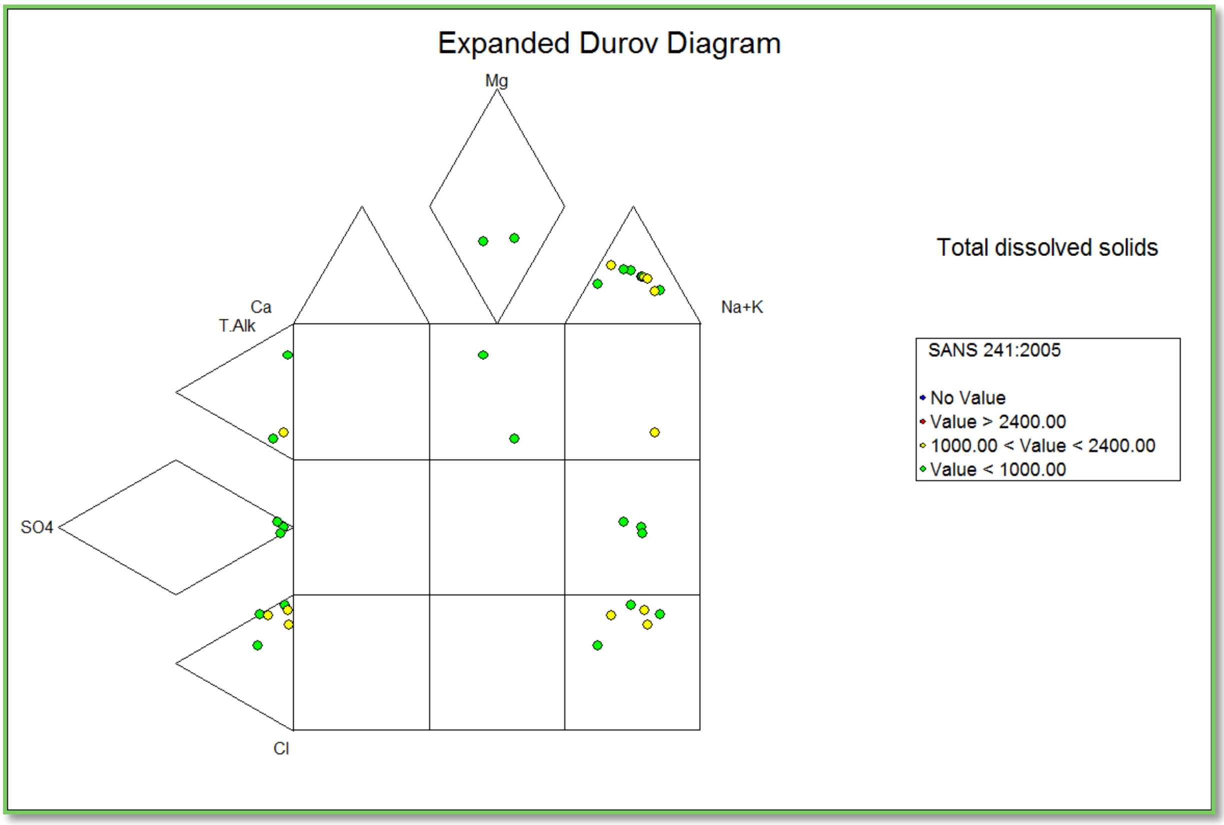


Figure 41: Expanded Durov diagram

As documented, the vulnerability is 61%. The impact of potential contamination, according to Section 2.2, is high due to agricultural activities and industry in the area.

Final category

The final category for the RU is summarised in **Table 45**.

Table 45: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	B	Good
Groundwater contamination	C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	D	Fair
FINAL	**C/D**	**Fair**

10.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 46**.

Table 46: Reserve

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
26.920	0.211	46%	27.623	3.749

11. Classification and the Reserve for RU6

11.1 Location

The quaternary catchments included in this RU are: W21A, W21B, W21C, W21D, W21E and W21F. The main towns in the area are Vryheid and Nondweni. The following protected areas are included in the RU: Waterhoek En Jachpad, Vryheid Mountain and Lenjane waterfall. The location of the RU is shown in **Figure 42**.

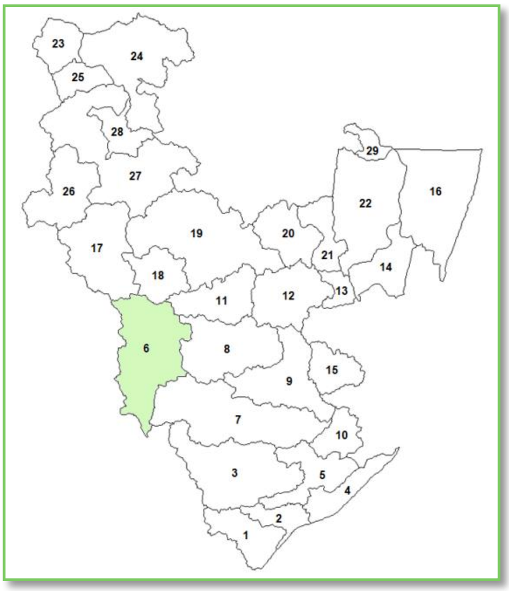


FIGURE 42: LOCATION

11.2 Climate

The rainfall is 600 to 900 mm per year, in summer. Mean temperatures for January are around 22°C, with a mean maximum of 29°C. In winter, mean annual temperatures in July are about 10°C, with a mean minimum of about 3°C.

11.3 Vegetation (taken from environment.gov.za)

The vegetation is open savanna, with scattered trees of Paperbark Thorn Acacia sieberiana, Sweet Thorn A. karroo, Scented Thorn A. nilotica and A. caffra. The herbaceous layer is quite variable, with secondary grassland, dominated by patches of tall Common Thatchgrass Hyparrhenia hirta, and sour grassland, dominated by Hairy Tridentgrass Tristachya leucothrix. Other grass species include Narrowheart Lovegrass Eragrostis racemosa, Pincushion Grass Microchloa caffra, Broadleaf Bluestem Diheteropogon amplectens, Trachypogon spicatus, Digitaria tricholaenoides, Elionurus muticus and Themeda triandra.

11.4 Demography and Land use

According to the 2001 census data, the total population in the study area is 156450. Land use includes mining (coal and granite) and farming (mainly broilers, forestry, maize, sheep and cattle). Large feedlots (**Photo 21**) are located in the vicinity of Vryheid. The Landcover for the RU is shown in **Figure 43**.

PHOTO 21: FEEDLOT IN THE VICINITY OF VRYHEID

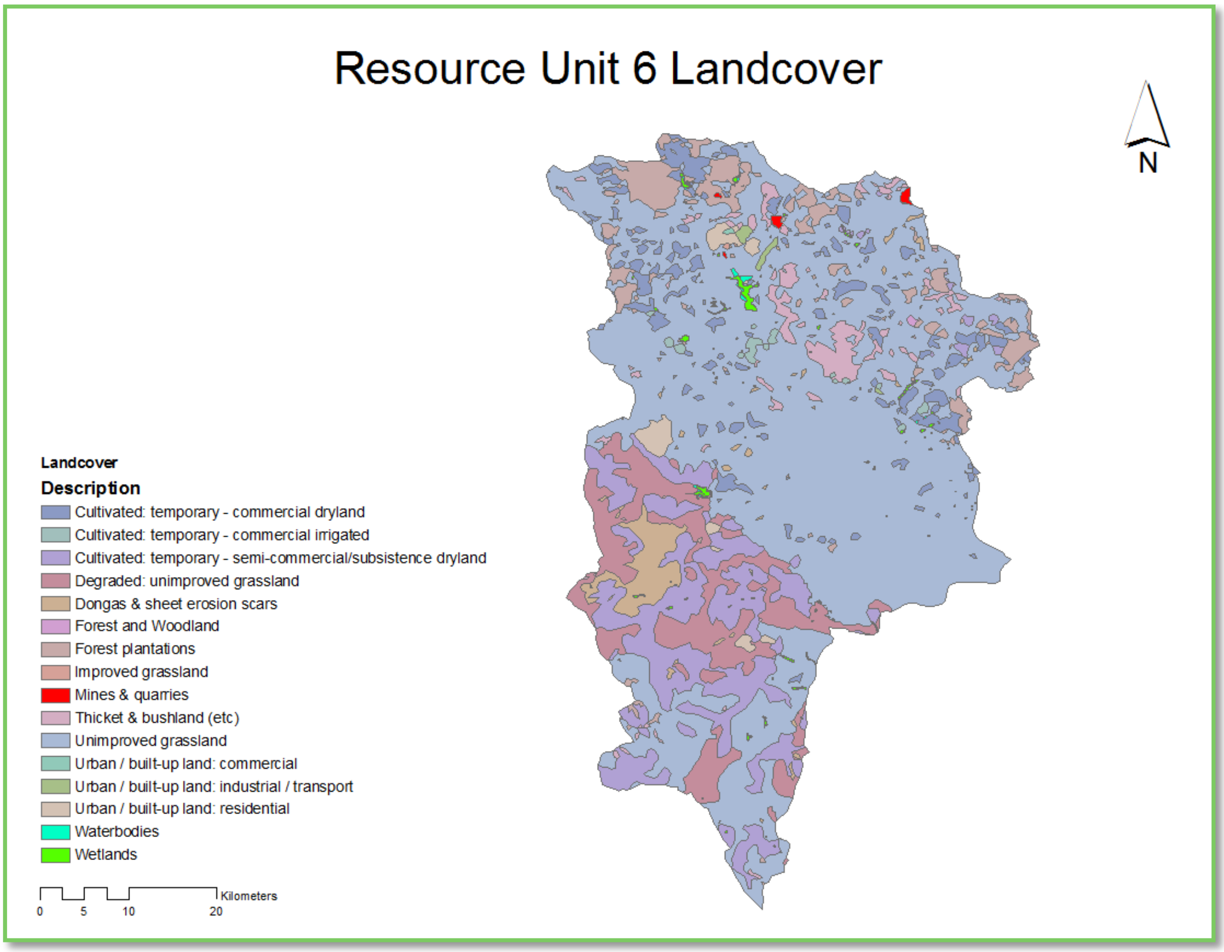


FIGURE 43: LANDCOVER

11.5 Surface water and Wetlands

The headwaters of the Whit Mfolosi River occur in the RU. The wetlands (**Photo 22**) within the RU are shown in **Figure 43**.

PHOTO 22: WETLAND IN THE VICINITY OF VRYHEID

11.6 Soils (taken from environment.gov.za)

The soil is shallow, derived from shales and mudstones of the Ecca Group of the Karoo Sequence. With a rainfall of less than 450 mm, it is characterised by subsoils, which are either duplex, which renders them potentially highly erodible, or dominated by black clays.

11.7 Geohydrology

Groundwater levels

It is clear the groundwater levels follow the topography, as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 44**. The most probable depth to groundwater level in the RU is 6.8 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

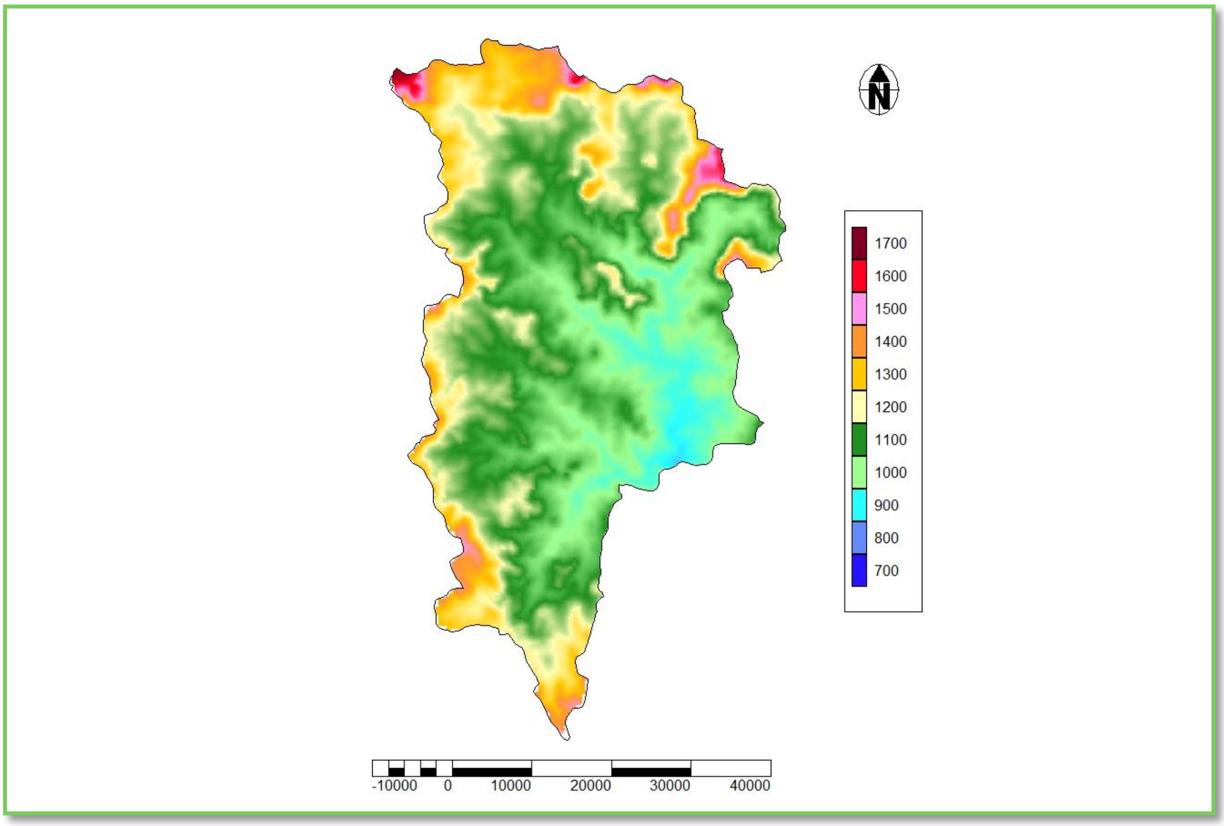


FIGURE 44: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 47**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 47: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
1853.167	78.179	127.198	122.491	6.6%	6.6%	4.1%	3.1%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 48**.

TABLE 48: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
211657	42331	0.381

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 49** is highlighted in red.

TABLE 49: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
39.431	80.667	45.869	18.093	37.781	7.914	127.198	20.240

Groundwater use

The groundwater use in the catchment is documented in **Table 50**.

TABLE 50: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
0.630	0.726	0.827	0.630	3.310	5.238	6.850	11.707

Groundwater quality

The TDS values for the RU are shown in **Figure 45**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines, with the exception of one borehole. This area should be treated as a hot spot rather than applying a poor classification to the whole resource unit. Treatment of the hot spot areas will be addressed under Resource Quality Objectives in Section 35.

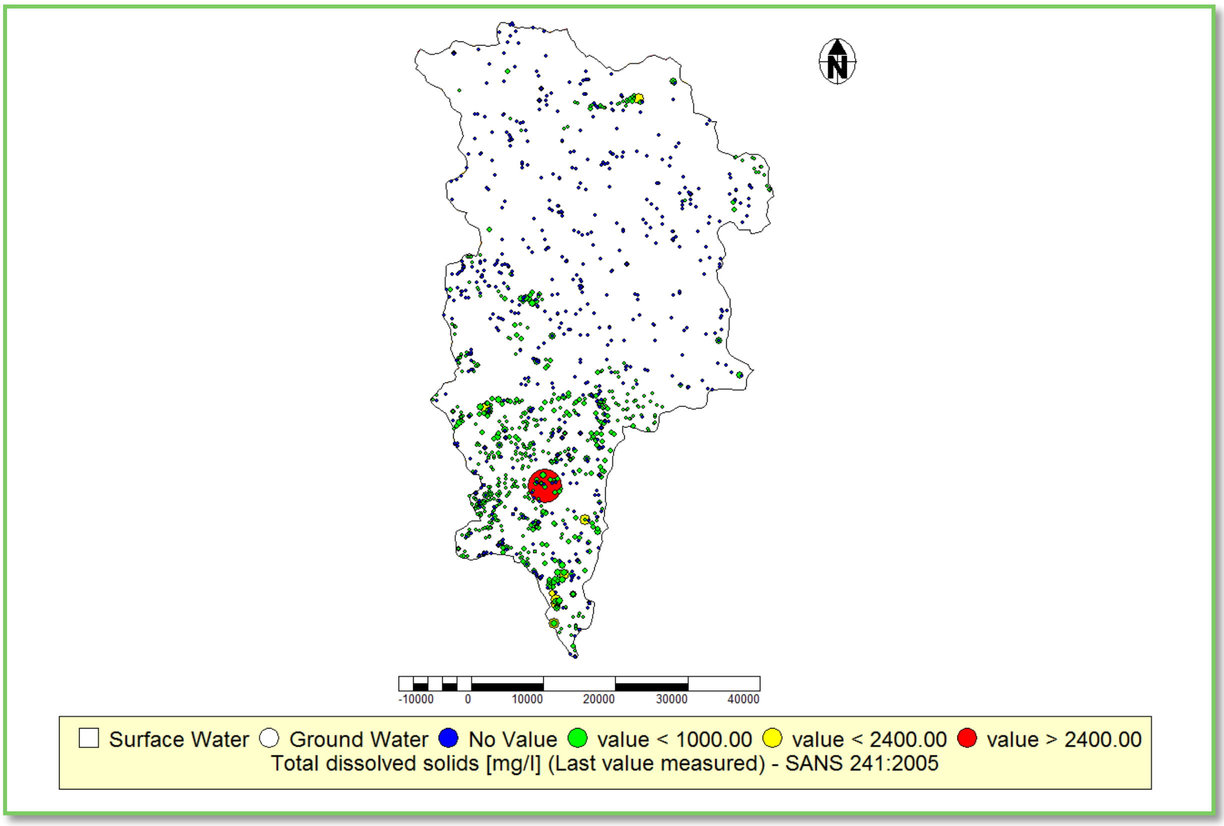


FIGURE 45: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 30**. The slope histogram is documented in Appendix D.

TABLE 51: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
6.8	6.6%	0.7	SaClLm-SaCl , LmSa-SaLm	Weathered/Fractured	Natal	61%

11.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 9.9%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled by assigning a normal distribution curve with a standard deviation of 1.171 Mm^3/a to the groundwater use estimate, to account for the associated uncertainty. The stochastic results are shown in **Figure 46**. It is clear from the results that the stress index will vary between 7% and 13%, with a certainty of 99.33%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

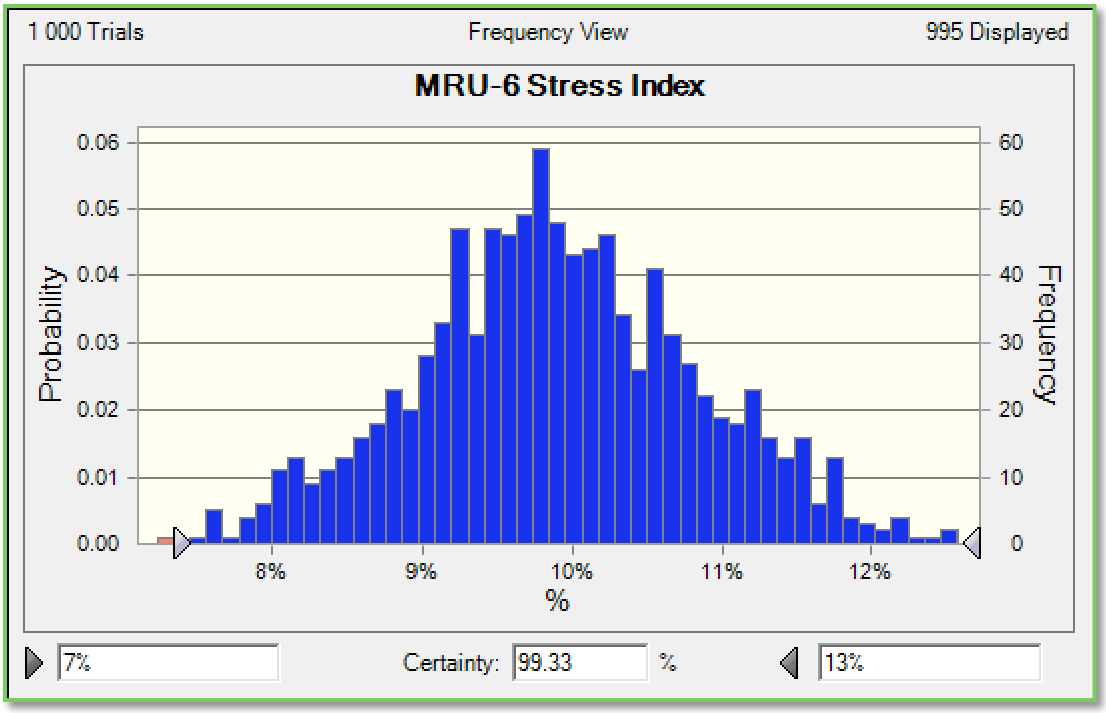


FIGURE 46: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 47**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. Most boreholes in the RU fall into the A or C categories. However there are 4 that can be classified as E. Therefore the water quality in the RU is classified as C/D.

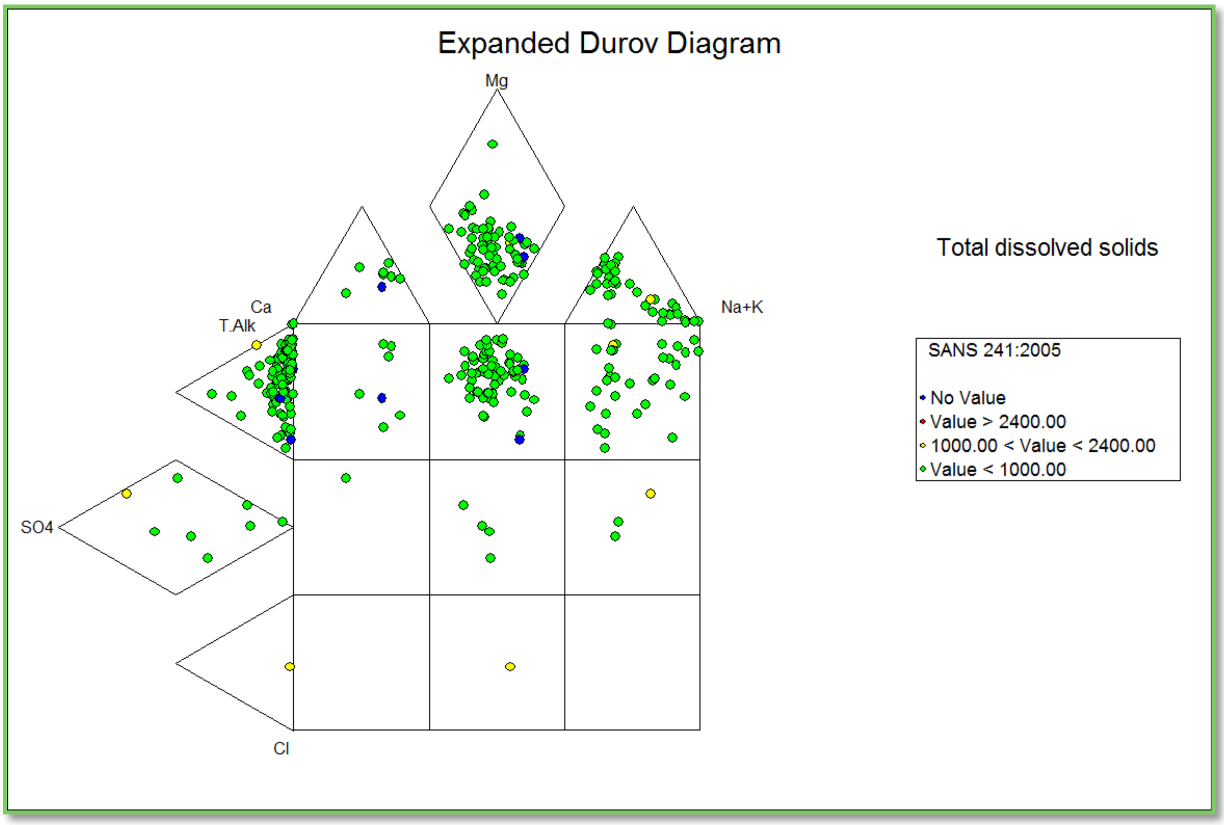


FIGURE 47: EXPANDED DUROV DIAGRAM

As documented the vulnerability is 61%. The impact of potential contamination, according to Section 2.2, is medium due to all the mining activities.

Final category

The final category for the RU is summarised in **Table 52**.

TABLE 52: CATEGORY FOR RU

Impact	Present status category	Water resource category
Groundwater usage	B	Good
Groundwater contamination	C/D	Fair
Potential groundwater contamination (vulnerability and impact)	C	Good/Fair
FINAL	**C**	**Good/Fair**

11.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 53**.

TABLE 53: RESERVE

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
20.240	0.381	17%	90.162	11.707

12. Classification and the Reserve for RU7

12.1 Location

The quaternary catchments located in the study area include W21G, W21H, W21J, W21K and W21L. The towns in the area are Ulundi and Umunywana. The location of the RU are shown in **Figure 48**. The following protected areas are included in the RU: Goudhoek Farm, Matshitsholo, Ophathe and the Hlhuluwe-Mfolozi Game Park.

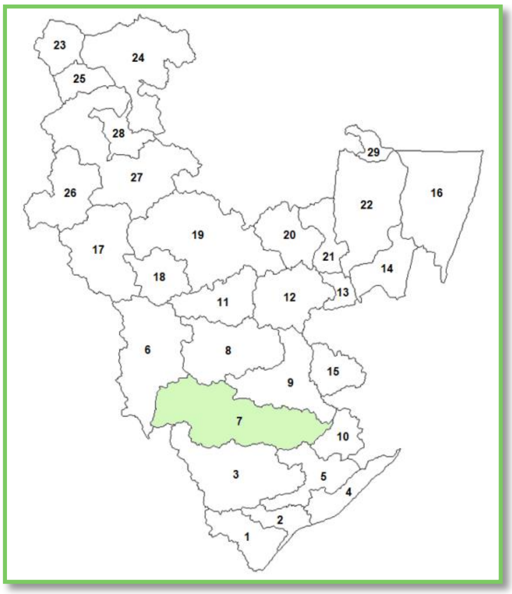


FIGURE 48: LOCATION

12.2 Climate

These areas are moist, cold montane grasslands with rainfall of 650 to 1 000 mm per year and little snow except on the tops of mountains. Rainfall occurs mainly in summer in the east and less seasonal in the west. Temperatures vary between -3°C and 40°C, with an average of 16°C.

12.3 Vegetation (taken from environment.gov.za)

In the western parts of the RU, the vegetation type is a dense, sour grassland with Redgrass *Themeda triandra, Speargrass Heteropogon contortus,* Hairy Tridentgrass *Tristachya leucothrix, Eragrostis curvula and Elionurus muticus* as some of the dominant species.

In the east, the vegetation is a mix of scrub and savanna. The most common tree species include Umbrella Thorn *Acacia tortilis,* Sweet Thorn *A. karroo,* Red Bushwillow

Combretum apiculatum, Boscia albitrunca, Euclea schimperi, Olea europaea subsp. *africana, Schotia brachypetala, Euphorbia* spp. and *Spirostachys africana.*

12.4 Demography and Land use

According to the 2001 census data, there are 137 345 people living in the RU. The main activities in the RU are agriculture and mining. The Landcover for the RU is shown in **Figure 49**.

PHOTO 23: MFOLOZI RIVER
(Source: www.panoramio.com)

12.5 Surface water and Wetlands

The Mfolozi River (**Photo 23**) is the main river in the study area. There are also many tributaries for the Mfolosi River within the RU. The wetlands are shown in **Figure 49**.

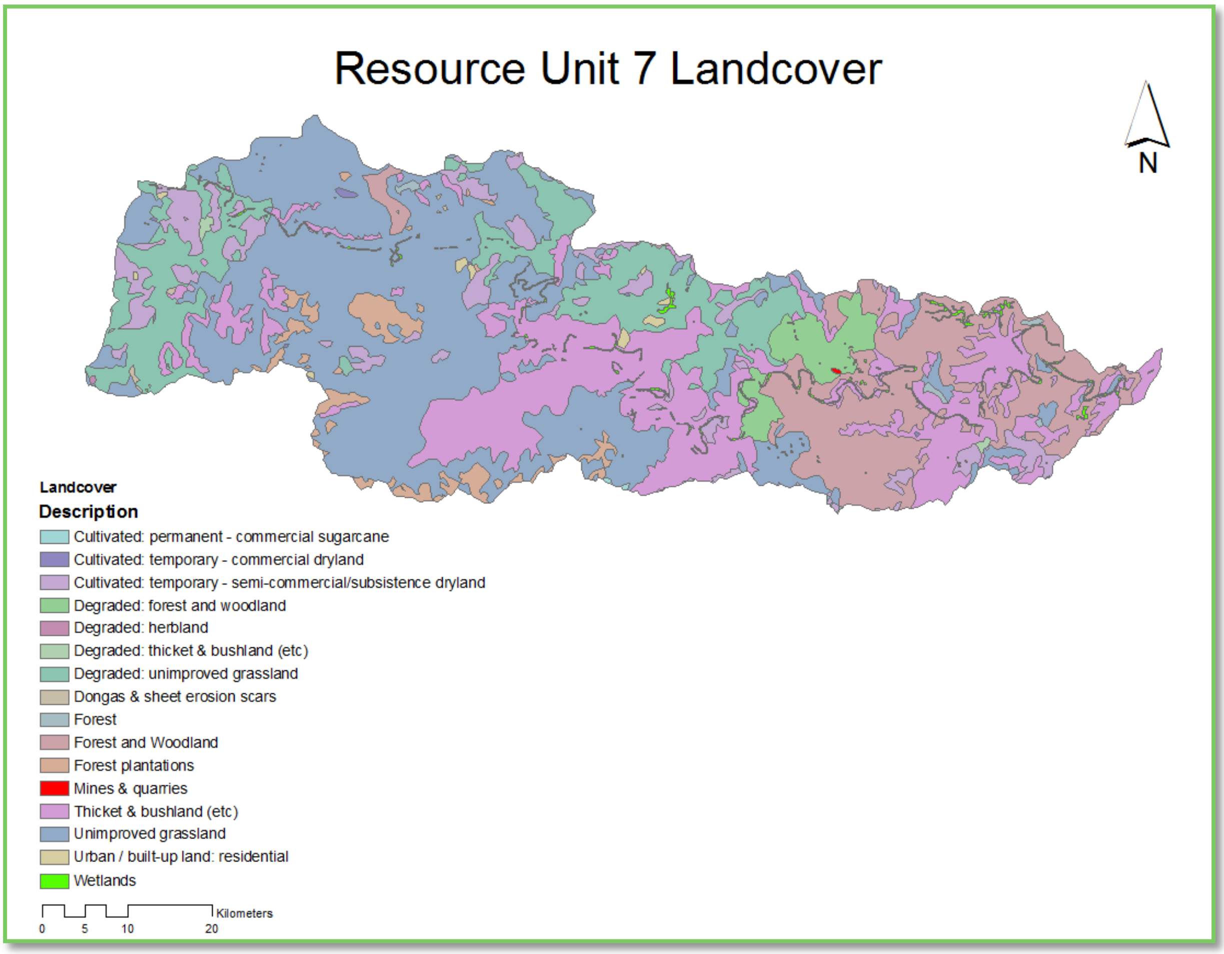


FIGURE 49: LANDCOVER

12.6 Soils (taken from environment.gov.za)

In the western sections of the RU, the soil is often shallow, rocky and leached, derived from Karoo Sequence sediments and dolerite. Where deep, the soils may be leached due to the high rainfall, and are fairly erodible, forming large dongas in some parts.

In the east, soils are either black clays, red, structured clays or duplex soils derived from Ecca Group shale and mudstone.

12.7 Geohydrology

Groundwater levels

It is clear that the groundwater levels follow the topography, as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 50**. The most probable depth to groundwater level in the RU is 11.2 mbgl, according to the histogram of water levels in the RU shown in Appendix B.

Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

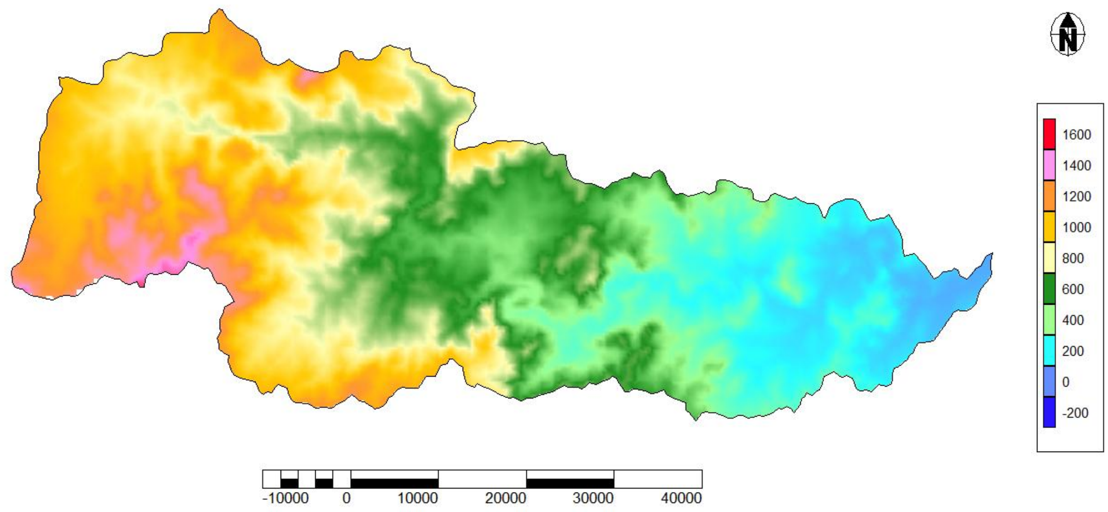


FIGURE 50: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 54**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 54: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
2170.050	87.414	185.627	129.948	6.0%	6.0%	3.5%	3.2%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 55**.

Table 55: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
125724	25145	0.226

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 56** is highlighted in red.

Table 56: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
58.465	92.378	48.508	20.213	41.672	12.111	185.627	21.770

Groundwater use

The groundwater use in the catchment is documented in **Table 57**.

Table 57: Groundwater use

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
0.650	0.122	0.630	0.122	2.520	3.690	1.607	5.071

Groundwater quality

The TDS values for the RU are shown in **Figure 51**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines, with the exception of boreholes to the east of the RU. These areas should be treated as hot spots rather than applying a poor classification to the whole resource unit. Treatment of the hot spot areas will be addressed under Resource Quality Objectives in Section 35.

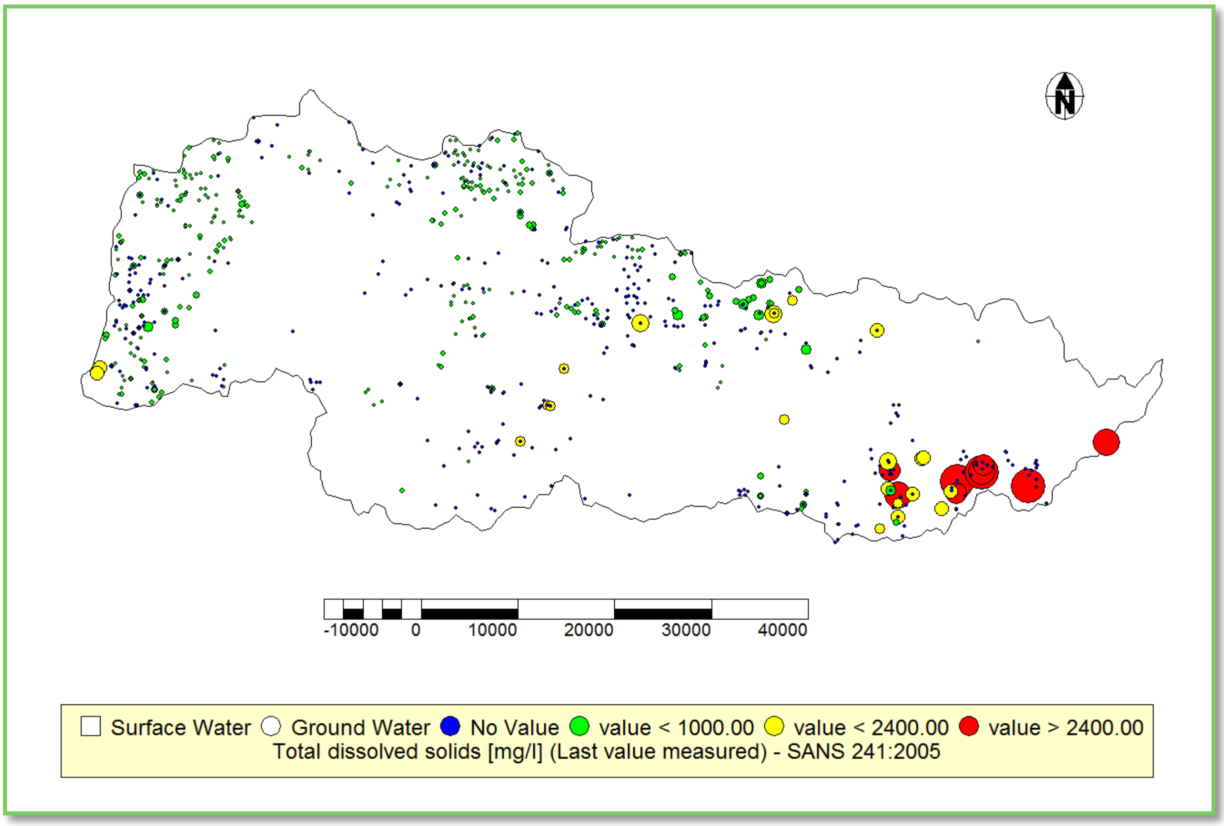


FIGURE 51: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 30**. The slope histogram is documented in Appendix D.

TABLE 58: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
11.2	6.0%	1.8	SaClLm-SaCl , SaLm-SaCl	Weathered/Fractured	Natal	55%

12.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 4.1%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled by assigning a normal distribution curve with a standard deviation of 0.507 Mm³/a to the groundwater use estimate, to account for the associated uncertainty. The stochastic results are shown in **Figure 52**. It is clear from the results that the stress index will vary between 3% and 5%, with a certainty of 98.99%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

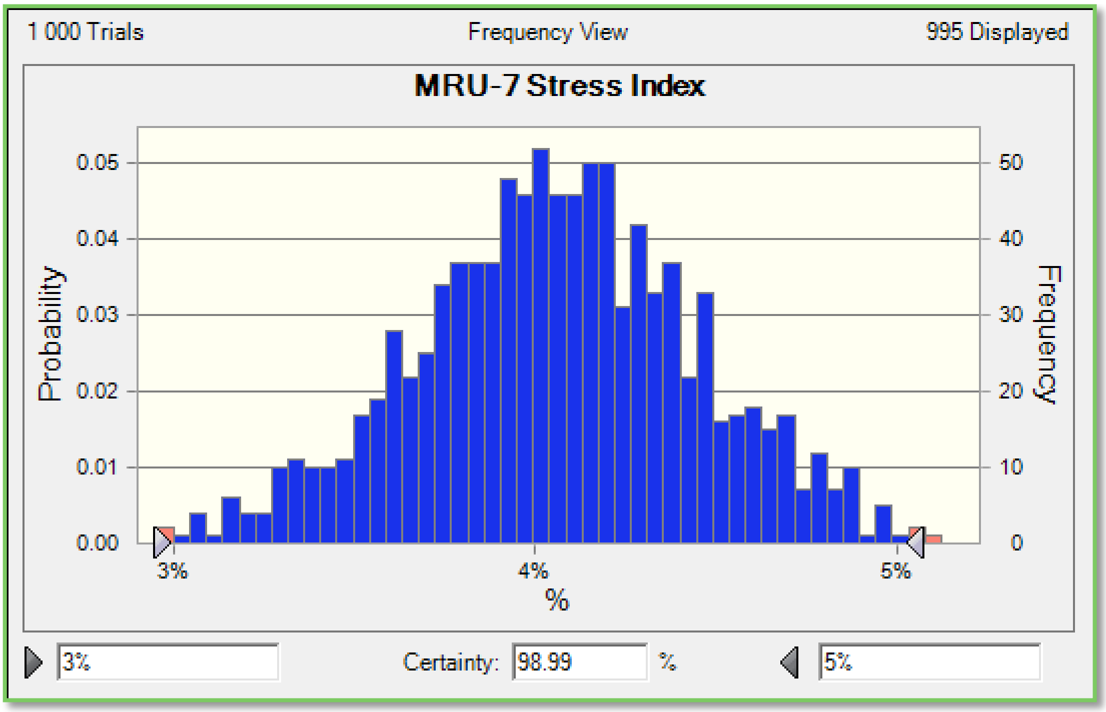


FIGURE 52: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 53**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. There are almost an even distribution of boreholes in categories A and C, therefore the contamination category for the RU is set as B.

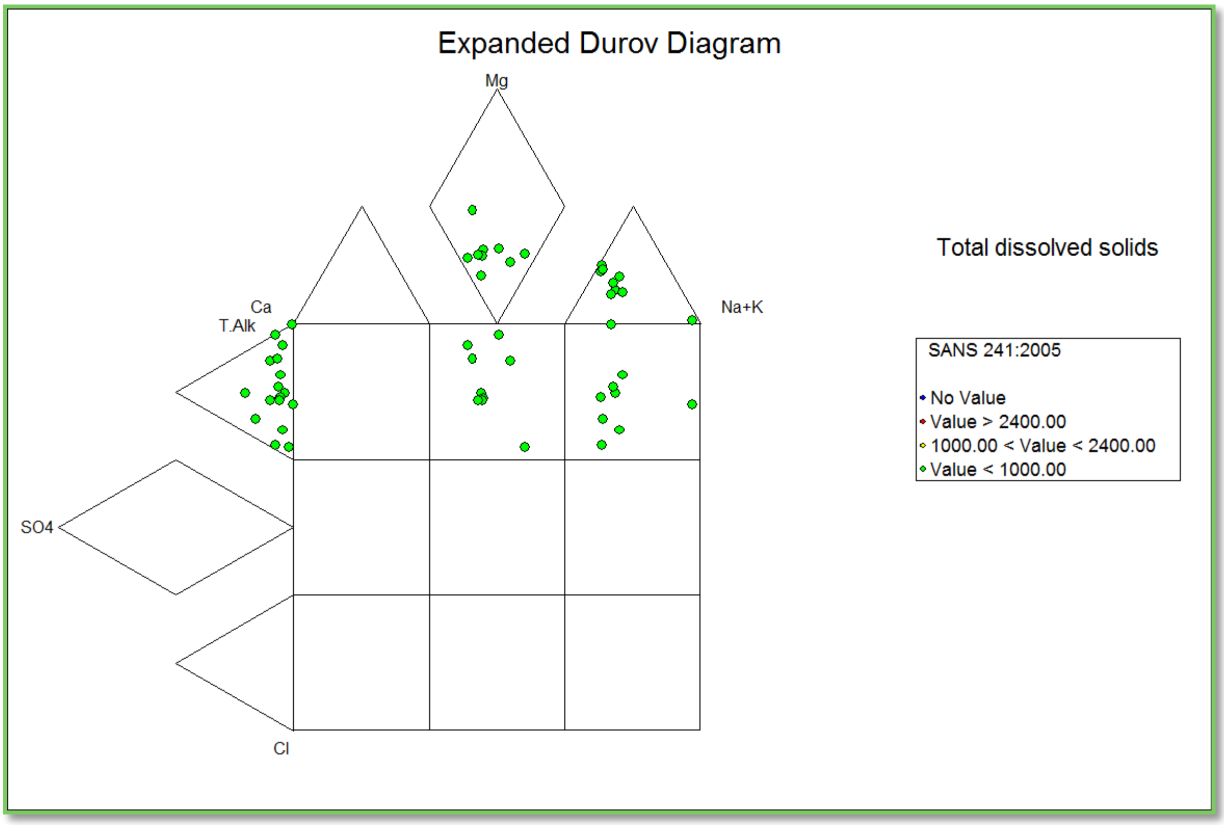


Figure 53: Expanded Durov diagram

As documented, the vulnerability is 55%. The impact of potential contamination, according to Section 2.2, is medium as there is mostly farming activities in the RU.

Final category

The final category for the RU is summarised in **Table 59**.

Table 59: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	A	Natural
Groundwater contamination	B	Good
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	**B**	**Good**

12.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 60**.

Table 60: Reserve

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
21.770	0.226	17%	102.881	5.071

13. Classification and the Reserve for RU8

13.1 Location

There are no major towns within this RU. Nlazatshe, Kwasceza, Nongoma, Swart Umfolozi and Gluckstadt are all small villages located in the RU. Quaternary catchments W22A, W22B, W22C, W22D, W22E, W22F and W22G are located within the RU, shown in **Figure 54**. The Rensburg cycad colony and Ngome Park are protected.

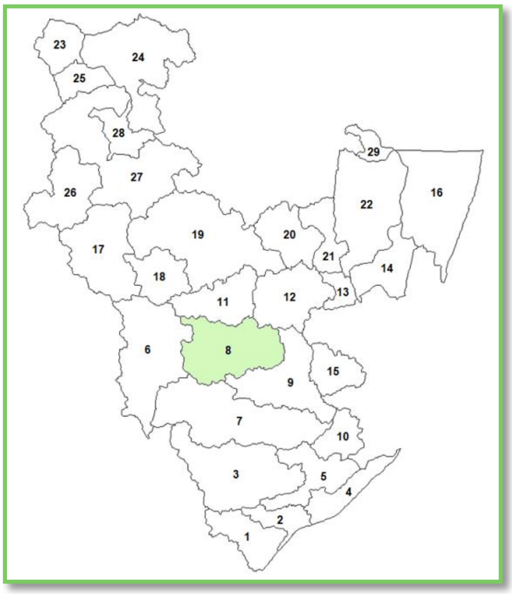


FIGURE 54: LOCATION

13.2 Climate

The rainfall is 800 to 900 mm per year in summer. Mean annual temperatures for January are around 24°C, with a mean maximum of about 30°C, while the winter mean annual July temperature is 16°C, with a mean minimum of 10°C.

13.3 Vegetation (taken from environment.gov.za)

The vegetation is a mix of scrub and savanna. The most common tree species include Umbrella Thorn Acacia tortilis, Sweet Thorn A. karroo, Red Bushwillow Combretum apiculatum, Boscia albitrunca, Euclea schimperi, Olea europaea subsp. africana, Schotia brachypetala, Euphorbia spp. and Spirostachys africana.

13.4 Demography and Land use

There are numerous agricultural activities, including forestry (**Figure 55**). There are also coal mines in the area. The total population (according to the 2001census) is 71400.

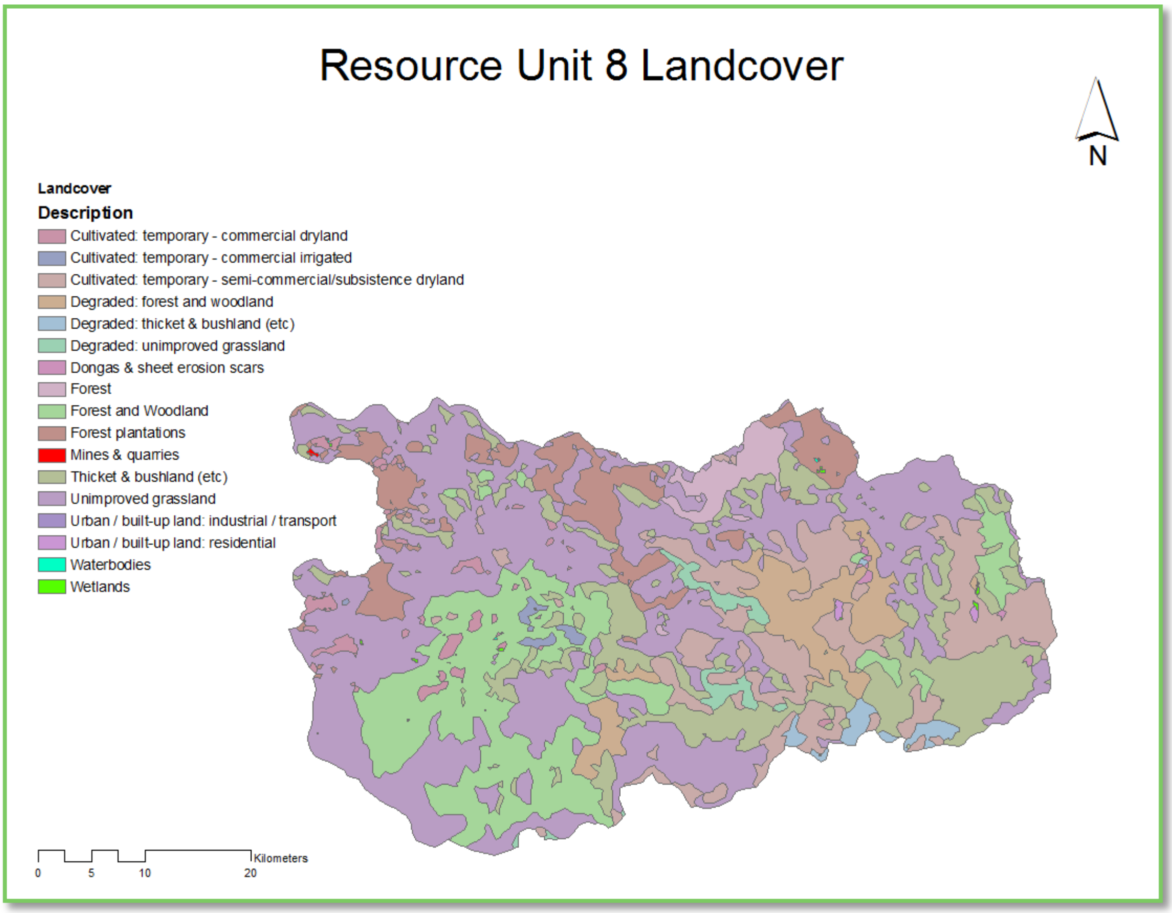


FIGURE 55: LANDCOVER

13.5 Surface water and Wetlands

The Black Umfolozi (**Photo 24**) and its tributaries run through the RU. The wetlands with are shown in **Figure 55**.

PHOTO 24: BLACK MFOLOZI RIVER

13.6 Soils (taken from environment.gov.za)

Soils are either black clays, red, structured clays or duplex soils derived from Ecca Group shale and mudstone.

13.7 Geohydrology

Groundwater levels

It is clear that the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 56**. The most probable depth to groundwater level in the RU is 7.3 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

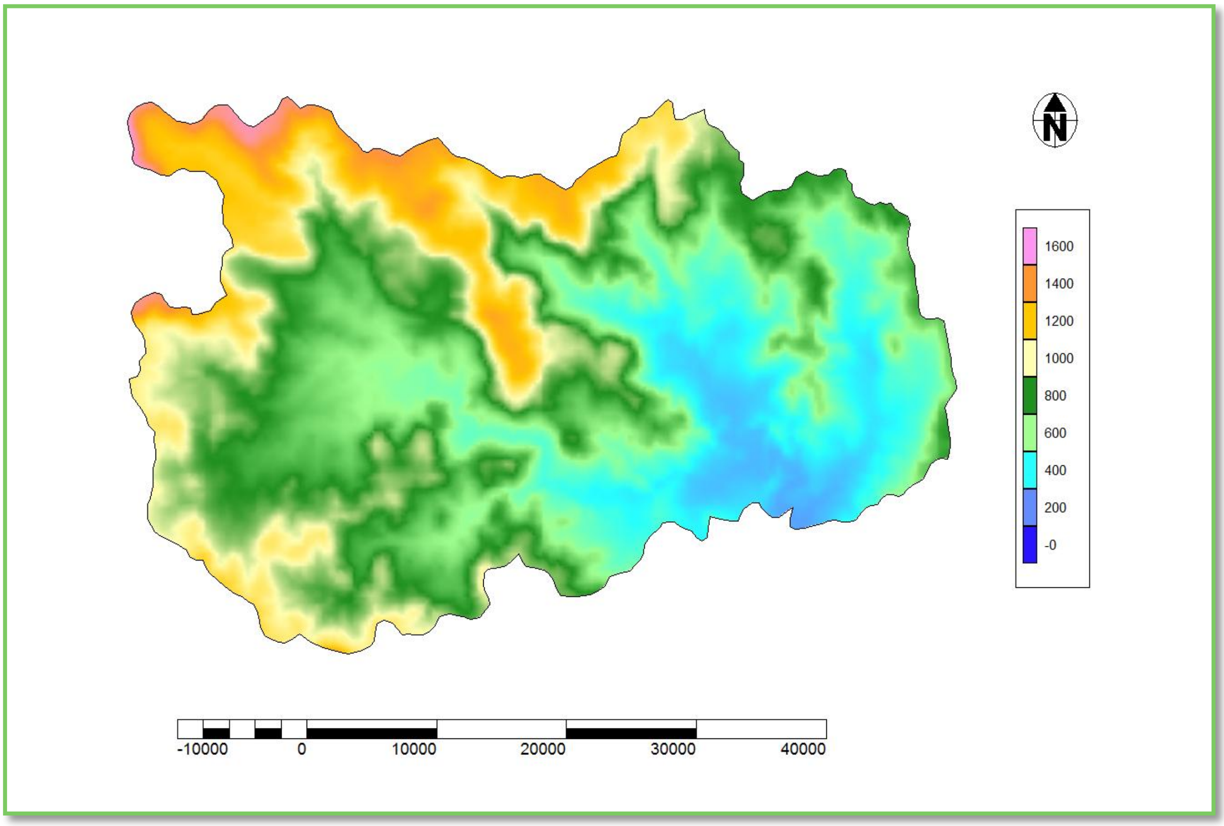


FIGURE 56: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 61**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 61: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
1655.578	63.913	93.304	103.694	6.3%	6.3%	1.7%	2.7%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 62**.

TABLE 62: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
82110	16422	0.148

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 63** is highlighted in red.

TABLE 63: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
25.689	90.265	49.965	20.310	41.854	5.997	93.304	20.630

Groundwater use

The groundwater use in the catchment is documented in **Table 64**.

TABLE 64: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
0.640	0.231	0.145	0.145	0.640	9.252	3.683	12.787

Groundwater quality

The TDS values for the RU are shown in **Figure 57**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines, with the exception of one borehole. This area should be treated as a hot spot rather than applying a poor classification to the whole resource unit. Treatment of the hot spot areas will be addressed under Resource Quality Objectives in Section 35.

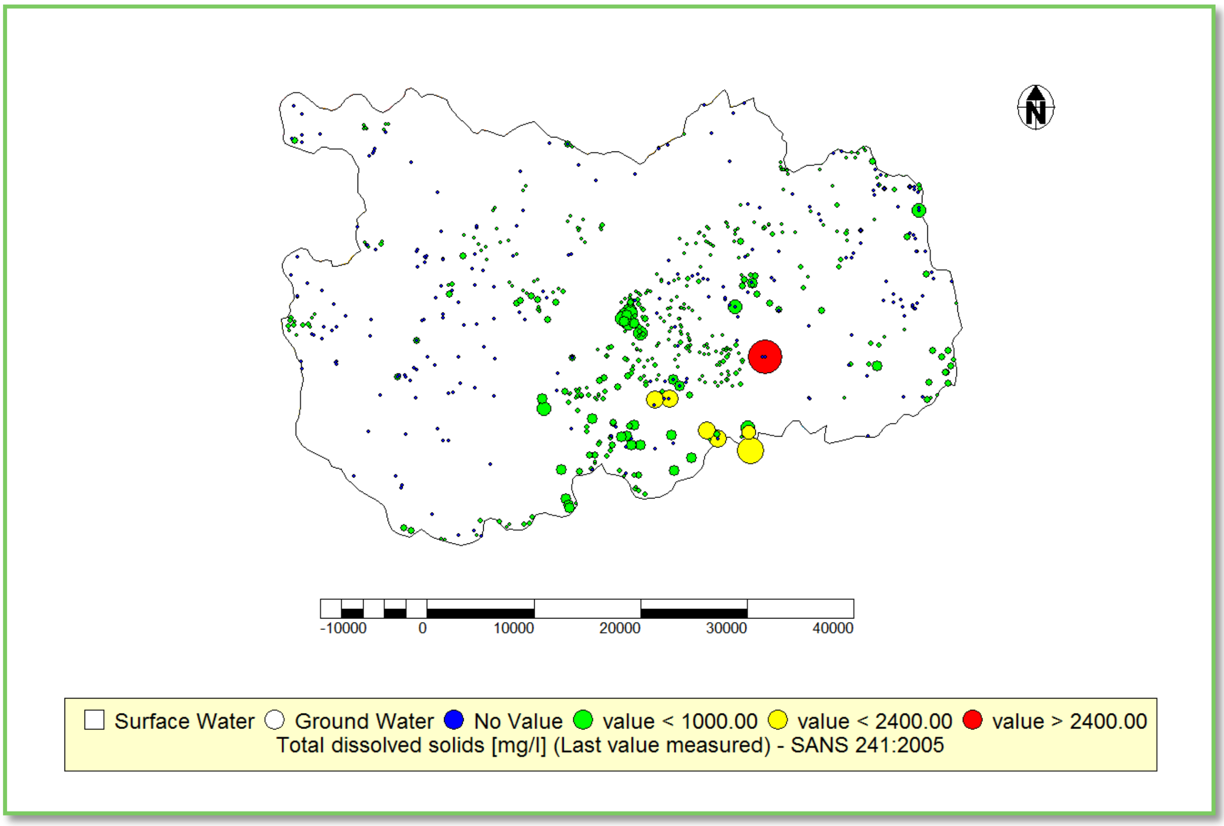


FIGURE 57: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 65**. The slope histogram is documented in Appendix D.

TABLE 65: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
7.3	6.3%	1.1	SaClLm-SaCl	Weathered/Fractured	Natal	60%

13.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 12.5%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled by assigning a normal distribution curve with a standard deviation of 1.279 Mm³/a to the groundwater use estimate, to account for the associated uncertainty. The stochastic results are shown in **Figure 58**. It is clear from the results that the stress index will vary between 9% and 16%, with a certainty of 99.43%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

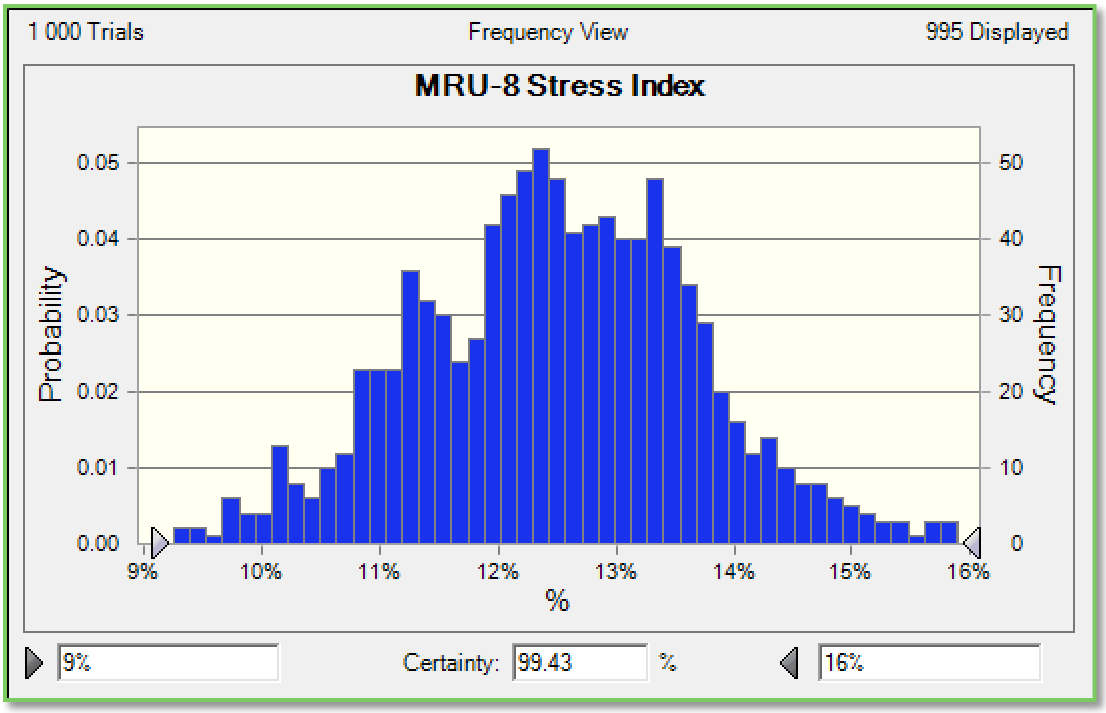


FIGURE 58: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 59**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. Most boreholes can be classified as C, however there are a few that are classified as E. Therefore the final category is set as a D.

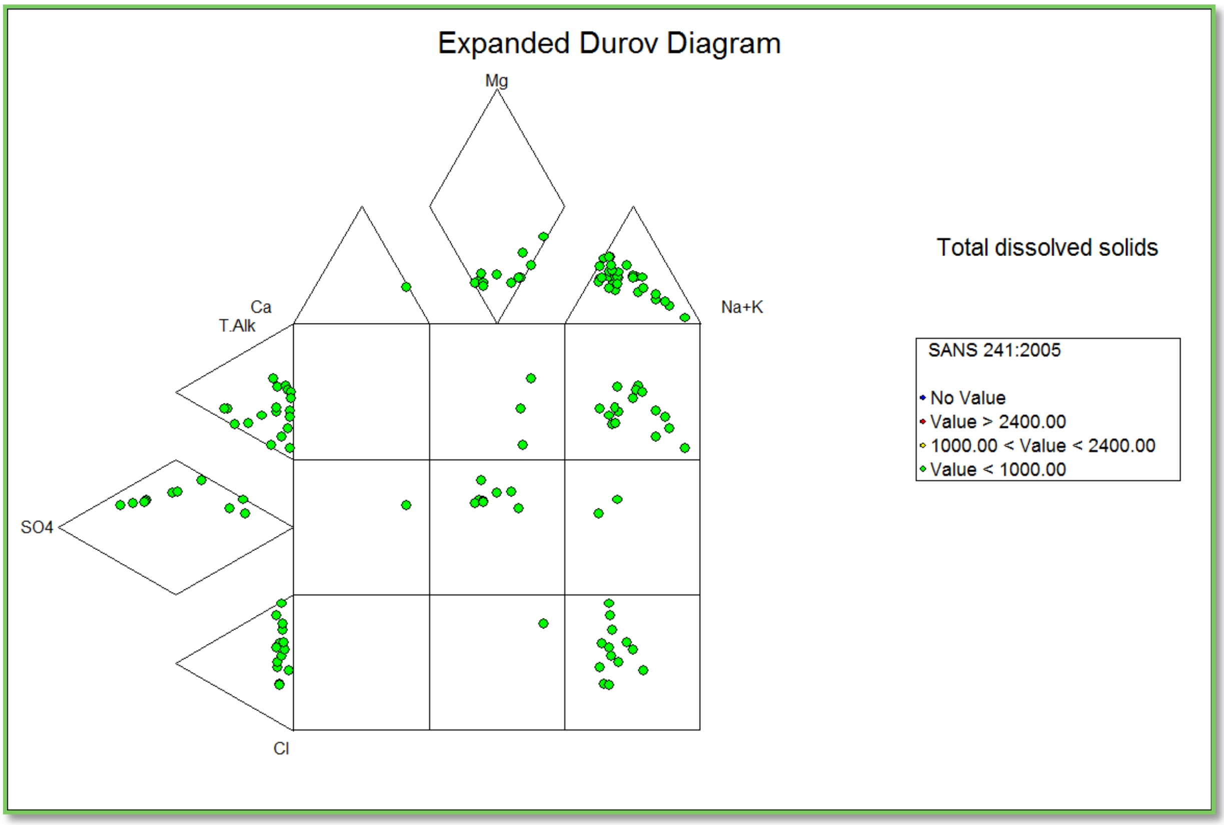


Figure 59: Expanded Durov diagram

As documented the vulnerability is 60%. The impact of potential contamination, according to Section 2.2, is medium due to forest plantations in the RU.

Final category

The final category for the RU is summarised in **Table 66**.

Table 66: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	B	Good
Groundwater contamination	D	Fair
Potential groundwater contamination (vulnerability and impact)	C	Good/Fair
FINAL	**C**	**Good/Fair**

13.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 67**.

Table 67: Reserve

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
20.630	0.148	20%	70.129	12.787

14. Classification and the Reserve for RU9

14.1 Location

The only village in the RU is Umunywana. The RU stretches over only three quaternary catchments, namely W22J, W22K and W22L. The location of the RU is shown in **Figure 60**. The Hlhuluwe-Mfolozi Game Park is protected in the area.

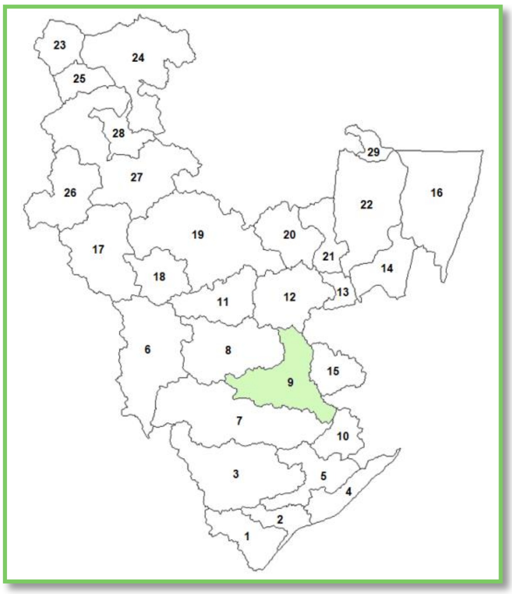


FIGURE 60: LOCATION

14.2 Climate

The rainfall is 800 to 900 mm per year in summer. Mean annual temperatures for January are around 24°C, with a mean maximum of about 30°C, while the winter mean annual July temperature is 16°C, with a mean minimum of 10°C.

14.3 Vegetation (taken from environment.gov.za)

The vegetation is a mix of scrub and savanna (**Photo 25**). The most common tree species include Umbrella Thorn Acacia tortilis, Sweet Thorn A. karroo, Red Bushwillow Combretum apiculatum, Boscia albitrunca, Euclea schimperi, Olea europaea subsp. africana, Schotia brachypetala, Euphorbia spp. and Spirostachys africana.

PHOTO 25: TYPICAL VEGETATION

(Source: www.panoramio.com)

14.4 Demography and Land use

According to the 2001 census data, there are 111150 people living in the RU. There are many farming activities, including cattle and game farming, sugarcane and subtropical fruit. Mines occur in the area, as shown in **Figure 61**.

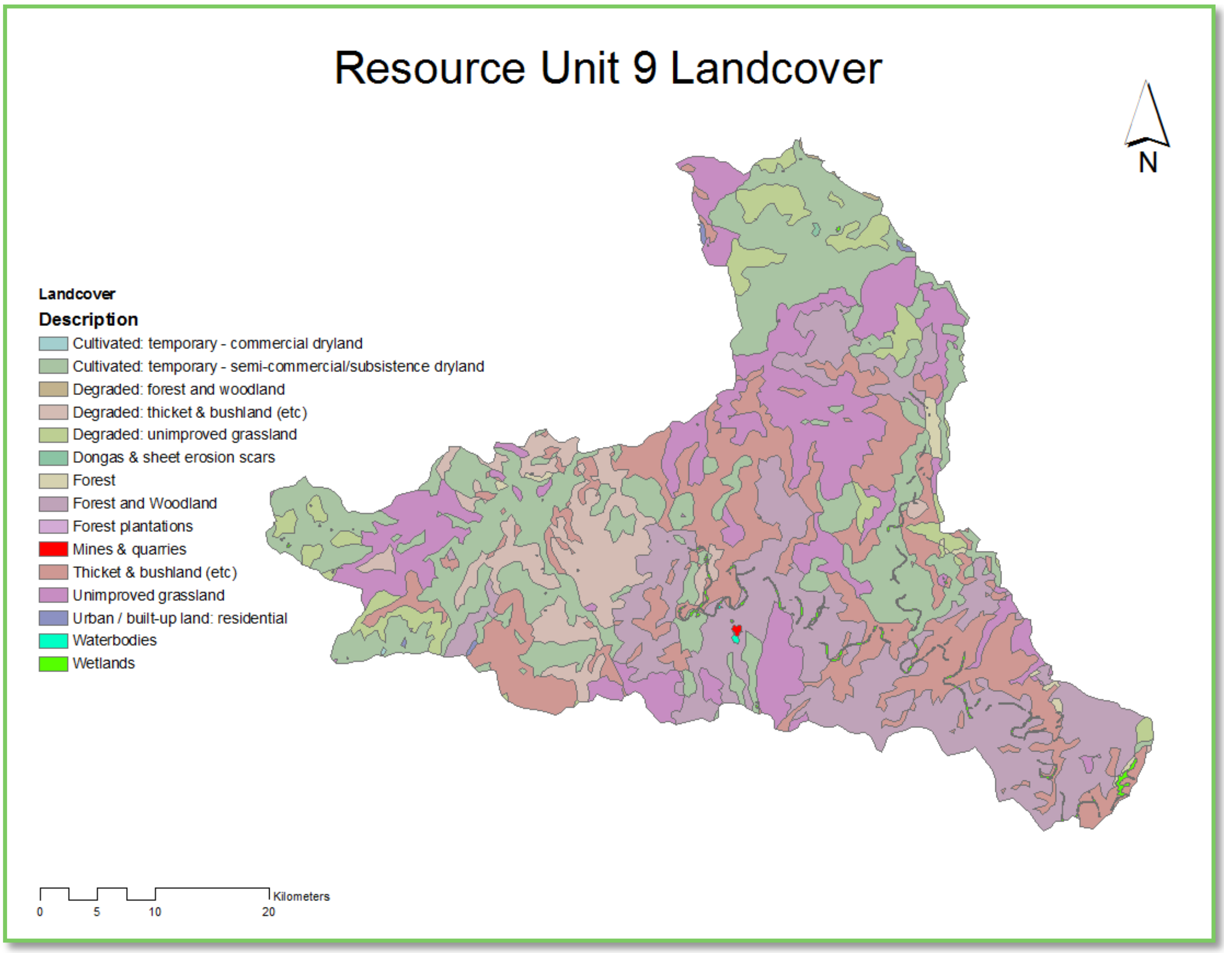


FIGURE 61: LANDCOVER

14.5 Surface water and Wetlands

The Black and White Mfolozi Rivers join to form the Mfolozi River. Wetlands in the study area are shown in **Figure 61**.

14.6 Soils (taken from environment.gov.za)

Soils are either black clays, red, structured clays or duplex soils derived from Ecca Group shale and mudstone.

14.7 Geohydrology

Groundwater levels

It is clear that the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 62**. The most probable depth to groundwater level in the RU is 7.2 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

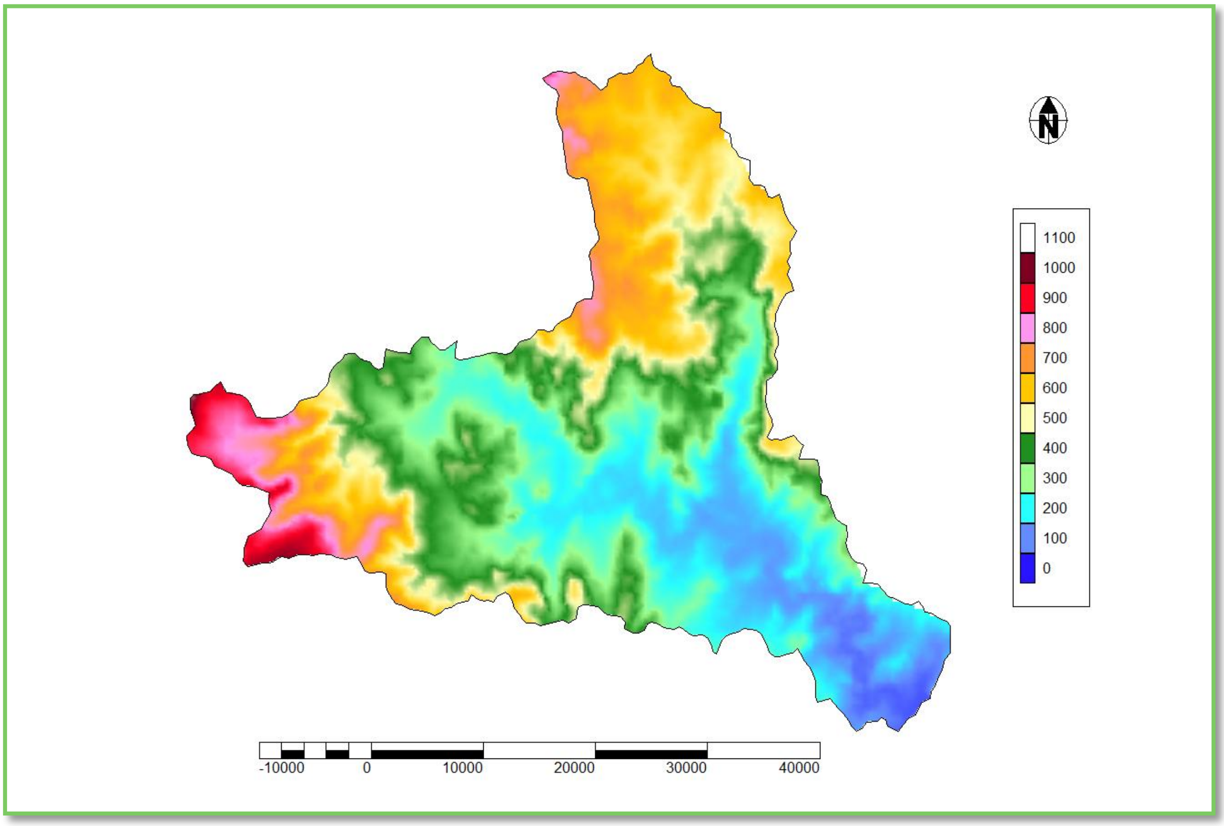


FIGURE 62: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 68**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 68: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
1226.812	36.989	57.285	64.924	5.3%	5.3%	7.0%	3.9%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 69**.

TABLE 69: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
183807	36761	0.331

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 70** is highlighted in red.

TABLE 70: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
21.433	46.003	26.997	12.743	23.038	5.662	57.285	12.790

Groundwater use

The groundwater use in the catchment is documented in **Table 71**.

TABLE 71: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
0.810	0.001	0.113	0.001	0.810	0.900	0.006	0.575

Groundwater quality

The TDS values for the RU are shown in **Figure 63**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines, with the exception of one borehole. This area should be treated as a hot spot rather than applying a poor classification to the whole resource unit. Treatment of the hot spot areas will be addressed under Resource Quality Objectives in Section 35.

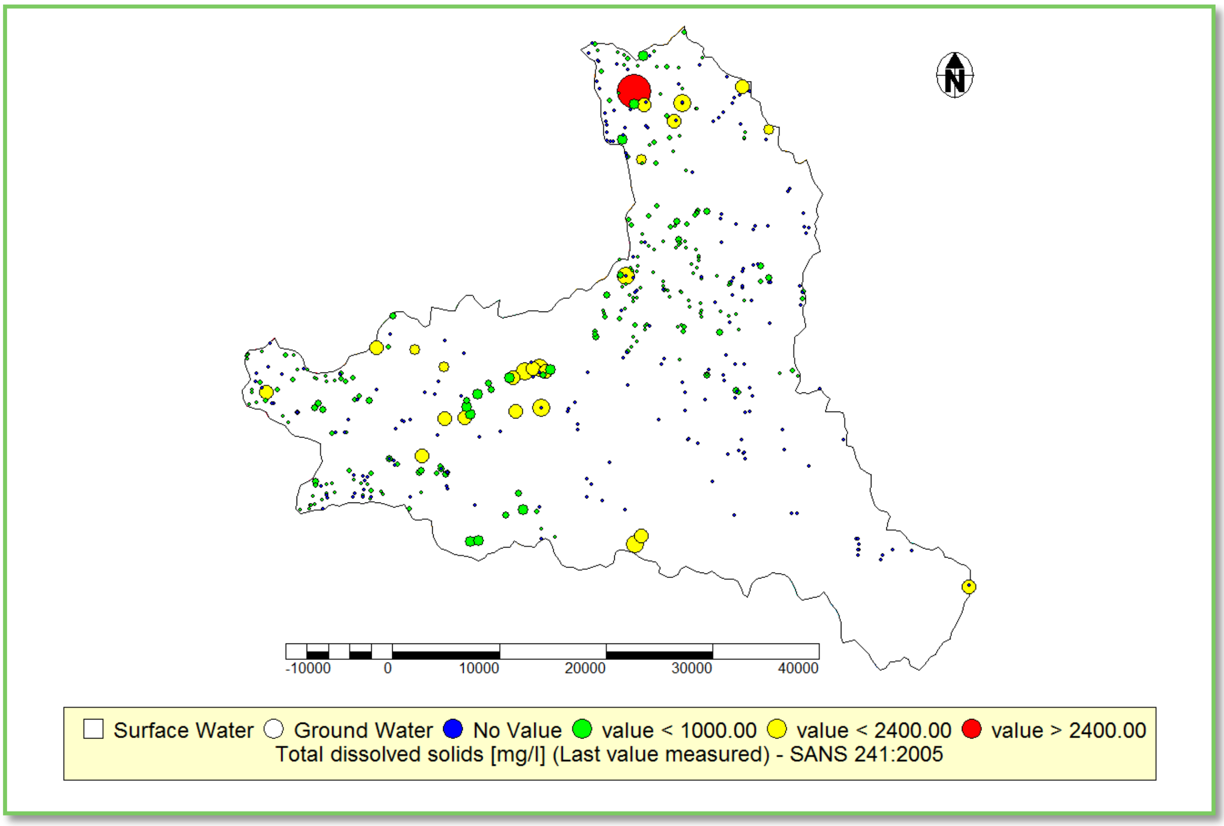


FIGURE 63: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 72**. The slope histogram is documented in Appendix D.

TABLE 72: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
7.2	5.3%	0.7	SaClLm-SaCl , SaLm-SaCl	Weathered/Fractured	Natal	59%

14.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 1.4%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled by assigning a normal distribution curve with a standard deviation of 0.058 Mm^3/a to the groundwater use estimate, to account for the associated uncertainty. The stochastic results are shown in **Figure 64**. It is clear from the results that the stress index will vary between 1% and 2%, with a certainty of 98.95%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

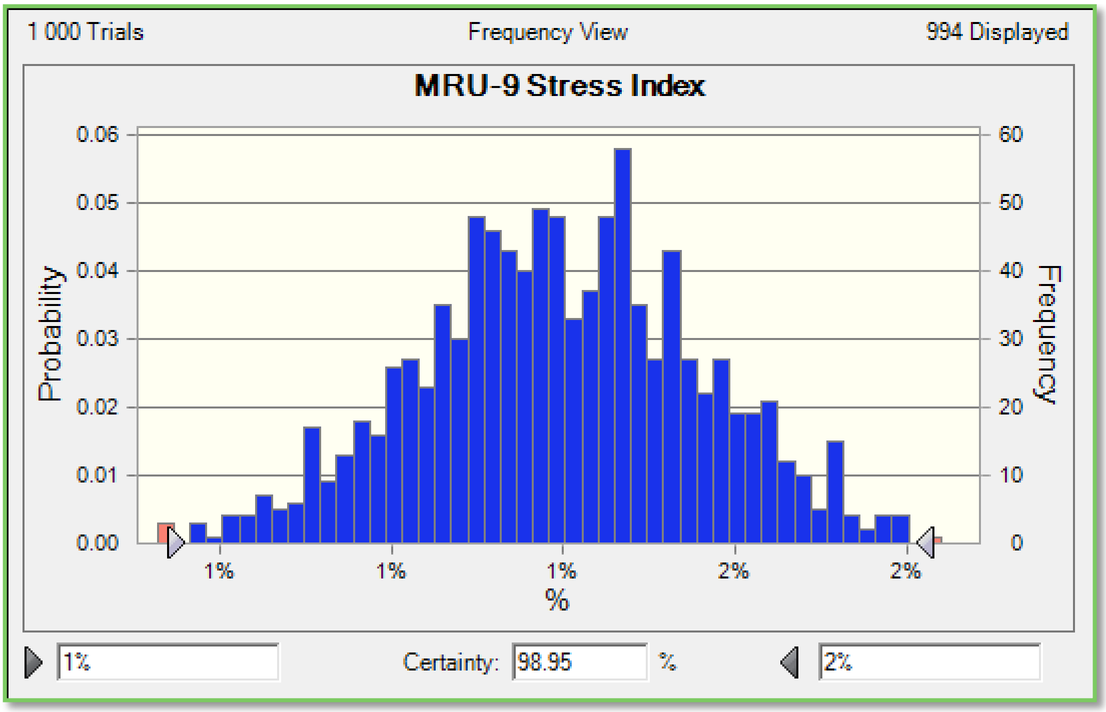


FIGURE 64: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 65**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. The majority of the boreholes can be classified as C.

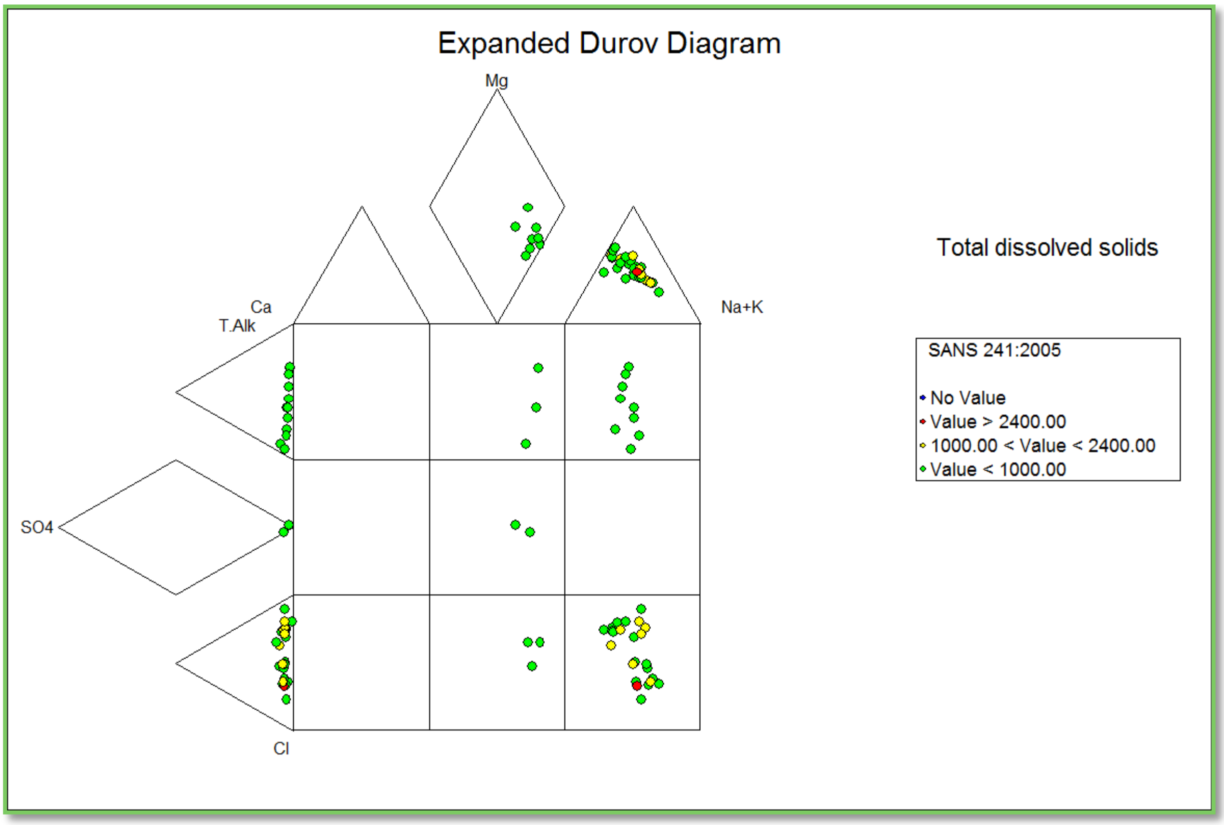


FIGURE 65: EXPANDED DUROV DIAGRAM

As documented the vulnerability is 59%. The impact of potential contamination, according to Section 2.2, is low due to limited agricultural activities.

Final category

The final category for the RU is summarised in **Table 73**.

TABLE 73: CATEGORY FOR RU

Impact	Present status category	Water resource category
Groundwater usage	A	Natural
Groundwater contamination	C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	**B**	**Good**

14.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 74**.

TABLE 74: RESERVE

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
12.790	0.331	20%	51.227	0.575

15. Classification and the Reserve for RU10

15.1 Location

This RU is situated just inland of Lake St Lucia and contains two quaternary catchments, namely W23A and W23B. There are no towns in the RU, as shown in **Figure 66**. Lake Eteza is protected in the RU.

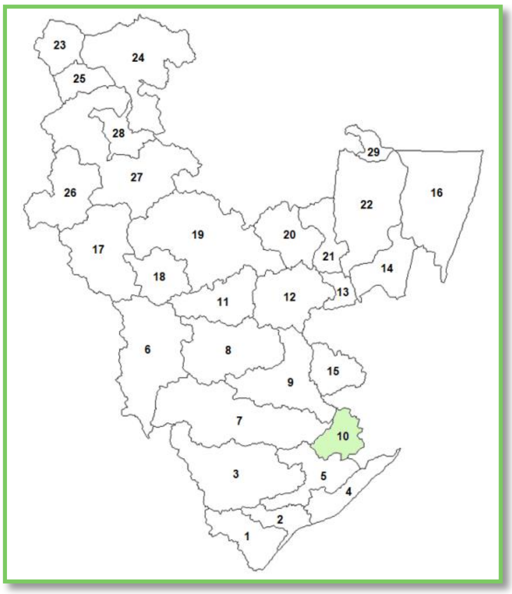


FIGURE 66: LOCATION

15.2 Climate

The climate is humid, with only one or two months of very little or no rain. The rainfall exceeds 1 000 mm per year. Mean annual temperatures for January are around 25°C, and those in July around 17°C.

15.3 Vegetation (taken from environment.gov.za)

Remaining forest patches are characterised by species such as Forest Iron Plum Drypetes gerrardii, Umzimbeet Millettia grandis, White Ironwood Vepris undulata, Protorhus longifolia, Trichilia emetica, Brachylaena spp., Celtis spp., Chaetacme aristata and Mimusops obovata. These forest patches are also characterised by a large

PHOTO 26: TYPICAL LAND USE

number of species of woody lianas. Much closer to the seashore, evergreen thicket occurs on littoral dunes. On the seaward side the canopy exhibits the typical clipped appearance of wind-pruning as a result of constant exposure to salt-laden easterly winds.

15.4 Demography and Land use

The total population, according to the 2001 census, is 45 950. The Landcover (**Figure 67**) includes agriculture, especially sugarcane and timber plantations (**Photo 26**). Fruits such as pineapples are also growing in the RU.

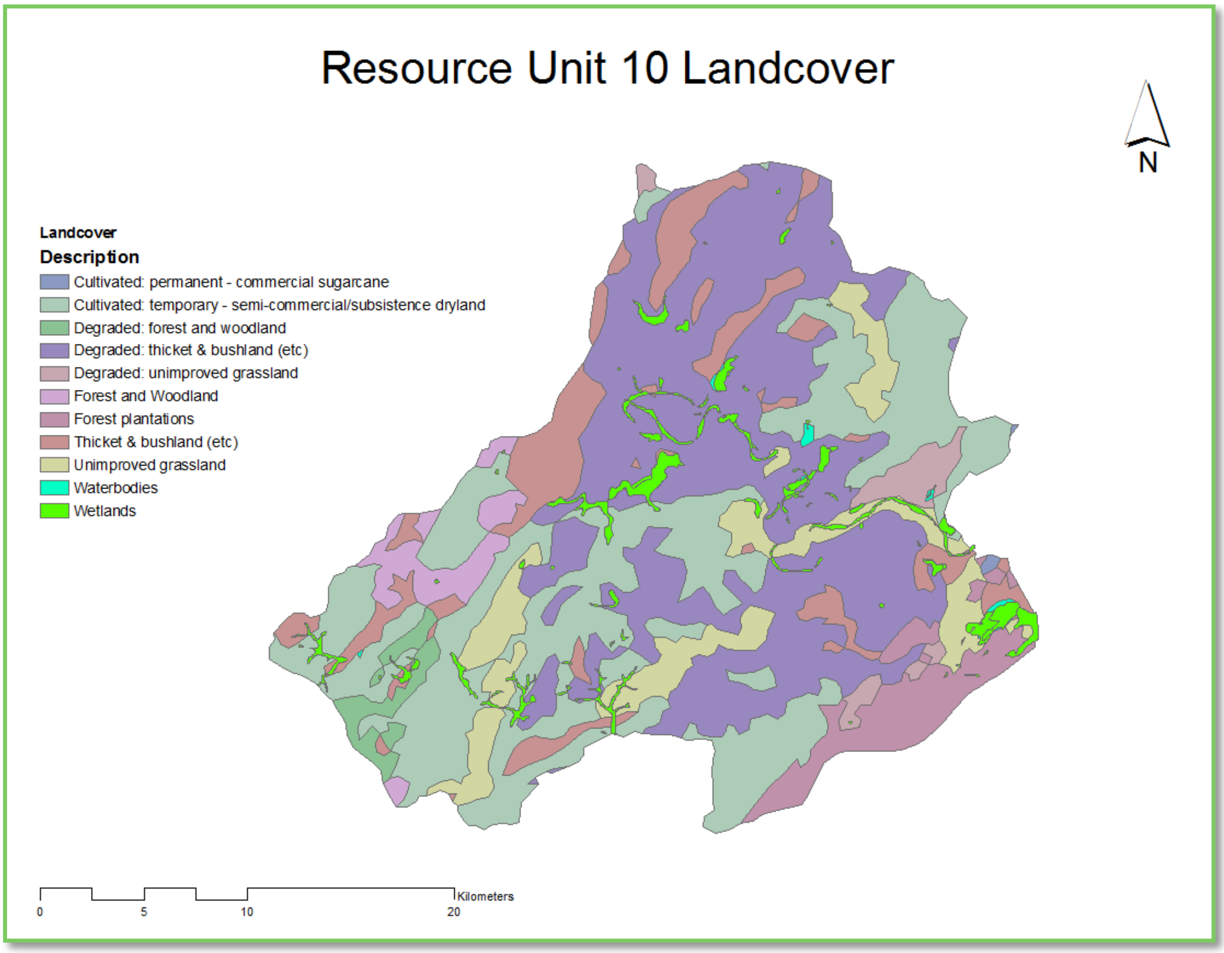


FIGURE 67: LANDCOVER

15.5 Surface water and Wetlands

The Mfolozi and Msunduzi Rivers join to flow into Lake St Lucia. The wetlands in the area are shown in **Figure 67**.

15.6 Soils (taken from environment.gov.za)

Sandy soils of Quaternary aeolian and marine origin.

15.7 Geohydrology

Groundwater levels

It is clear that the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 68**. The most probable depth to groundwater level in the RU is 6.6 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

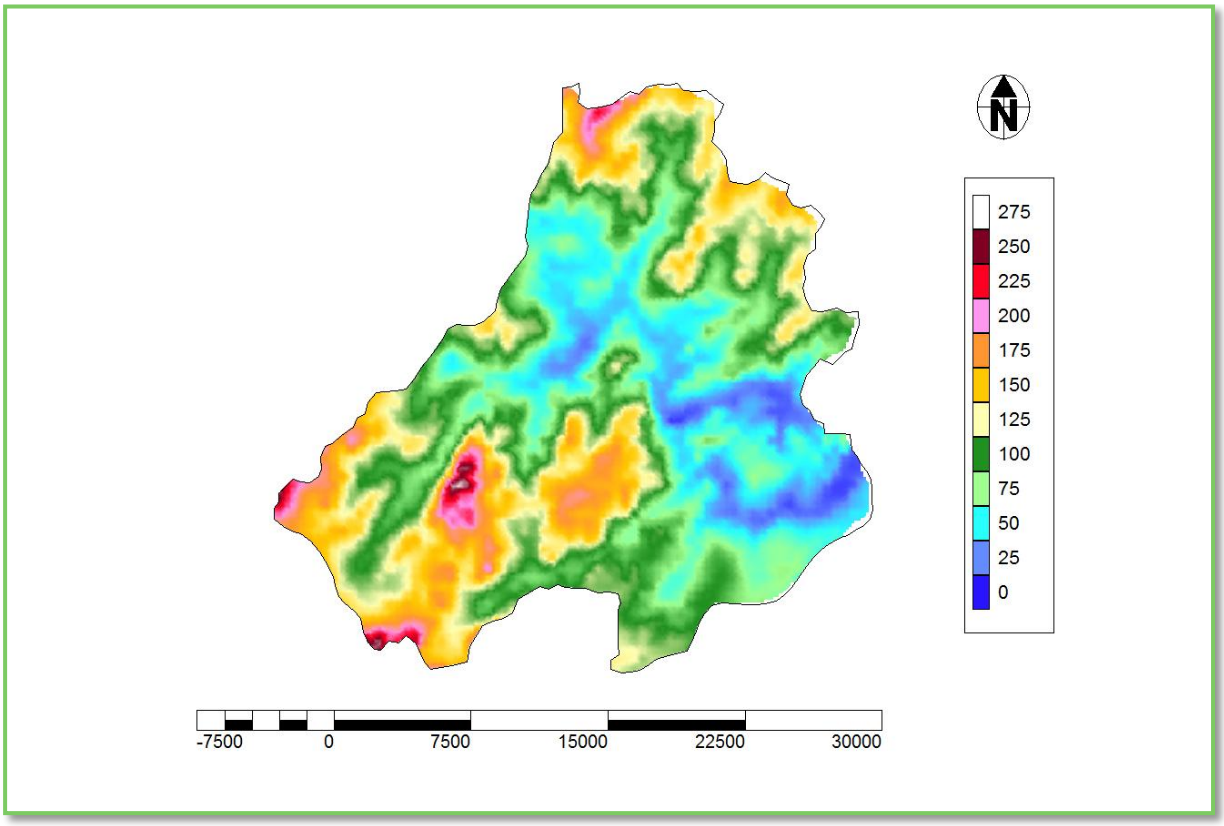


FIGURE 68: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 75**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 75: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
521.988	21.914	39.423	22.129	4.2%	4.2%	14.4%	3.5%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 76**.

TABLE 76: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
52843	10569	0.095

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 77** is highlighted in red.

TABLE 77: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
8.961	27.776	18.803	10.486	16.140	3.098	39.423	11.630

Groundwater use

The groundwater use in the catchment is documented in **Table 78**.

TABLE 78: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
0.360	0.000	0.002	0.000	0.360	1.620	0.000	1.525

Groundwater quality

The TDS values for the RU are shown in **Figure 69**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. There are numerous boreholes within the RU that exceed drinking water guidelines. These areas should be treated as hot spots rather than applying a poor classification to the whole resource unit. Treatment of the hot spot areas will be addressed under Resource Quality Objectives in Section 35.

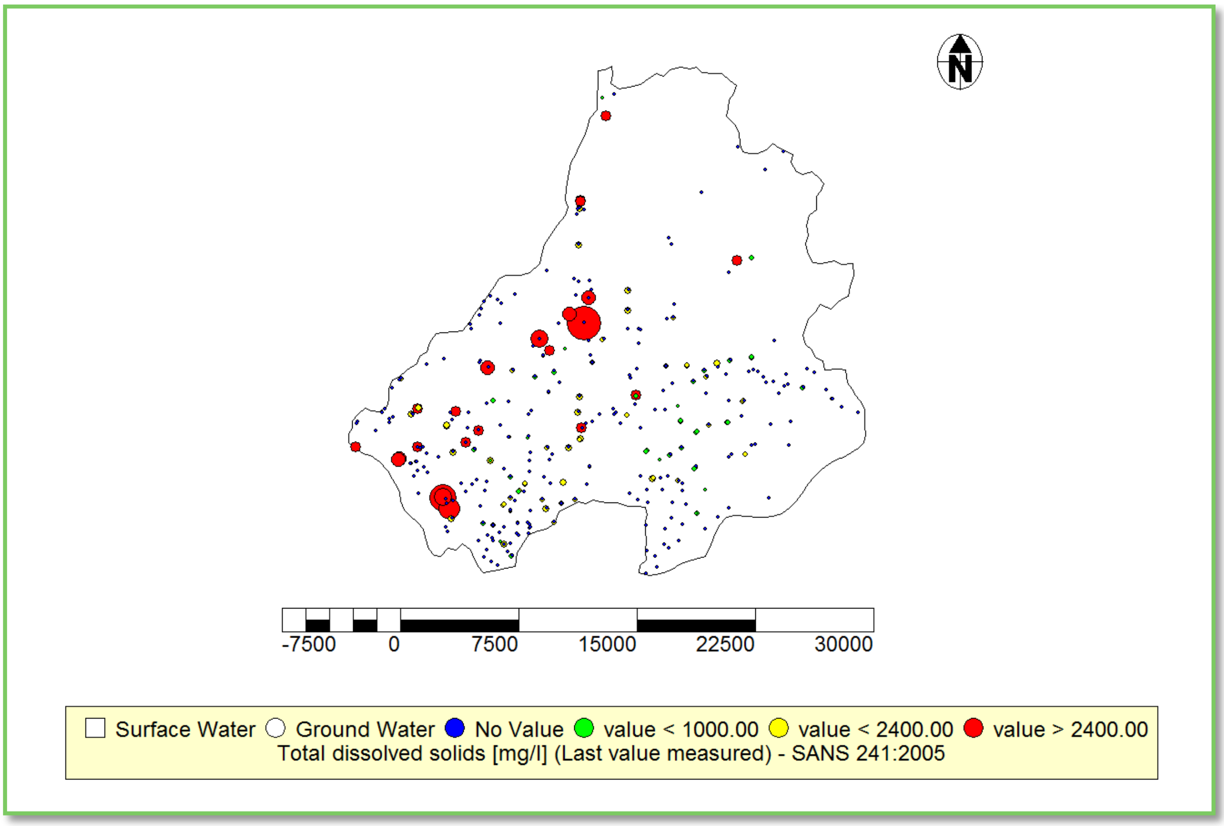


FIGURE 69: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 79**. The slope histogram is documented in Appendix D.

TABLE 79: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
6.6	4.2%	0.4	SaLm-SaCl, Sa	Weathered/Fractured	Natal	61%

15.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 7.3%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled by assigning a normal distribution curve with a standard deviation of 0.152 Mm^3/a to the groundwater use estimate, to account for the associated uncertainty. The stochastic results are shown in **Figure 70**. It is clear from the results that the stress index will vary between 5% and 9%, with a certainty of 99.22%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

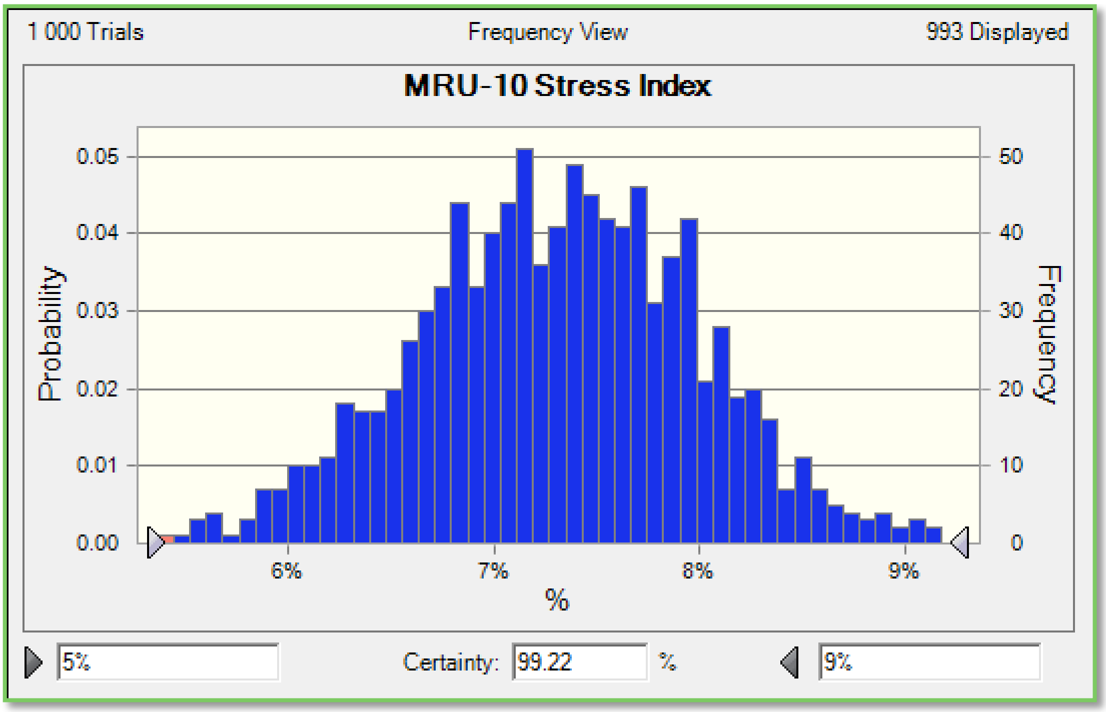


FIGURE 70: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 71**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. It is apparent that the contamination category, according to the explanation, is C.

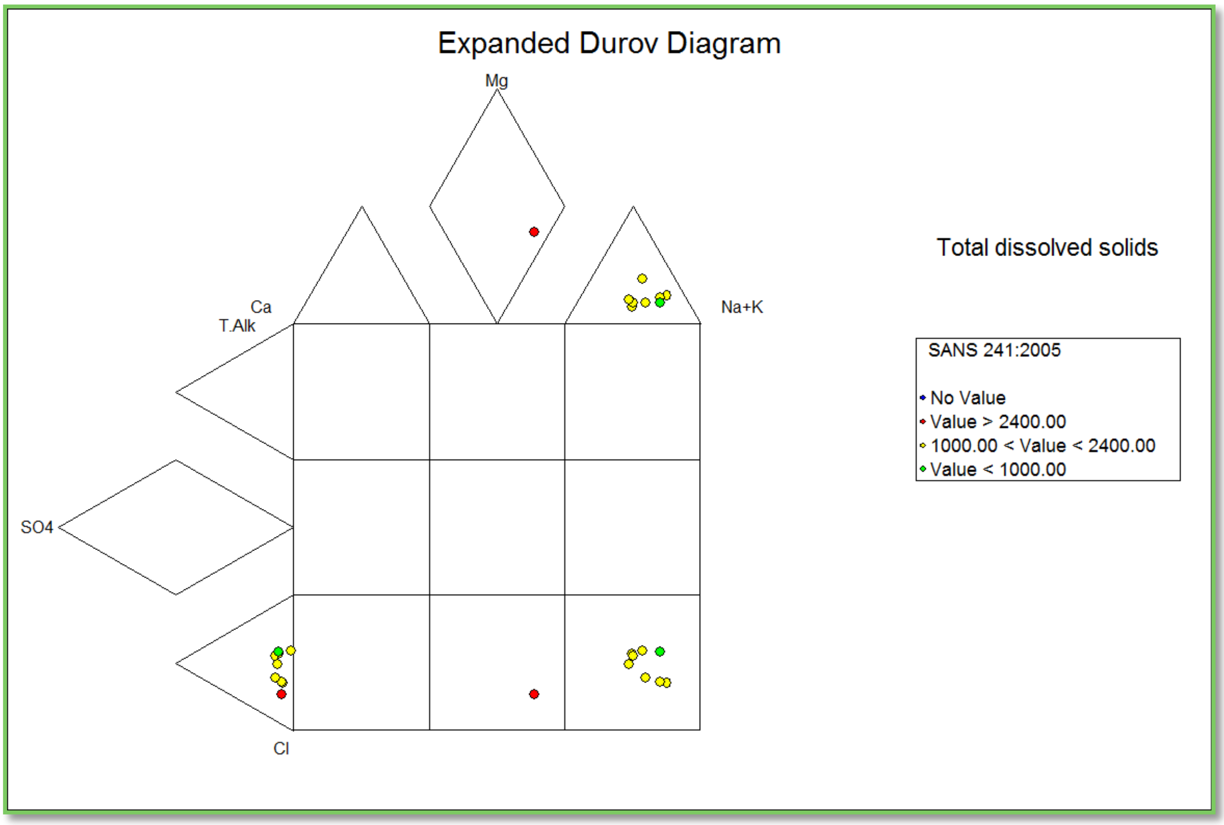


FIGURE 71: EXPANDED DUROV DIAGRAM

As documented the vulnerability is 61%. The impact of potential contamination, according to Section 2.2, is low due to limited farming and forestry.

Final category

The final category for the RU is summarised in **Table 80**.

TABLE 80: CATEGORY FOR RU

Impact	Present status category	Water resource category
Groundwater usage	B	Good
Groundwater contamination	C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	**B/C**	**Good/Fair**

15.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 81**.

TABLE 81: RESERVE

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
11.630	0.095	53%	8.879	1.525

16. Classification and the Reserve for RU11

16.1 Location

There are numerous small towns including Hlobane, Alpha and Ngome. Quaternary catchments W31A, W31B, W31C and W31D are included in the area, as shown in **Figure 72**. The Hlomo Hlomo Cycad Colony is protected in this RU.

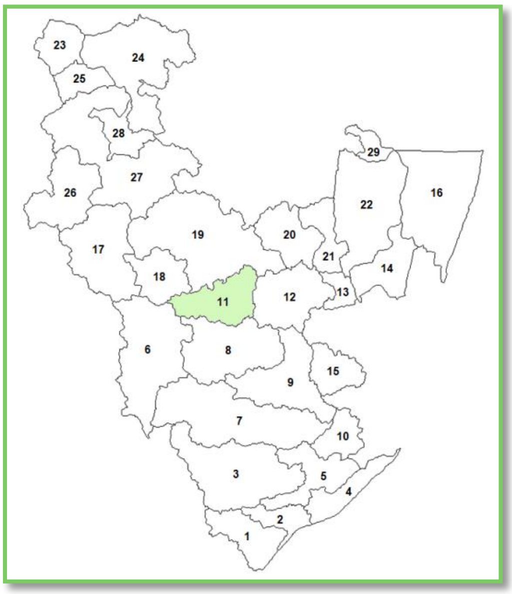


FIGURE 72: LOCATION

16.2 Climate

The rainfall is 600 to 900 mm per year, in summer. Mean temperatures for January are around 22°C, with a mean maximum of 29°C. In winter, mean annual temperatures in July are about 10°C, with a mean minimum of about 3°C.

16.3 Vegetation (taken from environment.gov.za)

The area is open savanna, with scattered trees of Paperbark Thorn *Acacia sieberiana*, Sweet Thorn *A. karroo*, Scented Thorn *A. nilotica and A. caffra*. The herbaceous layer is quite variable, with secondary grassland, dominated by patches of tall Common Thatchgrass *Hyparrhenia hirta*, and sour grassland, dominated by Hairy Tridentgrass *Tristachya leucothrix*.

16.4 Demography and Land use

The total population is 6050 (2001 census data). There are many mines (**Photo 27**) in the study area, including the Hlobane Colliery. Forestry is the main agriculture activity in the area. The Landcover is shown in **Figure 73**.

PHOTO 27: COAL MINING ACTIVITIES

16.5 Surface water and Wetlands

The headwaters of the Mkuze River occur in the study area. The wetlands are shown in **Figure 73**.

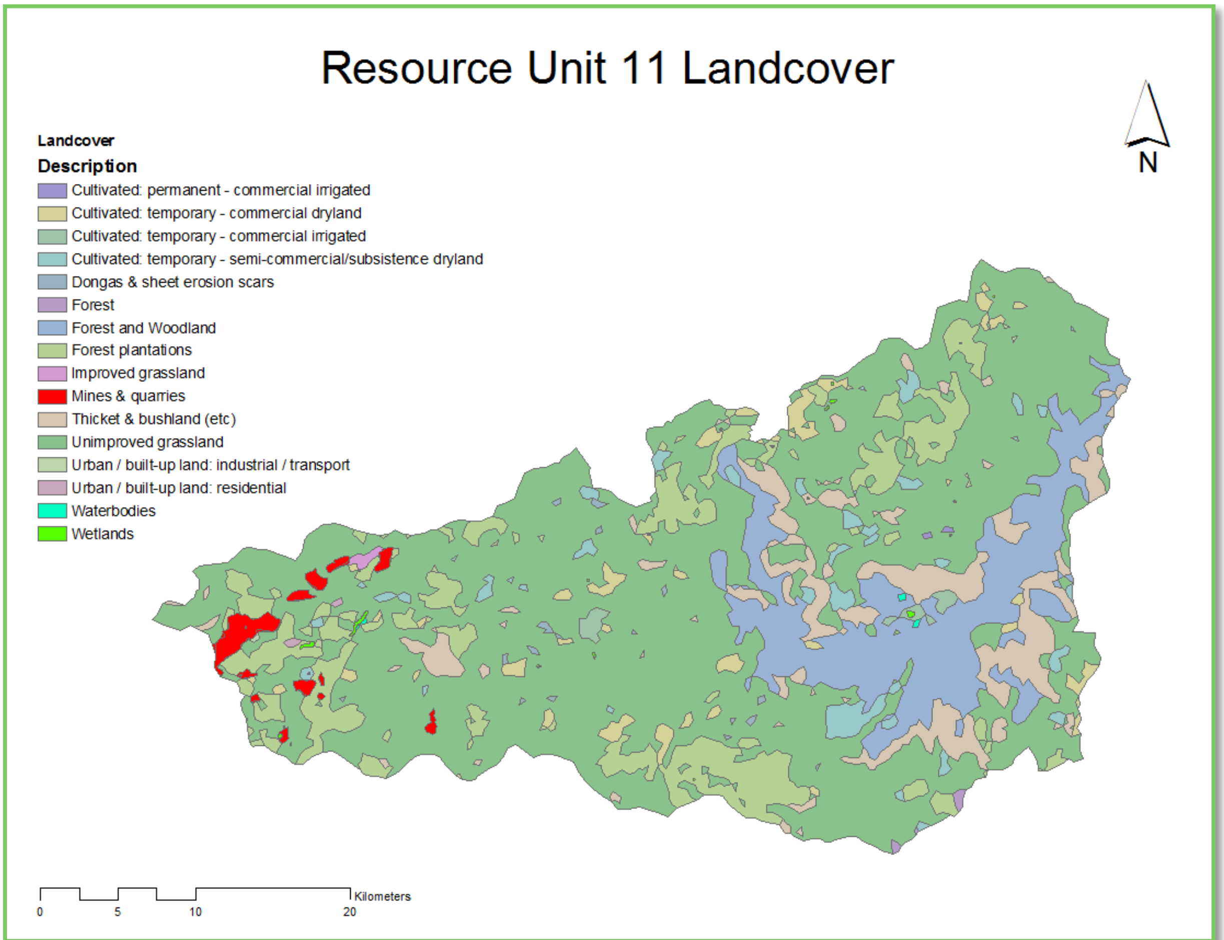


FIGURE 73: LANDCOVER

16.6 Soils (taken from environment.gov.za)

The soil is shallow, derived from shales and mudstones of the Ecca Group of the Karoo Sequence. With a rainfall of less than 450 mm, it is characterised by subsoils, which are either duplex, which renders them potentially highly erodible, or dominated by black clays.

16.7 Geohydrology

Groundwater levels

It is clear that the groundwater levels follow the topography, as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 74**. The most probable depth to groundwater level in the RU is 6.5 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

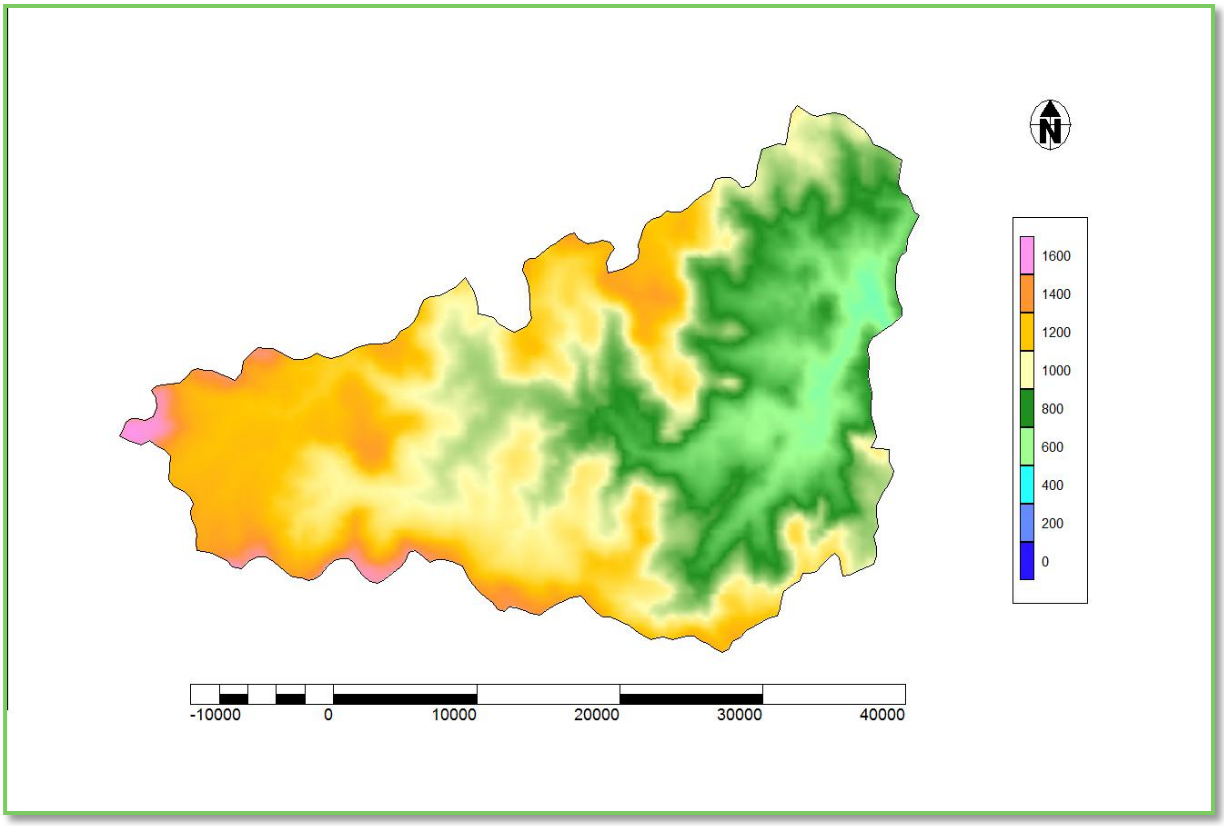


FIGURE 74: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 82**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 82: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
925.264	46.566	66.136	57.853	6.3%	6.3%	15.1%	2.6%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 83**.

TABLE 83: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
17453	3491	0.031

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 84** is highlighted in red.

TABLE 84: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
15.272	45.287	24.977	11.748	21.747	3.458	66.136	13.670

Groundwater use

The groundwater use in the catchment is documented in **Table 85**.

TABLE 85: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
0.070	0.669	0.173	0.070	0.690	1.080	1.629	2.677

Groundwater quality

The TDS values for the RU are shown in **Figure 75**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines.

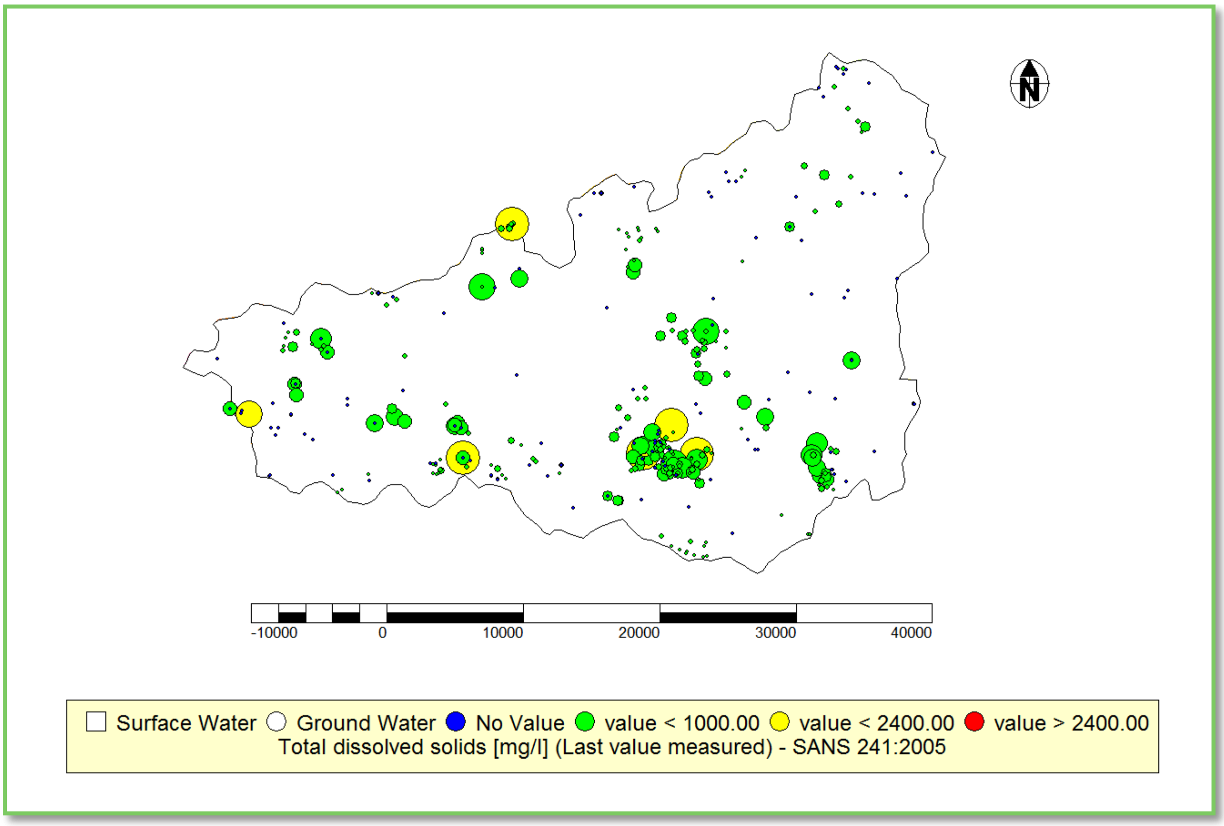


FIGURE 75: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 86**. The slope histogram is documented in Appendix D.

TABLE 86: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
6.5	6.3%	1.4	SaClLm-SaCl	Weathered/Fractured	Natal	60%

16.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 4.7%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled by assigning a normal distribution curve with a standard deviation of 0.268 Mm^3/a to the groundwater use estimate, to account for the associated uncertainty. The stochastic results are shown in **Figure 76**. It is clear from the results that the stress index will vary between 4% and 6%, with a certainty of 98.95%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

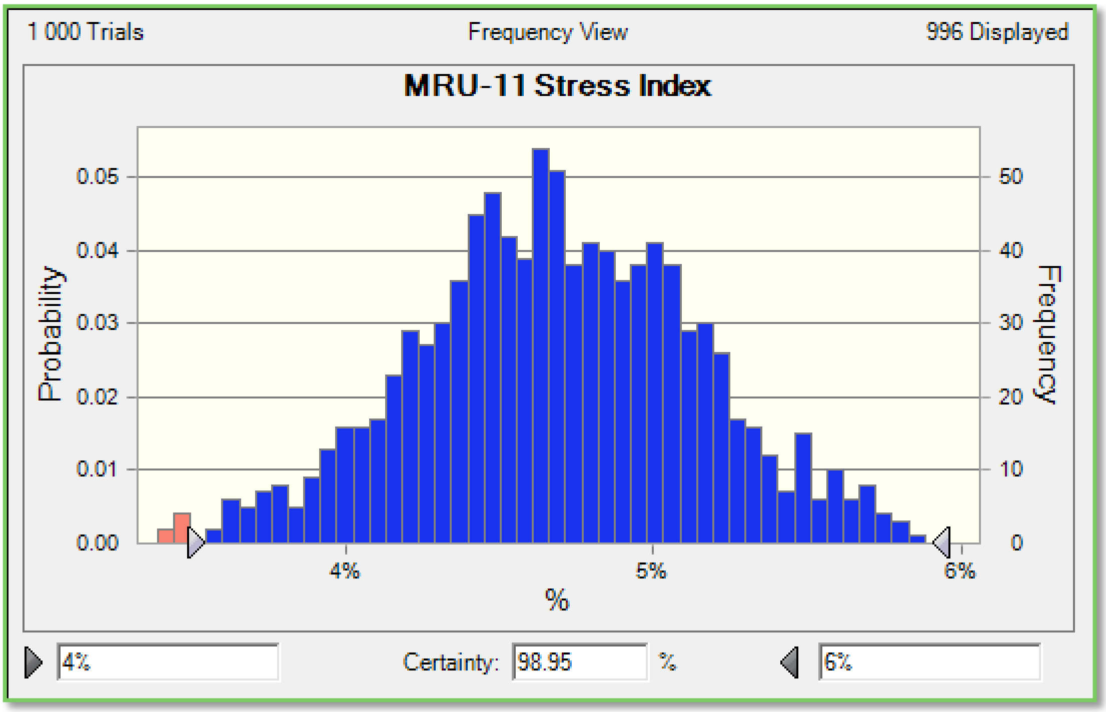


FIGURE 76: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 77**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. There is an even distribution between A and C, however there are also boreholes that fall into the E category and therefore the contamination category is C/D.

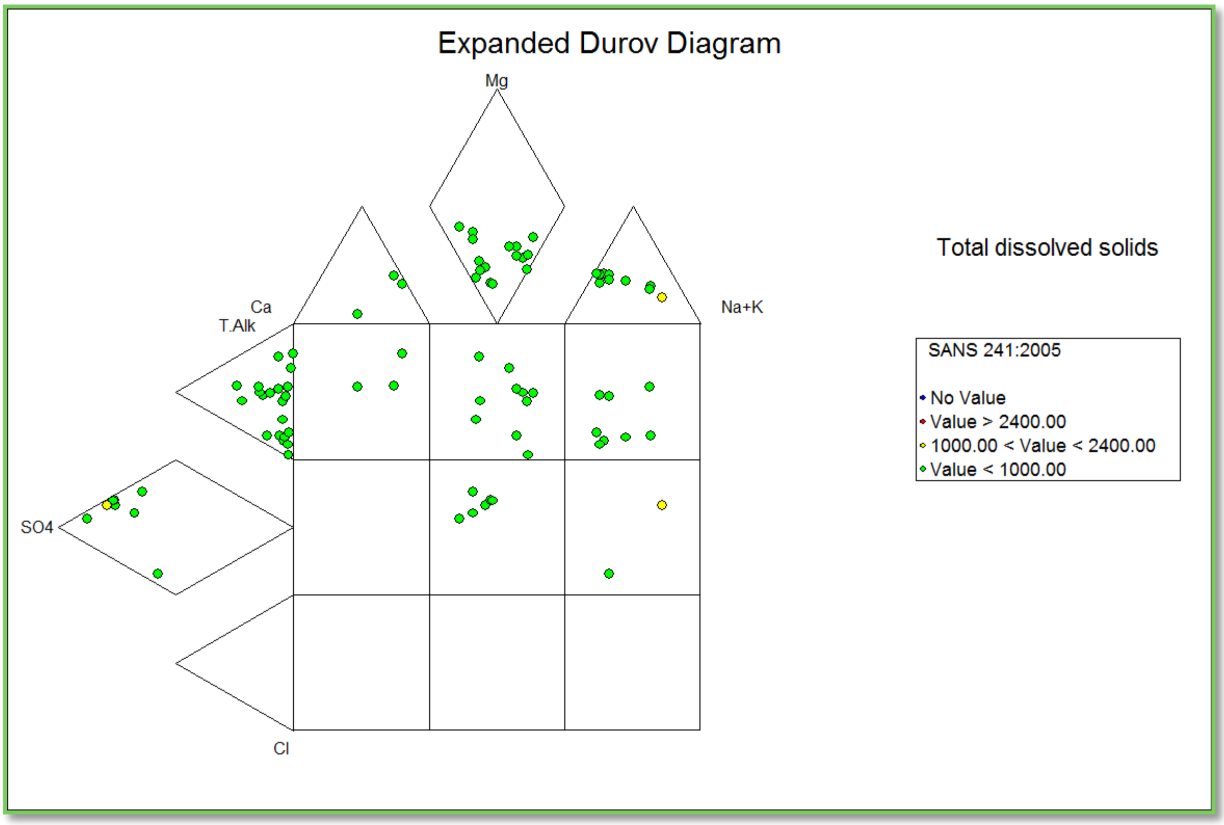


FIGURE 77: EXPANDED DUROV DIAGRAM

As documented the vulnerability is 60%. The impact of potential contamination, according to Section 2.2, is medium due to the mines, forestry and agriculture taking place in the RU.

Final category

The final category for the RU is summarised in **Table 87**.

TABLE 87: CATEGORY FOR RU

Impact	Present status category	Water resource category
Groundwater usage	B	Good
Groundwater contamination	C/D	Fair
Potential groundwater contamination (vulnerability and impact)	C	Good/Fair
FINAL	**C**	**Good/Fair**

16.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 88**.

TABLE 88: RESERVE

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
13.670	0.031	24%	41.475	2.677

17. Classification and the Reserve for RU12

17.1 Location

The quaternary catchments included in this RU (**Figure 78**) are W31E, W31F and W31G. The small towns located in the RU are Kongolana, Thokazi and Mahlangasi.

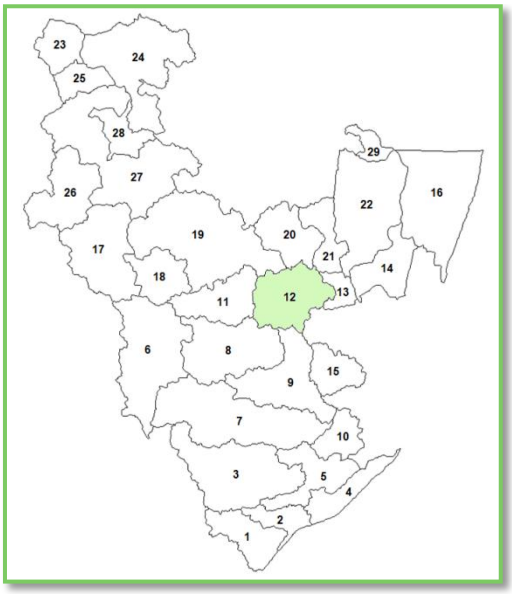


FIGURE 78: LOCATION

17.2 Climate

The rainfall is 800 to 900 mm per year in summer. Mean annual temperatures for January are around 24°C, with a mean maximum of about 30°C, while the winter mean annual July temperature is 16°C, with a mean minimum of 10°C.

17.3 Vegetation (taken from environment.gov.za)

The vegetation is a mix of scrub and savanna (**Photo 28**). The most common tree species include Umbrella Thorn Acacia tortilis, Sweet Thorn A. karroo, Red Bushwillow Combretum apiculatum, Boscia albitrunca, Euclea schimperi, Olea europaea subsp. africana, Schotia brachypetala, Euphorbia spp. and Spirostachys africana.

PHOTO 28: TYPICAL VEGETATION

17.4 Demography and Land use

The population is rural; according to the 2001 census data, the population amounts to 18 830. The land use is mainly cattle and game farming, sugarcane and subtropical fruit farming. There are some mines in the area. The Landcover is shown in **Figure 79**.

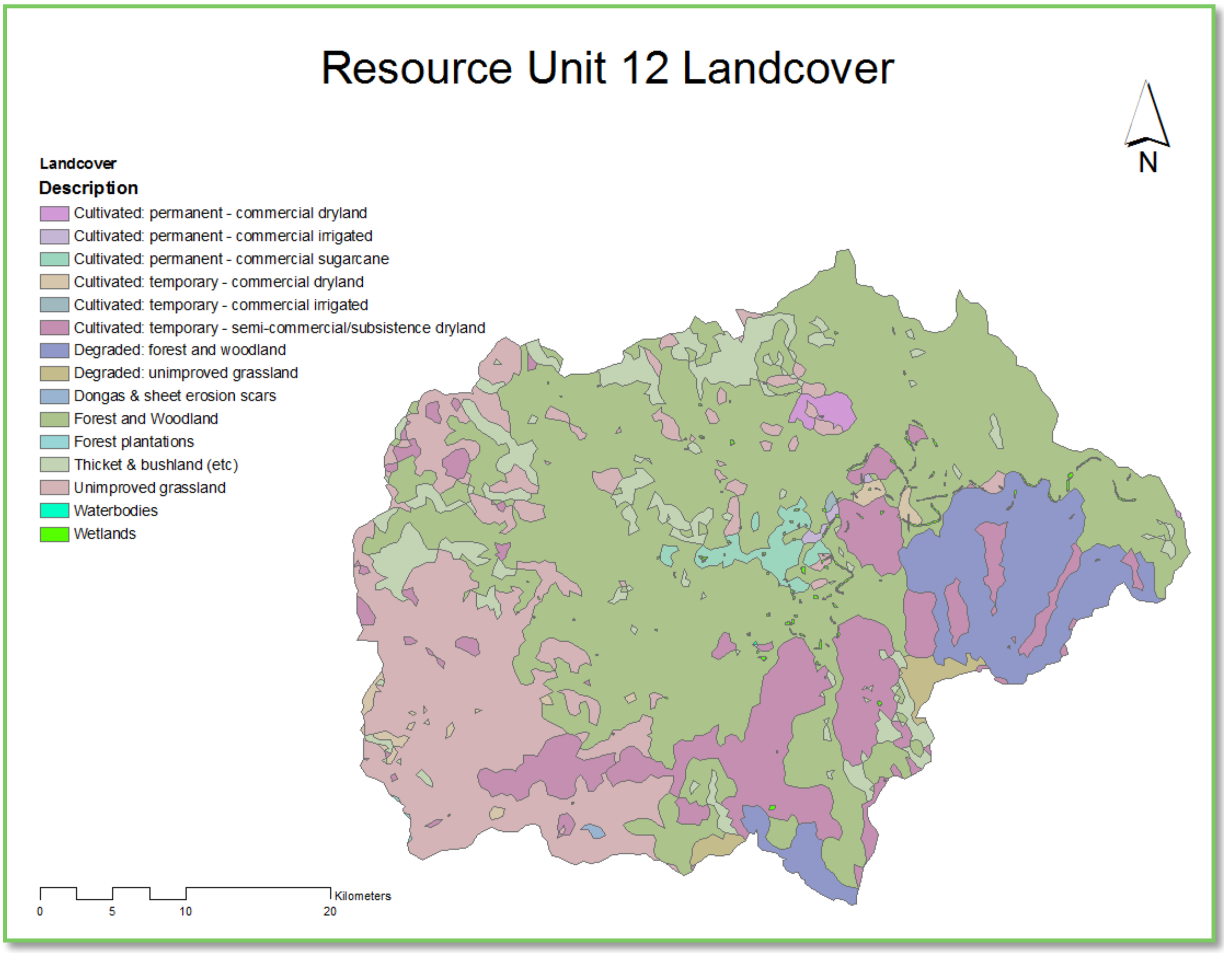


FIGURE 79: LANDCOVER

17.5 Surface water and Wetlands

The Mkuze River and its tributary the Nkunzana River flow through the RU. The wetlands are shown in **Figure 79**.

17.6 Soils (taken from environment.gov.za)

Soils are either black clays, red, structured clays or duplex soils derived from Ecca Group shale and mudstone.

17.7 Geohydrology

Groundwater levels

It is clear that the groundwater levels follow the topography, as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 80**. The most probable depth to groundwater level in the RU is 6.1 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

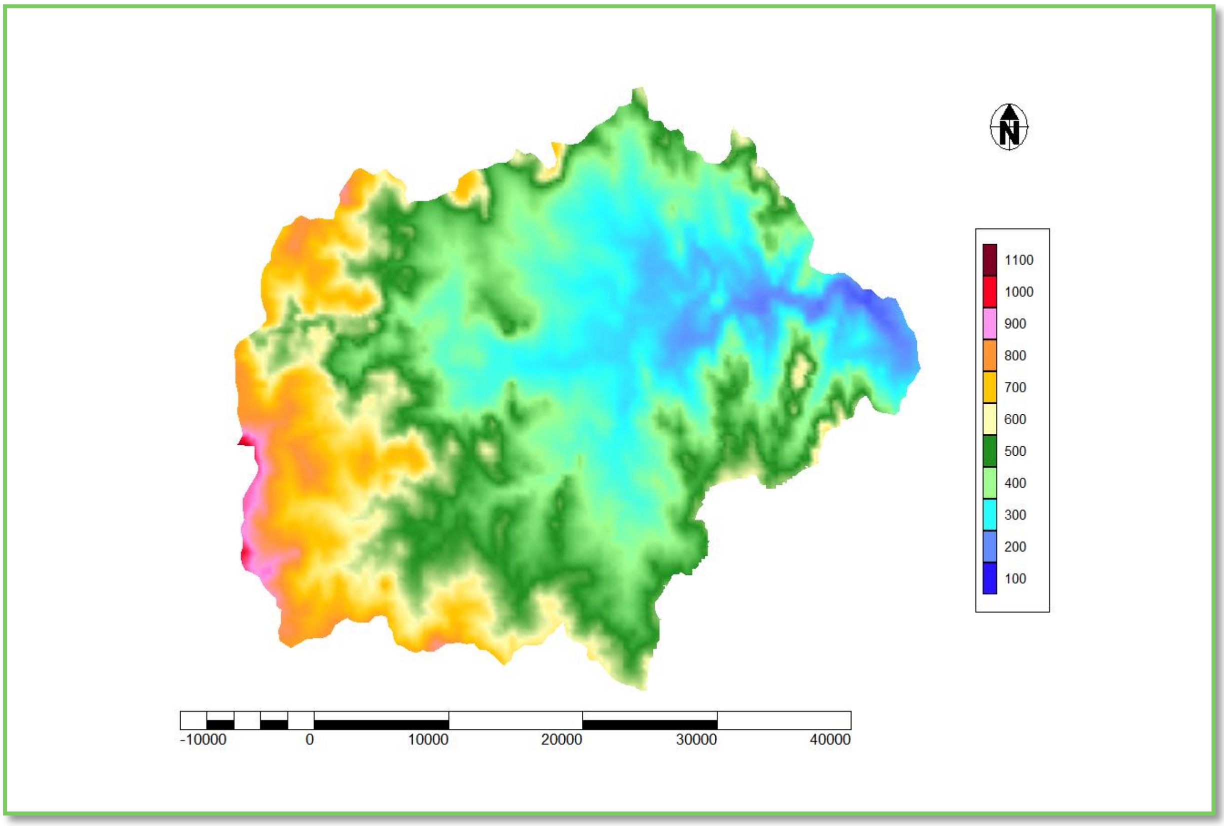


FIGURE 80: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 89**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 89: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
976.679	28.746	52.552	51.131	5.2%	5.2%	6.0%	2.7%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 90**.

TABLE 90: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
21655	4331	0.039

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 91** is highlighted in red.

TABLE 91: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
17.107	12.095	6.810	2.254	5.413	1.125	52.552	3.300

Groundwater use

The groundwater use in the catchment is documented in **Table 92**.

TABLE 92: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
1.880	0.007	0.003	0.003	1.880	5.400	0.039	5.400

Groundwater quality

The TDS values for the RU are shown in **Figure 81**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines.

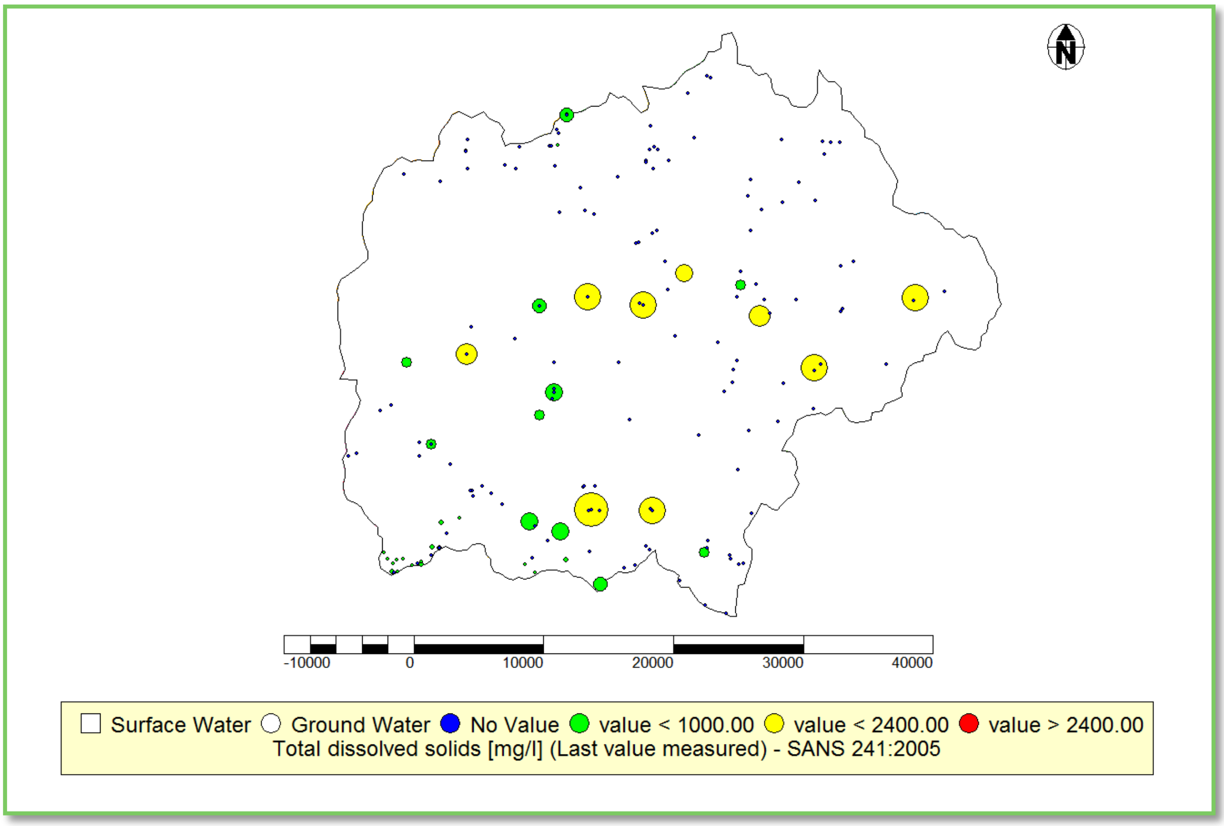


FIGURE 81: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 93**. The slope histogram is documented in Appendix D.

TABLE 93: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
6.1	5.2%	0.8	SaClLm-SaCl , SaLm-SaCl , LmSa-SaLm	Weathered/Fractured	Natal	60%

17.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 10.6%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled by assigning a normal distribution curve with a standard deviation of 0.540 Mm^3/a to the groundwater use estimate, to account for the associated uncertainty. The stochastic results are shown in **Figure 82**. It is clear from the results that the stress index will vary between 8% and 14%, with a certainty of 99.44%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

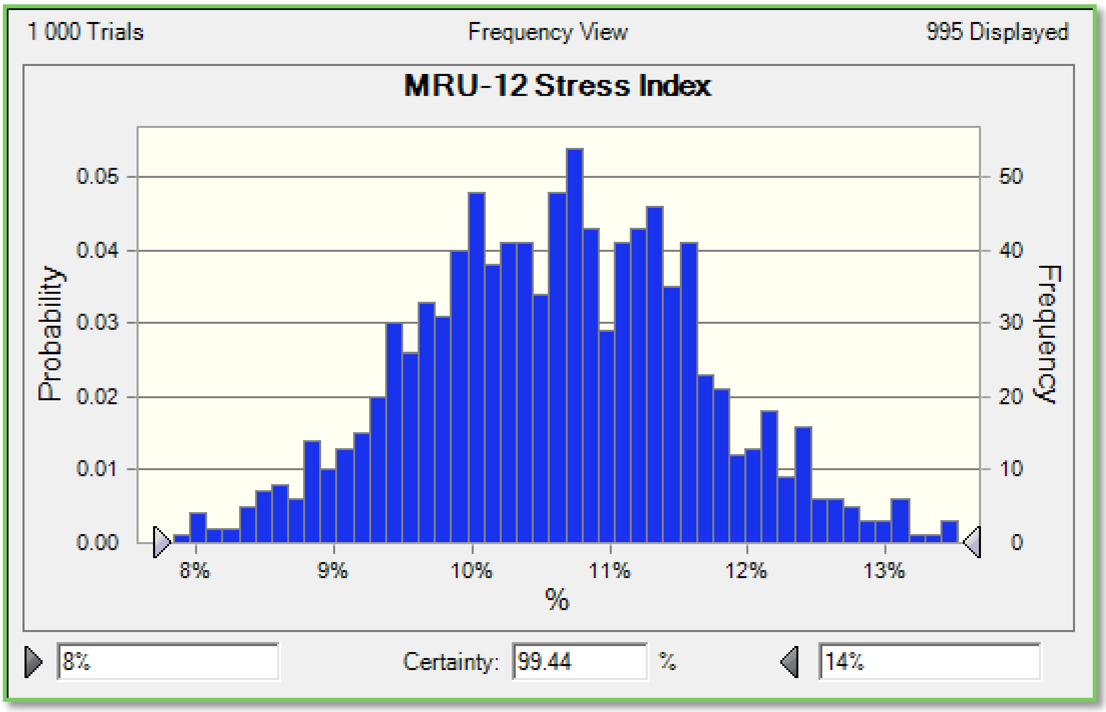


FIGURE 82: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 83**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. It is apparent that the contamination category, according to the explanation, is C.

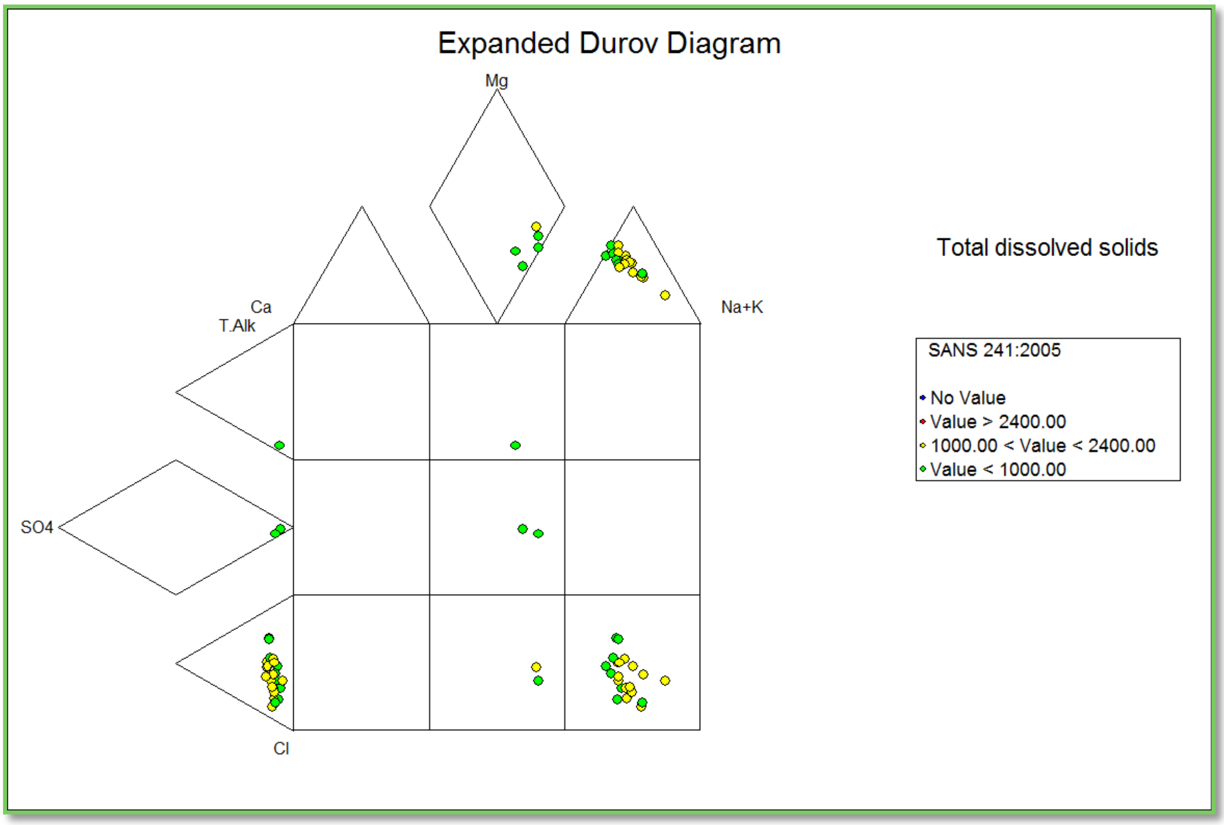


FIGURE 83: EXPANDED DUROV DIAGRAM

As documented the vulnerability is 60%. The impact of potential contamination, according to Section 2.2, is low due to the protected areas in the RU.

Final category

The final category for the RU is summarised in **Table 94**.

TABLE 94: CATEGORY FOR RU

Impact	Present status category	Water resource category
Groundwater usage	B	Good
Groundwater contamination	C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	**B**	**Good**

17.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 95**.

TABLE 95: RESERVE

Reserve			Allocation	
Baseflow Mm^3/a	BHN Mm^3/a	Reserve % Recharge	Allocation Mm^3/a	Current Use Mm^3/a
3.300	0.039	7%	42.391	5.400

18. Classification and the Reserve for RU13

18.1 Location

This RU only has one quaternary catchment, namely W31H. The town of Mkuze is situated in the RU. The location is shown in **Figure 84**. The Lebombo Mountains are protected in this RU.

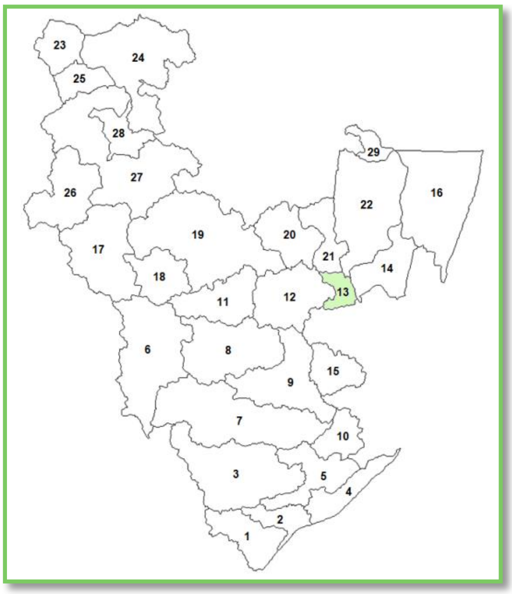


FIGURE 84: LOCATION

18.2 Climate

The rainfall is 800 to 900 mm per year in summer. Mean annual temperatures for January are around 24°C, with a mean maximum of about 30°C, while the winter mean annual July temperature is 16°C, with a mean minimum of 10°C.

18.3 Vegetation (taken from environment.gov.za)

The vegetation is a mix of scrub and savanna. The most common tree species include Umbrella Thorn Acacia tortilis, Sweet Thorn A. karroo, Red Bushwillow Combretum apiculatum, Boscia albitrunca, Euclea schimperi, Olea europaea subsp. africana, Schotia brachypetala, Euphorbia spp. and Spirostachys africana.

18.4 Demography and Land use

The major land uses are cattle and game farming, sugarcane and subtropical fruit. The total population, according to the 2001 census data, is 340. **Figure 85** shows the Landcover.

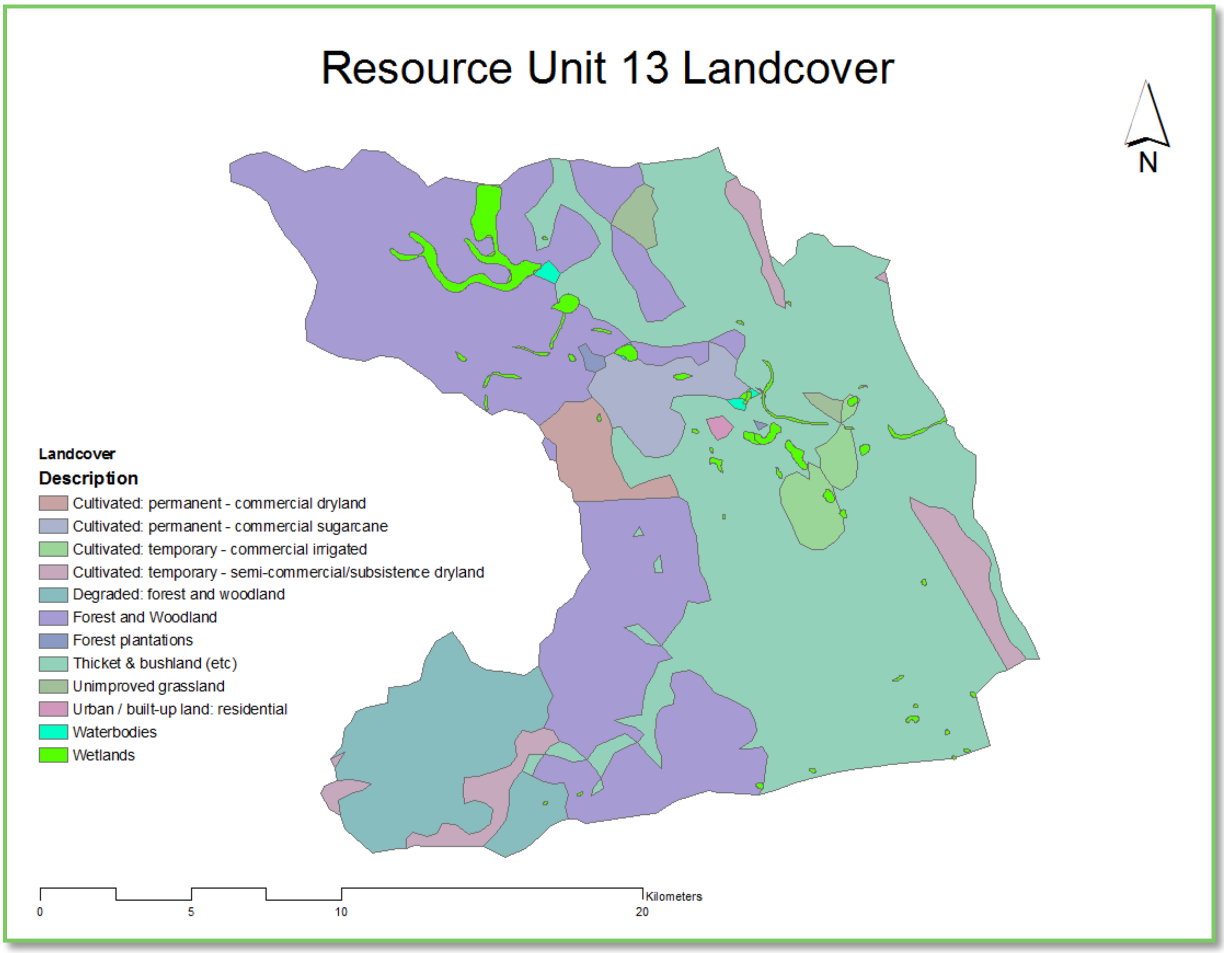


FIGURE 85: LANDCOVER

18.5 Surface water and Wetlands

The Mkuze River flows through the RU. The wetlands (**Photo 29**) are shown in **Figure 85**.

PHOTO 29: WETLAND IN RU

18.6 Soils (taken from environment.gov.za)

Soils are either black clays, red, structured clays or duplex soils derived from Ecca Group shale and mudstone.

18.7 Geohydrology

Groundwater levels

It is clear that the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 86**. The most probable depth to groundwater level in the RU is 8.8 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

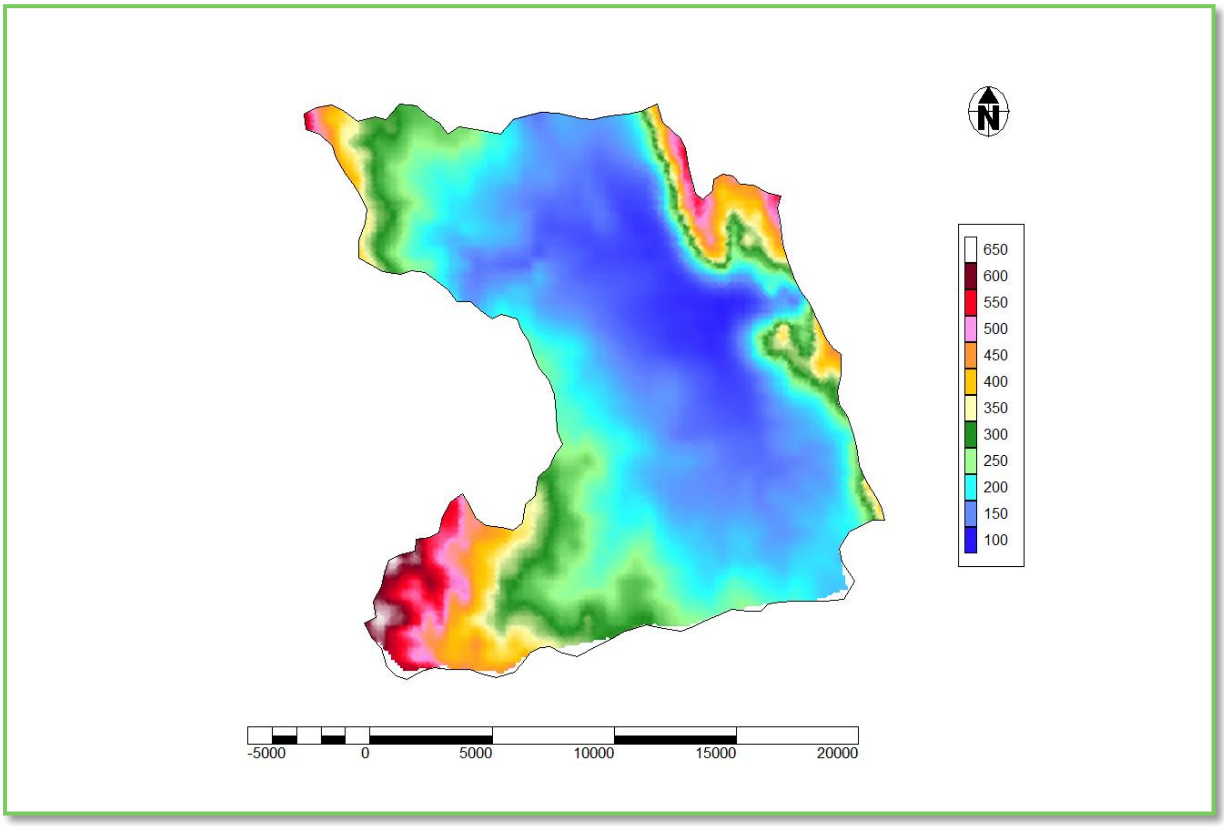


FIGURE 86: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 96**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 96: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
210.013	6.452	14.517	11.506	5.5%	5.5%	9.7%	3.7%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 97**.

TABLE 97: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
391	78	0.001

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 98** is highlighted in red.

TABLE 98: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
2.220	3.013	1.484	0.508	1.251	0.164	14.517	1.020

Groundwater use

The groundwater use in the catchment is documented in **Table 99**.

TABLE 99: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
1.100	0.000	0.003	0.000	1.100	1.260	0.000	1.259

Groundwater quality

The TDS values for the RU are shown in **Figure 87**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines.

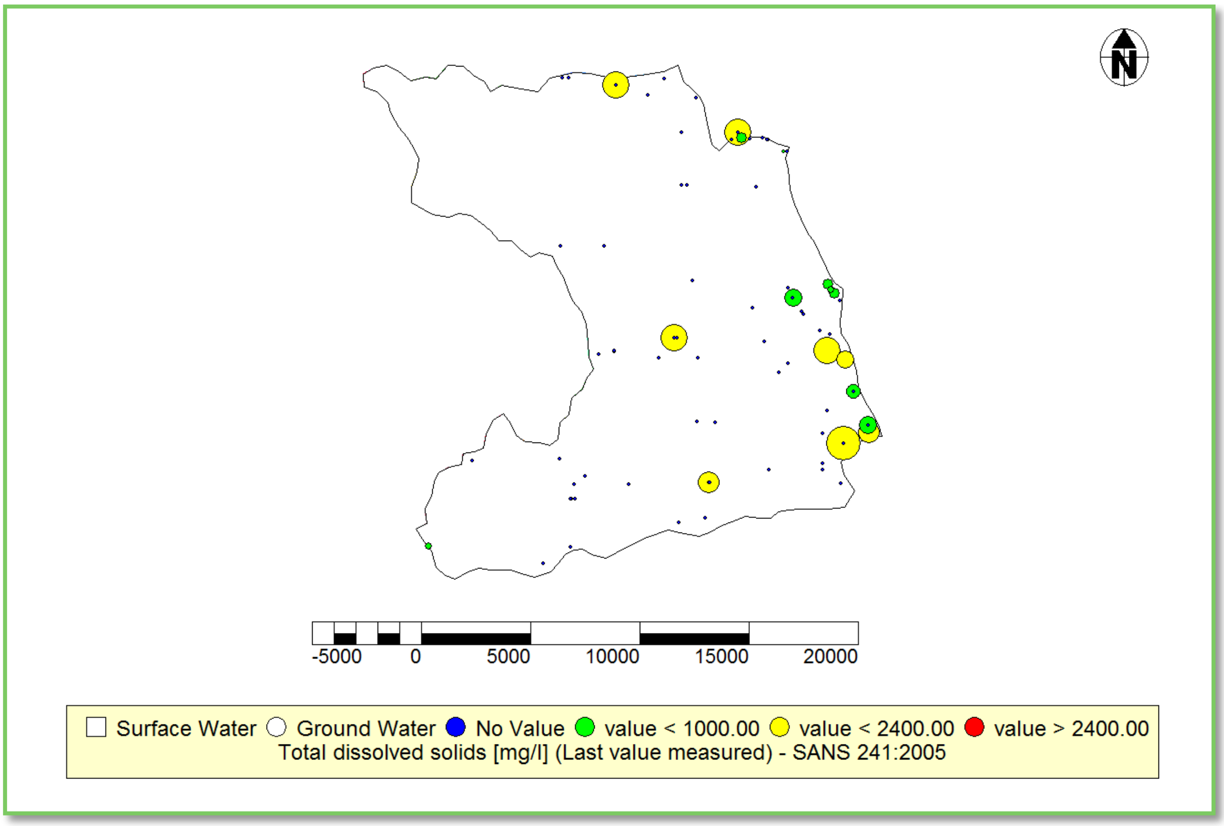


FIGURE 87: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 100**. The slope histogram is documented in Appendix D.

TABLE 100: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
8.8	5.5%	1.1	SaLm-SaCl , LmSa-SaLm	Weathered/Fractured	Natal	57%

18.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 11%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled by assigning a normal distribution curve with a standard deviation of 0.126 Mm^3/a to the groundwater use estimate, to account for the associated uncertainty. The stochastic results are shown in **Figure 88**. It is clear from the results that the stress index will vary between 8% and 14%, with a certainty of 99.51%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

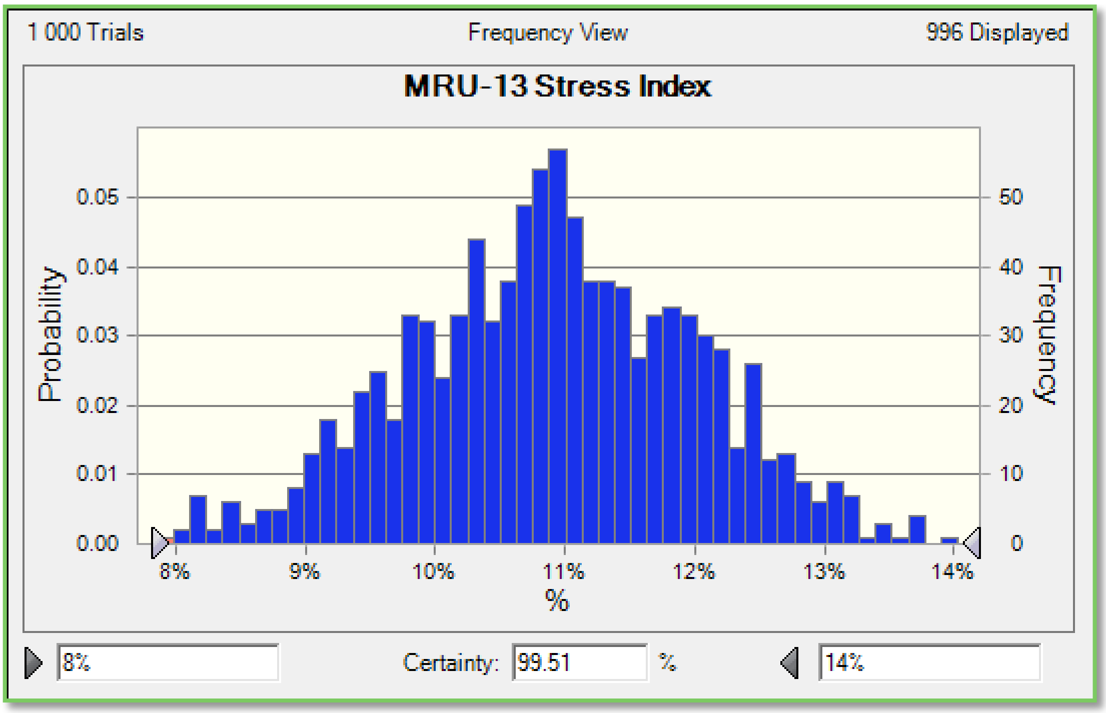


FIGURE 88: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 89**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. It is apparent that the contamination category, according to the explanation, is C.

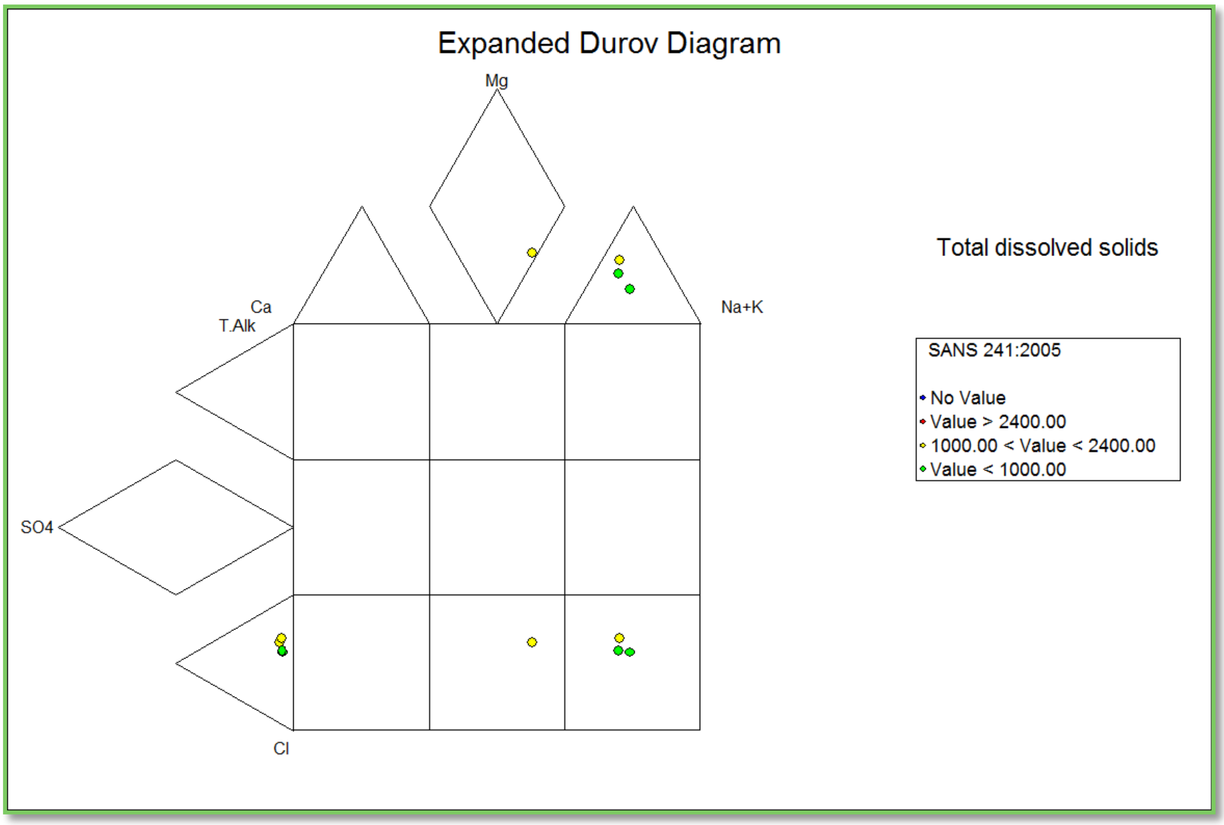


Figure 89: Expanded Durov diagram for RU

As documented the vulnerability is 57%. The impact of potential contamination, according to Section 2.2, is medium due to a large area of the RU being used for agriculture.

Final category

The final category for the RU is summarised in **Table 101**.

Table 101: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	B	Good
Groundwater contamination	C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	B/C	Good/Fair
FINAL	**B/C**	**Good/Fair**

18.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 102**.

Table 102: Reserve

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
1.020	0.001	9%	9.226	1.259

19. Classification and the Reserve for RU14

19.1 Location

The two quaternary catchments located in this RU are W31J and W32A. The Mkuze Game Reserve (**Photo 30**) and Sodwana are protected within the RU. There are no major towns. The location of the RU is shown in **Figure 90**.

PHOTO 30: MKUZE GAME RESERVE
(Source: www.panoramio.com)

19.2 Climate

The mainly summer rain, amounts to between 500 and 750 mm per year. Mean monthly temperatures vary from 24°C in summer to 17°C in winter, while maximum temperatures in summer may exceed 29°C and fall to around 9°C in winter.

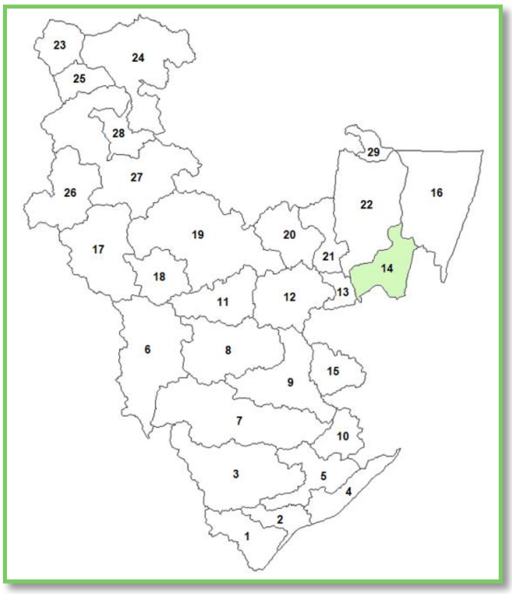


FIGURE 90: LOCATION

19.3 Vegetation (taken from environment.gov.za)

This is a dense bushveld related to forest, composed of large trees with a dense shrub layer. The principal trees are Flat Crown Albizia adianthifolia, Largeleaf Falsethorn A. versicolor, Knob Thorn Acacia nigrescens, Sclerocarya birrea subsp. caffra, Ziziphus mucronata, Dichrostachys cinerea subsp. africana, Maytenus senegalensis, Schotia brachypetala, Dombeya rotundifolia, Peltophorum africanum, Spirostachys africana and Euclea crispa subsp. crispa.

19.4 Demography and Land use

The main activities are cattle and game farming, and ecotourism. The total population, according to the 2001 census, is 11 030. The Landcover for the RU is shown in **Figure 91**.

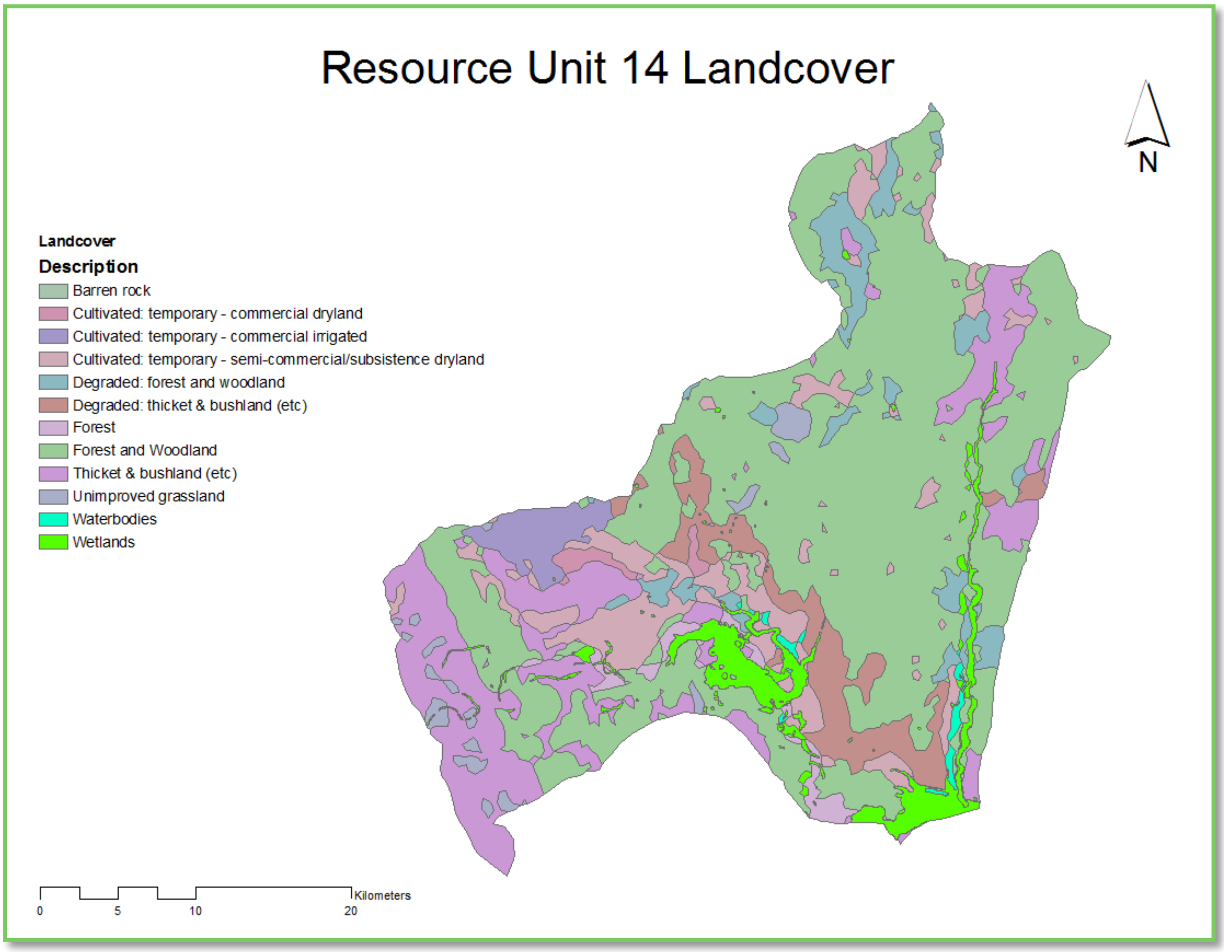


FIGURE 91: LANDCOVER

19.5 Surface water and Wetlands

The Mkuze flows through the RU. The wetlands in the RU are shown in **Figure 91**.

19.6 Soils (taken from environment.gov.za)

The soils are found on deep, light, Quaternary aeolian sand of marine origin.

19.7 Geohydrology

Groundwater levels

It is clear that the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 92**. The most probable depth to groundwater level in the RU is 7.8 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

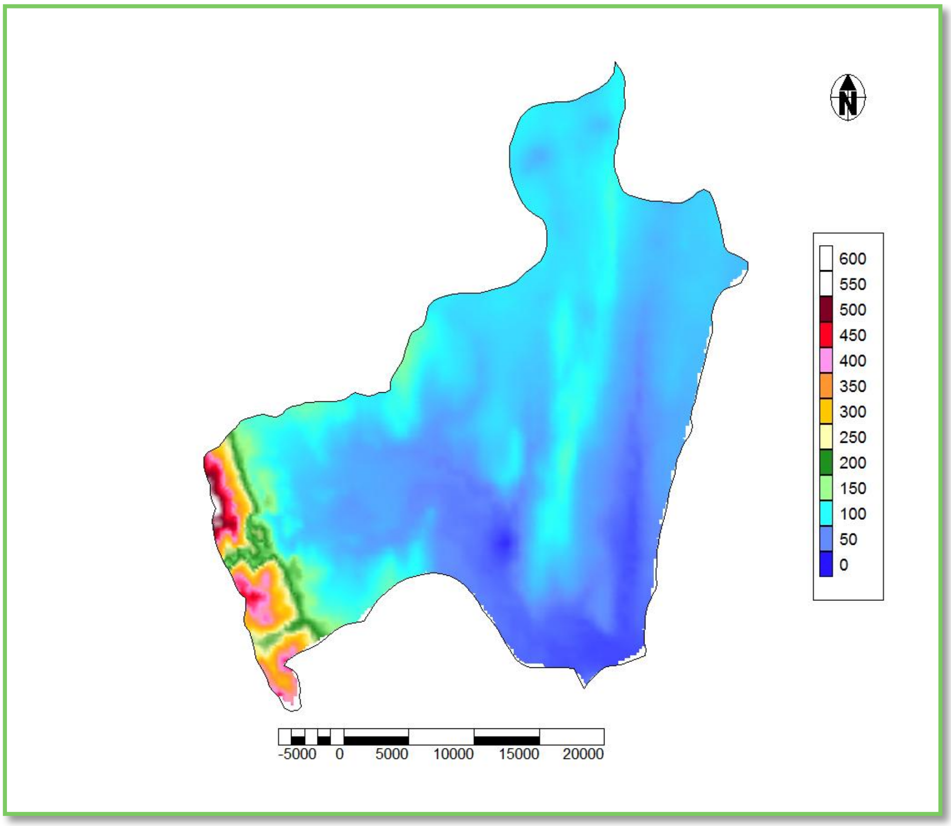


FIGURE 92: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 103**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 103: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
651.787	19.400	43.650	31.008	4.8%	4.8%	14.9%	4.1%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 104**.

TABLE 104: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
12685	2537	0.023

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 105** is highlighted in red.

TABLE 105: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
14.645	14.430	9.554	6.381	8.780	2.785	43.650	6.960

Groundwater use

The groundwater use in the catchment is documented in **Table 106**.

TABLE 106: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
0.330	0.010	0.016	0.010	0.330	3.294	1.230	4.501

Groundwater quality

The TDS values for the RU are shown in **Figure 93**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines, with the exception of one borehole. This area should be treated as a hot spot rather than applying a poor classification to the whole resource unit. Treatment of the hot spot areas will be addressed under Resource Quality Objectives in Section 35.

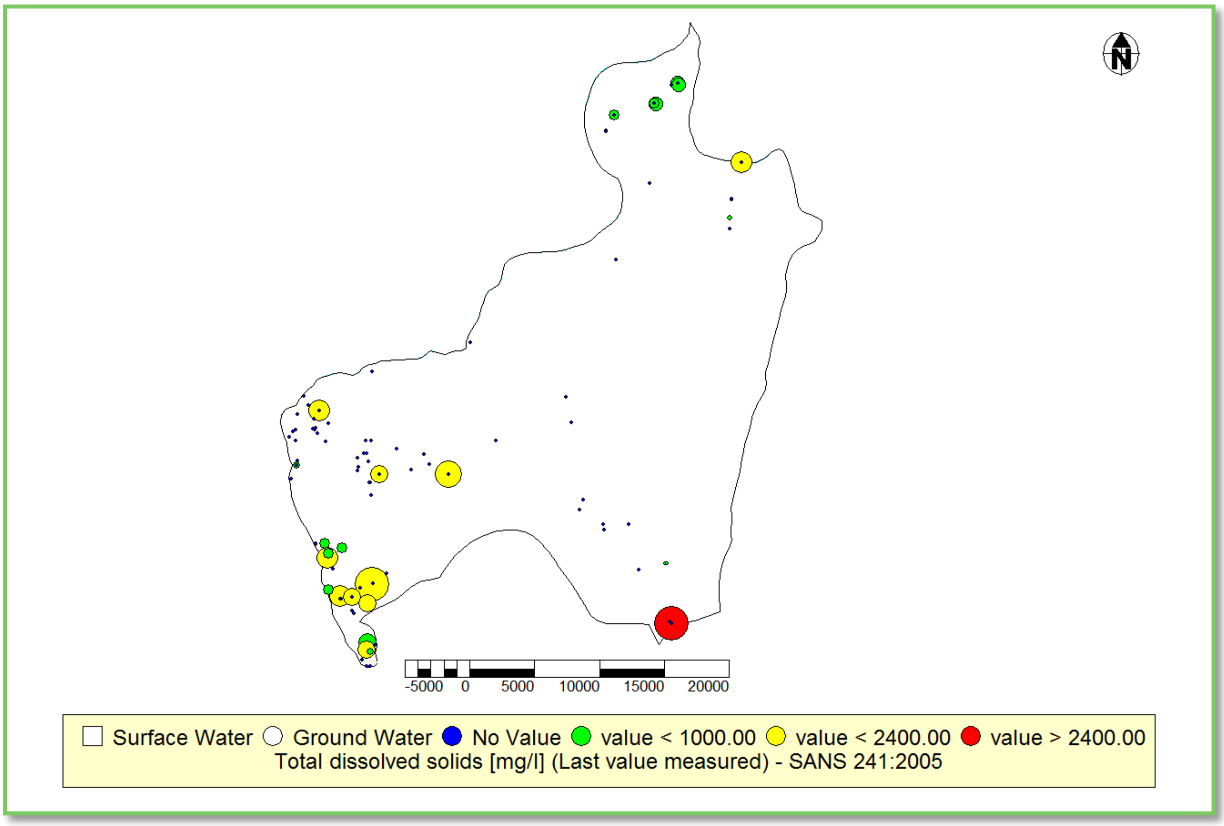


FIGURE 93: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 107**. The slope histogram is documented in Appendix D.

TABLE 107: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
7.8	4.8%	0.8	SaLm-SaCl, Sa	Weathered/Fractured	Natal	60%

19.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 14.6%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled by assigning a normal distribution curve with a standard deviation of 0.450 Mm^3/a to the groundwater use estimate, to account for the associated uncertainty. The stochastic results are shown in **Figure 94**. It is clear from the results that the stress index will vary between 11% and 18%, with a certainty of 98.7%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

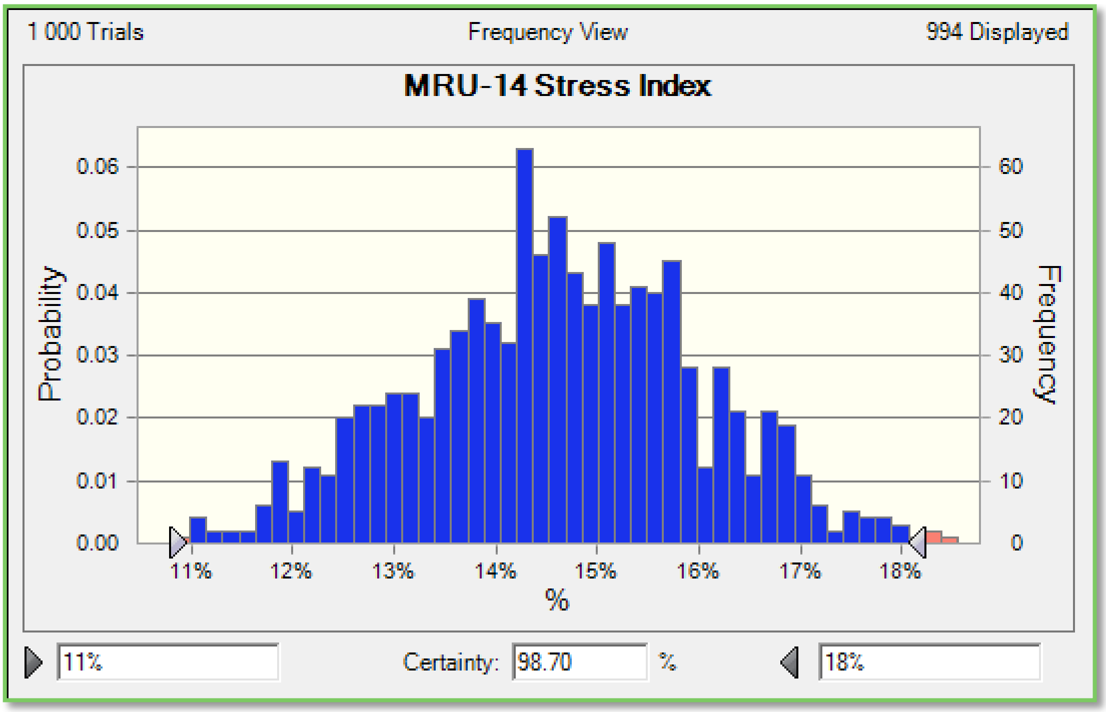


FIGURE 94: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 95**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. It is apparent that the contamination category, according to the explanation, is C.

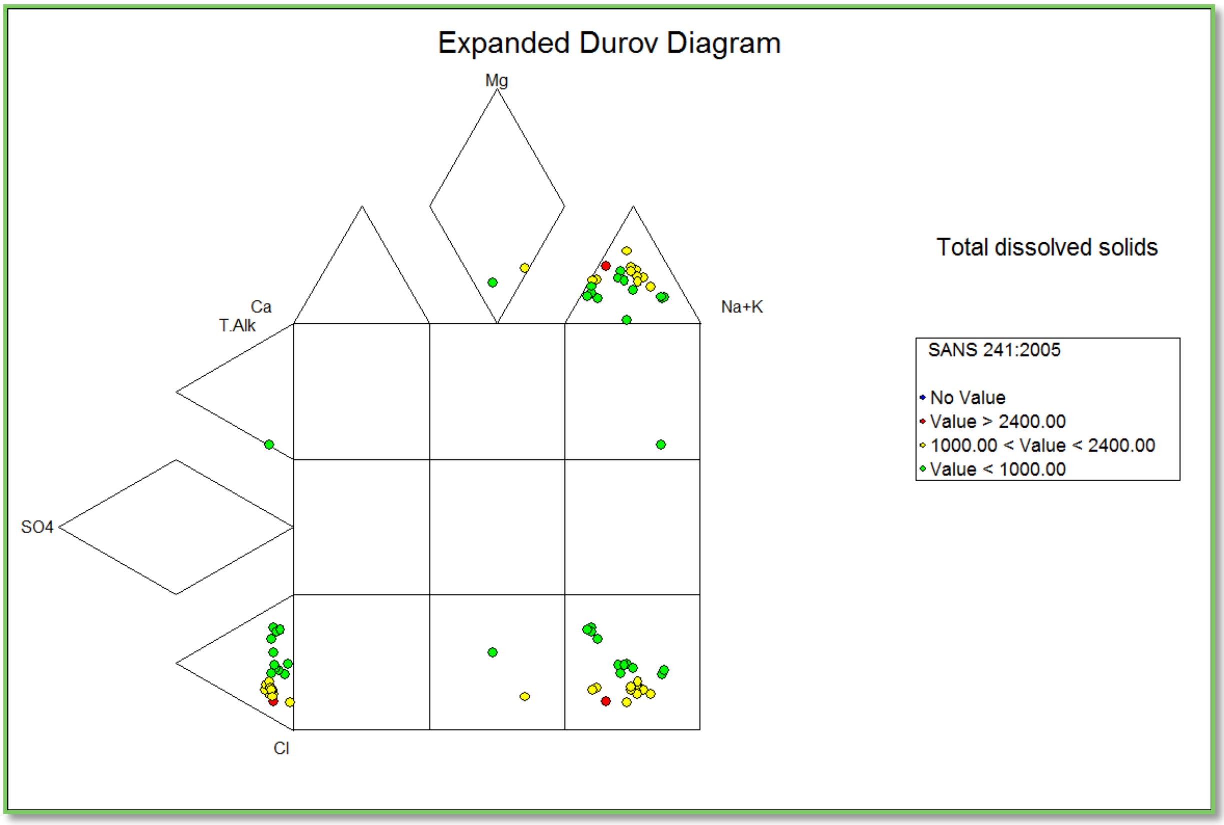


Figure 95: Expanded Durov diagram

As documented the vulnerability is 60%. The impact of potential contamination, according to Section 2.2, is medium due to a large area of the RU being used for agriculture.

Final category

The final category for the RU is summarised in **Table 108**.

Table 108: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	B	Good
Groundwater contamination	C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	C	Good/Fair
FINAL	**C**	**Good/Fair**

19.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 109**.

Table 109: Reserve

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
6.960	0.023	23%	19.524	4.501

20. Classification and theReserve for RU15

20.1 Location

The location of the RU is shown **Figure 96**. Hlabasi is the only town in the RU. The Hlhuluwe-Mfolozi Game Park (**Photo 31**) is protected in the RU.

PHOTO 31: HLHULUWE-MFOLOZI GAME PARK

(Source: www.panoramio.com)

20.2 Climate

The rainfall is 800 to 900 mm per year in summer. Mean annual temperatures for January are around 24°C, with a mean maximum of about 30°C, while the winter mean annual July temperature is 16°C, with a mean minimum of 10°C.

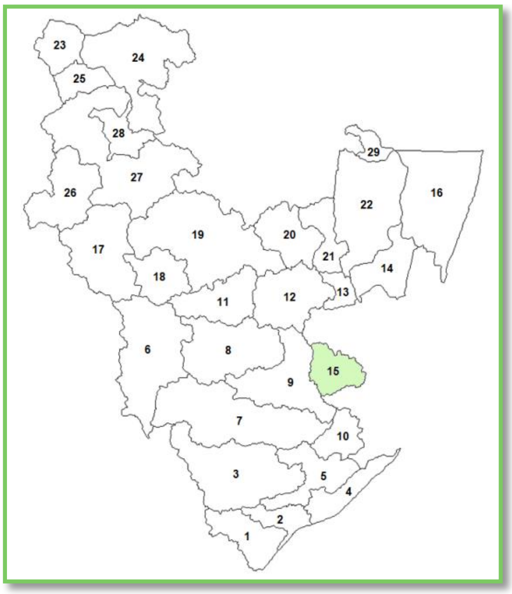


FIGURE 96: LOCATION

20.3 Vegetation (taken from environment.gov.za)

The vegetation is a mix of scrub and savanna. The most common tree species include Umbrella Thorn Acacia tortilis, Sweet Thorn A. karroo, Red Bushwillow Combretum apiculatum, Boscia albitrunca, Euclea schimperi, Olea europaea subsp. africana, Schotia brachypetala, Euphorbia spp. and Spirostachys africana.

20.4 Demography and Land use

The major land uses are cattle and game farming, sugar cane and subtropical fruit. There are also forests in the study area. The total population (Census 2001) is 43650. The Landcover is shown in **Figure 97**.

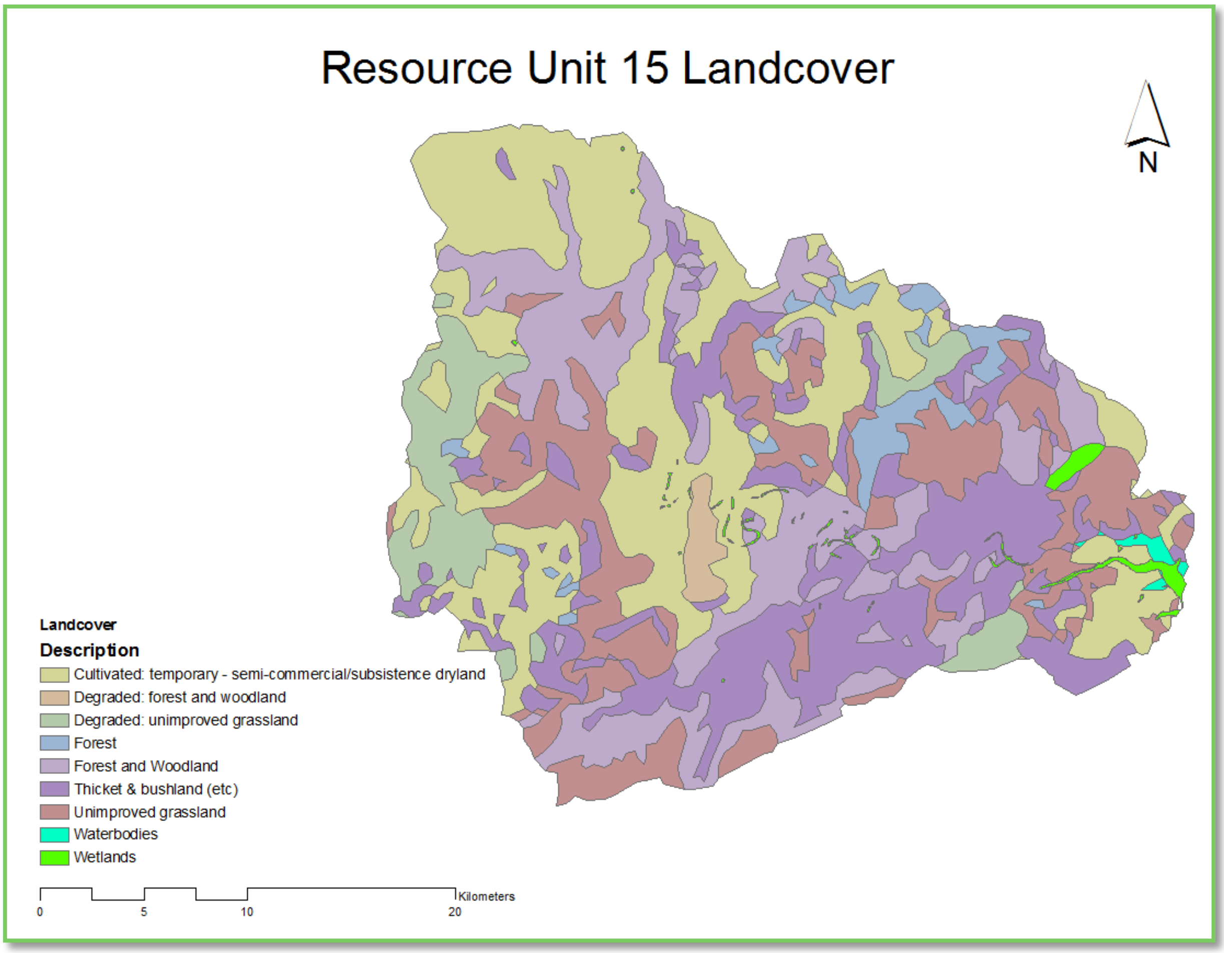


FIGURE 97: LANDCOVER

20.5 Surface water and Wetlands

The Nzimane and Hlhuluwe Rivers flow into the Hlhuluwe Dam. The wetlands in the area are shown in **Figure 97**.

20.6 Soils (taken from environment.gov.za)

Soils are either black clays, red, structured clays or duplex soils derived from Ecca Group shale and mudstone.

20.7 Geohydrology

Groundwater levels

It is clear that the groundwater levels follow the topography, as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 98**. The most probable depth to groundwater level in the RU is 4.9 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

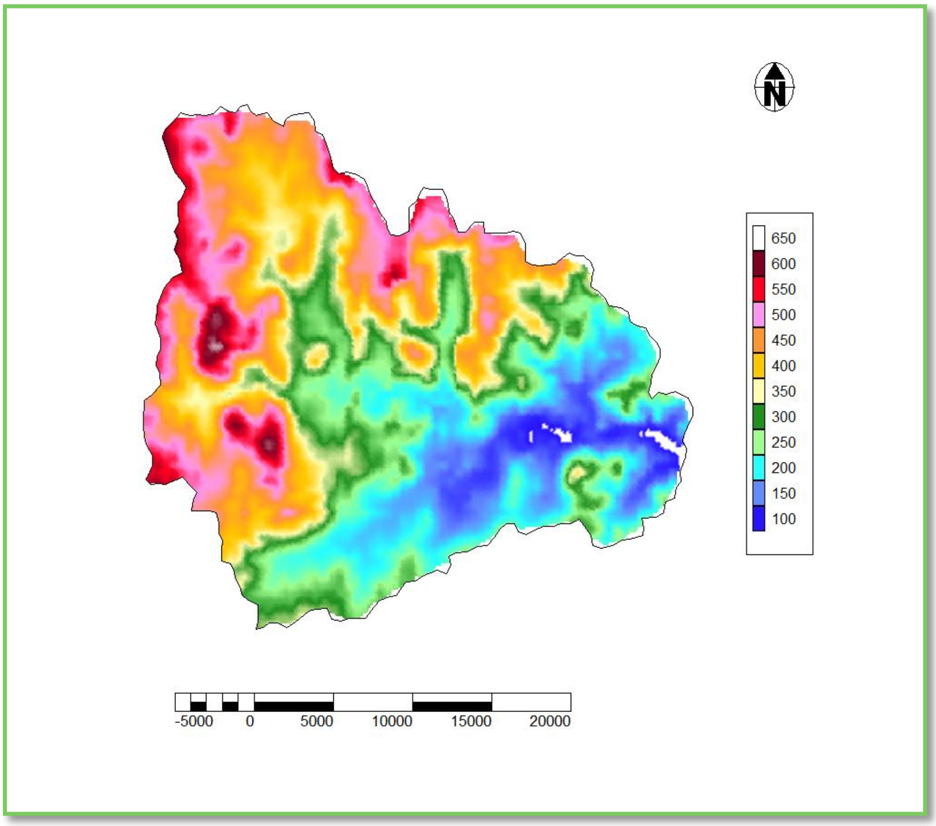


FIGURE 98: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 110**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 110: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
557.133	14.462	25.557	26.042	4.7%	4.7%	11.4%	3.3%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 111**.

TABLE 111: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
50198	10040	0.090

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 112** is highlighted in red.

TABLE 112: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
10.048	12.462	4.483	2.098	4.620	0.809	25.557	2.260

Groundwater use

The groundwater use in the catchment is documented in **Table 113**.

TABLE 113: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
0.480	0.064	0.000	0.000	0.480	0.450	0.124	0.483

Groundwater quality

The TDS values for the RU are shown in **Figure 99**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines.

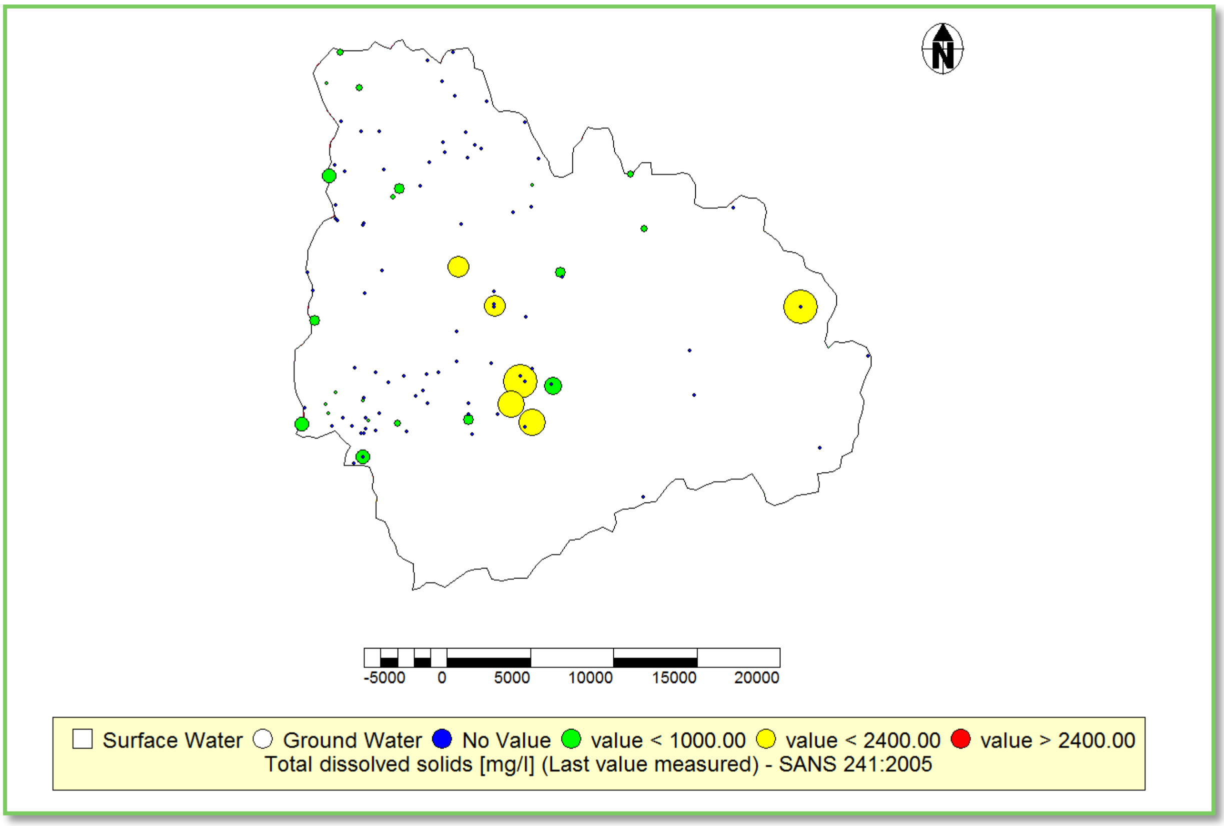


FIGURE 99: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 114**. The slope histogram is documented in Appendix D.

TABLE 114: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
4.9	4.7%	0.8	SaLm-SaCl	Weathered/Fractured	Natal	60%

20.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 2.2%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled by assigning a normal distribution curve with a standard deviation of 0.048 Mm³/a to the groundwater use estimate, to account for the associated uncertainty. The stochastic results are shown in **Figure 100**. It is clear from the results that the stress index will vary between 2% and 3%, with a certainty of 99.61%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

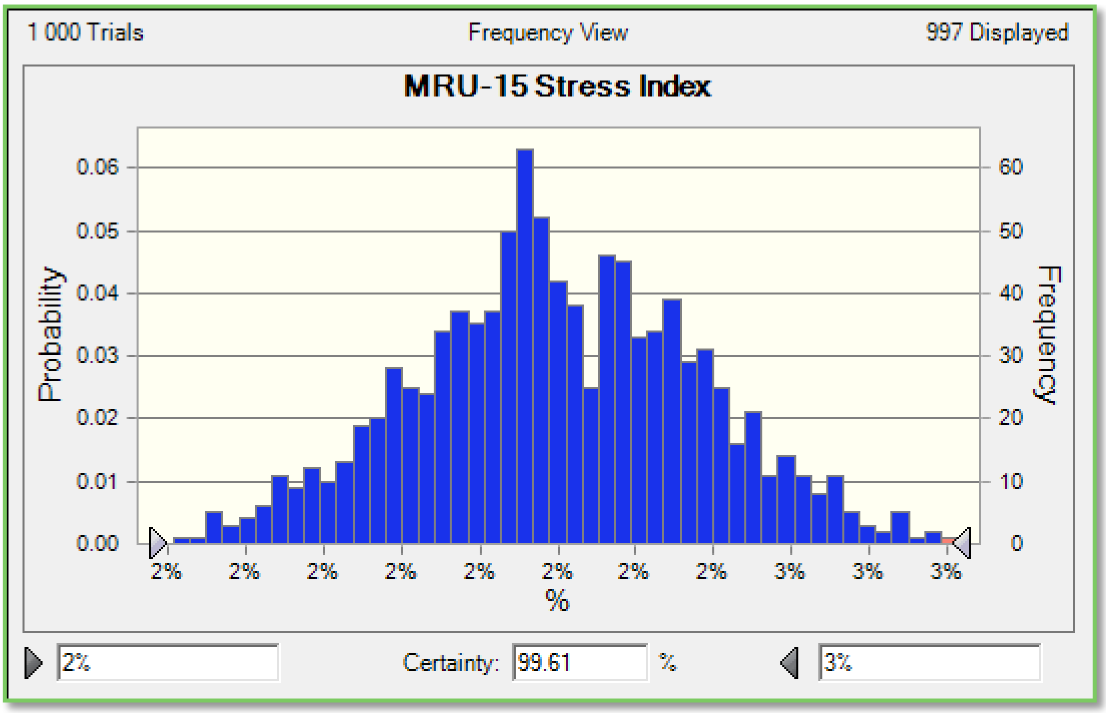


FIGURE 100: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 101**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. It is apparent that the contamination category, according to the explanation, is C.

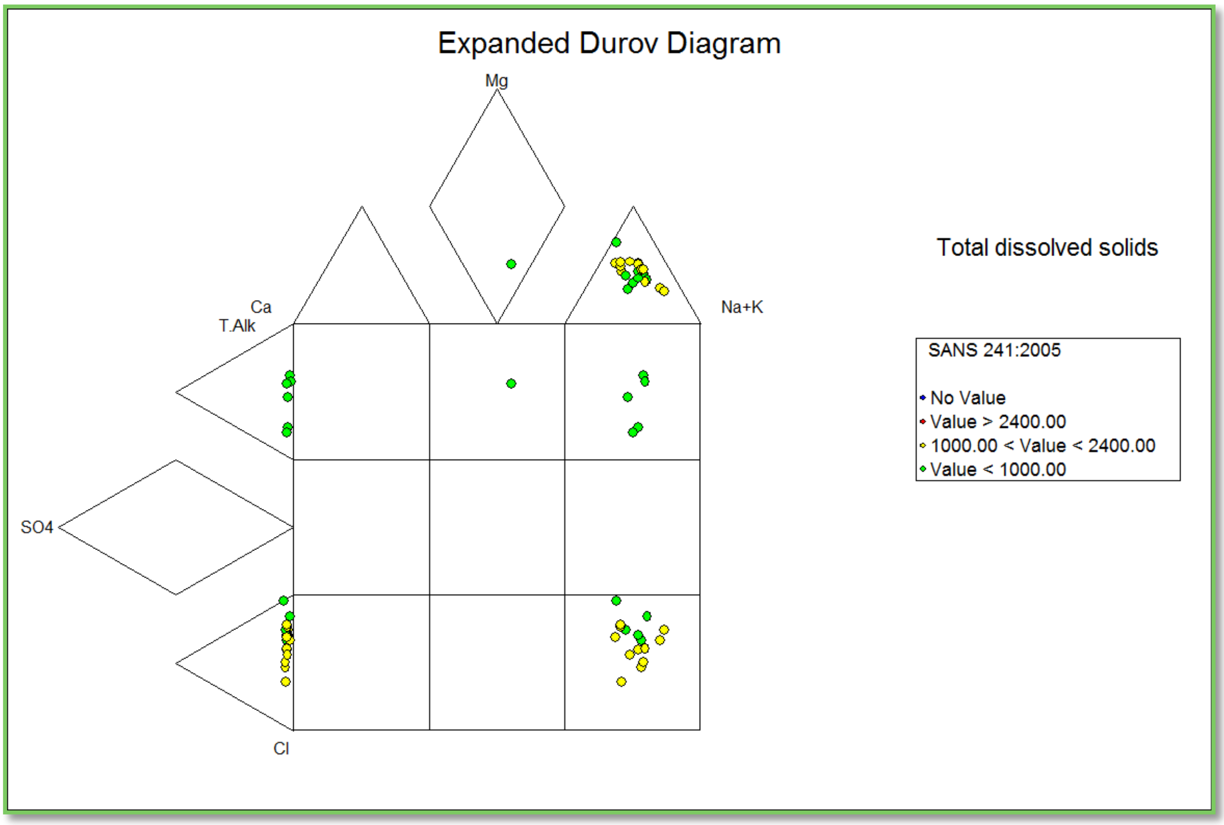


FIGURE 101: EXPANDED DUROV DIAGRAM

As documented the vulnerability is 60%. The impact of potential contamination, according to Section 2.2, is low due to a large portion of the RU being protected.

Final category

The final category for the RU is summarised in **Table 115**.

TABLE 115: CATEGORY FOR RU

Impact	Present status category	Water resource category
Groundwater usage	A	Natural
Groundwater contamination	C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	**B**	**Good**

20.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 116**.

TABLE 116: RESERVE

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
2.260	0.090	9%	23.208	0.483

21. Classification and the Reserve for RU16

21.1 Location

This RU consists of quaternary catchment W70A. Sodwana Bay and Emangusi are located in the study area. The Tembe Elephant Park, Sileza, Mabaso Tribal Park, Manguze Park, Lake Sabayi and the Coastal Park are all protected in the RU. The location of the RU is shown in **Figure 102**.

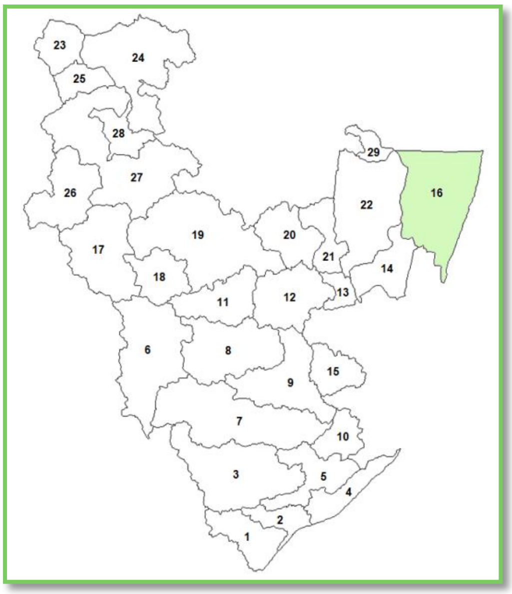


FIGURE 102: LOCATION

21.2 Climate

The climate is humid, with only one or two months of very little or no rain. The rainfall exceeds 1000 mm per year. Mean annual temperatures for January are around 25°C, and those in July around 17°C.

21.3 Vegetation (taken from environment.gov.za)

The remaining forest patches are characterised by species such as: Forest Iron Plum Drypetes gerrardii, Umzimbeet Millettia grandis, White Ironwood Vepris undulata, Protorhus longifolia, Trichilia emetica, Brachylaena spp., Celtis spp., Chaetacme aristata and Mimusops obovata. These forest patches are also characterised by a large number of species of woody lianas. Much closer to the seashore, evergreen thicket occurs on littoral dunes. On the seaward side, the canopy exhibits the typical clipped appearance of wind-pruning as a result of constant exposure to salt-laden easterly winds. Typical canopy species are: Coast Red Milkwood Mimusops caffra, Dune Jackalberry Diospyros rotundifolia, Natal Guarri Euclea natalensis, Brachylaena discolor and Apodytes dimidiata. Secondary woody vegetation is patchy and often characterised by Sweet Thorn Acacia karroo together with Scented Thorn A. nilotica and Splendid Thorn A. robusta. The grassy matrix includes species such as Ngongoni Bristlegrass Aristida junciformis, Eragrostis spp., Sporobolus spp., Hyparrhenia spp., Digitaria spp., Setaria spp. and occasionally Themeda triandra. The vegetation often has a shrubby appearance, due to many dwarf geoxylophytes, including Diospyros galpinii, Dwarf Mobola Parinari capensis subsp. incohata, Veined Medlar Pachystigma venosum, Eugenia albanensis, E. capensis, Ancylobotrys petersiana and Salacia kraussii. Locally, at swampy localities in northern KwaZulu-Natal, the Illala Palm Hyphaene coriacea, is very prominent.

21.4 Demography and Land use

The total population is 44100 (according to the 2001 census). There are many game parks in the area. The area is rural. Many of the people rely upon subsistence agriculture (**Figure 103**). The area is heavily grazed by livestock, and natural resources are used on a routine basis.

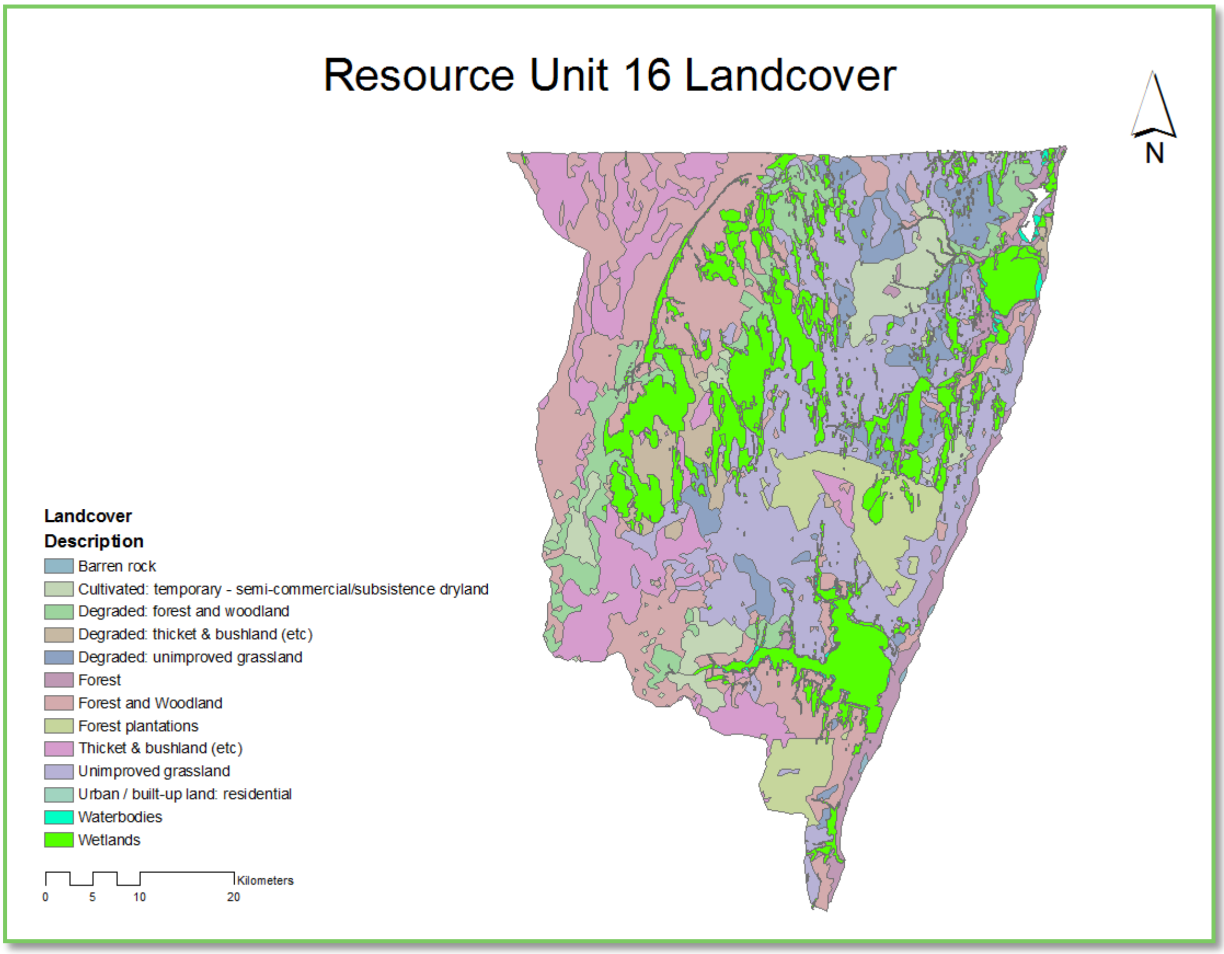


FIGURE 103: LANDCOVER

21.5 Surface water and Wetlands

There are no major rivers in the RU. However, there are numerous wetlands, the most important being Kosi Bay and Lake Sibaya.

The Kosi Bay Nature Reserve is situated on the coast in the northern part of KwaZulu Natal and surrounds the Kosi Bay lake system. The Kosi Bay System, a complex of six large lakes; two lesser lakes drain via channels into a sandy estuary (**Photo 32**) with varying levels of salinity. It is home to a variety of birds and wildlife, including hippopotamus and crocodile.

This is the most pristine lake system on the South African Coast. The 11000 hectare Kosi Bay Nature Reserve is a tropical paradise of crystal-clear blue water and marshland, raffia, wild date and palm, mangrove swamp and sycamore fig forest that combine to provide a home for approximately 250 species of bird, among which are the fish eagle and palmnut vulture, whitebacked heron and the night heron as well as purple and reed kingfisher.

PHOTO 32: KOSI BAY

The largest fresh water lake in Southern Africa, Lake Sibaya (**Photo 33**), has a surface are of 77 square kilometres and an average depth of 13 metres. Previously connected to the sea and with the closure of the estuary, numerous marine invertebrates and vertebrates are found here. Because of the phenomenon, the lake is also host to several endemic fish species, found nowhere else in the world. Between the eastern shore and the sea is a range of high dunes attaining altitudes of up to 165 m. To the west of the dunes, the land is very flat, and consequently the boundary of the catchment feeding the lake is difficult to define. Many smaller pans typical of those elsewhere in the area, surround the lake. The wetland also supports many of the rural people of this region, who in many cases are totally dependent on the water resource and its associated flora and fauna.

PHOTO 33: LAKE SIBAYA

Lake Sibaya is fed by groundwater. The chief mechanism by which the lake loses water is by evaporation, but it is suspected that a relatively small amount may be lost from the lake by seepage to the sea.

21.6 Soils (taken from environment.gov.za)

The soils are sandy of Quaternary aeolian and marine origin.

21.7 Geohydrology

Groundwater levels

It is clear that the groundwater levels follow the topography, as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 104**. The most probable depth to groundwater level in the RU is 2.4 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

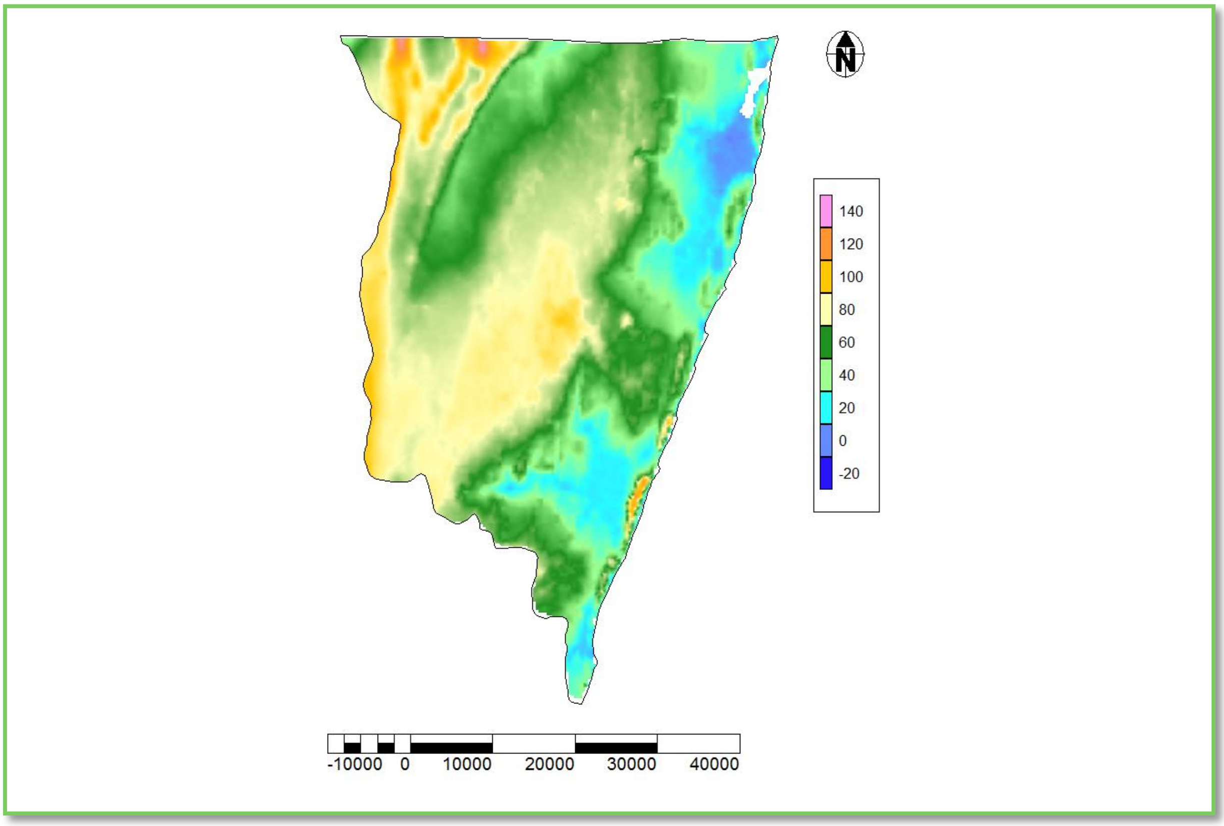


FIGURE 104: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 117**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 117: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
1853.724	82.848	202.330	156.863	8.5%	8.5%	25.0%	5.7%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 118**.

TABLE 118: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm^3/a
50715	10143	0.091

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 119** is highlighted in red.

TABLE 119: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm^3/a	Hughes Mm^3/a	Shultz Mm^3/a	Pitman Mm^3/a	vTonder Mm^3/a	MIN Mm^3/a	MAX Mm^3/a	Herold Mm^3/a
523.833	66.460	35.952	57.735	51.928	35.952	202.330	57.735

Groundwater use

The groundwater use in the catchment is documented in **Table 120**.

TABLE 120: GROUNDWATER USE

Groundwater Use							
GRDM Mm^3/a	WARMS Mm^3/a	Hydrocensus Mm^3/a	MIN Mm^3/a	MAX Mm^3/a	Forrest Mm^3/a	Crops Mm^3/a	TOTAL Mm^3/a
0.550	1.011	0.001	0.001	1.011	9.180	24.091	33.179

Groundwater quality

The TDS values for the RU are shown in **Figure 105**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines, with the exception of one borehole. This area should be treated as a hot spot rather than applying a poor classification to the whole resource unit. Treatment of the hot spot areas will be addressed under Resource Quality Objectives in Section 35.

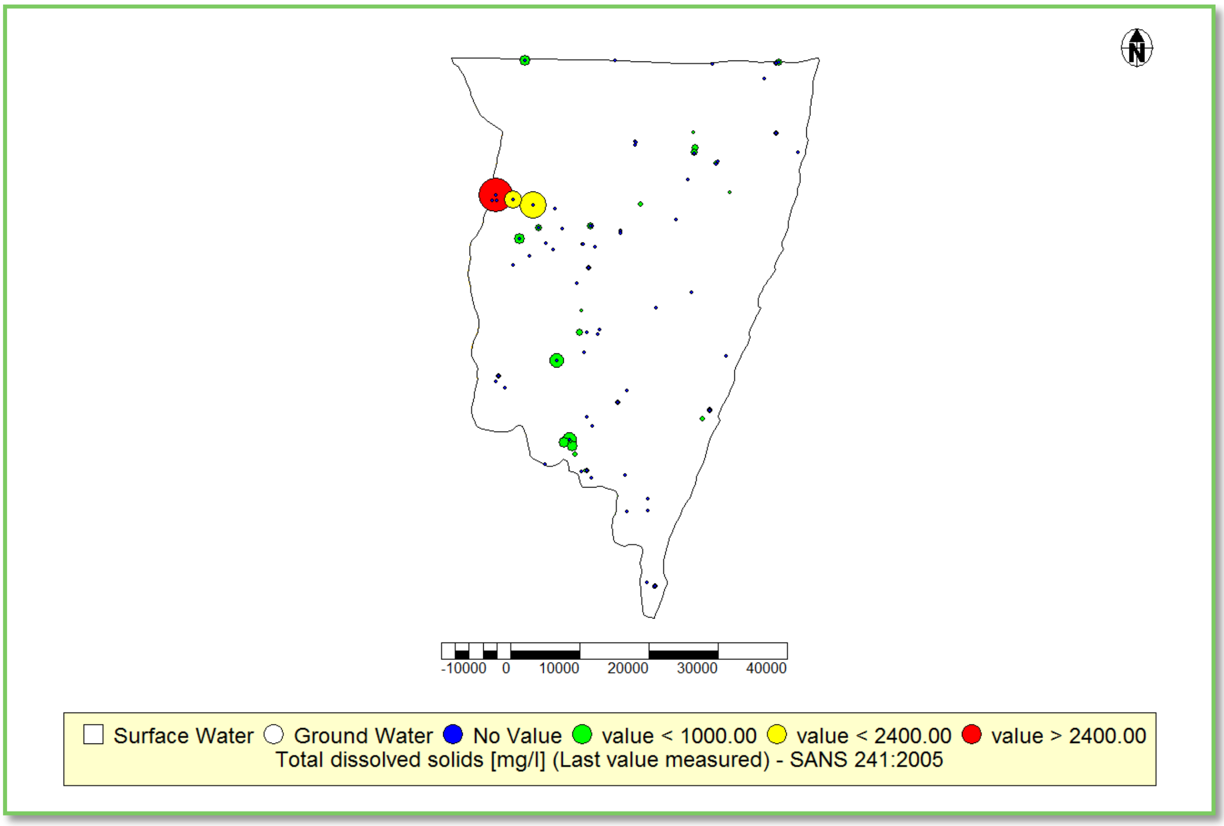


FIGURE 105: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 121**. The slope histogram is documented in Appendix D.

TABLE 121: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
2.4	8.5%	0.1	Sa	Weathered/Fractured	Natal	71%

21.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 21.2%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled by assigning a normal distribution curve with a standard deviation of 3.318 Mm^3/a to the groundwater use estimate, to account for the associated uncertainty. The stochastic results are shown in **Figure 106**. It is clear from the results that the stress index will vary between 16% and 27%, with a certainty of 99.34%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

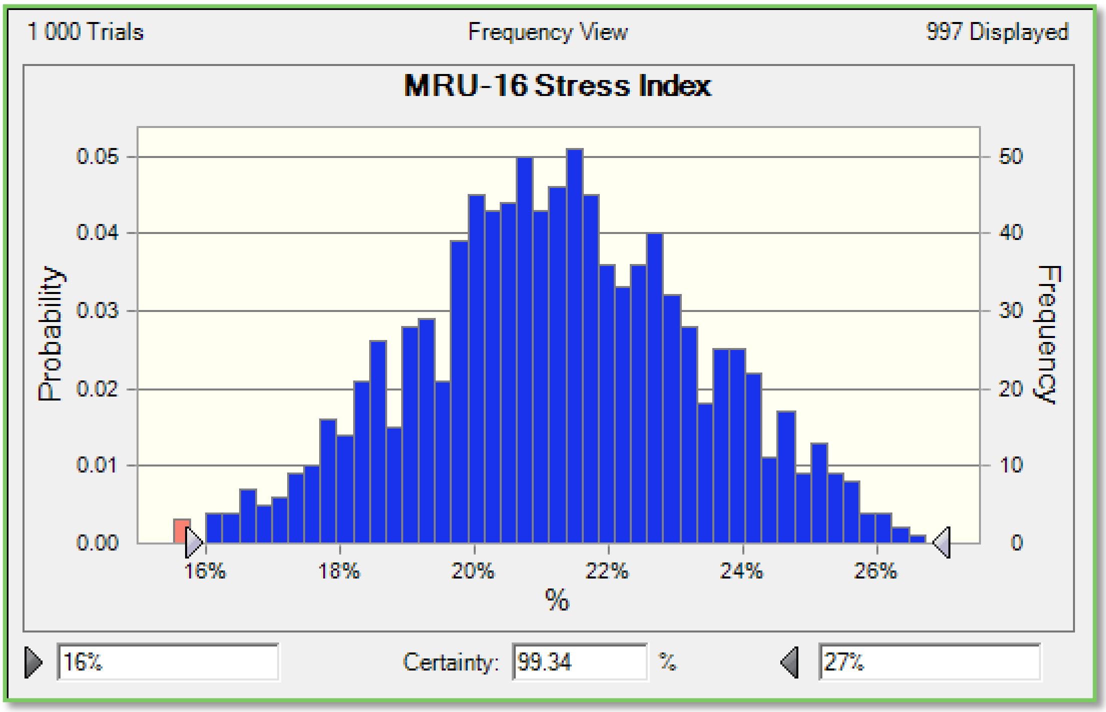


FIGURE 106: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 107**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. There is an even distribution of boreholes between category A and C, therefore the final category is B.

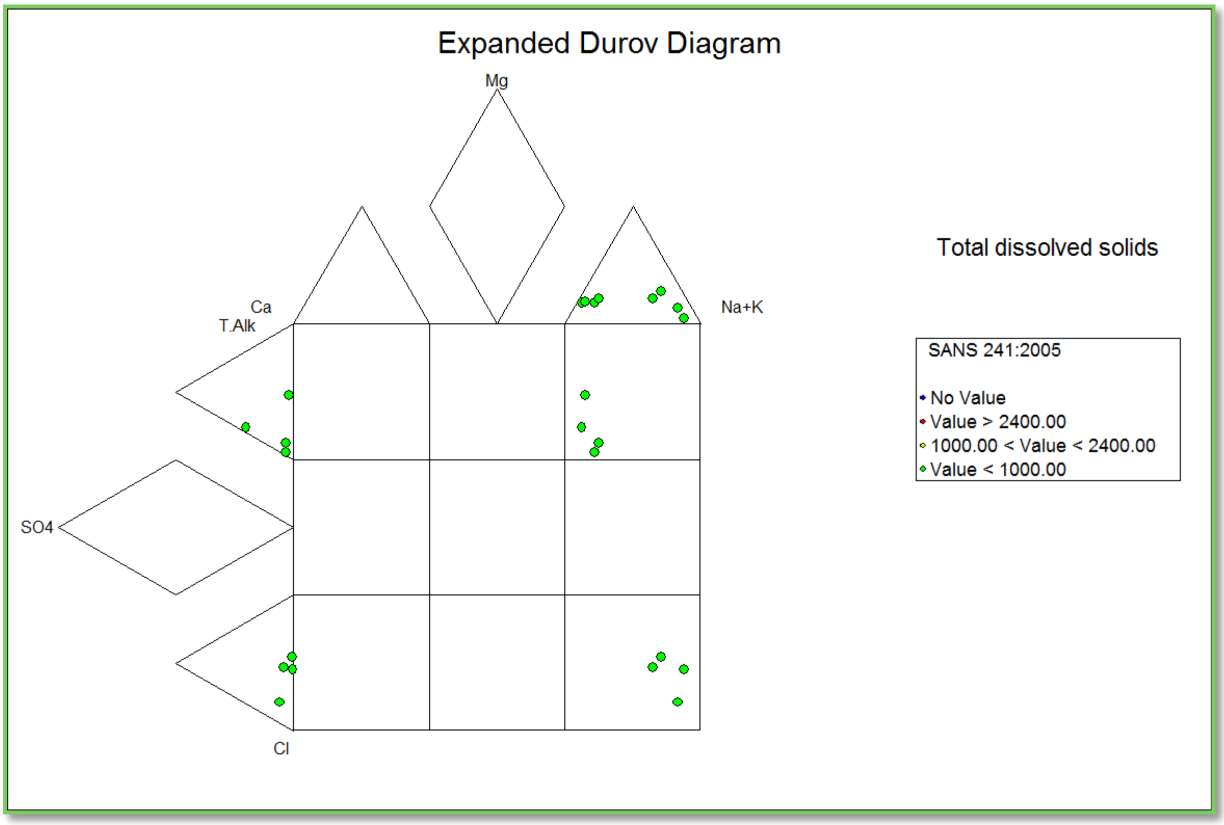


FIGURE 107: EXPANDED DUROV DIAGRAM FOR RU

As documented the vulnerability is 71%. The impact of potential contamination, according to Section 2.2, is high due to the large amount of agriculture taking place in the RU.

Final category

The final category for the RU is summarised in **Table 122**.

TABLE 122: CATEGORY FOR RU

Impact	Present status category	Water resource category
Groundwater usage	C	Good/Fair
Groundwater contamination	B	Good
Potential groundwater contamination (vulnerability and impact)	D	Fair
FINAL	**C**	**Good/Fair**

21.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 123**.

TABLE 123: RESERVE

Reserve			Allocation	
Baseflow Mm^3/a	BHN Mm^3/a	Reserve % Recharge	Allocation Mm^3/a	Current Use Mm^3/a
57.735	0.091	37%	65.857	33.179

22. Classification and the Reserve for RU17

22.1 Location

Luiperd Kloof and Pongola Bush Park are protected area. The towns located in the RU area Luneberg, Braunschweig, Grootspruit and Mpemvana. The quaternaries included in the RU are W41A, W41B, W41C, W42A, W42B and W42C. The location of the RU can be seen in **Figure 108**.

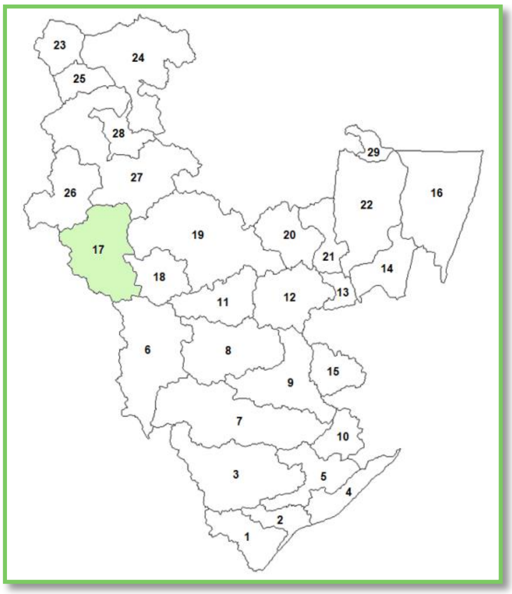


FIGURE 108: LOCATION

22.2 Climate

The summer rainfall ranges from 700 to 1 100 mm per year. Temperatures vary from -8°C to 39°C, with an average of 15°C.

22.3 Vegetation (taken from environment.gov.za)

These grasslands contains many endemic plant species: 78 endemic or near-endemic species occur on the Black Reef quartzites. These are mostly representatives of the Lilies (Liliaceae - now split into several families), Irises (Iridaceae), Daisies (Asteraceae), Mints (Lamiaceae) and Orchids (Orchidaceae).

22.4 Demography and Land use

According to the 2001 census data, there are 3970 people living in the RU. Forestry, grazing and ecotourism are the most important economic activities (**Figure 109**).

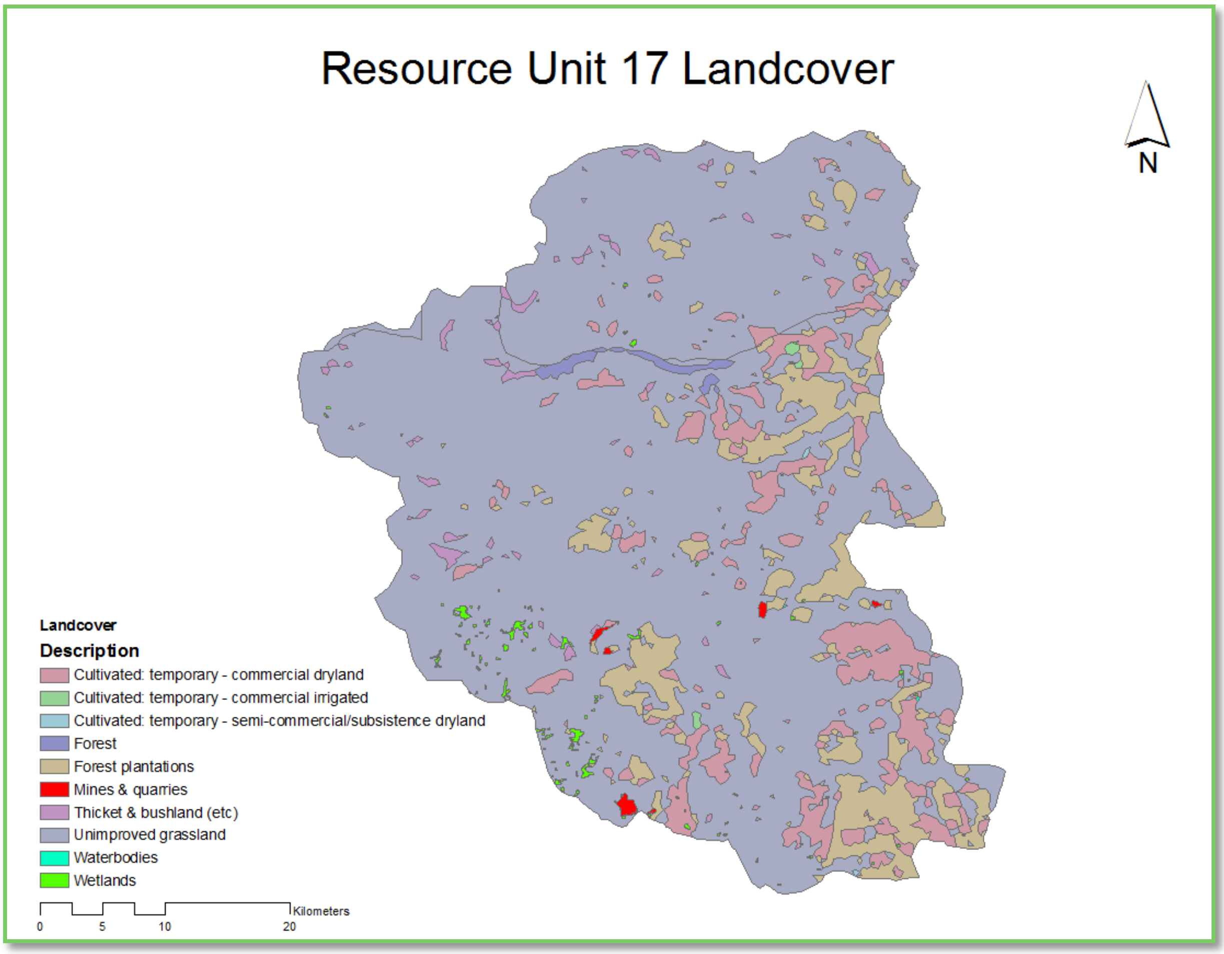


Figure 109: Landcover

22.5 Surface water and Wetlands

The headwaters of the Pongola (**Photo 34**) run through this RU. The wetlands in the RU are shown in **Figure 109**.

Photo 34: Headwaters of Pongola River
(Source: www.panoramio.com)

22.6 Soils (taken from environment.gov.za)

Soils are mostly shallow lithosols derived from a variety of rock types.

22.7 Geohydrology

Groundwater levels

It is clear that the groundwater levels follow the topography, as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in

Figure 110. The most probable depth to groundwater level in the RU is 8.2 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately, very little time series water level data are available to quantify the overall impact.

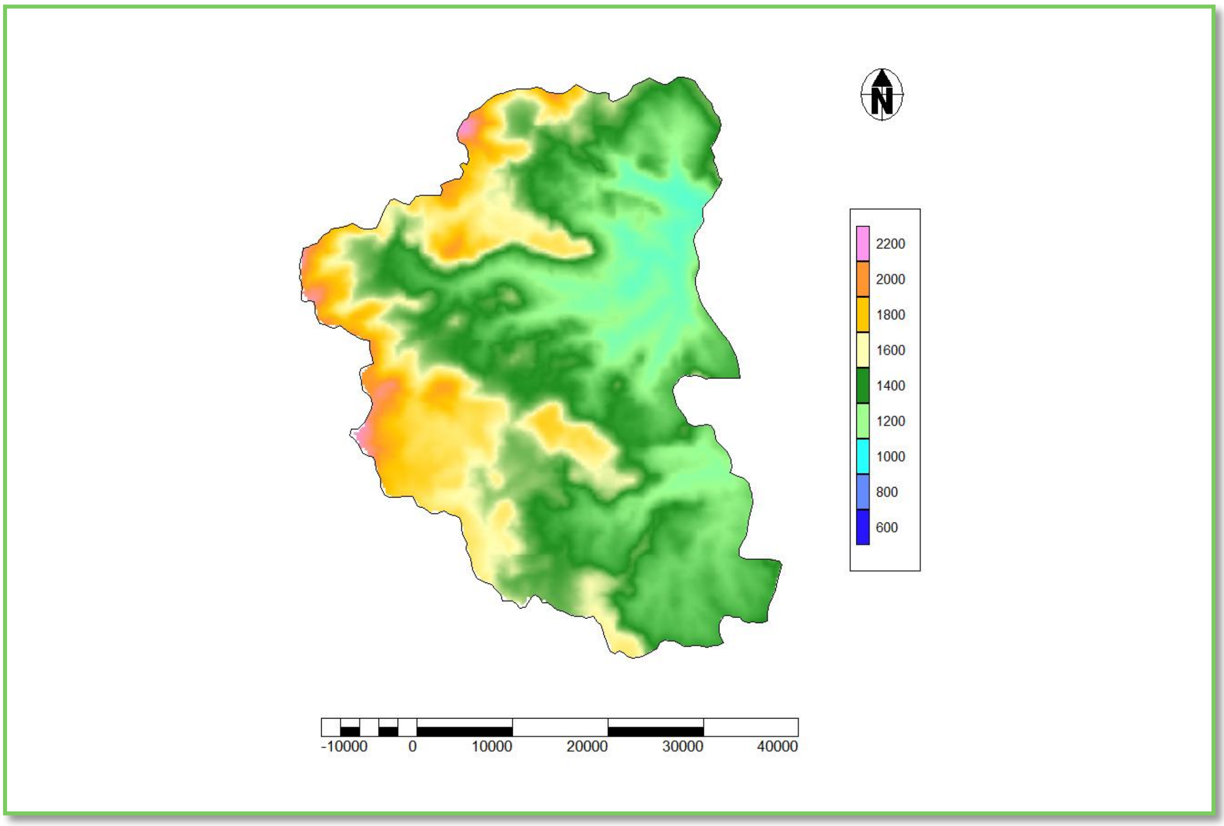


FIGURE 110: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 124**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 124: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
1874.429	127.222	180.595	178.254	9.5%	9.5%	9.4%	4.2%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 125**.

TABLE 125: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
10649	2130	0.019

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 126** is highlighted in red.

TABLE 126: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
51.182	199.174	107.209	64.525	101.195	18.623	180.595	65.310

Groundwater use

The groundwater use in the catchment is documented in **Table 127**.

TABLE 127: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
0.060	0.121	0.252	0.060	1.007	1.800	0.307	2.088

Groundwater quality

The TDS values for the RU are shown in **Figure 111**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines. However due to the mining and agricultural activities it is suspected that the water quality will be worse in places.

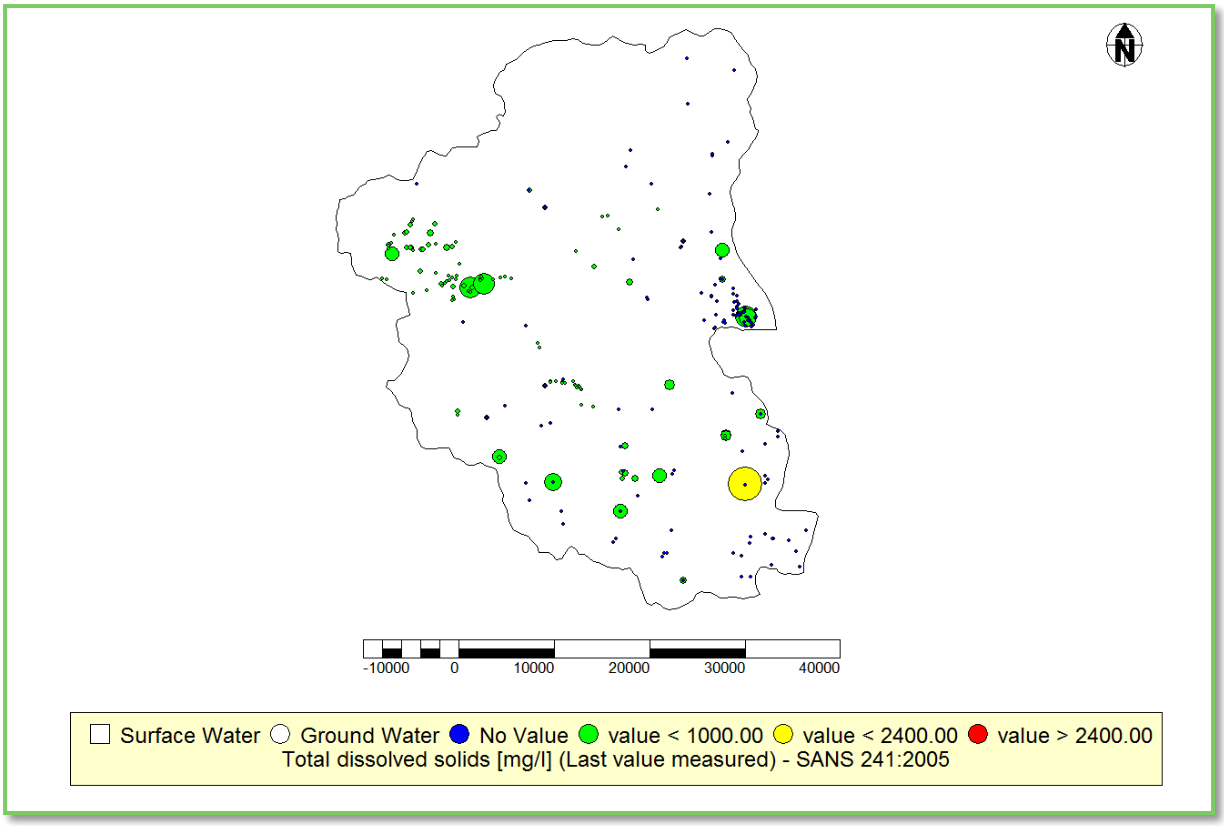


Figure 111: TDS values

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 128**. The slope histogram is documented in Appendix D.

Table 128: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
8.2	9.5%	0.9	LmSa-SaLm , SaLm	Weathered/Fractured	Natal	61%

22.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 1.2%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled by assigning a normal distribution curve with a standard deviation of 0.209 Mm^3/a to the groundwater use estimate, to account for the associated uncertainty. The stochastic results are shown in **Figure 112**. It is clear from the results that the stress index will vary between 1% and 2%, with a certainty of 99.03%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

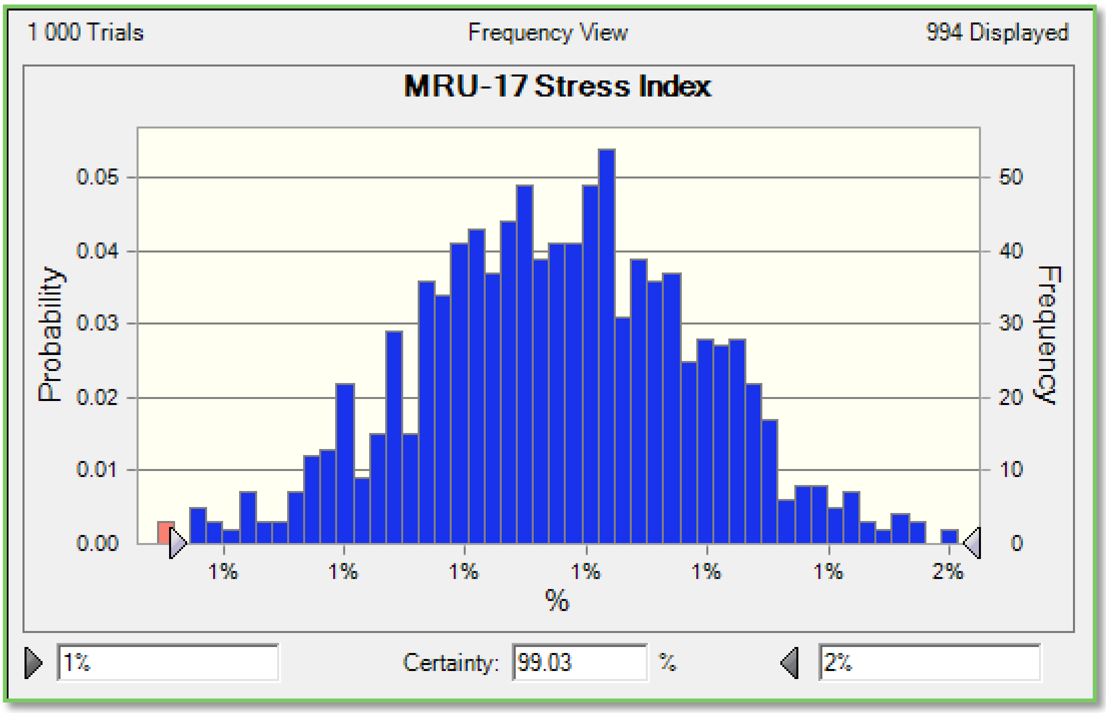


FIGURE 112: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 113**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. There is a relatively even distribution of boreholes between category A and C, therefore the final category is B.

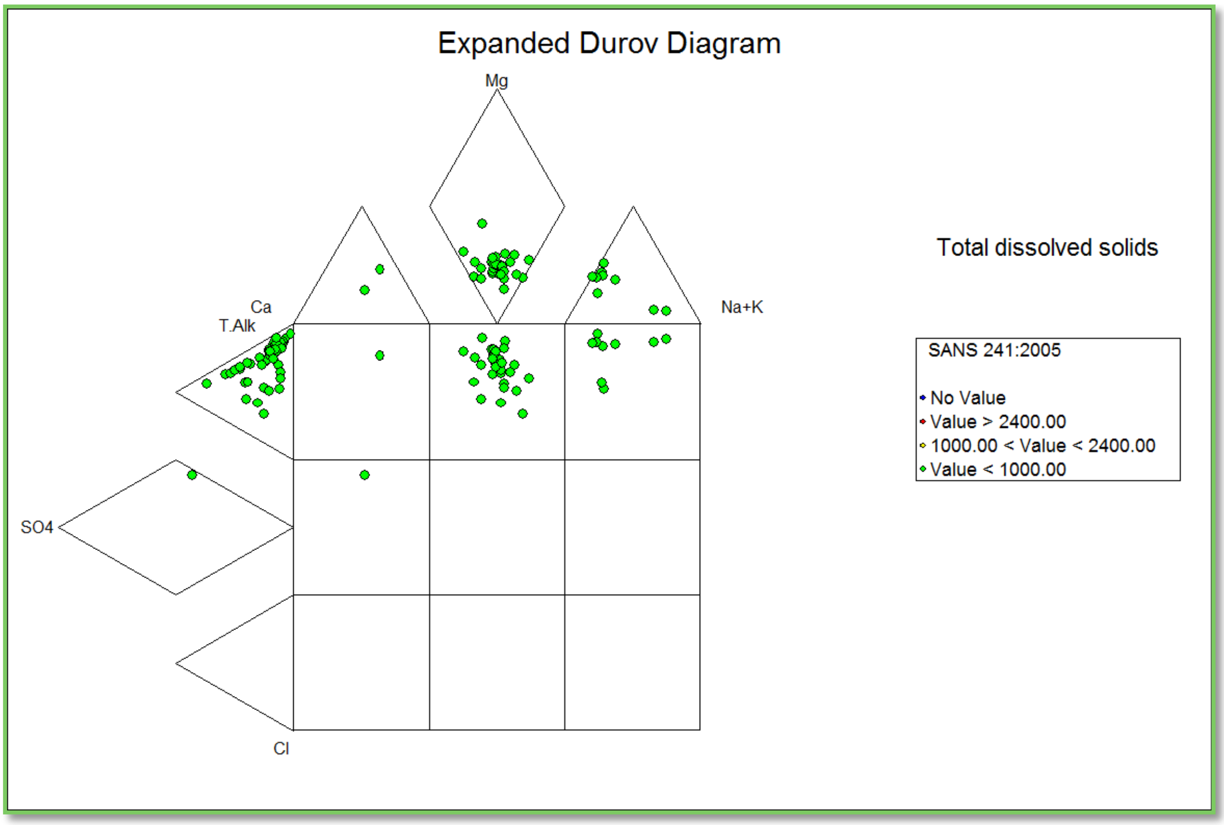


FIGURE 113: EXPANDED DUROV DIAGRAM

As documented the vulnerability is 61%. The impact of potential contamination, according to Section 2.2, is medium to the mines and agriculture taking place in the area.

Final category

The final category for the RU is summarised in **Table 129**.

TABLE 129: CATEGORY FOR RU

Impact	Present status category	Water resource category
Groundwater usage	A	Natural
Groundwater contamination	B	Good
Potential groundwater contamination (vulnerability and impact)	C	Good/Fair
FINAL	**B**	**Good**

22.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 130**.

TABLE 130: RESERVE

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
65.310	0.019	37%	110.837	2.088

23. Classification and the Reserve for RU18

23.1 Location

The quaternary catchments included by the RU are W41D, W41E and W41F. Bivane is the only town located in the RU. The location of the RU is shown **Figure 114**.

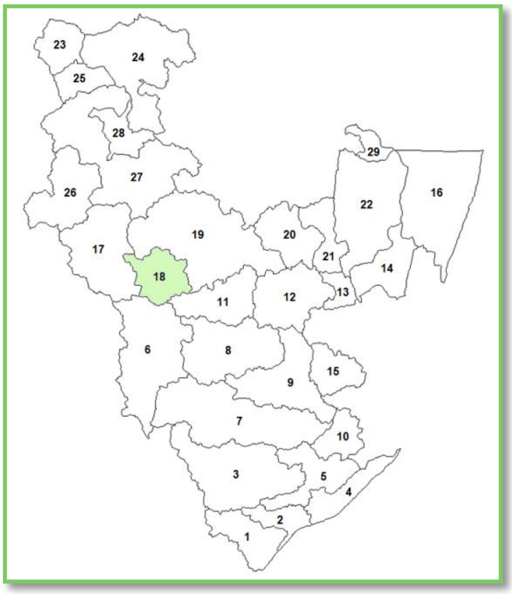


FIGURE 114: LOCATION

23.2 Climate

The summer rainfall ranges from 700 to 1 100 mm per year. Temperatures vary from -8°C to 39°C, with an average of 15°C.

23.3 Vegetation (taken from environment.gov.za)

Most of the RU comprises grasslands (**Photo 35**) containing many endemic plant species: 78 endemic or near-endemic species occur on the Black Reef quartzites. These are mostly representatives of the Lilies (Liliaceae - now split into several families), Irises (Iridaceae), Daisies (Asteraceae), Mints (Lamiaceae) and Orchids (Orchidaceae).

PHOTO 35: TYPICAL VEGETATION

In the centre of the RU the vegetation is a mix of scrub and savanna. The most common tree species include Umbrella Thorn *Acacia tortilis*, Sweet Thorn *A. karroo*, Red Bushwillow *Combretum apiculatum*, *Boscia albitrunca*, *Euclea schimperi*, *Olea europaea* subsp. *africana*, *Schotia brachypetala*, *Euphorbia* spp. and *Spirostachys africana*.

23.4 Demography and Land use

Forestry, grazing and ecotourism are the most important economic activities. Mining (mostly coal) also occurs in the RU as shown in **Figure 115**. The total population is 10450.

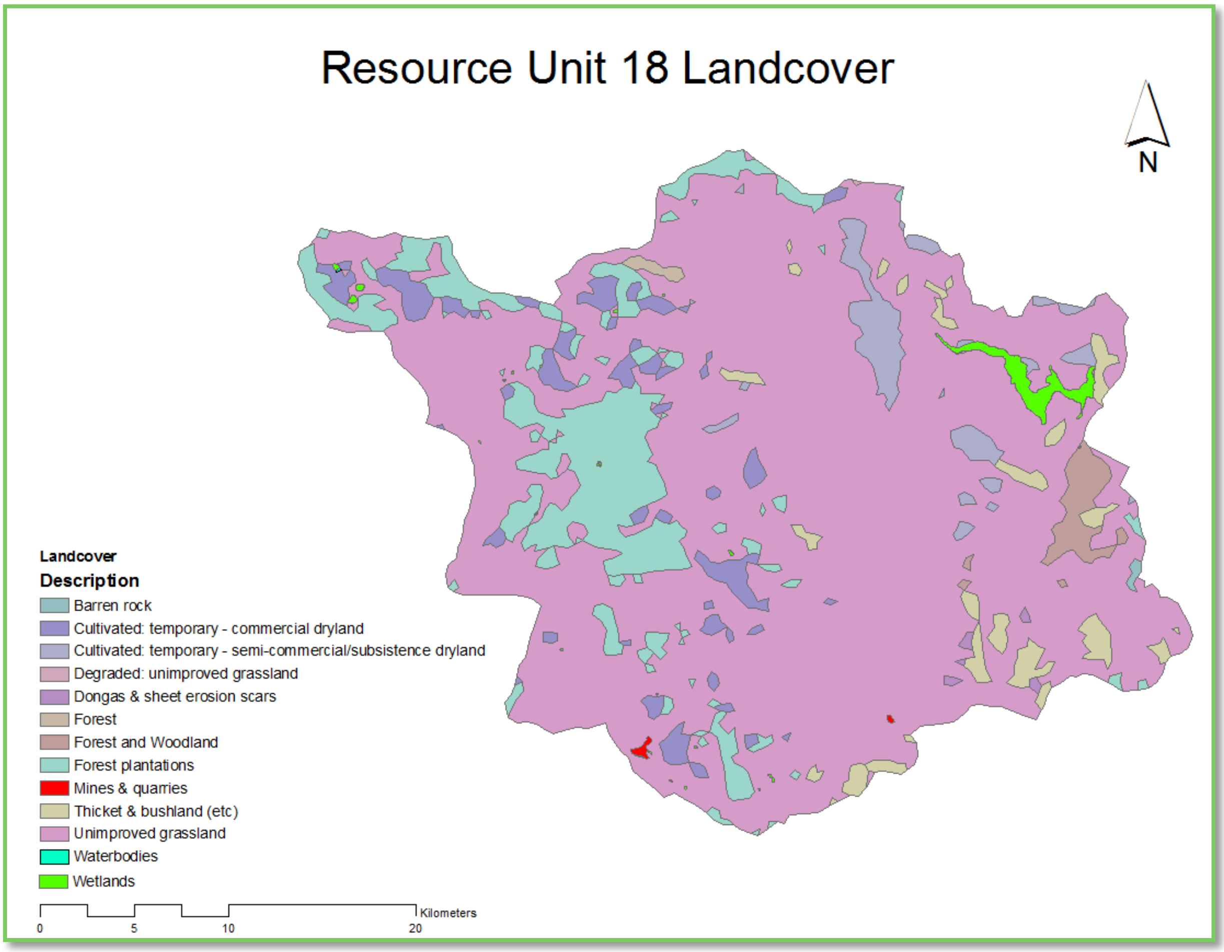


FIGURE 115: LANDCOVER

23.5 Surface water and Wetlands

The Bivane and Manzana Rivers flow through the RU. The wetlands within the RU are shown in **Figure 115**. The Bivane Dam is located within the RU.

23.6 Soils (taken from environment.gov.za)

For most of the study area the soils are mostly shallow lithosols derived from a variety of rock types. In the centre of the RU Soils are either black clays, red, structured clays or duplex soils derived from Ecca Group shale and mudstone.

23.7 Geohydrology

Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 116**. The most probable depth to groundwater level in the RU is 7.9 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

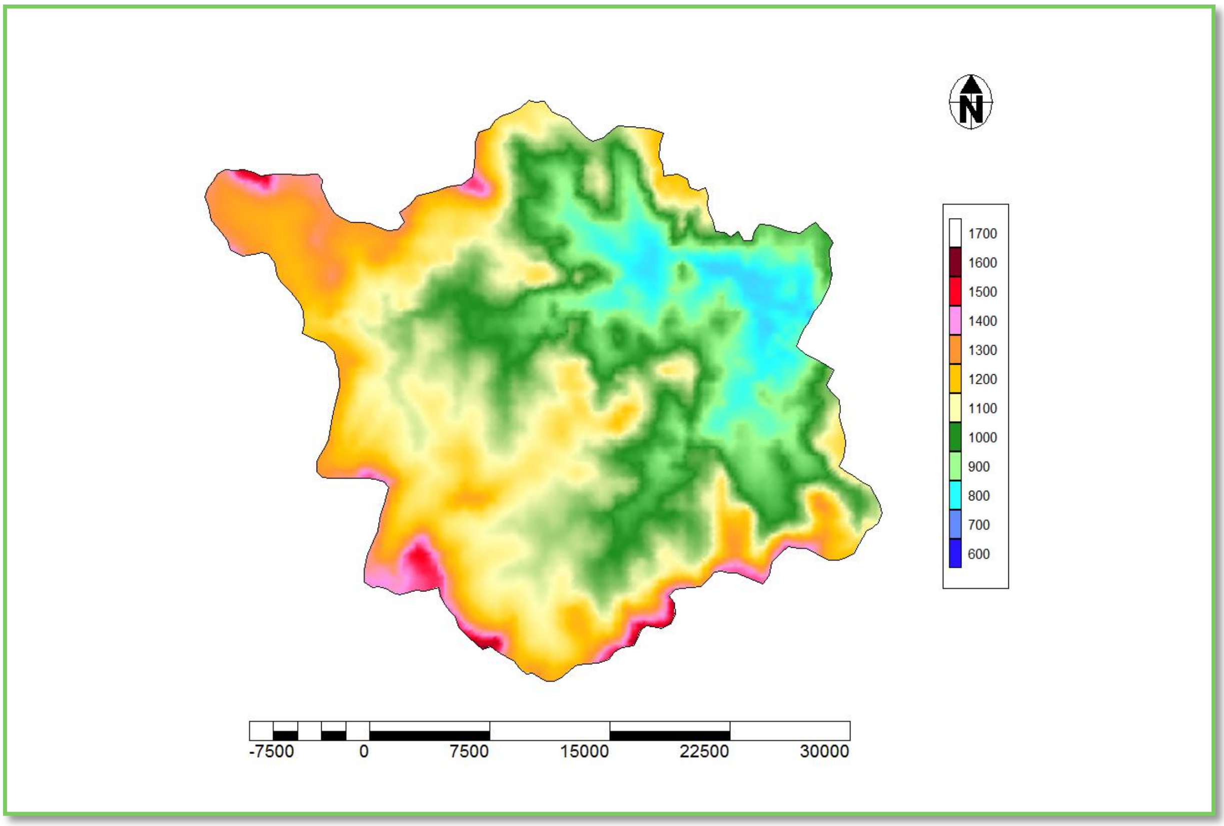


FIGURE 116: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 131**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 131: RECHARGE VALUES

Recharge							
MAP Mm^3/a	MIN Mm^3/a	MAX Mm^3/a	Volume Mm^3/a	Calculated %	CMB %	Landcover %	Geology %
746.378	51.235	73.735	66.498	8.9%	8.9%	6.1%	3.7%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 132**.

TABLE 132: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm^3/a
16731	3346	0.030

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 133** is highlighted in red.

TABLE 133: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm^3/a	Hughes Mm^3/a	Shultz Mm^3/a	Pitman Mm^3/a	vTonder Mm^3/a	MIN Mm^3/a	MAX Mm^3/a	Herold Mm^3/a
15.270	69.945	43.682	26.904	39.670	4.645	73.735	26.980

Groundwater use

The groundwater use in the catchment is documented in **Table 134**.

TABLE 134: GROUNDWATER USE

Groundwater Use							
GRDM Mm^3/a	WARMS Mm^3/a	Hydrocensus Mm^3/a	MIN Mm^3/a	MAX Mm^3/a	Forrest Mm^3/a	Crops Mm^3/a	TOTAL Mm^3/a
0.080	0.052	0.107	0.052	0.427	4.500	0.072	4.542

Groundwater quality

The TDS values for the RU are shown in **Figure 117**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines.

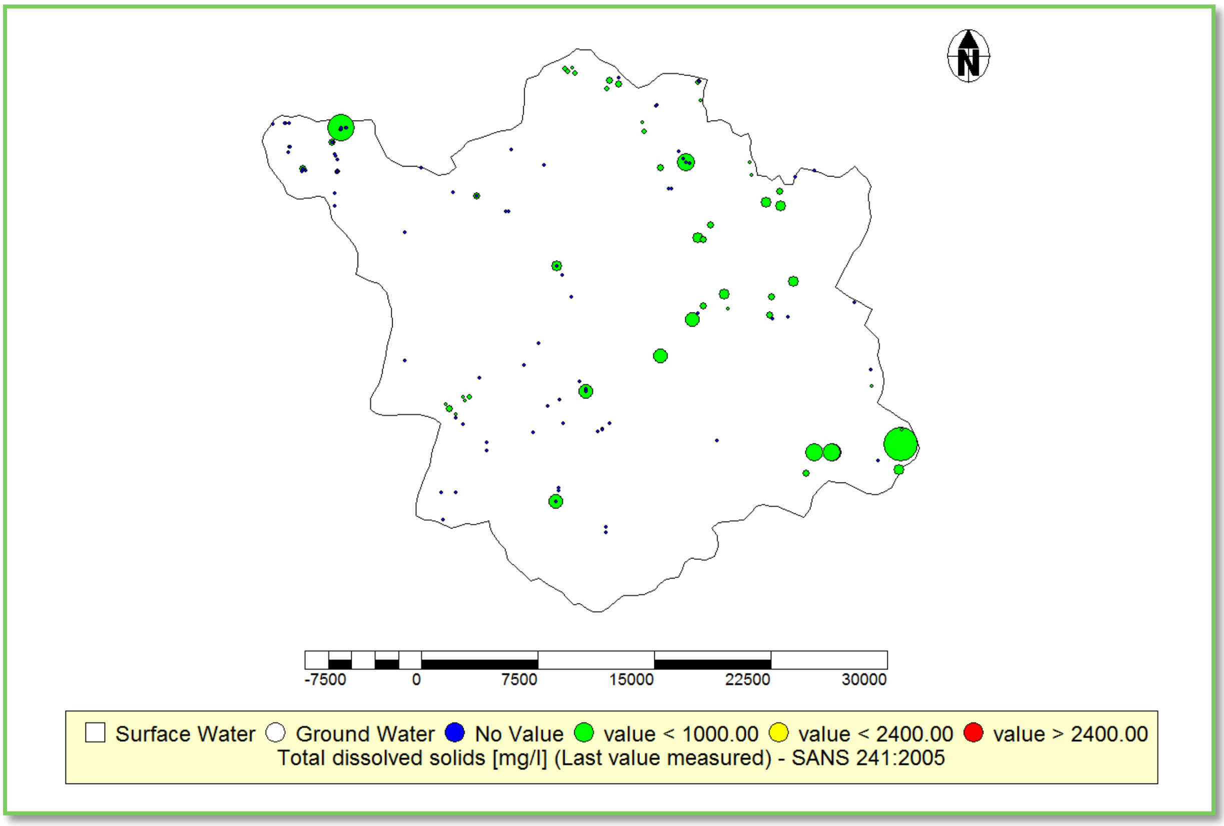


FIGURE 117: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 135**. The slope histogram is documented in Appendix D.

TABLE 135: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
7.9	8.9%	1.1	SaClLm-SaCl , LmSa-SaLm	Weathered/Fractured	Natal	61%

23.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 6.9%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 0.454 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in **Figure 118**. It is clear from the results that the stress index will vary between 5% and 9%, with a certainty of 99.11%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

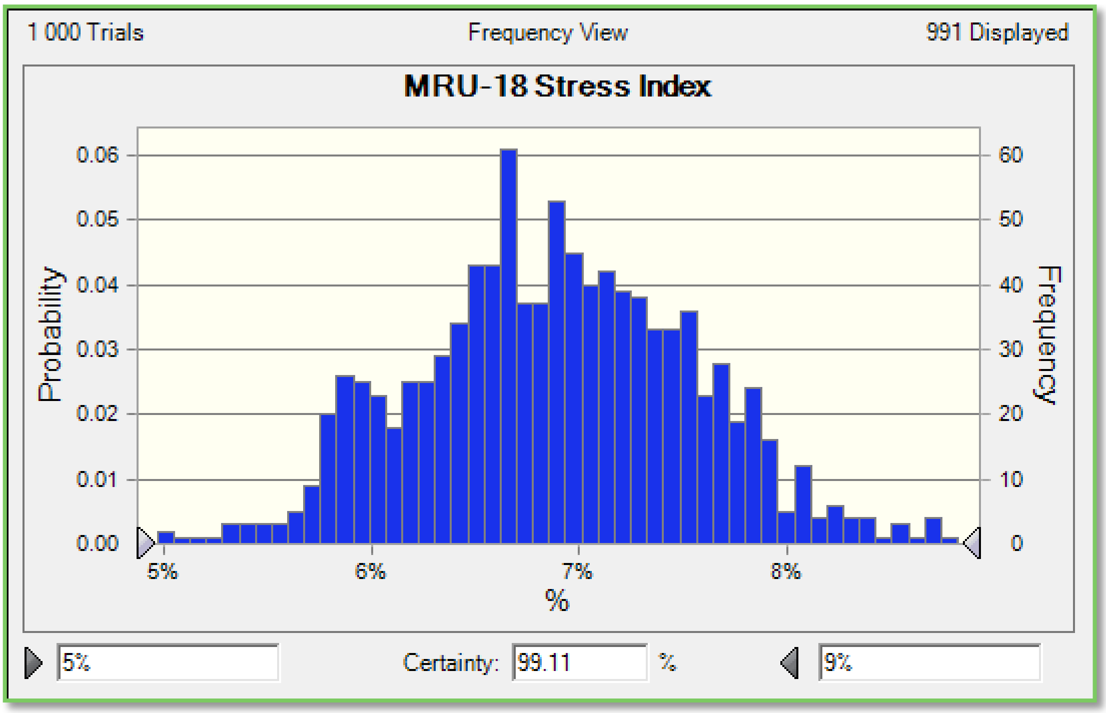


FIGURE 118: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 119**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. There is a relatively even distribution of boreholes between category A and C, therefore the final category is B.

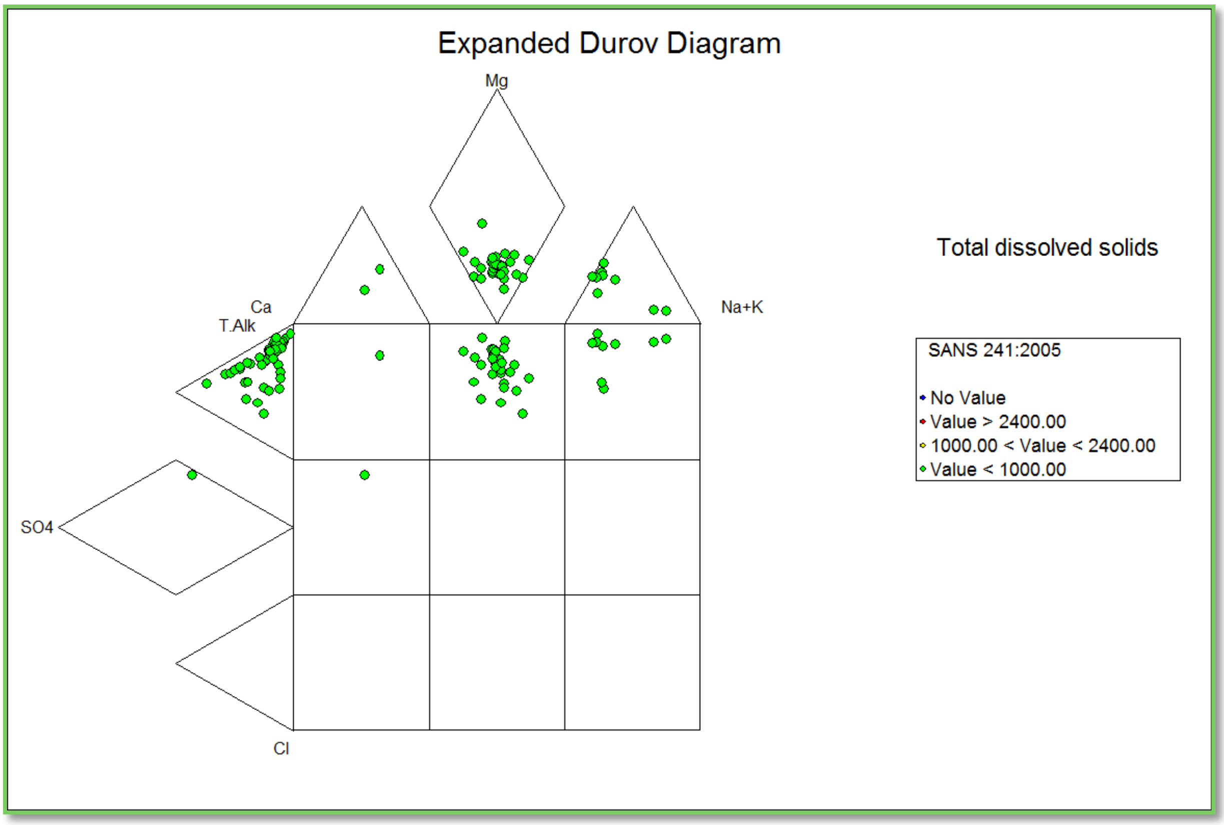


FIGURE 119: EXPANDED DUROV DIAGRAM

As documented the vulnerability is 61%. The impact of potential contamination according to Section 2.2, is medium due to the agricultural activities in the RU.

Final category

The final category for the RU is summarised in **Table 136**.

TABLE 136: CATEGORY FOR RU

Impact	Present status category	Water resource category
Groundwater usage	B	Good
Groundwater contamination	B	Good
Potential groundwater contamination (vulnerability and impact)	C	Good/Fair
FINAL	**B**	**Good**

23.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 137**.

TABLE 137: RESERVE

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
26.980	0.030	41%	34.945	4.542

24. Classification and the Reserve for RU19

24.1 Location

The quaternary catchments included in this RU are W42D, W42E, W42F, W42G, W42H, W42J, W42K, W42M, W42A, W43B, W43C and W44A. The location of the RU is shown in **Figure 120**. The towns located in the RU are Paulpietersburg, Commondale and Berbice. The protected areas included are Itala and Pongola Game Parks, and Witbad.

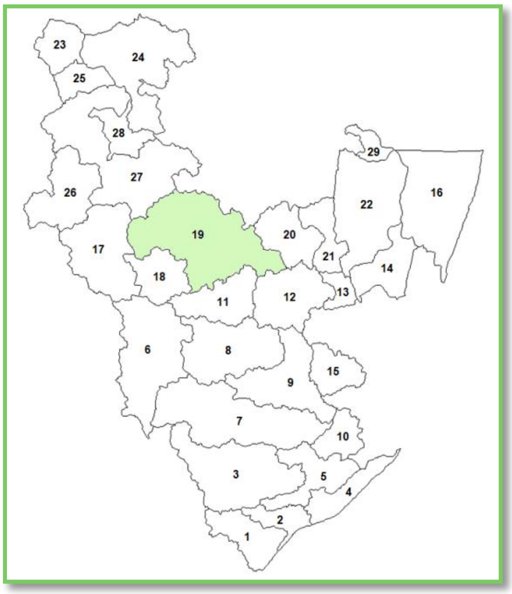


FIGURE 120: LOCATION

24.2 Climate

The summer rainfall ranges from 700 to 1100 mm per year. Temperatures vary from -8°C to 39°C, with an average of 15°C.

PHOTO 36: TYPICAL VEGETATION
(Source: www.panoramio.com)

24.3 Vegetation (taken from environment.gov.za)

Most of the RU comprises grasslands (**Photo 36**) contain many endemic plant species: 78 endemic or near-endemic species occur on the Black Reef quartzites. These are mostly representatives of the Lilies (Liliaceae - now split into several families), Irises (Iridaceae), Daisies (Asteraceae), Mints (Lamiaceae) and Orchids (Orchidaceae).

In the centre of the RU the vegetation is a mix of scrub and savanna. The most common tree species include Umbrella Thorn *Acacia tortilis*, Sweet Thorn *A. karroo*, Red Bushwillow *Combretum apiculatum*, *Boscia albitrunca*, *Euclea schimperi*, *Olea europaea* subsp. *africana*, *Schotia brachypetala*, *Euphorbia* spp. and *Spirostachys africana*.

PHOTO 37: RURAL POPULATION
(Source: www.panoramio.com)

24.4 Demography and Land use

Forestry, grazing and ecotourism are the most important economic activities. Mining (mostly coal) also occurs in the RU as shown in **Figure 121**. The total population is 61650. It is a rural area (**Photo 37**).

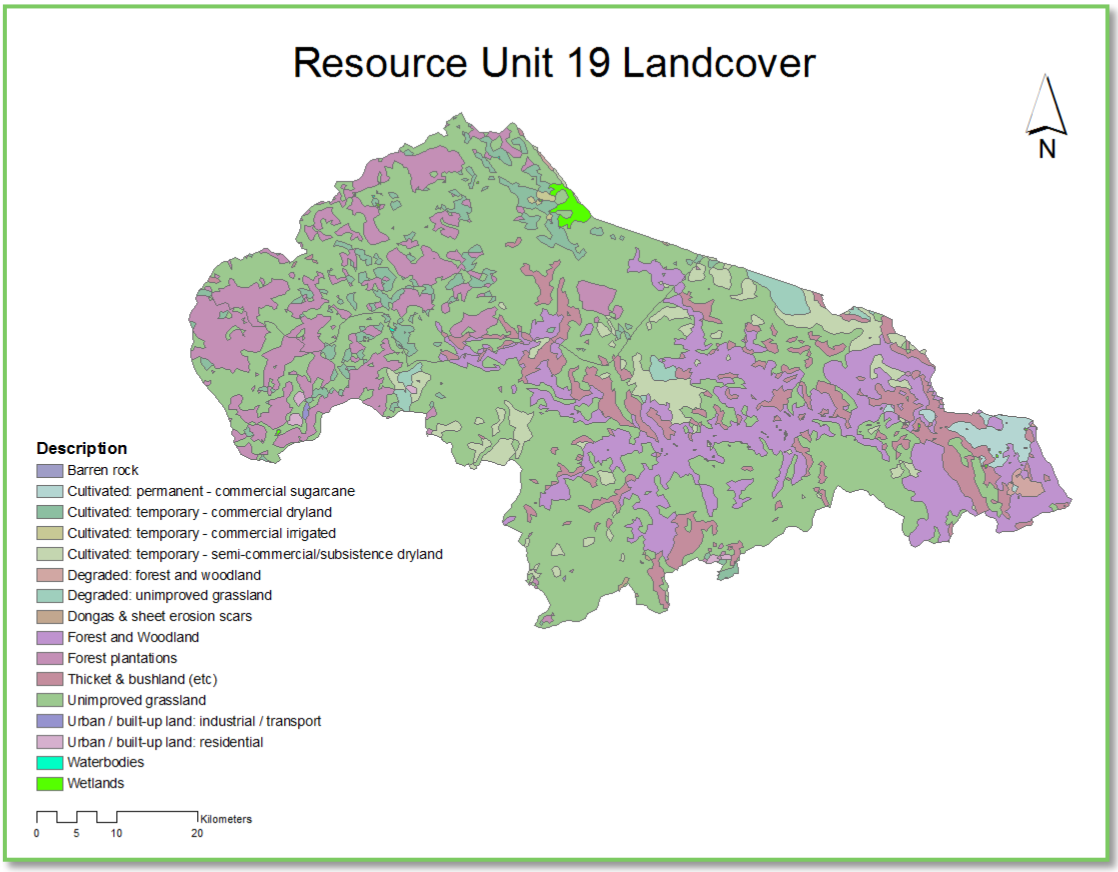


FIGURE 121: LANDCOVER

24.5 Surface water and Wetlands

The Pongola, Wit, Mozana, Ithalu Rivers are the main rivers in the study area. The location of wetlands is shown in **Figure 121**.

24.6 Soils (taken from environment.gov.za)

For most of the study area the soils are mostly shallow lithosols derived from a variety of rock types. In the centre of the RU Soils are either black clays, red, structured clays or duplex soils derived from Ecca Group shale and mudstone.

24.7 Geohydrology

Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 122**. The most probable depth to groundwater level in the RU is 6.9 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

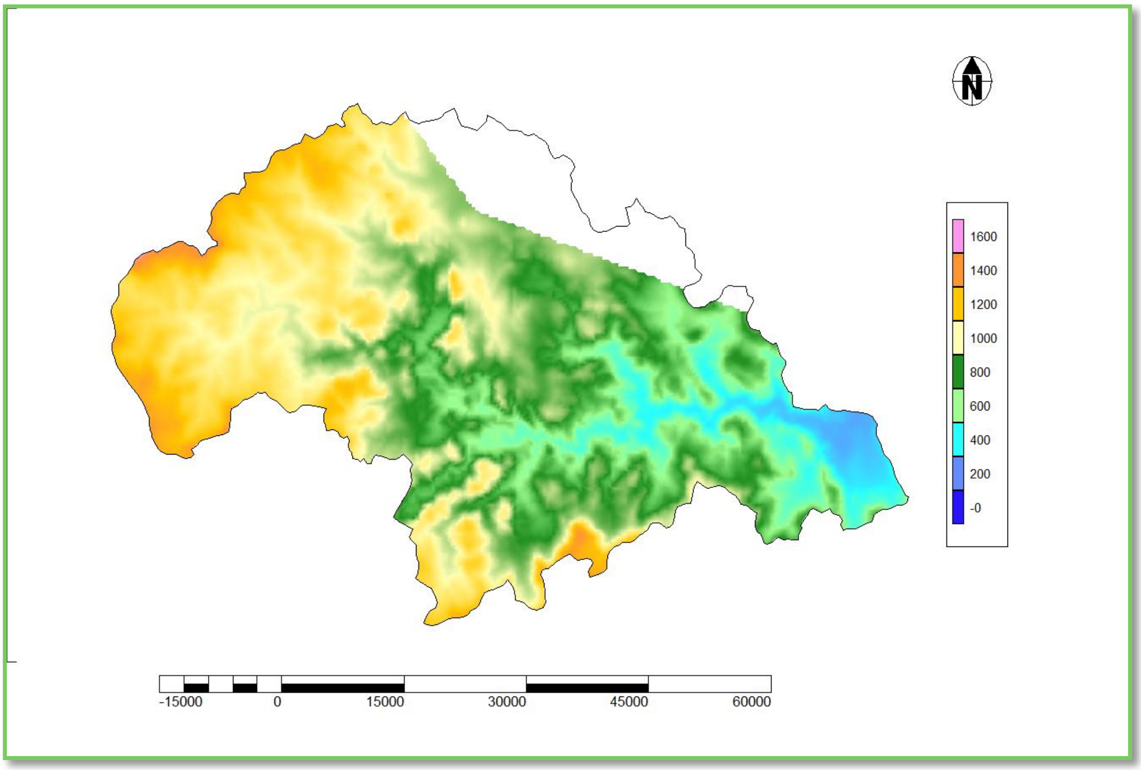


FIGURE 122: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 138**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 138: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
2581.238	148.441	227.594	224.301	8.7%	8.7%	3.6%	3.7%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 139**.

TABLE 139: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
100814	20163	0.181

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 140** is highlighted in red.

TABLE 140: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
51.928	219.079	138.691	89.317	127.402	18.702	227.594	89.734

Groundwater use

The groundwater use in the catchment is documented in **Table 141**.

TABLE 141: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
3.880	0.438	0.424	0.424	3.880	7.200	1.612	8.631

Groundwater quality

The TDS values for the RU are shown in **Figure 123**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines.

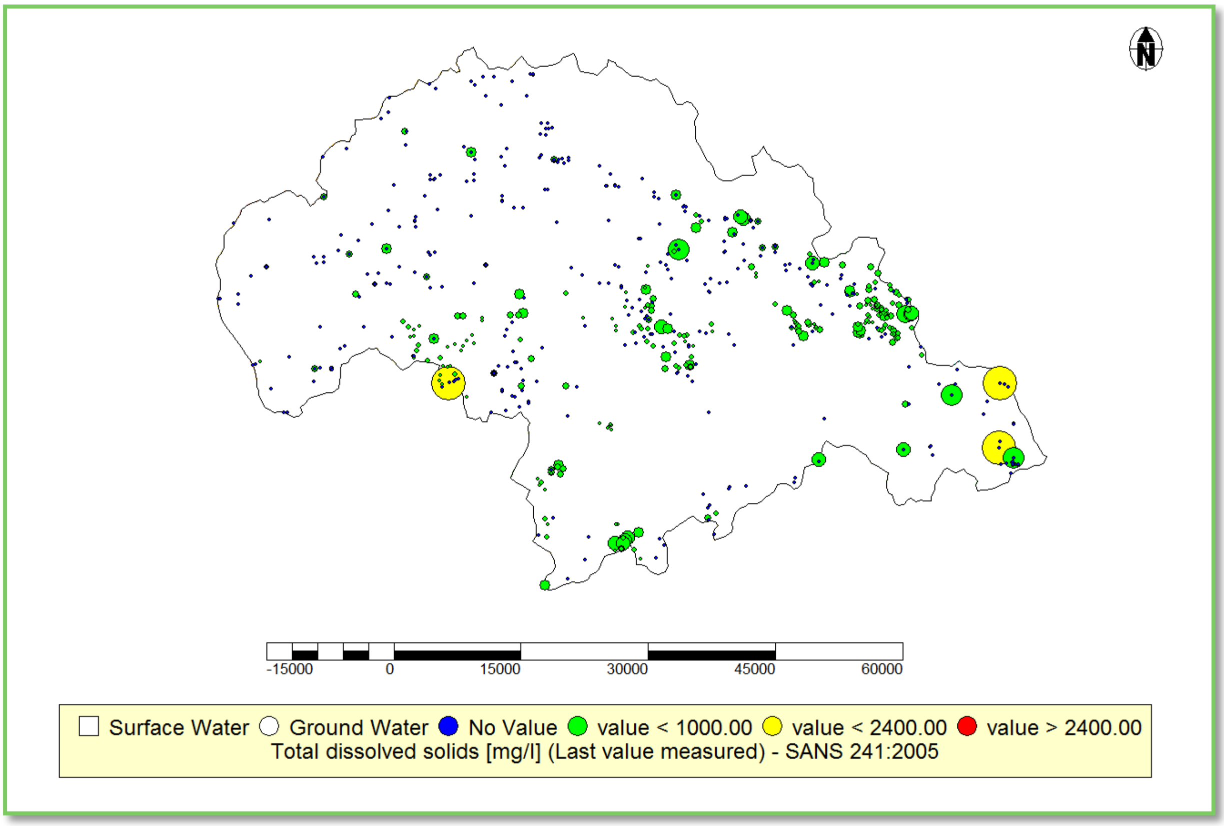


FIGURE 123: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 142**. The slope histogram is documented in Appendix D.

TABLE 142: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
6.9	8.7%	1.1	SaClLm-SaCl , LmSa-SaLm	Weathered/Fractured	Natal	62%

24.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 3.9%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 0.863 Mm^3/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in **Figure 124**. It is clear from the results that the stress index will vary between 3% and 5%, with a certainty of 99.37%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

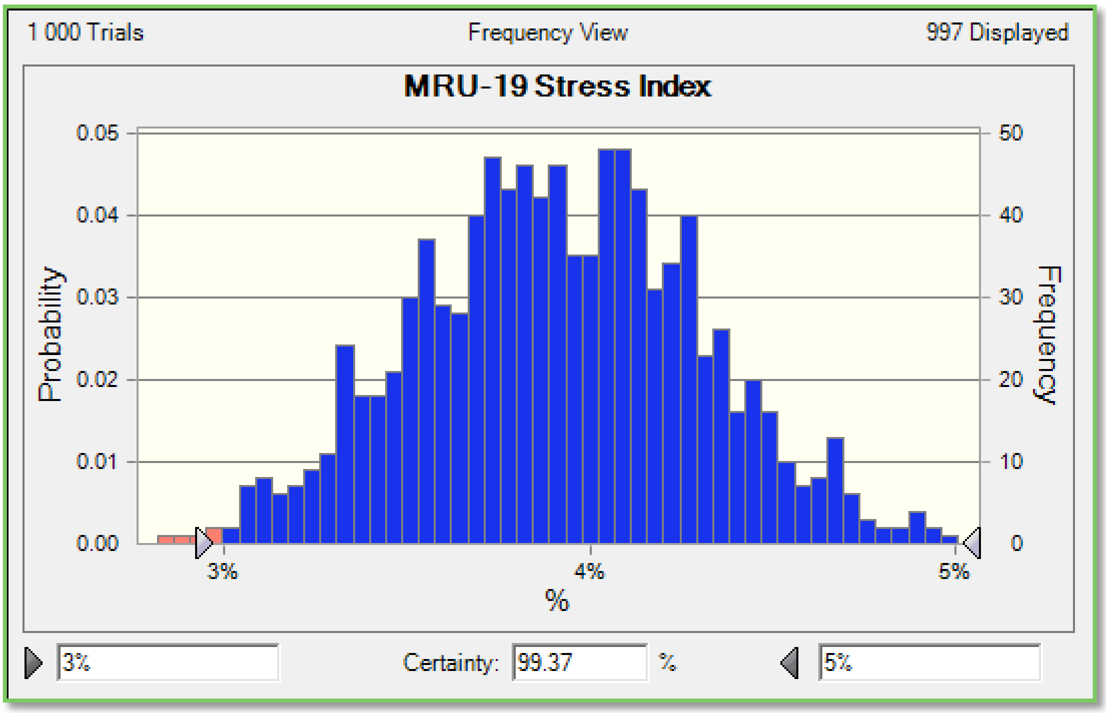


FIGURE 124: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 125**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. There is a relatively even distribution of boreholes between category A and C, therefore the final category is B.

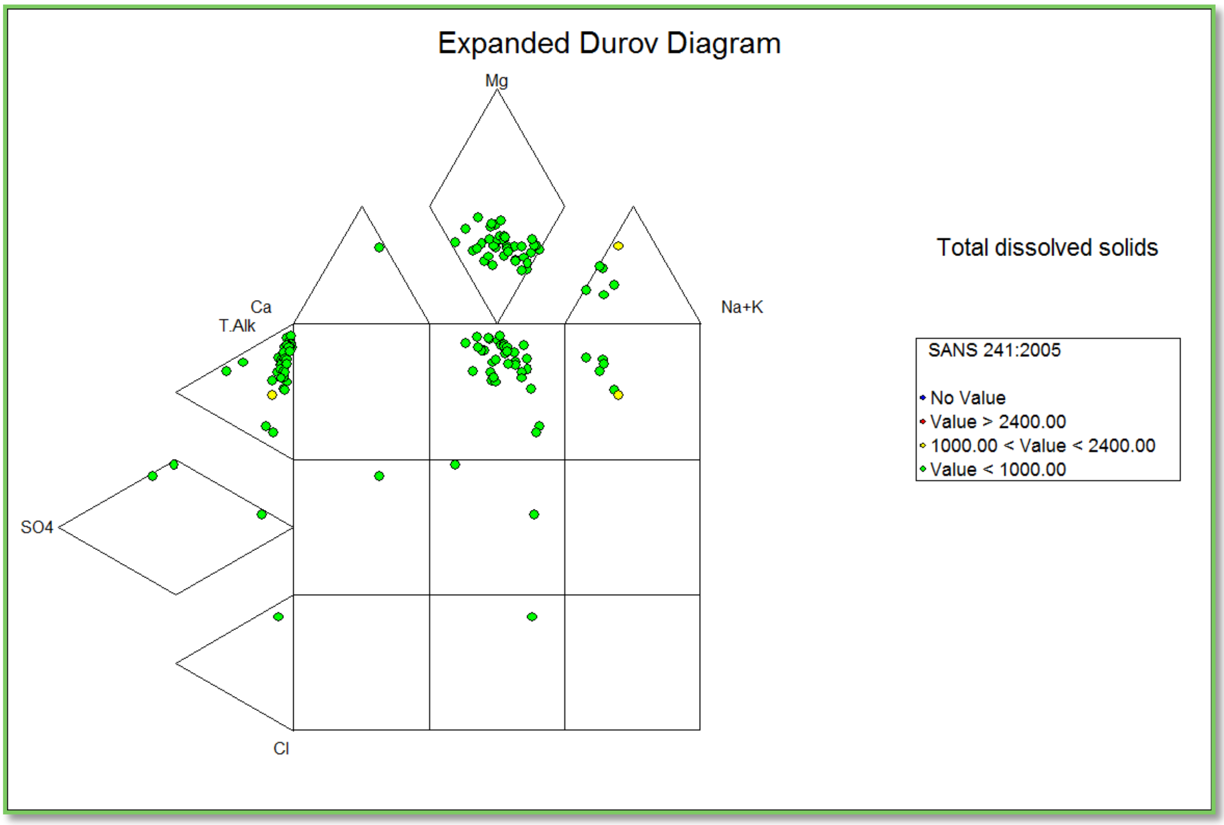


FIGURE 125: EXPANDED DUROV DIAGRAM

As documented the vulnerability is 62%. The impact of potential contamination according to Section 2.2, is medium due to the large number of tree plantations.

Final category

The final category for the RU is summarised in **Table 143**.

TABLE 143: CATEGORY FOR RU

Impact	Present status category	Water resource category
Groundwater usage	A	Natural
Groundwater contamination	B	Good
Potential groundwater contamination (vulnerability and impact)	C	Good/Fair
FINAL	**B**	**Good**

24.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 144**.

TABLE 144: RESERVE

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
89.734	0.181	40%	125.755	8.631

25. Classification and the Reserve for RU20

25.1 Location

The quaternary catchments included in the RU are W44B, W44C and W44D. Pongola and Golela are the towns in the RU. Protected areas include Pongola Dam and Leeukop. The location of the RU is shown in **Figure 126**.

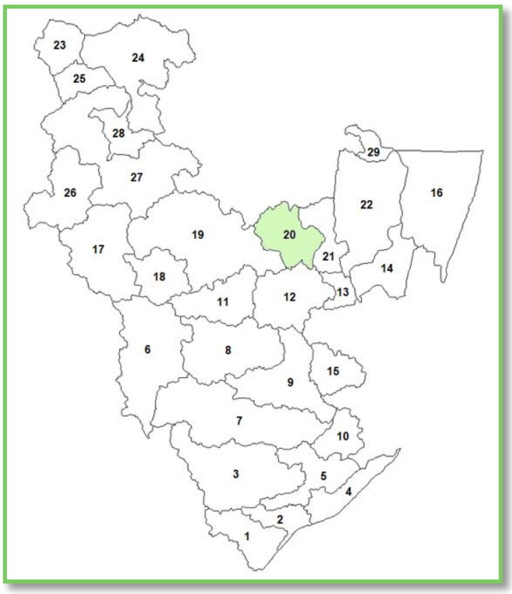


FIGURE 126: LOCATION

25.2 Climate

The annual summer rainfall for the area varies from 450 to 800 mm. Temperatures vary between -4°C and 45°C, with an average of 22°C.

25.3 Vegetation (taken from environment.gov.za)

In the northern sections of the RU, the vegetation can be described variously as dense bush on the uplands, open tree savanna in the bottomlands, and dense riverine woodland on banks. In the southern sections the vegetation is a mix of scrub and savanna.

PHOTO 38: SUGAR MILL AT PONGOLA

25.4 Demography and Land use

Cattle and game farming, ecotourism, and the cultivation of subtropical fruit, vegetables and sugarcane are important land uses. Forestry and mining (sand) also occurs. There is a sugar mill in Pongola (**Photo 38**).

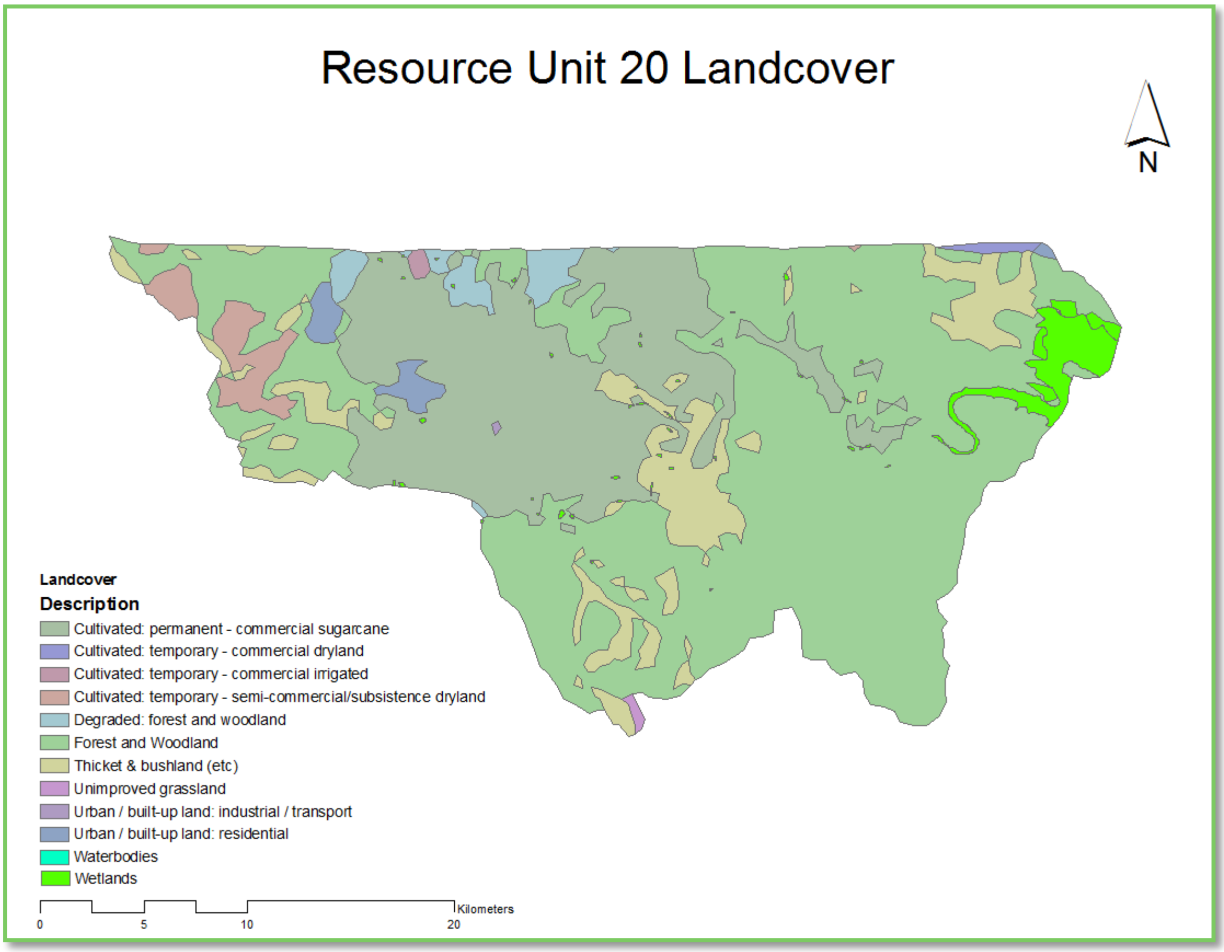


FIGURE 127: LANDCOVER

25.5 Surface water and Wetlands

The Pongola River and its tributaries flow through the RU. The wetlands in the RU are shown in **Figure 127.**

25.6 Soils (taken from environment.gov.za)

In the north, the substrate is characterised by sandy soils in the uplands and clayey soils with a high sodium content in the bottomlands. In the south, soils are either black clays, red, structured clays or duplex soils derived from Ecca Group shale and mudstone.

25.7 Geohydrology

Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 128**. The most probable depth to groundwater level in the RU is 6.4 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

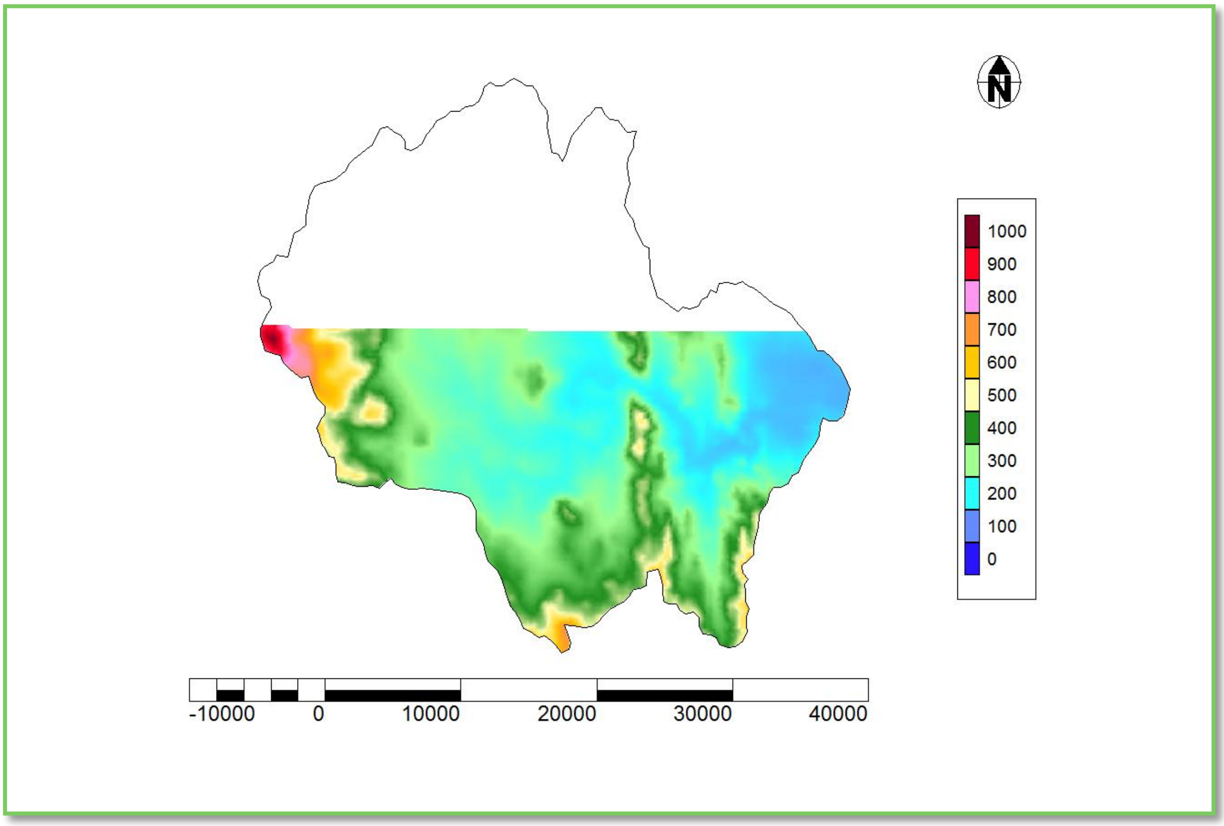


FIGURE 128: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 145**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 145: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
652.793	20.287	36.660	26.846	4.1%	4.1%	1.1%	2.8%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 146**.

TABLE 146: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
31749	6350	0.057

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 147** is highlighted in red.

TABLE 147: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
8.642	9.688	3.612	1.231	3.434	0.476	36.660	1.231

Groundwater use

The groundwater use in the catchment is documented in **Table 148**.

TABLE 148: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
1.380	0.091	0.006	0.006	1.380	9.000	0.217	9.160

Groundwater quality

The TDS values for the RU are shown in **Figure 129**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines.

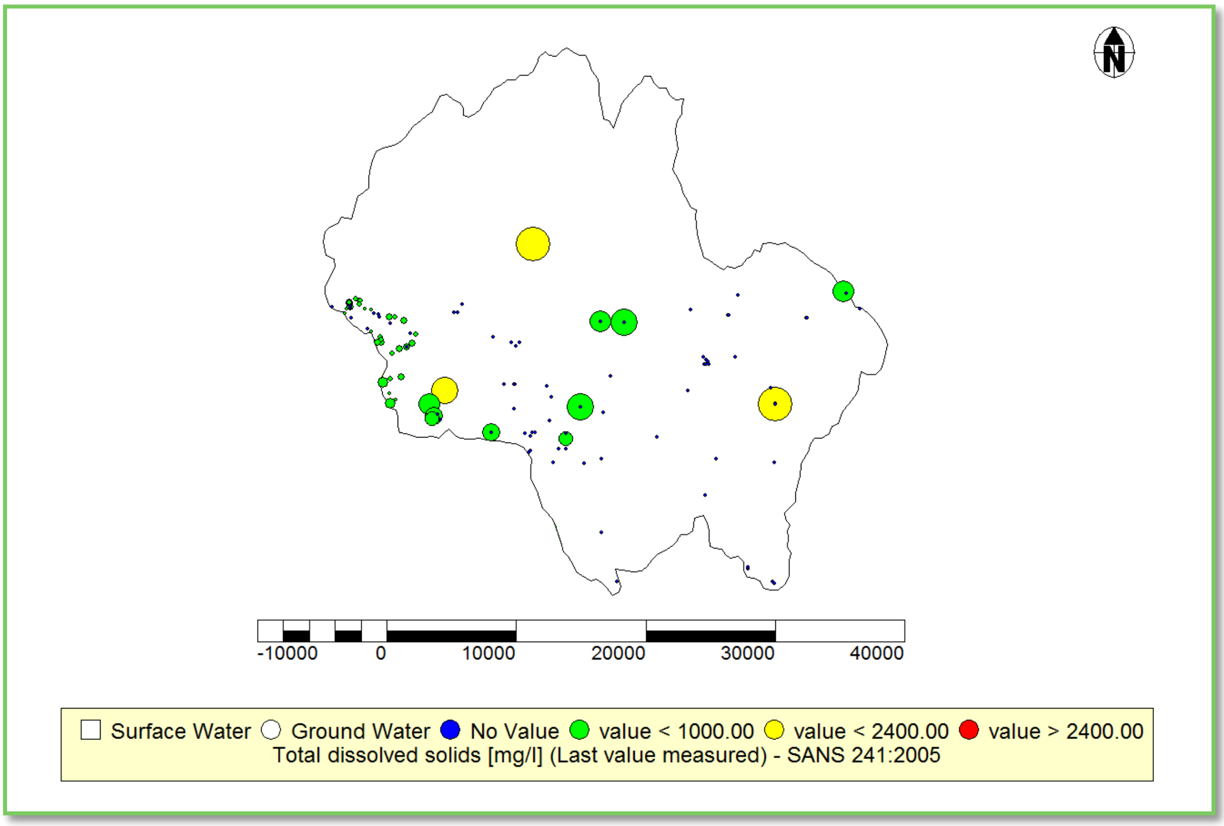


FIGURE 129: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 149**. The slope histogram is documented in Appendix D.

TABLE 149: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
6.4	4.1%	1.3	SaClLm-SaCl , SaCl-Cl	Weathered/Fractured	Natal	57%

25.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 34.3%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 0.916 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in **Figure 130**. It is clear from the results that the stress index will vary between 30% and 40%, with a certainty of 99.65%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

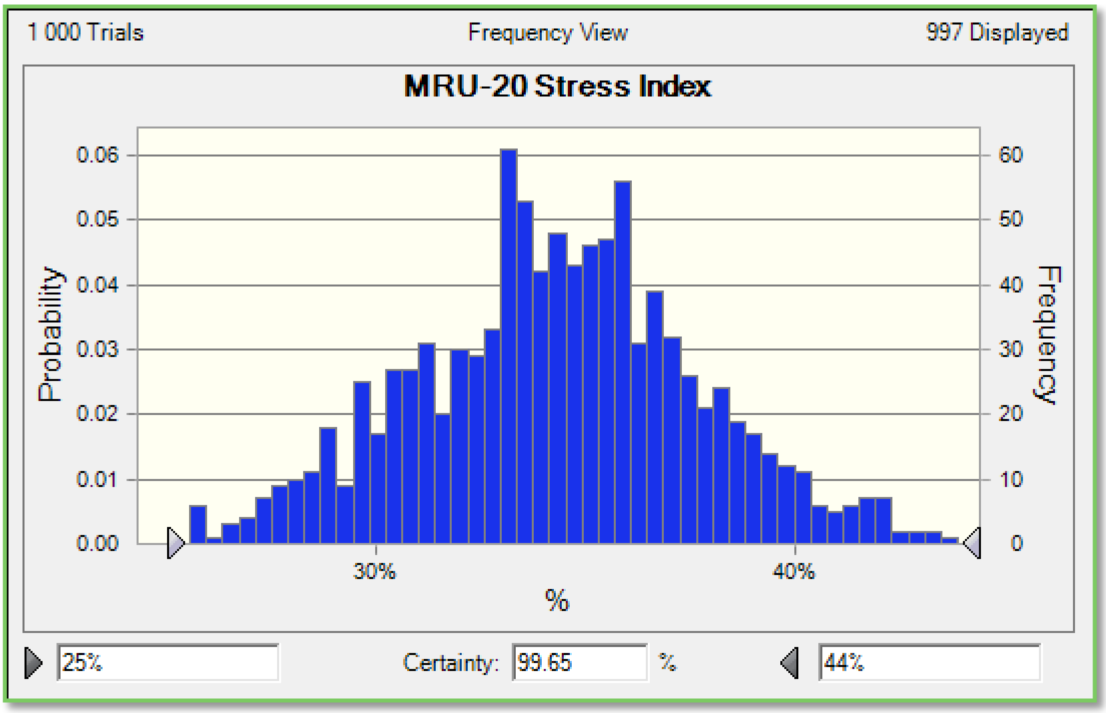


FIGURE 130: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 131**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. The majority of the boreholes are classified as C.

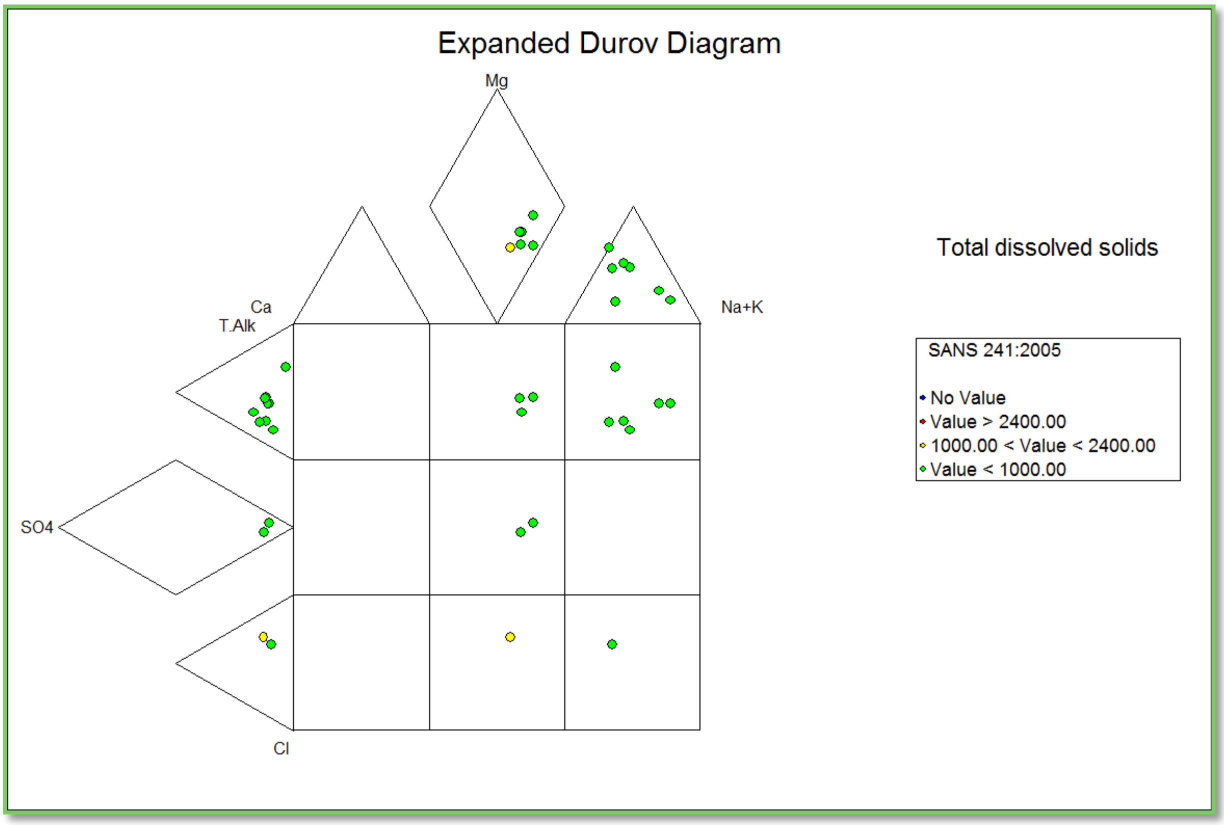


FIGURE 131: EXPANDED DUROV DIAGRAM

As documented the vulnerability is 57%. The impact of potential contamination according to Section 2.2, is medium due to a relatively large amount of agricultural activities.

Final category

The final category for the RU is summarised in **Table 150**.

TABLE 150: CATEGORY FOR RU

Impact	Present status category	Water resource category
Groundwater usage	C	Good/Fair
Groundwater contamination	C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	C	Good/Fair
FINAL	**C**	**Good/Fair**

25.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 151**.

TABLE 151: RESERVE

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
1.231	0.057	5%	16.398	9.160

26. Classification and the Reserve for RU21

26.1 Location

There is only one quaternary catchment in the study area, namely W44E. The Pongola Dam is protected within the RU. The towns include Lavumisa and Jozini. The location is shown in **Figure 132**.

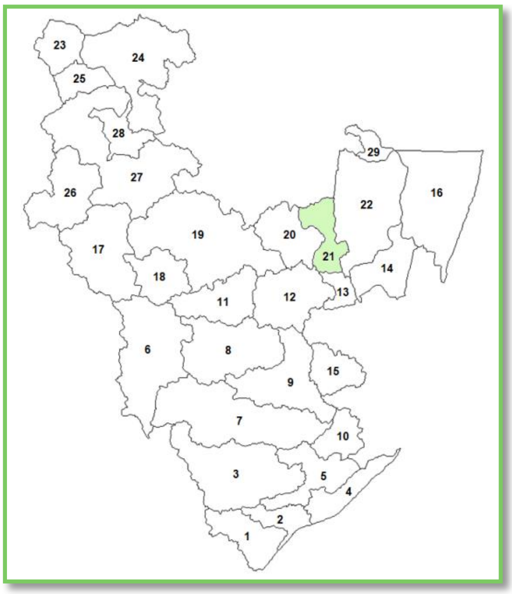


FIGURE 132: LOCATION

26.2 Climate

Rainfall varies from 550 to 600 mm per year, falling in summer. Temperatures range between -2°C and 43°C, with an average of 22°C.

26.3 Vegetation (taken from environment.gov.za)

The vegetation is open tree savanna with a moderately developed shrub layer and a dense herbaceous layer. The tree layer is characterised by Marula Sclerocarya birrea, Knob Thorn Acacia nigrescens, Live-long Lannea stuhlmannii, Lonchocarpus capassa and Peltophorum africanum.

PHOTO 39: COTTON PICKERS

(Source: www.panoramio.com)

26.4 Demography and Land use

The total population for the study area according to the 2001 census is 500. The land use in the RU includes ecotourism, game and cattle farming, and the cultivation of subtropical fruit, cotton (**Photo 39**), vegetables and sugarcane (**Figure 133**).

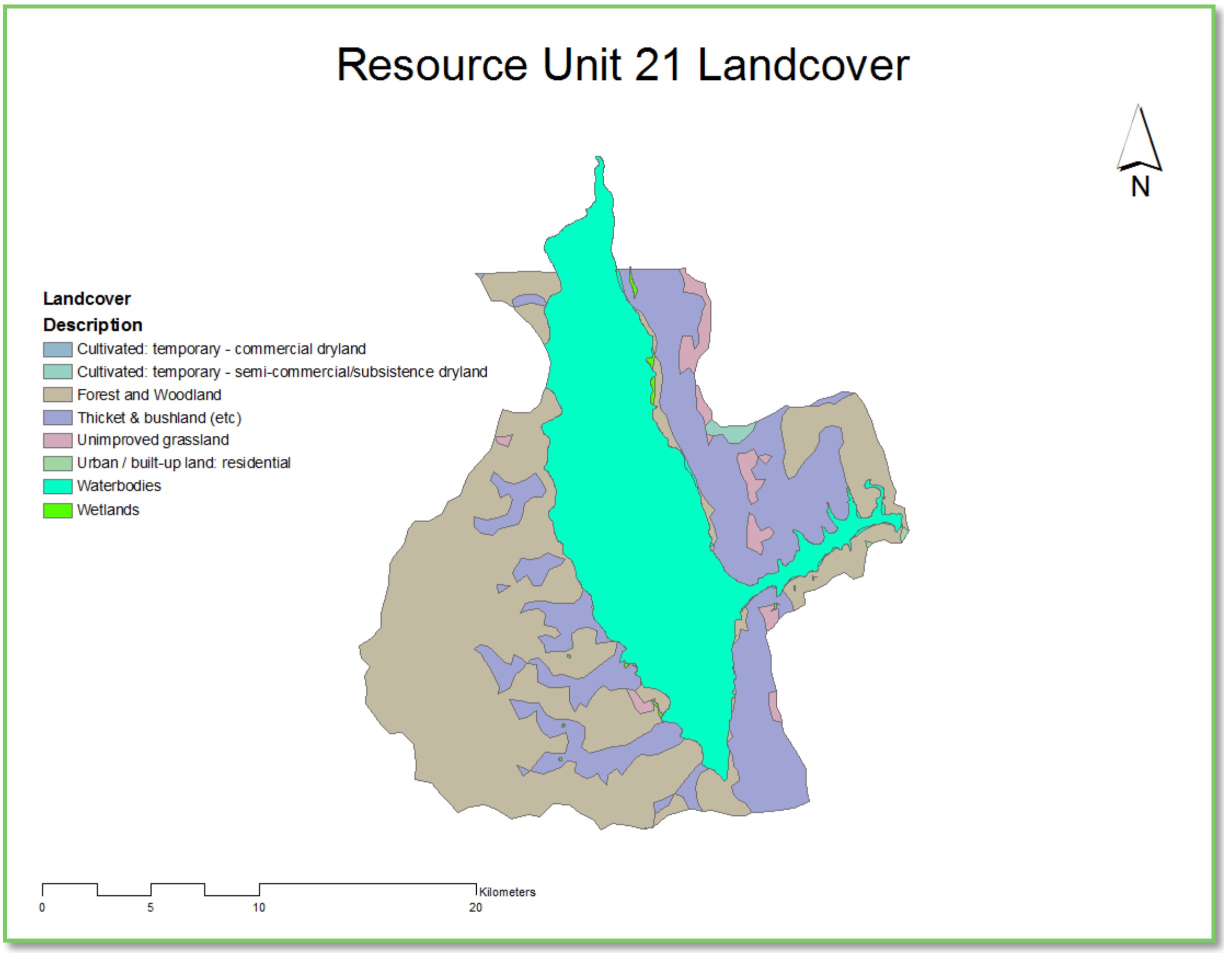


FIGURE 133: LANDCOVER

26.5 Surface water and Wetlands

The Pongola River flows into the Pongola Dam. The wetlands in the study area are shown in **Figure 133**.

26.6 Soils (taken from environment.gov.za)

The clay soils, is derived from basalt, and the influence vegetation.

26.7 Geohydrology

Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 134**. The most probable depth to groundwater level in the RU is 8.1 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

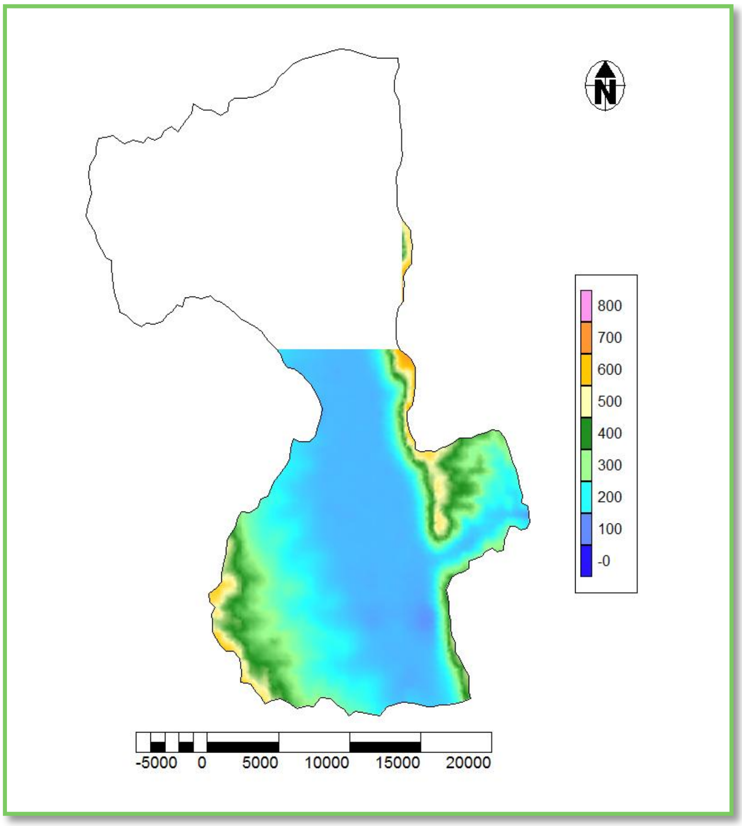


FIGURE 134: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 152**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 152: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
413.323	13.524	32.013	29.514	7.1%	7.1%	6.7%	3.8%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 153**.

TABLE 153: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
115	23	0.000

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 154** is highlighted in red.

TABLE 154: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
9.621	5.215	2.063	0.751	1.932	0.534	32.013	0.751

Groundwater use

The groundwater use in the catchment is documented in **Table 155**.

TABLE 155: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
0.020	0.000	0.003	0.000	0.020	5.400	0.000	5.400

Groundwater quality

The TDS values for the RU are shown in **Figure 135**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines.

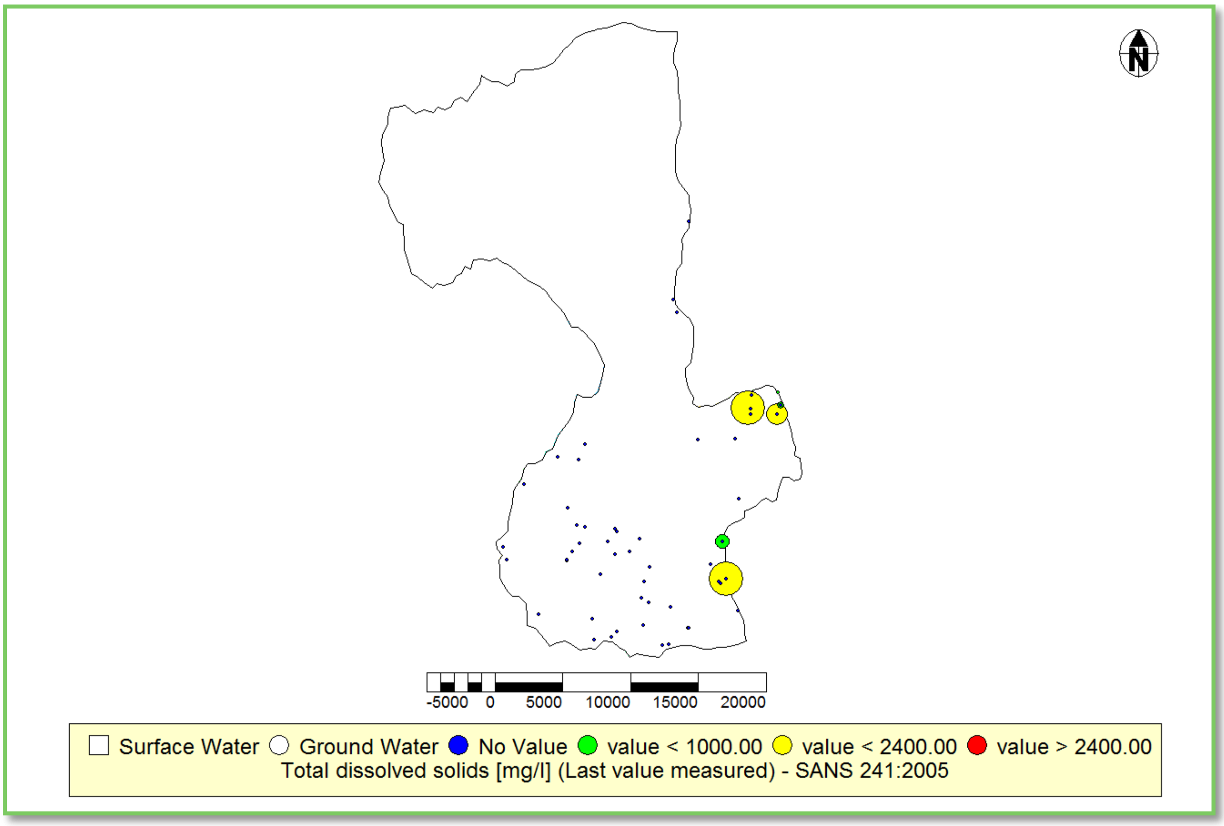


FIGURE 135: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 156**. The slope histogram is documented in Appendix D.

TABLE 156: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
8.1	7.1%	1.4	LmSa-SaLm	Weathered/Fractured	Natal	60%

26.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 18.3%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 0.540 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in **Figure 136**. It is clear from the results that the stress index will vary between 14% and 23%, with a certainty of 99.62%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

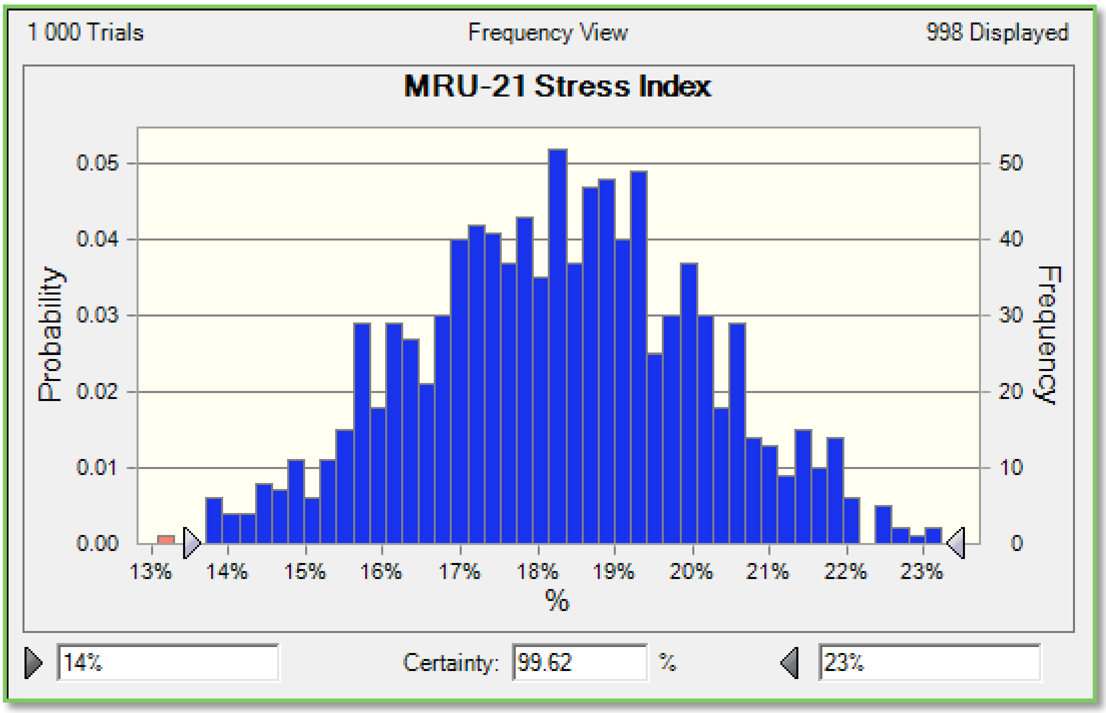


FIGURE 136: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 137**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. It is apparent that the contamination category, according to the explanation, is C.

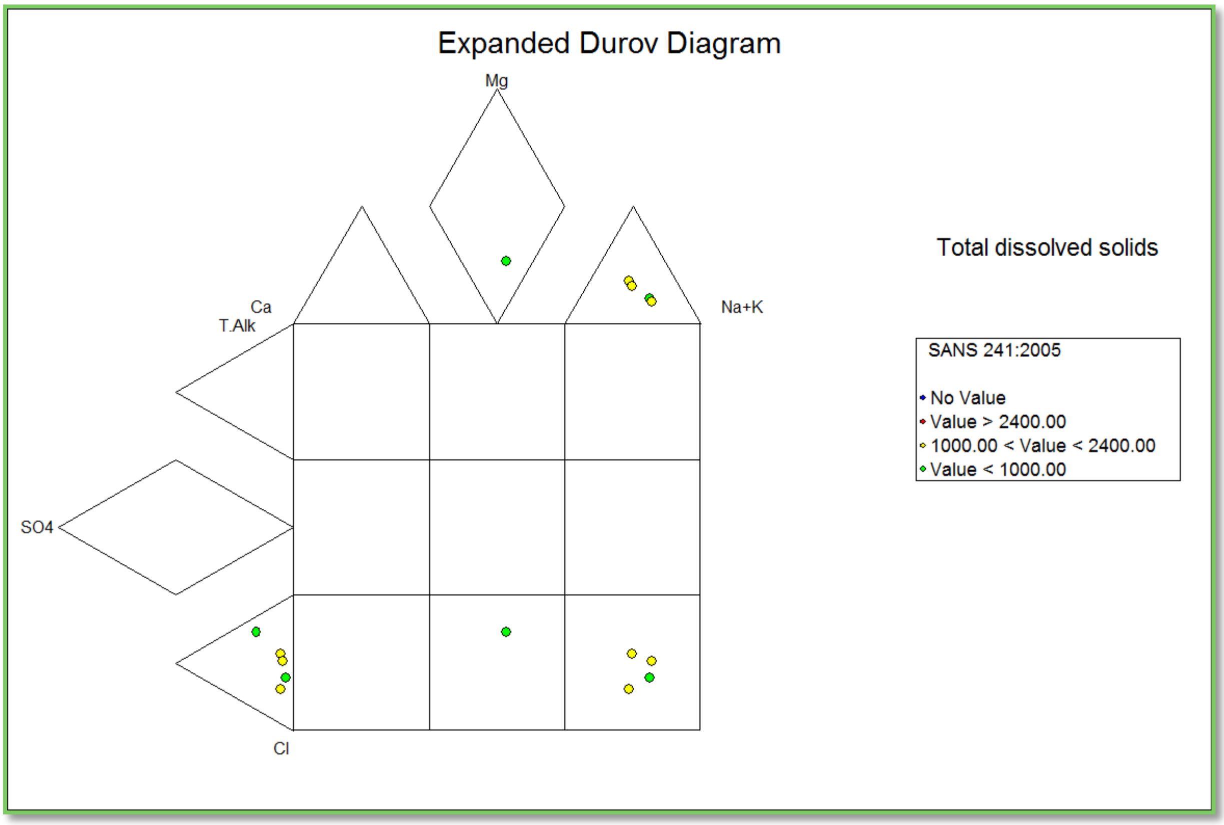


FIGURE 137: EXPANDED DUROV DIAGRAM

As documented the vulnerability is 60%. The impact of potential contamination according to Section 2.2, is high due to almost the whole RU being utilised for agriculture.

Final category

The final category for the RU is summarised in **Table 157**.

TABLE 157: CATEGORY FOR RU

Impact	Present status category	Water resource category
Groundwater usage	B	Good
Groundwater contamination	C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	D	Fair
FINAL	**C**	**Good/Fair**

26.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 158**.

TABLE 158: RESERVE

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
0.751	0.000	3%	23.363	5.400

27. Classification and the Reserve for RU22

27.1 Location

The location of the study area is shown in **Figure 138**. The quaternary catchments include W43F, W45A and W45B. Ingwavuma is the only town in the area. The protected areas include the Hlatikulu, Ndumo (**Photo 40**) and Tembe Elephant Parks.

PHOTO 40: NDUMO GAME PARK
(Source: www.panoramio.com)

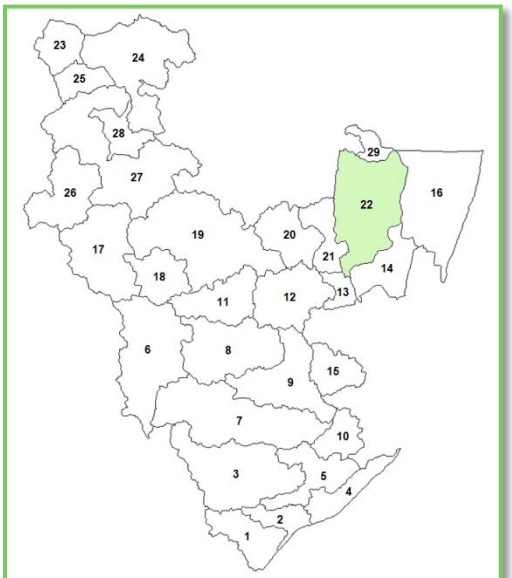


FIGURE 138: LOCATION

27.2 Climate

Annual rainfall ranges from 450 to 700 mm. Temperatures vary between -l°C and 46°C, with an average of 23°.

27.3 Vegetation (taken from environment.gov.za)

In the western parts of the RU most common tree species are Lebombo Ironwood Androstachys johnsonii, Red Bushwillow Combretum apiculatum, Shepherd's Tree Boscia albitrunca, Cassia abbreviate, Acacia nigrescens, Albizia harveyi, Kirkia acuminata, Croton gratissimus, Euphorbia confinalis, Terminalia phanerophlebia, Pterocarpus rotundifolia, Ozoroa engleri and Sterculia rogersii. The grass layer is moderately well developed, depending on the rockiness of the area. The eastern sections are a dense bushveld related to forest, composed of large trees with a dense shrub layer.

27.4 Demography and Land use

The main activities are cattle and game farming, forestry and ecotourism. There are 94828 (2001 census data) people living in the RU. The Landcover is shown in **Figure 139**.

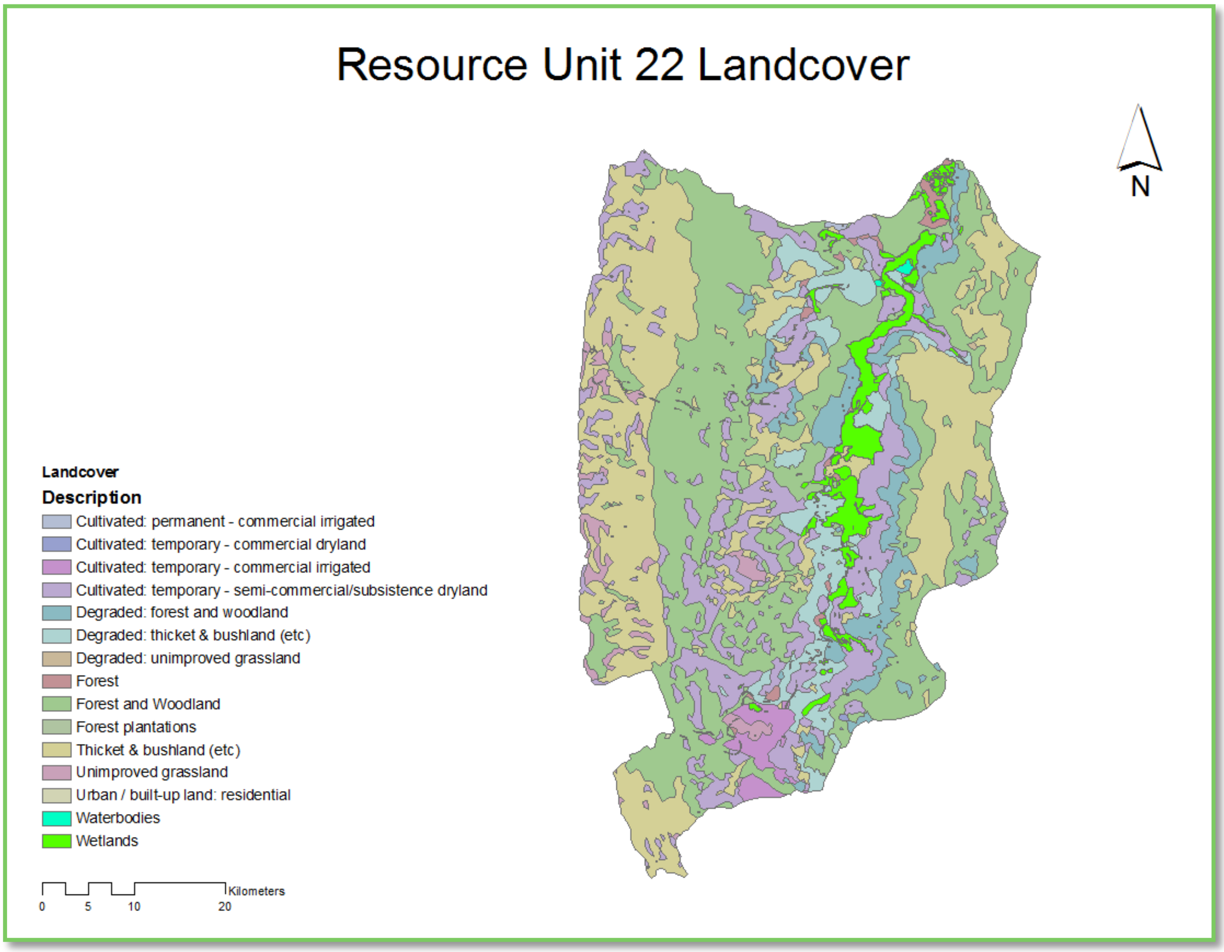


FIGURE 139: LANDCOVER

27.5 Surface water and Wetlands

The Pongola River and its tributaries drain the study area. The wetlands are shown in **Figure 139**.

27.6 Soils (taken from environment.gov.za)

In the western sections, the geology is rhyolite and granophyre. These give rise to shallow, acidic, sandy soils that can be classified as lithosols. Along the coast the soils are Quaternary aeolian sand of marine origin.

27.7 Geohydrology

Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 140**. The most probable depth to groundwater level in the RU is 9.2 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

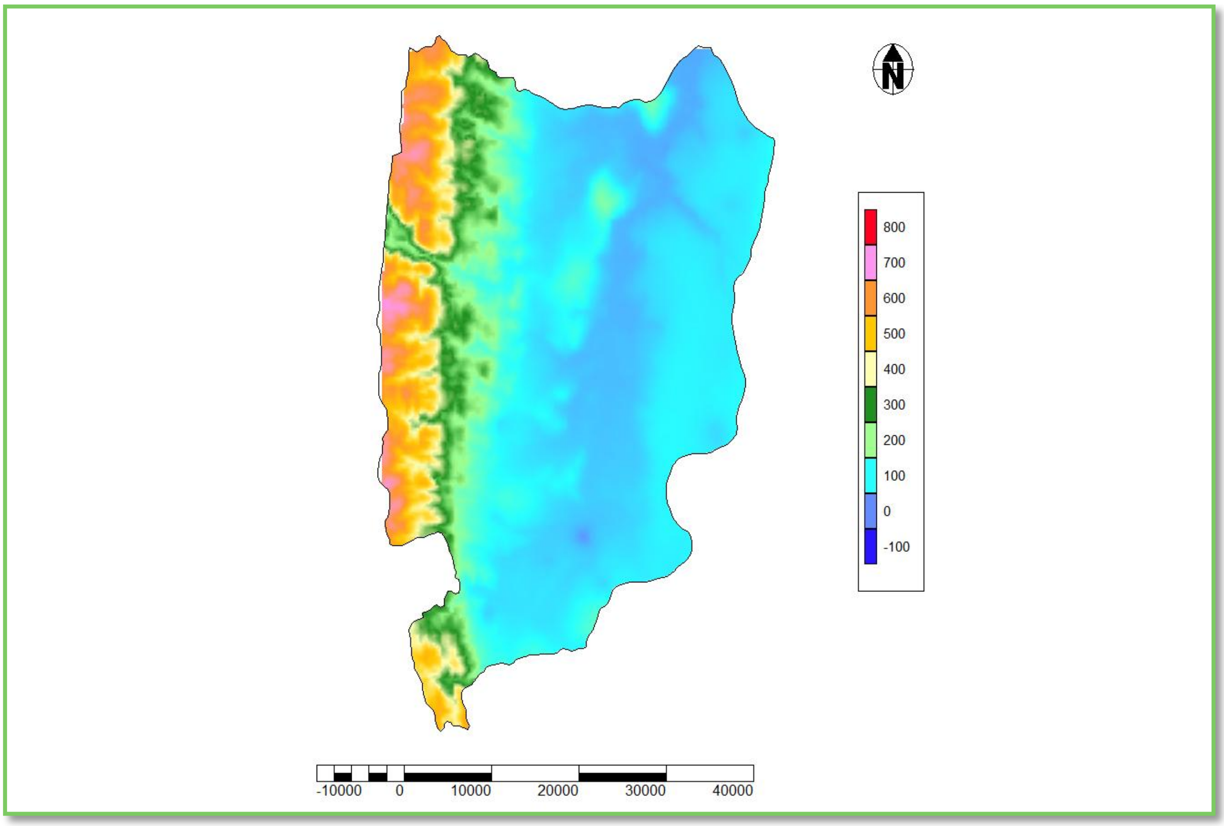


FIGURE 140: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 159**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

Table 159: Recharge values

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
1518.993	45.742	109.301	48.354	3.2%	3.2%	9.1%	3.4%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 160**.

Table 160: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
109052	21810	0.196

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 161** is highlighted in red.

Table 161: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
44.921	23.412	10.634	3.030	8.962	2.410	109.301	3.030

Groundwater use

The groundwater use in the catchment is documented in **Table 162**.

Table 162: Groundwater use

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
2.850	0.000	0.017	0.000	2.850	18.000	0.000	17.804

Groundwater quality

The TDS values for the RU are shown in **Figure 141**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. There are a number of boreholes that exceed the drinking water guidelines. These areas should be treated as hotspots rather than applying a poor classification to the whole resource unit. Treatment of the hot spot areas will be addressed under Resource Quality Objectives in Section 35.

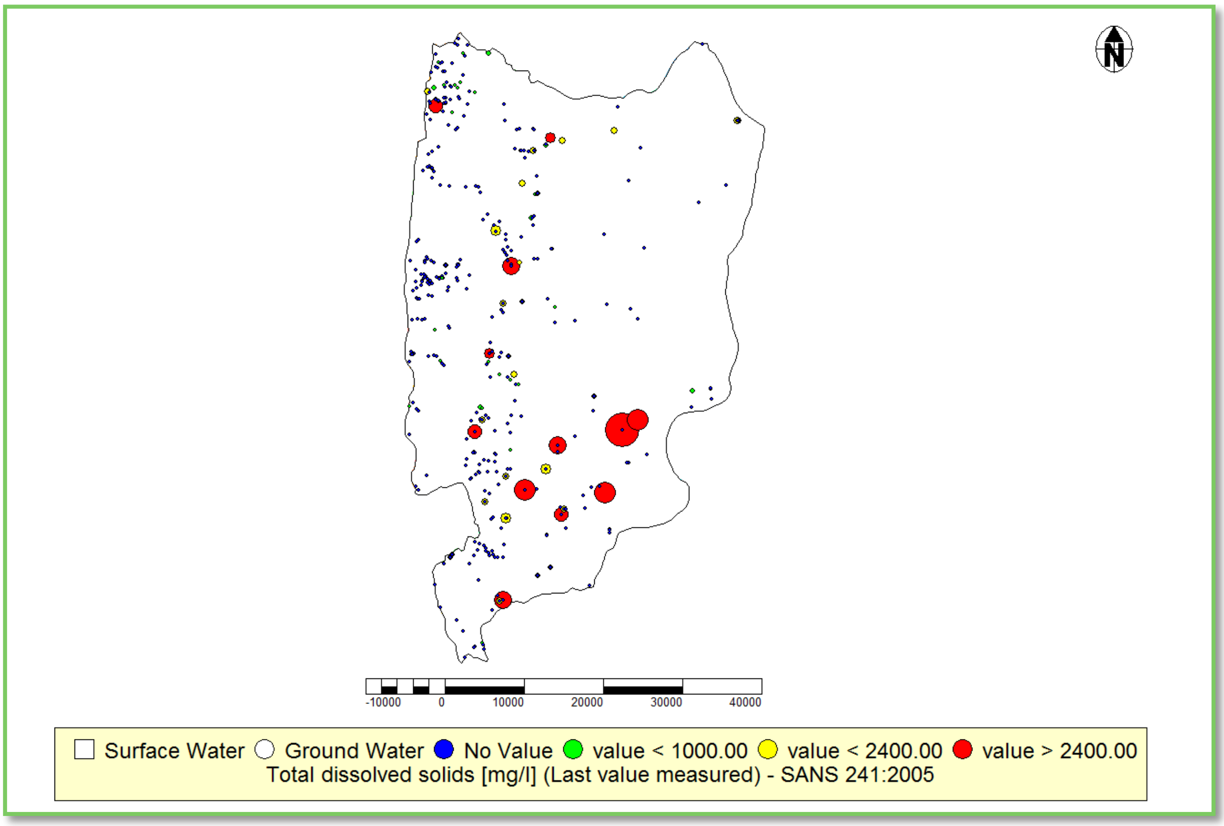


FIGURE 141: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 163**. The slope histogram is documented in Appendix D.

TABLE 163: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
9.2	3.2%	0.7	LmSa-SaLm , SaLm-SaCl, Sa	Weathered/Fractured	Natal	56%

27.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 37.2%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 1.780 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in **Figure 142**. It is clear from the results that the stress index will vary between 30% and 40%, with a certainty of 98.43%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

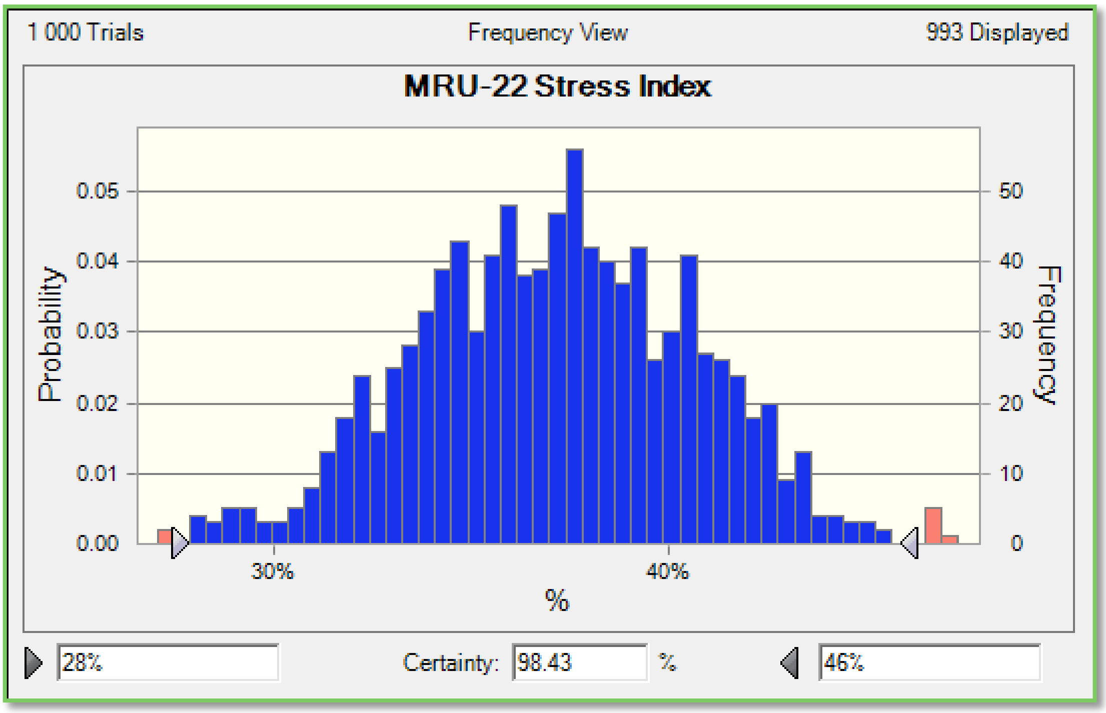


FIGURE 142: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 143**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. It is apparent that the contamination category, according to the explanation, is C.

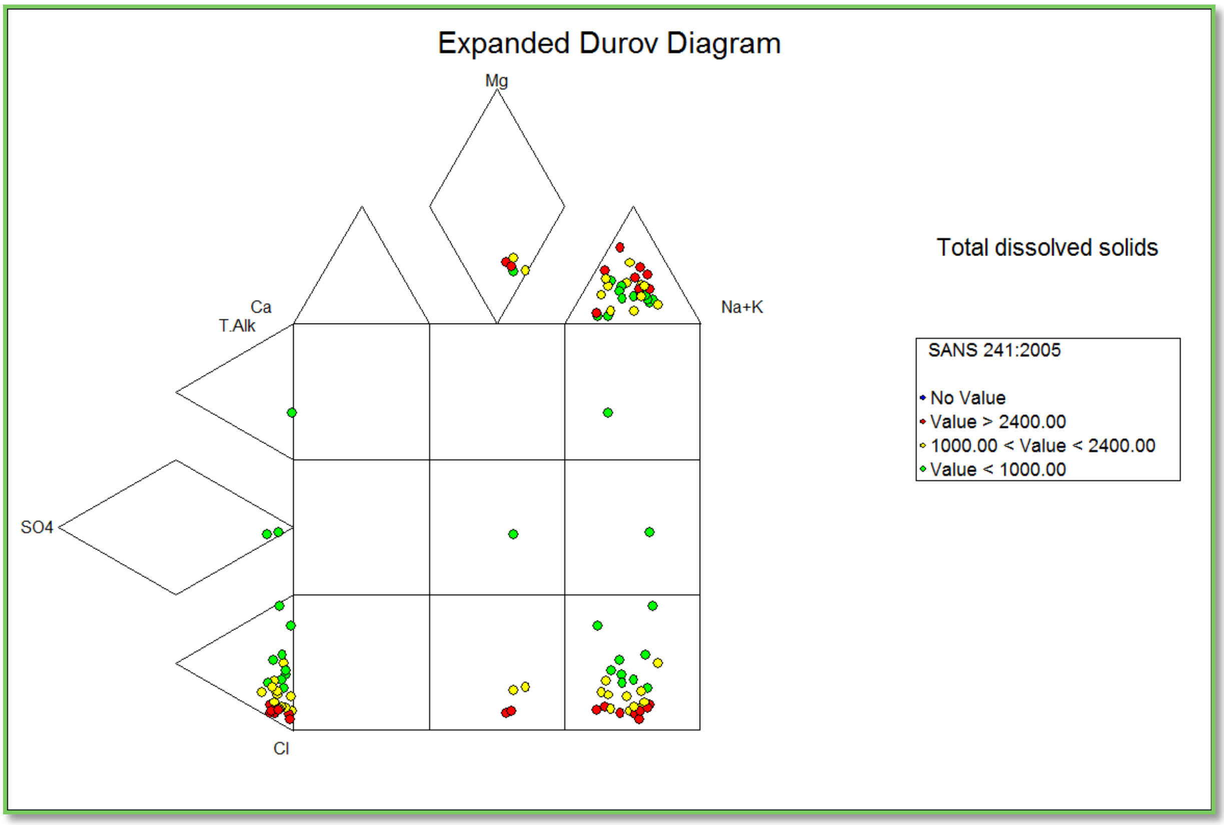


FIGURE 143: EXPANDED DUROV DIAGRAM

As documented the vulnerability is 56%. The impact of potential contamination according to Section 2.2, is medium due to subsistence farming in the RU.

Final category

The final category for the RU is summarised in **Table 164**.

TABLE 164: CATEGORY FOR RU

Impact	Present status category	Water resource category
Groundwater usage	C	Good/Fair
Groundwater contamination	C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	C	Good/Fair
FINAL	**C**	**Good/Fair**

27.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 165**.

TABLE 165: RESERVE

Reserve			Allocation	
Baseflow Mm^3/a	BHN Mm^3/a	Reserve % Recharge	Allocation Mm^3/a	Current Use Mm^3/a
3.030	0.196	7%	27.324	17.804

28. Classification and the Reserve for RU23

28.1 Location

The quaternary included in the RU is W55A. The town of Chrisiesmeer is situated within the RU. There are no protected areas. The location is shown in **Figure 144**.

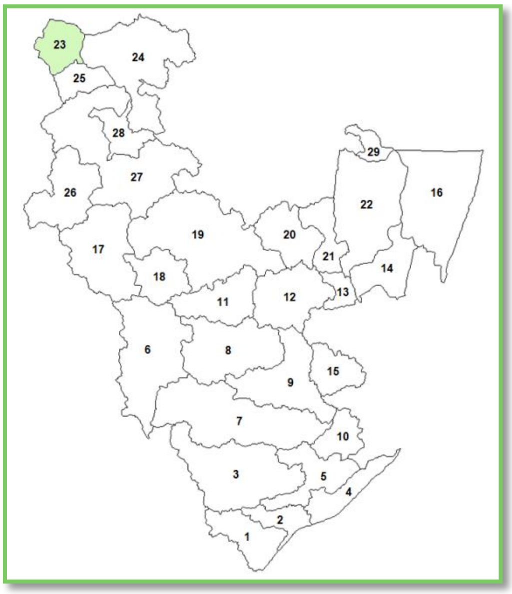


FIGURE 144: LOCATION

28.2 Climate

The summer rainfall ranges from 700 to 1 100 mm per year. Temperatures vary from --10°C to 39°C, with an average of 15°C.

28.3 Vegetation (taken from environment.gov.za)

The northern section of the RU have a grassland type that contains many endemic plant species: 78 endemic or near-endemic species occur on the Black Reef quartzites. Towards the south the grassland is dominated by Fan Lovegrass Eragrostis plana, Weeping Lovegrass E. curvula, Speargrass Heteropogon contortus, Trachypogon spicatus and Themeda triandra. Dicotyledonous forbs are not abundant, though many species occur in the area.

28.4 Demography and Land use

Forestry, grazing and ecotourism are the most important economic activities. There are numerous coal mines within the RU. The total population is 7500. The Landcover is shown in **Figure 145**.

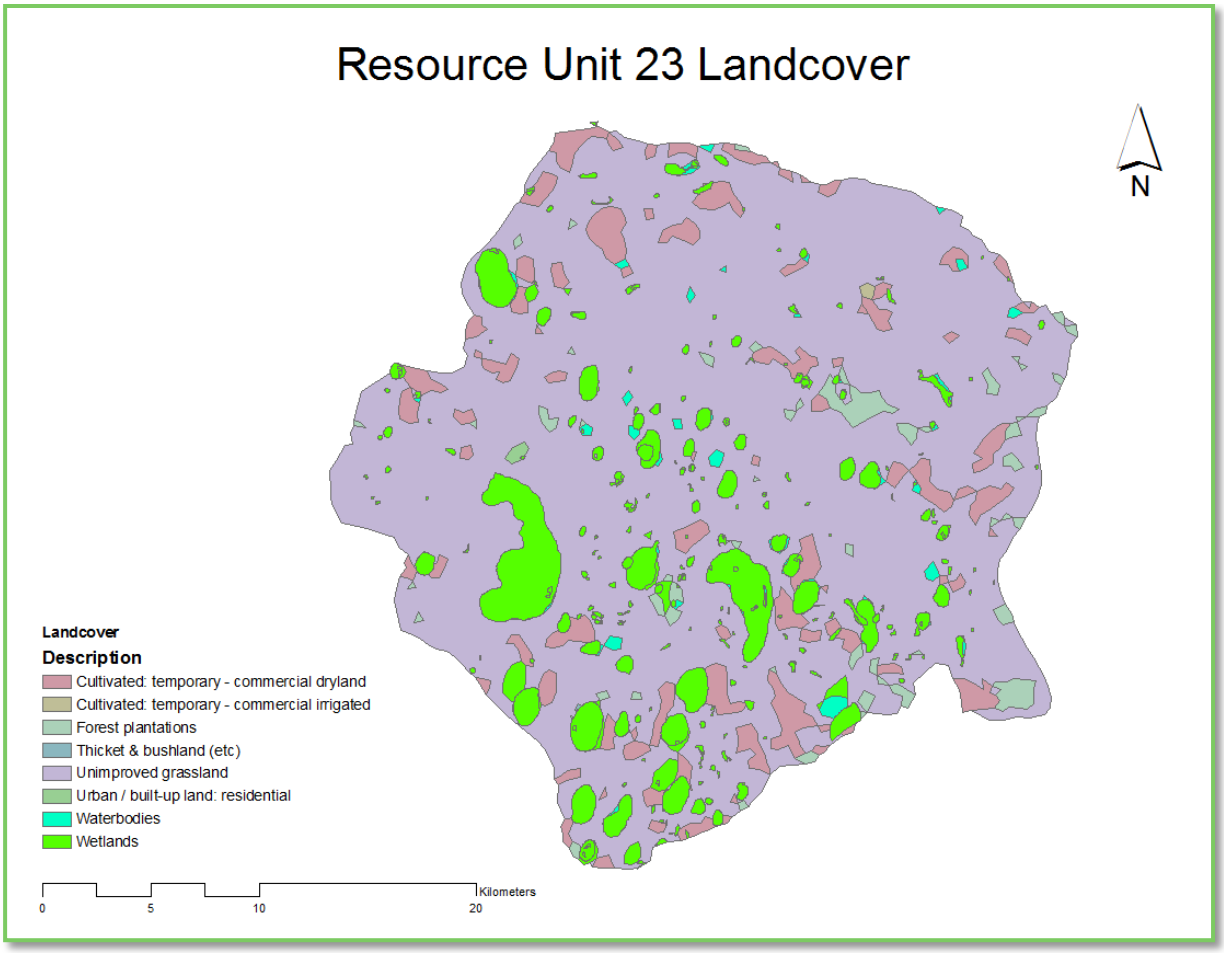


FIGURE 145: LANDCOVER

28.5 Surface water and Wetlands

The headwaters of the Usutu River flow through this RU. Chrissiesmeer is surrounded by more than 270 lakes and pans. The pans are perennial and generally fresh. One of the most important factors contributing to the perennial nature of the pans is the favourable water balance (i.e. the difference between rainfall and evaporation) of the region. The pans receive water in a number of different ways. Rain falling directly onto a pan surface adds water. Each pan is surrounded by its own watershed, and some of the rainwater falling within this catchment forms surface run-off and flows directly into the pan, whilst the remainder percolates into the ground to become groundwater. This groundwater regime forms an important part of pan hydrology.

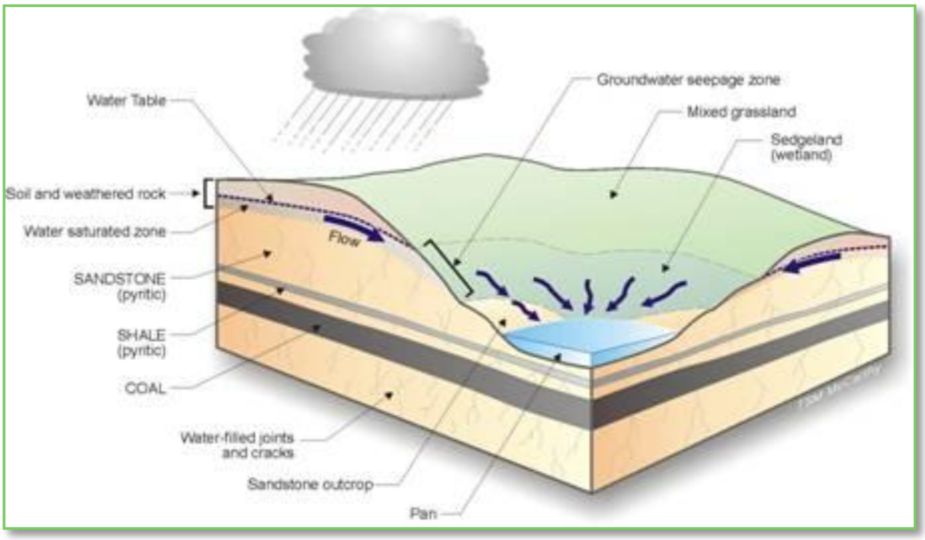


FIGURE 146: FUNCTIONING OF CHRISSIESMEER

Water quality is quite variable amongst different pans, and salinity ranges from about 200 to about 8000 parts per million total dissolved solids.

The area is currently the focus of interest from coal mining companies. Their intention is to undertake opencast mining within the area, which will fall within the local catchments of many of the pans. There is a very real danger that opencast mining within the catchments of pans in the area will destroy the natural hydrological functioning of the pan systems, and moreover will result in the pollution (**Photo 41**) of surrounding groundwater with sulphuric acid and various sulphate salts. The groundwater will become completely unpotable. In time, this polluted groundwater will leak into the pans and they too will become contaminated. Since the pans have no outlet, and hence cannot be flushed during heavy rains, salts will accumulate there, irreversibly polluting them. Although the process may be slowed down by careful backfilling, including the importation and use of suitable clays, this will only defer the generation of acid and will not stop it. In the long term, destruction of the pans will be inevitable if mining takes place.

PHOTO 41: EFFECTS OF COAL MINING

28.6 Soils (taken from environment.gov.za)

In the northern part of the RU soils are mostly shallow lithosols derived from a variety of rock types. Towards the south shales and sandstones of the Vryheid and Volksrust

Formations (Ecca Group, Karoo Sequence) predominate the underlying rock types, giving rise to deep, red to yellow, sandy soils.

28.7 Geohydrology

Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 147**. The most probable depth to groundwater level in the RU is 6.1 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

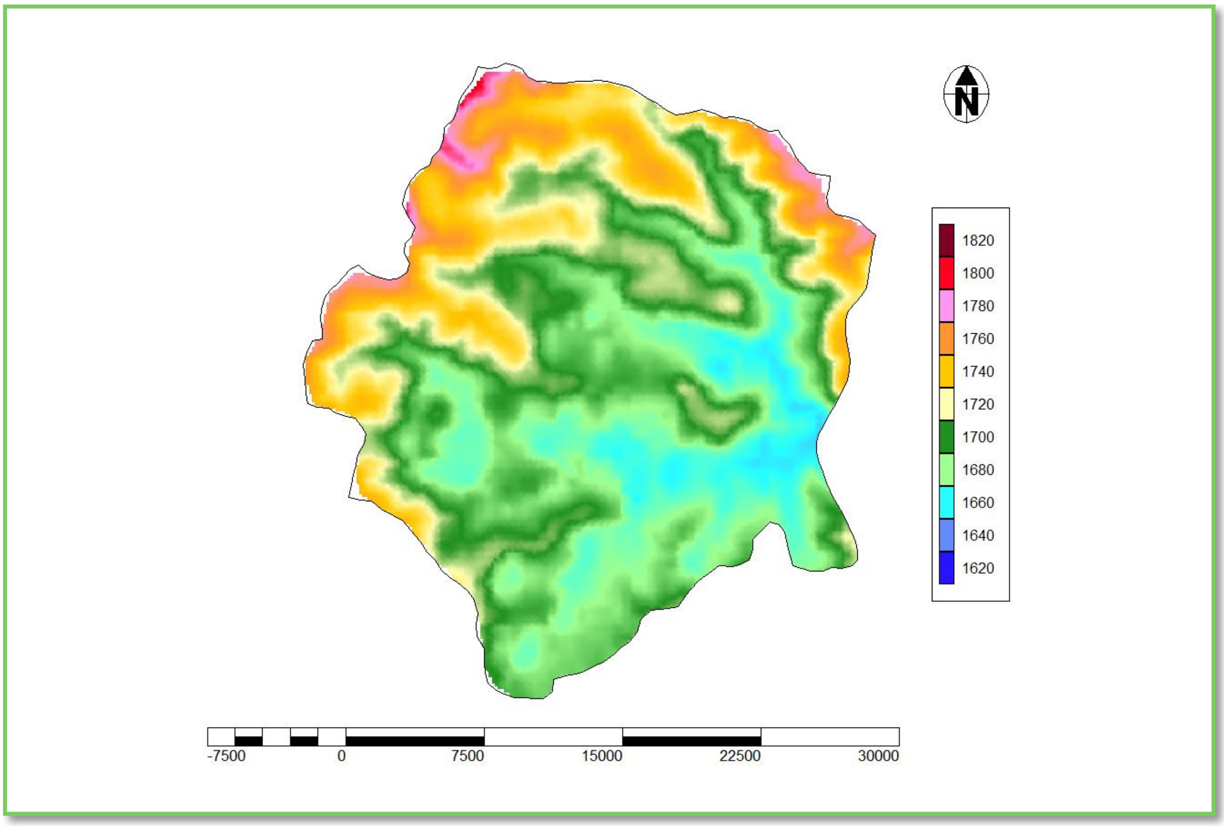


FIGURE 147: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 166**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 166: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
528.233	30.992	44.766	41.674	7.9%	7.9%	4.9%	5.0%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 167**.

TABLE 167: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
8625	1725	0.016

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 168** is highlighted in red.

TABLE 168: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
27.358	21.790	14.256	3.427	10.097	2.360	44.766	3.427

Groundwater use

The groundwater use in the catchment is documented in **Table 169**.

TABLE 169: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
0.000	0.166	0.001	0.000	0.166	8.676	9.998	18.658

Groundwater quality

The TDS values for the RU are shown in **Figure 148**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines. However there is a threat of contamination due to the planned coal mines.

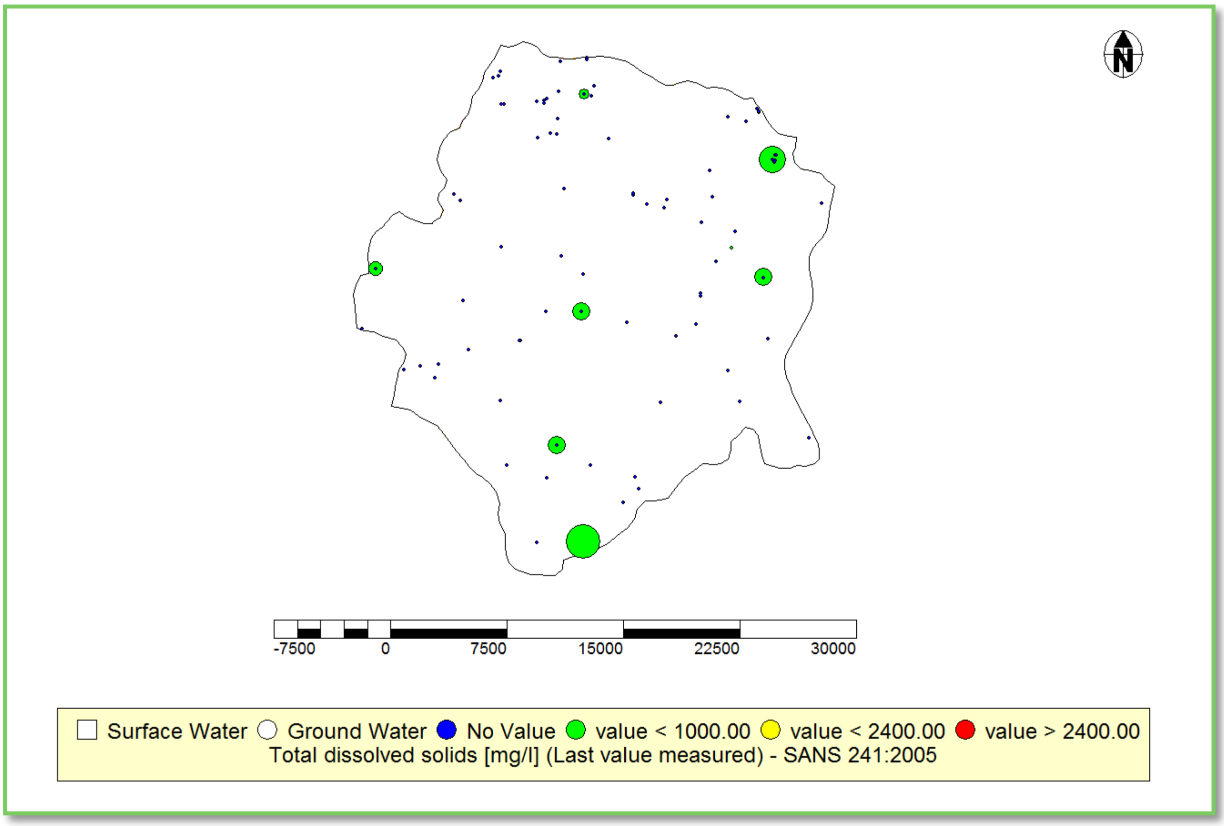


Figure 148: TDS values

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 170**. The slope histogram is documented in Appendix D.

Table 170: Aquifer vulnerability

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
6.1	7.9%	0.3	LmSa-SaLm	Weathered/Fractured	Natal	64%

28.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 44.8%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 1.866 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in **Figure 149**. It is clear from the results that the stress index will vary between 32% and 56%, with a certainty of 99.03%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

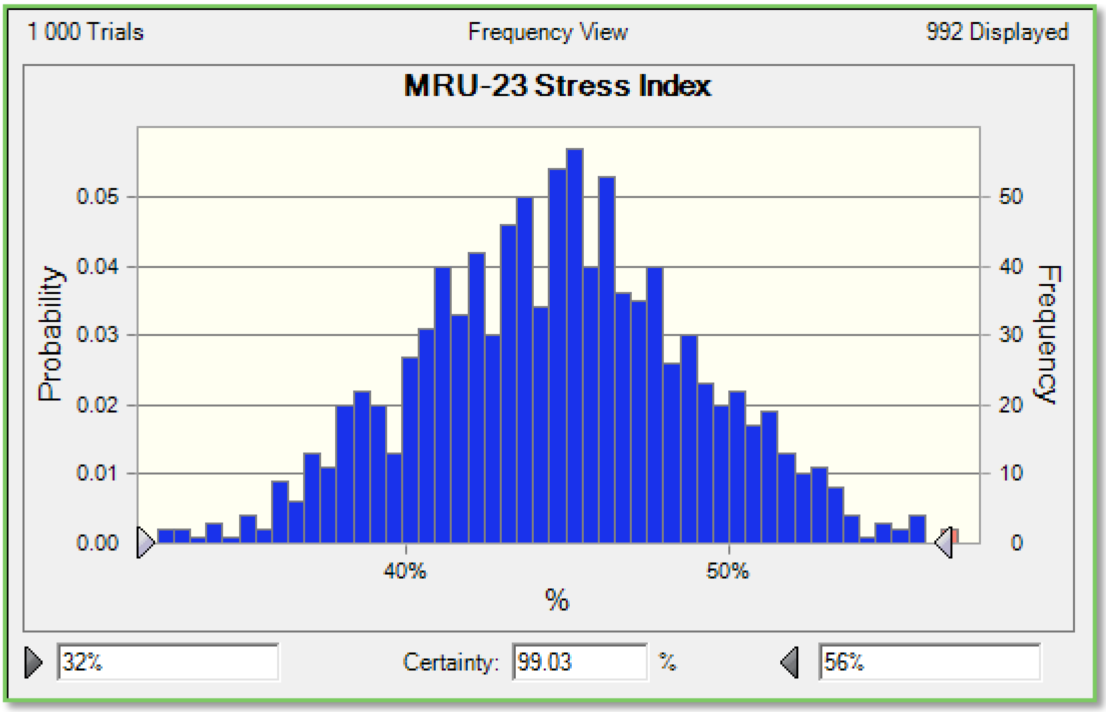


FIGURE 149: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 150**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. There is a relatively even distribution of boreholes between category A and C, therefore the final category is B.

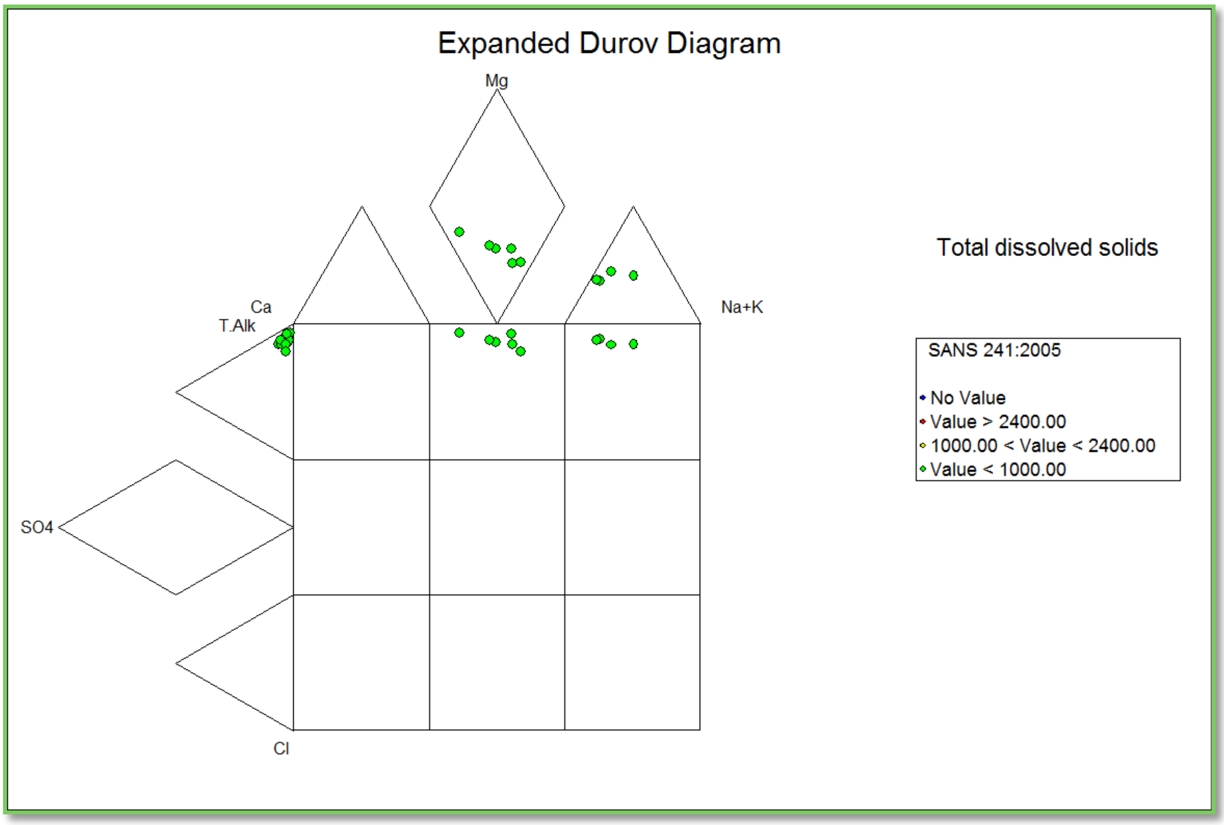


FIGURE 150: EXPANDED DUROV DIAGRAM

As documented the vulnerability is 64%. The impact of potential contamination according to Section 2.2, is high due to all the planned mining activities.

Final category

The final category for the RU is summarised in **Table 171**.

TABLE 171: CATEGORY FOR RU

Impact	Present status category	Water resource category
Groundwater usage	D	Fair
Groundwater contamination	B	Good
Potential groundwater contamination (vulnerability and impact)	D	Fair
FINAL	**D**	**Fair**

28.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 172**.

TABLE 172: RESERVE

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
3.427	0.016	8%	19.573	18.658

29. Classification and the Reserve for RU24

29.1 Location

The quaternary catchments included in this RU are W53E, W54C, W54D, W55B, W55C, W55D, W55E, W56A and W56B. The RU is located along the Swaziland border (**Photo 42**) as shown in **Figure 151**. The towns include Lotair, Lochiel and Waverley.

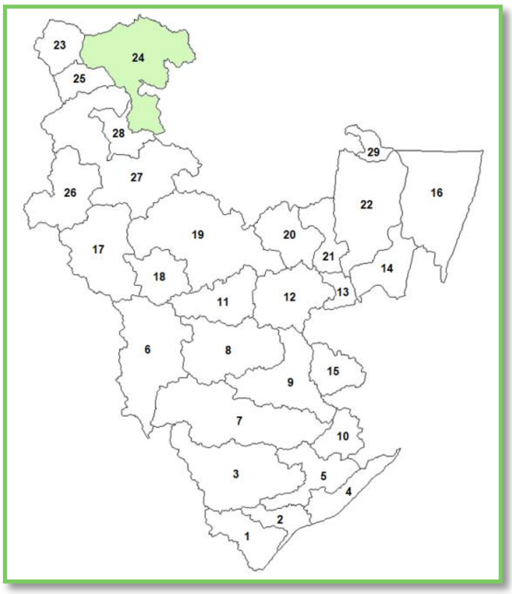


FIGURE 151: LOCATION

PHOTO 42: BORDER WITH SWAZILAND

(Source: www.panoramio.com)

29.2 Climate

The summer rainfall ranges from 700 to 1 100 mm per year. Temperatures vary from -8°C to 39°C, with an average of 15°C.

29.3 Vegetation (taken from environment.gov.za)

This grassland type contains many endemic plant species: 78 endemic or near-endemic species occur on the Black Reef quartzites. These are mostly representatives of the Lilies (Liliaceae - now split into several families), Irises (Iridaceae), Daisies (Asteraceae), Mints (Lamiaceae) and Orchids (Orchidaceae).

29.4 Demography and Land use

Forestry and associated paper mills; grazing and ecotourism are the most important economic activities. The total population in the RU (2001 census) is 162850. The Landcover for the RU is shown in **Figure 152**.

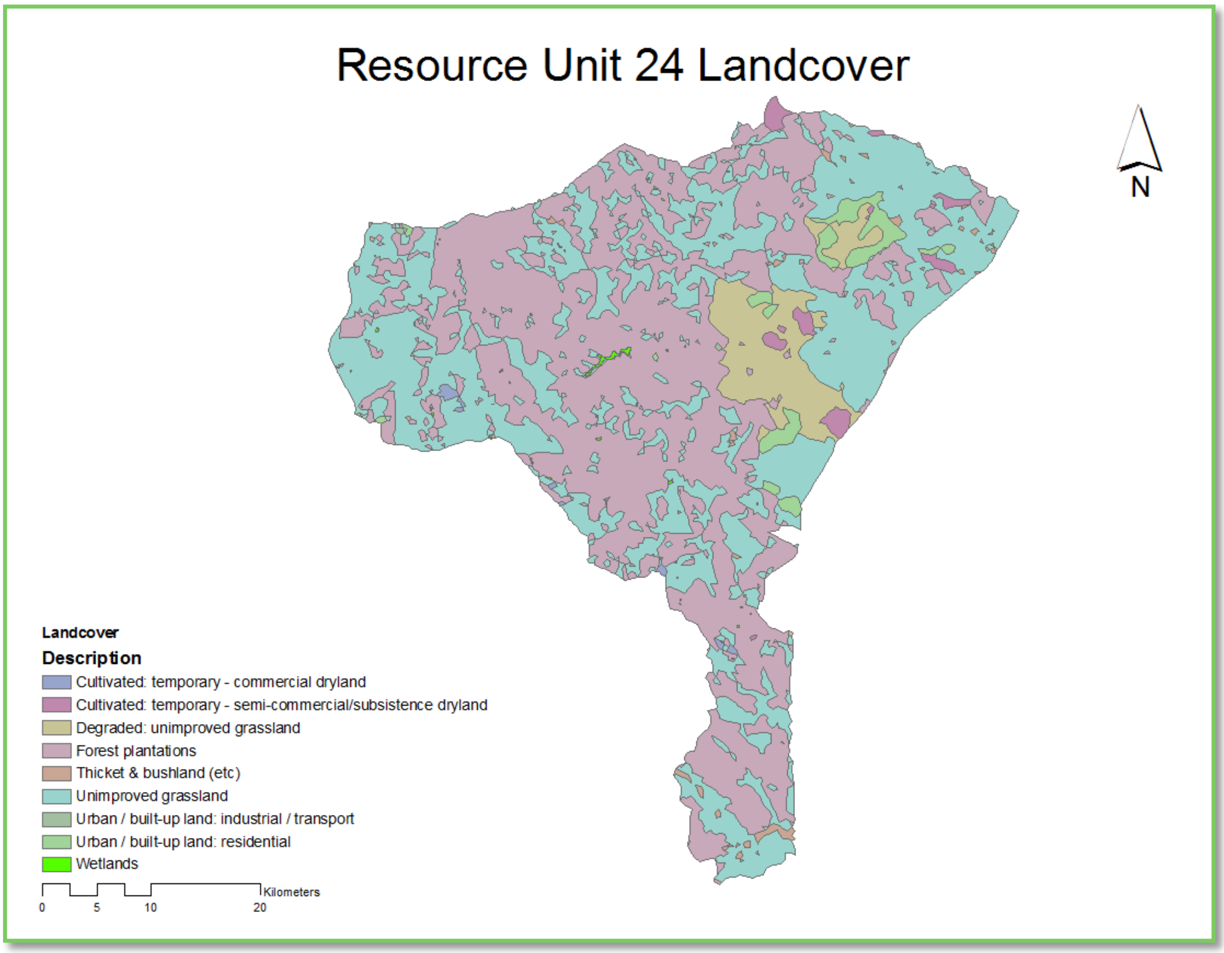


FIGURE 152: LANDCOVER

29.5 Surface water and Wetlands

The headwaters of the Little Usutu River flow through this RU. The wetlands for in this RU are shown in **Figure 152**.

29.6 Soils (taken from environment.gov.za)

Soils are mostly shallow lithosols derived from a variety of rock types.

29.7 Geohydrology

Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 153**. The most probable depth to groundwater level in the RU is 4.2 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

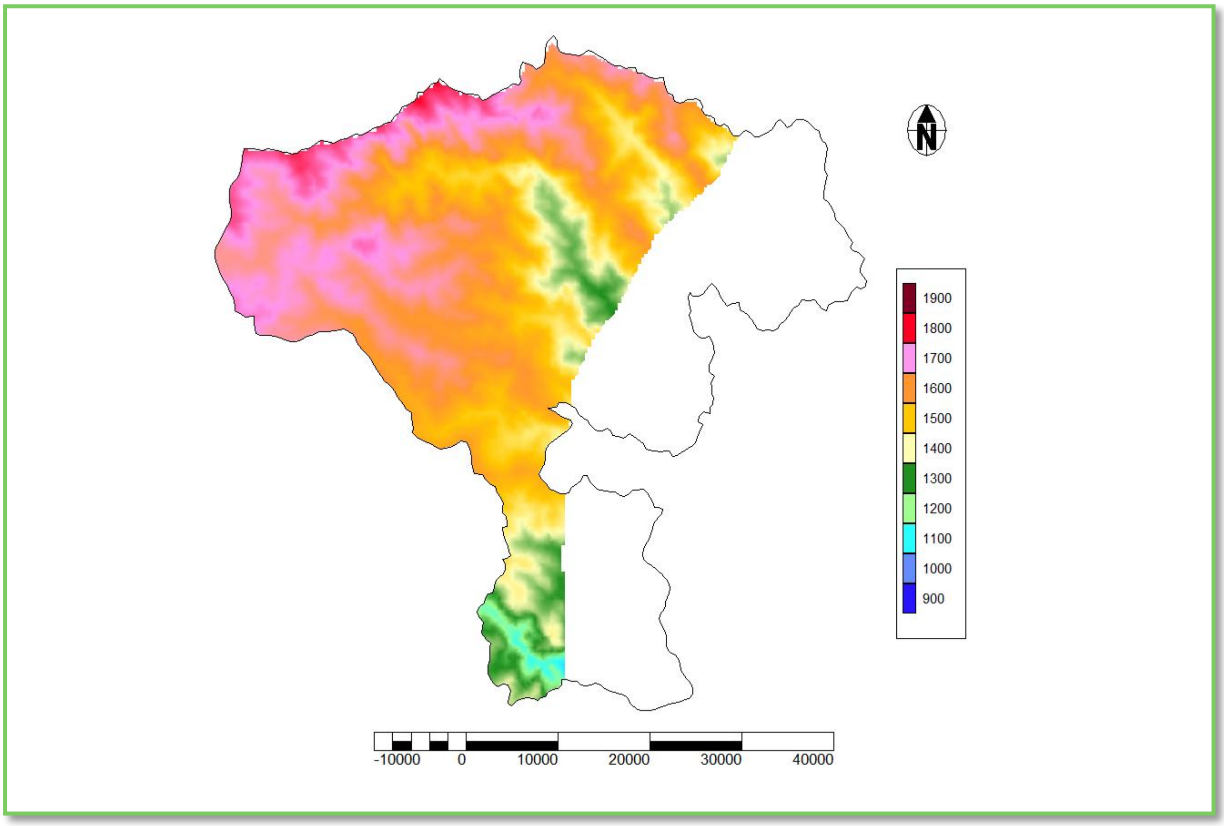


FIGURE 153: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 173**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 173: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
2212.780	161.015	282.390	195.502	8.8%	8.8%	4.5%	3.2%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 174**.

TABLE 174: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
274948	54990	0.495

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 175** is highlighted in red.

TABLE 175: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
64.826	258.598	206.568	130.012	176.962	23.563	282.390	130.012

Groundwater use

The groundwater use in the catchment is documented in **Table 176**.

TABLE 176: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
0.140	0.138	0.000	0.000	0.140	14.400	1.384	15.289

Groundwater quality

The TDS values for the RU are shown in **Figure 154**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines.

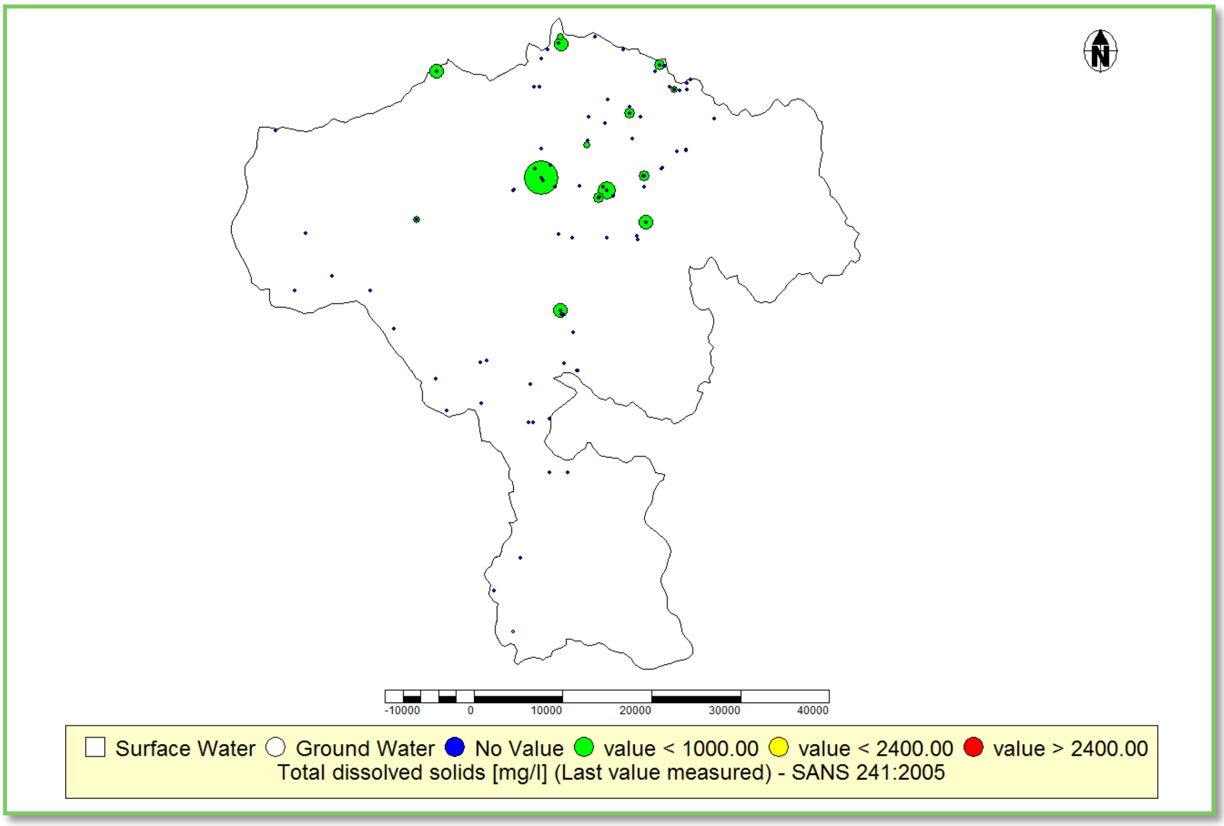


FIGURE 154: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 177**. The slope histogram is documented in Appendix D.

TABLE 177: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
4.2	8.8%	0.5	LmSa-SaLm	Weathered/Fractured	Natal	67%

29.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 8.1%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 1.529 Mm^3/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in **Figure 155**. It is clear from the results that the stress index will vary between 6% and 10%, with a certainty of 99.57%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

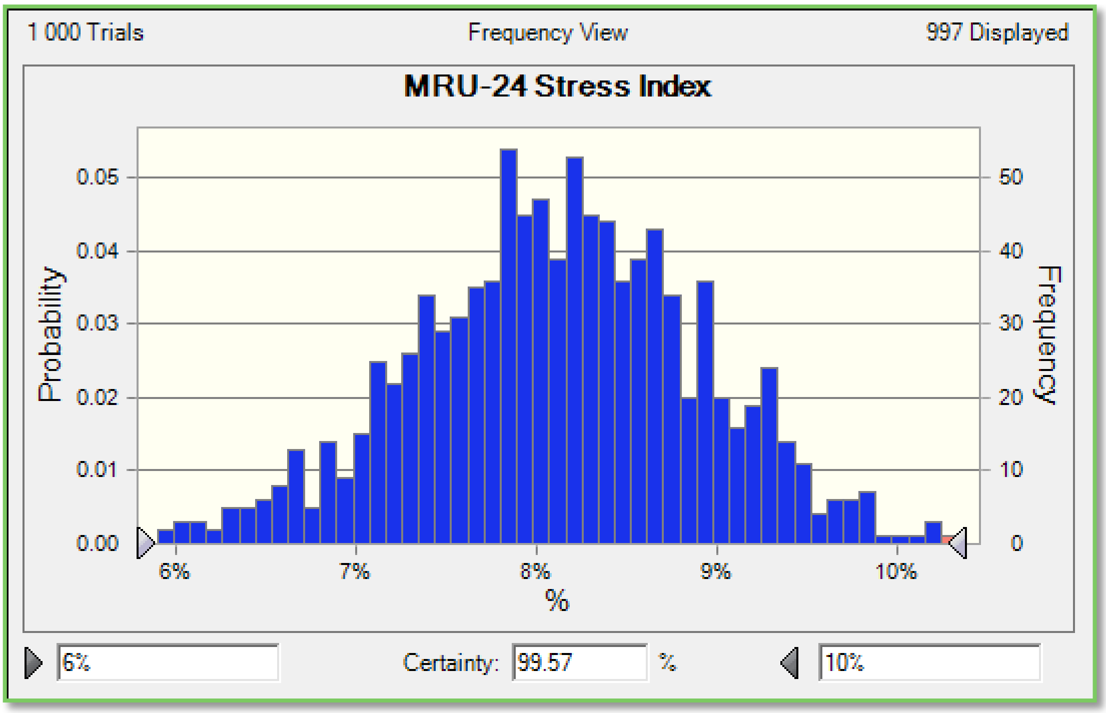


FIGURE 155: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 156**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. There is a relatively even distribution of boreholes between category A and C, therefore the final category is B.

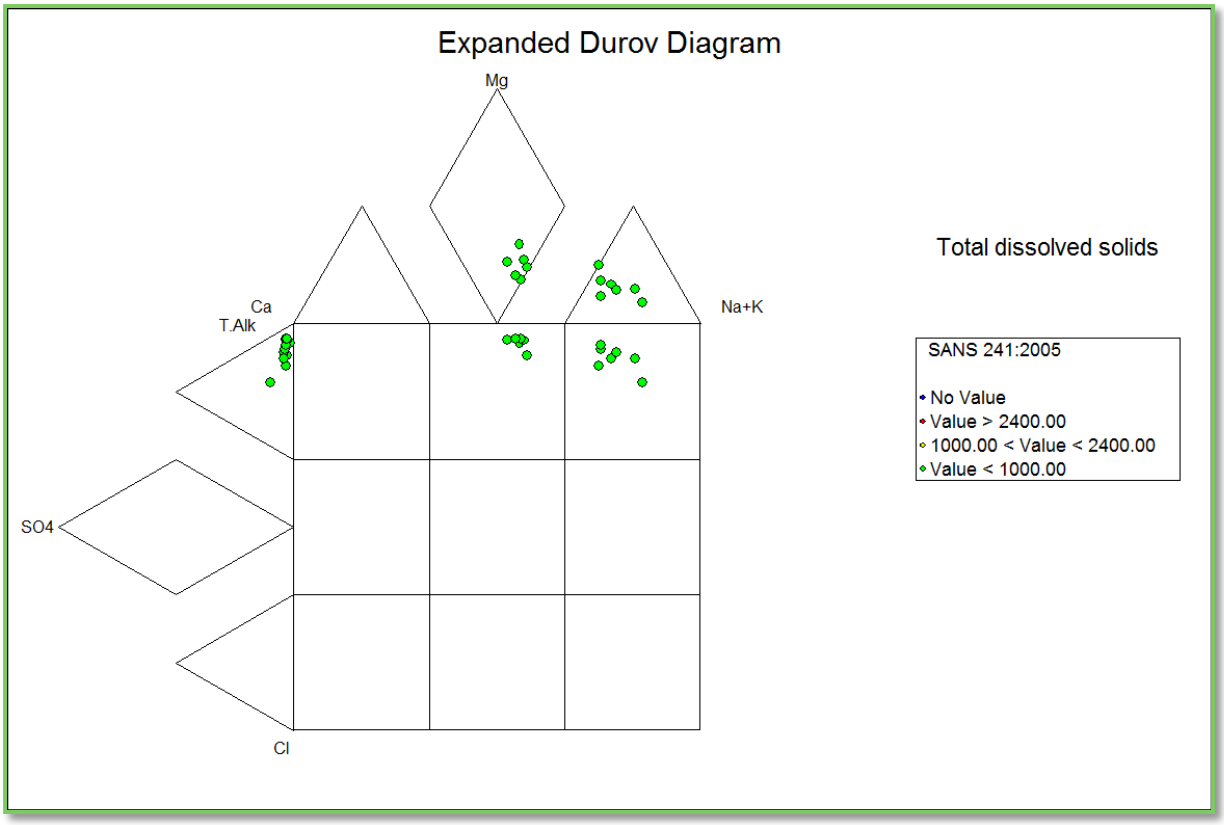


FIGURE 156: EXPANDED DUROV DIAGRAM

As documented the vulnerability is 67%. The impact of potential contamination according to Section 2.2, is high due to almost the whole RU being covered with forest plantations.

Final category

The final category for the RU is summarised in **Table 178**.

TABLE 178: CATEGORY FOR RU

Impact	Present status category	Water resource category
Groundwater usage	B	Good
Groundwater contamination	B	Good
Potential groundwater contamination (vulnerability and impact)	D	Fair
FINAL	**C**	**Good/Fair**

29.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 179**.

TABLE 179: RESERVE

Reserve			Allocation	
Baseflow Mm^3/a	BHN Mm^3/a	Reserve % Recharge	Allocation Mm^3/a	Current Use Mm^3/a
130.012	0.495	67%	49.706	15.289

30. Classification and the Reserve for RU25

30.1 Location

The southern part of Lotair is included in the RU. The RU comprises of only two quaternary catchments namely, W54A and W54B. The location is shown in **Figure 157**.

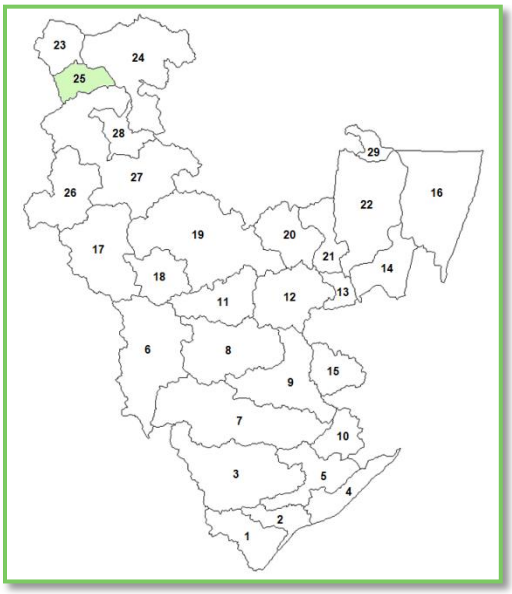


FIGURE 157: LOCATION

30.2 Climate

The annual rainfall is 700 to 950 mm, occurring in summer. Temperatures vary between -10°C and 35°C, with an average of 15°C.

30.3 Vegetation (taken from environment.gov.za)

This grassland is dominated by Fan Lovegrass Eragrostis plana, Weeping Lovegrass E. curvula, Speargrass Heteropogon contortus, Trachypogon spicatus and Themeda triandra. Dicotyledonous forbs are not abundant, though many species occur in the area.

30.4 Demography and Land use

Very suitable for crop production, with natural vegetation heavily used for grazing by sheep and cattle. Mining and forestry are also found in the RU. The Landcover is shown in **Figure 158**. The total population (2001 census) is 520 people.

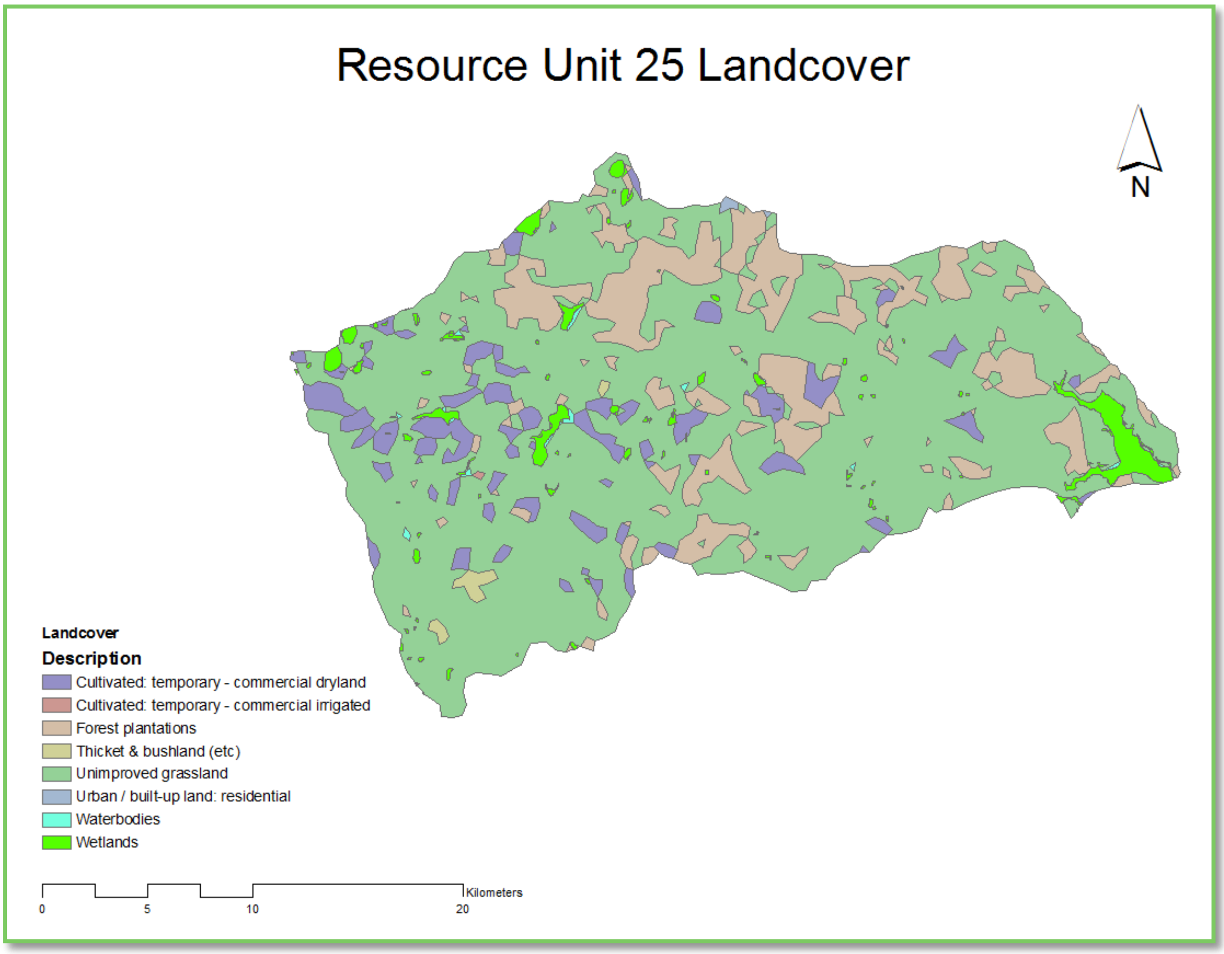


FIGURE 158: LANDCOVER

30.5 Surface water and Wetlands

The headwaters of the Great Usutu River flow through the RU. There are 2 dams in the RU namely Sandcliff and Westoe Dams (**Photo 43**). The wetlands in the RU are shown in **Figure 158**.

30.6 Soils (taken from environment.gov.za)

Shales and sandstones of the Vryheid and Volksrust Formations (Ecca Group, Karoo Sequence) predominate the underlying rock types, giving rise to deep, red to yellow, sandy soils.

PHOTO 43: WESTOE DAM
(Source: www.ewisa.co.za)

30.7 Geohydrology

Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 159**. The most probable depth to groundwater level in the RU is 3.5 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

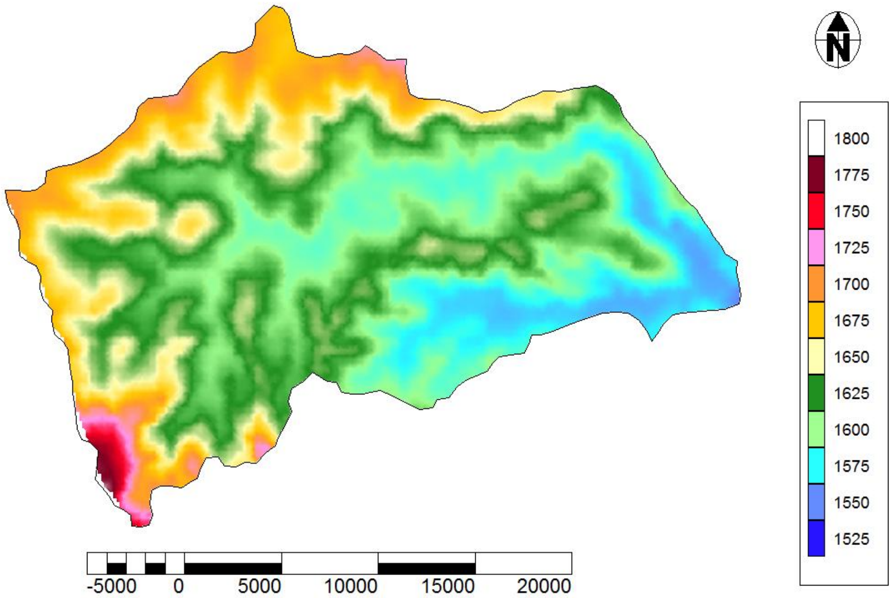


FIGURE 159: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 180**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 180: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
435.099	23.985	35.973	36.268	8.3%	8.3%	2.9%	5.1%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 181**.

TABLE 181: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
1107	221	0.002

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 182** is highlighted in red.

TABLE 182: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
9.410	19.717	13.364	4.340	9.911	1.162	35.973	4.340

Groundwater use

The groundwater use in the catchment is documented in **Table 183**.

TABLE 183: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
0.000	0.003	0.010	0.000	0.010	7.675	0.087	7.760

Groundwater quality

No groundwater quality is available for the RU.

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 184**. The slope histogram is documented in Appendix D.

TABLE 184: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
3.5	8.3%	0.2	LmSa-SaLm	Weathered/Fractured	Natal	67%

30.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 21.4%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 0.776 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in **Figure 160**. It is clear from the results that the stress index will vary between 16% and 27%, with a certainty of 99.04%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

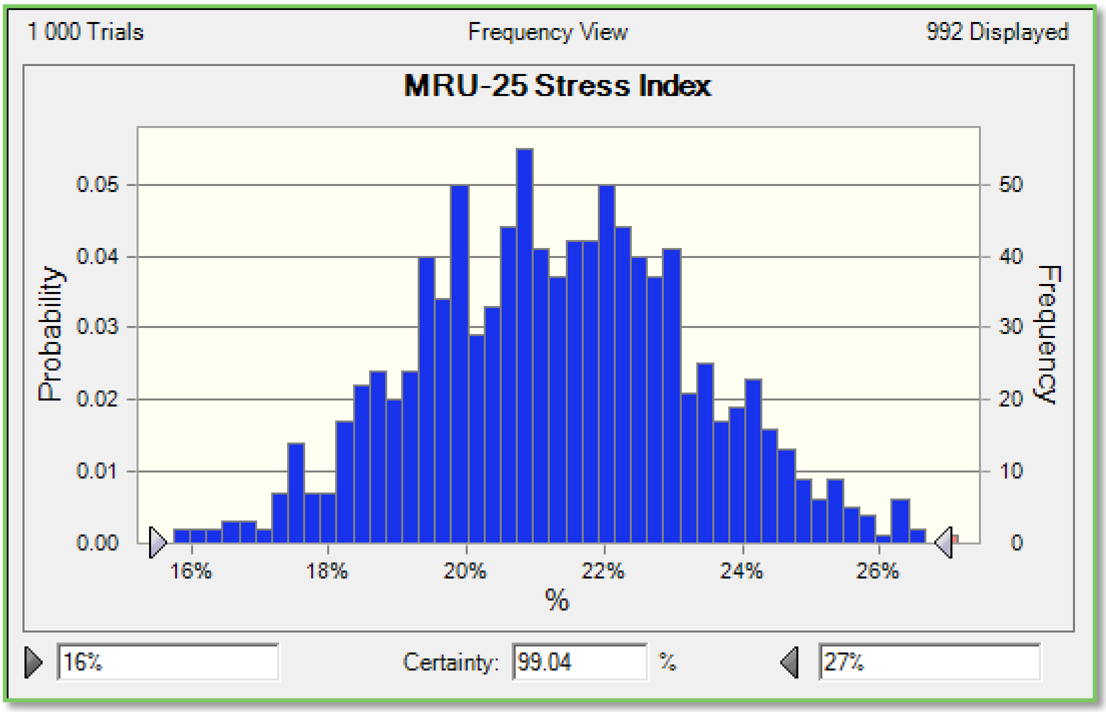


Figure 160: Stochastic results

Quality

There is no quality data available for this RU. As documented the vulnerability is 67%. The impact of potential contamination according to Section 2.2, is high due to almost the whole resource unit being used for agriculture.

Final category

The final category for the RU is summarised in **Table 185**.

Table 185: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	C	Good/Fair
Groundwater contamination	-	-
Potential groundwater contamination (vulnerability and impact)	D	Fair
FINAL	**C/D**	**Fair**

30.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 186**.

Table 186: Reserve

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
4.340	0.002	12%	24.166	7.760

31. Classification and the Reserve for RU26

31.1 Location

The quaternary catchments located in this RU are W51A, W51B and W52A. Drikiesdorp is the only town included in the RU. There are no protected areas. The location of the RU is shown in **Figure 161**.

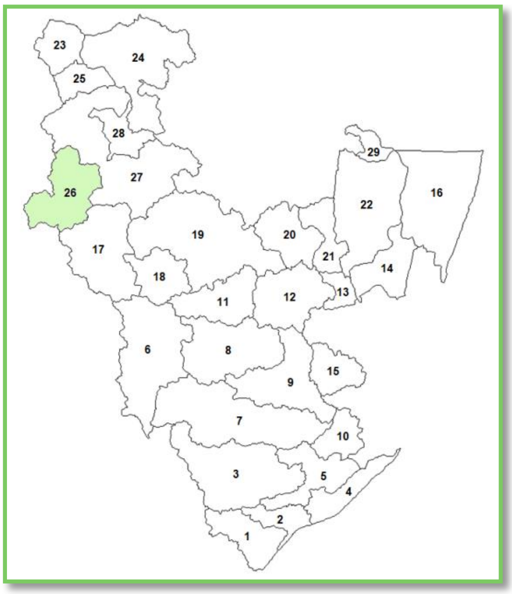


FIGURE 161: LOCATION

31.2 Climate

The annual rainfall is 700 to 950 mm, occurring in summer. Temperatures vary between -10°C and 35°C, with an average of 15°C.

31.3 Vegetation (taken from environment.gov.za)

This grassland is dominated by Fan Lovegrass Eragrostis plana, Weeping Lovegrass E. curvula, Speargrass Heteropogon contortus, Trachypogon spicatus and Themeda triandra. Dicotyledonous forbs are not abundant, though many species occur in the area.

31.4 Demography and Land use

The RU is suitable for crop production, with natural vegetation heavily used for grazing by sheep and cattle. Mines also occur in the RU. The total number of people living in the RU with the 2001 census is less than 500. The landcover is shown in **Figure 162**.

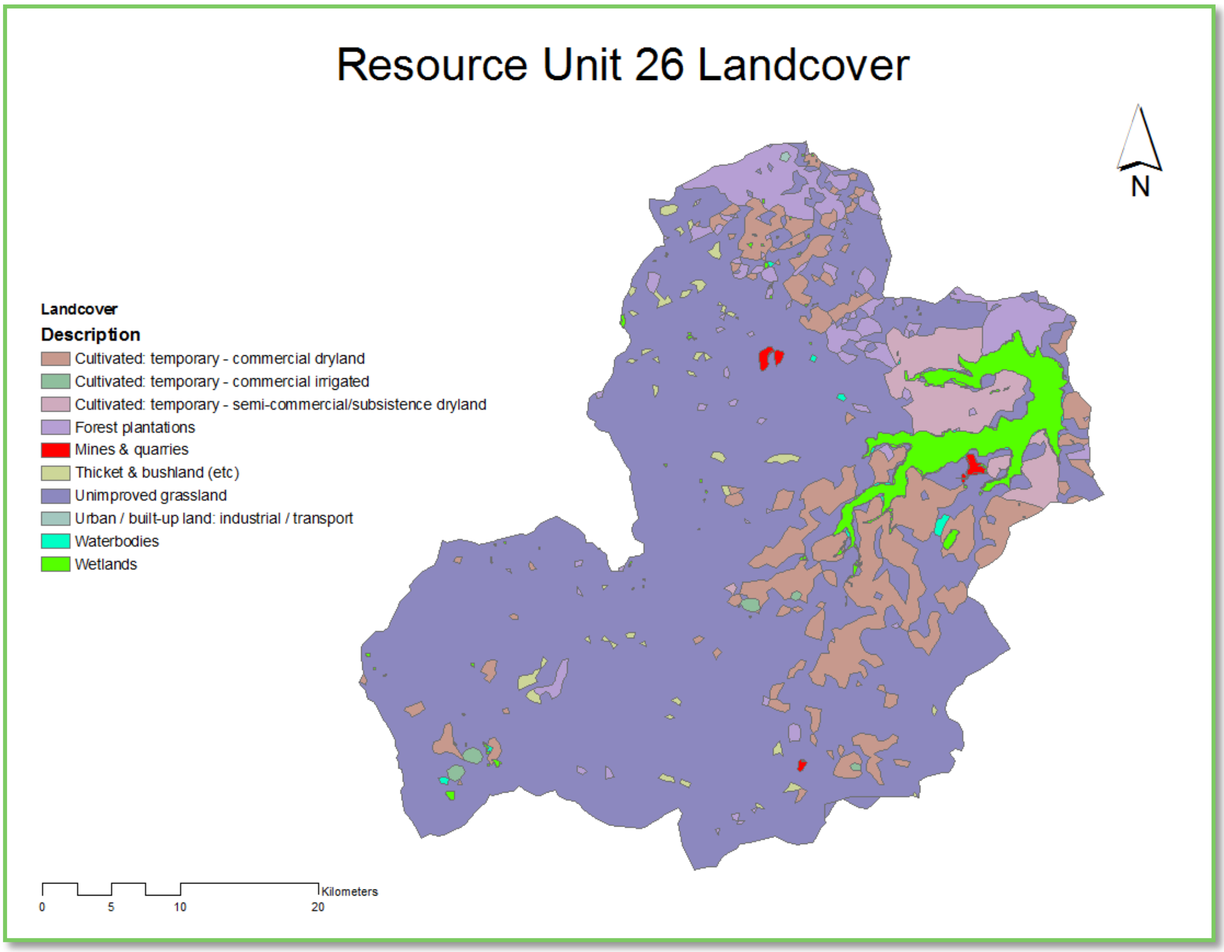


FIGURE 162: LANDCOVER

31.5 Surface water and Wetlands

The Assegaai River flows through the RU. The Heyshope Dam (**Photo 44**) is located in W51B. The wetlands in the RU are shown in **Figure 162**.

PHOTO 44: HEYSHOPE DAM
(Source: www.panoramio.com)

31.6 Soils (taken from environment.gov.za)

Shales and sandstones of the Vryheid and Volksrust Formations (Ecca Group, Karoo Sequence) predominate the underlying rock types, giving rise to deep, red to yellow, sandy soils.

31.7 Geohydrology

Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 163**. The most probable depth to groundwater level in the RU is 6.6 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

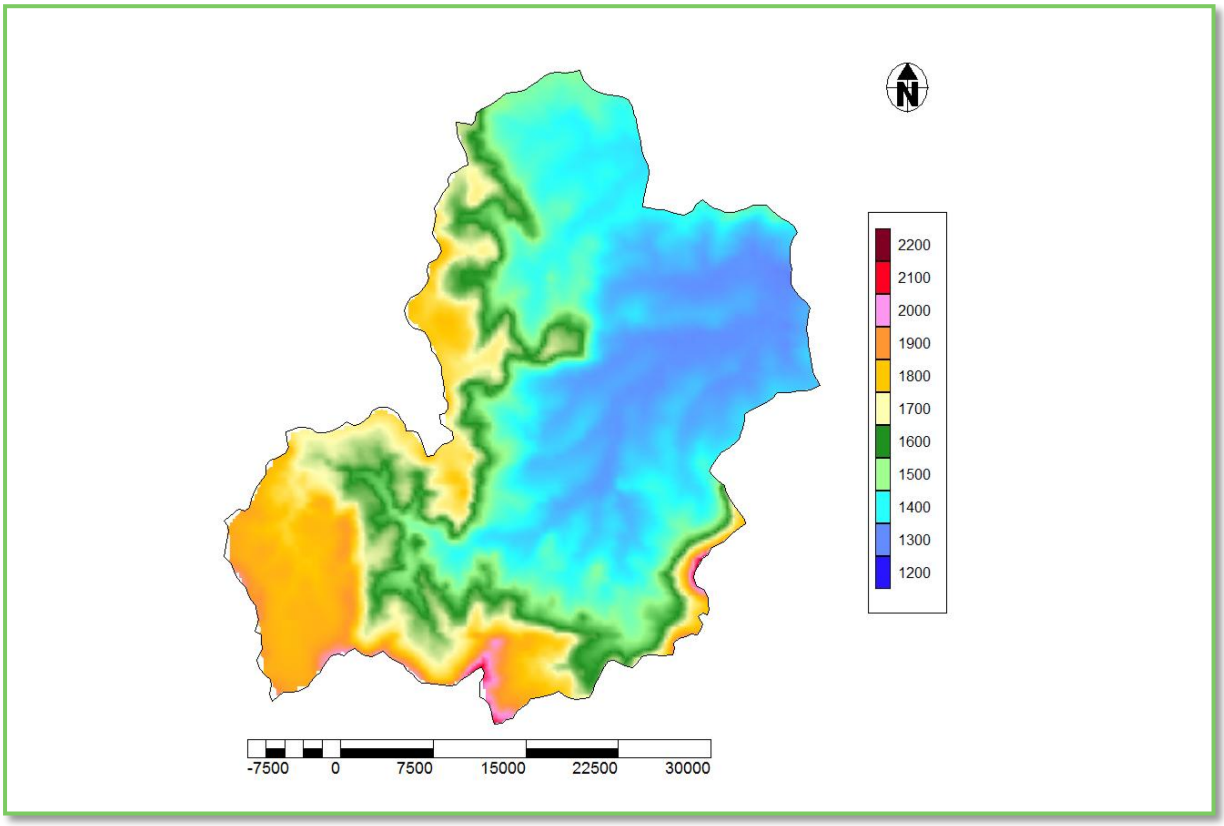


FIGURE 163: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 187**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 187: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
1246.242	72.690	91.644	95.851	7.7%	7.7%	8.9%	2.5%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 188**.

TABLE 188: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm^3/a
2918	584	0.005

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 189** is highlighted in red.

TABLE 189: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm^3/a	Hughes Mm^3/a	Shultz Mm^3/a	Pitman Mm^3/a	vTonder Mm^3/a	MIN Mm^3/a	MAX Mm^3/a	Herold Mm^3/a
45.893	64.802	39.306	14.975	31.390	7.634	91.644	14.975

Groundwater use

The groundwater use in the catchment is documented in **Table 190**.

TABLE 190: GROUNDWATER USE

Groundwater Use							
GRDM Mm^3/a	WARMS Mm^3/a	Hydrocensus Mm^3/a	MIN Mm^3/a	MAX Mm^3/a	Forrest Mm^3/a	Crops Mm^3/a	TOTAL Mm^3/a
0.950	0.390	0.021	0.021	0.950	5.400	0.056	5.450

Groundwater quality

The TDS values for the RU are shown in **Figure 164**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines. However it is expected that it will be worse due to the mines in the RU.

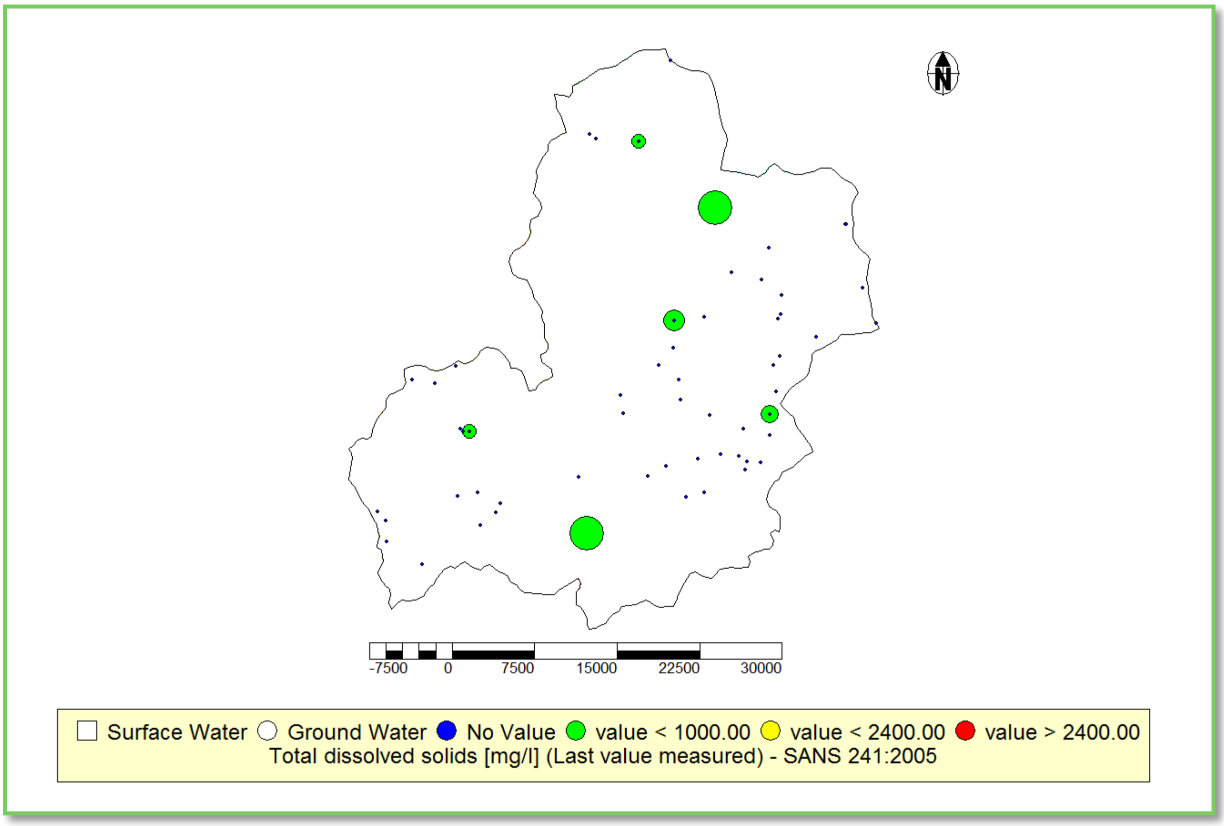


FIGURE 164: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 191**. The slope histogram is documented in Appendix D.

TABLE 191: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
6.6	7.7%	1.3	LmSa-SaLm , Sa-Lm	Weathered/Fractured	Natal	62%

31.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 5.7%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 0.545 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in **Figure 165**. It is clear from the results that the stress index will vary between 4% and 7%, with a certainty of 99.14%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

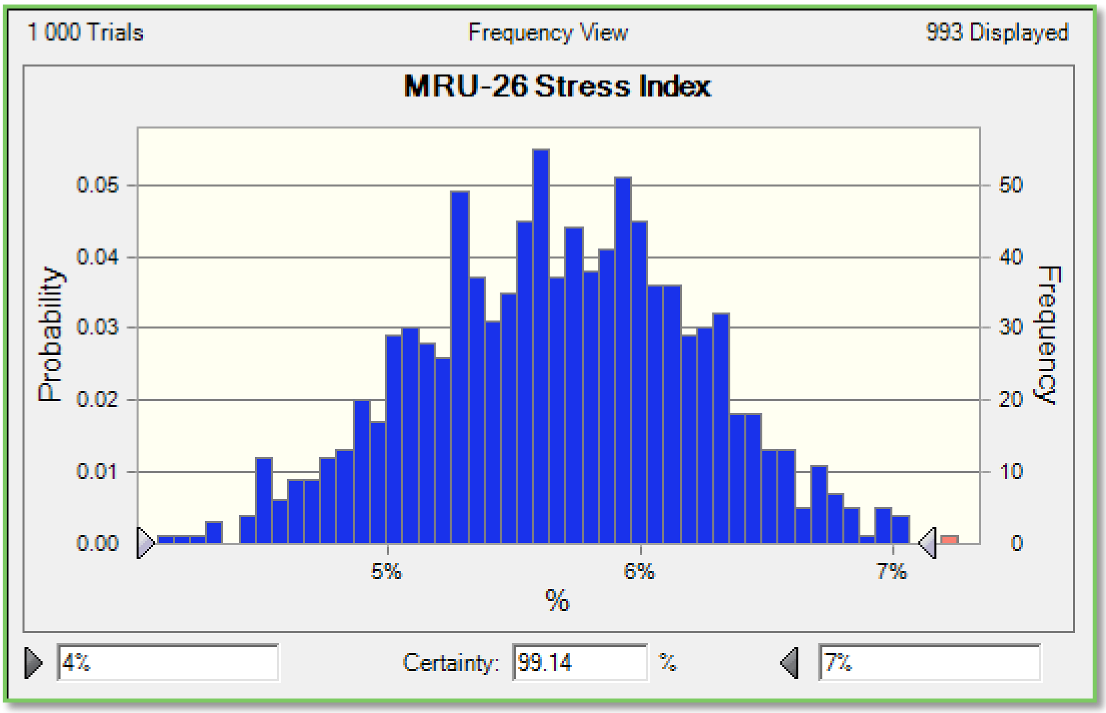


FIGURE 165: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 166**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. There is a relatively even distribution of boreholes between category A and C, therefore the final category is B.

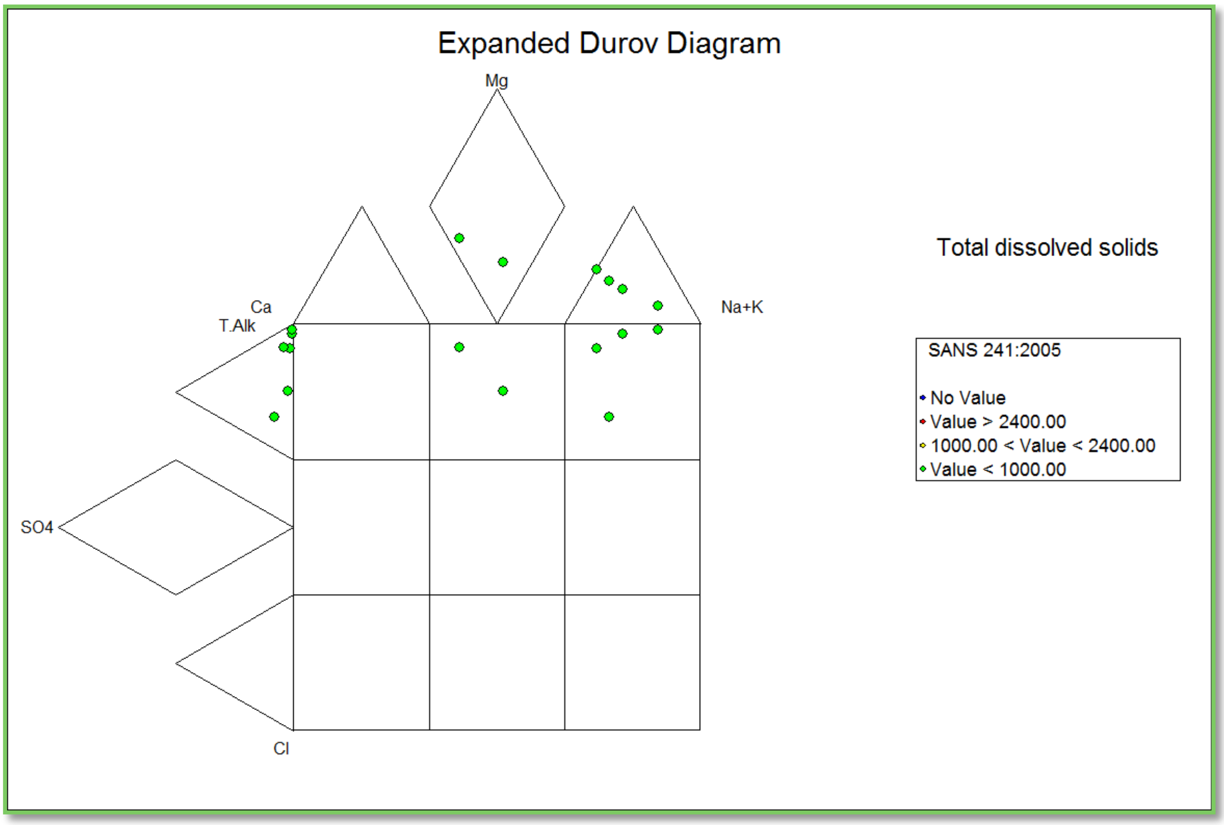


FIGURE 166: EXPANDED DUROV DIAGRAM

As documented the vulnerability is 62%. The impact of potential contamination according to Section 2.2, is medium due to agricultural activities and some mines.

Final category

The final category for the RU is summarised in **Table 192**.

TABLE 192: CATEGORY FOR RU

Impact	Present status category	Water resource category
Groundwater usage	B	Good
Groundwater contamination	B	Good
Potential groundwater contamination (vulnerability and impact)	C	Good/Fair
FINAL	**B/C**	**Good/Fair**

31.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 193**.

TABLE 193: RESERVE

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
14.975	0.005	16%	75.420	5.450

32. Classification and the Reserve for RU27

32.1 Location

The following quaternary catchments are included in the RU: W51C, W51D, W51E W51F, W52B, W53A, W53B and W53C. The towns located in the RU are Sheepmoor, Panbult, Iswepe, Anysspruit, Amsterdam, Piet Retief, Wittenberg and Sicunusa. The protected areas include the Jericho and Mogenstond Dams. The location of the RU is shown in **Figure 167**.

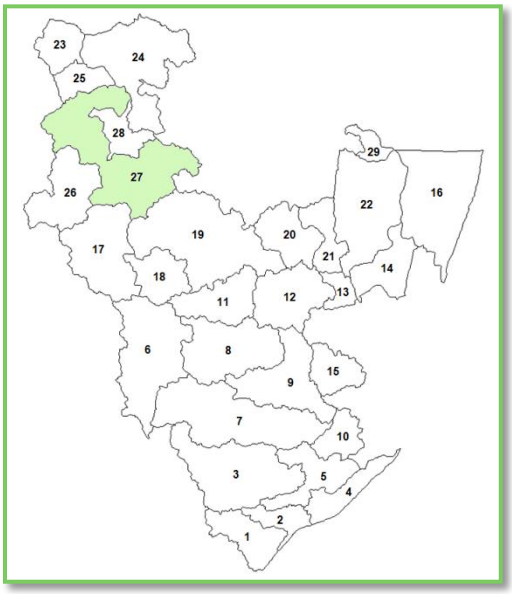


FIGURE 167: LOCATION

32.2 Climate

The summer rainfall ranges from 700 to 1100 mm per year. Temperatures vary from -8°C to 39°C, with an average of 15°C.

32.3 Vegetation (taken from environment.gov.za)

The grassland type in this RU contains many endemic plant species: 78 endemic or near-endemic species occur on the Black Reef quartzites. These are mostly representatives of the Lilies (Liliaceae - now split into several families), Irises (Iridaceae), Daisies (Asteraceae), Mints (Lamiaceae) and Orchids (Orchidaceae).

32.4 Demography and Land use

Forestry, grazing and ecotourism are the most important economic activities, together with coal mining. The total population in the RU is 77850. The Landcover is shown in **Figure 168**.

PHOTO 45: COAL MINING OUTSIDE ANYSSPRUIT

(Source: www.panoramio.com)

32.5 Surface water and Wetlands

The headwaters of the Ngwempisi and Assegaai Rivers run through this RU. There are 2 dams in the area, namely the Jericho and Mogenstond Dams. The wetlands in the RU are shown in **Figure 168**.

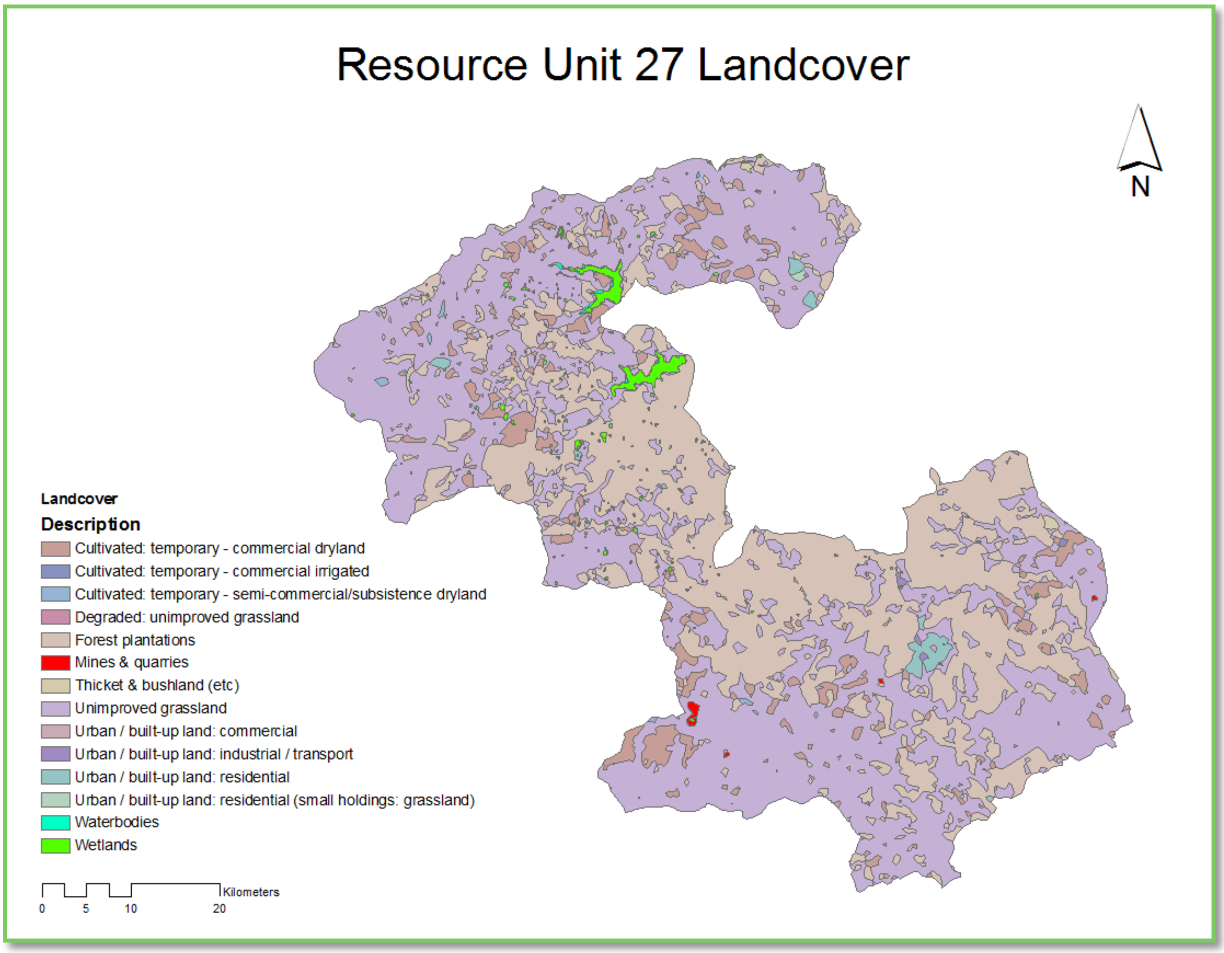


FIGURE 168: LANDCOVER

32.6 Soils (taken from environment.gov.za)

Soils are mostly shallow lithosols derived from a variety of rock types.

32.7 Geohydrology

Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 169**. The most probable depth to groundwater level in the RU is 7.2 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

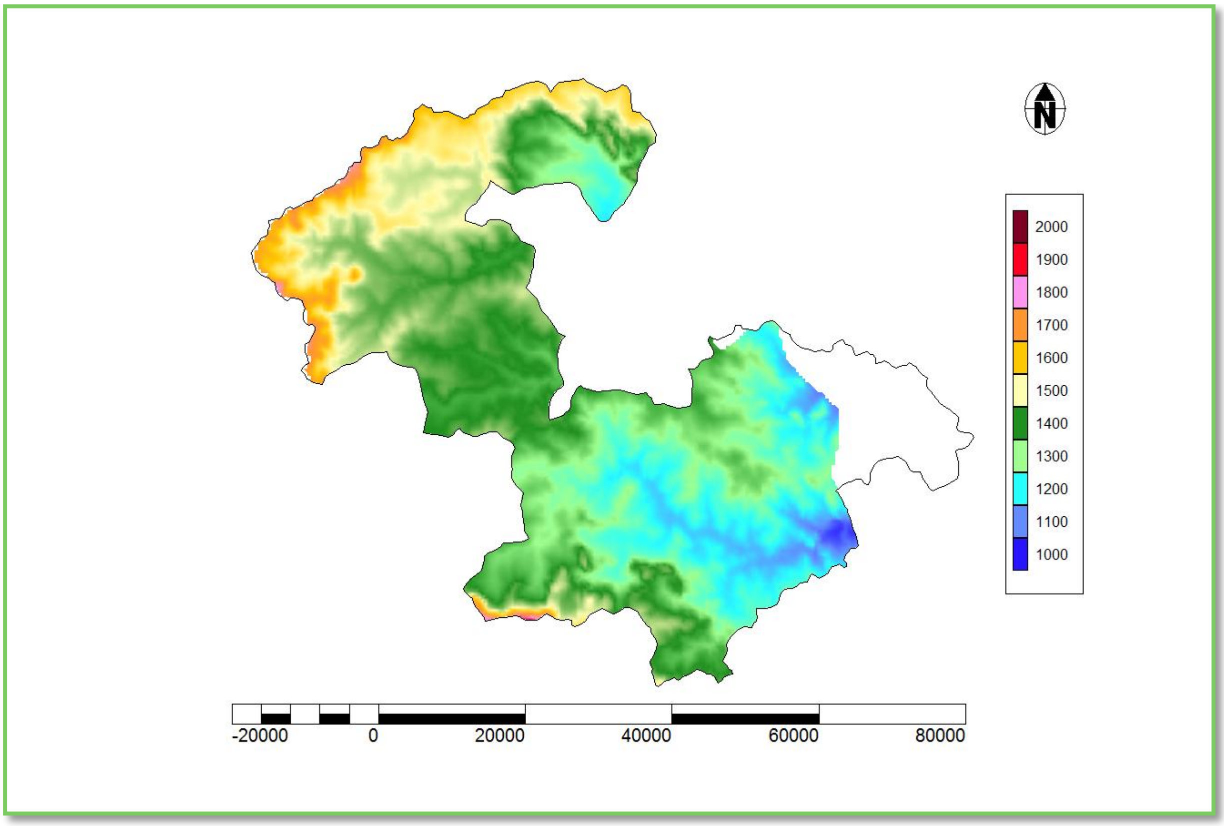


FIGURE 169: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 194**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 194: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
2819.279	192.192	256.755	233.433	8.3%	8.3%	3.6%	4.3%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 195**.

TABLE 195: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
205195	41039	0.369

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 196** is highlighted in red.

TABLE 196: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
112.033	165.545	108.552	48.318	87.934	25.774	256.755	48.318

Groundwater use

The groundwater use in the catchment is documented in **Table 197**.

TABLE 197: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
0.410	0.681	0.001	0.001	0.681	18.000	2.503	20.134

Groundwater quality

The TDS values for the RU are shown in **Figure 170**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines.

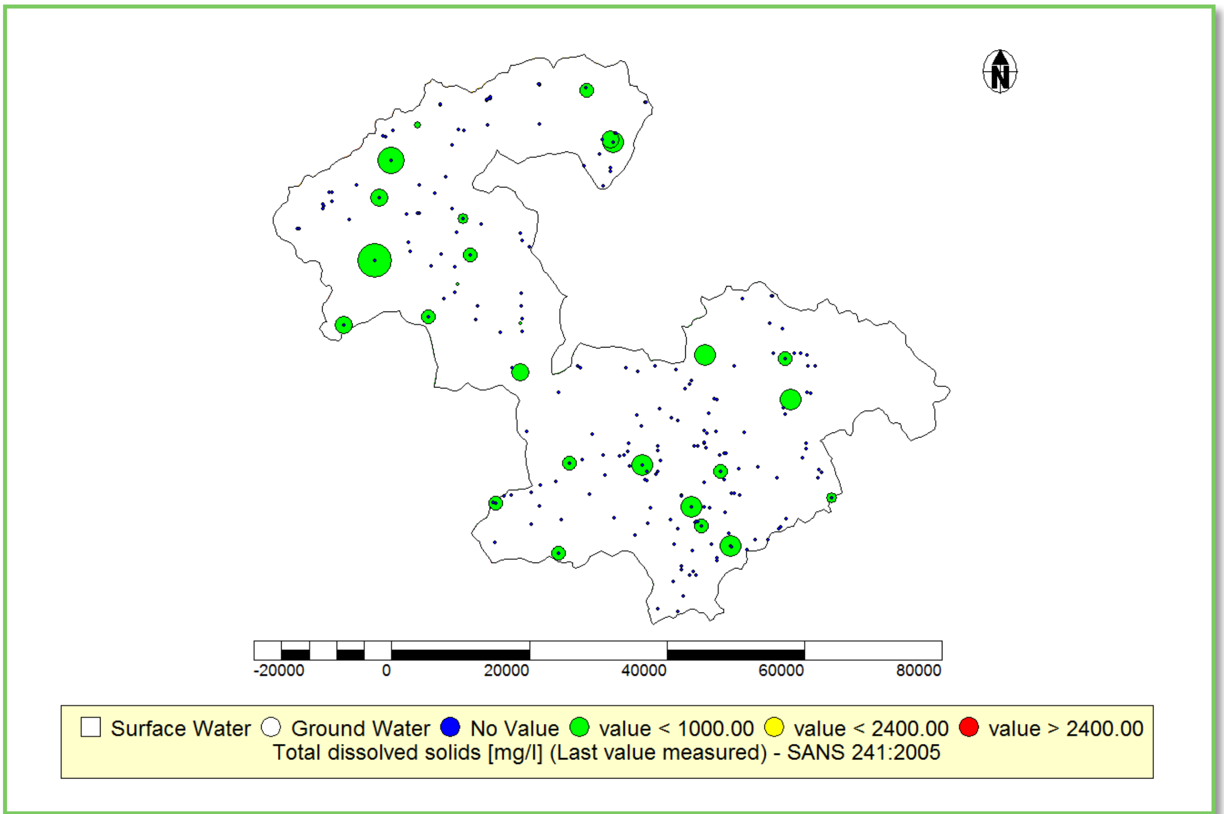


FIGURE 170: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 198**. The slope histogram is documented in Appendix D.

TABLE 198: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
7.2	8.3%	1.2	LmSa-SaLm	Weathered/Fractured	Natal	62%

32.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 8.8%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 2.013 Mm³/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in **Figure 171**. It is clear from the results that the stress index will vary between 6% and 11%, with a certainty of 99.24%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

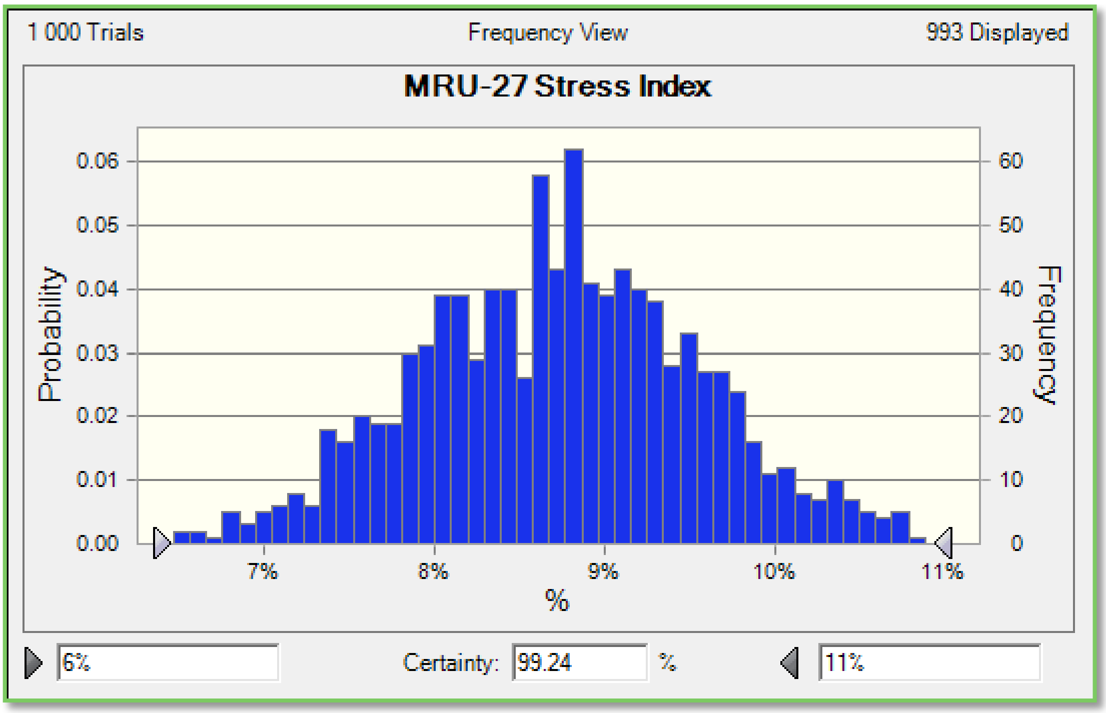


FIGURE 171: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 172**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. There is a relatively even distribution of boreholes between category A and C, therefore the final category is B.

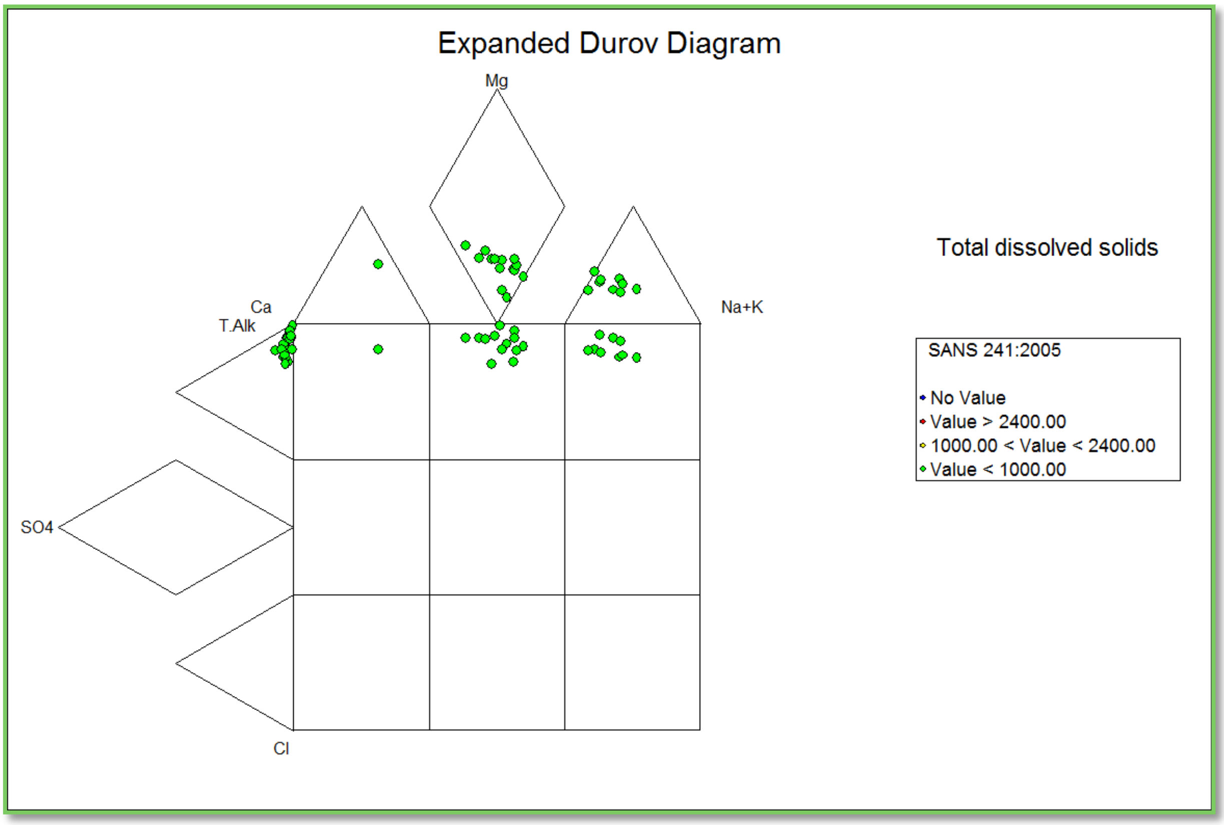


FIGURE 172: EXPANDED DUROV DIAGRAM

As documented the vulnerability is 62%. The impact of potential contamination according to Section 2.2, is high due to the large number of tree plantations.

Final category

The final category for the RU is summarised in **Table 199**.

TABLE 199: CATEGORY FOR RU

Impact	Present status category	Water resource category
Groundwater usage	B	Good
Groundwater contamination	B	Good
Potential groundwater contamination (vulnerability and impact)	D	Fair
FINAL	**C**	**Good/Fair**

32.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 200**.

TABLE 200: RESERVE

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
48.318	0.369	21%	164.612	20.134

33. Classification and the Reserve for RU 28

33.1 Location

The quaternary catchments include W52C and W52D. There are no towns or protected areas in the RU. The location of the RU is shown in **Figure 173**.

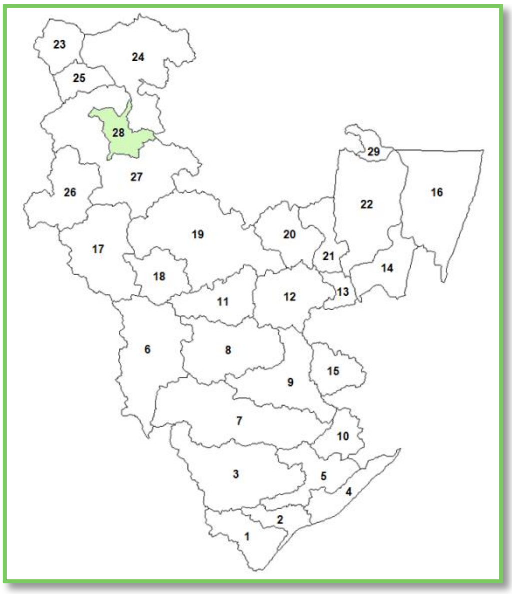


FIGURE 173: LOCATION

33.2 Climate

The summer rainfall ranges from 700 to 1100 mm per year. Temperatures vary from -8°C to 39°C, with an average of 15°C.

33.3 Vegetation (taken from environment.gov.za)

The grasslands in the RU contain many endemic plant species: 78 endemic or near-endemic species occur on the Black Reef quartzites. These are mostly representatives of the Lilies (Liliaceae - now split into several families), Irises (Iridaceae), Daisies (Asteraceae), Mints (Lamiaceae) and Orchids (Orchidaceae).

PHOTO 46: FORESTRY

(Source: www.panoramio.com)

33.4 Demography and Land use

Forestry (**Photo 46**) is the most important economical activity. The total population for the RU is less than 500. The Landcover is shown in **Figure 174**.

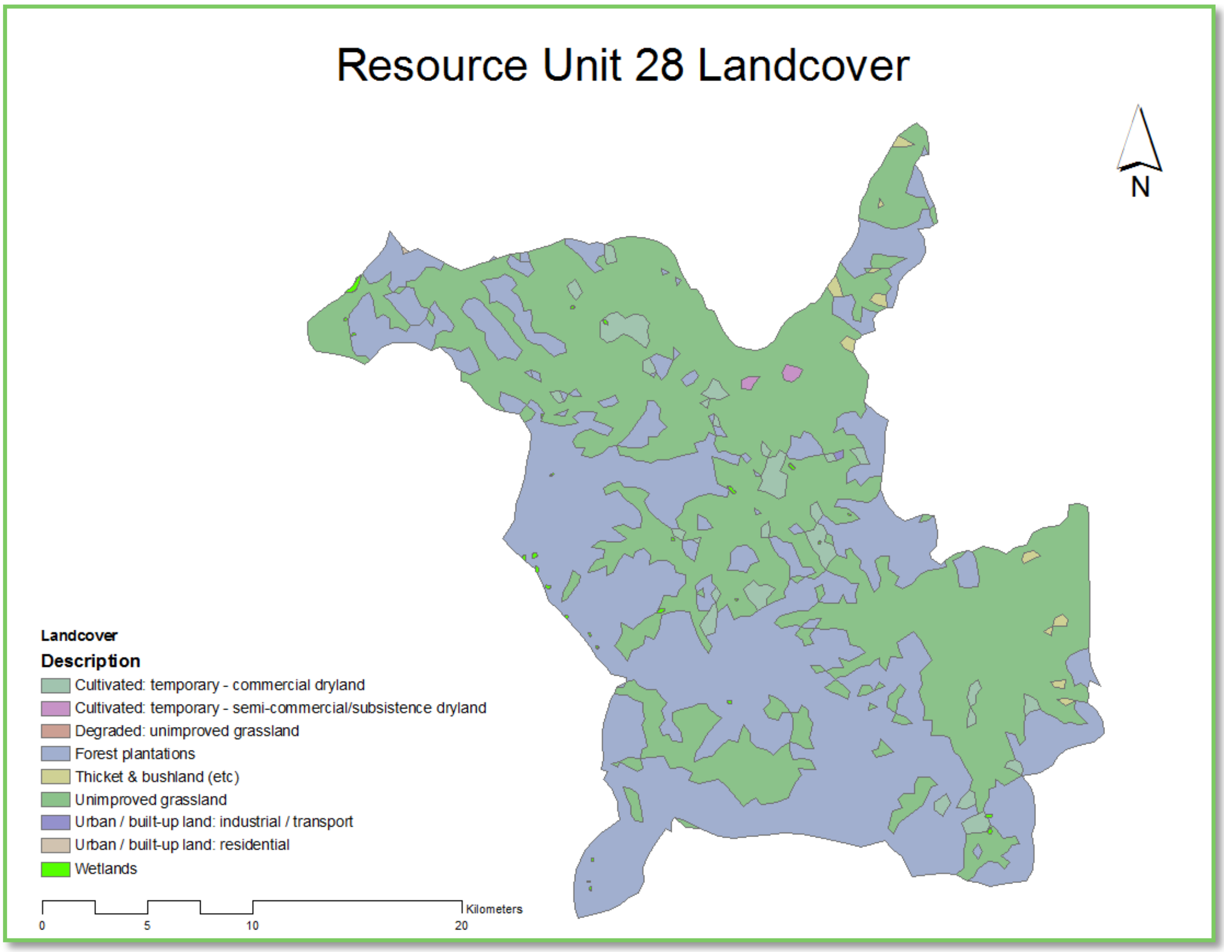


FIGURE 174: LANDCOVER

33.5 Surface water and Wetlands

The Hlelo River flows through the RU. The wetlands in the RU are shown in **Figure 174**.

33.6 Soils (taken from environment.gov.za)

Soils are mostly shallow lithosols derived from a variety of rock types.

33.7 Geohydrology

Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using

Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 175**. The most probable depth to groundwater level in the RU is 8.9 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

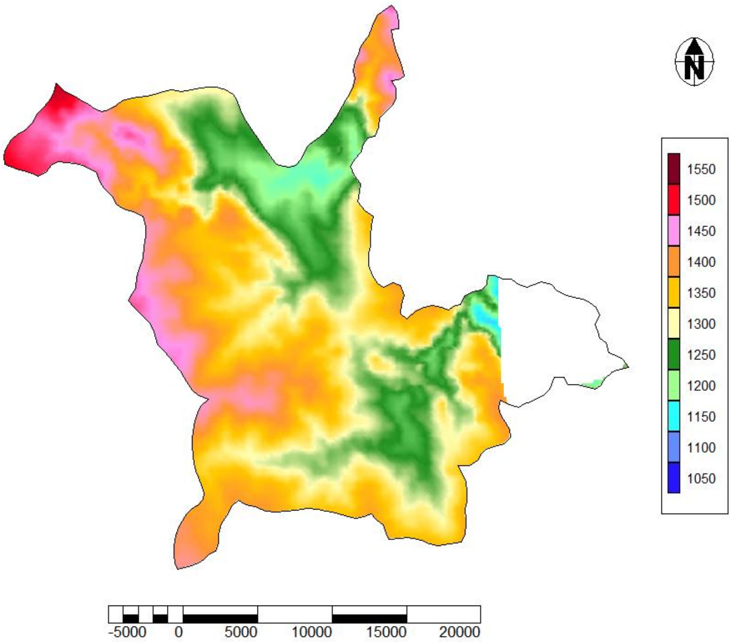


FIGURE 175: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 201**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

TABLE 201: RECHARGE VALUES

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
524.079	38.890	58.121	46.303	8.8%	8.8%	5.7%	4.2%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 202**.

TABLE 202: BASIC HUMAN NEEDS

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
27985	5597	0.050

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 203** is highlighted in red.

TABLE 203: GROUNDWATER CONTRIBUTION TO BASEFLOW

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
9.648	29.731	20.634	9.071	16.369	1.387	58.121	9.071

Groundwater use

The groundwater use in the catchment is documented in **Table 204**.

TABLE 204: GROUNDWATER USE

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
0.010	0.001	0.000	0.000	0.010	1.800	0.004	1.753

Groundwater quality

The TDS values for the RU are shown in **Figure 176**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines.

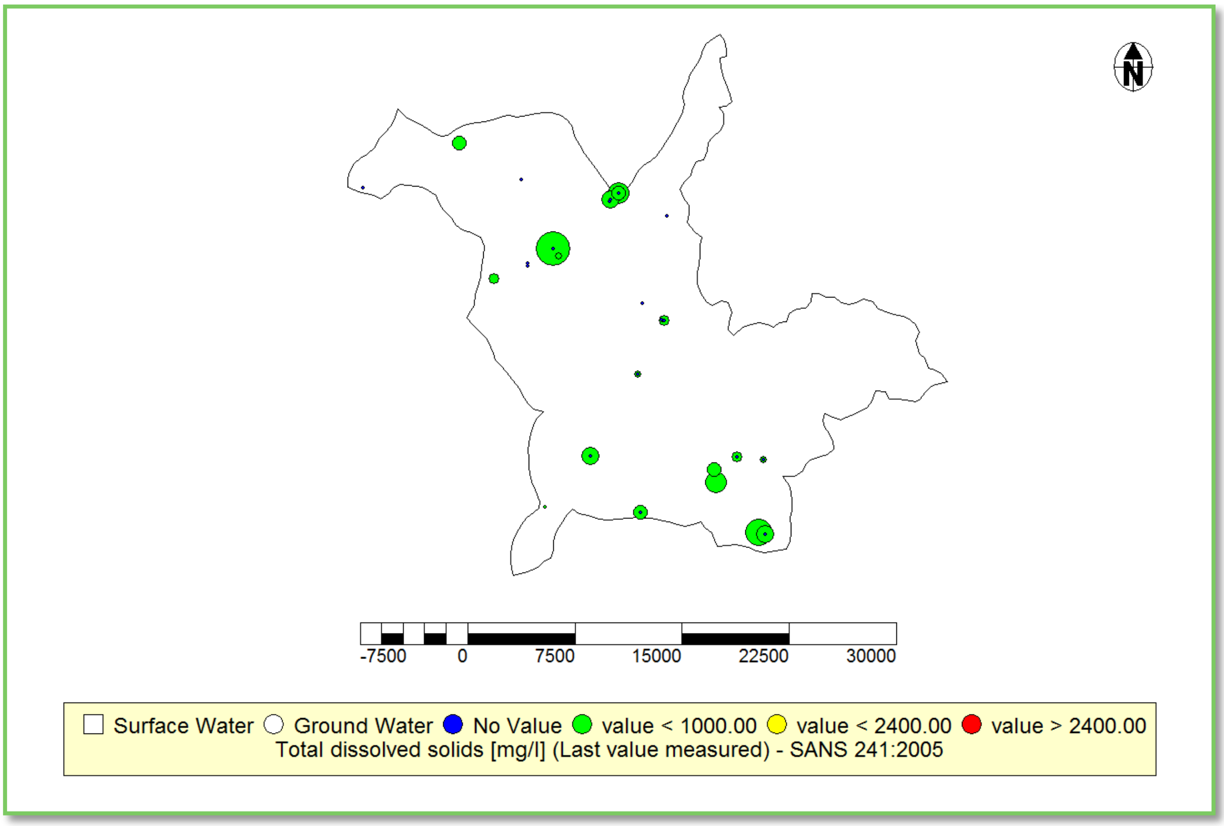


FIGURE 176: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 205**. The slope histogram is documented in Appendix D.

TABLE 205: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
8.9	8.8%	0.4	LmSa-SaLm	Weathered/Fractured	Natal	60%

33.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 3.9%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 0.175 Mm^3/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in **Figure 177**. It is clear from the results that the stress index will vary between 3% and 5%, with a certainty of 99.44%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

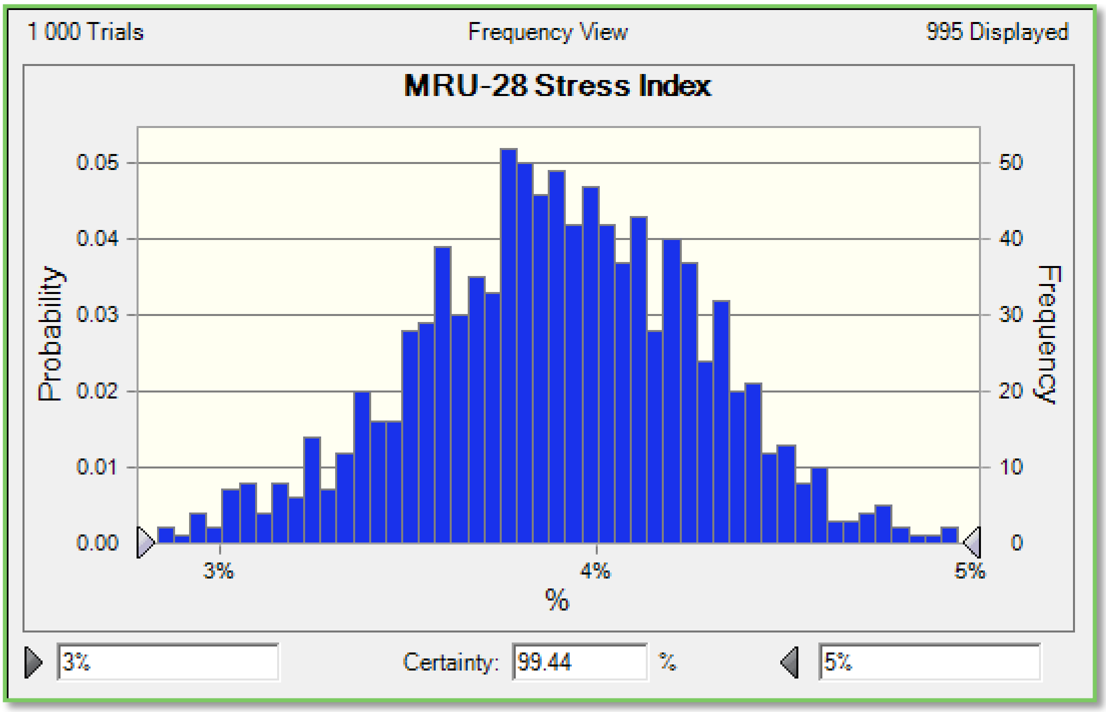


FIGURE 177: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 178**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. There is a relatively even distribution of boreholes between category A and C, therefore the final category is B.

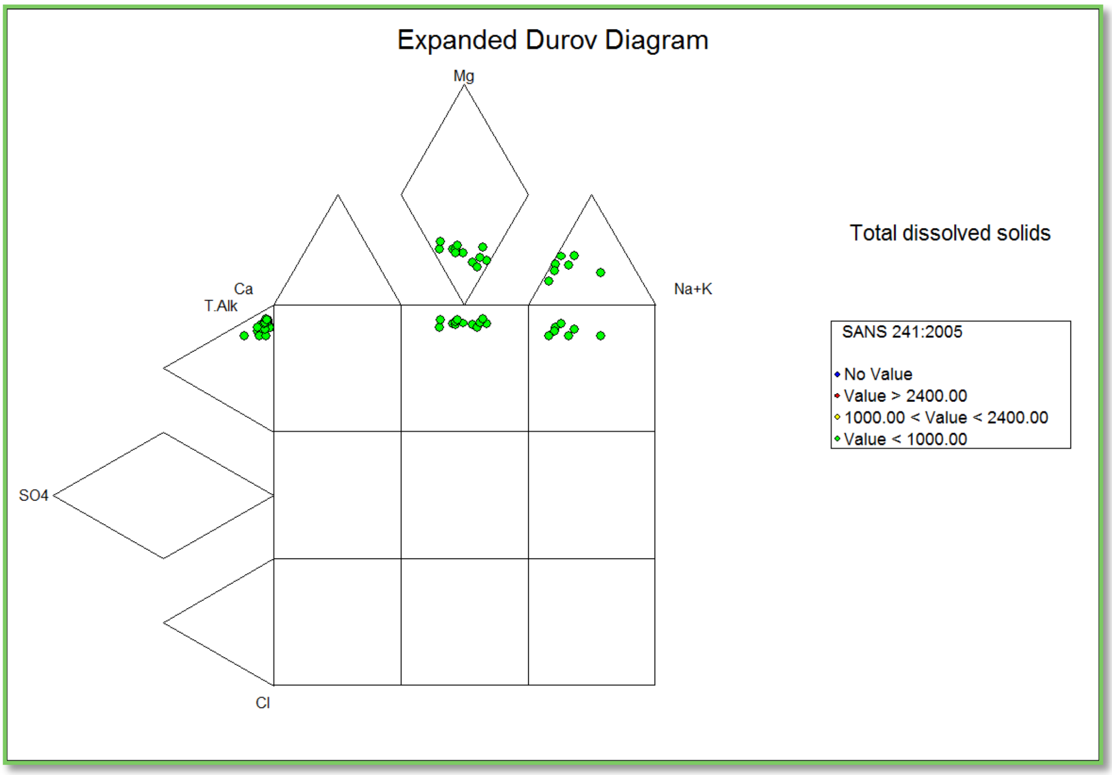


Figure 178: Expanded Durov diagram

As documented the vulnerability is 60%. The impact of potential contamination according to Section 2.2, is medium due to the tree plantations in the western sections of the RU.

Final category

The final category for the RU is summarised in **Table 206**.

Table 206: Category for RU

Impact	Present status category	Water resource category
Groundwater usage	A	Natural
Groundwater contamination	B	Good
Potential groundwater contamination (vulnerability and impact)	C	Good/Fair
FINAL	**B**	**Good**

33.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 207**.

Table 207: Reserve

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
9.071	0.050	20%	35.429	1.753

34. Classification and the Reserve RU29

34.1 Location

This RU consists of quaternary catchment W57K. The Ndumo Park is protected within the RU. The location of this RU is shown in **Figure 179**.

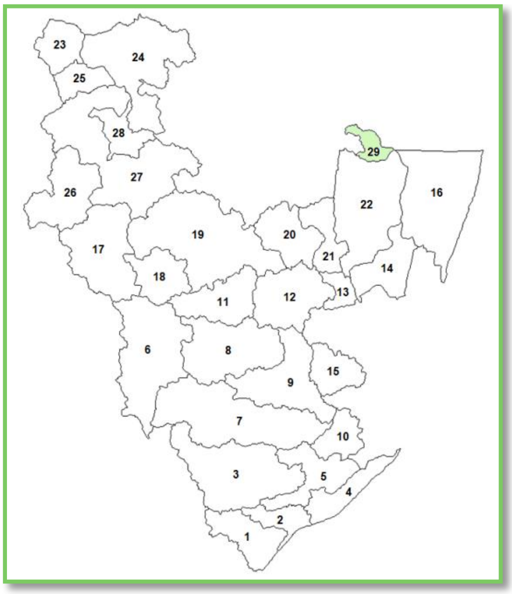


FIGURE 179: LOCATION

34.2 Climate

The rainfall is 800 to 900 mm per year in summer. Mean annual temperatures for January are around 24°C with a mean maximum of about 30°C, while the winter mean annual July temperature is 16°C with a mean minimum of 10°C.

34.3 Vegetation (taken from environment.gov.za)

The vegetation in this RU is a mix of scrub and savanna (**Photo 47**). The most common tree species include Umbrella Thorn Acacia tortilis, Sweet Thorn A. karroo, Red Bushwillow Combretum apiculatum, Boscia albitrunca, Euclea schimperi, Olea

PHOTO 47: VEGETATION

(Source: www.panoramio.com)

europaea subsp. africana, Schotia brachypetala, Euphorbia spp. and Spirostachys africana. The grasses Spreading Pricklegrass Aristida congesta subsp. barbicollis and Pinhole Grass Bothriochloa insculpta occur in areas of severe disturbance. Where disturbance is less severe, grass species such as Redgrass Themeda triandra and Speargrass Heteropogon contortus dominate.

34.4 Demography and Land use

According to the 2001 census there are 3300 people living in the RU. The major land uses are cattle and game farming, sugarcane and subtropical fruit. The Landcover for the RU are shown in **Figure 180**.

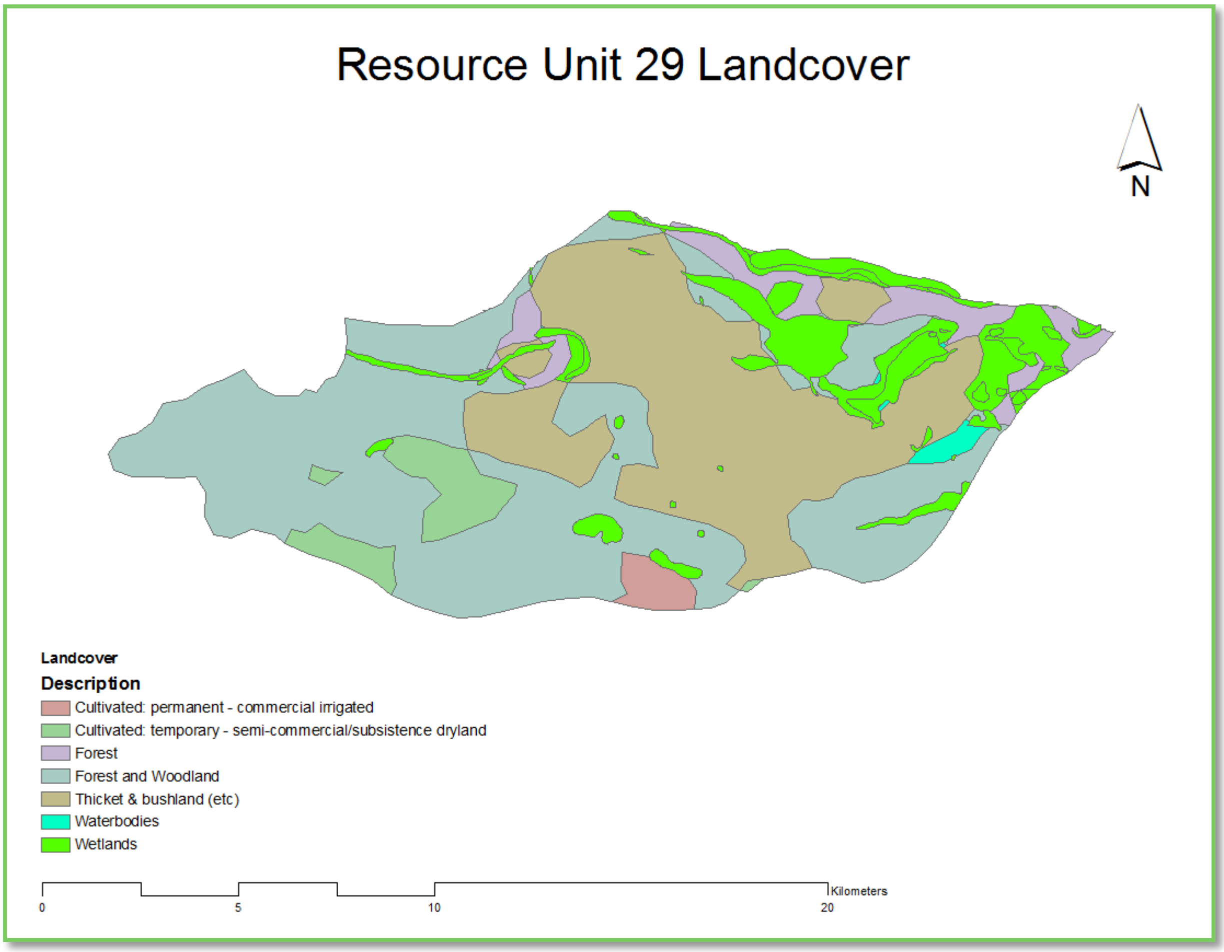


FIGURE 180: LANDCOVER

34.5 Surface water and Wetlands

The Great Usutu River flows through the RU. The wetlands are shown in **Figure 180**.

34.6 Soils (taken from environment.gov.za)

Soils are either black clays, red, structured clays or duplex soils derived from Ecca Group shale and mudstone.

34.7 Geohydrology

Groundwater levels

It is clear the groundwater levels follow the topography as seen from Figure A1 in Appendix A, and therefore groundwater contour maps were generated using Bayesian interpolation. The groundwater levels for the study area are shown in **Figure 181**. The most probable depth to groundwater level in the RU is 2.5 mbgl, according to the histogram of water levels in the RU shown in Appendix B. Groundwater levels are expected to be lower than normal due to prevailing drought conditions. Unfortunately very little time series water level data are available to quantify the overall impact.

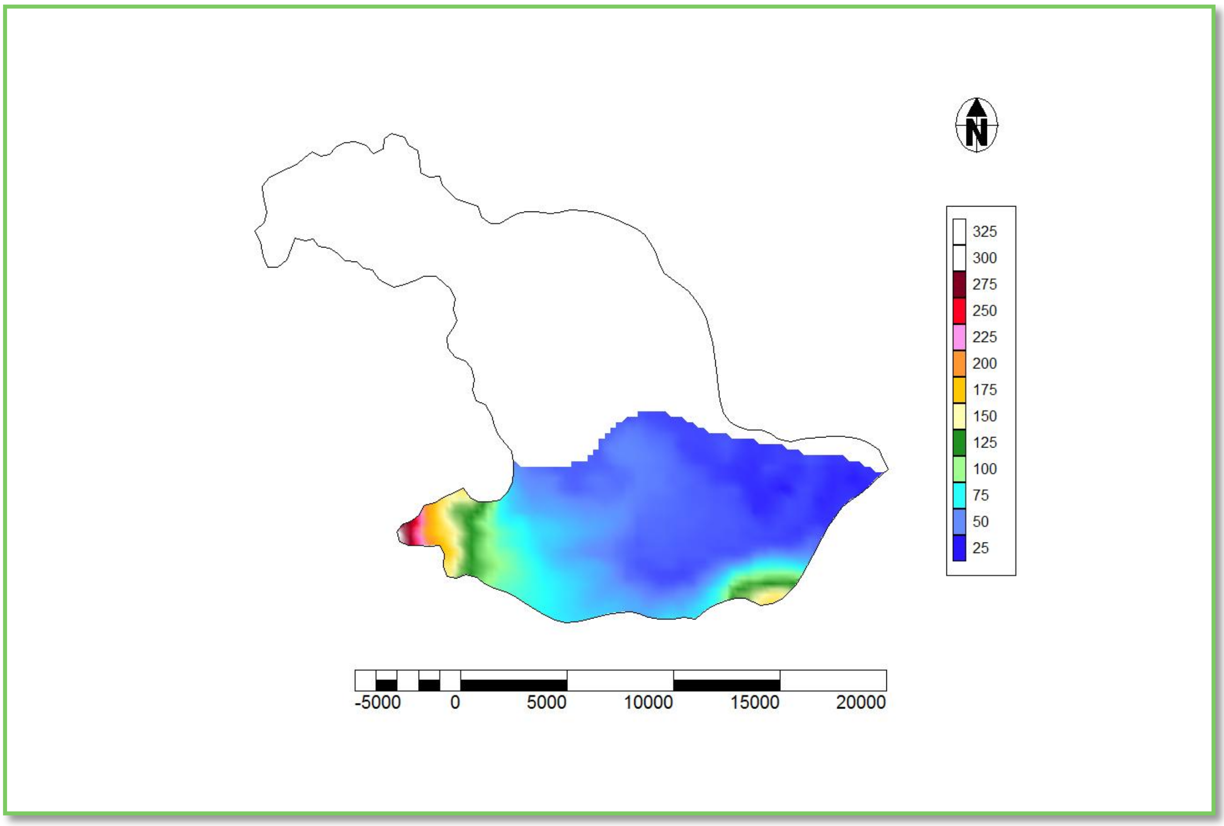


FIGURE 181: GROUNDWATER LEVELS

Groundwater recharge

The groundwater recharge calculated from the different methods is listed in **Table 208**. The different recharge methods applied are discussed in Section 2.2. The final recharge values for the RU are highlighted in red.

Table 208: Recharge values

Recharge							
MAP Mm³/a	MIN Mm³/a	MAX Mm³/a	Volume Mm³/a	Calculated %	CMB %	Landcover %	Geology %
189.028	6.020	13.545	11.808	6.2%	6.2%	10.9%	3.4%

Basic human needs

The method for determining BHNs is discussed in Section 2.2. The final value for the study area is highlighted in red in **Table 209**.

Table 209: Basic human needs

Basic Human Need		
Census(2001) Adjusted	Dependence 20%	Estimate Mm³/a
3795	759	0.007

Groundwater contribution to baseflow

The baseflow separation curves for the RU are shown in Appendix C. The final groundwater contribution to baseflow values for the RU in **Table 210** is highlighted in red.

Table 210: Groundwater contribution to baseflow

Groundwater Contribution to Baseflow							
GRDM Mm³/a	Hughes Mm³/a	Shultz Mm³/a	Pitman Mm³/a	vTonder Mm³/a	MIN Mm³/a	MAX Mm³/a	Herold Mm³/a
2.073	2.835	0.359	0.933	1.059	0.108	13.545	0.933

Groundwater use

The groundwater use in the catchment is documented in **Table 211**.

Table 211: Groundwater use

Groundwater Use							
GRDM Mm³/a	WARMS Mm³/a	Hydrocensus Mm³/a	MIN Mm³/a	MAX Mm³/a	Forrest Mm³/a	Crops Mm³/a	TOTAL Mm³/a
0.020	0.000	0.000	0.000	0.020	0.360	0.134	0.488

Groundwater quality

The TDS values for the RU are shown in **Figure 182**. They are classified according to SABS standards. Not all boreholes have quality data available, but those that do can be used to identify possible hot spots with regard to quality in the resource unit. The overall quality of the resource unit is well within the drinking water guidelines with the exception of two boreholes. These areas should be treated as hotspots rather than applying a poor classification to the whole resource unit. Treatment of the hot spot areas will be addressed under Resource Quality Objectives in Section 35.

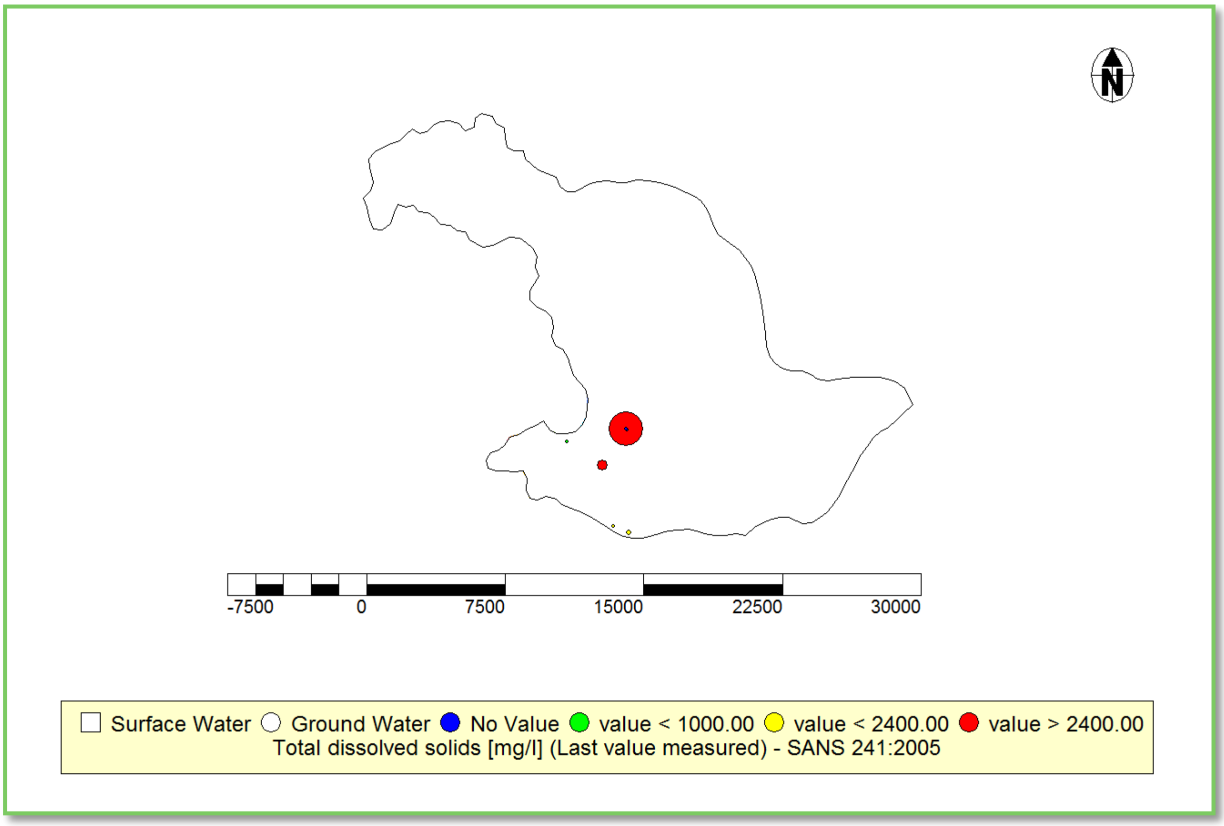


FIGURE 182: TDS VALUES

Aquifer vulnerability

The aquifer vulnerability calculations are summarised in **Table 212**. The slope histogram is documented in Appendix D.

TABLE 212: AQUIFER VULNERABILITY

Aquifer Vulnerability						
Level mbgl	Recharge %	Slope %	Soil Texture	Aquifer Type	Vadose Zone	Vulnerability %
2.5	6.2%	0.5	SaLm-SaCl , LmSa-SaLm, SaCl-Cl	Weathered/Fractured	Natal	66%

34.8 Classification

Groundwater usage

The stress index, defined as the ratio between total groundwater use and recharge, for the study area is calculated at 4.2%. Due to the uncertainty associated with the groundwater use component, the stress index was stochastically modelled through assigning a normal distribution curve with a standard deviation of 0.049 Mm^3/a to the groundwater use estimate to account for the associated uncertainty. The stochastic results are shown in **Figure 183**. It is clear from the results that the stress index will vary between 3% and 5%, with a certainty of 98.93%. Due to the small variablility in the obtained range and high certainty, the uncertainty in the groundwater use component will not affect the calculated stress index significantly.

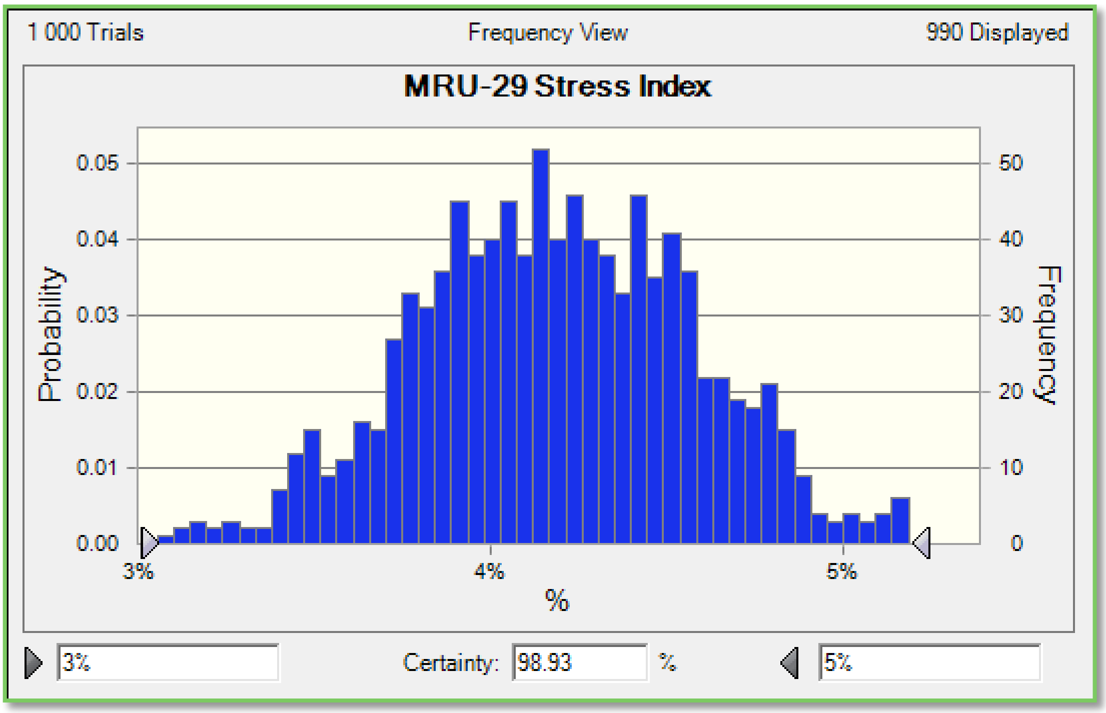


FIGURE 183: STOCHASTIC RESULTS

Quality

The expanded Durov diagram with the groundwater quality is shown in **Figure 184**. An explanation of the classification process by means of the expanded Durov diagram is given in Section 2.2. It is apparent that the contamination category, according to the explanation, is C.

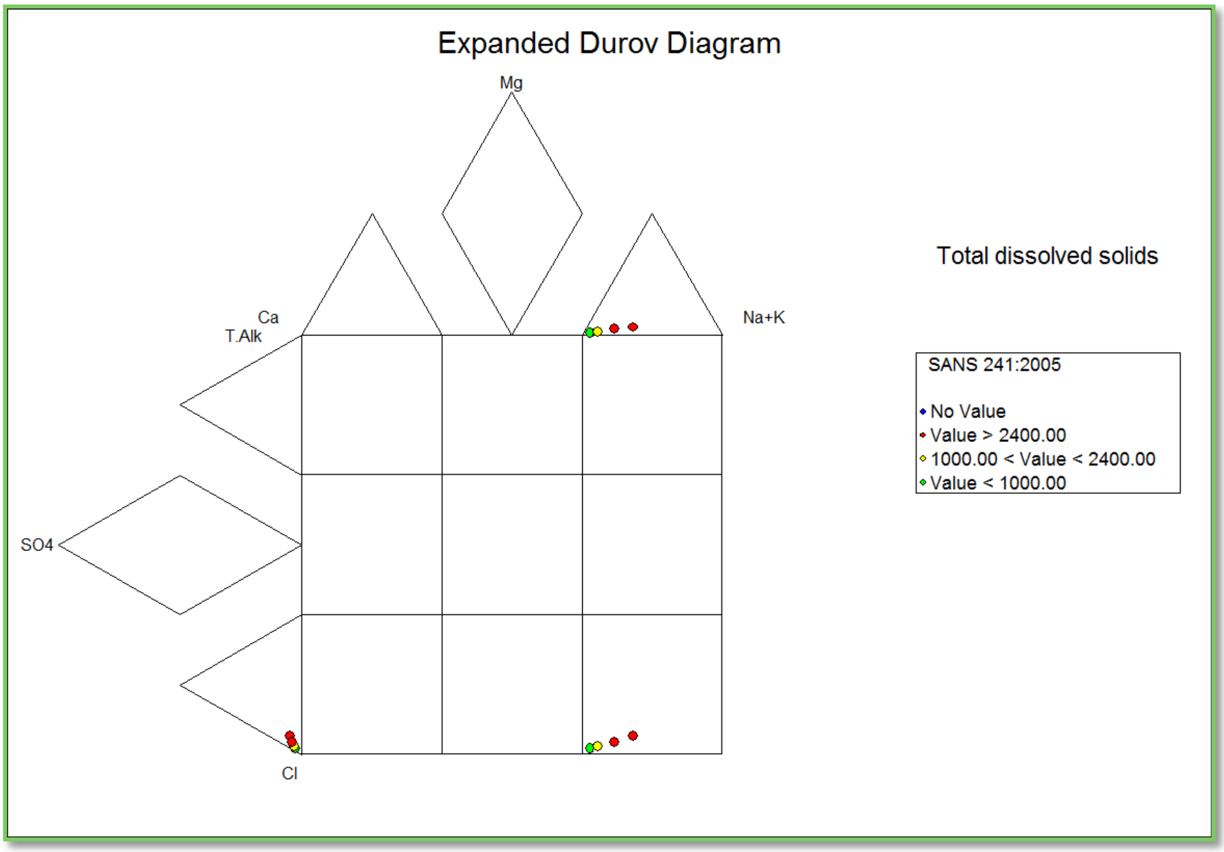


FIGURE 184: EXPANDED DUROV DIAGRAM

As documented the vulnerability is 66%. The impact of potential contamination according to Section 2.2, is low due to limited subsistence farming.

Final category

The final category for the RU is summarised in **Table 213**.

TABLE 213: CATEGORY FOR RU

Impact	Present status category	Water resource category
Groundwater usage	A	Natural
Groundwater contamination	C	Good/Fair
Potential groundwater contamination (vulnerability and impact)	B	Good
FINAL	**B**	**Good**

34.9 The Reserve

The groundwater Reserve for the RU is summarised in **Table 214**.

TABLE 214: RESERVE

Reserve			Allocation	
Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation Mm³/a	Current Use Mm³/a
0.933	0.007	8%	10.380	0.488

35. Resource Quality Objectives

35.1 Preamble

The RQOs are addressed as a separate section due to the vast extent of the study area. The RQOs presented in this section should serve as a general guide for RQOs to be applied to local scale and to address hot spots. Local scale is referred to in the following sections as management areas and should not be confused with the bigger WMA (Water Management Area).

35.2 Defining RQOs for Water level Management

Water use should be managed in a sustainable way regardless of drought conditions. The only way to ensure a borehole is sustainable is to monitor water levels with time. It is however not possible to monitor all boreholes in an area due to time, budget and capacity constraints. Resource units of the size described in this report should be broken down into smaller management areas. Within these management areas monitoring boreholes should be identified which is representative of the specific aquifer. This is done by comparing trends in time series data. Once a network of monitoring boreholes is identified the following criteria should be applied:

- Allow water levels to drop during dry periods, but never allow boreholes to reach the main water strike as this might cripple the borehole. This places responsibility in water user's hands to properly manage the resource. In general over abstraction by an individual will lead to failure of his borehole, before permanent damage to neighbouring boreholes.
- If the water levels don't recover to previous levels after a wet period, abstraction rates should be lowered. As long as water levels recover after wet periods the system is considered sustainable. **Figure 185** shows examples of boreholes in the vicinity of the study area that reflect sustainable behaviour. It is important to note that the boreholes shown in **Figure 186** are just for illustration purposes.

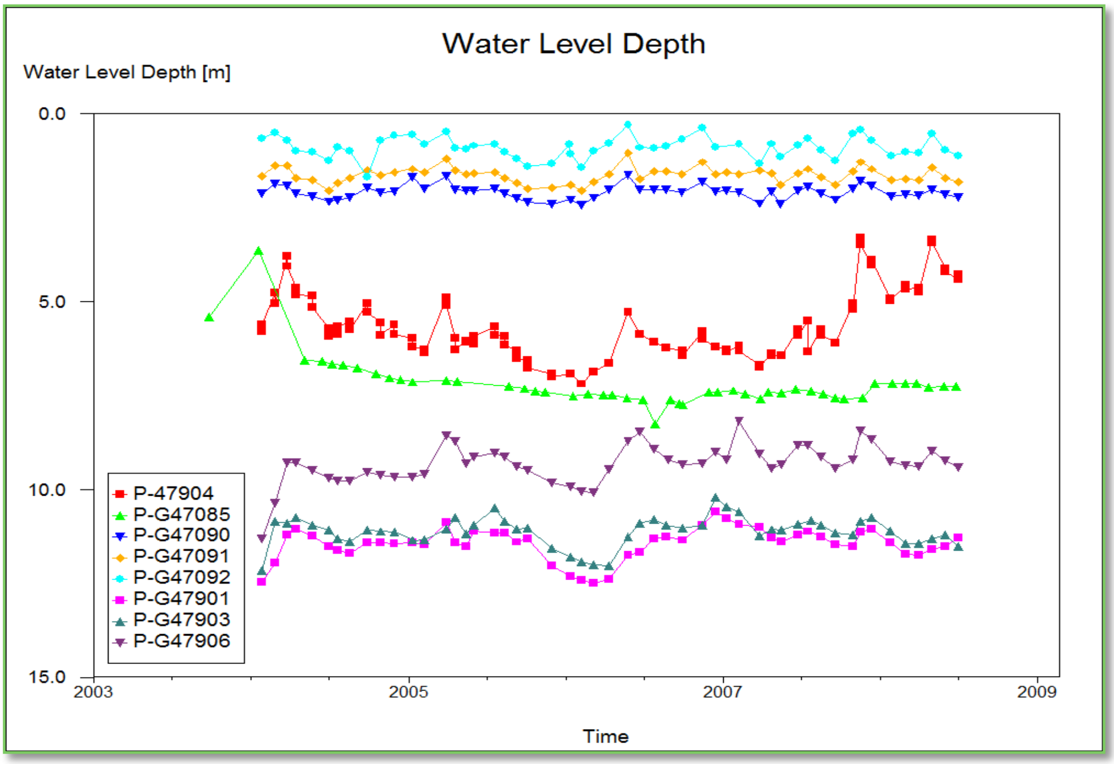


FIGURE 185: TIME SERIES WATER LEVELS OF BOREHOLES WITHIN THE WMA

A map (**Figure 187**) was produced based on water strike and water level information that shows the available drawdown to the borehole water strike. Within each of the stressed areas it is recommended that the individual boreholes be identified and managed accordingly.

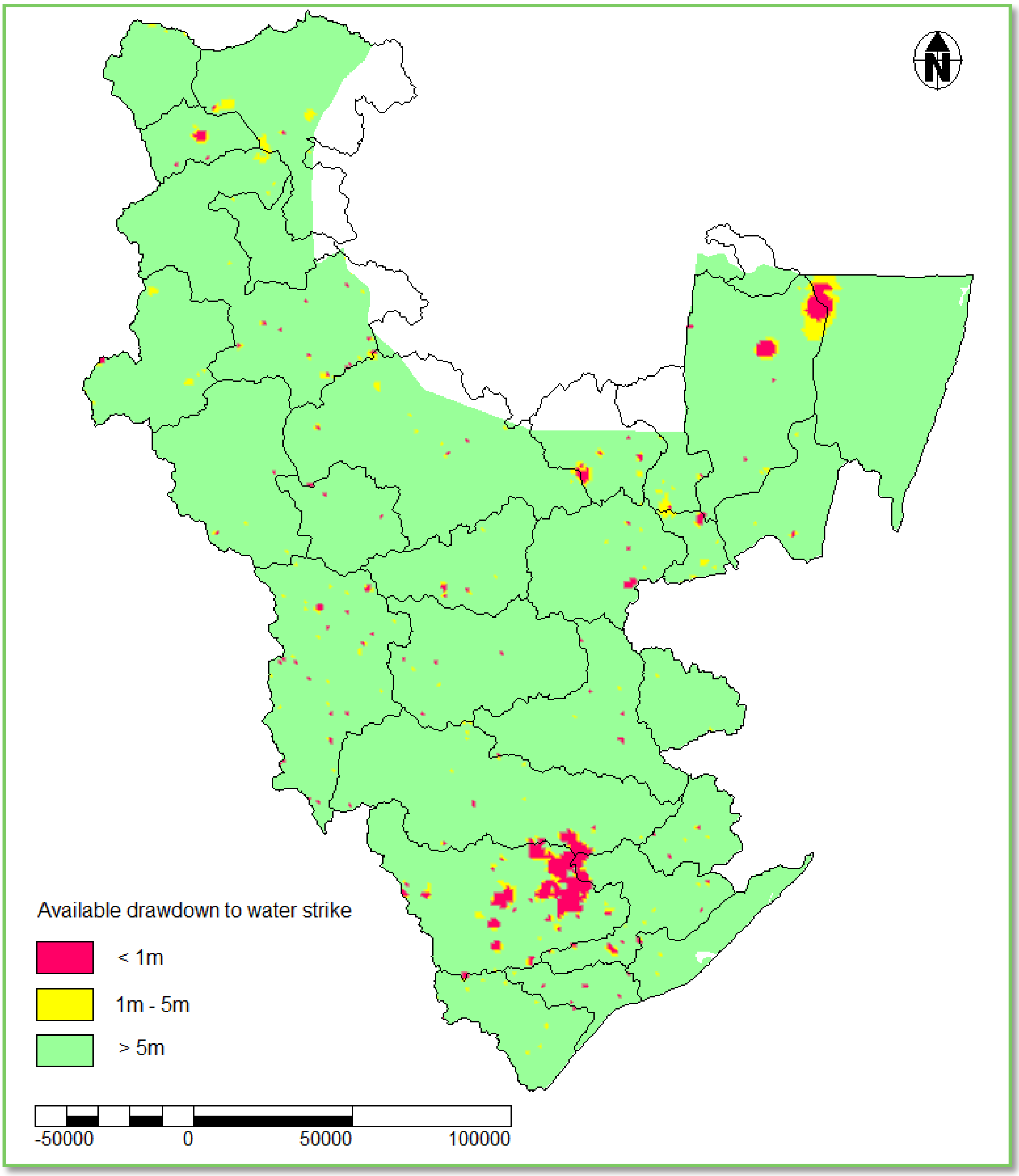


FIGURE 186: STRESSED BOREHOLES BASED ON WATER STRIKE INFORMATION

35.3 Defining RQOs for Rivers

Rivers can be groundwater fed and/or have riparian vegetation, which forms an ADE. Therefore both these issues are considered when setting the RQOs, as shown in **Figure 188**. Perennial rivers and non-perennial rivers with pools are normally fed by groundwater and therefore need to be protected by means of RQOs. The amount of groundwater flowing into the river needs to be calculated (i.e. groundwater contribution to baseflow). Once this has been established, the RQO can be set as a groundwater level or gradient to be maintained for a certain distance from the river.

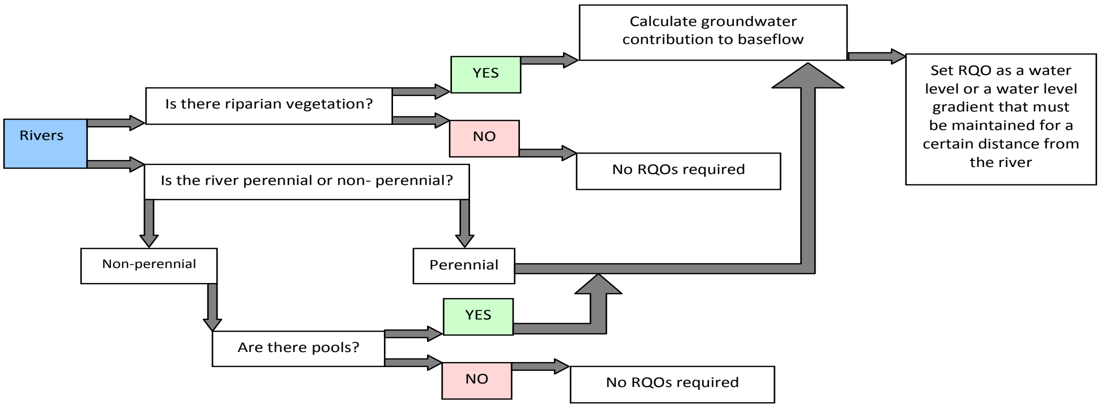


FIGURE 187: SETTING RQOS FOR RIVERS

35.4 Defining RQOs for Wetlands and Estuaries

RQOs for groundwater driven wetlands/estuaries must also be determined, as shown in **Figure 188**. The amount of groundwater flowing into these regions needs to be calculated. Once this has been calculated, the RQO can be set as a groundwater level or gradient to be maintained for a certain distance from the wetland/estuary.

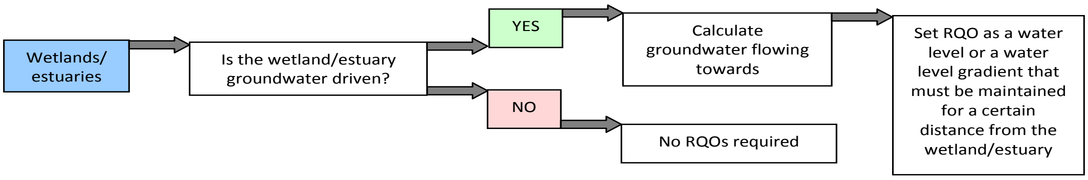


FIGURE 188: SETTING RQOS FOR WETLANDS AND ESTUARIES

35.5 Defining RQOs for Springs

Springs are groundwater driven and therefore need to be protected, as shown in the **Figure 189**. However, the way in which they are protected differs between hot and cold springs. Hot or thermal springs, according to Kent (1949), are those for which the water temperature is above 30°C. Their groundwater source is usually very deep beneath the earth's surface. Boreholes must therefore not intercept these aquifers and deplete the source. The geothermal gradient for groundwater; that is, the rate of increase in temperature with depth, is about or 1°C per 30 m depth (Van Tonder, 2003), although there are exceptions to this rule. The capture area for a cold water spring can be determined by standard methods. A minimum distance for any potentially harmful activities (boreholes, possible pollution sources) must be allocated outside the minimum distance.

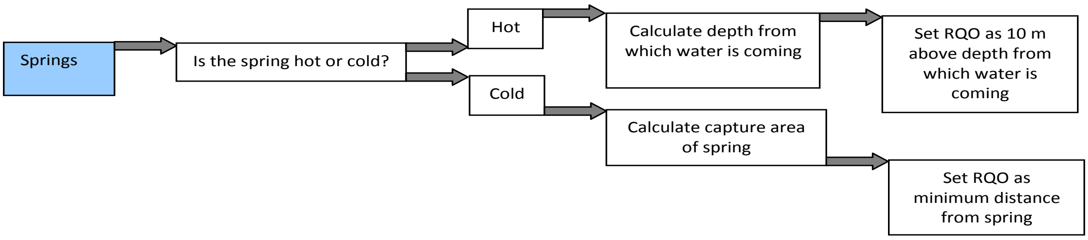
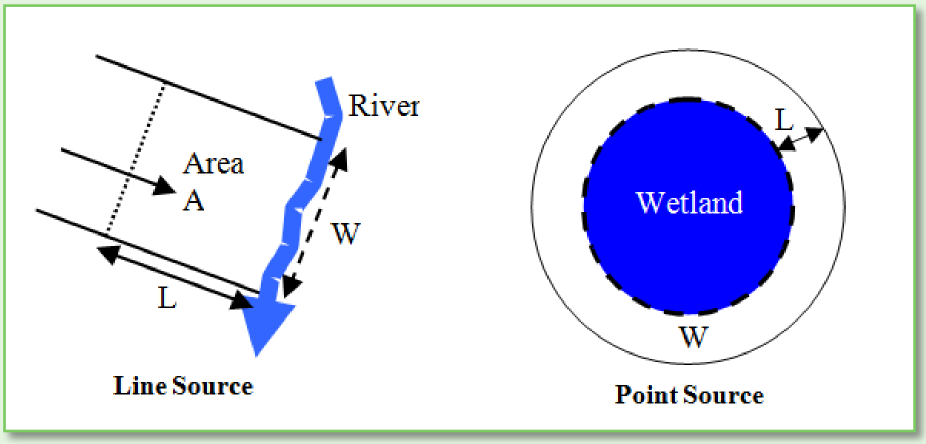


FIGURE 189: SETTING RQOS FOR SPRINGS

A NOTE ON RIVERS, WETLANDS AND SPRINGS . . .

The protection distances to rivers, wetlands and springs are based on the concept of preserving the flux to the entity in question. The flux in each case is determined on local scale e.g. the groundwater contribution to baseflow. By dividing the flux (L^3/T) through the recharge (L/T) associated with the region the area (L^2) to be protected is obtained. Once the area is known the associated protection distance (L) is calculated as shown in the Figure below.



On local level river stretches, wetlands and springs affected by current and future borehole development need to be identified and the associated protection distances calculated and enforced.

35.6 Defining RQOs for BHNs, Strategic use and International obligations

Groundwater use for basic human needs, strategic use, and international obligations must also be protected, as seen in **Figure 191**. The rates in the boreholes or flow across international boundaries must be calculated and protection zones delineated. Once this has been calculated, the RQO can be set as a groundwater level or gradient to be maintained for a certain distance, or as assurance of supply (sustainability) of the groundwater resource.

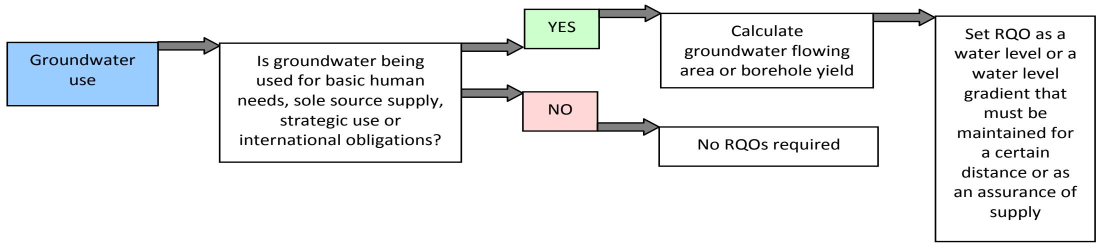


FIGURE 191: RQOS FOR BHNS, STRATEGIC USE AND INTERNATIONAL OBLIGATIONS

A NOTE ON BOREHOLES . . .

The radius of influence for boreholes can be used as a conservative guide for development of new boreholes. The radius of influence is determined by setting the drawdown to zero in the Cooper-Jacob equation. Due to the nature of the drawdown curve represented by the Cooper-Jacob equation it is not always a practical radius due to the fact that the drawdown curve tends to zero over a long distance. A more practical approach would be to set the drawdown to something like 10cm and calculate the radius of influence accordingly. The Table shows the practical implication of this if the following constant parameters are assumed:

- Abstraction = 1 m^3/d
- Transmissivity = 5 m^2/d
- Storativity = 0.001
- Time = 360 days

Allowed Drawdown (cm)	Radius of Influence (m)
0	2012
1	1469
5	418
10	87

Note that not setting the drawdown to zero makes the radius of influence dependent on both the abstraction and the time that abstraction takes place.

If a new borehole cannot be placed according the specified radius of influence due to physical constraints e.g. geophysical results or property boundaries the borehole may be placed on the optimal position taking into account all factors as long as proper water level management takes place as described earlier in Section 35.2.

35.7 Defining RQOs for Protected Areas

RQOs also need to be assigned to protected areas such as national parks and world heritage sites, as seen in the Figure below. The amount of groundwater flowing into these regions needs to be calculated. Once this has been done, the RQO can be set as a groundwater level or gradient to be maintained for a certain distance from the protected area.

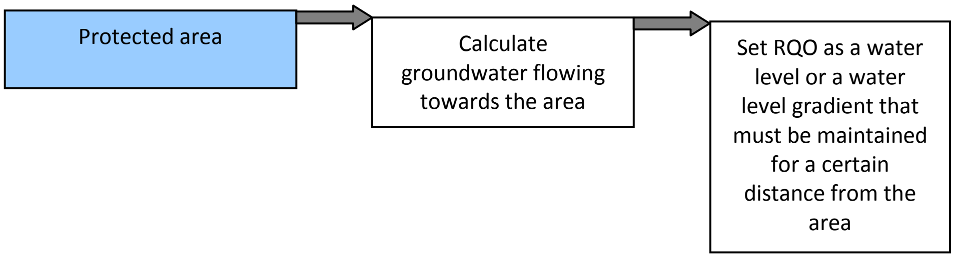


FIGURE 192: RQOS FOR PROTECTED AREAS

35.8 Defining RQOs for Contaminated Sites

General

To be able to calculate protection zones aquifer parameters are required. Due to the vast extent of the study area ranges of parameters exist, hence when a calculation is made the local aquifer parameters are required. **Table 215** shows typical ranges of aquifer parameters across the study area.

TABLE 215: GROUNDWATER PARAMETERS

Parameter	Range
Hydraulic conductivity [m/d]	0.001 – 0.0001
Hydraulic gradient	0.04 – 0.0001
Porosity	0.005 – 0.2

Mines, industry etc.

Most of the mines in the area are associated with coal mining. Coal mines are known for high sulphate values that occur at the source ~ 2000 mg/l. Pyrite (FeS_2) an iron disulphide, are one of the most important sulphides found in the waste rock of mines. When exposed to water and oxygen, it can react to form sulphuric acid. This process is known as acid mine drainage where low pH values result in heavy metals going into solution. Using the parameters shown in **Table 215**, the attenuation of the SO_4 concentration is within the drinking water guidelines at a distance of 500m when considering a constant source input.

A conservative approach is taken and a protection distance in the direction of the hydraulic gradient of a 1000m is recommended for mines and industrial areas. In practice preferred pathways exist in the form of fractures which can transport the pollutants orders of magnitude further than what is predicted in the porous media.

From a multitude of industrial and mining monitoring sites it is evident that pollutants moving through fractures are subject to a high degree of dilution resulting in less of a threat compared to the primary porosity movement.

All mining and industrial areas are to be treated as hotspots and monitoring boreholes close to the recommended protection distance of a 1000m in the direction of the groundwater gradient should from part of the monitoring network in the area. Sampling of these monitoring points should be done at least once a year with full chemical analysis to ensure safe drinking water outside the hot spot area.

Sanitation

All new sanitation developments and new water supply projects should adhere to the DWAF guidelines on sanitation. Existing installations not complying with the DWAF standard should form part of the monitoring network of the management area. Nitrate pollution in drinking water can be fatal especially to infants. Sampling of these monitoring points should be done at least once a year with microbial analysis to ensure safe drinking water.

35.9 Defining Protection Distances for RUs

Using average values for each of the RUs, the following protection distances were calculated using various aquifer parameters. These distances are listed in **Table 216**.

Table 216: Groundwater parameters

Resource Unit	Protection Distances																	
	River or Sea (m)			Wetland=0.5km² (m)			Wetland=1km² (m)			Wetland=5km² (m)			Sanitation (m)			Radius of Influence (m)		
	Transmissivity (m²/d)			Transmissivity (m²/d)			Transmissivity (m²/d)			Transmissivity (m²/d)			Transmissivity (m²/d)			Transmissivity (m²/d)		
	1	10	100	1	10	100	1	10	100	1	10	100	1	10	100	1	10	100
MRU-1	35	349	3491	524	1658	5243	624	1972	6235	932	2949	9324						
MRU-2	25	254	2538	447	1414	4471	532	1681	5317	795	2514	7950						
MRU-3	84	836	8359	811	2566	8113	965	3051	9648	1443	4562	14428						
MRU-4	17	166	1659	361	1143	3614	430	1359	4298	643	2032	6427						
MRU-5	38	380	3798	547	1729	5469	650	2057	6504	973	3075	9725						
MRU-6	49	492	4919	622	1968	6224	740	2341	7401	1107	3500	11068						
MRU-7	123	1225	12252	982	3106	9823	1168	3694	11681	1747	5524	17467						
MRU-8	68	684	6840	734	2321	7339	873	2760	8728	1305	4127	13051						
MRU-9	53	527	5274	644	2038	6445	766	2424	7664	1146	3624	11460						
MRU-10	39	392	3925	556	1758	5559	661	2091	6611	989	3126	9886						
MRU-11	98	981	9812	879	2780	8790	1045	3306	10453	1563	4943	15631						
MRU-12	81	810	8096	798	2525	7985	950	3003	9495	1420	4490	14199						
MRU-13	100	1004	10043	889	2812	8893	1058	3344	10576	1581	5001	15814						
MRU-14	80	798	7978	793	2507	7926	943	2981	9426	1410	4457	14095						
MRU-15	53	528	5276	645	2038	6446	767	2424	7666	1146	3625	11463	107	112	162	600	1897	6000
MRU-16	4	44	440	186	588	1861	221	700	2213	331	1046	3309						
MRU-17	34	338	3382	516	1632	5160	614	1941	6137	918	2902	9176						
MRU-18	53	527	5268	644	2037	6441	766	2422	7659	1145	3622	11453						
MRU-19	47	471	4707	609	1925	6088	724	2289	7240	1083	3424	10826						
MRU-20	170	1697	16969	1156	3656	11560	1375	4347	13747	2056	6501	20556						
MRU-21	94	940	9399	860	2721	8603	1023	3235	10231	1530	4838	15299						
MRU-22	125	1246	12458	990	3132	9905	1178	3725	11779	1761	5570	17614						
MRU-23	18	178	1785	375	1186	3749	446	1410	4458	667	2108	6667						
MRU-24	22	224	2241	420	1329	4201	500	1580	4996	747	2363	7471						
MRU-25	11	106	1058	289	913	2887	343	1086	3433	513	1623	5133						
MRU-26	69	688	6884	736	2328	7363	876	2769	8756	1309	4140	13093						
MRU-27	59	587	5871	680	2150	6800	809	2557	8086	1209	3824	12092						
MRU-28	19	190	1903	387	1224	3871	460	1456	4603	688	2177	6883						
MRU-29	31	313	3128	496	1569	4963	590	1866	5902	883	2791	8826						

36. Summary

The Usutu to Mhlathuze Water Management Area lies predominantly within KwaZulu-Natal, with the northern part in the Mpumulanga province. It borders on Swaziland and Mozambique in the north, as well as on the Inkomati, Upper Vaal and Thukela Water Management Areas. The WMA is also referred to as the 'W' Hydrological Drainage Region (Midgeley et al., 1994).

The main rivers in the water management area are the Usutu, Pongola, Mkuze, Mfolozi and Mhlathuze Rivers, which drain adjoining catchments and all flow in a general eastward direction. The Usutu River has several parallel tributaries in South Africa, which all flow together in Swaziland. The Pongola River catchment falls mainly within South Africa, and also drains the south-eastern corner of Swaziland. On the eastern side of Swaziland, the Usutu River forms the border between South Africa and Swaziland, and then between South Africa and Mozambique before flowing together with the Pongola River (on the South African/Mozambican border) to form the Maputo River in Mozambique, where it discharges into Maputo Bay. The Mkuze River drains via the Mkuze swamps into Lake St Lucia, the largest natural lake in South Africa, and then via the St Lucia estuary to the Indian Ocean. The Mfolozi and Mhlatuze Rivers discharge directly into the ocean. An endoreic area with no significant surface drainage exists in the vicinity of Lake Sibayi and Kosi Bay in the north-east of the water management area.

The catchment experiences a wide range of climatic conditions. The climate in the region varies from cool near the western escarpment to sub-tropical along the coast. Summers are generally hot with temperatures often exceeding 35oC. Winters are cold, particularly in the west and north, where temperatures fall below freezing and frost occurs regularly. Along the coast, conditions are generally more temperate.

Rainfall varies significantly throughout the catchment and exhibits a strong correlation with relief. Rainfall is strongly seasonal, with in excess of 80% occurring as thunderstorms during the period from October to March. The peak rainfall months are December to February in the inland areas, and November to March at the coast. Rainfall ranges from as high as 1500 mm per year to the east of the escarpment and near the coast, to about 600 mm per year in the north-central area near the Lebombo mountains. Potential evaporation varies between 1 300 and 1 500 mm per year.

This very extensive WMA is some 45 000 km² in total. Of this, some 6000 km² comprises the Zululand Coastal Plain. Elevation in the area varies from sea level in the east to an average of some 100 m over the width of the Zululand Coastal Plain, inland of which the meridionally-trending Lebombo range rises to some 700 m, inland, and falls abruptly to only some 250 m in the similarly trending 'Lowveld' further inland, where it rises progressively to a maximum elevation of some 1700 m on the Great Escarpment on the north-western boundary of the WMA. Physiographically, the inland portion of the WMA comprises a number of low-standing, generally east or south-east trending catchments of the major rivers that are separated by elevated interfluve ridges.

Distinctly different vegetation types occur over the water management area - from savannah grassland in the north-west, to dense coastal and swamp forests in the east. A huge amount of the natural vegetation has been destroyed due to farming and forestry. However, Ngongoni veld is still found in the upper less developed areas, and coastal forest and thorn veld in the coastal and more developed areas. Both these veld types are more than 70% transformed from their natural state. Important afromontane natural forests are found along the southern fringes of the WMA.

The agricultural sector in the WMA is well-developed. The major activities are crop farming, cattle farming, game farming, sugar plantations and forestry. The importance of the manufacturing sector can be attributed to the railway infrastructure, the harbour at Richards Bay (incorporating the world's largest coal export terminal), power supplies, and water. Key industries are pulp and paper manufacturing and aluminium smelting. Timber and sugar are critical raw materials. The relatively high contribution of the transport sector can be attributed to the shipment of coal across the WMA from the Mpumalanga Highveld, as well as the transport of timber.

There are several nature reserves in the area, among which are Hluhluwe (famous for the black rhinoceros), Mfolozi, Mkuze, St Lucia, Sodwana and Itala. The St Lucia Estuary was recently proclaimed a World Heritage Site.

The western or inland portion of the WMA and its limited portion south of the southern end of the Zululand Coastal Plain at Mtunzini, that involves the catchments of the smaller Mlalalazi and Matikulu Rivers, comprises 'hard rock' secondary porosity aquifers of the 'weathered and fractured' and 'fractured' classes. Faults, joints, and intrusive Karoo dolerite sheet and dyke contacts particularly in the Karoo sedimentary and volcanic rocks, in the regional 'hard-rocks', are zones of significant groundwater presence. Of the 'hard-rocks', the deeply weathered granite and granite-gneiss rocks, and the rocks of the Vryheid Formation, as well as those of the Natal Group in the southern portion of the region, are generally the best groundwater aquifers, the Dwyka Tillite Formation, where present, is the poorest.

By contrast, the aquifers of the Zululand Coastal Plain portion of the WMA are of the primary porosity or intergranular type.

Springs and seepages, although their flows are very markedly seasonally affected are extensively exploited as a domestic water supply source in the rural residential and agricultural 'hard-rock' portion of the WMA. On the Zululand Coastal Plain, the deep aquifer is exploited by appropriately installed fully cased and basally screened boreholes, while the shallow aquifer is exploited by the local population as a source of domestic water supply by shallow unlined open wells, shallow concrete ring-supported open wells, and more recently shallow hand pump-equipped screened tube wells, the latter two well forms were installed by relevant Governmental authorities. A very few deep (20 to 25 m) screen-well boreholes have been installed in a few places within the southern portion of the WMA to exploit the primary porosity aquifer present in the near-coastal portions of the WMA, represented by sandy alluvium beneath the beds of the larger rivers.

Groundwater quality in the WMA is variable, being best in the higher rainfall portions and poorest in the lower rainfall portions, as in the major river basins of the interior and in the 'rain shadow' or 'Lowveld' area immediately inland of the Lebombo range.

Due to the size of the study area, it is not feasible to determine a Groundwater Reserve for the entire. Therefore the study area is divided into smaller sub-regions, called Resource Units (RU). There are over a hundred quaternary catchments within the WMA, making delineation a complex process. The first step in the delineation process was to divide the study area into six sub-catchments. Each area is then divided into smaller resource units. Other aspects taken into consideration are:

- Geology
- Climate
- Recharge
- Surface water and groundwater stresses

The results of the classification and the Reserve are summarised in **Table 217**.

Table 217: Results of the Reserve Determination

Resource Unit	Classification		Recharge			Reserve			Allocation	
	Present Status Category	Resource Category	Total Area km²	Effective Area km²	Recharge Mm³/a	Baseflow Mm³/a	BHN Mm³/a	Reserve % Recharge	Allocation# Mm³/a	Current Use Mm³/a
MRU-1	B/C	Good/Fair	954.1	914.1	65.982	33.380	0.106	51%	19.902	12.594
MRU-2	B/C	Good/Fair	498.2	427.0	36.339	19.750	0.142	55%	11.219	5.228
MRU-3	B	Good	2418.6	2341.0	181.474	42.540	0.162	24%	132.613	6.159
MRU-4	C/D	Fair	731.1	727.7	63.178	39.580	0.185	63%	21.500	1.912
MRU-5	C/D	Fair	1059.6	1028.7	58.502	26.920	0.211	46%	27.623	3.749
MRU-6	C	Good/Fair	2417.5	2391.0	122.491	20.240	0.381	17%	90.162	11.707
MRU-7	B	Good	2855.8	2457.0	129.948	21.770	0.226	17%	102.881	5.071
MRU-8	C	Good/Fair	1900.3	1791.0	103.694	20.630	0.148	20%	70.129	12.787
MRU-9	B	Good	1665.8	1358.8	64.924	12.790	0.331	20%	51.227	0.575
MRU-10	B/C	Good/Fair	606.5	603.1	22.129	11.630	0.095	53%	8.879	1.525
MRU-11	C	Good/Fair	1140.2	1126.3	57.853	13.670	0.031	24%	41.475	2.677
MRU-12	B	Good	1437.3	1437.3	51.131	3.300	0.039	7%	42.391	5.400
MRU-13	B/C	Good/Fair	322.6	291.8	11.506	1.020	0.001	9%	9.226	1.259
MRU-14	C	Good/Fair	970.0	859.0	31.008	6.960	0.023	23%	19.524	4.501
MRU-15	B	Good	723.1	477.1	26.042	2.260	0.090	9%	23.208	0.483
MRU-16	C	Good/Fair	2589.0	1916.0	156.863	57.735	0.091	37%	65.857	33.179
MRU-17	B	Good	1901.0	1860.4	178.254	65.310	0.019	37%	110.837	2.088
MRU-18	B	Good	884.6	884.6	66.498	26.980	0.030	41%	34.945	4.542
MRU-19	B	Good	3247.0	2666.0	224.301	89.734	0.181	40%	125.755	8.631
MRU-20	C	Good/Fair	1036.8	973.4	26.846	1.231	0.057	5%	16.398	9.160
MRU-21	C	Good/Fair	711.4	550.4	29.514	0.751	0.000	3%	23.363	5.400

MRU-22	C	Good/Fair	2428.9	2390.5	48.354	3.030	0.196	7%	27.324	17.804
MRU-23	D	Fair	688.7	688.7	41.674	3.427	0.016	8%	19.573	18.658
MRU-24	C	Good/Fair	2434.5	2434.5	195.502	130.012	0.495	67%	49.706	15.289
MRU-25	C/D	Fair	533.0	533.0	36.268	4.340	0.002	12%	24.166	7.760
MRU-26	B/C	Good/Fair	1409.9	1409.9	95.851	14.975	0.005	16%	75.420	5.450
MRU-27	C	Good/Fair	3212.2	3172.6	233.433	48.318	0.369	21%	164.612	20.134
MRU-28	B	Good	611.8	611.8	46.303	9.071	0.050	20%	35.429	1.753
MRU-29	B	Good	301.0	205.2	11.808	0.933	0.007	8%	10.380	0.488

#Allocation = recharge – BHNs – baseflow - use

Guidelines for Resource Quality Objectives were provided for the following:

- Borehole management
- Wetlands and estuaries
- Springs
- Basic human needs, strategic use and international obligations
- Protected areas
- Contaminated sites

37. Recommendations

Based on the results of this study the project team would like to make the following recommendations:

- According to the definition of a comprehension Reserve (Parsons and Wentzel, 2005):

  '*Comprehensive GRDM determinations aim to produce high confidence results and are based on site-specific data collected by a team of specialists; used for all compulsory licensing exercises, as well as for individual licence applications that could have a large impact in any catchment, or a relatively small impact in ecologically important and sensitive catchments. It should take less than two years to complete. Due to lack of long-term geohydrological data sets, GRDM assessments will only rarely be done at this level*.'

  Although the project team aimed to achieve the highest confidence in the results of this GRDM investigation, the size of the WMA is too large to allow aquifer testing to obtain aquifer parameters and although more than one hydrocensus was conducted and numerous boreholes were sampled and chemistry analysed it is impossible to sample and test all the boreholes in the study area. It is however strongly recommended that comprehensive Reserve determinations be carried out on the resource units that are stressed and have a poor classification. These determinations must included extensive field work including drilling of boreholes and aquifer testing.

- Groundwater related data issues must be addressed. Project team members spent weeks trying to obtain data from various sources. The merging of the data into a single database for the project took much longer than expected due to the incompatibility and lack of structure of some of the various databases. Currently there are numerous databases for example WARMS, GRIP and NGDB/NGA. These need to be merged into a single database. Once this is complete the gaps in the data must be identified and addressed. This will provide an indication of where monitoring should take place.

- Numerical groundwater flow models were used to try and quantify the groundwater contribution to baseflow. However the results were discarded due to the scale of the models and the lack of aquifer parameters.

- Groundwater use in the study area is a concern. Because of the uncertainty in groundwater use, a stochastic analysis was applied assuming a normal distribution for the groundwater use. The stochastic analysis yielded a range of values with a specified confidence rather than a single value for the stress index. Resource Units with a wide range stress index should be targeted to obtain more accurate groundwater use data which will refine the stress index range.

- The formation of groundwater user associations must be encouraged. As already mentioned groundwater use information is a concern. Users of groundwater must therefore be encouraged to take responsibility for the resource by means of monitoring groundwater use, water levels and quality.

- National maps such as landcover must be updated. The land cover shown on these maps differs drastically from what was delineated from Google Earth.

- Numerous municipalities in the WMA were contacted for information. It became clear from these contact sessions that there is a lack of capacity and knowledge. A strategy must be developed and implemented to ensure local government has the skills to manage the groundwater resources.

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