






Prepared for the
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**Groundwater Reserve
Determination Studies in the
Letaba Catchment
Project Number 2005/018**

Submitted by

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**DEPARTMENT OF WATER AFFAIRS AND
FORESTRY**

**GROUNDWATER RESERVE
DETERMINATION STUDIES IN THE
LETABA CATCHMENT, PROJECT 2005/018**

REPORT 102197/G2

September 2006

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1 INTRODUCTION

The Directorate: Resource Directed Measures of the Department of Water Affairs and Forestry has appointed Africon to undertake a determination of the groundwater component of the RDM at a desk top level for the Letaba Catchment and to develop a Terms of Reference for a more comprehensive reserve determination based on these preliminary findings. The objectives of this report are to:

- Discuss the investigations done
- Report on the findings and
- Recommend further investigations based on the findings.

2 PROJECT BACKGROUND AND OBJECTIVES

The Directorate: Resource Directed Measures has identified the Letaba Catchment as a stressed river catchment where reserve determinations are required at a comprehensive level in order to comply with licensing requirements mandated by the National Water Act of 1998. The Act places emphasis on the protection of water resources for their sustainable utilization. This is reflected in the subsequent development of Resource Directed Measures (RDM), which consists of three important aspects, namely: classification; the reserve; and resource quality objectives.

3 LITERATURE/DATABASE REVIEW

3.1 Literature

The following reports and documents were studied and information utilized in this RDM determination:

- Ashton P, Love D, Mahachi H, Dirks P 2001 *An overview of the impacts of mining and mineral processing operations on water resources and water quality in the Zambezi, Limpopo and Olifants Catchments in Southern Africa*, MMSD Southern Africa Research Reports, South Africa
- Dennis I (2005) *Groundwater Resource Directed Measures Version 3*
- Department of Water Affairs and Forestry (DWAF) 2000 *1:2000000 map, Water Management Areas of the Republic of South Africa*
- Department of Water Affairs and Forestry (DWAF) 2004 *Directorate: National water resource and planning, Internal strategic perspective: Luvuvhu/Letaba WMA*, pp166

- Department of Water Affairs and Forestry (DWAF) 2003 Luvuvhu/Letaba Water Management Area: Water Resources Situation Assessment, Main Report DWAF Report No. P/02000/00/0101
- Fouche P and Moolman 2006 Resource Units Report: Appendix 1 Habitat Integrity Index Letaba catchment reserve determination study, DWAF Report No. RDM/B800/CON/COMP/0704, South Africa
- Haupt C.J and Sami K 2004 Groundwater Report - Letaba catchment reserve determination study, Department of Water Affairs and Forestry, Report no RDM/B800/02/CON/COMP/0504, pp35
- Heath, RG 2006 Resource Units Report - Letaba catchment reserve determination study, DWAF Report No. RDM/B800/CON/COMP/0704, South Africa
- Heath, RG 2006 Ecological Water Requirements Quantity Report - Letaba catchment reserve determination study DWAF Report No. RDM/B800/CON/COMP/0904
- Haumann, K 2006 Hydrology Support & Water Resource Evaluation - Letaba Catchment DWAF Report No. RDM/B800/01/CON/COMP/1104, South Africa
- Kotze J 2003 Level of Reserve Determination Required for the Groundwater Component – Letaba River catchment Limpopo Province.
- Parsons R (2004) *The GRDM training Manual (2004)*
- Sobczyk M.E, Kirsten W.F.A and Hammond T 1989 Soil analyses in the land types of the maps 2230 Tzaneen and 2430 Pilgrim's Rest, Memoir in Agricultural and natural resources, Vol. no. 12, South Africa, pp415
- State of Rivers Report 2001 Letaba and Luvuvhu River Systems, WRC Report no.TT165/01, Pretoria, South Africa, pp44
- Marneweck, GC 2006 Wetland Scoping Report - Letaba catchment reserve determination study DWAF Report No. RDM/B800/CON/COMP/0604,

3.2 Sources of Data

The following sources of data were collected and utilized for the investigation and interpretation of the groundwater resources and quality:

- Groundwater data from the GPM Consulting database which is a database presently being updated with data from the GRIP Project.
- Groundwater data from the NGDB at DWAF, both geohydrological and chemistry data.
- Groundwater data from AGES's GRIP data base for the districts falling within the Letaba Catchment. This data consists only of the field data collected during the GRIP project such as coordinates, EC, water level etc.
- GRAII data from DWAF (limited)
- GWREG2 data from DWAF (limited)
- Water use maps for Groot Letaba and Middle Letaba obtained from Tlou & Mallory.
- Estimations of groundwater surface water interaction for selected quaternary catchments, provided by Karim Sami.
- Instream Flow Requirements (IFR) as determined by the Surface Water Reserve Determination (Heath, 2006).
- Wetland locations as identified in the NLC 2000 project, provided by Marneweck (2006)
- Hydrogeological map series 1:500 000, Sheets Phalaborwa and Pietersburg

3.3 GRDM database

A copy of the GRDM program, Version 3, developed and compiled by Dennis and van Tonder were obtained from DWAF. This software comprises a graphical interface with different layers of data on a regional or national scale, a 'road map' to estimate the reserve components and special tools to assist in the resource evaluation. The relevant layers in the GIS section of the software are:

- Quaternary catchment boundaries
- Geology
- Vegetation
- Land cover
- Soil types
- Recharge
- Baseflow
- Surface water – Groundwater interaction category

A number of maps, as produced in this report, are based on the GRDM software.

In addition to the data listed above, the GRDM software provides the following datasets on a 1km grid as compiled in the GRA II project:

- Borehole density
- Chloride in groundwater
- Mean annual precipitation
- National landcover (1995)
- Hazard rating
- Reclassified aquifer dependent ecosystems
- Rain seasons
- Recharge (mm)
- Recharge as a percentage of rainfall
- Chloride in rainfall
- Storage coefficient
- Mean thickness of the saturated zone
- Transmissivity
- Groundwater level in metres above mean sea level
- Groundwater level in metres below ground level
- Variation in groundwater levels based on the national groundwater database (NGDB) boreholes
- Borehole yield
- Protected areas
- Groundwater contribution to baseflow expressed as an index
- Surface water interactions per quaternary catchment
- Total groundwater use
- Chemistry points from NGDB
- Static groundwater levels and median groundwater levels determined using data from NGDB



Photo 1: Splash screen for the GRDM software

4 INITIAL SITE VISIT

The initial field site visit by the project team took place from the 19th to 21st of October 2005 and the following notes were taken during the field visit:

4.1 Day 1

Travel from Thohoyandou to Middel Letaba Dam along the Levubu – Letaba watershed. All drainages are dry with no indication of flow or subsurface flow. Villages are all supplied by pipeline with surface water from various dams in the area. Pipe line markers visible along road. Klein Letaba water course dry. The country side shows heavy overgrazing which will lead to quick runoff with little or no recharge to the groundwater. Middel Letaba River dry above the Middle Letaba Dam, while ecological release from the dam continues. Travel along the Malototsie Catchment past Modjadji to Magoebaskloof. Erosion visible in numerous of the drainage channels passed. Irrigation possibly from boreholes noted in the Modjadjikloof area. Large areas of afforestation around the Tzaneen Dam.

4.2 Day 2

Travel from Magoebaskloof towards Haenertsburg then to Ebenaezer Dam and down to the Great Letaba valley. Water released from the Ebenaezer Dam flow down the Great Letaba River to the Tzaneen Dam. Travel through Letsitele into the Letsitele River Catchment. The Letsitele is flowing where the drainage is crossed. A canal system feed the irrigation in the Letsitele area and along the Great Letaba River. The Great Letaba was flowing near the Hans Merenski Nature Reserve gate. Some water flow noted in the Merekome drainage. Travel towards Giyani and noted overgrazing in this flat lower catchment area. Subsurface drainage in the Malototsie River visible where hollows occur, dugged in the sandy riverbed. Travel through Giyani towards the Nsami Dam.

The Nsami River drainage dry where crossed above the dam. Lower parts of the Koedoes and Brandboontjie River catchments indicate agricultural use and irrigation. Rivers are dry when flowing into Middle Letaba.

4.3 Day 3

Travel from Thohoyandou to Mooketsi and into the upper reaches of the Middle Letaba, Koedoes and Brandboontjie Rivers. Overgrazing again noted in and around villages. Villages bulk water supply from pipeline from the Rietspruit Dam in the Middle Letaba. Scattered irrigation along the Brandboontjie drainage. Several private dams occur in the Koedoes River and irrigation takes place from the dams. Possible irrigation from boreholes could occur in the area. High up in the Koedoes and Middle Letaba catcmnts the presence of springs were noted. The flow and usage are not known.

5 DESCRIPTION OF THE STUDY AREA

5.1 Location and Demography

5.1.1 Location and extent of study area

The Letaba River Catchment falls within the Levubu and Letaba Water Management Area (WMA) no.2 of the Water Management Areas of South Africa (DWAF, 2000) (see Figure 1). The catchment is further sub-divided into tertiary catchments B81 (Groot Letaba), B82 (Klein/Middle Letaba) and B83 (Lower Letaba). The catchment covers a total area of 13400 km². It lies between the latitudes 23°00' S and 24°15' S and longitudes 30°00' E and 31°45' E (figure 2).

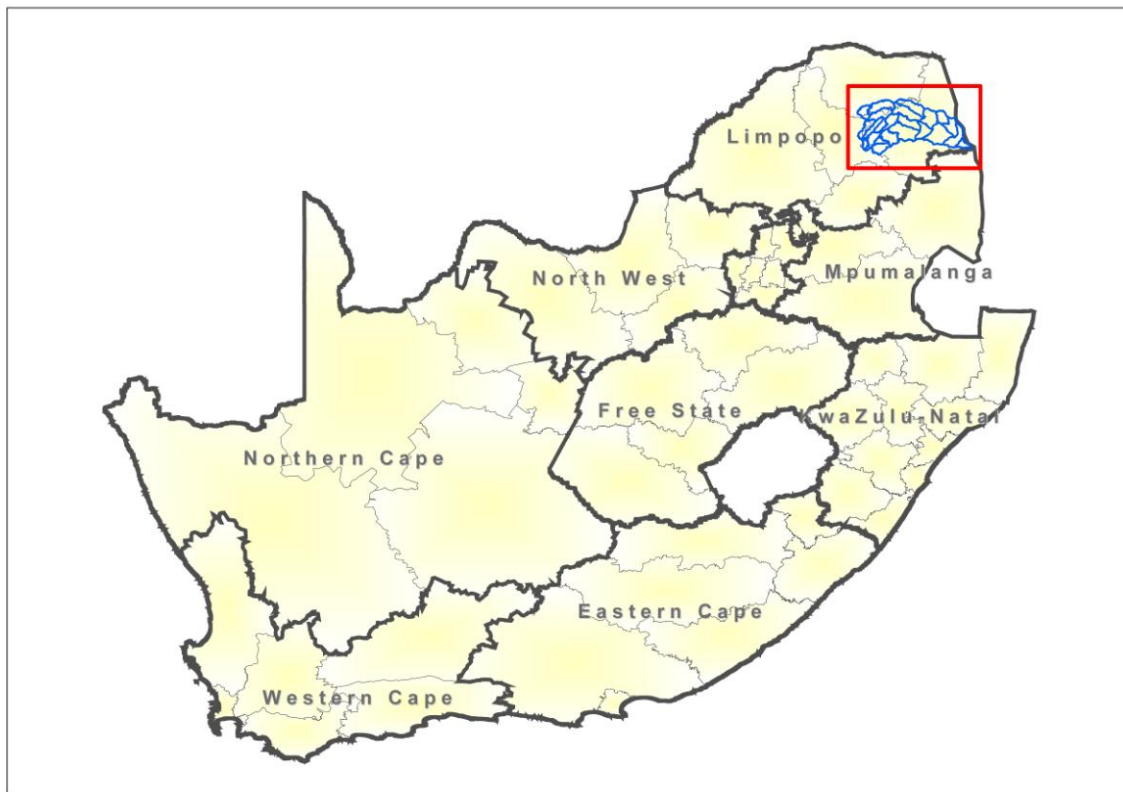


Figure 1: Location of the Levubu and Letaba Water Management Area (WMA)

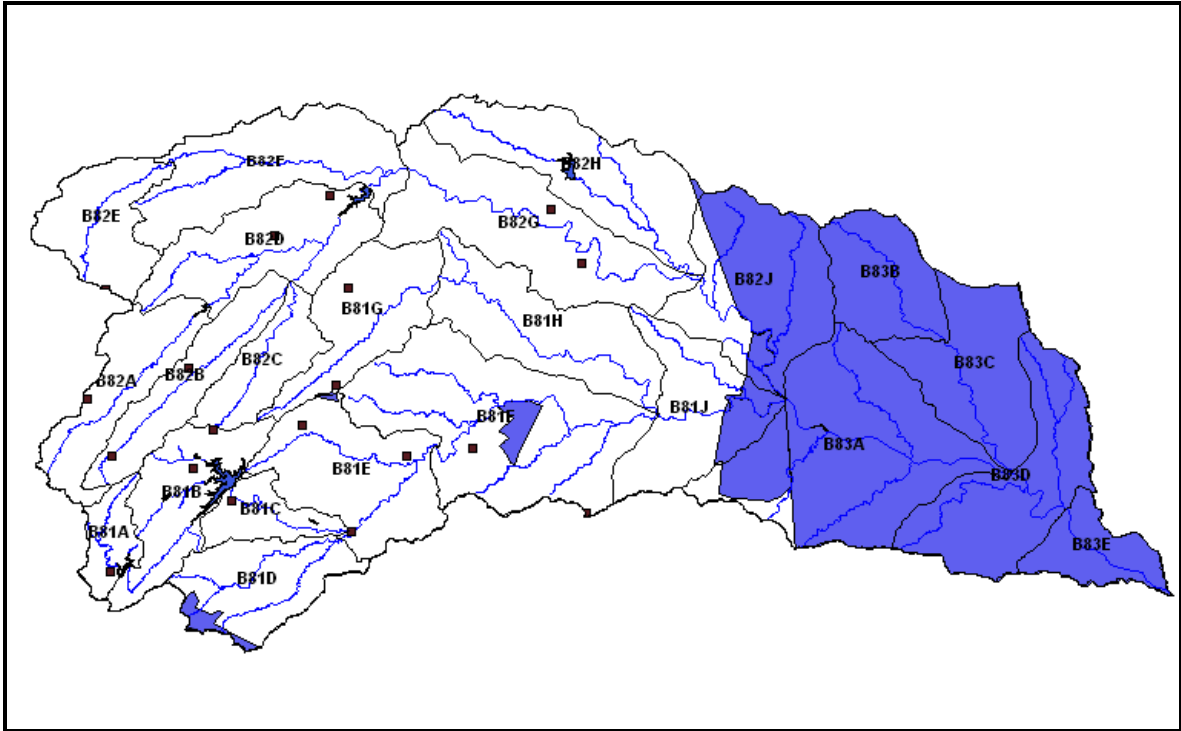


Figure 2: The study area (Letaba River Catchment)

[blue areas indicate protected areas, e.g. National Park, Nature Reserve]

The Letaba River catchment has been described on the basis of major rivers in the catchment. These are the Groot Letaba, Klein/Middle Letaba and Lower Letaba.

The Groot Letaba area includes Tzaneen, Politsi, Maleketla, Ga-Modjadji, Duiwelskloof, Hidreth ridge and La Cotte. The area covers quaternary catchments B81 A-J. Klein/ Middle Letaba area covers areas such as Olyfberg, Duiwelskloof, Mooketsi, Soekmakaar, Mamaila, Ha-Magoro, Nkomo and Giyani. This area falls under quaternary catchments B82A-J. The Lower Letaba area occurs after the confluence of the Groot Letaba and Klein Letaba Rivers. This includes areas such as Boulders, Letaba, Shimuwini, Mopani and the Kruger National Park covering quaternary catchment B83A-E.

5.1.2 Topography

The Letaba River Catchment is characterized by steep mountainous areas, especially in the upper reaches of the Groot Letaba, Klein Letaba, Koedoes, Brandboontjies, Molototsi, Letsitele, Thabina and Middle Letaba Rivers. Moderate relief occurs from the middle stream of the Molototsi up to its confluence with the Groot Letaba, middle stream of the Klein and Groot Letaba Rivers up to their confluence and along the Nsama River. The altitude of this area ranges from 400-800 metres above mean sea level (mamsl). After the confluence of the Klein and Groot Letaba Rivers, the area is low lying with altitude that ranges from 300-400 mamsl. The different topographic regions in the Letaba River Catchment are shown in Figure 3 below.



Figure 3: Aerial photo of the Letaba catchment, identifying the different topographic regions (Source: Google Earth)

5.1.2.1 Groot Letaba area

Steep mountainous areas occur especially around quaternary catchments B81A-D and the upper part of B81G. The altitude of these areas varies from 800-1800 mamsl. After the Tzaneen dam, the area is characterized by moderate relief with altitude that ranges from 500-800 mamsl (around the B81E, F and lower part of B81G quaternary catchments). Quaternary catchment B81G, H and I are in low lying areas with altitude that ranges from 400-500 mamsl.

5.1.2.2 Klein Letaba area

Steep mountainous areas occur around the quaternary catchments B82A, E and the upper parts of B82B, C, D and F. The altitude of these areas varies between 700-1400 mamsl. The lower parts of quaternary catchments B82B, C, D and F and quaternary catchment B82G and H are characterized by moderate to low relief with altitude that ranges between 400-600 mamsl.

5.1.2.3 Lower Letaba area

The Lower Letaba area is a low lying area with an altitude that varies between 200-300 mamsl. This area is found in quaternary catchment B83A-E.

5.1.3 Demography

5.1.3.1 Groot Letaba area

The population of this area has been obtained from the GRDM software and is presented in Table 2 below. This area has the highest population (614110 people) in the catchment. Towns include include Tzaneen, Letsitele, Politsi, Maleketla, Ga-Modjadji, Duiwelskloof, Hidreth ridge, Nkambak and Maleketla and La Cotte.

Table 1: Population per quaternary catchment in the Groot Letaba area obtained from the GRDM software.

Quaternary Catchment	Population	Major Towns / Villages
B81A	800	Haenertsburg
B81B	2275	Politsi
B81C	40500	Tzaneen
B81D	145569	Letsitele
B81E	68496	Nkambak and Maleketla
B81F	98655	La Cotte
B81G	185088	Ga-Modjadji and Hidreth Ridge
B81H	54181	
B81J	18546	
Total	614110	

5.1.3.2 Klein/Middle Letaba

The population of this area has been obtained from GRDM software and is presented in Table 2 below. This area has a population of 461112 people. Towns include Mooketsi, Olyfberg, Munnik, Ha-Magoro, Mamaila, Giyani and Nkomo.

Table 2: Population per quaternary catchment in the Klein/Middle Letaba area obtained from the GRDM software.

Quaternary Catchment	Population	Major Towns / Villages
B82A	35180	Munnik
B82B	200	Mooketsi and Olyfberg
B82C	20725	
B82D	12802	Ha-Magoro and Mamaila
B82E	40700	
B82F	178013	
B82G	110015	Giyani and Nkomo
B82H	57357	
B82J	6120	
Total	461112	

5.1.3.3 Lower Letaba

Since this area falls entirely in the KNP there are no significant settlements or population.

5.2 Climate

The Mean Annual Precipitation (MAP) of the Letaba River catchment is 623.58 mm while the Mean Annual Evaporation (MAE) is 1637 mm. The Mean Annual Runoff (MAR) is estimated to amount to 44.32 mm/a. The MAR in the Letaba Catchment varies from more than 10% of the mean annual precipitation (MAP) in the wet mountainous zone to less than 2% in the drier parts of the catchment.

Table 3: The Mean Annual Precipitation, Run-off and the Potential Evaporation per quaternary catchment.

Quaternary Catchment	Area km ²	MAP		MAR		MAR/MAP	MAE
		mm	M m ³ /a	mm	M m ³ /a	%	mm
B81A	169.10	1194.02	201.91	378.3	63.96	31.7%	1500
B81B	481.20	1163.10	559.68	323.5	155.68	27.8%	1500
B81C	208.40	879.75	183.34	82.5	17.19	9.4%	1500
B81D	478.80	918.22	439.64	203.4	97.39	22.2%	1500
B81E	664.90	667.08	443.54	44.4	29.52	6.7%	1550
B81F	1199.70	544.46	653.19	15.7	18.84	2.9%	1600
B81G	512.40	626.66	321.10	31.5	16.14	5.0%	1600
B81H	667.70	510.14	340.62	10.7	7.14	2.1%	1650
B81J	567.00	501.81	284.53	9.4	5.33	1.9%	1700
Groot Letaba	4949.20	692.55	3427.55	83.08	411.19	12.0%	
B82A	466.60	720.57	336.22	49.6	23.14	6.9%	1550
B82B	406.30	701.96	285.21	44.6	18.12	6.4%	1550
B82C	299.70	711.99	213.38	47.3	14.17	6.6%	1550
B82D	631.70	622.86	393.46	26.2	16.55	4.2%	1600
B82E	423.40	656.01	277.75	32.1	13.59	4.9%	1600
B82F	759.80	676.25	513.81	36.3	27.58	5.4%	1600
B82G	920.10	523.71	481.87	15.5	14.26	3.0%	1650
B82H	748.60	516.35	386.54	14.4	10.78	2.8%	1650
B82J	793.70	539.63	428.30	17.2	13.65	3.2%	1700
Klein/Middle Letaba	5449.90	608.55	3316.55	27.86	151.84	4.6%	
B83A	1250.00	514.70	643.38	10.2	12.75	2.0%	1750
B83B	438.80	596.22	261.62	19.5	8.56	3.3%	1750
B83C	591.40	538.51	318.47	12.0	7.10	2.2%	1850
B83D	712.80	551.69	393.24	13.2	9.41	2.4%	1850
B83E	266.60	586.71	156.42	16.9	4.51	2.9%	1900
Lower Letaba	3259.60	543.97	1773.13	12.99	42.33	2.4%	
Total	13658.70	623.58	8517.23	44.32	605.36	7.1%	

More than 60% of the MAR in this catchment derives from only 6% of the area (State of Rivers Report, 2001). The change in topography (altitude and relief) gives rise to varied climatic characteristics. The mountain zone receives rainfall of 2000 mm/a and the dry lowveld in the KNP receives 400 mm/a (State of Rivers Report, 2001).

More than 85% of the rain falls during the summer months. Evaporation increases gradually from 1500 mm/a in the west to 1900 mm/a in the east. About 60% of the

evaporation occurs during the 6 months from October to March. Temperatures range from a high average of 21°C in the upper catchments, to a very high average of 25°C in the KNP. Frost rarely occurs (DWAF, 2004). The MAP and the MAE per quaternary catchments are presented in Table 3 above. The spatial distribution of rainfall is shown in Figure 4.

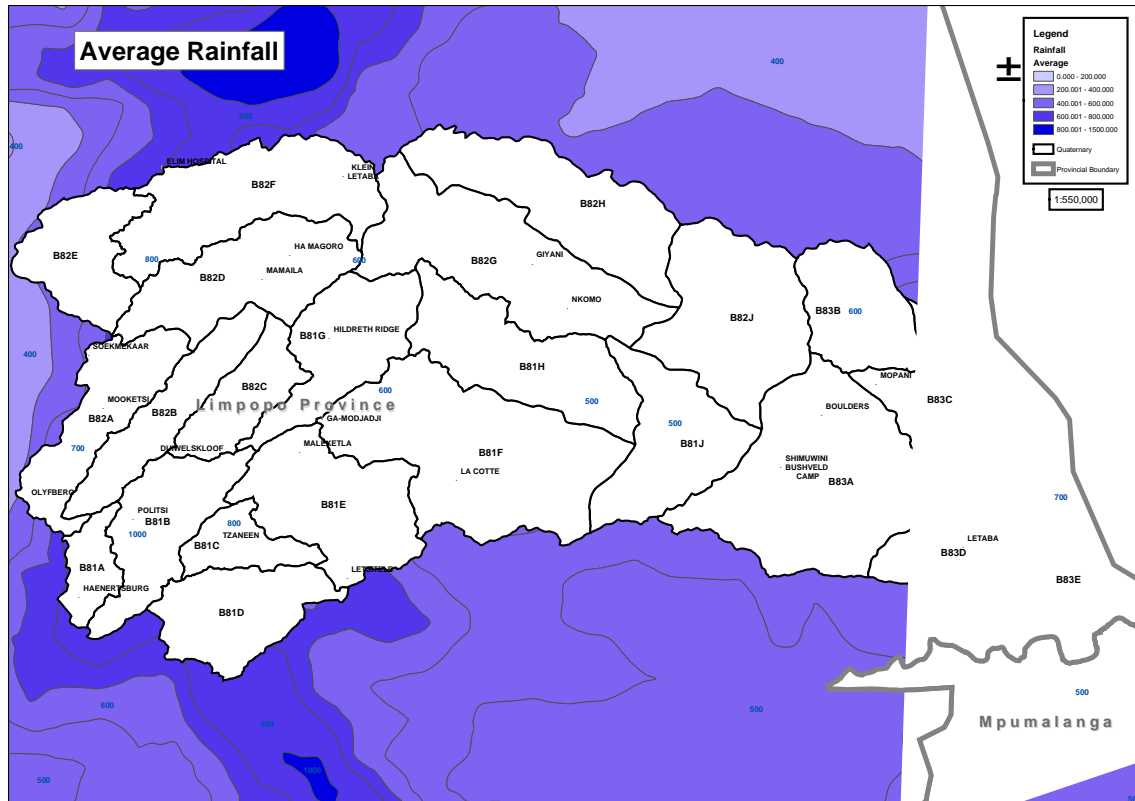


Figure 4: Spatial rainfall distribution in Letaba catchment

5.3 Land cover / land use

The Letaba River Catchment (and particularly the Groot Letaba sub-area) is a highly productive agricultural area with mixed farming including cattle ranching, game farming, dry land crop production and irrigated cropping. Agriculture, within the irrigation sector in particular, is the main economic base of the region. These areas occur mainly along the Groot Letaba River, and its tributaries, the Middle Letaba, Lower Klein Letaba, and the Letsitele Rivers (DWAF, 2004).

Figure 5 shows the landcover and land use of the Letaba catchment as mapped by the NLC 1995 project.

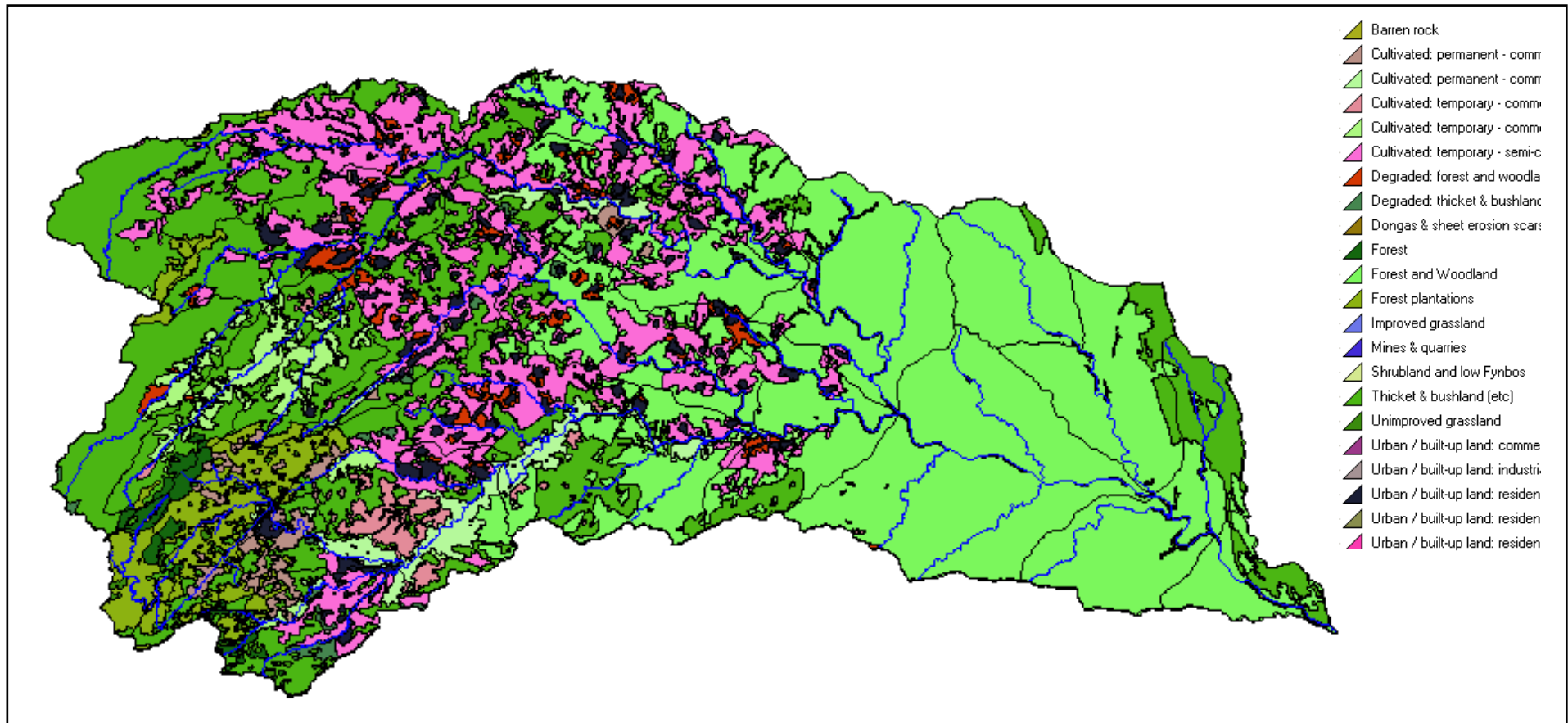


Figure 5: Land cover (Source: GRDM software)

5.3.1 Groot Letaba area

The Groot Letaba area below and around the Tzaneen dam is a mountainous area which is heavily afforested (see Figure 6). Isolated settlements also occur in Tzaneen, Chowan, Moime and Mogoboya residential areas.



Figure 6: Plantations in catchments B81A and B81B between the Escarpment and the Tzaneen Dam (Source: Google Earth)

The upper Thabina River is a mountainous stream originating in the Wolkberg region of the Dranskensberg at greater than 1200 meters above mean sea level. Villages and agricultural plots occur immediately adjacent to the river (Heath, 2006).

The middle stream of the Groot Letaba River is mostly characterized by gentle slopes which are dominated by cultivation and settlement. The Molototsi River is predominantly in the former Gazankulu homeland and comprises of rural settlements, agriculture and cattle grazing (Heath, 2004). Dry water courses occur in tributaries of the Molototsi river valley which is dominated by settlements and cultivation. This is a signal of high abstraction of surface water for either irrigation or domestic use. Cultivated lands and settlements also occur along the Nwanedzi River valley.

The Wolkberg wilderness area, Hans Merensky Nature Reserve and the Ga-Modjadji Nature Reserve are the protected areas that are found in the Groot Letaba area. The Ga-Modjadji Nature Reserve, Cycad forest and Malematsa forest occur on steep slopes within the area.

Murchison range, Spitskop, Gravellootekop and Freestate Koppies occur in the Groot Letaba area below the Mulati River. Along the Letsitele River, forestry, agriculture (commercial), rural settlements and communal lands occur before reaching the Letsitele Town.

5.3.2 Klein/Middle Letaba

Mountainous areas (steep slopes) occur around Duiwelskloof residential area where the Brandboontjies River originates. This area is mostly dominated by woodlands. The Lindersloop and Maralame streams also originate from steep mountainous areas. These drain into the Koedoesriver. The Koedoes and Brandboontjies Rivers occur in gentle slopes which are mostly dominated by cultivated lands. Some patches of settlement also occur in this area (e.g. Duiwelskloof, Ga-Ramoadi and Ga-Kgapane).



Figure 7: Agricultural area in B82A to B82C catchments (Source: Google Earth)

Along the Klein Letaba River the area is dominated by cattle farming. Extensive subsistence cultivation and settlement (low cost housing) also occur. The Nsama River valley is dominated by Irrigation (subsistence farming) and settlement. Steep mountainous area occurs near Basani settlement. Scattered tree and bushes occur around the KaMakhaveni and KaSiyandani settlements where there are gentle slopes. Recreational activities (golf course) and a park in Kremetart settlement occur just below the Shamavunga Mountain near the Klein Letaba River Valley.



Figure 8: Klein and Middle Letaba catchment with Middle Letaba Dam (Source: Google Earth)

5.3.3 Lower Letaba area

The entire Lower Letaba area falls within the KNP and it is a conservation area. Land use in the entire eastern portion of the sub-catchment is wildlife conservation, with the Kruger National Park occupying the largest area. Several smaller game reserves and game farms are also located close to the western border of the Kruger National Park in some of the driest areas of the sub-catchment (Ashton et al, 2001).

5.4 Flora and Fauna

Vegetation types in the Letaba River Catchment area have been obtained from State of Rivers Report (2001) and Heath (2006) and are described as follows:

5.4.1 Groot Letaba area

- Northeastern mountain grassland and afromontane forest occurs upstream of Broederstroom, Letsitele, Groot Letaba, Thabina River and Politsi Rivers.
- Sour low bushveld, mixed bushveld and patches of afromontane forest is found around the Tzaneen dam, middle stream of Letsitele River, upstream and middle stream of the Molototsi River and downstream of the Thabina River.
- Mixed lowveld bushveld is found around Nwanedzi River and upstream of the Molototsi Rivers.
- Mopane shrubveld and Mopane bushveld occurs in the middle stream of the Groot Letaba up to the confluence with the Molototsi, down stream of the Molototsi up to the confluence with the Groot Letaba.
- Mopane bushveld occurs around the middle stream of Groot Letaba down to the confluence with the Klein Letaba.

5.4.2 Klein/Middle area

- Sour low bushveld, mixed lowveld bushveld, mixed bushveld and patches of afromontane forest occurs upstream of Klein Letaba and Nsama Rivers, around the Middle Letaba, Brandboontjies and Mosukodutsi Rivers.
- Mixed lowveld bush veld occurs around the middle stream of Klein Letaba river
- Mopane bush veld occurs downstream of Nsama and down stream of Klein Letaba up to the confluence with the Groot Letaba River.

5.4.3 Lower Letaba area

Vegetations types that are found in this area are mopane bushveld, mopane shrub veld, Lebombo arid mountain bushveld and sweet lowveld bushveld.

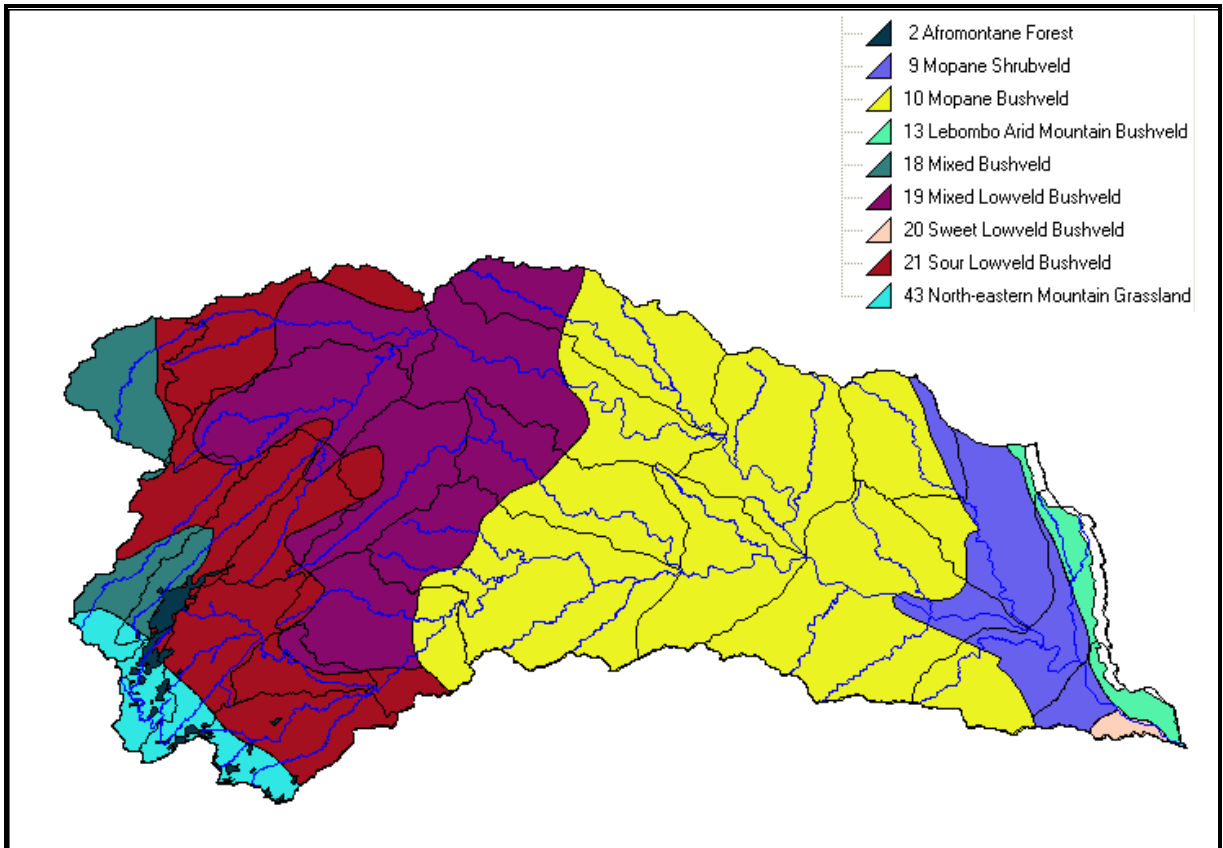


Figure 9: Natural Vegetation, after Acocks Veldtypes (Source: GRDM software)

5.5 Soils

The characteristics of soils in the Letaba river catchment have been obtained from Ashton et al (2001) and are as follows:

- Large areas of moderately deep to deep, reddish clay-rich soils occur in the upper reaches of the catchment, occasionally becoming leached to form pale-coloured kaolinitic deposits.
- Areas of sandy colluvial soils occur at the foot of the escarpment, grading into red sandy-clay soils in the western part of the sub-catchment
- Shallow, brownish to greyish-brown sandy soils cover coarsely weathered rock in the central and eastern portion of the sub-catchment
- Transported alluvial deposits of coarse to fine-grained sands and silts are located along drainage lines.

The average soil conditions of the Groot Letaba area, Klein/Middle Letaba area and the Lower Letaba area described below, have been obtained from the Sobczyk et al (1989).

5.5.1 Groot Letaba area

Below and around the Tzaneen dam, the average soil conditions vary from coarse sandy clay loam to sandy clay with clay content 10-50%, sandy clay to clay with 20-60% of clay content along the Groot Letaba River and medium or coarse sandy clay loam to sandy clay with the clay content 10-50% along the Politsi River. In the middle stream of the Groot Letaba, the average soil conditions vary from medium or coarse sandy clay loam to sandy loam with clay content of 8-45%.

Upstream of the Molototsi River, the average soil conditions range from medium or coarse sandy clay loam to sandy clay with clay content 6-50%. Downstream of the Molototsi River up to the confluence with the Groot Letaba River, the average soil conditions vary from medium or coarse sandy clay loam to sandy loam with clay content ranging from 8-40%. Along the Letsitele and Thabina Rivers, the average soil conditions range from medium or coarse sandy loam to sandy clay loam with 10-60% clay content. Along the GaSelati River, the average soil conditions range from medium sandy clay loam with clay content of 20-40%.

5.5.2 Klein/Middle Letaba area

Along the Nsama River, the average soil conditions vary from medium or sandy clay loam with the clay content 15-45%. Upstream of the Klein Letaba River, the average soil conditions range from medium or coarse sandy loam to sandy clay loam with 6-50 % clay .The average soil conditions ranging from medium or coarse sandy loam to sandy clay loam with clay content of 3-50% occur upstream of the Brandboontjies, Kodoesriver and Middle Letaba River

5.5.3 Lower Letaba area

Medium or coarse sandy loam to sandy clay loam soils with a clay content varying from 6-40% occurs at the confluence of the Groot and Klein Letaba and stretches up to where the Tsende River joins the Letaba River. The average soil conditions ranging from fine or medium sandy clay loam to sandy clay loam with clay content of 10-45% occur along the Tsende River up to the confluence with the Letaba. These soils form a straight pattern along the banks of the Letaba River up to where the Shinobyeni non-perennial stream joins the Letaba River. The average soil conditions ranging from fine/medium sandy clay loam to sandy loam with clay content of 8-45% occur on the eastern and western part of the Letaba up to where the Letaba River joins the Olifants River.

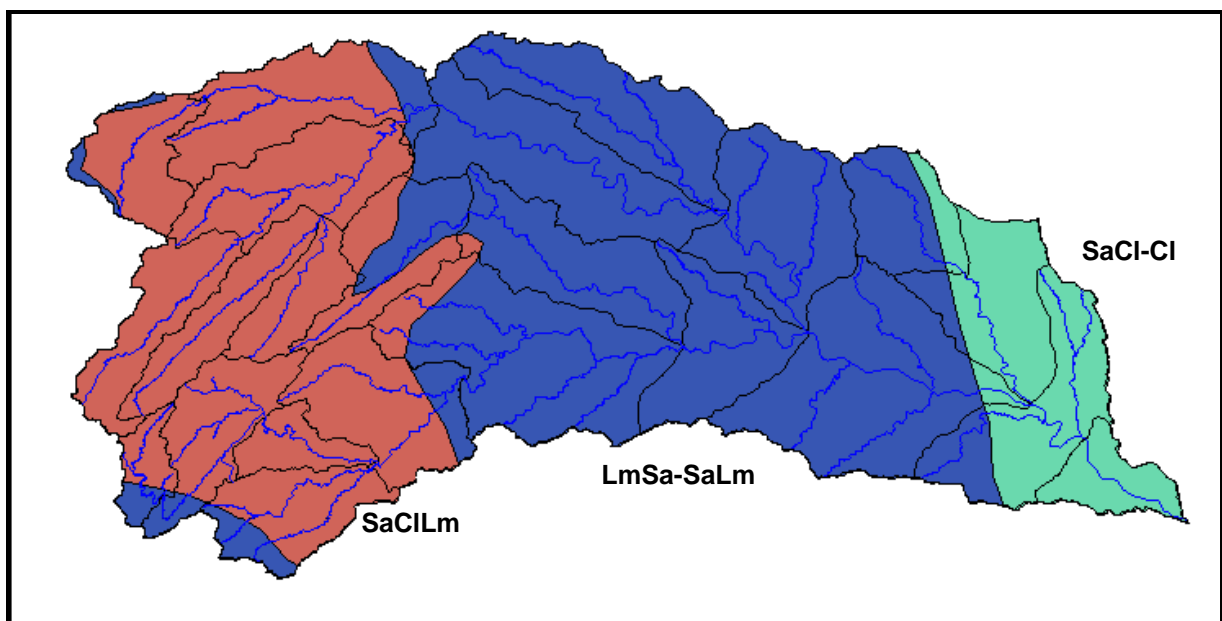


Figure 10 Soil map of Letaba catchment (Source: GRDM software)

5.6 Hydrology

The Letaba River catchment drains in an easterly direction, extending from the Drakensberg Escarpment to the junction of the Drakensberg to the Olifants near the Mozambique border in the KNP (Fouche and Moolman, 2006).

5.6.1 Groot Letaba area

The Groot Letaba area is drained by the Groot Letaba River, Letsitele, Thabina, Debengeni, Politsi, Ga-Selati, Molototsi and Morotshwe perennial Rivers. The Groot Letaba, Letsitele, Thabina and Debengeni Rivers rise from the Great Escarpment Mountains. The Molototsi, Letsitele and Thabina are tributaries of the Groot Letaba River. Non-perennial rivers in this area include Lephepane, Manelanela, Setshetshe, Mphake, Mogotsi, Lenyenye, Malikhwela, Molatjie, Gedaan, Phakani, Hlangana, Leoke, Seretoa, Ratluga, Merekome, Madikoma and Maba, Linderskop, Modobatse, Maleta, Maralane, and Setlhakane Rivers. The Lenyenye, Malikhwela, Molatjie, Gedaan, Phakani and Hlangana Rivers originate from Seribane Mountains and drain into the Groot Letaba River.

5.6.2 Klein/Middle Letaba area

The Klein/Middle Letaba area is drained by the Nsama, Koedoesriver, Brandboontjies, Klein and Middle Letaba Rivers. The Klein and Middle Letaba Rivers originate from steep mountainous area. The Koedoesriver and Mosukodutsi River also originate from mountainous area and they drain into the Mosukodutsi River before it joins the Middle Letaba River. The Shikari, Nwandi, Seoketse non-perennial streams also originate from mountainous area and are drained into the Klein Letaba area. The Musama, Shikukwane, and Shipakweni non-perennial streams occur in gentle slopes and are drained into the Nsama River above the Nsama Dam. The Magobe, Hlantswavuhlalu and Shinkanka non-perennial streams also occur in gentle slopes and are also drained into the Nsama River before it joins the Klein Letaba River. The Shisese, KaMililibone, Minangwe non-perennial streams also occur near the confluence of the Klein Letaba and the Groot Letaba.

5.6.3 Lower Letaba area

The area is drained by the Letaba, Tsende, Ngwenyeni and Nwanedzi perennial rivers. Non-perennial rivers include Tsale, Shipikani, and Shibiyeni.

5.7 Geology and Geohydrology

5.7.1 Geology

The Letaba River catchment is underlain by rocks of the Transvaal Sequence, which form the major portion of the Drakensberg Mountain range. Quartzites, silicified sandstones, chert, hornfels, basic lava and dolomite dominate the lithology. The dolomite outcrops, in particular, are important sources of good quality water in the upper catchment and contribute water throughout the year. These rocks form prominent landscape units along the watershed (Ashton et al, 2001).

Further to the east and north-east, rocks of the Gravelotte Group (part of the Murchison Sequence) and Rooiwater Complex outcrop are visible as a range of low hills that trend south-west to north-east (Ashton et al, 2001). The Murchison sequence is ancient supra-crustal rocks preserved in the basement gneisses and has three occurrences in the study area. These are the Giyani group, Gravelotte group and Pietersburg group (Haupt and Sami, 2004).

In the south-west of the catchment, felsites and gabbros of the Rooiwater Complex are found at the foot of steep hill slopes. Similar outcrops, comprising rocks of the Banderlierkop Complex, outcrop in the north-western portion of the catchment. Both of these rock types are relatively easily eroded and contribute increased levels of sediments in the valley depressions and river channels. Granitic and gneissic rocks of the crystalline Basement Complex underlie most of the central and eastern portions of the catchment. These rocks outcrop at various points across the Lowveld, forming prominent hills or koppies (Ashton et al, 2001). The more significant granite bodies are the Lekkersmaak granite, Willie granite, Baderouke granite and the Miranda granite (Haupt and Sami, 2004).

The eastern portion of the catchment is marked by the Lebombo Mountains, consisting of acidic and intermediate rhyolites and lavas of the Karoo Sequence. Small areas of Quaternary deposits line the broad shallow bed of the Great Letaba River along its lower reaches.

A large number of dolerite dykes and sills have intruded the Basement Complex granites and gneisses. These rocks are less resistant to weathering than their granite and gneiss host rocks and give rise to negatively weathered linear features in the landscape, often forming or delineating drainage lines that become filled with coarse rock and gravel fragments (Ashton, 2001).

The geological formations in each area are described in the Table 4 below.

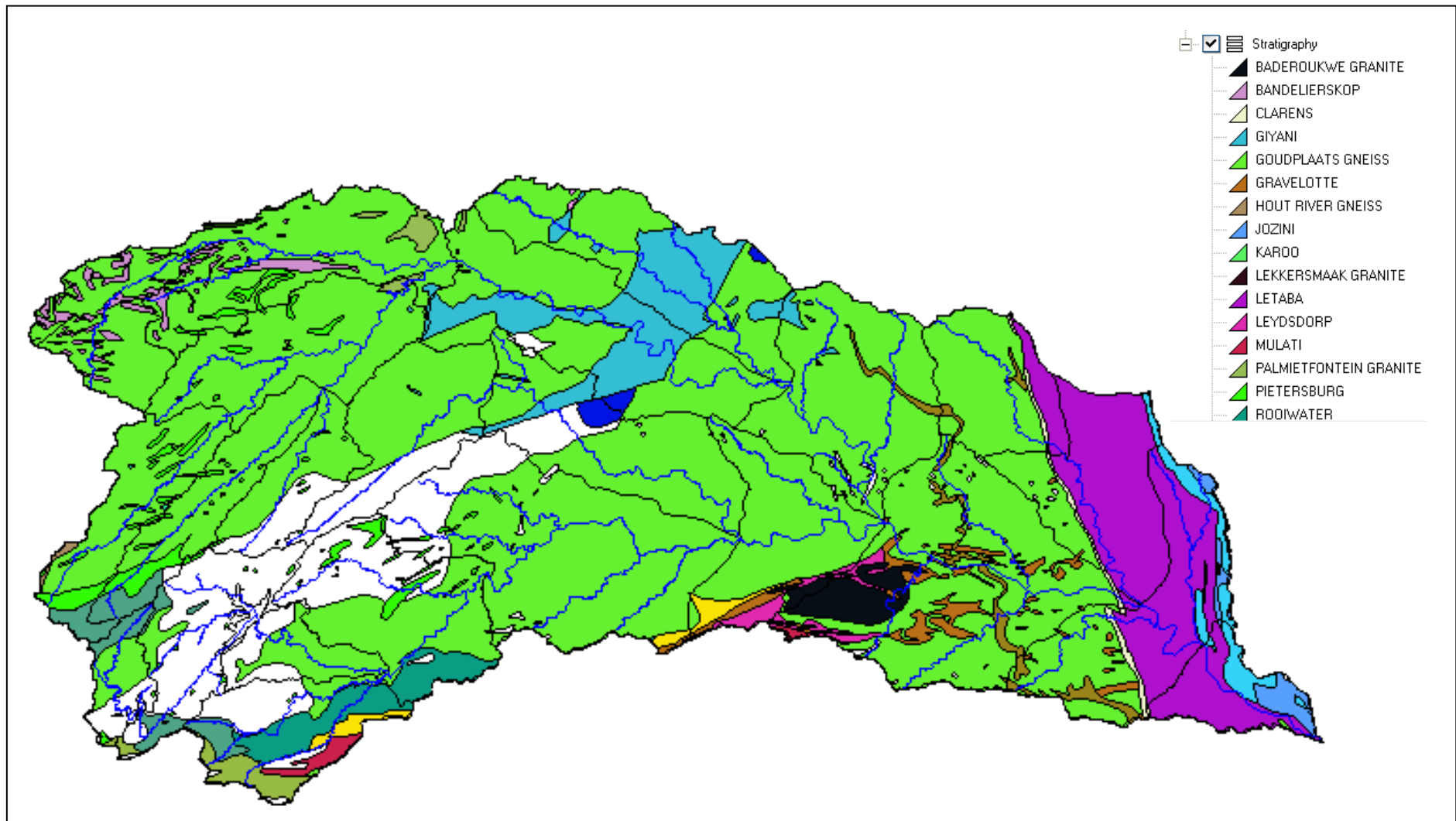


Figure 11: Geology of the Letaba River Catchment (Source: GRDM software)

Table 4: Description of geology

Area	Geological formation
Groot Letaba	<ul style="list-style-type: none"> • Goudplaats gneiss (grey biotite gneiss and migmatite with anatectic mobilisates) occurs around the Koedoes, Brandboontjies, middle and down stream of the Molototsi, middle stream of the Groot Letaba down to the confluence with the Klein Letaba. The Koedoes lineament clearly visibly runs along the Koedoes River within this formation. • Shale and basalt of the Wolkberg group occurs in the Wolkberg area • Leucocratic biotite granite occurs along the Politsi, Debengeni, Hans Merensky dam, Groot Letaba River, Tzaneen dam and extends towards the upstream of the Molototsi River. The Tzaneen lineament visibly occurs along the Groot Letaba River and extends towards the Molototsi River in this formation. • Ultramafic schist and amphibolite of the Mothiba formation, Pietersburg Group occur in patches in the Groot Letaba area in areas such as Nwamita's location, Modjadji's location, Delkraal and Tupong and Ramotoallaskloof • Baderoukwe granite occurs in the Groot Letaba nature reserve • Lekkersmaak granite of the Vorster Suite formation is found around the Mulati, Ga-Selati, and Rietspruit Rivers. There are also some patches of Mulati granite in this formation.
Klein/Middle Letaba	<ul style="list-style-type: none"> • Amphibolite, mafic granulite and metapelite of the Bandelierkop formation occur in patches between the Middle and Klein Letaba Rivers. • Hornblende granite and porphoritic hypersthene syenite of the Schiel complex Tshilaluke and Murongolo Rivers • Giyani gneiss middle stream of the Klein River extends towards the middle stream of the Nsami River up to Bububu River in the KNP. Serpentine and metapyroxenite occur within this formation
Lower Letaba	<ul style="list-style-type: none"> • Alluvium occurs along the Lower Letaba River inside the KNP. • Timbavati gabbro mostly occurs in patches in the Lower Letaba River before it enters the KNP. This formation is a dyke which cuts along the Lower Letaba River and extends across the Ngwenyeni River. • Chloritic schist, chlorite-talc schist, quartzitic schist, quartzite, metaquartzite of the Gravelotte group of the Mulati and Leydsdrop formation occurs in patches along the Malopeni, Shikome river and near Nwanedzi river. • Basalt of the Letaba formation in the KNP. • Basalt of the Jozini formation in the KNP • Makhutswi gneiss occurs along the Ngwenyeni, Nhlanganini and Kangobeni rivers • Red rocks member sandstone and Tshipise member of the Clarens formation forms a boundary between Makhutswi gneiss and basalt of the Letaba formation in the Lower Letaba area

5.7.2 Hydrogeology

The hydrogeology of the Letaba River Catchment is characterized by secondary or fractured aquifers formed by mainly metamorphic basement rocks of the Goudplaats Gneiss, Giyani and Greenstone belts, igneous rocks of the Lebombo granite, Makhutswi Granite, various younger granitoid intrusion of the Vorster Suite and gabbroic intrusions of the Rooiwater Suite Timbavati Gabbro. Intergranular aquifers (unconsolidated to semi- consolidated materials, with primary porosity) occur on the Letaba River, mainly inside the KNP (Haupt and Sami, 2004).

5.7.2.1 Groot Letaba area

Groundwater occurs in intergranular and fractured aquifers with borehole yields ranging from 0.5 - 2 l/s along the Tzaneen Dam, Groot Letaba, Thabina and Letsitele Rivers. Surface lithology is characterized by acidic/intermediate/alkaline intrusive rocks (various granitoids). As the Letsitele River joins the Thabina River, the surface lithology becomes predominantly gneissoid rocks with xenoliths of undifferentiated metamorphic rocks (Goudplaats gneiss). There is a major inferred fault along the Thabina River Valley.

Area of large groundwater abstraction for irrigation use occurs along the Groot Letaba River valley, with groundwater abstraction varying between 1 and 2 million m³/a. Just before the Malele stream (which is a tributary of the Groot Letaba River), a small portion of the Pietersburg gneiss formation occurs. Groundwater occurs also in intergranular and fractured aquifers but with borehole yields ranging from 0.1 - 0.5 l/s.

Along the Molototsi River, little variations in hydrogeology occur in upstream, middle stream and down stream areas of the river as follows:

- Upstream: Groundwater occurs in intergranular and fractured aquifers with borehole yields ranging from 0.5 - 2 l/s. Surface lithology is characterized by acidic/intermediate/alkaline intrusive rocks (various granitoids).
- Middle stream: Groundwater occurs in intergranular and fractured aquifers with borehole yields ranging from 2 - 5 l/s while the surface lithology is predominantly gneissoid rocks with xenoliths of undifferentiated metamorphic rocks (Goudplaats gneiss). There is also an inferred fault. A small patch of the Pietersburg gneiss formation occurs within the Goudplaats gneiss in this area.
- Downstream: Groundwater occurs in intergranular and fractured aquifers but with a higher borehole yield (>5 l/s). This yield decreases to 0.5 - 2 l/s when the Molototsi River joins the Groot Letaba River. The surface lithology is predominantly gneissoid rocks with xenoliths of undifferentiated metamorphic rocks (Goudplaats gneiss).

5.7.2.2 Klein/Middle Letaba area

Before joining the Middle Letaba, there is a major inferred fault along the Klein Letaba River. Groundwater occurs in intergranular and fractured aquifers but with borehole yields ranging from 2 - 5 l/s while the surface lithology is predominantly gneissoid rocks with xenoliths of undifferentiated metamorphic rocks (Goudplaats gneiss).

After joining the Middle Letaba, groundwater also occurs in intergranular and fractured aquifers but with borehole yields ranging from 2 - 5 l/s. The main geological formations are Giyani gneiss and Makhutswi granite. Major inferred fault zones occur along the Giyani formation. There is large scale groundwater abstraction (ranging from 1-2 million m³/a) for domestic use in the Giyani area.

Along the Nsama River, the main geological formations are Goudplaats gneiss (upstream) with borehole yields ranging from 2 - 5 l/s. There is also a small portion of Giyani gneiss with borehole yields ranging from 0.5 - 2 l/s. The borehole yields of Giyani gneiss decreases in the middle stream to >0.1 l/s while the borehole yield of the Goudplaats gneiss remains the same (2 - 5 l/s).

5.7.2.3 Lower Letaba area

After the confluence of the Klein and Groot Letaba, major inferred fault zones occur (in the Lower Letaba area). Major geologic formations are Makhutswi granite (with borehole yields ranging from 0.1 - 0.5 l/s) and predominantly meta-arenaceous rocks (quartz, gneiss and migmatite) with borehole yields ranging from 2 - 5 l/s. Along the Shipikani stream (tributary of the Lower Letaba River), the main geological formation is Timbavati gabbro with borehole yields ranging from 0.5 - 2 l/s. In the KNP, groundwater occurs in intergranular (alluvial) aquifers and in massive extrusive basalt rocks of the Letaba formation. These formations have borehole yields ranging from 0.5 - 2 l/s.

5.7.3 Aquifer types

The main characteristics of each of the main aquifers as well as the status quo of groundwater abstraction and exploitation potential in the Letaba catchment were obtained from *Kotze, J (2003)* and summarised in the following sections.

5.7.3.1 Alluvial Aquifers

Primary aquifers, consisting of saturated alluvium, are often present along major river drainage systems and are composed of unconsolidated clayey silts to coarse gravels and boulders. The highest yielding aquifer of this type is present in the south-eastern and eastern regions of the Letaba catchment, mostly in the Kruger Park.

These aquifers extending along the river course can be up to 500 m in width and up to 10 m thick. The average borehole yield of this aquifer is more than 5 l/s. During the rainy season, up to 20 l/s per borehole can be abstracted. However,

the yield diminishes during the dry season if the volume of storage is limited or if there is no recharge from the host rock.

Groundwater quality in these aquifers is highly variable and a decrease in yield in the dry season is normally accompanied by an increase in salinity.

Alluvial aquifers along major river courses are considered major aquifers and exist in delicate equilibrium with surface water and ecosystems present along the river course.

5.7.3.2 *Fractured Intrusive Granatoid and Gabbroic Aquifers*

The following granite intrusions occur mostly in the western part of the area: Lebombo Granite, Makhutzi Granite, various granatoid intrusions of the Vorster and gabbroic and dioritic Rooiwater Suite and the Lebombo Granite in the eastern part of the catchment (mainly the Kruger Park area).

Acid, intermediate and alkaline intrusive granatoid rocks of the above-mentioned geological sequences are widespread in the western and eastern parts of the Letaba catchment. In the Drakensberg Escarpment, the aquifers are mainly hosted by granite type rocks with scattered xenoliths of ultramafic schists, amphibolite and magnetite quartzite of the Pietersburg Group. Numerous north-east, south-west striking dykes have also intruded the area. The main aquifers in the Drakensberg Escarpment around Tzaneen are associated with fractured dyke contact zones and lithological contact zones (DWAF, 1990). To a lesser extent, as a result of the steep topography, an intermittent weathered zone aquifer is found where deep weathering occurs. Groundwater yields typically vary between 0.5 and 3.0 l/s and groundwater quality is expected to be good, with TDS being less than 500 mg/l. Furthermore, it should be noted that groundwater has a rapid turn-over time in the aquifers and is soon discharged in the form of springs, contributing significantly to stream flow. Spring yields vary between 1 and 3 l/s.

In the south, gabbroic and dioritic rocks of the Rooiwater Complex intrude the granatoid rocks of the Drakensberg Foothills and valleys. The aquifers are of a composite type, consisting of fractured and weathered zone aquifers (DWAF, 1990). Scientifically sited boreholes yield more than 3 l/s and approximately 30% of all boreholes drilled are expected to be dry.

During the period 1995 to 2001, approximately 3000 rural water supply boreholes were installed in the Letaba catchment to supply the basic human need requirements of the communities living in the catchment. A fair proportion of these boreholes are situated in the granite aquifer. Boreholes, with an average borehole yield ranging between 0.5 to 3.0 l/s were drilled in the mostly Granite and Fractured Basement Gneiss Aquifers. However, as a result of the lack of sanitation facilities, elevated nitrate concentrations commonly occur in groundwater. The hardness of granites and consequent shallow depth of weathering aggravates the impact of contamination of granite aquifers in the absence of adequate sanitation systems and uncontrolled animal grazing, both of which are part of the rural population's lifestyle.

The Granite Aquifers seem to be a very good groundwater resource, provided that good aquifer management practices are applied and low yielding hand pumps are

installed to meet the ever growing Basic Human Need requirement for hundreds of thousands of people living in informal settlements in the area around Tzaneen, Letsitele and environs.

Localised use of granite aquifers for domestic and game watering purposes in granite aquifers also takes place on private game farm property to the east. Several boreholes have been drilled in the Kruger Park and are utilised by private game reserves in the vicinity. Although the Park obtains most of its domestic supplies from surface water, there is a concern that private game reserves might overexploit groundwater resources to supplement game viewing water holes. In the light of this, a fear exists that the park is not in a position to manage their groundwater resources.

These aquifers are very vulnerable and sensitive to changes in rainfall patterns during droughts. During times of drought, boreholes dry out if not managed properly. Extensive forestry and agricultural activities in and around Tzaneen also impacts on the volumes and quality of groundwater flowing back to the Letaba River as baseflow.

5.7.3.3 Fractured Basement Gneiss

This aquifer underlies the largest part of the central Letaba catchment from north of Polokwane in the east to Tzaneen past Phalaborwa, to approximately the Kruger Park boundary. These aquifers are composed of fractured gneissoid rocks with xenoliths of undifferentiated metamorphic rocks and meta-arenaceous rocks (quartzite, gneiss and migmatite). Groundwater yields generally vary between 0.5 and 2.0 l/s, with localised zones where yields range between 2.0 and 5.0 l/s and occasionally more than 5 l/s.

The Bandelierkop Aquifers (old Venda area) also classify as this type and consist of mafic volcanics and pelitic rocks infolded in the basement gneissic rocks. Numerous dykes have intruded the region. Fractures and faults formed by the various deformational phases and dykes are thought to constitute the main aquifers as a result of deeper weathering. A considerable number of water supply boreholes were installed in this aquifer to meet the basic human need requirements of several rural communities during the period 1995 to 2001.

Groundwater development for irrigation purposes takes place on a large scale from this aquifer at Letsitele (1 to 2 million m³), Mooketsi (2 to 5 million m³) and Levubu (1 to 2 million m³). From Levubu right through to Louis Trichardt (which falls outside the Letaba catchment), large-scale groundwater abstraction takes place for irrigation purposes. Very few intrusive hydrogeological investigations have been carried out to conceptualise and quantify groundwater flow, recharge and the water balance to enable long-term aquifer management.

Large-scale irrigation of permanent crops, i.e. citrus, mango, avocado, banana, litchi and macadamia nuts takes place at Letsitele and Mooketsi to the east and north of Tzaneen, conjunctively using surface and groundwater. The 1000 ha large tea plantations of SAPICO are situated on the plateau. The sole reliance of farmers on permanent crops makes agriculture, which is the most important

economic activity in the greater Tzaneen area, very sensitive and highly dependent on the water supply conditions. Farmers should be advised to generate a substantial amount of their income from cash crops in order to survive the 'dry' years. There is also a tendency amongst farmers to expand their permanent crop capacity in 'wet' years as a result of water savings realised by employing more water efficient irrigation systems (Mr. J Venter, pers. comm.). In general, large-scale irrigation and agricultural activities reduce considerably towards the 'drier' east.

According to a simple streamflow analysis carried out by Mr. J Venter of DWAF, Tzaneen, using long-term streamflow figures for the Letaba River, the period 2003 to 2013 is postulated to represent a dry climatic cycle of below average streamflow (J Venter, pers. comm.). Given the expansion of the area under permanent crops in the 'wet cycle', the economic impact of a drought will be disastrous for this area. In addition to the above, the large-scale irrigation practices in the area will result in a considerable amount of return water flow to the Letaba River system, which could result in elevated chemical constituent concentrations in the river, particularly in the dry times. It is also expected that increasing concentrations of potentially toxic insecticides and herbicides could accumulate in the groundwater baseflow to the Letaba River.

In general, all aspects surrounding the groundwater/surface water interaction need to be investigated further. No intrusive studies have been carried out to date.

In addition to the above, localised groundwater use for domestic and game watering purposes is widespread at the various game farms in the area from Phalaborwa to Hoedspruit and various rural water supply boreholes exist with yields ranging between 0.5 and 3.0 l/s.

Hundreds of thousands of people living in rural communities on this aquifer rely on groundwater supply for basic human need requirements. In particular, large-scale groundwater use takes place north of Phalaborwa and Tzaneen to meet this basic need. Personal communication with Pierre Mouton of Water Management Systems (WMS) indicates that finding water to the east becomes increasingly more difficult. Some of the communities to the east of Tzaneen, that are dependent on groundwater to meet their basic human need requirements, are Letsitele, Letaba Estates, Nkowakow, Lenyenye and Ritavi and in the northern part of the Letaba catchment, Giyani, Bolobedu and Namakgate. In all the above-mentioned rural communities there is a huge potential for expansion of groundwater use (Pierre Mouton, WMS, pers. comm.). Associated with the rural community lifestyle is increased nitrate and organic contamination as a result of uncontrolled animal grazing along riverbeds and lack of sanitation systems, all resulting in poorer quality groundwater baseflow reaching the Letaba River. Furthermore, there is an urgent requirement for the monitoring of the Groot and Klein Letaba River systems in terms of flow and quality (Pierre Mouton, WMS, pers. comm.).

These aquifers are very vulnerable and sensitive to changes in rainfall patterns during droughts. During times of drought, boreholes dry out if not managed properly. Complicating aquifer management is the fact that no hydrogeological

conceptual model is available to define groundwater flow and quantify groundwater recharge and flow dynamics.

5.7.3.4 Greenstone Belt Aquifer

This aquifer includes highly metamorphosed ultramafic to mafic schist, amphibolite, mafic metalava, quartzitic schist, quartzite and ironstone. Local fractured aquifers dominate this region as a result of the intense folding and associated fracturing. Borehole yields typically vary between 2 and 5 l/s. Large-scale groundwater abstraction currently takes place at Giyani (0.1 to 1.0 million m³) for domestic purposes. Localised low yielding boreholes (0.5 to 3.0 l/s) are also in use by various rural communities to meet their basic human need requirements.

Similarly, as in the case of fractured basement and granite aquifers, the rural lifestyle in the communities and lack of sanitation facilities results in elevated nitrate concentrations, which could, in turn, contaminate baseflow to the Letaba River.

5.7.3.5 Carbonatite Aquifer

This is a very important, relatively pristine, undeveloped aquifer near Phalaborwa with very high yielding boreholes, ranging from 2.5 to between 20 and 40 l/s. This aquifer has the future potential to supply enough water to meet the domestic water demands of 200 000 people. Very little is known about this aquifer and its relation to surrounding aquifers. Intrusive studies to conceptualise this aquifer, its recharge, flow mechanisms, water balance and long-term sustainable yield need to be undertaken.

Although this aquifer is situated in the Komati and Crocodile River catchments, mine dewatering at the Phalaborwa apatite and carbonatite intrusion results in 500 l/s of groundwater being pumped into the Letaba River. The long-term water quality aspects, as a result of mining activities, need to be investigated further. In addition to the above, this water could be utilised more efficiently, e.g. by piping it to water users in water scarce areas rather than allowing it to evaporate instead.

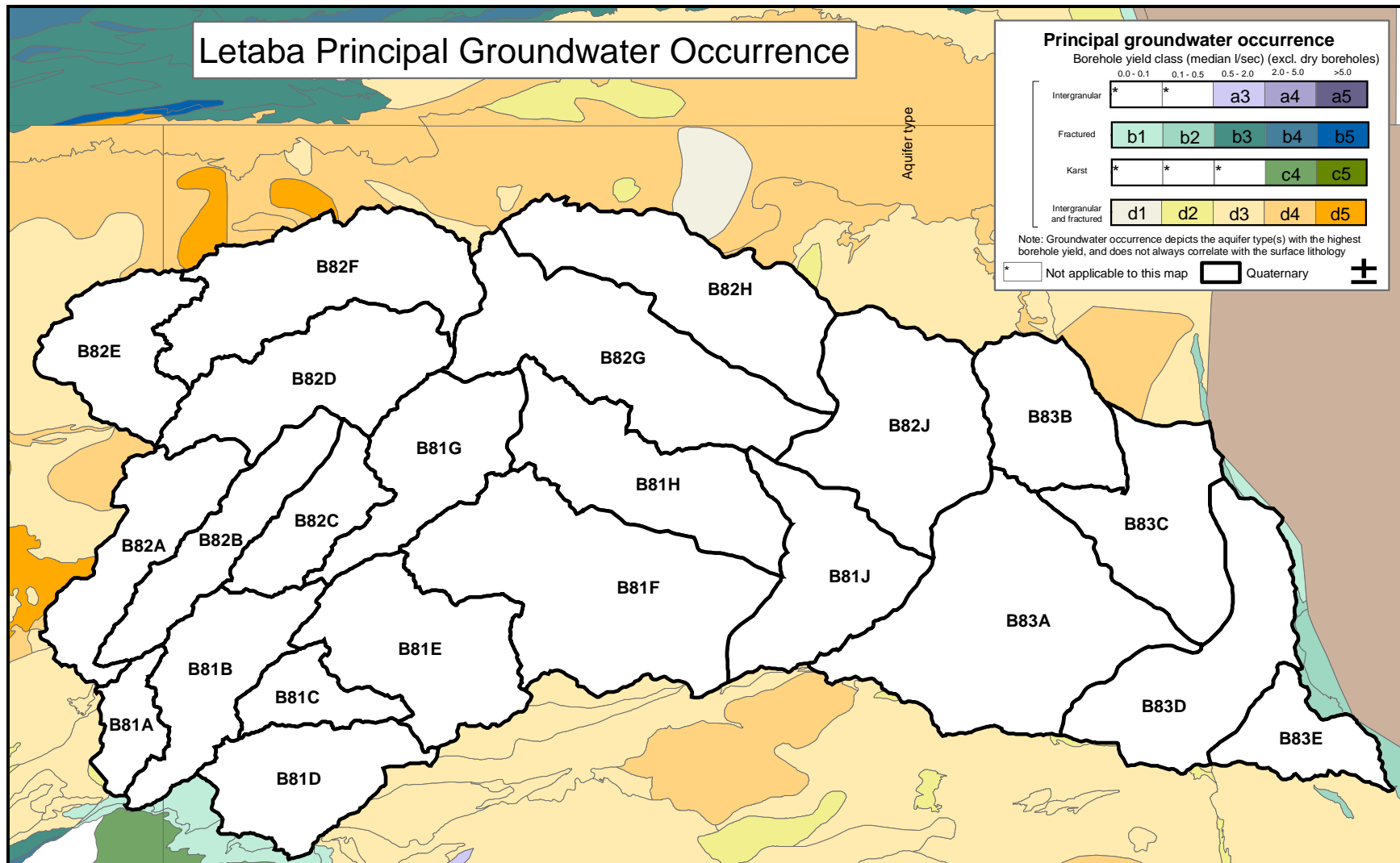


Figure 12: Aquifer types and borehole yields (after Hydrogeological Map Series, 1:500 000)

5.7.4 Recharge

The recharge towards the aquifers is one of the main parameters in the resource evaluation and Reserve determination process. For the rapid and intermediate Reserve determination, undertaken in this study, available sources of recharge estimations were utilized (see Table 5). However, the estimations differ significantly. The default values in the GRDM software are generally similar to the estimations from the GRA II project, except for the mountainous catchments B81A and B81B. In these catchments the default values, clearly underestimate the recharge potential.

Based on the topography, rainfall distribution, and aquifer types in the different catchments, the recharge estimation from the GRA II project was considered the most appropriate distribution and taken for the Reserve determination.

However, there is concern about the accuracy of these values, especially along the escarpment, where recharge towards the regional aquifer could occur outside of the quaternary catchment boundaries, and outside of the study area. It is recommended to verify the recharge estimation in these catchments, as this can have a significant impact on the final Reserve determination and the amount of groundwater that can be allocated for future use.

Table 5: Recharge Estimations for the study area

Quaternary Catchment	MAP M m ³ /a	Recharge Estimations [million m ³ /a]					Final Estimate	
		Vegter	Z_RECH	Sami	GRA II	GRDM	M m ³ /a	% MAP
B81A	201.91	37.59	23.32	28.04	33.59	12.54	33.59	16.6%
B81B	559.68	90.22	74.82	74.13	76.70	41.04	76.70	13.7%
B81C	183.34	6.43	19.92	14.68	10.60	10.59	10.60	5.8%
B81D	439.64	33.39	53.32	28.89	26.23	26.22	26.23	6.0%
B81E	443.54	4.42	37.68	21.60	18.83	18.90	18.83	4.2%
B81F	653.19	4.19	38.93	22.04	16.99	17.13	16.99	2.6%
B81G	321.10	2.73	25.92	14.01	12.96	12.87	12.96	4.0%
B81H	340.62	1.83	16.75	10.23	6.66	6.66	6.66	2.0%
B81J	284.53	1.46	16.32	8.32	7.14	7.05	7.14	2.5%
B82A	336.22	11.92	31.40	18.86	17.00	16.21	17.00	5.1%
B82B	285.21	9.88	30.03	15.22	16.29	15.85	16.29	5.7%
B82C	213.38	7.47	22.35	11.70	12.04	11.78	12.04	5.6%
B82D	393.46	9.92	28.27	16.96	13.31	13.42	13.31	3.4%
B82E	277.75	7.30	21.95	13.11	10.84	10.75	10.84	3.9%
B82F	513.81	14.67	43.60	25.63	21.70	21.89	21.70	4.2%
B82G	481.87	3.09	25.94	15.22	10.89	10.87	10.89	2.3%
B82H	386.54	2.39	19.64	11.85	7.96	7.96	7.96	2.1%
B82J	428.30	2.84	26.89	14.29	12.12	12.12	12.12	2.8%
B83A	643.38	3.37	39.03	19.71	17.31	17.34	17.31	2.7%
B83B	261.62	1.76	18.99	10.40	9.00	9.04	9.00	3.4%
B83C	318.47	5.51	18.63	10.59	8.09	8.10	8.09	2.5%
B83D	393.24	2.19	25.68	14.99	13.02	11.77	13.02	3.3%
B83E	156.42	0.91	8.76	7.09	4.28	3.75	4.28	2.7%
Total	8517.23	265.46	668.12	427.54	383.52	323.83	383.52	4.5%

* Sources partly uncertain

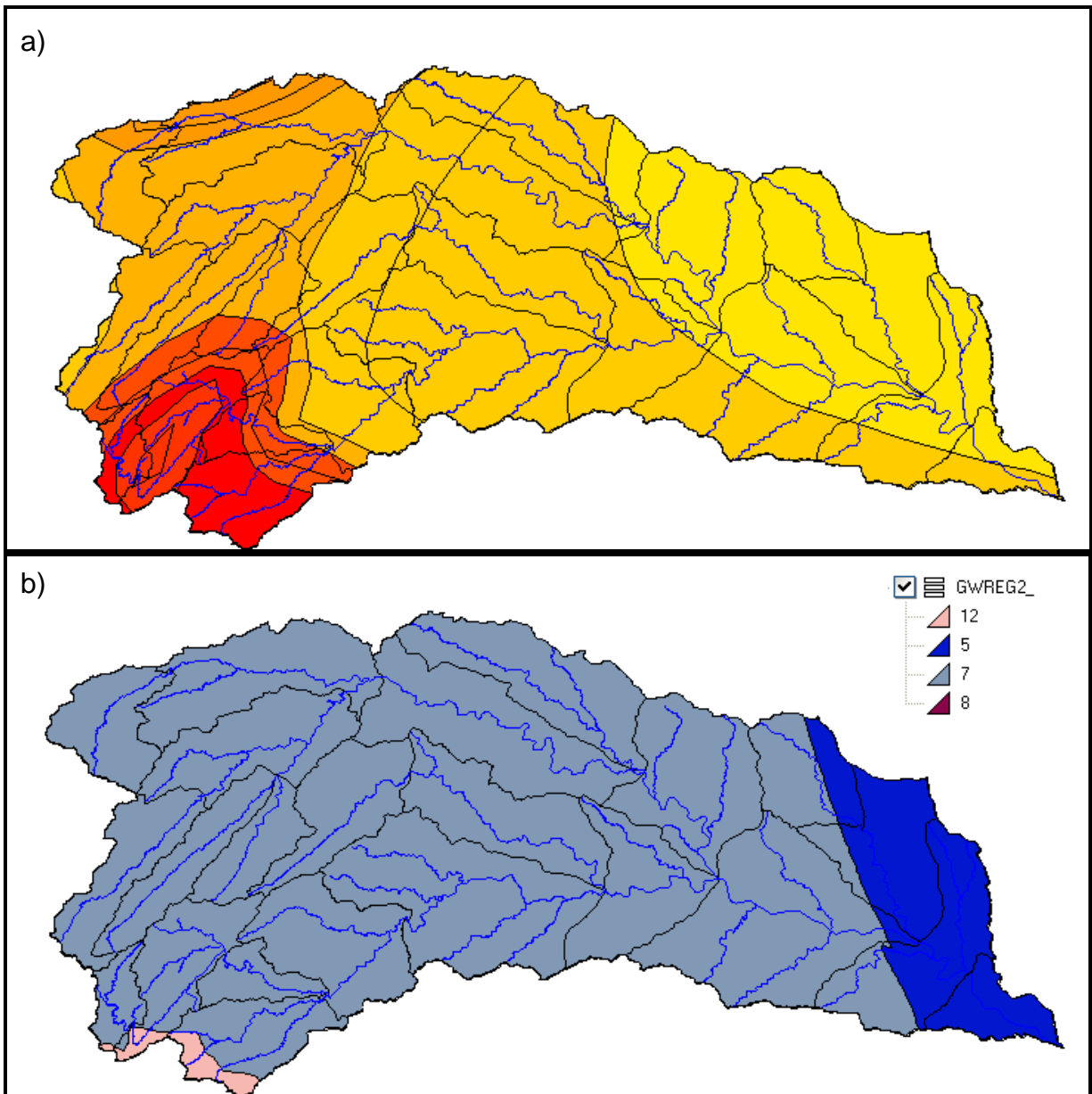


Figure 13: Recharge distribution in Letaba catchment;

a) after Vegter, 1995 [red: 12 – 18 mm/a, yellow: 1 – 2 mm/a]; b) after GRA II, 2005 [in mm/a];
(Source: GRDM software)

5.7.5 Groundwater contribution to surface water bodies

The second important parameter in the Reserve determination process is the amount of groundwater that flows from the regional aquifer into the rivers and contribute to the baseflow or low flow. A minimum flow needs to be maintained in the river to sustain the ecological function of the surface water body. The groundwater contribution is an important factor to maintain the ecological flow requirements.

Similar to the discussion on the recharge estimation above, the different baseflow estimations differ significantly (see Table 6). The main differences are due to a different definition of baseflow. The Pitman and Hughes interpretation of baseflow

includes all water that migrates through the subsurface, hence it includes seepage from perched aquifers, high lying springs and interflow. A large fraction of this water never reaches the regional aquifer, hence does not form part of the groundwater resources.

The groundwater contribution to baseflow is considered to be the portion of ground water which contributes to the low flow of streams originating from the regional groundwater body, hence baseflow can therefore be regarded as that portion of the total water resource that can either be abstracted as ground water or surface water.

Table 6: Baseflow Estimations and Groundwater Contribution to Baseflow for the study area; all values in million m³/a (Sources: GRDM software, Haupt & Sami (2005))

Quaternary Catchment	Baseflow Estimation				GW Contr. to Baseflow		Final Estimate
	Hughes	Pitman	Schulz	GRDM	GRDM	Haupt	
B81A	41.7	25.0	33.7	31.0	9.9	2.7	9.9
B81B	97.1	57.5	71.7	69.0	22.7	7.7	22.7
B81C	6.8	2.0	3.9	3.0	3.4	2.0	3.4
B81D	39.8	13.0	39.1	26.0	9.5	7.8	9.5
B81E	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B81F	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B81G	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B81H	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B81J	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B82A	7.3	1.0	3.4	3.0	4.8	1.0	4.8
B82B	5.8	0.8	2.8	2.0	4.2	0.8	4.2
B82C	4.5	0.6	2.1	2.0	3.1	0.6	3.1
B82D	5.5	1.0	3.2	2.0	5.5	1.0	5.5
B82E	4.4	0.7	2.5	2.0	3.9	0.7	3.9
B82F	8.9	1.3	4.6	4.0	7.4	1.3	7.4
B82G	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B82H	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B82J	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B83A	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B83B	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B83C	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B83D	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B83E	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	221.7	102.9	167.0	144.0	74.3	25.6	74.3

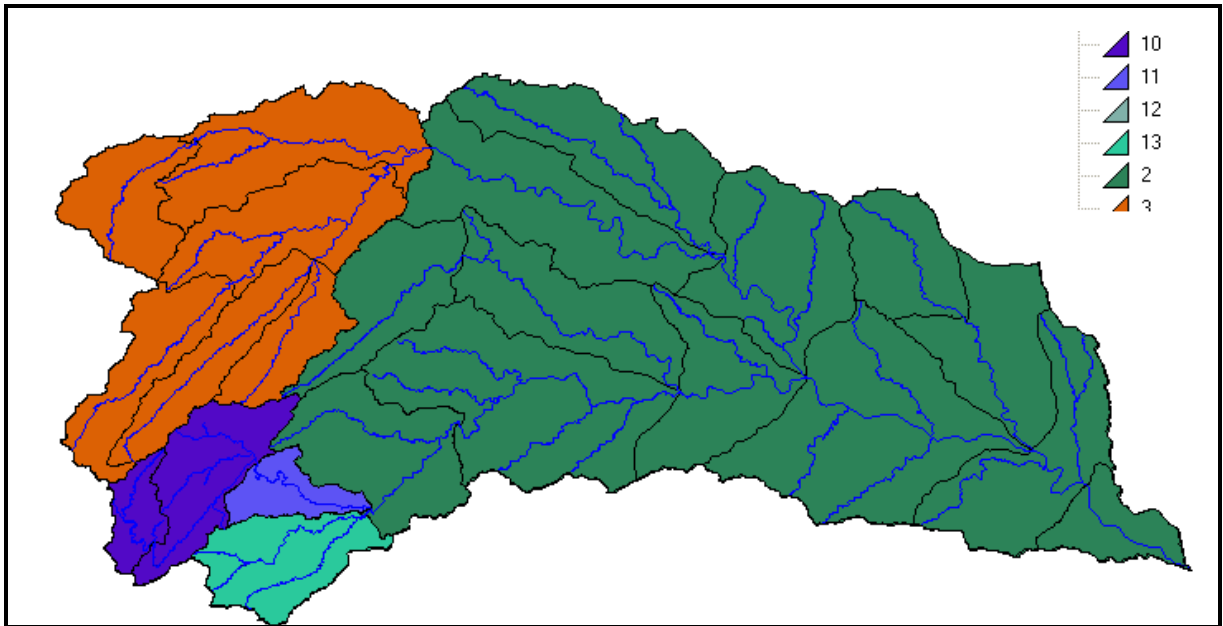


Figure 14: Baseflow distribution in Letaba catchment; classes in mm/a (Source: GRDM software, after Vegter, 1995)

The degree of groundwater – surface water interaction can be described in terms of the percentage of baseflow to recharge. Grouping the results in classes of (1) negligible, (2) less than 25%, (3) less than 50% and (4) more than 50% gives an indication of the significance of groundwater – surface water interaction and of the vulnerability of the surface water system to reduction in baseflow (see Figure 15).

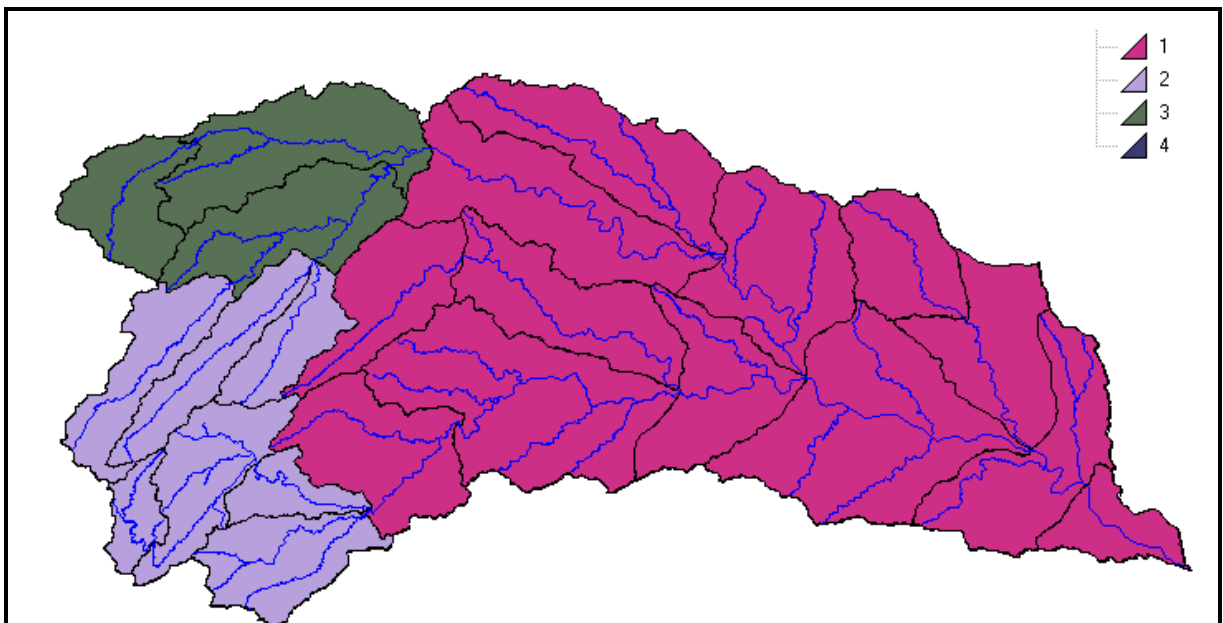


Figure 15: Surface water – groundwater interaction category (Source: GRDM software)

5.7.6 Boreholes within the study area

No detail hydro census was performed in order to identify and locate existing boreholes in the study area. Existing databases as discussed in section 3.2 were used to determine the presence of boreholes in the study area (Figure 16). At least 1500 boreholes were identified from these databases. However, it must be noted that probably not all of these are still in existence and use.

From Figure 16 it can be seen that the majority of boreholes are present within quaternary catchments B81 & B82 with less boreholes present in B83 (KNP). The boreholes are concentrated around villages.

5.7.7 Groundwater quality within the study area

The retrieval and analysis of groundwater samples from boreholes did not form part of the scope of work. Historical data were however requested from the National Groundwater Data Base at the Department of Water Affairs & Forestry and interpreted in order to form a general idea of the groundwater quality within the study area. A total number of 1455 boreholes were identified with the majority of sampling dates ranging from 1995 to 2005.

A map illustrating the spatial distribution of electrical conductivity and nitrate over the study area was constructed and is presented in Appendix A. The boreholes were further classified according to DWAF criteria into Class 0, I, II and III with Class 0 water being ideal and Class III water unacceptable for domestic use (see Table 7).

Table 7: Water Quality Classes for domestic use (DWAF)

Constituent	Class 0	Class 1	Class 2	Class 3	Class 4
pH	5 - 9.5	4.5 - 5 or 9.5 - 10	4 - 4.5 or 10 - 10.5	3 - 4 or 10.5 - 11	< 3 or > 11
TDS	< 450	450 - 1000	1000 - 2400	2400 - 3400	> 3400
EC (mS/m)	< 70	70 -150	150 - 370	370 - 520	> 520
Nitrate (as NO ₃)	< 6	6 - 10	10 - 20	20 - 40	> 40
Fluoride	< 0.7	0.7 - 1	1 - 1.5	1.5 - 3.5	< 3.5
Sulphate	< 200	200 - 400	400 - 600	600 - 1000	> 1000
Magnesium	< 70	70 - 100	100 - 200	200 -400	> 400
Sodium	< 100	100 -200	200 - 400	400 -1000	> 1000
Chloride	< 100	100 -200	200 - 600	600 - 1200	> 1200
Potassium	< 25	25 - 50	50 - 100	100 -500	> 500
Calcium	< 80	60 - 150	150 -300	> 300	
Iron	< .01	0.5 - 1	1 - 5	5 - 10	> 10

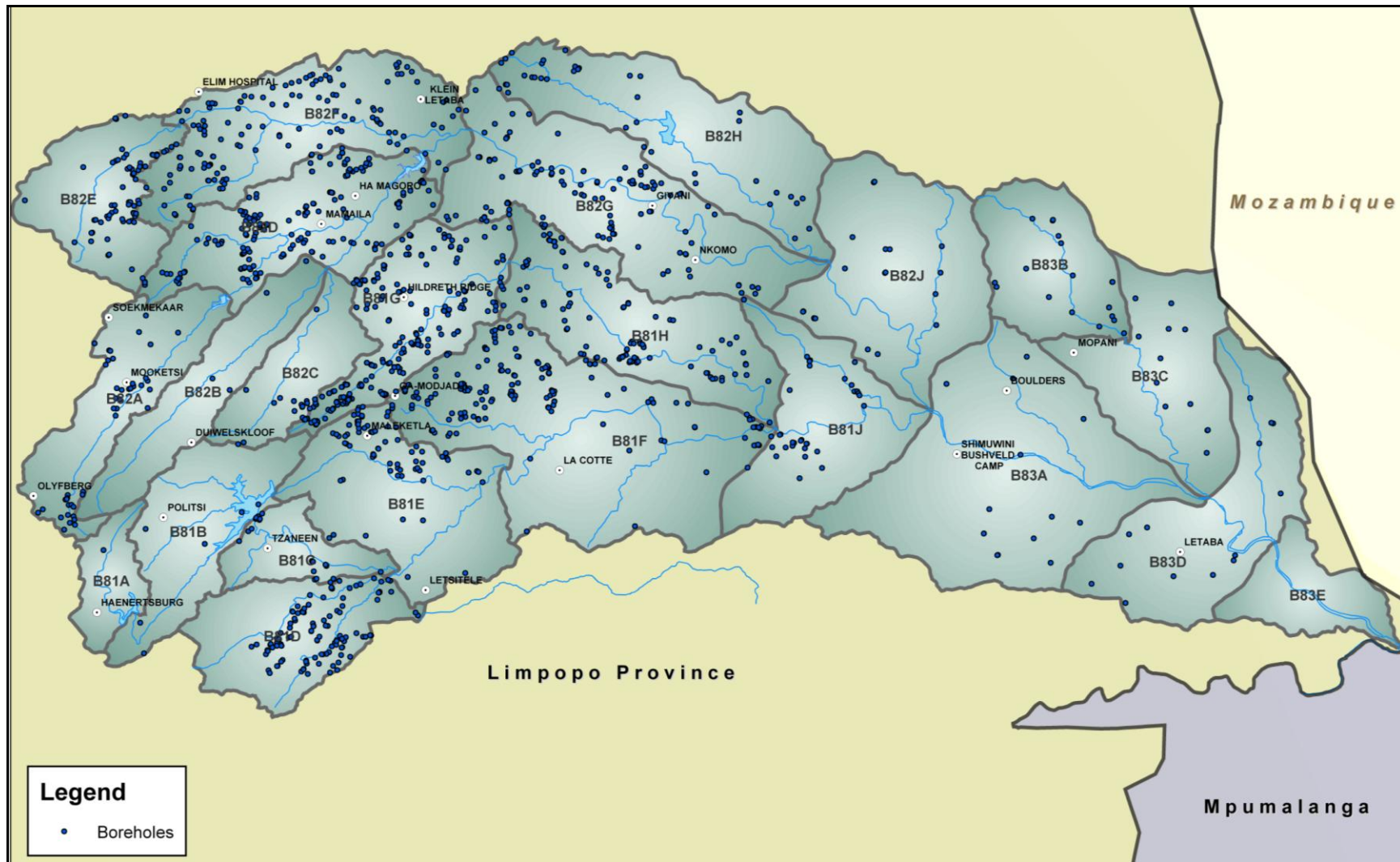


Figure 16: Location of boreholes within the study area.

From these maps it can be seen that the groundwater quality are generally good with exceptions in the densely populated areas. Especially nitrate concentrations in boreholes around these areas is a matter of concern and can be attributed to a lack of/poor sanitation services such as pit latrines in close proximity to production boreholes.

The data acquired from DWAF were used to construct Piper and Durov Diagrams. These diagrams are used to classify water into various types. Histograms of the nitrate concentrations were compiled with concentrations intervals of 25 mg/l used. This interval was chosen to simulate DWAF's groundwater classification as close as possible with nitrate concentrations exceeding 100 mg/l being unacceptable (Class III water). Each quaternary catchment was also investigated individually as each will form a resource unit on its own during the reserve determination. The Piper, Durov and Histograms for each quaternary catchment are attached to this document in Appendix B.

A Piper diagram for the whole Letaba catchment is presented in Figure 17 with the nitrate distribution of the whole catchment presented in Figure 18.

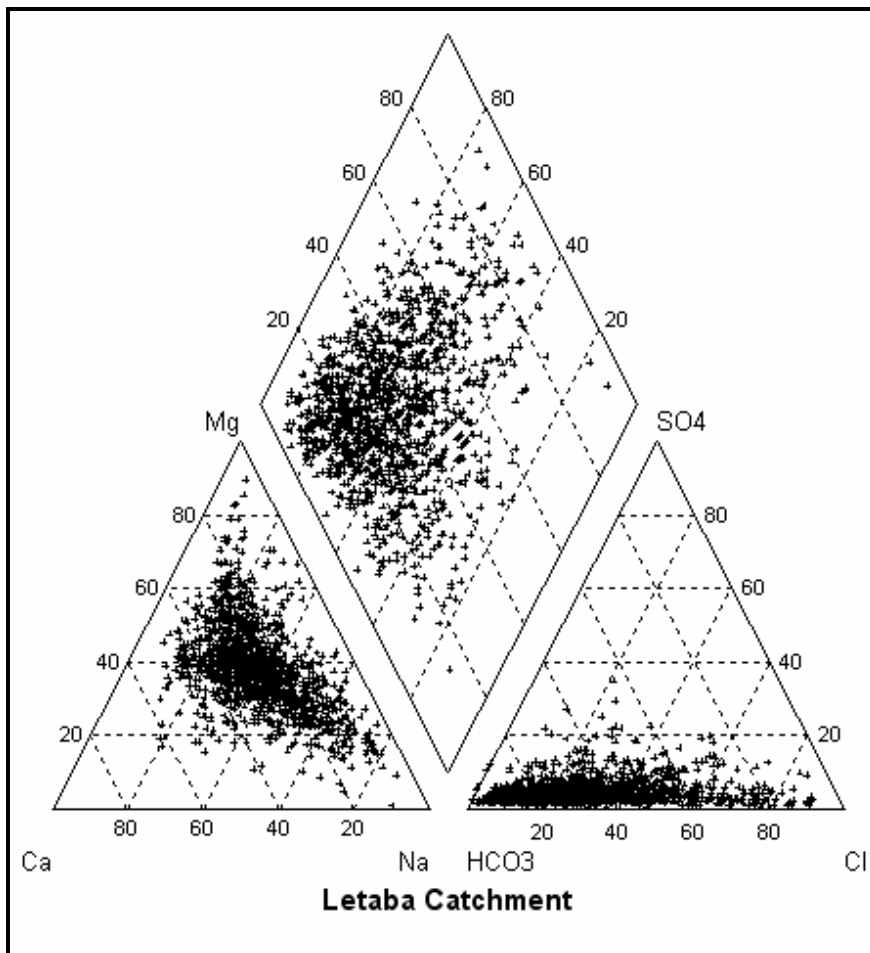


Figure 17: Piper diagram for the entire Letaba Catchment.

From the Piper diagram it can be concluded that there are generally an evenly spread around the middle indicating on no dominant cat- or anions. There are however a denser grouping towards the Ca/Mg (HCO_3)₂ field.

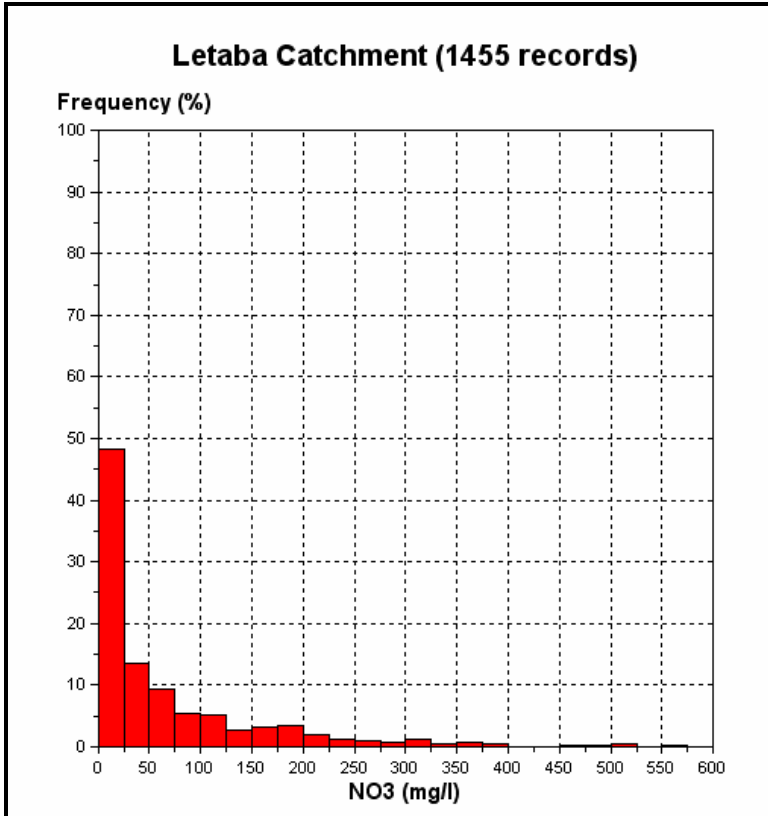


Figure 18: Histogram of the nitrate contribution for the entire Letaba Catchment.

From the Histogram it becomes clear that significant nitrate pollution has taken place with 25% of the samples having a nitrate concentration of more than 100 mg/l NO₃.

5.7.7.1 Tertiary catchment B81

The chemical data obtained from DWAF for catchment B81 are summarized in terms of pH, EC, TDS, NO₃, SO₄ and F (Table 8). The minimum, maximum, average and standard deviation for each quaternary catchment were calculated.

Table 8: Summary of chemical data for secondary catchment B81.

Quart. catchment	B81A	B81B	B81C	B81D	B81E	B81F	B81G	B81H	B81J	B81	
Nr. of records (763)	1	6	19	125	73	166	224	114	35	Average	
pH	Min	8.1	6.8	6.4	7.0	6.8	7.1	6.5	7.5	7.6	7.1
	Max	8.1	8.3	8.8	9.3	8.5	8.7	8.8	8.8	8.6	8.7
	Average	8.1	7.8	7.8	7.8	7.8	8.0	7.9	8.1	8.1	7.9
	Std. Deviation	~	0.66	0.57	0.35	0.42	0.31	0.41	0.28	0.22	0.4
EC	Min	19	10	8	7	11	12	7	26	59	17.7
	Max	19	558	129	280	171	689	1202	810	1232	565.5
	Average	19	195	50	50	52	164	104	205	250	120.9
	Std. Deviation	~	229	35	28	36	118	107	117	207	109.4
TDS	Min	135	74	64	32	88	95	63	151	407	123.2
	Max	135	3366	871	1916	1223	4826	7039	4835	7964	3574.9
	Average	135	1322	352	386	390	1110	735	1395	1661	831.5
	Std. Deviation	~	1445	239	199	269	706	650	681	1285	684.4
NO ₃	Min	1.42	0.7	0.2	0.2	0.2	0.3	0.2	0.2	0.4	0.4
	Max	1.42	514.3	169.7	319.0	221.5	684.1	510.3	545.7	330.8	366.3
	Average	1.42	123.6	19.8	19.6	22.6	77.2	58.7	90.7	76.0	54.4
	Std. Deviation	~	214.7	41.0	33.7	40.3	100.7	85.1	106.9	95.1	89.7
SO ₄	Min	<4	4.9	4.1	4.0	4.3	4.4	4.0	6.7	8.7	5.1
	Max	<4	124.5	17.3	42.9	37.1	260.1	88.3	237.7	590.6	174.8
	Average	<4	69.8	8.4	9.1	11.6	34.6	17.0	35.4	83.9	33.7
	Std. Deviation	~	41.5	5.0	6.4	7.1	36.2	13.0	33.1	99.0	30.2
F	Min	0.17	0.14	0.13	0.10	0.04	0.12	0.10	0.18	0.33	0.1
	Max	0.17	1.08	1.68	3.54	2.61	3.22	3.14	3.02	3.18	2.4
	Average	0.17	0.52	0.40	0.31	0.29	0.61	0.57	0.74	0.83	0.5
	Std. Deviation	~	0.42	0.36	0.41	0.58	0.34	0.43	0.47	0.49	0.4

From Table 8 it can be concluded that quaternary catchments B81B, B81H and B81J have the highest averages for most of the parameters.

In both the Piper and Durov diagrams (Appendix B) the boreholes are generally evenly spread around the middle indicating on no dominant cat- or anions. There are however a move towards Ca/Mg (HCO₃)₂ type of water in some of the quaternary catchments (B81D, B81E, & B81G).

The Histograms show that unacceptable high nitrate concentrations, exceeding the limits of Class III for domestic use, exist in quaternary catchments B81B, B81F, B81G, B81H & B81J.

A summary of the chemical interpretation is given in Table 9.

Table 9: Water type and nitrate distribution in secondary catchment B81.

Quaternary catchment	Water Type	% of samples > 100 mg/l NO ₃
B81B	No dominant cat- or anions.	35 %
B81C	No dominant cat-or anions.	5 %
B81D	Ca/Mg (HCO ₃) ₂	0 %
B81E	Ca/Mg (HCO ₃) ₂	< 5%
B81F	No dominant cat-or anions.	30 %
B81G	Ca/Mg (HCO ₃) ₂	25 %
B81H	No dominant cat-or anions.	35 %
B81J	No dominant cat-or anions.	25 %

5.7.7.2 Tertiary catchment B82

The chemical data obtained from DWAF for catchment B82 are summarized in terms of pH, EC, TDS, NO₃, SO₄ and F (Table 10). The minimum, maximum, average and standard deviation for each quaternary catchment were calculated.

Table 10: Summary of chemical data for secondary catchment B82.

Quart. catchment	B82A	B82B	B82C	B82D	B82E	B82F	B82G	B82H	B82J	B82	
Nr. of records (634)	47	2	23	179	69	142	116	36	20	Average	
pH	Min	7.0	7.4	6.5	6.8	7.0	6.5	7.3	7.6	7.9	7.1
	Max	8.5	8.3	8.1	8.6	8.5	8.8	9.0	8.6	8.8	8.6
	Average	7.8	7.9	7.5	8.0	7.8	7.9	8.1	8.1	8.4	7.9
	Std. Deviation	0.27	0.67	0.45	0.33	0.35	0.39	0.30	0.20	0.31	0.4
EC	Min	17	54	8	17	23	14	42	42	116	36.9
	Max	480	79	62	330	190	145	1147	290	253	330.6
	Average	68	66	33	92	75	64	167	166	180	101.3
	Std. Deviation	66	18	13	51	41	26	139	58	42	50.6
TDS	Min	92	371	71	150	131	96	297	306	905	268.8
	Max	2982	658	468	2136	1335	1025	7099	1799	2016	2168.6
	Average	501	514	237	694	547	486	1167	1159	1337	737.9
	Std. Deviation	424	203	100	330	301	214	801	335	287	332.7
NO₃	Min	0.0	17.3	2.2	0.0	0.0	0.0	0.0	0.6	0.5	2.3
	Max	345.8	41.4	77.2	331.2	281.8	1311.0	706.3	355.2	208.3	406.5
	Average	28.2	29.3	23.7	70.0	53.3	195.3	69.4	102.0	37.5	67.6
	Std. Deviation	57.5	17.0	21.1	72.1	60.5	231.9	89.6	83.8	59.4	77.0
SO₄	Min	4.2	8.7	4.6	4.0	5.1	4.2	6.0	5.8	13.8	6.3
	Max	47.6	9.2	17.3	139.6	83.8	63.4	247.5	74.9	73.2	84.0
	Average	14.9	8.9	7.6	20.9	26.0	14.6	29.0	24.5	34.2	20.0
	Std. Deviation	10.7	0.3	3.5	17.6	20.4	11.2	31.7	16.4	16.0	14.2
F	Min	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.10	0.41	0.1
	Max	2.03	0.57	1.15	1.05	2.97	2.03	2.97	1.03	1.02	1.6
	Average	0.36	0.37	0.29	0.36	0.57	0.37	0.57	0.46	0.65	0.4
	Std. Deviation	0.32	0.28	0.32	0.19	0.37	0.34	0.37	0.20	0.16	0.3

From Table 10 it can be seen that quaternary catchments B81G, B81H and B81J have exceptional high EC averages compared to the other quaternary catchments.

In both the Piper and Durov diagrams the boreholes generally show Ca/Mg(HCO₃)₂ type of water. Only the samples from catchments B82H and B82J show an even spread around the middle indicating on no dominant cat- and anions. The samples from B82G plot in two clusters; a cluster with Ca/Mg(HCO₃)₂ type water and a cluster with no dominant cat- or anions.

The Histograms show that unacceptable high nitrate concentrations, exceeding the limits of Class III for domestic use, exist in quaternary catchments B82D, B82F & B82H.

A summary of the chemical interpretation are given in Table 11.

Table 11: Water type and nitrate distribution in secondary catchment B82.

Quaternary catchment	Water Type	% of samples > 100 mg/l NO ₃
B82A	Ca/Mg (HCO ₃) ₂	< 5 %
B82C	Ca/Mg (HCO ₃) ₂	0 %
B82D	Ca/Mg (HCO ₃) ₂	30 %
B82E	Ca/Mg (HCO ₃) ₂	15 %
B82F	Ca/Mg (HCO ₃) ₂	50 %
B82G	Ca/Mg (HCO ₃) ₂ and no dominant cat- or anions.	25 %
B82H	No dominant cat- or anions.	45 %
B82J	No dominant cat- or anions.	10 %

5.7.7.3 Tertiary catchment B83

This catchment primarily covers the Kruger National Park with very little potential pollution sources. This statement is supported by the relatively good groundwater quality.

The chemical data obtained from DWAF for catchment B83 are summarized in terms of pH, EC, TDS, NO₃, SO₄ and F (Table 12). The minimum, maximum, average and standard deviation for each quaternary catchment were calculated.

From Table 12 it can be seen that average concentrations for all of the parameters are much lower than in tertiary catchments B81 & B82. However, there are still elevated levels of EC and TDS. There were no data for B83E.

Table 12: Summary of chemical data for secondary catchment B83.

Quart. Catchment		B83A	B83B	B83C	B83D	B83
Nr. of records (59)		14	19	12	14	Average
pH	Min	8.4	8.4	8.7	7.5	8.2
	Max	8.8	9.2	9.2	9.0	9.0
	Average	8.7	8.8	8.9	8.6	8.7
	Std. Deviation	0.10	0.18	0.16	0.40	0.2
EC	Min	115	80	95	32	80.4
	Max	244	372	160	251	256.8
	Average	166	158	117	142	145.8
	Std. Deviation	35	83	20	55	48.4
TDS	Min	928	619	759	257	640.8
	Max	1582	2636	1372	1985	1893.8
	Average	1311	1240	1000	1151	1175.7
	Std. Deviation	195	561	176	399	332.9
NO ₃	Min	0.0	1.3	2.6	0.0	1.0
	Max	16.3	23.1	21.6	27.0	22.0
	Average	5.0	7.9	13.2	6.2	8.1
	Std. Deviation	4.5	4.7	5.7	7.6	5.6
SO ₄	Min	6.0	5.5	<4	4.8	5.4
	Max	65.5	81.0	<4	205.9	117.5
	Average	25.0	25.5	<4	32.5	27.7
	Std. Deviation	14.8	23.6	~	60.9	33.1
F	Min	0.35	0.31	0.62	0.36	0.4
	Max	1.37	1.32	1.25	2.47	1.6
	Average	0.85	0.83	0.82	0.95	0.9
	Std. Deviation	0.28	0.24	0.18	0.53	0.3

In both the Piper and Durov diagrams (Appendix B) the boreholes generally show neutral chemistry with no dominant cat- and anions. Only boreholes in B83C show a more Na/K (HCO₃) type water.

The Histograms show (Appendix B) that all samples within this catchment are well within acceptable drinking water standards.

A summary of the chemical interpretation are given in Table 13.

Table 13: Water type and nitrate distribution in secondary catchment B83.

Quaternary catchment	Water Type	% of samples > 100 mg/l NO ₃
B83A	No dominant cat- or anions.	0 %
B83B	No dominant cat- or anions.	0 %
B83C	Na/K (HCO ₃)	0 %
B83D	No dominant cat- or anions.	0 %

5.7.8 Groundwater use within the study area

It was decided to rely for this level of Reserve determination mainly on existing data sets about the current groundwater use. The most recent estimates were obtained from the GRA II project and the data are incorporated in the GRDM software as default values (see Table 14).

However, there appears to be some discrepancies in the data. The hydrogeological map series shows groundwater abstraction zones in the B82B and B81E catchments, which would confirm the data (see Figure 19). On the other hand, the NGDB and the GRIP database does not indicate any significant number of boreholes in the B82B catchment and a population of 200 does not require an urban groundwater abstraction of 4.56 million m³/a. Haupt & Sami (2005) estimated the groundwater use in these two catchments to 0.01 million m³/a each, based on number of boreholes and average borehole yield.

Table 14: Groundwater use in Study Area (Source: GRDM Software, GRA II Project)

Quaternary Catchment	Groundwater Abstraction (million m ³ /a)						Total GRDM	Haupt & Sami
	Rural	Urban	Irrigation	Stock	Mining	Industry		
B81A	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.39
B81B	0.00	0.00	0.00	0.05	0.00	0.00	0.05	2.70
B81C	0.00	0.00	0.00	0.01	0.00	0.01	0.03	0.05
B81D	0.71	1.35	0.00	0.00	0.00	0.00	2.06	6.79
B81E	0.48	1.35	0.00	0.01	0.05	0.00	1.89	0.01
B81F	0.55	0.00	0.00	0.00	0.00	0.01	0.56	0.61
B81G	0.70	0.00	0.00	0.00	0.00	0.00	0.70	1.07
B81H	0.30	0.00	0.00	0.00	0.00	0.00	0.30	0.60
B81J	0.12	0.00	0.00	0.00	0.00	0.00	0.12	0.16
B82A	0.24	0.00	0.18	0.00	0.00	0.00	0.43	1.35
B82B	0.00	4.56	0.00	0.00	0.00	0.00	4.56	0.00
B82C	0.04	0.00	0.00	0.00	0.00	0.01	0.05	0.00
B82D	0.82	0.00	0.00	0.00	0.00	0.00	0.82	4.22
B82E	0.28	0.00	0.07	0.00	0.00	0.02	0.38	2.07
B82F	1.07	0.00	0.00	0.00	0.00	0.00	1.07	1.14
B82G	0.62	0.62	0.00	0.00	0.00	0.01	1.25	0.62
B82H	0.35	0.00	0.00	0.00	0.00	0.00	0.35	0.16
B82J	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00
B83A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B83B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B83C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B83D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B83E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	6.29	7.88	0.25	0.10	0.05	0.05	14.62	21.94

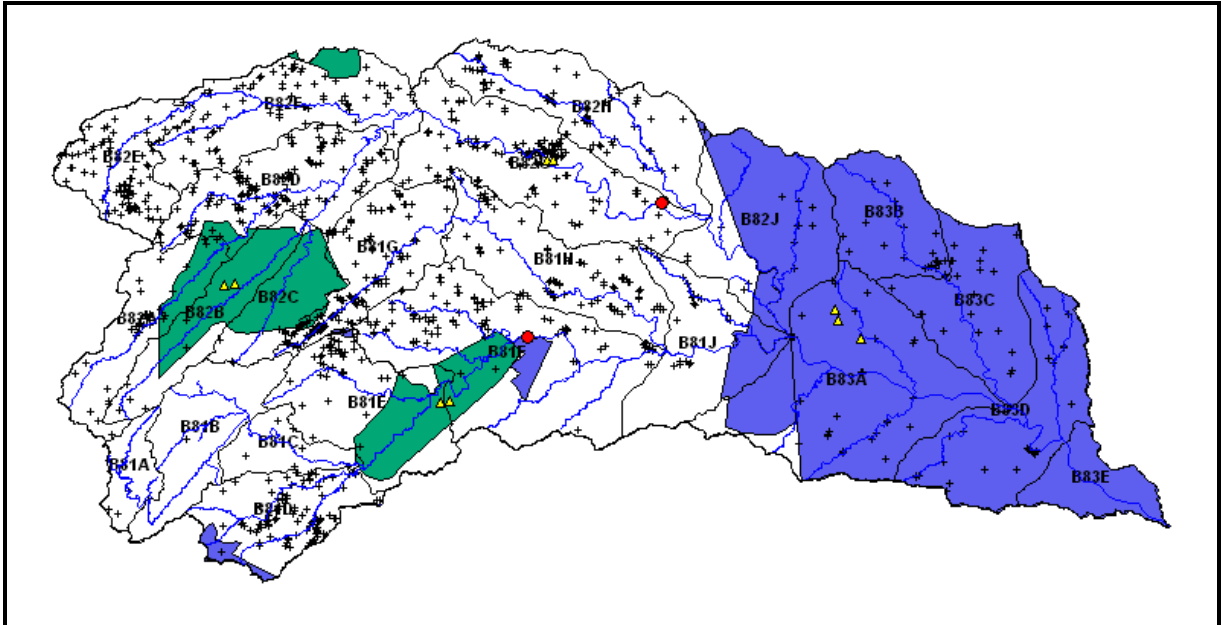


Figure 19: Boreholes and groundwater abstraction areas in Letaba catchment (Sources: GRDM software, NGDB and Hydrogeological Map Series, 1:500 000)

[+ - Boreholes; green zones and yellow triangles - groundwater abstraction areas, red dots - hot springs; blue areas – protected areas]

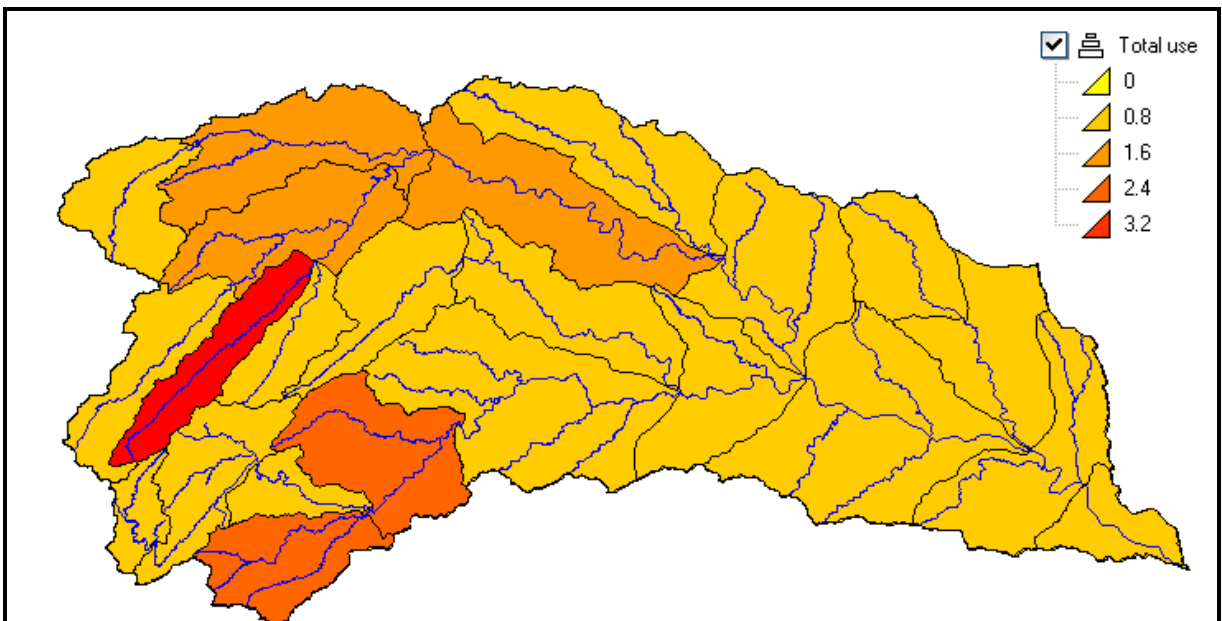


Figure 20: Groundwater abstraction per quaternary catchment in Letaba catchment (Source: GRDM software)

The groundwater abstraction in other catchments also differs significantly between the two sources (see Table 14). The total groundwater abstraction of 22 million m^3/a , as estimated by Haupt & Sami (2005) does not seem realistic, as most villages in the Letaba catchment are now mainly supplied from surface water sources. It was therefore decided to use the default data as provided in the GRDM software. However, it is strongly recommended to verify the groundwater use in certain catchments.

In addition to the abstraction of groundwater via boreholes, land use activities can result in localized decline of groundwater tables and reduction of baseflow. These activities are commonly summarized as Streamflow Reduction Activities (SRA). The main activities that are relevant in the Letaba catchment are afforestation, infestation with alien vegetation and irrigation, especially in the mountainous catchments along the escarpment.

Haupt & Sami (2005) estimated the impact of stream flow reduction activities on baseflow in these catchments. Due to afforestation and alien vegetation the streamflow is reduced by approximately 78 million m³/a, which equals 35% of baseflow. The highest impact is experienced in the B81A and B81B catchments along the escarpment that are covered by forest plantations.

However, the activities relate mostly to localized impacts on perched aquifers and the interflow component of baseflow. Under the assumption that the activities impact equally on the contribution to baseflow, the low flow reduction would amount to 26 million m³/a. This is considered as a worst case scenario.

5.8 Summary of water resources and future use

The Letaba Surface Water System is under stress and future increase in groundwater abstraction need to be investigated, should the reserve allow it (Haumann, 2006).

An increase in emerging farmers, population growth and an increased water demand from game farming will put an additional demand on an already stressed resource (both surface and groundwater). This additional need is currently unknown.

6 RESOURCE UNITS

6.1 Definition and Process

Due to the large size of the study area, it is not feasible to determine a Groundwater Reserve for the entire area. Therefore the study area is divided into smaller sub-regions, called resource units. 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.

By definition, quaternary catchments are used as the primary delineation of water resource units in RDM assessments. In the case of desktop or rapid assessments, insufficient information will be available for refining resource units further, and most assessments will therefore be based on quaternary catchments. Basic information about quaternary catchments can be obtained from the GRDM Assessment Software.

Groundwater resource units relate specifically to geohydrological characteristics, but may coincide with other significant water resource units or ecoregions, or parts thereof. In some instances, subsurface conditions could play an influential role in controlling hydrological and ecological conditions. Because of the number of factors to be considered, setting resource unit boundaries is an iterative process, requiring modification until all component requirements have been accommodated. However, it is necessary to delineate zones of similar hydrogeology and ecology within the study area.

Three additional criteria are recognised that could be used as the basis for delineation, namely physical, management or functional criteria. These could be used singularly, or in conjunction with other criteria. It is necessary to specify which criteria or characteristics were used in the delineation process, and motivate why the particular characteristic was considered the most appropriate.

Typically, delineation based on physical criteria would consider one or more of the following:

- Aquifer type
- Geology
- Climate
- Topography and geomorphology
- Recharge
- Groundwater levels and flow directions
- Groundwater quality
- Groundwater use (and stress)
- Groundwater-dependent ecosystems.

6.2 Description of delineated Resource Units

In the following sections each identified and delineated Resource Unit, as listed in Table 15, will be described. This includes a short description of characteristics of the Resource Unit as well as the reasoning for its delineation.

The resource units for the study area are based on the quaternary catchments present within the study area. The aquifer type is not a relevant factor, as described in section 5.6.3. The geology is similar over the whole study area, except in the eastern part, where larger alluvium deposits overlay the fractured bedrock. However, there are protected areas within these catchments. Most of these protected areas are nature reserves, as shown in Figure 2.

The delineation of the resource units is shown in Figure 21.

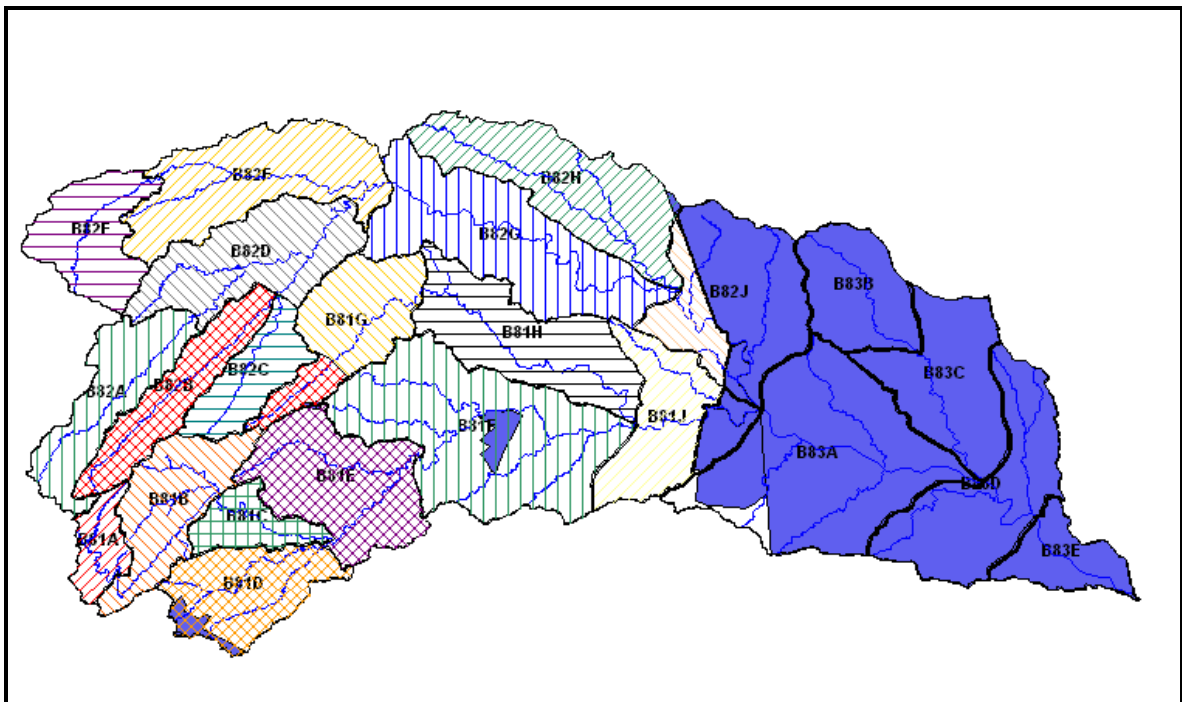


Figure 21: Resource Units in Study Area

Table 15: List of Resource Units

Resource Unit	Area			Description
	Total km ²	protected km ²	effective km ²	
B81A	169		169	Escarpment, Ebenhaeser Dam
B81B	481		481	Tzaneen Dam
B81C	208		208	
B81D	479	39	440	Wolkberg mountains, Letsitele
B81E	665	3	662	
B81F	1200	52	1148	Hans Merentsky NR
B81G-1	108	2	107	Ga-Modjadji, Molototsi River valley
B81G-2	403		403	
B81H	668		668	
B81J-1	474		474	
B81J-2	110	110	0	Kruger National Park
B82A	467		467	
B82B	406		406	
B82C	300		300	
B82D	632		632	
B82E	423		423	
B82F	760		760	
B82G	920		920	Giyani
B82H	749	6	743	
B82J-1	216		216	
B82J-2	577	577	0	Kruger National Park
B83A	1250	1166	84	Kruger National Park
B83B	439	439	0	Kruger National Park
B83C	591	591	0	Kruger National Park
B83D	713	713	0	Kruger National Park
B83E	267	267	0	Kruger National Park
Total	13673	3963	9711	

6.2.1 Groundwater Resource Unit 1: B81A

This resource unit covers an area of 169.1 km² and include the town of Haenertsburg. The resource unit is located in a steep mountainous area (above 1500 mamsl, see Figure 22) and it is drained by the Broederstroom River. The mean annual precipitation is 1194 mm while the mean annual runoff is 378 mm/a.

The Mean Annual Evaporation (MAE) is 1500 mm. The main geological formations of this resource unit consist of Turfloop granite, Goudplaats gneiss (grey biotite gneiss and migmatite with anactectic mobilisates) and leucocratic biotite. Basalt of the Wolkberg formation also occurs as a small patch within the Goudplaats gneiss formation. It has a population of 800 people while the groundwater use is 0.01 million m³/a, mainly for domestic use and livestock watering.

6.2.2 Groundwater Resource Unit 2: B81B

The resource unit covers an area of 481.2 km² with the two major towns being Modjadjiskloof and Politsi. It is located at an altitude of between 800-1300 mamsl (see Figure 22). The mean annual precipitation is 1163 mm while the mean annual runoff is 481 mm/a. The Mean Annual Evaporation (MAE) is 1500 mm. The main geological formations are leucocratic biotite granite, Turfloop granite and Goudplaats gneiss (grey biotite gneiss and migmatite with anactectic mobilisates).

The Mahitse River (non-perennial) occurring in the upper reaches of the Groot Letaba and Politsi River (perennial) drain the resource unit. It has a population of 2275 people. The groundwater use (domestic & livestock) in this area is estimated to be 0.0497 million m³/a.

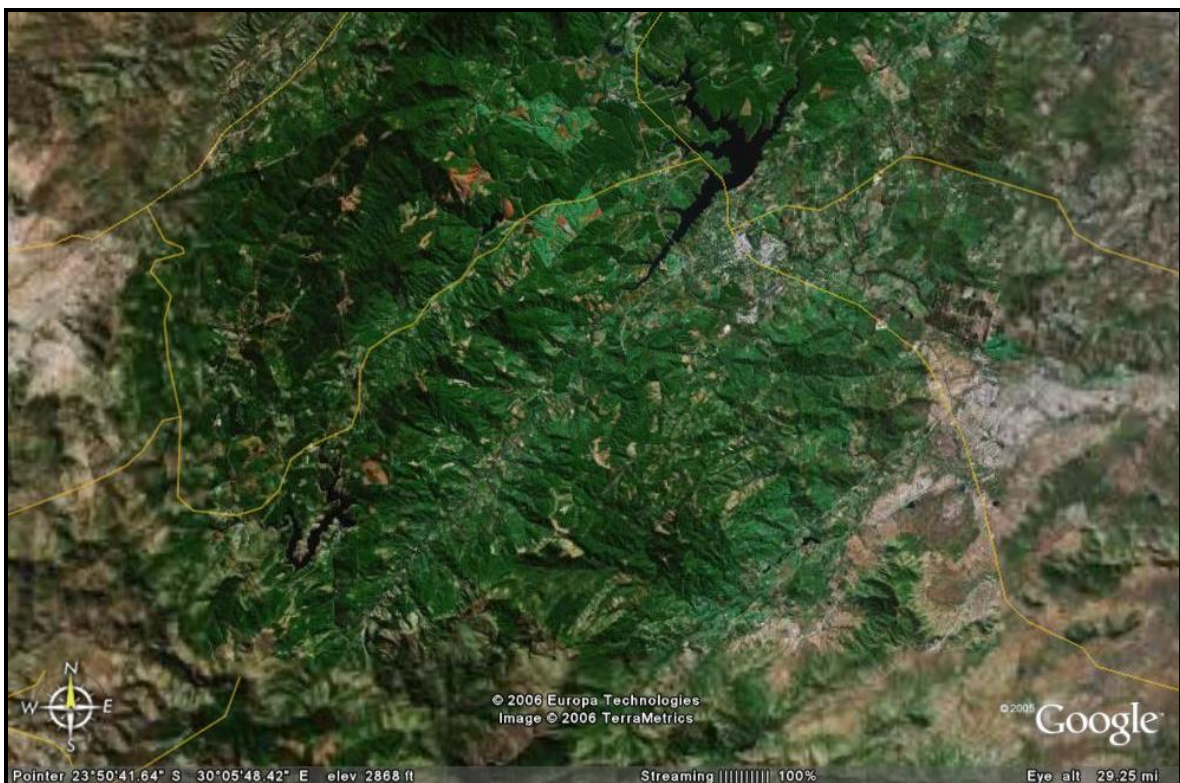


Figure 22: Resource Units B81A and B81B along the escarpment (Source: Google Earth)

6.2.3 Groundwater Resource Unit 3: B81C

This resource unit covers an area of 208.4 km² and it includes the town of Tzaneen. The altitude ranges from 600-1100 mamsl. The mean annual precipitation is 880 mm while the mean annual runoff is 83 mm/a. The Mean Annual Evaporation (MAE) is 1500 mm. The main geological formations comprise of Turfloop granite, Goudplaats gneiss (grey biotite gneiss and migmatite with anactectic mobilisates) and leucocratic biotite. Basalt of the Wolkberg formation also occurs as a small patch within the Goudplaats gneiss formation.

The Groot Letaba River (after the Tzaneen dam) drains the resource unit and has a population of 40500 people. The groundwater use is estimated to be 0.0267

million m³/a wherein 0.0137 million m³/a is used for livestock watering and 0.013 million m³/a is used for industrial purposes.

6.2.4 Groundwater Resource Unit 4: B81D

This resource unit covers an area of 481.2 km². It includes the Politsi town. It is located in steep mountainous area with an altitude that ranges from 600-1700 mamsl. The Wolkberg wilderness area is found within this resource unit. This is a protected area which covers an area of 243.80 km². The mean annual precipitation is 918.22 mm while the mean annual runoff is 203 mm/a. The MAE is 1500 mm. The geological formations consist of basalt of the Wolkberg formation, Turfloop granite, leucocratic biotite granite, Goudplaats gneiss and diorite of the Rooiwater complex.

This unit is drained by the Letsitele and Thabina perennial Rivers (Figure 23) and has a population of 2275 people. The groundwater use is estimated to be 2.0584 million m³/a wherein 1.3449 million m³ is used for municipal use, 0.0702 million m³ for rural domestic use and 0.0035 million m³ for livestock watering.



Figure 23: Letsitele catchment (B81D) with Letstele and Thabina Rivers (Source: Google Earth)

6.2.5 Groundwater Resource Unit 5: B81E

The resource unit covers an area of 664.9 km². It includes the towns of Nkambak and Maleketla. It is located at an altitude which ranges from 500-800 mamsl. The mean annual precipitation is 668 mm while the mean annual runoff is 203 mm/a. The MAE is 1500 mm. The geological formations comprise of leucocratic biotite granite, Goudplaats gneiss and small patches of quartzite of the Pietersburg formation.

It is drained by the perennial Nwanedzi River which is a tributary of the Letaba River. The groundwater use is estimated to be 1.8903 million m³/a wherein 1.3499 million m³/a is for municipal use, 0.48 million m³/a rural use, 0.0078 million m³/a for livestock watering and 0.526 million m³/a for mining.

Marneweck (2006) stated the possibility of wetlands in the B81D and B81E catchments, as identified by the NLC 2000 project. However, aerial photos of this area clearly demonstrate that these 'wetlands' are in fact farm dams and dams in drainage lines (see Figure 24).

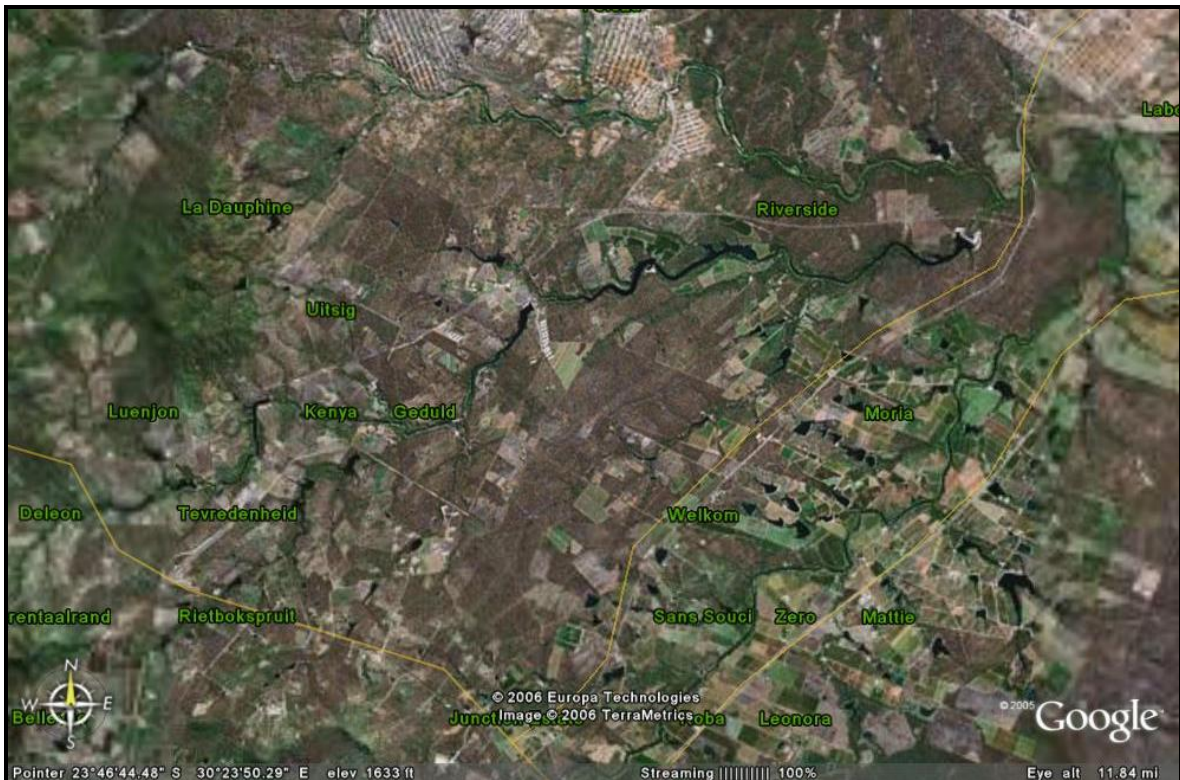


Figure 24: Farm dams in B10E catchment (Source: Google Earth)

6.2.6 Groundwater Resource Unit 6: B81F

This resource unit covers an area of 1200 km² of which 52 km² is protected area. It includes the La Cotte Town. It is a low lying area with an altitude that ranges between 400 and 700 mamsl sea level. The mean annual precipitation of the resource unit is 545 mm/a while the mean annual runoff is 16 mm/a. The MAE is 1500 mm. The main geological formation consist of Goudplaats gneiss.

Leucocratic biotite granite, biotite granite of the Randian formation and quartzite of the Pietersburg formation.

The land use includes cultivation and forestry (see Figure 25). It is drained by the Leshogole, Merekome, Lerwatlou and Makwena non perennial rivers. These rivers are tributaries of the Groot Letaba River. The groundwater use is estimated to be 0.55 million m³/a of which 0.547 million m³/a is for rural use, 0.002 million m³/a for livestock watering and 0.006 million m³/a for industrial use.

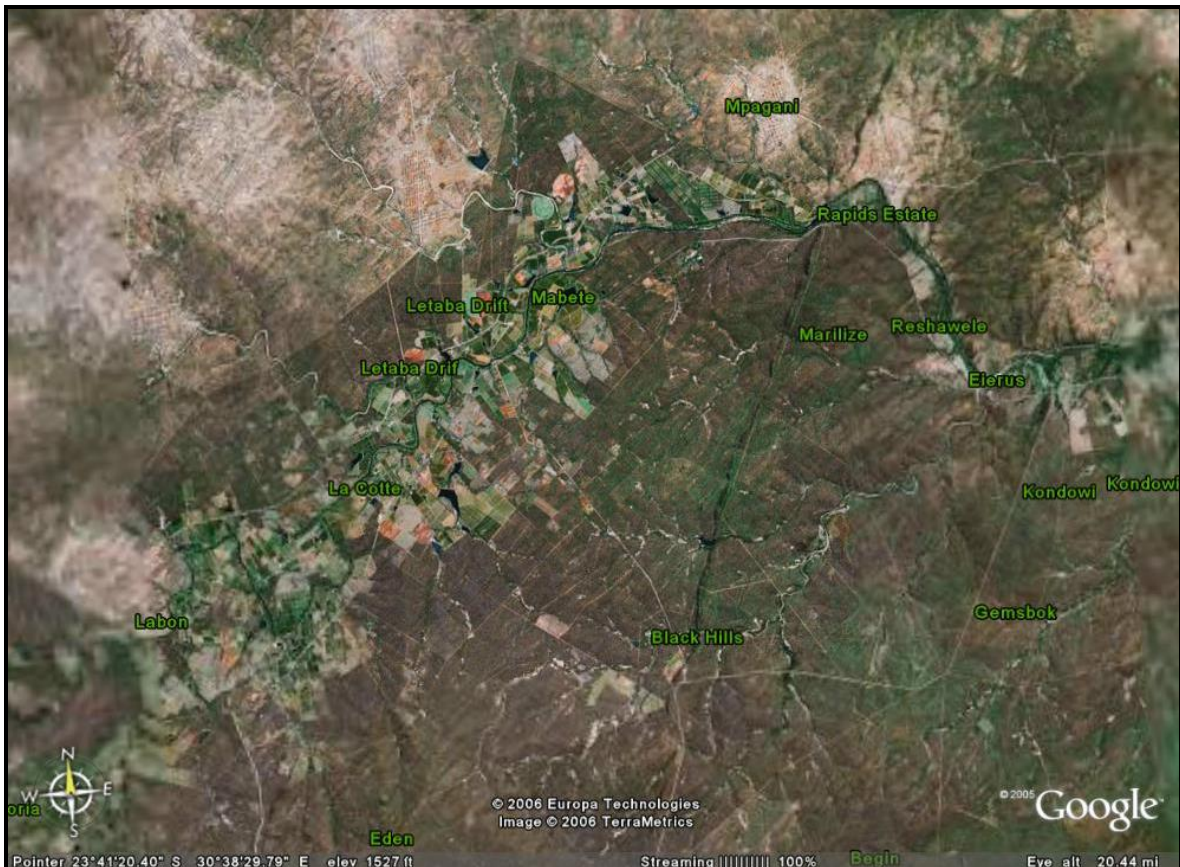


Figure 25: Resource Unit B81F with Hans Merentsky Nature Reserve (Source: Google Earth)

6.2.7 Groundwater Resource Unit 7: B81G upper part

The resource unit covers an area of 108 km² of which 2 km² is protected area. It covers the upper part of the Molototsi River including the GaModjadji town. This is a steep mountainous area with an altitude ranging from 600-1000 mamsl. The MAE is 1600 mm. Geological formations of the area comprise of leucocratic biotite granite and Pietersburg quartzite. The land use include cultivation (especially along river banks), urban residential areas and degraded thicket and bushes.



Figure 26: The steep valley of Ga-Modjadji, forming the Resource Unit B81G-1 (Source: Google Earth)

6.2.8 Groundwater Resource Unit 8: B81G lower part

The lower part of the B81G quaternary catchment was delineated as single resource unit due its difference in topography, hydrology and landuse (see Figure 27).

The resource unit covers an area of 403 km². It covers the lower part of the Molototsi River and includes the Hidreth Ridge town. This is low lying dry area with altitude ranging from 500-600 mamsl. The MAE is 1700 mm. Geological formations of the comprise of Goudplaats gneiss and Giyani gneiss. The land use include cultivation (especially along river banks), urban residential areas, degraded thicket and bushes.



Figure 27: Differences between forestry and agriculture in the west and dry land and subsistence farming in the east (Source: Google Earth)

6.2.9 Groundwater Resource Unit 9: B81H

The resource unit covers an area of 668 km². It covers the middle stream of the Molotosi River down to the confluence with the Groot Letaba River. It is located at an altitude which ranges from 400-700 mamsl. The mean annual precipitation is 510 mm while the mean annual runoff is 11 million m³/a. The MAE is 1500 mm. The geological formations of the resource comprise of leucocratic biotite granite, Goudplaats gneiss and small patches of quartzite of the Pietersburg formation, Giyani gneiss and the Shamiriri granite.

It is drained by the perennial Molotosi River which is a tributary of the Groot Letaba River. The groundwater use (mainly rural use) is estimated to be 0.302 million m³/a. The dominant vegetation type consist of mopane bushveld and mixed lowveld bushveld.

6.2.10 Groundwater Resource Unit 10: B81J western part

The resource unit covers an area of 474 km². It is located at a low lying area with an altitude of 400 mamsl. The MAE is 1700 mm. The geological formations of the resource unit include Ledysdorp lava, goudplaats gneiss, tuff of the Rubbervale formation, Baderoukwe granite and gravelotte of the Wiegel formation.

It is drained by the non-perennial Mbhawula River which is a tributary of the Groot Letaba River. The dominant vegetation type is Mopane bushveld. The land use types of the resource unit include thicket and bushes and forest and woodland.

6.2.11 Groundwater Resource Unit 11: B81J eastern part

The eastern part of the quaternary catchment B81J was delineated separately as it falls completely within the Kruger National Park.

The resource unit covers an area of 110 km². It falls within the Groot Letaba Nature Reserve with an altitude of 400 mamsl. The MAE is 1700 mm. The geological formations consist of Ledysdorp lava, goudplaats gneiss, Baderoukwe granite and biotite granite.

It is drained by the non-perennial KaMilibone River and the Groot Letaba River (down to the confluence with the Klein Letaba River). The dominant vegetation type is Mopane bushveld. The land use types of the resource unit include thicket and bushes and forest and woodland.



Figure 28: Difference in land use between the National Park and the rural villages (Source: Google Earth)

6.2.12 Groundwater Resource Unit 12: B82A

The resource unit covers an area of 467 km² and lies at an altitude that ranges between from 900-1200 mamsl. It includes the towns of Munnik. The mean annual precipitation is 721 mm while the mean annual runoff is 50 mm/a. The MAE is 1550 mm. The geological formations consist of leucocratic biotite granite, Goudplaats gneiss and small patches of quartzite of the Pietersburg formation, Giyani gneiss and the Shamiriri granite.

The resource unit is drained by the perennial Middel Letaba River. It has a population of 35180 people. The groundwater use (mainly rural use) is estimated to be 0.302 million m³/a. The dominant vegetation types are northern eastern mountain grassland (on the upper reaches of the Middle Letaba River), mixed lowveld bushveld and sour lowveld bushveld.

6.2.13 Groundwater Resource Unit 13: B82B

The resource unit covers an area of 406 km². It includes towns such as Mooketsi and Olyfberg. The altitude ranges between 600-1800 mamsl. The mean annual precipitation is 702 mm while the mean annual runoff is 45 mm/a. The MAE is 1550 mm. The geological formations comprise of goudplaats gneiss and small patches of quartzite of the Pietersburg formation.

The resource unit is drained by the perennial Koedoes River. It has an estimated population of 200 people. The groundwater use is estimated to be 4.5629 million m³/a of which 4.5589 million m³/a is for municipal use and 0.004 million m³/a for livestock use. The dominant vegetation types are north-eastern mountain grassland and afro-montane forest (on the upper reaches of the Koedoes River), mixed lowveld bushveld and sour lowveld bushveld.

6.2.14 Groundwater Resource Unit 14: B82C

The resource unit covers an area of 300 km² and lies at an altitude that ranges between 600 and 1500 mamsl. It covers the whole Brandboontjies River down to the confluence with the Koedoes River where they flow into the Mosukodutsi River. The mean annual precipitation is 712 mm while the mean annual runoff is 47 mm/a. The MAE is 1550 mm. The geological formations comprise of goudplaats gneiss and small patches of quartzite of the Pietersburg formation.

The resource unit is drained by the perennial Koedoes River and has a population of approximately 20725 people. The groundwater use is estimated to be 0.005 million m³/a of which 0.043 million m³/a is for rural use and 0.007 million m³/a is for livestock use. The dominant vegetation types are sour lowveld bushveld and mixed lowveld bushveld. The dominant land uses include cultivation, settlement and thicket and bushes.

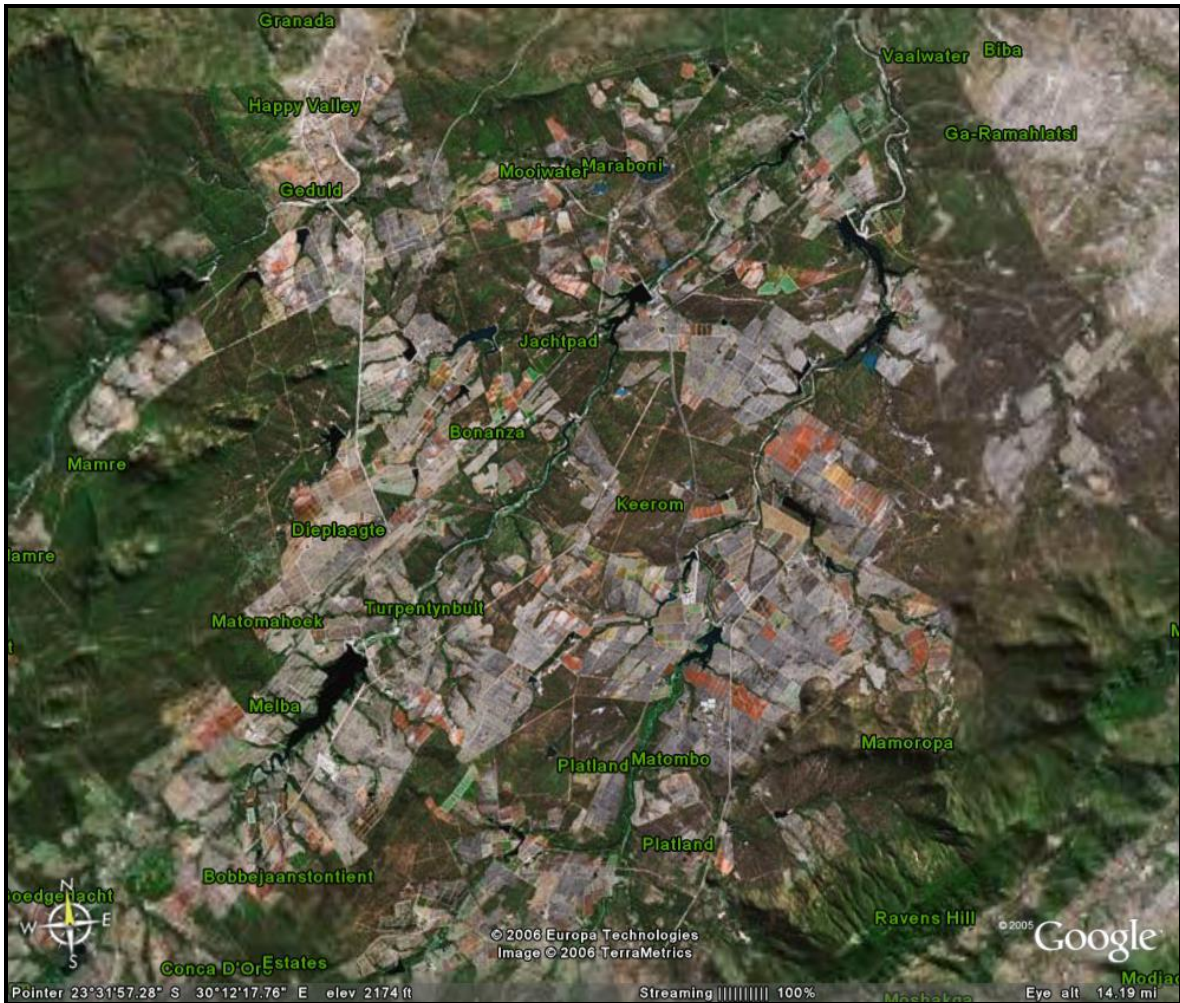


Figure 29: Agricultural landuse in the lower reaches of the Resource Units B82A, B82B and B82C (Source: Google Earth)

6.2.15 Groundwater Resource Unit 15: B82D

The resource unit covers an area of 632 km² and includes the areas of Ha-Magoro and Mamaila. It lies at an altitude of between 600-800 mamsl. The mean annual precipitation is 623 mm while the mean annual runoff is 26 mm/a. The MAE is 1600 mm. The geological formations of the resource unit are similar to those of groundwater resource B82B and B82C above, except that a patch of Palmietfontein granite occurs within the Goudplaats gneiss formation.

The resource unit is drained by the non-perennial Lebjelebore River, the Musukodutsi and perennial Middle Letaba (middle stream) Rivers. It has a population of 128 202 people. The groundwater use is estimated to be 0.8166 million m³/a of which 0.816 million m³/a are for municipal use and 0.006 million m³/a is for livestock use. The dominant vegetation type is mixed lowveld bushveld. The dominant land uses include residential urban area, cultivated lands, thicket and bushes and forest plantations. There are also barren rocks along the Middle Letaba River banks.



Figure 30: Middle Letaba Dam, situated in Resource Unit B82D (Source: Google Earth)

6.2.16 Groundwater Resource Unit 16: B82E

The resource unit covers an area of 423 km² with an altitude ranging between 800-1200 mamsl. It covers the upper reaches of the Klein Letaba River. The mean annual precipitation is 656 mm while the mean annual runoff is 32 mm/a. The MAE is 1600 mm. The geological formations comprises of the Goudplaats gneiss and the Bandelierkop gneiss.

The resource unit is drained by the perennial Middle Letaba River and has a population of 40 700 people. The groundwater use is estimated to be 0.3756 million m³/a of which 0.0031 million m³/a are used by mining, 0.018 for industrial use and 0.00745 million m³/a is for livestock use. The dominant vegetation types are sour lowveld bushveld and mixed lowveld bushveld. The dominant land use is thicket and bushes. Other land uses include cultivation, forest plantation and urban residential areas.

6.2.17 Groundwater Resource Unit 17: B82F

The resource unit covers an area of 760 km² with an altitude ranging between 500-900 mamsl. The mean annual precipitation is 676 mm while the mean annual runoff is 36 mm/a. The MAE is 1600 mm. The geological formations comprise Goudplaats gneiss, Bandelierkop gneiss and quartzite of the Pietersburg formation.

The resource unit is drained by the non perennial Seoketse River and the Klein Letaba River. It has a population of 40 700 people. The groundwater use is estimated to be 0.8166 million m³/a of which 0.816 million m³/a is for municipal use and 0.006 million m³/a for livestock use. The dominant vegetation types are sour lowveld bushveld and mixed lowveld bushveld. The dominant land use is thicket and bushes. Other land uses include cultivation, degraded forest and urban residential areas.

6.2.18 Groundwater Resource Unit 18: B82G

The resource unit covers an area of 920 km². It covers the middle stream of the Klein Letaba River down to the confluence with the Nsama River. It includes the Giyani and Nkomo towns. The altitude ranges between 400-800 mamsl. The mean annual precipitation is 524 mm while the mean annual runoff is 16 mm/a. The MAE is 1650 mm. The geological formations comprise of the Goudplaats gneiss and the Giyani gneiss.

The resource unit is drained by the non-perennial Magobe river, Nsama and the Klein Letaba River. It has a population of 110015 people. The groundwater use is estimated to be 1.2488 million m³/a of which 0.619 million m³/a is for rural use, 0.008 million m³/a is for industrial use and 0.6218 million m³/a is municipal use. The dominant vegetation types are Mopane bushveld and mixed lowveld bushveld. The dominant land use is thicket and bushes, cultivation, forest and woodland and urban residential areas.



Figure 31: Town of Giyani in Resource Unit B82G (Source: Google Earth)

6.2.19 Groundwater Resource Unit 19: B82H

The resource unit covers an area of 749 km². It covers the middle stream of the Klein Letaba River down to the confluence with the Nsama River. The altitude ranges between 400-600 mamsl. The mean annual precipitation is 516 mm while the mean annual runoff is 14 mm/a. The MAE, geology, land use and vegetation type of this resource unit are similar to that of Groundwater resource unit: B82J. The only difference (with respect to geology) is that a patch of leucocratic biotite granite occurs within the Goudplaats gneiss formation.

The resource unit is drained by the Klein Letaba River. The resource unit has a population of 57357 people. The groundwater use is estimated to be 0.349 million m³/a which are mainly rural use.

6.2.20 Groundwater Resource Unit 20: B82J western part

This resource unit covers an area of 216 km² and is located in a low lying area with altitude 400 mamsl. The mean annual precipitation is 516 mm while the mean annual runoff is 17 mm/a. The MAE is 1700 mm. The geological formations comprise of goudplaats gneiss, biotite granite of the Randian formation and Giyani gneiss.

This resource unit is drained by the Nalatsi and the perennial Klein Letaba Rivers. The population is estimated to be ~6120 people. Groundwater (mainly rural use) within the resource unit is estimated to be 0.02 million m³/a. The dominant vegetation cover is Mopane bushveld. The dominant land cover in this resource unit is forest and woodland. Cultivated lands, thicket and bushes and urban residential areas also occur within the resource unit. Thicket and bushes mostly occur along the banks of the Nalatsi River. Barren rocks occur along the banks of the Klein Letaba River.

6.2.21 Groundwater Resource Unit 21: B82J eastern part

Most of the characteristics of this resource unit are the same as those in Groundwater Resource Unit 20: B82J_1. The only major differences are:

- Groundwater Resource Unit 20: B82J_2 entirely falls within the Kruger National Park and is therefore a protected area with limited land uses.
- Groundwater Resource Unit 20: B82J_2 is further drained by the perennial Byashishi River.

6.2.22 Groundwater Resource Unit 22: B83A

This resource unit covers an area of 216 km² and located in a low lying area with altitude between 300 and 400 mamsl. The mean annual precipitation of the resource unit is 515 mm while the mean annual runoff is 10 mm/a. The MAE is 1700 mm. The geological formations comprise of Baderoukwe granite, Gravelotte and Ledysdorp lava.

This resource unit is drained by the non-perennial Ngwenyeni, Shipikani & Nharrhweni Rivers and the perennial Letaba River. Groundwater use is estimated to be 0.0006 million m³/a and is used for livestock watering. The dominant vegetation covers are Mopane bushveld and Mopane shrubveld. The dominant land use is forest and woodland. Cultivated lands, thicket and bushes and urban residential areas also occur within the resource unit. Thicket and bushes mostly occur along the banks of the Nalatsi River. Barren rocks occur along the banks of the Klein Letaba River.



Figure 32: Lower Letaba Catchment within the Kruger National Park (Source: Google Earth)

6.2.23 Groundwater Resource Unit 23: B83B

This resource unit covers an area of 440 km² and is located in a low lying area altitude 300 mamsl. The mean annual precipitation of the resource unit is 596 mm while the mean annual runoff is 20 mm/a. The MAE is 1700 mm. The geological formations comprise of the Goudplaats gneiss, Basalt of the Letaba formation and small patches of arenite (siltstone) of the Clarens formation.

This resource unit is drained by the perennial Tsende River. Groundwater use is estimated to be 0.0006 million m³/a and is used for livestock watering. The dominant vegetation cover are Mopane bushveld and Mopane shrubveld. The

dominant land uses in this resource unit are forest and woodland and thicket and bushes.

6.2.24 Groundwater Resource Unit 24: B83C

This resource unit covers an area of 591 km² and is located in a low lying area with altitude 300 mamsl. The mean annual precipitation of the resource unit is 539 mm while the mean annual runoff is 12 mm/a. The MAE is 1700 mm. The geological formations comprise of Goudplaats gneiss, Basalt of the Letaba formation and small patches of arenite (siltstone) of the Clarens formation.

This resource unit is drained by the perennial Tsende River. The dominant vegetation types are Mopane bushveld, Lebombo arid mountain bushveld and Mopane shrubveld. The dominant land uses in this resource unit are forest and woodland and thicket and bushes.

6.2.25 Groundwater Resource Unit 25: B83D

This resource unit covers an area of 713 km² and is located in a low lying area with altitude between 300 and 400 mamsl. The mean annual precipitation is 552 mm while the mean annual runoff is 13 mm/a. The MAE is 1700 mm. The geological formations comprise of Gravelotte & Timbavati gabbro, Basalt of the Letaba formation, basalt of the Jozini formation and arenite (siltstone) of the Clarens formation.

This resource unit is drained by the perennial Nwanedzi, Makhadi, Manyeleti and the Letaba Rivers. The dominant vegetation types are Mopane bushveld, Mopane shrubveld and Lebombo arid mountain bushveld. The dominant land uses in this resource unit are forest and woodland, thicket and bushes.

6.2.26 Groundwater Resource Unit 26: B83E

This resource unit covers an area of 267 km² and is located in a low lying area with altitude 200-300 mamsl. The mean annual precipitation of the resource unit is 587 mm while the mean annual runoff is 17 mm/a. The MAE is 1700 mm. The geological formations comprise of Tshokwane granophyre, Timbavati gabbro, Basalt of the Letaba formation, basalt of the Jozini formation and arenite (siltstone) of the Clarens formation.

This resource unit is drained by the perennial Nwanedzi, Makhadi, Manyeleti and the Letaba River. The dominant vegetation types are sweet lowveld bushveld, Lebombo arid mountain bushveld and Mopane shrubveld. The dominant land uses in this resource unit are forest and woodland, thicket and bushes.

7 RDM ASSESSMENT

This phase includes:

- The classification or categorization of each resource unit
- The determination of the groundwater reserve
- Setting Resource Quality Objectives (RQOs)

7.1 Classification

Classification of resource units includes reviewing reference conditions, current status and future management. Water quantity and water quality aspects are taken into account. Classification is based on methods designed by Prof Gerrit van Tonder (2005); however other methodologies as suggested by Colvin (2005) are also taken into account.

In this process both the Reserve Categories (i.e. A to F) and the Water Resource Classification (i.e. natural, good, fair and poor), as proposed by DWAF (see Figure 27), will be used to describe the present ecological status (PES) of the groundwater in the different Resource Units.

According to Parsons (2005) the words 'class' and 'classification' are used to describe the management class of a water resource, as set through the public process. The word 'category' is used for all sorting or grouping prior to the public process. In other words, categorisation is based only on technical input by experts in a particular field. Classification implies both technical and public input into the classification process.

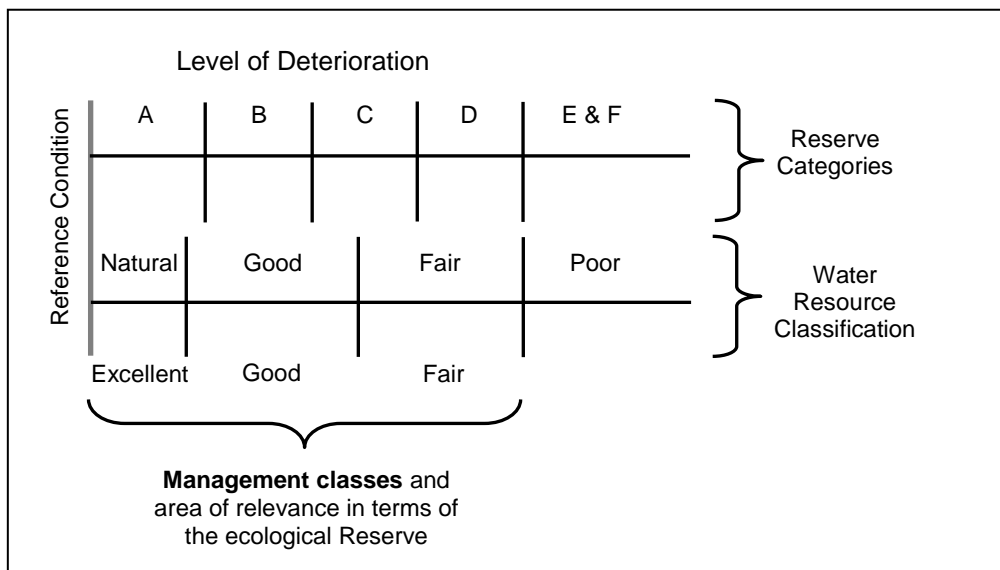


Figure 33: Relationship between various classification systems (after Parsons, 2005)

7.1.1 Water Quantity

The present status of a groundwater resource unit can be assessed in terms of sustainable use, observed ecological impacts or water stress. Since no information about ecological impacts of groundwater abstraction is available, the concept of water stress was applied for the classification process.

The concept of stressed water resources is addressed by the National Water Act, but is not defined. Part 8 of the Act gives some guidance by providing the following qualitative examples of 'water stress':

- Where demands for water are approaching or exceed the available supply;
- Where water quality problems are imminent or already exist; or
- Where water resource quality is under threat.

The water quality aspects are dealt with in section 7.1.2 below. 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 (Parsons, 2005). However, this concept does not take cognizance of the impact of other land use practices on groundwater and surface water resources. It is therefore proposed to modify the stress index by taking stream flow reduction activities and the groundwater contribution to baseflow into account. The modified stress index reads then:

$$\text{Stress Index} = \frac{\text{Groundwater Abstraction} + \text{Stream flow Reduction}}{\text{Recharge} - \text{Baseflow}}$$

The present status category was then assigned according to the classes described in Table 16.

Table 16: Guide for determining the level of stress of a groundwater resource unit, based on abstraction, stream flow reduction activities, baseflow and recharge (modified after Parsons, 2005)

PRESENT STATUS CATEGORY	DESCRIPTION	STRESS INDEX (abstraction + SRA / recharge – baseflow)
A	Unstressed or low levels of stress	< 0.05
B		0.05–0.20
C	Moderate levels of stress	0.20–0.40
D		0.40–0.65
E	Stressed	0.65–0.95
F	Critically stressed	> 0.95

Applying this modified concept, the present status categories in terms of water quantity are estimated and the results per resource unit are listed in Table 17 below. As discussed in section 5.6.8 the estimation of the current groundwater use in the resource units is uncertain in some of the quaternary catchments. The PES when of using the groundwater use data from Haupt & Sami (2005) is added to Table 17 for comparison purposes.

Table 17: Present Status Category for Resource Units, based on Stress Index

Resource Unit	Water Quantity					Stress Index with	
	Recharge M m ³ /a	Baseflow M m ³ /a	SRA M m ³ /a	GW-Use M m ³ /a	Stress Index % Class	GW-Use (Haupt) % Class	
B81A	33.6	9.9	4.6	0.01	19.4% B	21.0% C	
B81B	76.7	22.7	9.3	0.05	17.3% B	22.2% C	
B81C	10.6	3.4	1.1	0.03	16.3% B	16.6% B	
B81D	26.2	9.5	2.1	2.06	24.9% C	53.2% D	
B81E	18.8	0.0		1.89	10.0% B	0.1% A	
B81F	17.0	0.0		0.56	3.3% A	3.6% A	
B81G-1	7.0	0.0		0.10	1.4% A	4.3% A	
B81G-2	6.0	0.0		0.50	8.3% B	12.8% B	
B81H	6.7	0.0		0.30	4.5% A	9.0% B	
B81J-1	5.9	0.0		0.12	2.0% A	2.7% A	
B81J-2	1.4	0.0		0.00	0.0% A	0.0% A	
B82A	17.0	4.8	0.5	0.43	7.9% B	15.4% B	
B82B	16.3	4.2	1.0	4.56	45.5% D	7.9% B	
B82C	12.0	3.1	1.6	0.05	17.9% B	17.3% B	
B82D	13.3	5.5	1.0	0.82	23.5% C	67.0% E	
B82E	10.8	3.9	0.6	0.38	13.8% B	38.1% C	
B82F	21.7	7.4	0.3	1.07	9.9% B	10.4% B	
B82G	10.9	0.0		1.25	11.5% B	5.7% B	
B82H	8.0	0.0		0.35	4.4% A	2.0% A	
B82J-1	3.3	0.0		0.02	0.6% A	0.0% A	
B82J-2	8.8	0.0		0.00	0.0% A	0.0% A	
B83A	17.3	0.0		0.00	0.0% A	0.0% A	
B83B	9.0	0.0		0.00	0.0% A	0.0% A	
B83C	8.1	0.0		0.00	0.0% A	0.0% A	
B83D	13.0	0.0		0.00	0.0% A	0.0% A	
B83E	4.3	0.0		0.00	0.0% A	0.0% A	
Total	383.7	74.3	22.1	14.53	11.8% B	14.2% B	

The groundwater resources in the resource units B81D, B82B and B82D are considered moderately stressed. If applying the groundwater use data from Haupt & Sami (2005), the groundwater resources in the resource units B81A, B81B and B82E are also moderately stressed, while the groundwater in resource unit B82D is considered stressed.

7.1.2 Water Quality

The groundwater quality is described in detail in section 5.6.7 and section 6. The categorization is based on

- the level of observed contamination and
- the expected contamination due to land use and vulnerability, see Table 18.

In most resource units the expected land use impact is considered moderate due to high density of rural villages, small to medium waste sites, small sewage sites and the use of irrigation. In the National Park and neighboring game reserves the expected impact is low.

In the catchments along the escarpment the dense vegetation and clay soil result in a medium vulnerability, while the conditions in the lowland indicate a medium to high vulnerability of the aquifers to contamination. There are mostly no confining or protecting layers, and any contamination can move directly with the infiltration into the aquifers.

Table 18: Present Status Category, based on vulnerability and expected land use impact (after Parsons, 2005)

	VULNERABILITY			
		Low	Medium	High
EXPECTED LAND USE IMPACT	Low Impact	A	B	B
	Moderate Impact	B	C	D
	High Impact	C	D	E

The analysis of the water quality in the catchments with high density of rural villages indicates a localized to widespread contamination of the aquifers with Nitrates, Chlorides, Sulphates and other chemicals, typical for human settlements. This continues downstream of these areas into the protected areas of the Kruger National Park. However, in general the categorisation based on observed contamination is less than what could be expected from the current land use and the aquifer vulnerability.

The assigned PES for water quality is therefore based on the observed data, where sufficiently available, rather than the expected contamination (see Table 19).

Contamination is defined as concentrations of chemical parameters in groundwater above the natural background concentration that could render the water unfit for human consumption (i.e. domestic use), cattle (i.e. stock watering) or irrigation (i.e. agricultural).

Table 19: Present Ecological Status for water quality in the Resource Units, based on observed contamination, expected land use impact and vulnerability

Resource Unit	Description of contamination and possible sources	PES	Expected Impact	Vulnerability	PES		Final PES
B81A	Inadequate data.	B	Low	Medium	B		B
B81B	NO ₃ pollution.	D	Moderate	Medium	C		D
B81C	No significant contamination.	B	Moderate	Medium	C		B
B81D	No significant contamination.	B	Moderate	High	D		C
B81E	No significant contamination.	B	Moderate	High	D		C
B81F	NO ₃ pollution.	C	Moderate	High	D		C
B81G-1	No significant contamination.	B	Low	Medium	B		B
B81G-2	NO ₃ pollution.	C	Moderate	High	D		C
B81H	NO ₃ pollution.	D	Moderate	High	D		D
B81J-1	NO ₃ pollution.	C	Moderate	High	D		C
B81J-2	No significant contamination.	B	Low	Medium	B		B
B82A	Localized NO ₃ and EC pollution	C	Moderate	Medium	C		C
B82B	Inadequate data.	B	Moderate	Medium	C		B
B82C	No significant contamination.	B	Moderate	Medium	C		B
B82D	NO ₃ pollution.	C	Moderate	High	D		C
B82E	NO ₃ pollution.	C	Moderate	High	D		C
B82F	NO ₃ pollution.	D	Moderate	High	D		D
B82G	NO ₃ pollution.	D	Moderate	High	D		D
B82H	NO ₃ pollution.	D	Moderate	High	D		D
B82J-1	NO ₃ pollution.	C	Moderate	High	D		C
B82J-2	No significant contamination.	B	Low	Medium	B		B
B83A	No significant contamination.	B	Low	Medium	B		B
B83B	No significant contamination.	B	Low	Medium	B		B
B83C	No significant contamination.	B	Low	Medium	B		B
B83D	No significant contamination.	B	Low	Medium	B		B
B83E	No significant contamination.	B	Low	Medium	B		B

The water quality is of concern in all resource units with high density of rural villages, showing moderate levels of localized contamination. In addition, resource units with high agricultural activity, such as B81E or B82A to B82C, show a similar effect of localized contamination, but to a lesser degree. The resource units B82F, B82G and B82H are considered more stressed due to a moderate level of more widespread contamination.

There are cases of high levels of localized contamination in all of these resource units, especially with Nitrate, which renders parts of the groundwater resource unfit for domestic use.

7.1.3 Combined Classification

When taking both the water quantity and the water quality into account, the Present Status Category can be defined for each Resource Unit (see Table 20). To describe the combined status of the water resource, the worst of both aspects is considered.

Table 20: Present Ecological Status and proposed Desired Ecological Status of the Resource Units

Resource Unit	Present Ecological Status			Proposed Desired Ecological Status		
	Quantity	Quality	Combined	Quantity	Quality	Reasons
B81A	B	B	B	C	B	Headwaters
B81B	B	D	D	C	B	Headwaters
B81C	B	B	B	C	B	Agriculture / rural
B81D	C	C	C	C	C	Rural villages
B81E	B	C	C	D	C	Agriculture
B81F	A	C	C	D	C	Agriculture
B81G-1	A	B	B	C	B	Headwaters
B81G-2	B	C	C	C	C	Rural villages
B81H	A	D	D	C	C	Rural villages
B81J-1	A	C	C	C	B	Upstream of NR
B81J-2	A	B	B	A	B	Nature Reserve
B82A	B	C	C	C	B	Headwaters
B82B	D	B	D	D	B	Head / Agriculture
B82C	B	B	B	D	B	Head / Agriculture
B82D	C	C	C	C	C	Rural villages
B82E	B	C	C	C	C	Rural villages
B82F	B	D	D	C	C	Rural villages
B82G	B	D	D	C	C	Rural villages
B82H	A	D	D	C	C	Rural villages
B82J-1	A	C	C	C	B	Upstream of NR
B82J-2	A	B	B	A	B	Nature Reserve
B83A	A	B	B	A	B	Nature Reserve
B83B	A	B	B	A	B	Nature Reserve
B83C	A	B	B	A	B	Nature Reserve
B83D	A	B	B	A	B	Nature Reserve
B83E	A	B	B	A	B	Nature Reserve

The principles for assigning the proposed desired ecological status for the resource units are:

- the present ecological status in terms of water quality should be maintained or approved on, deterioration of water quality needs to be avoided;
- protected areas, such as Nature Reserves, require a B class in both water quantity and water quality to ensure sustainability of protected ecology, whereby groundwater abstraction should be restricted to Schedule 1 and General Authorisation;
- Resource units, directly upstream of protected areas, require a B class in water quality to ensure that the B class in the protected areas is maintained;

- Resource units containing the headwaters of the main rivers and aquifers require a B class in water quality to protect water resources further downstream;
- Resource units that mainly comprise rural villages and small towns, that are partly or fully dependent on groundwater for stockwatering, small hold agriculture and domestic use, require at least a C class in both water quantity and water quality to protect the livelihood of the rural population;
- Resource units with mainly commercial agriculture and forestry require a C class in water quality to ensure sufficient water quality for irrigation; however, a D class can be accepted for water quantity, provided that this does not have a negative impact on the assigned DES class in downstream resource units.

In general, the aim of future water resource management should be to achieve

- a good ecological status in the protected areas,
- a good ecological status in the resource units adjacent to the protected areas,
- a good ecological status in the resource units along the escarpment, and
- a good to fair ecological status in the highly populated resource units between the escarpment and the low veld.

7.2 Reserve Determination

The groundwater component of the Reserve is the part of the groundwater resource that sustains basic human needs and aquatic ecosystems. To be able to quantify the groundwater component of the Reserve, it is required to estimate the volume of groundwater needed to satisfy basic human needs (BHN) and groundwater discharged to surface water bodies to maintain the ecological integrity of the surface water bodies.

The Groundwater Reserve is set per resource unit with an associated confidence level. The following factors were taken into account:

- Aquifer classification,
- Aquifer heterogeneities,
- Water quality issues,
- Upstream / downstream users,
- Population growth,
- Potential for increased groundwater use,
- Ecological flow requirements,
- Protected areas, such as National Parks,
- Riparian ecosystems as they play a large role in the groundwater balance

The aquifer classification and water quality issues are addressed in section 7.1 above. The impact of groundwater use on other users and the surface water system is described in section 5.6. The potential for increased groundwater demand is addressed in section 5.7.

The Basic Human Need component of the Reserve is calculated based on current population numbers and the minimum requirement per Water Services Act (Act No. 108 of 1997) of 25 l/c/d.

The Ecological Reserve is estimated based on the maintenance low flow as determined by the specialists undertaking the river quantity component of the Reserve assessment. This amount is the minimum requirement to sustain the ecological integrity during low flow conditions and is considered to be provided from the regional groundwater. The instream flow requirements, as determined by the surface water Reserve assessment, are listed in Table 21 for the selected EWR sites.

Table 21: Instream Flow Requirements for the EWR sites in the Letaba River expressed as a percentage of natural MAR (Heath, 2006)

EWR site	REC	Maintenance low flows(%)	Drought low flows (%)	High flows (%)	Long term mean of MAR (%)
EWR 1	C	10.47	15.76	15.76	27.56
EWR 2	D	32.06	4.32	11.11	38.78
EWR 3	C/D	1.29	0.23	11.78	14.15
EWR 4	C/D	2.82	0.44	15.84	20.76
EWR 5	C	8.48	0.30	24.27	24.27
EWR 6	C	2.17	0.93	7.86	10.74
EWR 7	C	3.23	0.09	7.65	11.26

As the maintenance low flow was calculated only for these 7 EWR sites, and not for each quaternary catchment, it was decided to disaggregate the flow volume by the size and MAR of the contributing quaternary catchments. Quaternary catchments with zero baseflow were not considered in this exercise. An average contribution per unit area was then determined and used to set the maintenance low flows for the remaining catchments.

However, this approach cannot be applied consistently throughout the Letaba catchment. The following problems were encountered:

- The maintenance low flow requirement at EWR2 (Letsitele River, B81D) is higher than the catchment recharge and cannot be provided from groundwater alone. In this case it was decided to use the groundwater contribution to baseflow as ecological Reserve component.
- There is only one EWR site in the Klein / Middle Letaba catchment, situated below the confluence of Klein and Middle Letaba. Disaggregation might result in underestimation of flow requirements, especially in the higher lying catchments.
- The combined maintenance low flows from the sites EWR1, EWR2 and EWR5, which represent the perennial part of the Letaba River, is not sufficient to provide the required maintenance low flow at site EWR7, although the sites EWR3, EWR4 and EWR6 do not require the amount of water that is available from upstream sites.

Since the sites EWR4, EWR6 and EWR7 are situated within the protected areas, this approach is still acceptable, as groundwater abstraction above Schedule 1 and General Authorisation (GA) should not be permitted in these areas to protect the terrestrial and aquatic ecosystems.

The results of the Reserve assessment are documented in Table 22. Based on the difference between recharge and Reserve, the total allocable groundwater in the Letaba catchment amounts to 261 million m³/a. However, a significant portion of it is currently deemed unfit for human consumption. Other portions are probably not fully available due to possible impacts on other users and the environment. This number also does not take into account the groundwater use from Schedule 1 and General Authorisation.

If taking the proposed desired ecological status for water quantity into account, the actual allocable groundwater in the Letaba catchments amount to 144 million m³/a.

The groundwater allocation should be accommodated by concise licensing conditions that comply with the RQOs as set out in the following section.

Table 22: RDM Assessment for delineated Resource Units

Resource Unit	Classification				Area			Resource Evaluation				Reserve Components		Allocable Groundwater	
	Present Stress	Qual.	Proposed Quant.	Qual.	Total km ²	protected km ²	effective km ²	MAR M m ³ /a	Recharge M m ³ /a	Baseflow M m ³ /a	GW-Use M m ³ /a	BHN M m ³ /a	EFR M m ³ /a	Reserve M m ³ /a	Class M m ³ /a
B81A	B	B	C	B	169		169	64.0	33.6	9.9	0.01	0.007	6.70	26.88	13.43
B81B	B	D	C	B	481		481	155.7	76.7	22.7	0.05	0.021	16.30	60.38	30.68
B81C	B	B	C	B	208		208	17.2	10.6	3.4	0.03	0.370	1.80	8.43	4.24
B81D	C	C	C	C	479	39	440	97.4	26.2	9.5	2.06	1.328	31.22	15.36	10.49
B81E	B	C	D	C	665	3	662	29.5	18.8	0.0	1.89	0.625	0.00	18.20	12.24
B81F	A	C	D	C	1200	52	1148	18.8	17.0	0.0	0.56	0.900	0.00	16.09	11.04
B81G-1	A	B	C	B	108	2	107		7.0		0.10	0.400		6.60	2.80
B81G-2	B	C	C	C	403		403		6.0		0.50	1.300		4.70	2.40
B81H	A	D	C	C	668		668	7.1	6.7	0.0	0.30	0.494	0.00	6.16	2.66
B81J-1	A	C	C	B	474		474		5.9		0.12	0.169		5.73	2.36
B81J-2	A	B	A	B	110	110	0		1.4		0.00	0.000		0.00	0.00
B82A	B	C	C	B	467		467	23.1	17.0	4.8	0.43	0.321	0.77	13.68	6.80
B82B	D	B	D	B	406		406	18.1	16.3	4.2	4.56	0.002	0.60	14.28	10.59
B82C	B	B	D	B	300		300	14.2	12.0	3.1	0.05	0.189	0.47	9.85	7.82
B82D	C	C	C	C	632		632	16.6	13.3	5.5	0.82	1.170	0.55	10.14	5.32
B82E	B	C	C	C	423		423	13.6	10.8	3.9	0.38	0.371	0.45	8.47	4.34
B82F	B	D	C	C	760		760	27.6	21.7	7.4	1.07	1.624	0.91	16.07	8.68
B82G	B	D	C	C	920		920	14.3	10.9	0.0	1.25	1.004	0.00	9.89	4.36
B82H	A	D	C	C	749	6	743	10.8	8.0	0.0	0.35	0.523	0.00	7.43	3.18
B82J-1	A	C	C	B	216		216		3.3		0.02	0.056		3.24	1.32
B82J-2	A	B	A	B	577	577	0		8.8		0.00	0.000		0.00	0.00
B83A	A	B	A	B	1250	1166	84	12.8	17.3	0.0	0.00	0.000	0.00	0.00	0.00
B83B	A	B	A	B	439	439	0	8.6	9.0	0.0	0.00	0.000	0.00	0.00	0.00
B83C	A	B	A	B	591	591	0	7.1	8.1	0.0	0.00	0.000	0.00	0.00	0.00
B83D	A	B	A	B	713	713	0	9.4	13.0	0.0	0.00	0.000	0.00	0.00	0.00
B83E	A	B	A	B	267	267	0	4.5	4.3	0.0	0.00	0.000	0.00	0.00	0.00
Total	B	C	C	B	13673	3963	9711	605.4	383.7	74.3	14.53	10.88	41.83	261.59	144.76

7.3 Resource Quality Objectives

Resource quality objectives are measurable indicators (eg gradients, water levels, quality ranges) set to ensure the sustainable functioning of the groundwater system. Table 23 gives a summary of RQOs and indicators that are applicable in the Letaba catchment. The relevant RQOs per resource unit are documented in Table 24. However, it must be noted that the values given are a guideline for small scale users and need to be adjusted for large scale abstraction.

Table 23: Resource Quality Objectives and indicators, relevant to the study area

Resource	Resource Quality Objective	Indicator - Measurement
Perennial River	Maintain water level or groundwater gradient	Distance of borehole to river Drawdown in abstraction borehole Water level in monitoring borehole Groundwater gradient Groundwater contribution to baseflow
	Maintain water quality	Concentration of selected parameters in groundwater
Riparian Zone	Maintain water level or groundwater gradient	Distance of borehole to river Drawdown in abstraction borehole Water level in monitoring borehole Groundwater gradient Groundwater contribution to baseflow
River Pools	Maintain water level or groundwater gradient	Distance of borehole to river Drawdown in abstraction borehole Water level in monitoring borehole Groundwater gradient Groundwater contribution to baseflow
Cold Spring	Maintain water level or groundwater gradient	No boreholes within capture zone
Hot Springs	Boreholes must be at least 10m above spring depth	Water temperature
Basic Human Needs	Maintain water level or groundwater gradient	No boreholes within protection radius Drawdown in abstraction borehole
	Maintain water quality	Concentration of selected parameters in groundwater
Strategic Use	Maintain water level or groundwater gradient	No boreholes within protection radius Water level in monitoring boreholes
	Maintain water quality	Concentration of selected parameters in groundwater
Protected Area	Maintain water level or groundwater gradient	No boreholes within protection radius

Table 24 Relevant Resource Quality Objectives per Resource Unit

RU	Distance to River ¹⁾	Abstraction drawdown ²⁾	Water level decline ³⁾	Capture Zone ⁴⁾	Protected Area ⁵⁾	Water Quality ⁶⁾
B81A	50 m	20 m	5 m	No borehole	N/a	Class II
B81B	50 m	20 m	5 m	No borehole	N/a	Class II
B81C	50 m	10 m	3 m	N/a	N/a	Class I
B81D	50 m	10 m	3 m	No borehole		Class I
B81E	100 m	10 m	3 m	N/a		Class I
B81F	100 m	10 m	2 m	N/a		Class I
B81G-1	50 m	10 m	3 m	No borehole		Class I
B81G-2	100 m	5 m	1 m	N/a	N/a	Class I
B81H	100 m	5 m	1 m	N/a	N/a	Class I
B81J-1	100 m	5 m	1 m	N/a	N/a	Class I
B81J-2	N/a	N/a	N/a	N/a	No borehole	Class II
B82A	50 m	20 m	5 m	No borehole	N/a	Class II
B82B	50 m	20 m	5 m	No borehole	N/a	Class II
B82C	50 m	20 m	5 m	N/a	N/a	Class II
B82D	100 m	10 m	2 m	N/a	N/a	Class I
B82E	100 m	10 m	2 m	N/a	N/a	Class I
B82F	100 m	5 m	1 m	N/a	N/a	Class I
B82G	100 m	5 m	1 m	N/a	N/a	Class I
B82H	100 m	5 m	1 m	N/a	N/a	Class I
B82J-1	100 m	5 m	1 m	N/a	N/a	Class I
B82J-2	N/a	N/a	N/a	N/a	No borehole	Class II
B83A	N/a	N/a	N/a	N/a	No borehole	Class II
B83B	N/a	N/a	N/a	N/a	No borehole	Class II
B83C	N/a	N/a	N/a	N/a	No borehole	Class II
B83D	N/a	N/a	N/a	N/a	No borehole	Class II
B83E	N/a	N/a	N/a	N/a	No borehole	Class II

- 1) No licensed groundwater abstraction within the postulated distance to river
- 2) Maximum allowable drawdown in abstraction borehole
- 3) Maximum allowable drawdown in monitoring borehole (long-term water level decline)
- 4) No licensed groundwater abstraction within capture zones of springs
- 5) No licensed groundwater abstraction above Schedule 1 and General Authorisation in protected areas
- 6) Preferred class of water quality

8 RECOMMENDATIONS

During the Rapid Reserve Determination a few issues were identified which need to be addressed and followed up with fieldwork. These issues mainly pertain to groundwater use, wetlands, recharge, baseflow and groundwater quality.

8.1 Groundwater Use

The available data about the current groundwater abstraction are contradictory and uncertain in some catchments. It is therefore recommended to undertake a detailed hydrocensus to verify the groundwater use in resource units B81D, B81E and B82B.

8.2 Wetlands

Undertake field verification of wetlands (locations, type, groundwater dependency) in resource units B81C, B81D and B81E. Undertake field verification of possible wetlands in resource units B81A, B82A and B82B.

8.3 Recharge

Undertake comprehensive and aquifer specific recharge estimation in catchments along the escarpment. This should include:

- Determining the extent of the recharge areas per aquifer and per quaternary catchment taken into account that recharge to a specific aquifer can occur outside of the quaternary catchments;
- Estimating the rate of recharge with a combination of methods, as suitable for the catchments, e.g. GIS based, SVF, Soil Moisture;
- Calibration of the recharge estimation with Chloride Mass Balance and Isotopes.

8.4 Baseflow

The values available for baseflow and groundwater contribution to baseflow vary significant and require verification. The following should be undertaken:

- Spring hydrocensus along the escarpment to verify baseflow calculations;
- Estimate the impact of stream flow reduction activities (i.e. afforestation, alien vegetation) on baseflow and groundwater contribution to baseflow in the catchments along the escarpment.
- Use of environmental tracers and or isotopes to estimate the groundwater contribution to baseflow.

8.5 Groundwater Quality

It can be concluded that widespread nitrate contamination of groundwater occurs throughout the catchment, especially where boreholes are located close to densely populated villages. The pollution can mainly be attributed to poor

sanitation practices. In order to prevent and minimize the further contamination of the groundwater resource, the following are recommended for existing well fields, as well as for future or planned groundwater exploration. Priority must be given to the following resource units:

- B81B, B81F, B81G-2, B81H, B81J-1
- B82D, B82E, B82F, B82G, B82H, B82J-1

8.5.1 Sanitary Survey

A sanitary survey of the potential pollution sources is as important as determining water quality parameters of the source. It assesses existing sources of contamination and potential activities in a catchment which may lead to the contamination of identified sources. It also provides guidance on the potential contaminants which may be present and on what analyses need to be performed to characterize quality. Without such a survey, the fact that water meets a specified standard does not give assurance that the water will remain safe for long term consumption. A sanitary survey consists of three aspects:

Chemical survey

Existing water quality should be obtained to provide information on potential problems in the catchment. This was done during the reserve study and nitrate contamination was identified as a problem in boreholes located close to densely populated villages. Samples need to be taken to verify the extent of pollution.

Physical survey

This survey should identify land uses, activities and wastewater discharges in the source catchment area or the groundwater recharge area so that distances and directions to contaminant sources can be established. Typical expected pollution sources in the Letaba Catchment would include cattle kraals, waste disposal sites, unsewered sanitation, graves and agricultural activities.

8.6 Future use

The additional water allocation due to an increase in emerging farmers, population growth and an increased water demand from game farming need to be projected.

8.7 Comprehensive Reserve Determination

The need arises in the following resource units to undertake a comprehensive Reserve Determination, for which the recommendations above would be essential inputs:

- B81B – water quality, streamflow reduction
- B81D – groundwater use
- B81H – water quality
- B82B – groundwater use
- B82D – groundwater use, water quality
- B82F – water quality
- B82G – water quality
- B82H – water quality

In addition, a comprehensive Reserve Determination should be undertaken in resource units, once the applications for groundwater abstraction exceeds 75% of the allocable water with respect to the classification of the desired ecological status.

APPENDIX A
GROUNDWATER QUALITY MAPS

APPENDIX B

CHEMICAL DIAGNOSTIC DIAGRAMS

APPENDIX C

GRDM fact sheets