DETERMINATION OF WATER RESOURCE CLASSES, RESERVE AND RESOURCE QUALITY OBJECTIVES STUDY FOR SECONDARY CATCHMENTS A5 – A9 WITHIN THE LIMPOPO WATER MANAGEMENT AREA (WMA 1) AND SECONDARY CATCHMENT B9 IN THE OLIFANTS WATER MANAGEMENT AREA (WMA 2)

EWR REPORT: GROUNDWATER

FINAL

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Reports that will be produced as part of this project are indicated below.

The bold type indicates this report.

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TERMINOLOGY AND ABBREVIATIONS

ACRONYMS	DESCRIPTION
BHN	Basic Human Needs
DEM	Digital Elevation Model
DTM	Digital Terrain Model
DWS	Department of Water and Sanitation
EWR	Ecological Water Requirements
GRAII	Groundwater Resource Assessment II
GRIP	Groundwater Resource Information Project
GW	Groundwater
GWBF	Groundwater Contribution to Baseflow
HYDSTRA	Hydro-informatics database
IFR	Instream Flow Requirement
IUA	Integrated Units of Analysis
IWRM	Integrated Water Resource Management
IWMI	International Water Management Institute
KNP	Kruger National Park
LLRS	Luvuvhu and Letaba Reconciliation Strategy
NGA	National Groundwater Archive
PSP	Professional Service Provider
RDM	Resource Directed Measures
RQIS	Resource Quality Information Services
RQO	Resource Quality Objectives
RSA	Republic of South Africa
RU	Resource Unit
SC	Secondary Catchment
WARMS	Water Use Authorisation and Registration Management System
WRUI	Water Resource Use Importance
WMA	Water Management Area

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1 INTRODUCTION

1.1 Background

The Department of Water and Sanitation (DWS), Chief Directorate (CD): Water Ecosystems Management (WEM) initiated a three-year study, extended to a fourth year, to Determine Water Resource Classes, the Ecological Reserve and Resource Quality Objectives for Secondary Catchments A5-A9 in the Limpopo Water Management Area (WMA 1) and Secondary Catchment B9 in the Olifants Water Management Area (WMA 2). This project aligns with the Department's mandate to protect water resources as stipulated in Chapter 3 of the National Water Act.

The Resource Directed Measure (RDM) tools implemented in these catchments aim to ensure sustainable utilisation of water resources to meet the ecological, social and economic needs of the communities dependent on them and provide a mechanism against which the objectives set can be monitored for compliance.

1.2 Objectives

The overall objective of this project is to classify and determine the Reserve and Resource Quality Objectives for all significant water resources in the Secondary catchments (A5-A9) of the Limpopo WMA and B9 in the Olifants WMA.
The Scope of Work as stipulated in the Terms of Reference calls for the following:

- Coordinate the implementation of the Water Resources Classification System (WRCS), as required in Regulation 810 in Government Gazette 33541, by classifying all significant water resources in the Limpopo WMA (secondary catchments A5-A9) and Olifants WMA (secondary catchment B9).
- Determine the water quantity and quality components of the groundwater and surface water (rivers and wetlands) Reserve.
- Determine Resource Quality Objectives (RQOs) using the Department of Water and Sanitation Procedures to Determine and Implement Resource Quality Objectives.

1.3 Aim of this Report

The aim of this report is to determine the groundwater component of the BHN and EWR Reserve (i.e., Step 4 of the eight-step GRDM: Reserve determination procedure) for the aquifer-specific Groundwater Resource Units (GRUs) delineated as part of Step 2 of the Reserve determination process (see DWS, 2022a).

Groundwater's contribution to the EWR (as groundwater contribution to baseflow) is presented and where sufficient data is available, this determination is supported by numerical groundwater flow models.

This report describes the BHN requirements for the current population, who are reliant upon taking water from the groundwater resource for their essential needs of drinking water, food preparation, and personal hygiene. The BHN is based on the current population (Census 2022 as presented in DWS, 2023), of those either living within the catchment and directly dependent on the catchment or, more critically, not being supplied from a formal water supply scheme.

1.4 Aquifer Types

The study area is dominated by Intergranular and fractured aquifer systems with borehole yields between 0.1 and > 5 L/s (Figure 1-1). The dominant rock types in the study area are the Goudplaats, Hout River, Alldays and Sand River Gneiss as well as the Beit Bridge complex including the number of granitic intrusions. These rocks form the major subgroups of the Basement Crystalline Complex as they form part of the Achaean eon 3.1 to 2.5 Ga. Aquifers are developed within the weathered overburden and fractured bedrock of these hard crystalline or re-crystallised rocks of igneous or metamorphic origin. Crystalline rocks are characterised by very low primary porosity (fresh or unweathered crystalline rocks contain virtually no water), and almost all groundwater movement and storage in these rocks takes place via fractures, faults, weathered zones and other secondary features that enhance the aquifer potential only locally. Intrusive batholiths and fractured contact zones can displace the host rocks during intrusion to create space for the ascending magma. These 10 to 100 metres wide zones are highly productive and can yield in boreholes in excess of 30 L/s (Du Toit, 2001). Several exceptionally high yielding areas within the crystalline basement aquifer system occur in the Dendron (Mogwadi), Vivo, Baltimore and Tolwe regions (Figure 1-1). These aquifers have provided for large scale irrigation for the last few decades.

The southwest of the study area is dominated by the Waterberg Group sandstones and the Karoo Super Group rocks which are classified as a fractured aquifer with expected borehole yields between 0.1 and > 2 L/s (Figure 1-1). Primary aquifers (or intergranular aquifers) occur throughout the study area and exist in the vicinity of drainage channels where alluvial material overlies or replaces the weathered overburden creating a distinct intergranular aquifer type. The elongated alluvial aquifers follow rivers (so called valley trains), sand rivers or drainage lines with limited width and depth, which typically vary according to the topography and climate.

The mountainous area east of Mokopane is also of special interest as far groundwater is concerned as this area consists primarily of dolomite and has considerable groundwater resources. The karst aquifer with expected yields of more than > 5L/s is however heavily exploited, within quaternary catchment A61F (DWAF, 2004)

Three main types of aquifers occur within the study area, namely

- Intergranular (alluvial aquifer).
- Intergranular (“primary” or weathered sandy aquifers) and fractured (“secondary” aquifers).
- Karst aquifer system.

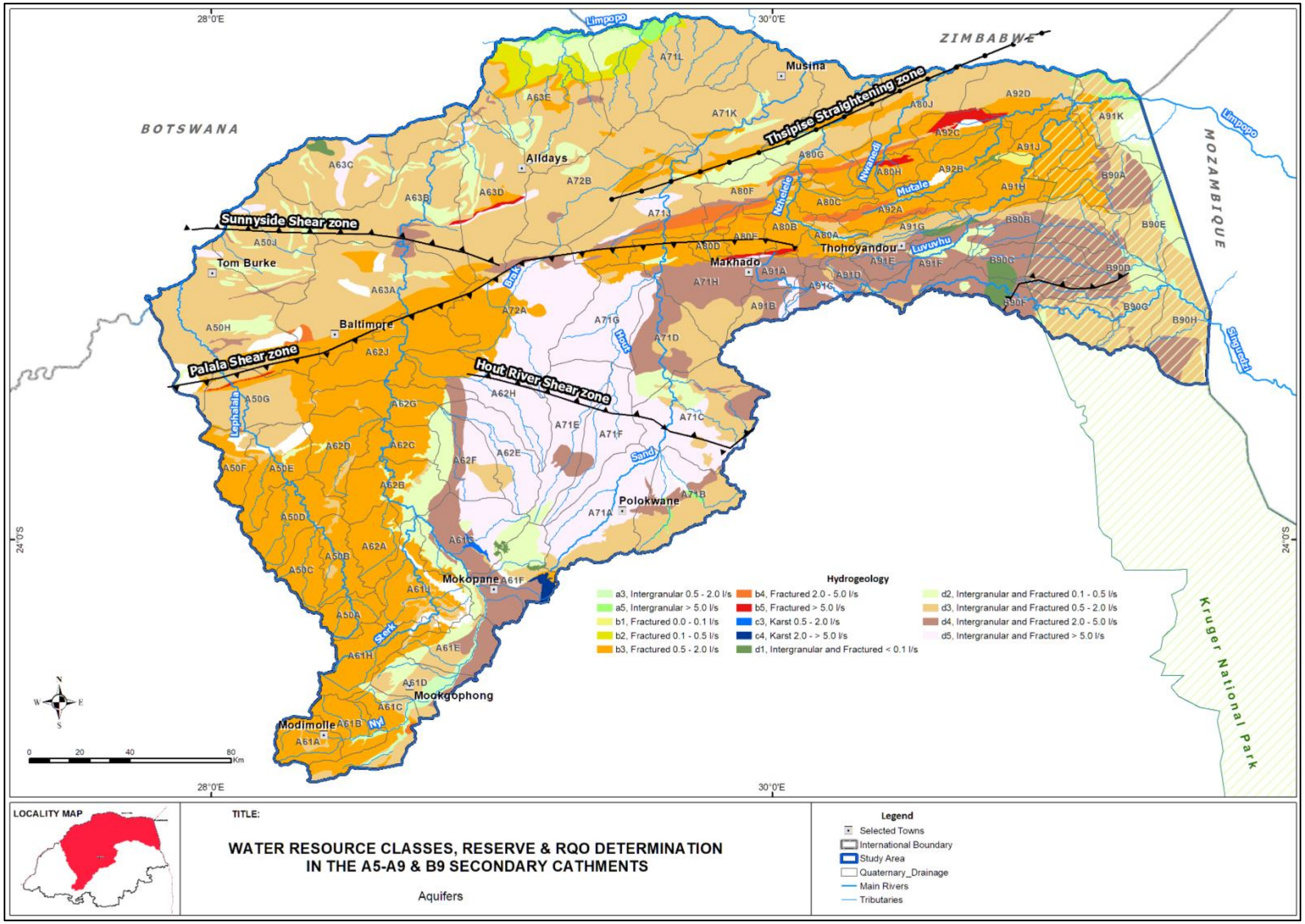

Figure 1-1. Aquifer type and yield.

1.4.1 Groundwater Levels and Flow Direction

Regionally groundwater levels mimic surface topography and shallow groundwater flow is from higher lying ground towards surface drainages. The main flow direction is towards (and along) the Limpopo River towards the north and northeast (Figure 1-2). Based on the status quo assessment (DWS, 2022a) average water levels for the study area are 20 metres below groundwater level (mbgl). The deepest average water strikes are observed within the Waterberg Karoo Coal Basin, i.e., 89 mbgl, with all other geological setting similar with an average of approx. 40 mbgl.

This is also reflected in the groundwater levels, as the Waterberg Karoo Coal Basin has an average water level of 34 mbgl, whereas the other geological setting of approx. 15-20 mbgl (Figure 1-2). The deeper water recorded water strikes and water levels may be because of deep drilling into the underlying confined Waterberg Group strata. The reflection of shallow water levels and water strikes observed at the other geological setting could imply that the weathered aquifer system is targeted, rather than the deeper aquifer systems.

1.5 Delineation of GRUs

The delineation of GRUs depends on the hydrogeological characteristics of the area (e.g., aquifer types and flow regimes), and due to the nature of groundwater flows, hydraulic boundaries for groundwater flow are often different to that of surface water systems. Although the hydraulic boundaries may differ, the delineation should consider that a Class, Reserve and RQOs must be set for each unit, and therefore linkages with other components must be considered, and each unit will have to be managed.

DWS, 2022 (status quo) provided an overview of the development of the GRUs for the study area and details about the criteria that were considered when selecting GRU boundaries.

The approach that was followed was Step 2 of the eight-step groundwater Reserve determination procedure that was outlined in the Groundwater Reserve Determination Measures (GRDM) manual (WRC, 2013). Three overarching criteria were considered, including physical criteria, management criteria, and functional criteria.

The delineated GRUs generally combine a couple of quaternary catchments so that the integration of surface water and groundwater systems can be achieved. The revised GRUs are presented in Figure 1-3 and is summarised in Table 1-1. All GRUs coincide with the sub-catchments except for A63/A71-3, which straddles the Mogalakwena- and Sand River sub-catchments. The tributaries draining the associated quaternary catchments drain directly into the Limpopo River. These catchments also straddle the Limpopo Karoo Basin, so as a result they were delineated as a single GRU.

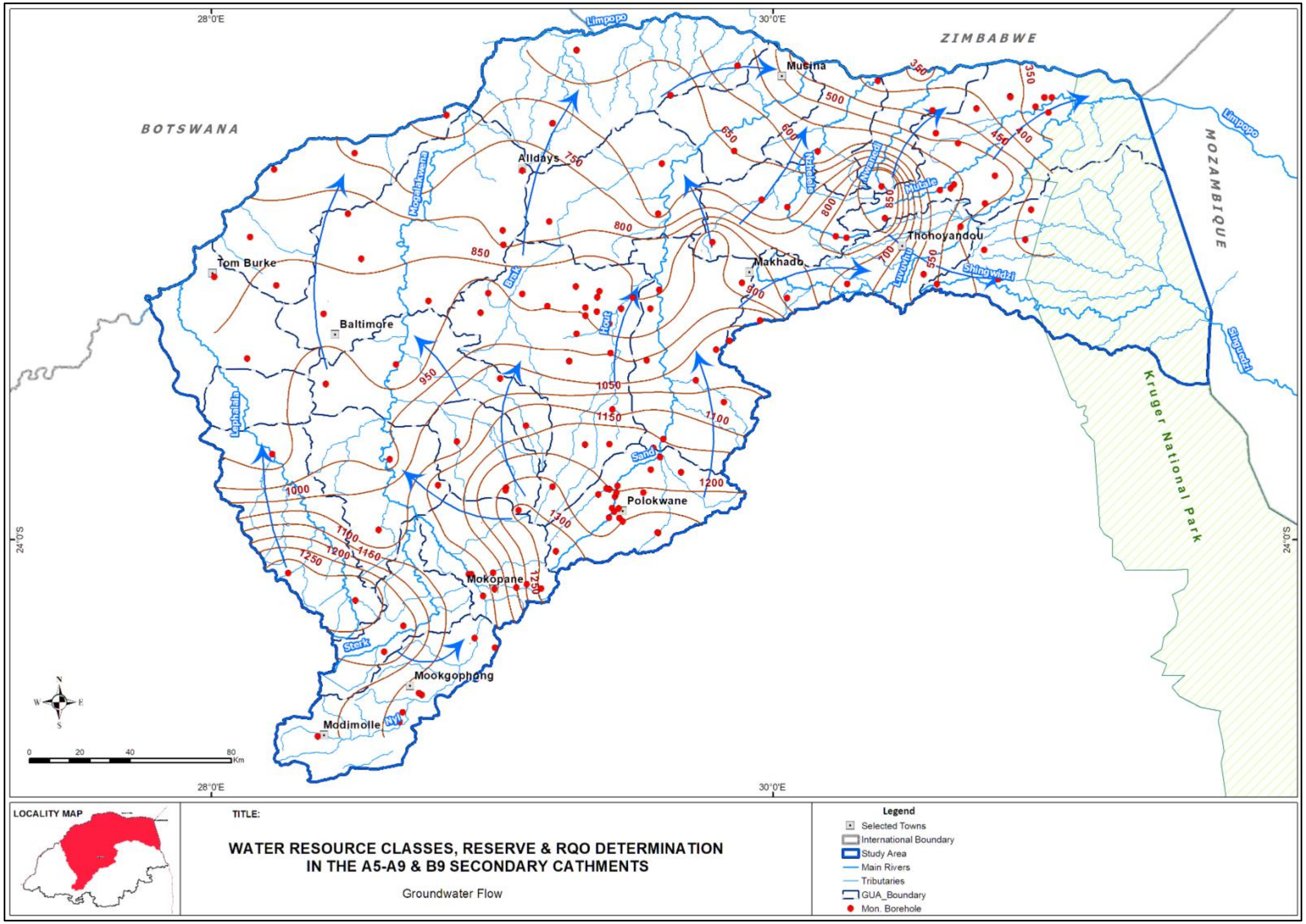

Figure 1-2. Regional groundwater levels and flow direction.

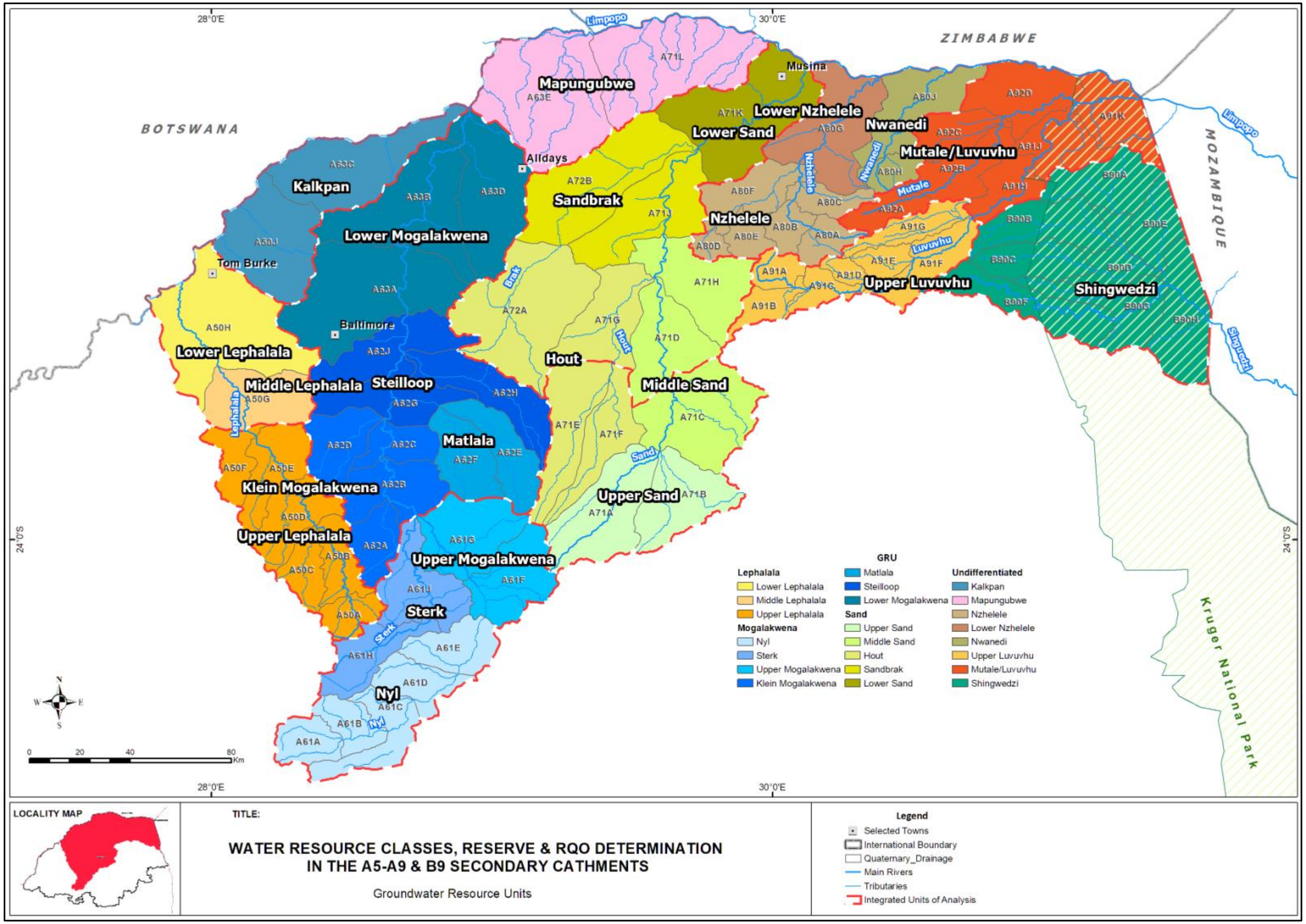

Figure 1-3. Delineated Groundwater Resource Units.

1.6 Available Data

In addition to information held in literature, because groundwater is significantly used in the Limpopo WMA, there is extensive point data for the region (i.e., information from boreholes), held in databases including:

- the Limpopo Groundwater Resource Information Project (GRIP), the NGA, and Hydstra databases, all held at the DWS and containing borehole information such as coordinates, geology, yield, groundwater level and in some cases groundwater quality.
- WMS containing groundwater quality information from boreholes.
- WARMS containing a register of all licenses for groundwater abstraction.

The DWS long-term monitoring data were assessed and described in the Status Quo assessment regarding water levels in the catchments, and trends within that dataset.

Table 1-1. Description of delineated groundwater resource unit.

Drainage system	GRU	Nr of Quats.	Catchments	Name	Dominant geology
Lephalala	A50-1	6	A50A,B,C,D,E,F	Upper Lephalala	Waterberg Group
	A50-2	1	A50G	Middle Lephalala	Bushveld Complex
	A50-3	1	A50H	Lower Lephalala	Basement Complex
Upper Mogalakwena	A61-1	5	A61A,B,C,D,E	Nyl River Valley	Bushveld Complex, Lebombo Group
	A61-2	2	A61H,J	Sterk	Bushveld Complex, Waterberg Group
	A61-3	3	A61F,G	Upper Mogalakwena	Bushveld- and Basement Complex, Dolomites
Middle- and Lower Mogalakwena	A62-1	3	A62A,B,C,D	Klein Mogalakwena	Bushveld Complex, Waterberg Group
	A62-2	2	A62E,F	Matlala	Bushveld- and Basement Complex,
	A62-3	3	A62G,H,J	Steilloop	Waterberg Group
	A63-1	3	A63A,B,D	Lower Mogalakwena	Basement Complex, Karoo Super Group, Lebombo Group
Upper Sand	A71-1	2	A71A,B	Upper Sand	Basement Complex, Alluvium
	A71-2	3	A71C,D,H	Middle Sand	Basement Complex
	A71-3	4	A71E,F,G	Hout	Basement Complex
Lower Sand	A71-4	2	A71J, A72B	Sandbrak	Basement Complex, Karoo Super Group, Lebombo Group
	A71-5	1	A71K	Lower Sand	Basement Complex, Karoo Super Group
Kolope/Kongoloop	A63-3/A71-6	2	A63E, A71L	Mapungubwe	Basement Complex, Karoo super Group
Kalkpan/Maasstroom	A50-4/A63-2	2	A63C, A50J	Kalkpan	Basement Complex
Upper Nzhelele	A80-1	6	A80A, B,C,D,E,F	Upper Nzhelele	Soutpansberg Group, Karoo Super Group, Lebombo Group, Basement Complex
Lower Nzhelele	A80-2	1	A80G	Lower Nzhelele	Soutpansberg Group, Karoo Super Group, Basement Complex
Nwanedi	A80-3	2	A80H,J	Nwanedi	Soutpansberg Group, Karoo Super Group, Basement Complex
Upper Luvuvhu	A91-1	7	A91A,B,C,D,E,F,G	Upper Luvuvhu	Soutpansberg Group, Basement Complex
Mutale /Luvuvhu	A91-2	7	A91H,J,K, A92A,B,C,D	Mutale /Luvuvhu	Soutpansberg Group, Basement Complex
Shingwedzi	B90-1	8	A90A,B,C,D,E,F,G,H	Shingwedzi	Basement Complex, Soutpansberg Group

2 GROUNDWATER RESERVE

The National Water Act (Act No. 36 of 1998) introduced a series of measures intended to protect all water resources. These measures are referred to as Resource Directed Measures, and where it is related to groundwater, as Groundwater Resource Directed Measures (GRDM).

Groundwater Reserve Determination

The groundwater component of the Reserve is the part of the groundwater resource that sustains basic human needs and, in some instances, contributes to EWR. To be able to quantify the groundwater component of the Reserve, the volume of groundwater needed for BHN and contributing to EWR needs to be quantified.

The groundwater component of the Reserve is defined by the following relationship:

$$Reserve(\%) = \frac{EWRgw + BHNgw}{Re} \times 100$$

Where:

Re = recharge
BHN_{gw} = basic human needs derived from groundwater
EWR_{gw} = groundwater contribution to EWR

2.1 Recharge

The recharge distribution is largely controlled by the precipitation distribution, which in turn is related to the topography. At the broadest scale, areas of high rainfall largely correspond (at least in the theoretical datasets) to areas of high recharge. In certain areas the correlation is not direct and the underlying geology, and aquifer type, influences the recharge.

A study from Sorensen et al., (2021) statically investigated the response of groundwater levels over time (hydrographs) with geomorphological conditions within the Mogalakwena and Sand River catchments. The study found rainfall and aridity are driving factors for groundwater level responses with either a string or subdued reflection from rainfall (recharge) with seasonal fluctuations observed, however some boreholes only showed rainfall response to large recharge events. Groundwater abstraction has an impact on correlation of rainfall, recharge, and groundwater responses such as at clustered groundwater abstraction sites (wellfields) used for large scale water supply and should be taken with consideration within such areas.

Recharge rates per quaternary catchment were based on collated recharge values from previous studies, the GRA II project (DWAF, 2004), Vegter's (1995) and modelled priority areas (documented in progress reports as part of this study) (Figure 2-1).

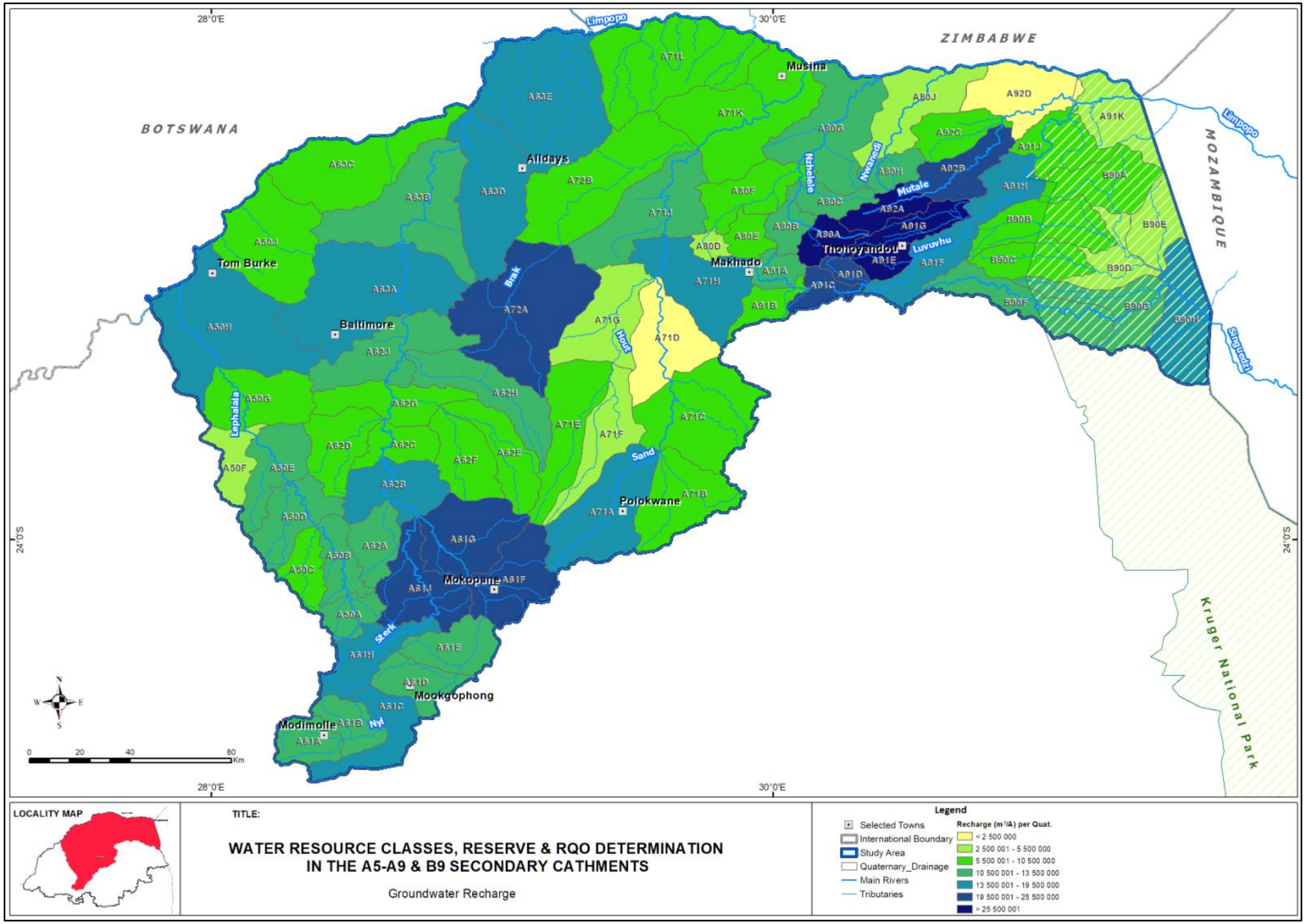

Figure 2-1. Groundwater recharge per quaternary catchment.

2.1.1 Upper Lephalala

The recharge varies spatially from as high as 18 mm/a in the higher lying areas to around 5 mm/a in the lower parts of the catchment. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis are summarised in Table 2-1.

Table 2-1. Recharge estimation (Upper Lephalala).

Description	GRU	Quat	MAP (mm)	Area (km^2)	GRA II		Applied
					(Wet) Mm^3	(Dry) Mm^3	Mm^3
Upper Lephalala	A50-1	A50A	654.1	298	11.35	8.28	12.95
		A50B	599.0	406	12.05	8.64	13.52
		A50C	593.0	362	10.36	7.40	11.00
		A50D	558.2	637	12.57	8.89	13.95
		A50E	517.0	629	10.95	7.63	11.71
		A50F	495.8	372	5.35	3.70	6.14

2.1.2 Lower Lephalala

The low and variable rainfall together with evaporation rates considerably exceeding rainfall result in a low expectation of natural recharge to groundwater over most of the area. The recharge varies spatially from 8 mm/a to less than 2 mm/a in the lower parts of the catchment. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis are summarised in Table 2-2.

Table 2-2. Recharge estimation (Lower Lephalala).

Description	GRU	Quat	MAP (mm)	Area (km^2)	GRA II		Applied
					(Wet) Mm^3	(Dry) Mm^3	Mm^3
Middle Lephalala	A50-2	A50G	435.3	821	9.20	6.26	9.20
Lower Lephalala	A50-3	A50H	407.2	1945	15.11	9.91	15.11

2.1.3 Kalkpan

The low and variable rainfall together with evaporation rates considerably exceeding rainfall result in a low expectation of natural recharge to groundwater over most of the area. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis are summarised in Table 2-3.

Table 2-3. Recharge estimation (Kalkpan).

Description	GRU	Quat	MAP (mm)	Area (km^2)	GRA II		Applied
					(Wet) Mm^3	(Dry) Mm^3	Mm^3
Kalkpan	A50-4/A63-2	A50J	391.1	1255	8.84	5.91	9.29
		A63C	377.7	1323	8.14	5.32	9.21

2.1.4 Upper Nyl and Sterk

Mean annual precipitation varies from 600 mm in the Nyl River valley and Mokopane to about 450 mm north of Doorndraai dam (Table 2-4). The Upper Mogalakwena ranges from 12 mm/a to more than 20 mm/a. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis are summarised in Table 2-4.

Table 2-4. Recharge estimation (Upper Nyl and Sterk).

Description	GRU	Quat	MAP (mm)	Area (km^2)	GRA II (Wet) Mm^3	GRA II (Dry) Mm^3	Applied Mm^3
Nyl River Valley	A61-1	A61A	629.1	381	11.86	8.57	15.01*
		A61B	629.1	362	10.89	7.86	13.70*
		A61C	632.7	587	16.44	11.83	18.00*
		A61D	630.2	456	12.37	8.91	15.23*
		A61E	624.6	547	10.57	7.57	14.72*
Sterk	A61-2	A61H	636.0	585	18.94	13.74	19.99
		A61J	630.7	818	23.46	17.01	24.28
Upper Mogalakwena	A61-3	A61F	597.2	789	22.40	16.07	22.30*
		A61G	584.8	927	20.80	14.82	19.31

* - indicates quaternary catchments where potential lateral inflow (or induced recharge) exists.

2.1.5 Lower Mogalakwena

Mean annual precipitation varies from 600 mm in the south to less than 400 mm in the north (Table 2-5). In lower lying areas the low and variable rainfall together with evaporation rates (2 000 mm) considerably exceeding rainfall result in a low expectation of natural recharge to groundwater. Recharge vary spatially from as high as 18 mm/a in the Waterberg region to less than 3 mm/a at the confluence with the Limpopo River. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis are summarised in Table 2-5.

Table 2-5. Recharge estimation (Lower Mogalakwena).

Description	GRU	Quat	MAP (mm)	Area (km^2)	GRA II (Wet) Mm^3	GRA II (Dry) Mm^3	Applied Mm^3
Klein Mogalakwena	A62-1	A62A	610.2	428	11.07	7.98	12.16
		A62B	528.7	710	14.20	9.96	14.74
		A62C	478.3	385	6.53	4.50	6.71
		A62D	488.8	603	10.15	7.02	10.54
Matlala	A62-2	A62E	460.4	621	8.59	5.88	8.56
		A62F	478.1	620	9.18	6.33	9.06
Steilloop	A62-3	A62G	437.3	627	8.25	5.63	8.26
		A62H	439.3	871	10.94	7.45	10.78
		A62J	450.1	930	12.44	8.50	12.38
Lower Mogalakwena	A63-1	A63A	433.1	1928	18.20	12.36	17.83
		A63B	393.9	1505	11.35	7.61	11.17
		A63D	412.3	1319	13.99	9.43	13.59

2.1.6 Limpopo Tributaries

The Mapungubwe (Limpopo Tributaries) region receives on average 300 mm rainfall per annum making it one of the arid areas in the Limpopo WMA (Table 2-6). Recharge are low over most of the area however, recharge can be slightly higher in the fault zones, and significantly higher in the alluvial area where no surface runoff is evident. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis and are summarised in Table 2-6.

Table 2-6. Recharge estimation (Mapungubwe).

Description	GRU	Quat	MAP (mm)	Area (km^2)	GRA II (Wet) Mm^3	GRA II (Dry) Mm^3	Applied Mm^3
Limpopo Tributaries	A63-3/71-3	A63E	357.9	1992	13.72	8.99	13.67
		A71L	287.8	1765	9.57	6.02	9.62

2.1.7 Upper Sand

The climate of the Upper Sand is semi-arid with mean annual rainfall spatially varying between 350 mm and 700 mm. The flat and almost featureless plateau can be described as an extremely old erosion surface underlain by crystalline bedrock into which several mature rivers have incised themselves. Low and variable rainfall together with evaporation rates (2000 mm) considerably exceeding rainfall result in a low expectation of natural recharge to groundwater. Recharge varies from approximately 10 mm/a to less than 3 mm/a north of Mogwadi. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis are summarised in Table 2-7.

- The groundwater balance of A71-1 is complex with wastewater effluent infiltration together with groundwater abstraction throughout the GRU. The recharge values include induced recharge (or groundwater from storage) of around 24 Mm^3/a, in addition to the natural recharge of around 16 Mm^3/a.
- Potential lateral inflows were simulated east of GRU A71-2 from the escarpment as well as from the Blouberge in GRU A71-3.
- The simulated contribution of seepage to the wetland system in A71-3 is likely to occur during only storm rainfall-runoff events (associated with increased infiltration to groundwater).

Table 2-7. Recharge estimation (Upper Sand).

Description	GRU	Quat	MAP (mm)	Area (km^2)	GRA II (Wet) Mm^3	GRA II (Dry) Mm^3	Applied Mm^3
Upper Sand	A71-1	A71A#	468.3	1144	16.71	11.48	40.16*
		A71B	450.4	882	9.99	6.81	14.38*
Middle Sand	A71-2	A71C	417.8	1331	10.43	7.04	19.69*
		A71D	390.0	892	2.39	1.60	4.64
		A71H	490.8	1012	15.07	10.40	16.97
Hout	A71-3	A71E	420.8	893	6.38	4.31	8.66
		A71F	400.2	683	4.29	2.88	4.38
		A71G	427.2	875	4.80	3.26	9.23*
		A72A	464.5	1908	19.96	13.72	21.69*

* - indicates quaternary catchments where potential lateral inflow (or induced recharge) exists.
# -artificial recharge included

2.1.8 Lower Sand

The Lower Sand receives on average 350 mm rainfall per annum making it one of the arid areas in the Limpopo WMA (Table 2-8). Recharge are considered to be low over most of the area however, recharge can be slightly higher in the fault zones, and significantly higher in the alluvial area where no surface runoff is evident. Recharge vary from approximately 8 mm/a to less than 2 mm/a in the northeast. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis are summarised in Table 2-8.

Table 2-8. Recharge estimation (Lower Sand).

Description	GRU	Quat	MAP (mm)	Area (km^2)	GRA II (Wet) Mm^3	GRA II (Dry) Mm^3	Applied Mm^3
Sandbrak	A71-4	A71J	396.1	1162	12.80	8.57	11.88
		A72B	343.9	1554	9.05	5.96	8.81

Lower Sand	A71-5	A71K	304.7	1668	9.47	6.12	9.44

2.1.9 Nzhelele/Nwanedi

The upper reaches of the drainage region drain the mountainous region to the south and has a relatively high rainfall (Table 2-9). For a small portion in the Soutpansberg the MAP is 1 000 mm and higher. In comparison the plains north of the Soutpansberg have a relatively low rainfall of only 300 mm per annum. Recharge varies from approximately 18 mm/a to less than 2 mm/a in the northeast. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis are summarised in Table 2-9.

Table 2-9. Recharge estimation (Nzhelele/Nwanedi).

Description	GRU	Quat	MAP (mm)	Area (km^2)	GRA II		Applied
					(Wet) Mm^3	(Dry) Mm^3	Mm^3
Upper Nzhelele	A80-1	A80A	938.0	287	26.11	20.40	26.68
		A80B	659.3	251	12.11	8.85	11.87
		A80C	576.3	294	11.26	8.00	10.95
		A80D	621.9	128	4.59	3.30	4.70
		A80E	622.3	247	9.79	7.01	9.91
		A80F	388.1	630	7.78	5.18	7.77
Lower Nzhelele	A80-2	A80G	332.6	1230	11.84	7.76	10.44
Nwanedi	A80-3	A80H	620.6	266	10.75	7.72	10.41
		A80J	292.1	870	4.43	2.82	4.10

2.1.10 Upper Luvuvhu

The upper reaches of the drainage region drains the mountainous region in the central section of the GRU and has a relatively high rainfall, with a MAP up to 1 500 mm and higher. In comparison the far east and west of the GRU experience relatively lower rainfall of only 450 mm per annum. Recharge varies from approximately 21 mm/a to less than 12 mm/a. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis are summarised in Table 2-10.

Table 2-10. Recharge estimation (Upper Luvuvhu).

Description	GRU	Quat	MAP (mm)	Area (km^2)	GRA II		Applied
					(Wet) Mm^3	(Dry) Mm^3	Mm^3
Upper Luvuvhu	A91-1	A91A	696	232	11.1	8.3	10.04
		A91B	620	275	8.0	5.8	17.96*
		A91C	866	250	20.1	15.5	22.59*
		A91D	1287	132	23.0	19.1	22.99
		A91E	1078	223	26.3	20.9	28.17
		A91F	662	580	14.6	10.5	19.80*
		A91G	950	406	67.1	51.8	51.83

* - indicates quaternary catchments where potential lateral inflow (or induced recharge) exists.

2.1.11 Lower Luvuvhu/Mutale

The higher elevation / mountainous area of the drainage region has a relatively high rainfall, with a MAP up to 1 000 mm and higher. In comparison the far north and east, lower lying in elevation, experiences relatively lower rainfall of only 200 mm per annum. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis are summarised in Table 2-11.

Table 2-11. Recharge estimation (Mutale and Lower Luvuvhu).

Description	GRU	Quat	MAP (mm)	Area (km^2)	GRA II		Applied
					(Wet) Mm^3	(Dry) Mm^3	Mm^3
Mutale and Lower Luvuvhu	A91-2	A91H	722	450	15.94	11.65	17.17
		A91J	450	570	7.49	5.12	7.02
		A91K	373	669	4.00	2.53	3.66
		A92A	997	329	51.34	39.63	51.34
		A92B	711	565	25.43	18.56	28.07
		A92C	423	455	6.79	4.59	5.94
		A92D	301	805	2.47	1.58	2.46

2.1.12 Shingwedzi

The drainage region's MAP ranges from up to 650 mm to as low as 400mm. Recharge varies from approximately 12 mm/a to less than 3 mm/a. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis are summarised in Table 2-12.

Table 2-12. Recharge estimation (Shingwedzi).

Description	GRU	Quat	MAP (mm)	Area (km^2)	GRA II		Applied
					(Wet) Mm^3	(Dry) Mm^3	Mm^3
Shingwedzi	B90-1	B90A	465	693	7.32	5.01	7.06
		B90B	470	754	8.54	5.88	8.56
		B90C	498	535	6.28	4.36	6.32
		B90D	471	447	4.57	3.14	4.60
		B90E	466	474	4.49	2.94	4.48
		B90F	539	819	11.37	7.99	11.28
		B90G	535	698	12.67	8.89	12.46
		B90H	538	890	15.26	10.18	14.93

2.2 Groundwater Contribution to Baseflow

Depending on the prevailing gradient, a river might receive (gaining stream or effluent groundwater conditions) or lose (losing stream or influent groundwater conditions) water from the aquifer (Figure 2-2).

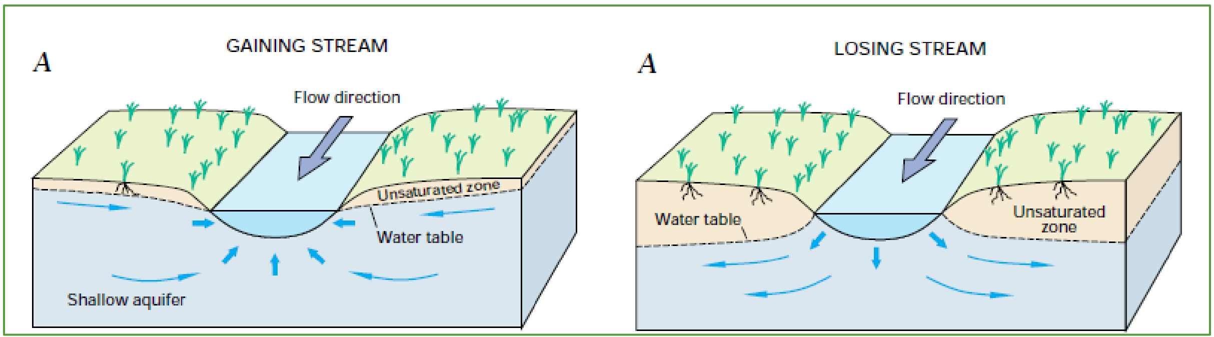

Figure 2-2. Conceptualisation of surface-groundwater interactions.

Within gaining stream systems, the piezometric surface must slope laterally towards the stream (effluent stream). Groundwater moves toward and always emerges into the stream. The stream acts as a drain, is effluent and perennial (Vegter and Pitman, 2003). Some conditions that must be met for the groundwater contributing to baseflow to be sustainable (Smakhtin, 2001), include:

a) the draining aquifer must be recharged seasonally with adequate amounts of water;
b) the water table must be shallow enough to be intersected by the stream; and
c) the aquifer's size and hydraulic properties must be sufficient to maintain flows throughout the dry season.

Within losing stream systems, the piezometric surface is always below the streambed level (Influent stream) and slopes downward away from the stream. This classification is characteristic of, but not necessarily limited to, ephemeral streams (Tanner, 2013). The occurrence of transmission losses when the stream is flowing means that the stream recharges the groundwater system.

The study area comprises a nearly 50% split between perennial and ephemeral rivers (Figure 2-3). The rivers to the west of the study area, the Lephalala and Mogalakwena rivers are perennial systems. East of these rivers is the ephemeral Sand River system, bordered by the perennial Nzhelele, Ṅwaneḓi and Luvuvhu Rivers. The Shingwedzi River to the east of the study area which flows into the Kruger National Park is an ephemeral system.

The distribution of groundwater contribution to baseflow closely correlates with the distribution of recharge. Rainfall has a dominant control on recharge, and aquifers with high recharge, can also be reasonably expected to have high groundwater discharge, given a state of dynamic equilibrium in the long term.

The EWR sites with a degree of groundwater dependence is listed in Table 2-13 and shown spatially in Figure 2-4.

A description of baseflow and groundwater contribution to baseflow volumes is provided from section 2.2.1 to section 2.2.12.

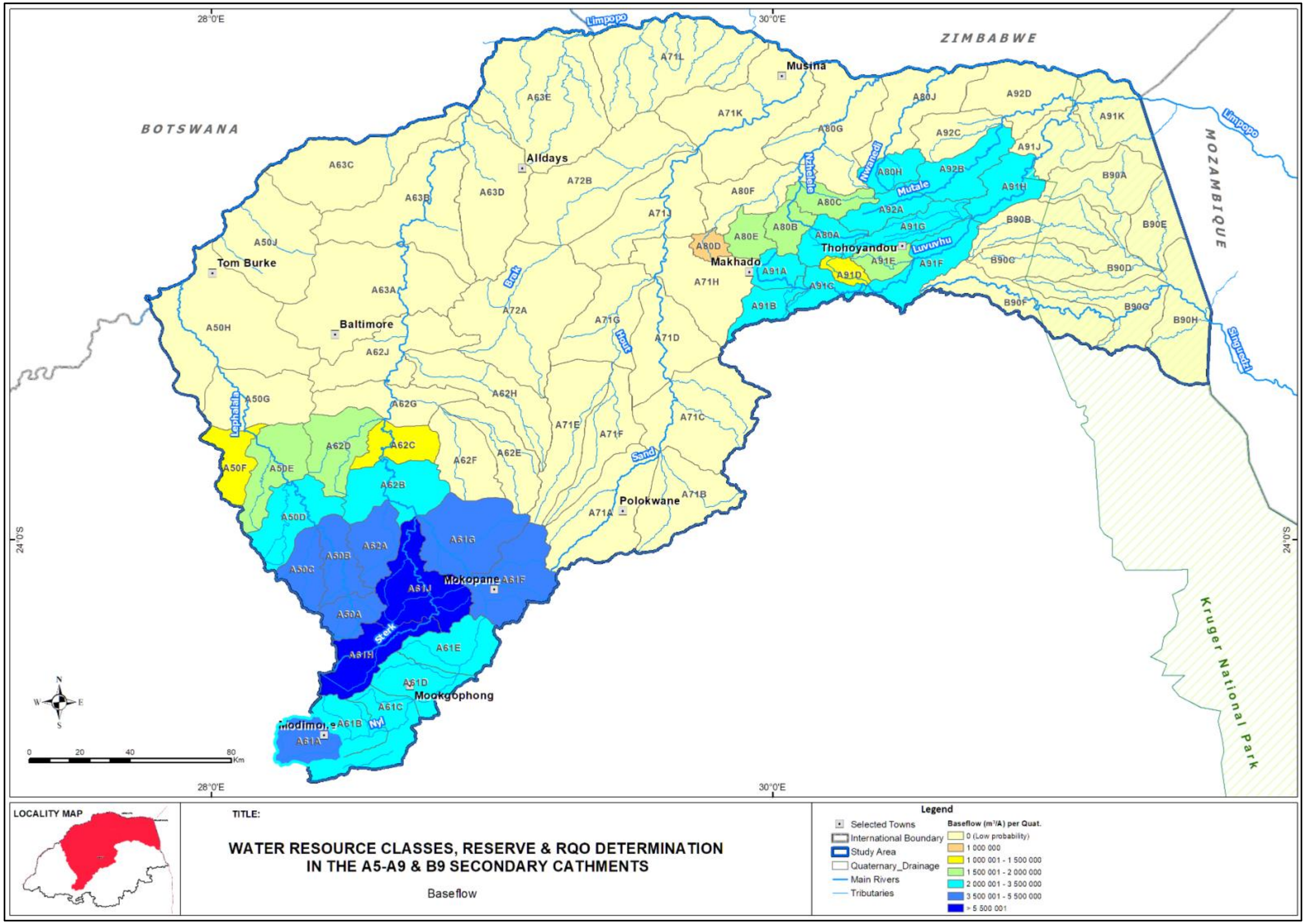

Figure 2-3. Baseflow distribution, per quaternary catchment.

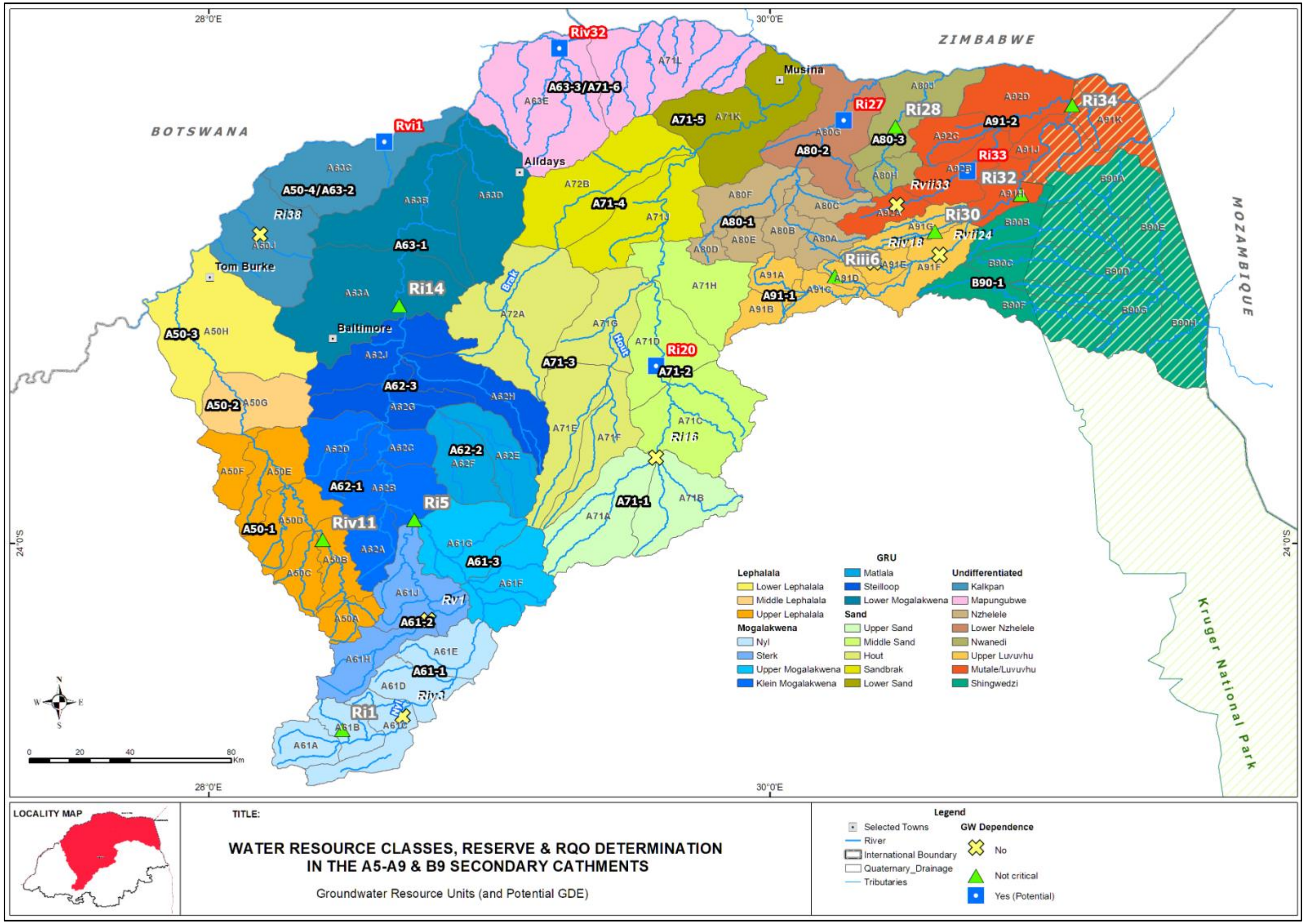

Figure 2-4. EWR Sites and Groundwater Dependence.

Table 2-13. Groundwater dependent EWR sites.

Nodes	IUA	River	Groundwater Dependence
Ri20	Upper Sand	Sand	Broad dry riverbed, sandy, with potentially deep sands. Trees along the bank seem to be terrestrial and not phreatophytic.
Riii6	Upper Luvuvhu	Latonyanda	Not critical
Ri32	Upper Luvuvhu	Luvuvhu	Not critical
Ri30	Upper Luvuvhu	Mutshindudi	Not critical
Ri33	Lower Luvuvhu/ Mutale	Mutale	Extensive seepage wetlands that are therefore partially groundwater dependent
Ri34	Lower Luvuvhu/ Mutale	Mutale	Not critical
Ri28	Nzhelele /Ṅwanḓi	Ṅwanḓi	Not critical
Ri27	Nzhelele /Ṅwanḓi	Nzhelele	Broad macro-channel and sandy. Groundwater important for dry season baseflow
Riv32	Mapungubwe	Kolope	Plants along the channel are phreatophytic so depth to groundwater is important.
Ri38	Kalkpan se Loop	Kalkpan se Loop	The marginal zone vegetation is a groundwater dependent ecosystem but within a greater riparian channel which will experience intermittent / seasonal flows. A thermal spring feeds the channel.
Ri14	Mogalakwena	Mogalakwena	Not critical
Riv11	Upper Lephalala	Lephalala	Not critical
Ri5	Upper Nyl/Sterk	Mogalakwena	Not critical
Ri1	Upper Nyl/Sterk	Olifantspruit	Not critical

2.2.1 Upper Lephalala

Effluent conditions are expected in the upper reaches while seasonal alternating effluent / influent conditions can occur along the lower reaches of the Lephalala River. However, in the upper reaches of the catchment a higher gradient towards the river course is observed and where the alluvium is lacking the surface-groundwater exchange is directly from the regional aquifer to the river. Comparison of groundwater contribution to baseflow estimates for the Lephalala drainage region are summarised in Table 2-14.

Table 2-14. Upper Lephalala groundwater contribution to baseflow estimates (in Mm^3/a).

Quat	WRSM Current	WRSM Natural	GRAII Mean	HUGHES/ SPATSIM	Hydro-graph	2011 Reserve	2023
A50A	8.57	8.91	4.15	4.50		3.57	4.50
A50B	10.33	10.38	5.43	4.86	5.70	5.04	5.56
A50C	6.13	6.28	4.82	4.23		3.16	4.82
A50D	3.37	3.37	2.12	3.95		1.82	3.37
A50E	3.30	3.34	1.89	2.87		0.88	2.87
A50F	1.76	1.76	1.05	1.45		0.48	1.45

2.2.2 Lower Lephalala

Seasonal alternating effluent / influent conditions can occur along the lower reaches of the Lephalala River. It is expected that surface-groundwater exchange between the alluvium and the Lephalala River occurs on a far shorter time scale in comparison to the interaction between the regional and alluvial aquifers. Regional aquifers of the lower catchment show marginal gradients towards the Lephalala River course and exchange water with the river only indirectly via the alluvial deposits. Comparison of groundwater contribution to baseflow estimates for the Lephalala drainage region are summarised in Table 2-15. Groundwater contribution to baseflow occur along the Limpopo River (A50H) which is underestimated by the current yield estimates as is evident from the hydrograph separation results.

Table 2-15. Lower Lephalala groundwater contribution to baseflow estimates (in Mm³/a).

Quat	WRSM Current	WRSM Natural	GRAII Mean	HUGHES/ SPATSIM	Hydro-graph	2011 Reserve	2023
A50G	0.00	0.02	0.00	0.08		0.25	0.02
A50H	0.00	0.00	0.00	0.07	4.70*	0.46	0.03

* - Limpopo Flows

2.2.3 Kalkpan

Aquifers of the lower catchment show marginal gradients towards the Limpopo River and exchange water with the river only indirectly via the alluvial deposits. There is a low probability of groundwater contribution to baseflow (but higher along stretches of the Limpopo River). Comparison of groundwater contribution to baseflow estimates for the Lephalala drainage region are summarised in Table 2-16. Groundwater contribution to baseflow occur along the Limpopo River which is underestimated by the current yield estimates.

Table 2-16. Kalkpan groundwater contribution to baseflow estimates (in Mm³/a).

Quat	WRSM Current	WRSM Natural	GRAII Mean	HUGHES/ SPATSIM	2011 Reserve	2023
A50J	0.01	0.16	0.00	0.06	0.61	0.06
A63C	0.01	0.06	0.00	0.07	0.84	0.06

2.2.4 Upper Nyl and Sterk

The Upper Mogalakwena River stretch can be classified into a continuous interaction bedrock system (Waterberg Group) in the upper reaches, while the middle (Nyl River Valley) and low reaches (Dorps River Valley) can be classified as a porous media (alluvial sediments). The Nyl river valley can be regarded as a gaining river while in the lower reaches seasonal alternating effluent / influent conditions can be experienced.

Apart from exceptionally wet periods, flow in the river is sustained mainly by groundwater. Groundwater is generally toward the main River channel; however, intermittency implies local inversions from effluent to influent conditions by secondary permeability variations in the underlying lithology. Numerous seasonal and some perennial springs occur in the dolomitic formations, which contribute significantly, to the baseflow component of the Dorps River (A61G). However, some springs occurring in the lower Dorps River catchment have been affected by the abstraction from boreholes. Comparison of groundwater contribution to baseflow estimates for the Upper Mogalakwena drainage region are summarised in Table 2-17.

Table 2-17. Upper Nyl and Sterk groundwater contribution to baseflow estimates (in Mm^3/a).

Quat	WRSM Current	WRSM Natural	GRAII Mean	HUGHES/ SPATSIM	Hydro-graph	GW Model	2011 Reserve	2023 *	Wetland/ Seepage
A61A	4.82	0.16	3.75	3.27	1.50	5.04	2.15	4.87	1.6
A61B	2.90	0.32	2.85	1.82		2.34	1.51	5.08	3
A61C	0.94	0.48	3.37	0.90		2.65	1.67	4.81	3.5
A61D	2.38	0.80	3.09	1.26		2.19	1.82	5.01	3
A61E	2.50	1.28	3.25	1.05		3.03	1.66	4.08	2
A61H	11.06	11.13	6.81	5.73	5.50	3.34	4.89	5.73	
A61J	9.24	9.42	9.15	9.07		10.22	6.39	9.20	
A61F	4.54	4.97	5.15	3.78		5.92	3.12	4.76	
A61G	4.35	4.59	4.87	4.12		3.50	3.36	4.24	

* - Includes Wetlands and Seepages (modelled)

2.2.5 Lower Mogalakwena

The Middle Mogalakwena River stretch can be classified into a localized interacting weathered hard rock system (Bushveld Complex) in the upper reaches, while the Waterberg Group will be in continuous interaction with the river and the probability of baseflow is regarded as high. In the lower reaches alluvium replaces the weathered material and can be classified as a porous media with a semi-pervious layer. In both cases seasonal alternating effluent / influent conditions can be experienced. Comparison of groundwater contribution to baseflow estimates for the Middle- and Lower Mogalakwena drainage region are summarised in Table 2-18.

Table 2-18. Lower Mogalakwena groundwater contribution to baseflow estimates (in Mm^3/a).

Quat	WRSM Current	WRSM Natural	GRAII Mean	HUGHES / SPATSIM	Hydro-graph	2011 Reserve	2023
A62A	6.31	6.38	4.55	3.90		3.90	4.55
A62B	4.40	4.46	2.46	2.89		1.40	2.89
A62C	1.89	1.95	1.10	1.09		0.62	1.10
A62D	1.09	1.15	1.81	1.84		1.22	1.22
A62E	0.23	0.24	0.00	0.54		0.34	0.24
A62F	0.03	0.09	0.00	0.66		0.41	0.09
A62 G	0.11	0.15	0.00	0.12		0.14	0.12
A62H	0.15	0.15	0.00	0.56		0.40	0.15
A62J	0.13	0.15	0.00	0.06		0.67	0.13
A63A	0.00	0.01	0.00	0.06		0.03	0.01
A63B	0.00	0.00	0.00	0.06	2.10	0.02	0.01
A63D	0.00	0.00	0.00	0.07		0.37	0.00

2.2.6 Mapungubwe

The Limpopo Tributaries have a low probability of groundwater contribution to baseflow. According to baseflow data in the GRA II dataset groundwater baseflow to surface water courses does not exist in the area, hence, natural recharge must be lost through riverine vegetation and spring discharge. Comparison of groundwater contribution to baseflow estimates for the Limpopo Tributaries drainage region are summarised in Table 2-19. Groundwater contribution to baseflow occurs along the Limpopo River which is underestimated by the current yield estimates as is evident from the hydrograph separation results (A71L).

Table 2-19. Mapungubwe groundwater contribution to baseflow estimates (in Mm³/a).

Quat	WRSM Current	WRSM Natural	GRAII Mean	HUGHES / SPATSIM	Hydro-graph	2011 Reserve	2023
A63E	0.04	0.07	0.00	0.06		0.54	0.06
A71L	0.00	0.03	0.00	0.05	6.60*	0.31	0.04

* - Limpopo Flows

2.2.7 Upper Sand

Alluvium is present to various degrees in all the major surface water drainage courses grading from clay through sand to pebbles and in places is covered superficially by deposits of calcrete. In general, the thickness and lateral extent of the alluvium increases down-gradient towards the north. The porous nature of the alluvium makes this a natural repository for groundwater recharged periodically from ephemeral flows in the drainage courses. However, the natural groundwater-surface water interaction has been modified by the artificial recharge of treated sewage effluent that is continuously being discharged from the municipal sewage treatment works into the Sand River. This effluent is either abstracted directly from the Sand River by some riparian farmers downstream for irrigation purposes or it serves as a source of recharge of the groundwater stored in the alluvium. Comparison of groundwater contribution to baseflow estimates for the Upper Sand drainage region are summarised in Table 2-20.

Table 2-20. Upper Sand groundwater contribution to baseflow estimates (in Mm³/a).

Quat	WRSM Current	WRSM Natural	GRAII Mean	HUGHES/ SPATSIM	Hydro-graph	GW Model	2011 Reserve	2023*	Wetland/ Seepages
A71A	0.00	0.20	0.00	0.18	1.10	0.49	0.34	0.20	
A71B	0.00	0.05	0.00	0.18		0.40	0.32	0.12	
A71C	0.00	0.02	0.00	0.16		0.96	0.26	0.09	
A71D	0.01	0.06	0.00	0.18		0.71	0.19	0.12	
A71H	0.04	0.13	0.00	0.16	1.00	0.46	0.59	0.16	
A71E	0.00	0.03	0.00	0.12		0.56	0.39	0.32	0.25
A71F	0.00	0.02	0.00	0.09		0.16	0.24	0.31	0.25
A71G	0.00	0.01	0.00	0.11		0.44	0.22	0.06	
A72A	0.00	0.02	0.00	0.12		0.64	0.55	0.07	

* - Includes Wetlands and Seepages (modelled)

2.2.8 Lower Sand

The Lower Sand have a low probability of groundwater contribution to baseflow. According to baseflow data in the GRA II dataset groundwater baseflow to surface water courses does not exist in the area, hence, natural recharge must be lost through riverine vegetation and spring discharge. Groundwater contribution to baseflow occur along the Limpopo River which is underestimated by the current yield estimates (A71K). Comparison of groundwater contribution to baseflow estimates for the Lower Sand drainage region are summarised in Table 2-21.

Table 2-21. Lower Sand groundwater contribution to baseflow estimates (in Mm³/a).

Quat	WRSM Current	WRSM Natural	GRAII Mean	HUGHES/ SPATSIM	2011 Reserve	2023
A71J	0.00	0.00	0.00	0.03	0.76	0.39
A72B	0.00	0.00	0.00	0.02	0.55	0.28
A71K	0.00	0.00	0.00	0.03	0.37	0.19

2.2.9 Nzhelele/Nwanedi

In the upper catchments groundwater contributes to base flow via sub surface seepage and springs. The probability of baseflow diminishes down-gradient towards the northeast. Comparison of groundwater contribution to baseflow estimates for the Nwanedi and Nzhelele drainage region are summarised in Table 2-22. Groundwater contribution to baseflow occur along the Limpopo River which is underestimated by the current yield estimates (A80J) as is evident from the groundwater model simulated results.

Table 2-22. Nzhelele/Nwanedi groundwater contribution to baseflow estimates (in Mm^3/a).

Quat	WRSM Current	WRSM Natural	GRAII Mean	HUGHES/ SPATSIM	GW Model	2011 Reserve	2023*	Wetland/ Seepages
A80A	7.29	7.81	2.28	9.80	3.99	3.90	7.64	2
A80B	3.94	4.05	1.98	3.53	1.63	2.28	4.40	1.5
A80C	3.28	3.37	1.81	2.53	4.23	1.58	2.90	
A80D	1.55	1.55	0.99	1.54	1.45	1.01	1.49	
A80E	3.70	3.88	1.82	2.97	1.28	1.96	2.46	
A80F	0.33	0.35	0.00	2.04	3.19	0.16	0.34	
A80G	0.00	0.02	0.00	1.70	3.94#	0.21	0.12	
A80H	5.69	0.37	2.39	4.60	1.16	1.93	2.16	
A80J	0.60	0.64	0.00	0.56	7.25#	0.10	0.58	

* - Includes Wetlands and Seepages (modelled)
# - Includes groundwater contribution to the Limpopo River

2.2.10 Upper Luvuvhu

The Luvuvhu drainage region more specifically the Upper Luvuvhu stretch can be classified as a continuous interaction bedrock system (Great Escarpment rocks) with some trenches being porous media underlain by a semi-pervious layer. Along the lower reaches where the alluvium thins or does not exist at all the river stretch can be classified as localized interacting weathered hard rock system. The Great Escarpment Mountain range is an important area for groundwater recharge and drainage base flow. In the upper catchments groundwater contributes to base flow via sub surface seepage and springs. The probability of baseflow diminishes down-gradient towards the northeast. Comparison of groundwater contribution to baseflow estimates for the Upper Luvuvhu drainage region are summarised in Table 2-23.

Table 2-23. Upper Luvuvhu groundwater contribution to baseflow estimates (in Mm^3/a).

Quat	WRSM Current	WRSM Natural	GRAII Mean	HUGHES/ SPATSIM	Hydro-graph	GW Model	2023
A91A	2.89	4.46	2.81	4.48		3.41	3.41
A91B	5.01	5.48	3.05	3.14		1.76	3.14
A91C	4.30	9.94	2.92	8.32	2.40	6.37	5.34
A91D	1.57	15.42	1.06	11.48	5.40	4.02	4.71
A91E	7.97	8.32	1.87	12.78		4.15	7.97
A91F	6.24	33.68	3.00	6.63		11.58	6.63
A91G	9.37	42.00	2.90	11.05	7.60	15.04	10.21

2.2.11 Lower Luvuvhu/Mutale

In the upper catchments groundwater contributes to base flow via sub surface seepage and springs. The probability of baseflow diminishes down-gradient towards the northeast. Comparison of groundwater contribution to baseflow estimates for the Mutale and Lower Luvuvhu drainage region are summarised in Table 2-24. Groundwater contribution to baseflow occur along the Limpopo River which is underestimated by the current yield estimates (A92D) as is evident from the groundwater model simulated results.

Table 2-24. Lower Luvuvhu/Mutale groundwater contribution to baseflow estimates (in Mm^3/a).

Quat	WRSM Current	WRSM Natural	GRAII Mean	HUGHES/ SPATSIM	Hydro-graph	GW Model	2023*	Wetland/ Seepages
A91H	0.26	0.26	2.12	1.86	7.00	0.70	1.58	0.3
A91J	0.00	0.00	0.00	0.43	3.20	0.77	0.81	0.6
A91K	0.00	0.00	0.00	1.33		2.09#	1.50	1.5
A92A	1.22	0.00	2.48	3.11	1.30	0.67	1.76	0.5
A92B	2.24	2.28	2.60	2.25		0.85	3.55	1.3
A92C	0.00	0.00	0.00	0.33		0.33	0.15	0.15
A92D	0.01	0.01	0.00	0.13		6.10#	0.24	0.23

* - Includes Wetlands and Seepages (modelled)
# - Includes groundwater contribution to the Limpopo River

2.2.12 Shingwedzi

The Shingwedzi GRU has a low probability of groundwater contribution to baseflow, and no sustainable yield is derived from surface flow in the Shingwedzi catchment (DWA, 2014). However, EWR flows and groundwater contribution to baseflow will be quantified as part of the surface run-off model and the development of the groundwater balances during the latter parts of the study. Comparison of groundwater contribution to baseflow estimates for the Shingwedzi drainage region are summarised in Table 2-25.

Table 2-25. Shingwedzi groundwater contribution to baseflow estimates (in Mm^3/a)

Quat	WRSM Current	WRSM Natural	GRAII Mean	HUGHES/ SPATSIM	Hydro-graph	2023
B90A	0.00	0.00	0.07	0.20		0.03
B90B	0.00	0.00	0.09	0.18	0.09	0.09
B90C	0.00	0.00	0.08	0.20	0.12	0.08
B90D	0.00	0.00	0.05	0.18	0.84	0.05
B90E	0.00	0.00	0.05	0.19		0.02
B90F	0.01	0.01	0.18	0.23	0.11	0.11
B90G	0.00	0.00	0.14	0.23		0.07
B90H	0.00	0.01	0.17	0.26	0.13	0.13

2.3 The Groundwater BHN Reserve

The groundwater component of the BHN Reserve was calculated based on the current population (DWS, 2023), of those either living within the catchment and directly dependent on the catchment, or more critically, not being supplied with water from a formal water supply scheme.

While in South Africa the standard quantum for the purposes of the BHNR has previously been 25 litres per person per day, higher allocations can be motivated for considering local climatic conditions, lifestyles, culture, and conditions of access (King & Pienaar 2011). A volume of 50 litres of water per day is considered more appropriate. The volume of 50 litres per person per day was multiplied by the total number of people reliant on ground and surface water sources in each quaternary catchment. This was then converted into an annual volume (m^3/year).

In 2022, there were just under 851 000 households (~3 063 515 people) living in the 76 quaternary catchments that make up the study area (Table 2-26) Of these, just over 131 000 households were dependent on the BHNR with 11.1% reliant on groundwater resources. The number of households using boreholes and springs were collated to establish the groundwater BHN, while an average of 3.6 people were included per household.

Table 2-26. The total number of households and the proportion of households that are dependent on groundwater.

Description	GRU	Quat	Total households 2022	% Boreholes	% Springs	% Rivers	% Dams/ pools	People relying on GW 2022 (3.6)	GW l/day	M³/a
Upper Lephalala	A50-1	A50A	218	61.6%	0.3%	2.1%	2.2%	486	24 291	8 866.4
		A50B	230	60.3%	0.3%	1.6%	1.1%	501	25 061	9 147.3
		A50C	220	63.0%	0.5%	1.7%	1.1%	504	25 197	9 196.9
		A50D	301	50.7%	0.4%	5.1%	0.9%	554	27 680	10 103.1
		A50E	292	49.3%	0.4%	4.8%	0.7%	522	26 103	9 527.4
		A50F	183	48.2%	0.4%	7.6%	0.7%	321	16 053	5 859.2
Middle Lephalala	A50-2	A50G	7 499	13.4%	0.1%	3.4%	0.4%	3 645	182 274	66 530.1
Lower Lephalala	A50-3	A50H	10 570	16.2%	0.1%	0.8%	2.1%	6 208	310 390	113 292.5
Kalkpan	A50-4	A50J	558	56.0%	0.4%	4.0%	0.5%	1 133	56 627	20 668.8
		A63C	542	63.1%	0.3%	0.5%	0.3%	1 237	61 855	22 577.1
Nyl River Valley	A61-1	A61A	13 619	1.7%	0.1%	0.1%	0.1%	906	45 276	16 525.6
		A61B	1 542	11.3%	0.1%	0.2%	0.2%	634	31 699	11 570.1
		A61C	485	61.5%	0.3%	1.3%	1.5%	1 081	54 041	19 725.1
		A61D	8 432	3.2%	0.0%	0.1%	0.1%	978	48 909	17 851.7
		A61E	360	59.9%	0.3%	1.5%	1.4%	779	38 966	14 222.7
Sterk	A61-2	A61H	417	59.9%	0.4%	1.4%	1.8%	905	45 258	16 519.1
		A61J	649	51.0%	0.2%	2.8%	2.4%	1 197	59 842	21 842.3
Upper Mogalakwena	A61-3	A61F	40 696	11.3%	0.1%	0.1%	0.1%	16 675	833 762	304 323.1
	A61-3	A61G	30 287	13.3%	0.2%	0.2%	0.7%	14 651	732 536	267 375.8
Klein Mogalakwena	A62-1	A62A	3 453	13.9%	0.0%	0.5%	2.2%	1 727	86 362	31 522.2
		A62B	10 544	17.1%	0.1%	1.1%	3.2%	6 544	327 203	119 428.9
		A62C	3 085	8.1%	0.3%	4.2%	0.1%	937	46 857	17 102.9
		A62D	3 003	9.6%	0.0%	0.8%	0.1%	1 044	52 188	19 048.6
Matlala	A62-2	A62E	16 503	10.7%	0.1%	0.5%	0.5%	6 366	318 307	116 182.2
		A62F	8 984	19.2%	0.0%	0.3%	1.6%	6 224	311 188	113 583.5
Steilloop	A62-3	A62G	6 792	9.4%	0.1%	9.7%	1.3%	2 344	117 202	42 778.6
		A62H	12 545	14.2%	0.2%	0.6%	1.4%	6 527	326 361	119 121.8
		A62J	3 742	18.8%	6.6%	1.8%	0.4%	3 427	171 371	62 550.5
Lower Mogalakwena	A63-1	A63A	6 632	31.5%	0.2%	2.0%	6.6%	7 557	377 863	137 919.8
		A63B	6 206	29.4%	0.2%	3.3%	4.6%	6 611	330 562	120 655.2
		A63D	7 553	17.5%	0.2%	6.3%	3.2%	4 816	240 796	87 890.4
Limpopo Tributaries	A63/ 71-3	A63E	2 395	35.5%	0.5%	23.5%	4.1%	3 103	155 167	56 636.0
		A71L	2 191	33.4%	0.5%	25.9%	4.4%	2 673	133 671	48 789.8
Upper Sand	A71-1	A71A	104 510	6.2%	0.0%	0.0%	0.2%	23 585	1 179 255	430 427.9
		A71B	61 994	4.5%	0.1%	0.7%	1.2%	10 147	507 365	185 188.1
Middle Sand	A71-2	A71C	29 137	17.3%	0.1%	0.2%	0.5%	18 235	911 750	332 788.9
		A71D	1 397	50.9%	1.2%	1.6%	7.6%	2 620	131 019	47 821.9
		A71H	32 212	13.9%	0.1%	0.2%	0.9%	16 244	812 217	296 459.3

Description	GRU	Quat	Total households 2022	% Boreholes	% Springs	% Rivers	% Dams/ pools	People relying on GW 2022 (3.6)	GW l/day	M³/a
Hout	A71-3	A71E	18 059	7.5%	0.0%	0.9%	2.3%	4 895	244 753	89 334.9
		A71F	19 021	23.5%	0.1%	0.1%	1.3%	16 147	807 338	294 678.3
		A71G	7 145	17.4%	0.2%	4.1%	0.5%	4 531	226 538	82 686.2
		A72A	32 992	13.8%	1.2%	1.4%	1.9%	17 744	887 199	323 827.6
Sandbrak	A71-4	A71J	1 443	55.3%	1.9%	4.3%	2.5%	2 972	148 581	54 231.9
		A72B	1 698	50.3%	1.4%	9.6%	2.9%	3 167	158 355	57 799.4
	A71-5	A71K	16 835	4.5%	0.1%	3.1%	0.5%	2 787	139 357	50 865.3
Upper Nzhelele	A80-1	A80A	20 581	2.8%	3.4%	8.0%	7.4%	4 627	231 351	84 443.0
		A80B	16 658	7.2%	0.8%	1.2%	5.0%	4 802	240 102	87 637.2
		A80C	3 963	20.4%	3.5%	17.3%	0.5%	3 413	170 675	62 296.4
		A80D	159	56.8%	2.0%	2.8%	2.4%	336	16 817	6 138.2
		A80E	4 987	17.4%	10.4%	9.2%	0.2%	4 980	249 024	90 893.8
		A80F	1 710	26.0%	1.1%	3.0%	6.2%	1 669	83 453	30 460.5
Lower Nzhelele	A80-2	A80G	2 267	41.0%	1.1%	16.4%	3.5%	3 439	171 939	62 757.6
Nwanedi	A80-3	A80H	2 003	17.7%	13.8%	18.8%	6.8%	2 272	113 587	41 459.3
		A80J	6 025	32.5%	0.1%	3.6%	3.8%	7 073	353 669	129 089.2
Upper Luvuvhu	A91-1	A91A	1 065	19.0%	0.6%	0.8%	0.7%	748	37 393	13 648.4
		A91B	7 183	14.5%	1.2%	2.8%	0.9%	4 043	202 164	73 789.9
		A91C	10 693	15.1%	0.4%	1.9%	1.7%	5 985	299 259	109 229.5
		A91D	6 175	4.6%	6.5%	9.1%	8.5%	2 476	123 777	45 178.4
		A91E	51 914	2.3%	1.0%	3.7%	1.0%	6 259	312 958	114 229.8
		A91F	43 452	5.6%	0.1%	0.8%	2.9%	9 016	450 824	164 550.6
		A91G	36 854	3.9%	4.5%	7.9%	2.6%	11 144	557 221	203 385.8
Mutale/Luvuvhu	A91-2	A91H	19 151	3.0%	2.8%	6.5%	1.2%	4 030	201 478	73 539.5
		A91J	519	8.0%	0.1%	7.6%	0.3%	151	7 535	2 750.3
		A91K	40	64.5%	0.0%	0.0%	0.0%	92	4 603	1 680.1
		A92A	11 409	5.1%	13.1%	38.4%	1.1%	7 505	375 229	136 958.7
		A92B	11 463	2.0%	2.7%	4.7%	1.3%	1 973	98 669	36 014.2
		A92C	3 719	10.4%	0.1%	0.6%	8.7%	1 399	69 935	25 526.2
		A92D	4 232	27.7%	0.1%	10.6%	1.8%	4 237	211 842	77 322.3
Shingwedzi	B90-1	B90A	1 591	1.6%	0.0%	0.2%	0.6%	93	4 669	1 704.2
		B90B	19 884	2.7%	0.1%	0.2%	0.3%	1 966	98 303	35 880.5
		B90C	7 695	10.3%	0.1%	0.1%	0.3%	2 897	144 841	52 866.8
		B90D	4	62.3%	0.0%	0.0%	0.0%	10	479	175.0
		B90E	5	62.3%	0.0%	0.0%	0.0%	10	508	185.4
		B90F	17 615	13.4%	0.1%	0.9%	0.3%	8 561	428 054	156 239.6
		B90G	714	11.3%	0.0%	1.3%	0.1%	292	14 605	5 330.9
		B90H	75	33.7%	0.2%	10.0%	1.3%	92	4 599	1 678.5

2.4 Groundwater Quality

Although the groundwater Reserve does not address groundwater quality issues directly, these will be addressed as part of the Water Resource Classification and RQOs in the study area. The groundwater quality of quaternary catchments with available hydrochemistry data was summarised against the domestic target water quality ranges, as shown in Table 2-27.

Approximately 2100 groundwater quality samples were collated from the available databases (e.g., GRIP and WMS). Major elements (pH, EC, Ca, Mg, Na, K, SO_4 Cl, NO_3 as N and F) were compared to the water quality guidelines for acceptable drinking water specified by the Department of Water and Sanitation, inclusive of three water quality classes.

Exceedances of the limits for major elements like calcium and magnesium are not considered a human health risk and are geogenic (natural) for the Bushveld Complex and other granitic intrusion which occur throughout the Limpopo Province.

The most noticeable elements of concern for water consumption are nitrate (measured as nitrogen (N), with some exceedances observed for fluoride, and sodium. BHN quality is regarded as the Upper limit of Class I water quality.

The main inputs of nitrate to groundwater in rural environments are derived from anthropogenic activities such as inappropriate on-site sanitation and wastewater treatment, improper sewage sludge, drying and disposal, and livestock concentration at watering points near boreholes. However, the extensive occurrence of nitrate in groundwater in uninhabited regions may suggest non-anthropogenic sources possibly related to evaporative enrichment of dry and wet deposition, biogenic point sources through N-fixing organisms, or to a geogenic origin (Tredoux and Talma, 2006). Several samples show major ion concentrations (i.e. Na and F) with elevated salts. This can mostly be related to evaporative concentration of elements in discharge areas or due to low recharge values as well as long residence times for selected samples. The occurrence of fluoride is primarily controlled by geology and climate. Therefore, there are no preventative measures under the given spatial limits of water supply to avoid contamination.

Table 2-27. Groundwater Quality (Class) (in mg/l).

Description	GRU	Quat	pH	N	EC (mS/m)	N	Calcium	N	Magnesium	N	Sodium	N	Potassium	N	Chloride	N	Sulphate	N	Nitrate as N	N	Fluoride	N
Class 0			6-9		0-70		0-80		0-30		0-100		0-25		0-200		0-100		0-6		0-0.7	
Class I			5-6 or 9-9.5		70-150		80-150		30-70		100-200		25-50		200-400		100-200		6-10		0.7-1	
Class II			4-5 or 9.5-10		150-370		150-300		70-100		200-400		50-100		400-600		200-600		10-20		1-1.5	
Class III			<4 or >10		>370		>300		>100		>400		>100		>600		>600		>20		>1.5	
Upper Lephalala	A50-1	A50A	6.9	1	310.0	1	29.0	1	12.9	1	31.0	1	0.7	1	9.2	1	4.9	1	0.00	0	0.32	1
		A50B	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.00	0	0.00	0
		A50C	7.8	2	34.2	2	25.6	2	15.2	2	18.0	2	0.8	2	20.9	2	5.0	2	0.00	0	0.12	2
		A50D	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.00	0	0.00	0
		A50E	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.00	0	0.00	0
		A50F	7.8	3	174.0	3	95.1	3	53.9	3	173.0	3	6.5	3	324.2	3	27.4	3	0.57	1	3.06	3
Middle Lephalala	A50-2	A50G	8.1	67	127.0	67	72.0	67	48.7	67	137.8	67	2.9	67	157.8	67	39.4	67	115.06	11	1.21	67
Lower Lephalala	A50-3	A50H	8.1	48	126.1	48	69.9	48	58.6	48	106.9	48	9.0	48	110.4	48	30.5	48	48.91	13	0.96	48
Kalkpan	A50-4	A50J	8.1	3	142.3	3	56.8	3	69.1	3	86.6	3	14.0	3	186.1	3	73.8	3	81.40	1	0.70	3
		A63C	7.8	8	234.8	8	129.3	8	0.9	8	365.1	8	7.9	8	437.3	8	497.9	8	0.10	4	5.25	8
Nyl River Valley	A61-1	A61A	7.6	5	43.0	5	39.1	5	15.9	5	17.1	5	1.2	5	10.7	5	11.5	5	0.31	3	0.10	5
		A61B	8.7	3	30.0	3	19.8	3	3.3	3	18.4	3	1.0	3	15.7	3	9.0	3	3.20	1	0.17	3
		A61C	7.8	3	9.6	3	4.9	3	2.3	3	2.8	3	0.5	3	5.7	3	4.0	3	0.00	0	0.18	3
		A61D	7.8	11	57.2	11	41.8	11	22.5	11	37.7	11	1.8	11	30.2	11	12.0	11	0.94	9	0.50	11
		A61E	8.4	2	36.5	2	29.6	2	1.9	2	39.8	2	0.6	2	12.2	2	4.8	2	0.00	0	4.18	2
Sterk	A61-2	A61H	8.3	2	83.2	2	49.0	2	29.1	2	63.8	2	3.0	2	151.8	2	23.0	2	0.00	0	7.50	2
		A61J	8.2	5	58.0	5	51.8	5	19.0	5	24.2	5	1.2	5	21.3	5	12.1	5	0.00	0	0.39	5
Upper Mogalakwena	A61-3	A61F	8.1	63	101.0	63	59.5	63	74.2	63	43.7	63	1.4	63	49.9	63	20.6	63	72.20	9	0.28	62
	A61-3	A61G	8.2	76	117.5	75	61.2	75	67.9	74	89.1	74	3.0	75	94.1	75	38.8	74	103.73	3	0.44	76
Klein Mogalakwena	A62-1	A62A	8.2	23	56.2	23	46.8	23	14.7	23	39.2	23	1.2	23	28.4	23	6.7	23	0.00	0	0.35	23
		A62B	8.1	77	116.5	77	77.5	77	39.3	77	90.4	77	1.8	77	138.0	77	12.4	77	12.66	6	0.79	77
		A62C	8.1	25	101.0	25	68.1	25	47.3	25	102.2	25	2.1	25	125.3	25	14.3	25	34.35	4	0.45	25
		A62D	7.8	27	144.5	28	99.4	28	68.5	28	99.6	28	4.7	28	198.3	28	15.4	28	95.85	11	0.37	28
Matlala	A62-2	A62E	8.1	96	109.8	96	46.2	96	33.0	96	117.8	96	8.3	96	120.5	96	25.5	96	59.88	9	0.52	96
		A62F	8.1	59	206.0	59	88.4	59	56.3	59	207.1	59	9.6	59	359.1	59	27.2	59	10.06	2	1.15	59
Steilloop	A62-3	A62G	8.1	34	153.0	34	94.5	34	70.4	34	119.3	34	3.9	34	236.4	34	14.9	34	83.42	12	0.51	34
		A62H	8.2	101	109.0	101	52.2	101	35.1	101	126.7	101	11.8	101	144.5	101	23.9	101	0.30	5	0.34	101
		A62J	7.8	36	280.0	36	92.1	36	98.6	36	258.8	36	7.0	36	642.0	36	46.9	36	28.31	5	0.25	36
Lower Mogalakwena	A63-1	A63A	8.0	78	157.9	78	69.9	78	63.8	78	102.5	78	2.7	78	205.5	78	33.3	78	74.14	10	0.39	78
		A63B	8.1	30	119.4	30	72.3	30	59.8	30	92.8	30	2.6	30	106.8	30	26.5	30	85.09	5	0.82	30
		A63D	8.2	41	96.8	41	73.6	41	58.5	41	66.8	40	2.4	41	77.4	41	17.8	41	44.46	2	0.54	41
Limpopo Tributaries	A63/ 71-3	A63E	8.1	6	185.5	6	58.2	6	79.6	6	124.5	6	3.9	6	215.5	6	41.1	6	0.10	2	0.47	6
		A71L	7.7	4	195.5	4	79.5	4	48.5	4	268.5	4	0.9	4	411.0	4	45.5	4	0.10	4	0.35	4
Upper Sand	A71-1	A71A	8.1	92	78.5	92	41.3	92	31.5	92	69.1	92	5.8	92	59.6	92	24.6	92	7.19	23	0.32	92
		A71B	8.1	119	97.2	119	41.1	119	38.6	119	96.6	119	6.7	119	87.2	119	27.6	119	35.93	15	0.56	119
Middle Sand	A71-2	A71C	8.0	115	114.8	115	51.4	115	45.1	115	130.0	115	8.6	115	102.0	115	34.9	115	81.23	10	0.43	115
		A71D	8.2	2	134.5	2	59.6	2	60.4	2	159.5	2	3.3	2	253.8	2	52.5	2	56.50	2	0.59	2

Description	GRU	Quat	pH	N	EC (mS/m)	N	Calcium	N	Magnesium	N	Sodium	N	Potassium	N	Chloride	N	Sulphate	N	Nitrate as N	N	Fluoride	N
Class 0			6-9		0-70		0-80		0-30		0-100		0-25		0-200		0-100		0-6		0-0.7	
Class I			5-6 or 9-9.5		70-150		80-150		30-70		100-200		25-50		200-400		100-200		6-10		0.7-1	
Class II			4-5 or 9.5-10		150-370		150-300		70-100		200-400		50-100		400-600		200-600		10-20		1-1.5	
Class III			<4 or >10		>370		>300		>100		>400		>100		>600		>600		>20		>1.5	
		A71H	8.1	51	158.0	51	70.9	51	85.4	51	120.2	51	6.4	51	167.4	51	34.2	51	41.03	18	0.24	51
Hout	A71-3	A71E	8.1	100	90.2	100	42.9	100	26.3	100	93.4	100	9.2	100	89.9	100	23.4	100	40.99	6	0.40	100
		A71F	8.1	59	70.2	59	31.7	59	19.5	59	77.5	59	6.0	59	57.4	59	18.1	59	41.28	2	0.43	59
		A71G	8.3	22	134.5	22	63.9	22	67.6	22	117.6	22	12.8	22	190.1	22	39.0	22	20.76	4	0.28	22
		A72A	8.1	209	157.5	210	59.4	209	76.4	209	133.5	210	10.9	209	218.3	209	33.4	210	23.41	28	0.28	209
Sandbrak	A71-4	A71J	7.8	2	95.3	2	51.3	2	39.8	2	62.0	2	2.0	2	173.7	2	41.9	2	0.00	0	0.39	2
		A72B	7.7	1	110.0	1	66.1	1	45.0	1	112.0	1	2.8	1	109.0	1	25.6	1	34.70	1	0.66	1
	A71-5	A71K	7.8	7	146.0	7	102.0	7	79.8	7	80.2	7	4.5	7	183.1	7	101.6	7	18.60	2	0.74	7
Upper Nzhelele	A80-1	A80A	7.8	51	34.1	51	18.2	51	12.1	51	19.3	51	0.4	51	16.3	51	4.9	51	2.87	3	0.14	51
		A80B	7.9	33	104.9	33	67.2	33	63.2	33	63.3	33	0.8	33	65.9	33	13.4	33	57.74	3	0.32	33
		A80C	7.7	44	35.2	44	18.9	44	15.6	44	21.3	44	0.8	44	23.2	44	6.2	44	7.55	5	0.21	42
		A80D	6.9	1	8.0	1	3.1	1	5.9	1	3.5	1	0.1	1	4.9	1	0.8	1	0.30	1	0.10	1
		A80E	7.9	15	143.0	15	71.0	15	57.2	15	102.3	15	1.0	15	137.5	15	24.6	15	0.30	1	0.28	15
		A80F	8.1	3	1092.0	3	385.7	3	793.2	3	918.9	3	19.6	3	3593.1	3	965.9	3	0.00	0	0.51	3
Lower Nzhelele	A80-2	A80G	8.0	16	152.1	16	73.4	16	59.7	16	140.9	16	1.5	16	197.3	16	60.1	16	0.00	0	0.41	16
Nwanedi	A80-3	A80H	7.0	27	11.0	27	3.1	27	2.7	27	8.5	27	0.6	27	12.1	27	4.0	27	6.54	1	0.16	26
		A80J	8.0	27	117.0	27	50.1	27	52.9	27	105.6	27	5.3	27	154.0	27	24.2	27	21.54	6	0.50	27
Upper Luvuvhu	A91-1	A91A	7.3	1	25.0	1	21.7	1	11.3	1	12.7	1	1.1	1	10.1	1	1.3	1	5.09	1	0.10	1
		A91B	8.1	17	46.0	17	29.0	17	28.4	17	21.5	17	1.8	17	19.3	17	8.5	17	13.26	5	0.20	17
		A91C	8.0	33	28.2	33	18.0	33	15.0	33	11.2	33	1.7	33	14.8	33	5.4	33	20.88	7	0.19	33
		A91D	7.4	7	14.4	7	9.6	7	6.3	7	6.1	7	1.8	7	6.6	7	4.0	7	0.30	1	0.16	7
		A91E	7.8	49	28.6	49	23.6	49	14.1	49	12.5	49	0.7	49	12.6	49	5.2	49	12.42	10	0.16	49
		A91F	8.1	169	74.9	169	56.0	169	38.5	169	40.6	169	1.2	169	48.3	169	11.1	169	6.28	28	0.31	169
		A91G	7.7	66	38.5	66	35.6	66	19.0	66	15.0	66	0.4	66	15.4	66	4.5	65	10.00	18	0.15	63
Mutale/Luvuvhu	A91-2	A91H	8.0	55	42.5	55	30.9	55	20.7	55	21.2	55	0.5	55	22.6	55	5.7	55	7.52	7	0.20	55
		A91J	7.9	5	33.9	5	14.6	5	10.3	5	38.5	5	1.6	5	32.8	5	8.3	5	5.51	1	0.24	5
		A91K	8.6	2	612.3	2	36.7	2	53.7	2	90.7	2	1.1	2	100.1	2	9.9	2	0.00	0	0.65	2
		A92A	7.6	31	14.2	31	8.4	31	5.7	31	7.1	31	0.6	31	9.4	31	5.4	31	11.20	2	0.15	30
		A92B	7.6	55	22.0	55	10.2	55	7.0	55	16.2	55	0.7	55	17.5	55	4.4	55	1.16	10	0.18	54
		A92C	8.1	47	107.9	47	32.3	47	54.4	47	99.5	46	1.9	47	156.9	47	24.6	47	10.15	9	0.45	45
		A92D	8.1	67	145.0	67	46.4	67	74.6	67	164.5	67	3.6	67	185.3	67	26.6	67	62.96	6	0.61	67
Shingwedzi	B90-1	B90A	8.1	7	94.0	7	69.9	7	49.8	7	68.7	7	0.9	7	68.9	7	6.0	7	4.82	2	0.37	7
		B90B	8.0	38	97.6	38	70.1	38	47.2	38	71.3	38	1.0	38	76.0	38	10.3	38	70.03	5	0.34	38
		B90C	8.1	34	144.0	34	77.0	34	62.1	34	141.4	34	1.8	34	154.7	34	25.0	34	235.39	7	0.53	34
		B90D	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.00	0	0.00	0
		B90E	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.00	0	0.00	0
		B90F	8.0	82	123.4	82	64.3	82	74.4	82	103.2	82	3.0	82	119.6	82	15.8	82	56.66	22	0.38	82
		B90G	8.4	2	205.0	2	92.3	2	146.8	2	86.8	2	1.7	2	280.4	2	44.3	2	0.00	0	0.21	2
		B90H	7.9	4	489.1	4	57.4	4	61.9	4	99.1	4	1.0	4	118.2	4	10.9	4	0.00	0	0.54	4

3 ALLOCABLE GROUNDWATER

Groundwater allocations must be tightly managed to ensure that BHN and aquatic ecosystems are sustained. To calculate the allocable groundwater volume, the relationship between recharge from rainfall, groundwater inflow, groundwater outflow, BHN, and groundwater contribution to baseflow was considered. The determination of the volume of groundwater that can be allocated to users and potential users must be based on a comprehensive analysis of different scenarios (i.e., the next step in the determination process) that consider the diverse environmental, social, and economic factors that affect groundwater availability and demand.

The prescribed GRDM algorithm was used, and an "allocable groundwater" volume (Mm^3/a) was calculated for the water resource unit (in this case, the quaternary catchment). This algorithm is explained in the GRDM protocols, and it indicates the component of the annual recharge that is still available after BHN, baseflow requirements and the current water use is subtracted from the calculated groundwater recharge.

A groundwater quantity ranking approach was applied using the stress index (SI) principle. The stress index provides a measure of the groundwater balance in a groundwater unit (in this case, the quaternary catchment), indicating the fraction of how much of the groundwater recharge [volume] is used, i.e. (i) the amount required for BHN (25 l /c /d), (ii) the volume of groundwater supporting the base flow (i.e. the baseflow requirement of the quaternary catchment), and (iii) the actual groundwater use/abstraction. When the SI is =1> 1.00, all the recharged groundwater is "allocated ". The "safe" cut-off is 0.65 or 65% of the groundwater recharge. SI is an indicator of the groundwater use impact (Table 3-1).

Table 3-1. GRDM Classification System.

Index	Description
< 0.20 (20 %)	Low
0.20 (20 %) - 0.40 (40 %)	Moderate
0.40 (40 %) - 0.65 (65%)	Moderate to High
0.65 (65 %) - 0.95 (95%) High	High
> 0.95 (95 %)	Critical

3.1 Groundwater Use

The spatial distribution of the known wellfields and larger groundwater abstractions areas are shown in Figure 3-1. Groundwater extraction volumes were obtained from the Limpopo groundwater database (GRIP) for the rural villages and water schemes and registered groundwater uses from the WARMS dataset. The following were considered:

- The GRIP data was filtered to include the listed production boreholes equipped and tested above 0.3 L/s with a recommended duty cycle of 24 hrs (and converted to m^3/year).
- The WARMS dataset (provided in m^3/year) was filtered to include active registrations. Notable duplicate entries were excluded.
- Where local town groundwater abstraction data (i.e., Musina and Polokwane) were available, it was incorporated into the groundwater use dataset.

Musina (Quaternary Catchment A71K)

Musina Town abstracts water from wells in alluvial sand. The Musina Local Municipality operates approximately 32 boreholes along the river (VSA VRM, 2022) (Figure 3-2), however operation and maintenance are an ongoing process to augment the water requirements of the town (DWS, 2022b). Groundwater abstraction accounted for 11.25 Mm^3/a in 2022.

Observations during the drilling testing execution phase suggest that many of the boreholes and wells on the riverbank have a direct connection with the flow within the river limiting further development of the alluvium aquifer.

Polokwane (Quaternary Catchment A71A)

The Polokwane Municipality water supply is augmented with several groundwater (wellfield) resources, namely, Sand River South, Sterkloop, Seshego, Bloodriver, Sand River North and Polokwane Town (City of Polokwane, 2019) (Figure 3-3).

The alluvial aquifer and intergranular and fractured aquifers are recognized as the major aquifers in the area. The rivers act as the discharge area or recharge depends on the season (wet-dry season). The ponds and riverbanks are recharge zones, and the alluvial aquifer also recharges the gneiss aquifer (DWS, 2020). Artificial Recharge occurs through discharge from the Polokwane WwTW and Seshego WwTW.

A summary of the groundwater abstraction from the wellfields is summarised below (City of Polokwane, 2019):

1. Sand River North Well Field – 27 boreholes at 2.1 Mm^3/a
2. Sand South Well Field – 10 boreholes at 1.0 Mm^3/a
3. Blood River and Pilgrimshoop Well Fields – 8 boreholes at 1.4 Mm^3/a
4. Sterkloop Boreholes – 8 boreholes at 1.1 Mm^3/a
5. Polokwane Individual Boreholes – 5 boreholes at 0.45 Mm^3/a
6. Seshego Individual Boreholes – 9 boreholes at 0.53 Mm^3/a

While groundwater provides a large component of the bulk water supply to Polokwane, surface water resource remains the main water supply.

Schroda/Greefswald (Venetia Mine) (Quaternary Catchment A63E and A71L)

Commissioned in 1992, Venetia is an open pit mine located in the quaternary A63E catchment (Figure 3-4). To sustain its current mining operations, the mine abstracts water from two alluvial aquifers (Greefswald and Schroda) (developed in 1990), that lies at the confluence of the Limpopo and Shashe Rivers, located within the Mapungubwe National Park. The management (i.e., abstraction) of the wellfields are driven by the Mine. To date no abstraction volumes or monitoring data were made available.

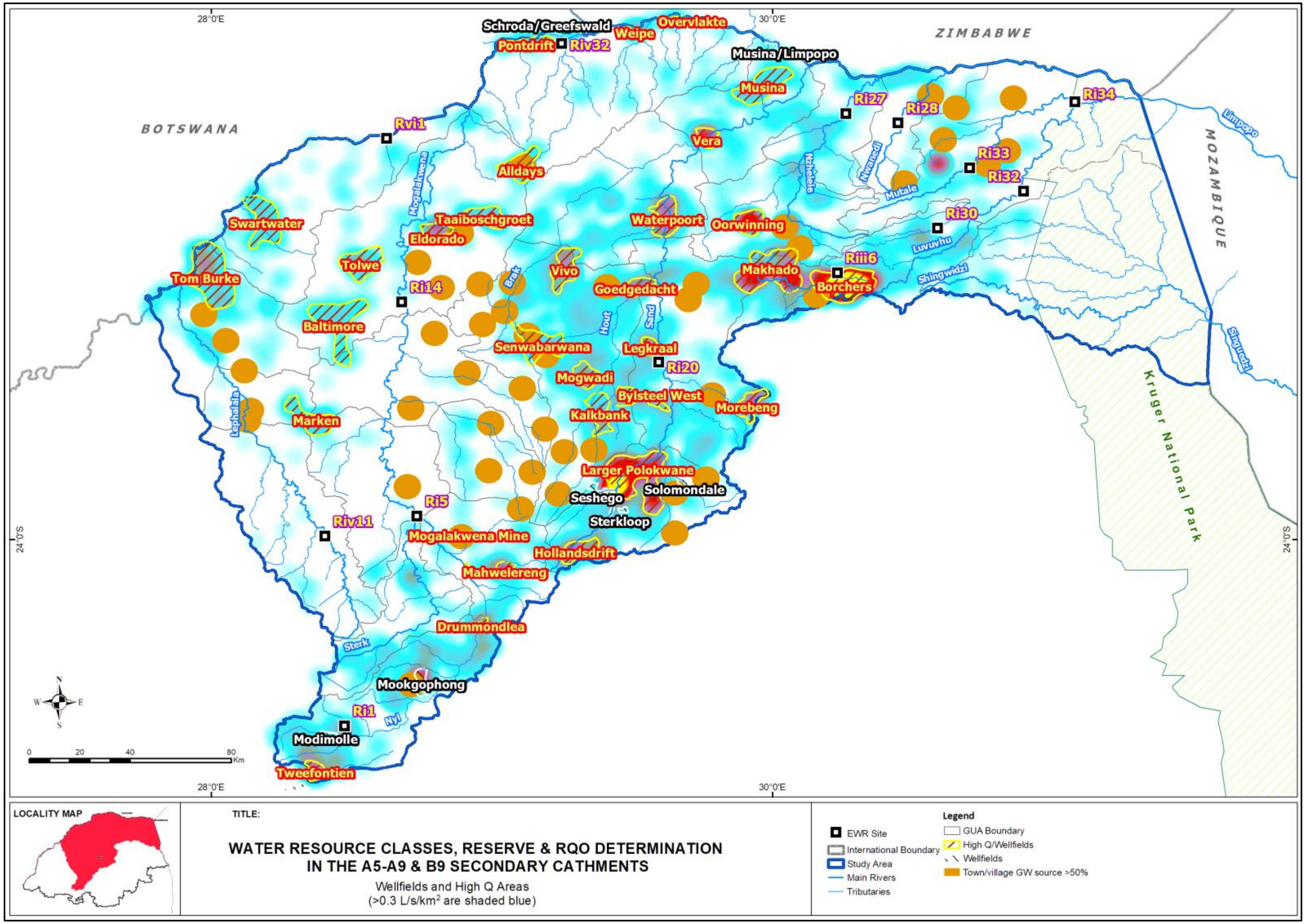

Figure 3-1. High abstraction zones and known wellfields.

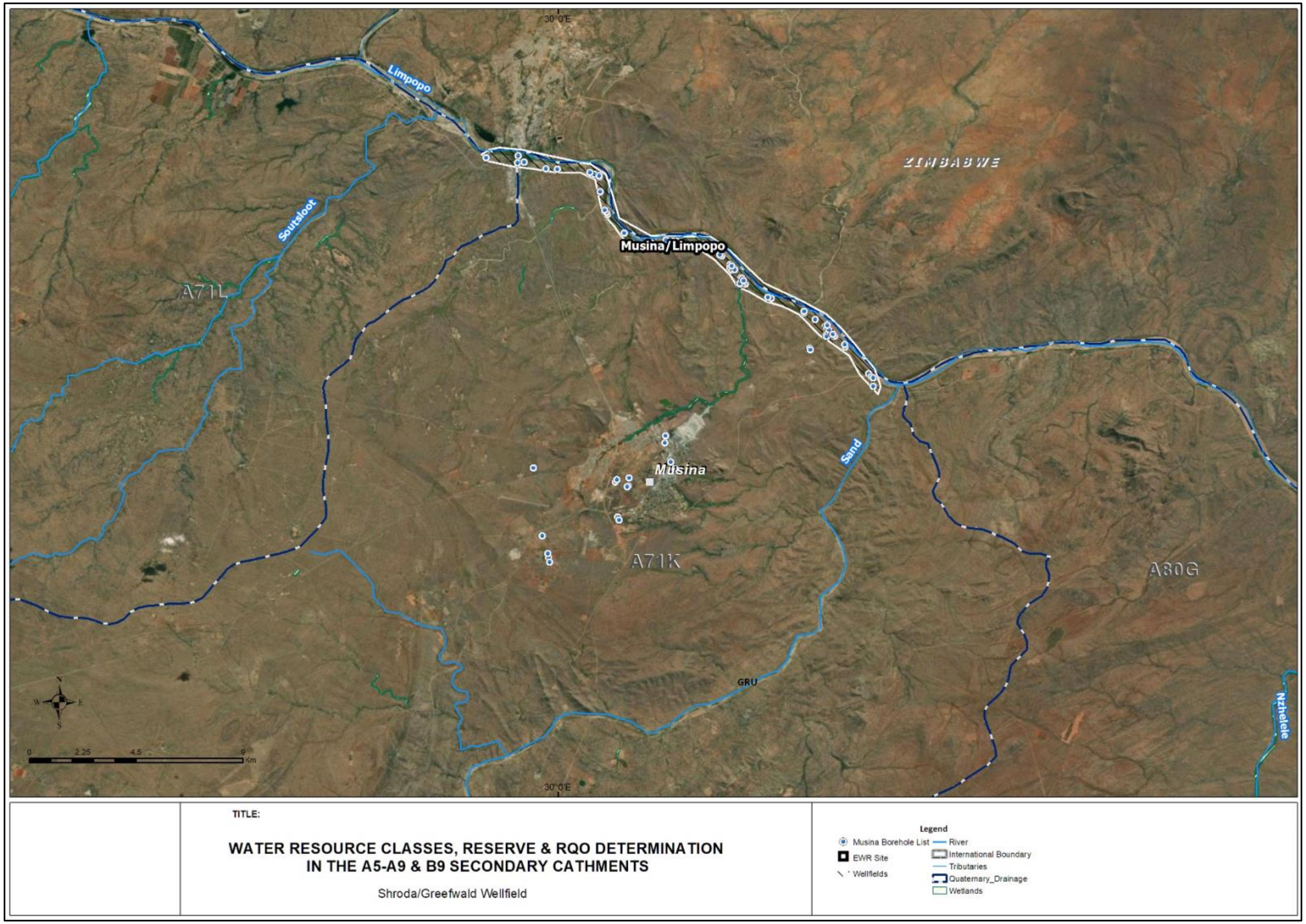

Figure 3-2. Musina wellfield.

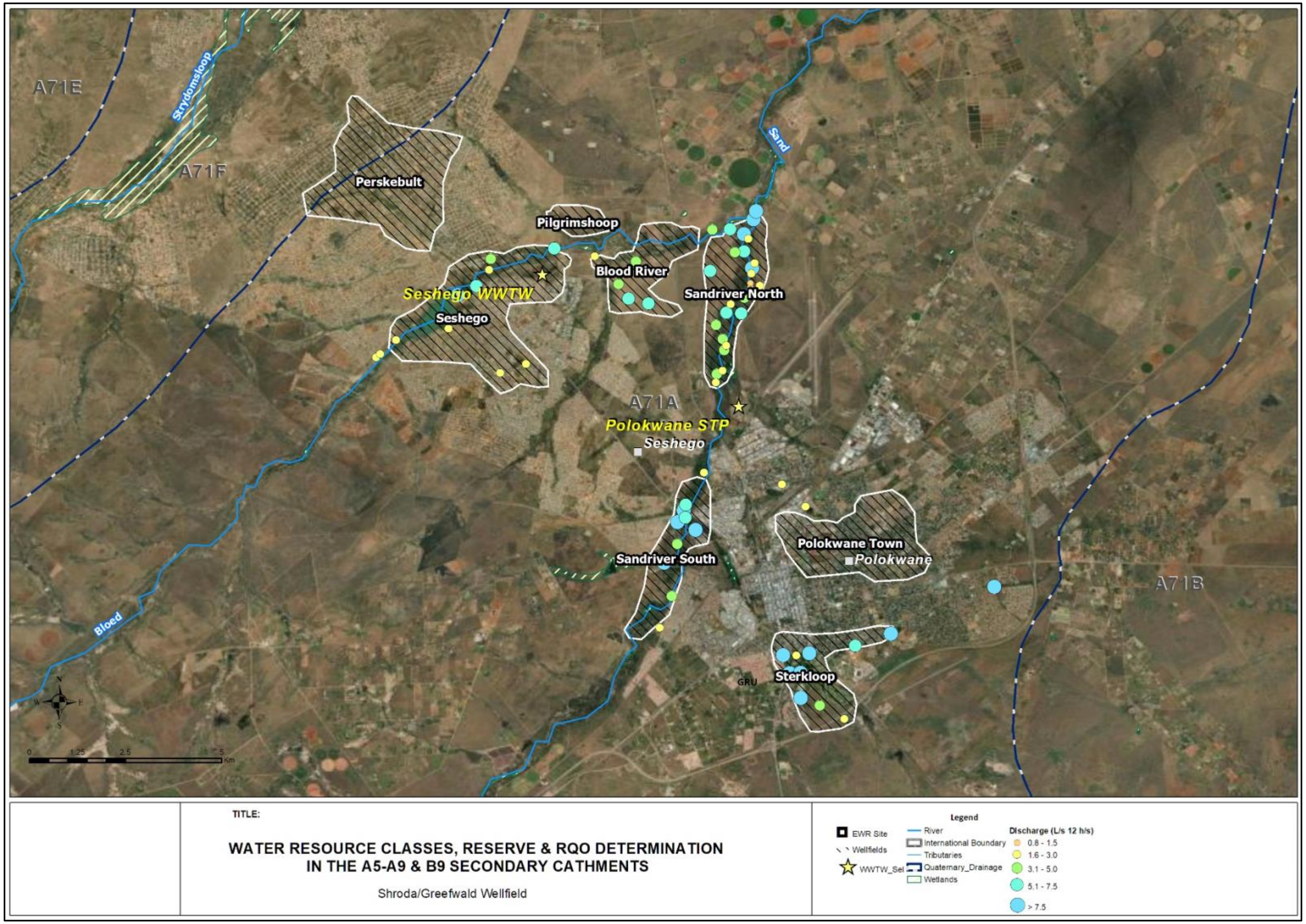

Figure 3-3. Polokwane wellfields.

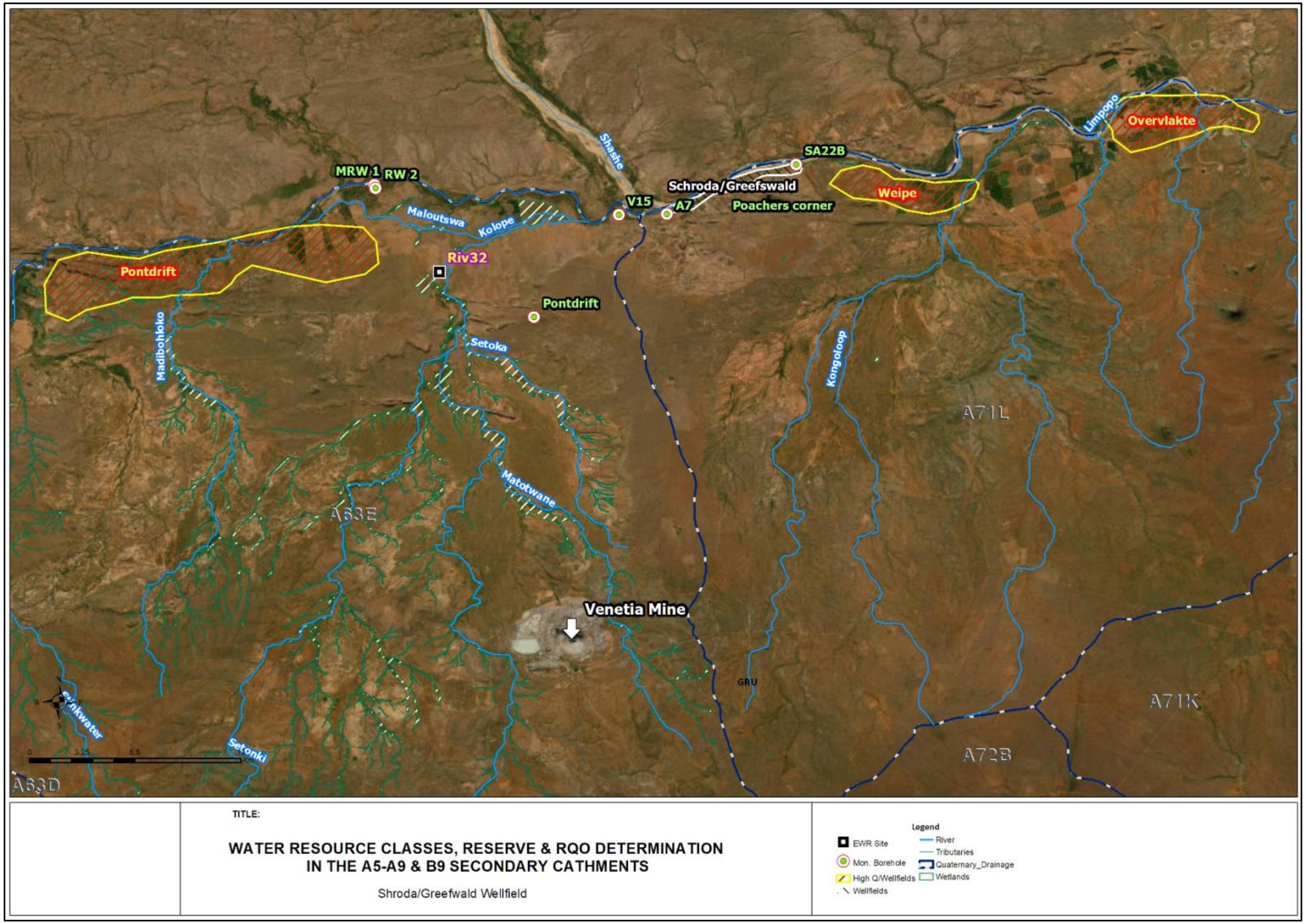

Figure 3-4. Schroda/Greefswald wellfields.

South Africa National Parks (Mapungubwe) has several monitoring boreholes located amongst the wellfields to monitor groundwater levels and groundwater quality. Riparian stress monitoring is also done on behalf of the Mine by a third-party environmental consultant. Aquifer Dependent Ecosystems includes the Samaria and Kalopi Wetlands, and Greefswald Gallery Forest.

Several other groundwater abstractions occur on the neighbouring farms (i.e, Pontdrift, Wepe) for agricultural practices.

3.2 Groundwater Allocation

A first order "Allocable Groundwater" estimation is presented in Table 3-2 for each quaternary catchment area derived using the GRDM methodology.

- * - indicates quaternary catchments where potential lateral inflow (or induced recharge) exists.
- $^{\#}$ - indicates simulated wetland/alluvium seepages added to groundwater contribution to baseflow.

Table 3-2. Allocable groundwater for the Study Area.

Description	GRU	Quat	Area	MAP	Recharge	Population	BHN	GW Cont. BF	Total Reserve	GW Use	Balance (i.e. Allocable GW)	Stress Index/factor
Unit			(km²)	mm	Mm³/a	GW Based	Mm³/a	Mm³/a	Mm³/a	Mm³/a	Mm³/a	
Upper Lephalala	A50-1	A50A	298	654	12.95	486	0.009	4.50	4.51	0.15	8.29	1%
		A50B	406	599	13.52	501	0.009	5.56	5.57	0.18	7.76	1%
		A50C	362	593	11.00	504	0.009	4.82	4.83	0.28	5.89	3%
		A50D	637	558	13.95	554	0.010	3.37	3.38	0.29	10.28	2%
		A50E	629	517	11.71	522	0.010	2.87	2.88	0.24	8.59	2%
		A50F	372	496	6.14	321	0.006	1.45	1.45	0.14	4.56	2%
Middle Lephalala	A50-2	A50G	821	435	9.20	3645	0.067	0.02	0.09	2.02	7.09	22%
Lower Lephalala	A50-3	A50H	1945	407	15.11	6208	0.113	0.03	0.15	6.20	8.77	41%
Kalkpan	A50-4	A50J	1255	391	9.29	1133	0.021	0.06	0.08	4.25	4.96	46%
		A63C	1323	378	9.21	1237	0.023	0.06	0.08	1.58	7.55	17%
Nyl River Valley	A61-1	A61A	381	629	15.01*	906	0.017	4.87	4.89	2.04	8.08	14%
		A61B	362	629	13.70*	634	0.012	5.08	5.09	0.61	8.01	4%
		A61C	587	633	18.00*	1081	0.020	4.81	4.83	3.26	9.92	18%
		A61D	456	630	15.23*	978	0.018	5.01	5.02	4.66	5.54	31%
		A61E	547	625	14.72*	779	0.014	4.08	4.09	9.32	1.31	63%
Sterk	A61-2	A61H	585	636	19.99	905	0.017	5.73	5.74	2.79	11.46	14%
		A61J	818	631	24.28	1197	0.022	9.20	9.22	1.72	13.34	7%
Upper Mogalakwena	A61-3	A61F	789	597	22.30*	16675	0.304	4.76	5.06	5.99	11.26	27%
	A61-3	A61G	927	585	19.31	14651	0.267	4.24	4.50	10.67	4.13	55%
Klein Mogalakwena	A62-1	A62A	428	610	12.16	1727	0.032	4.55	4.58	0.70	6.88	6%
		A62B	710	529	14.74	6544	0.119	2.89	3.01	0.98	10.75	7%
		A62C	385	478	6.71	937	0.017	1.10	1.12	0.26	5.33	4%
		A62D	603	489	10.54	1044	0.019	1.22	1.24	1.20	8.10	11%
Matlala	A62-2	A62E	621	460	8.56	6366	0.116	0.24	0.36	3.18	5.02	37%
		A62F	620	478	9.06	6224	0.114	0.09	0.20	5.22	3.64	58%
Steilloop	A62-3	A62G	627	437	8.26	2344	0.043	0.12	0.16	0.79	7.30	10%
		A62H	871	439	10.78	6527	0.119	0.15	0.27	3.07	7.45	28%
		A62J	930	450	12.38	3427	0.063	0.13	0.19	0.79	11.40	6%
Lower Mogalakwena	A63-1	A63A	1928	433	17.83	7557	0.138	0.01	0.15	18.72	-1.04	105%
		A63B	1505	394	11.17	6611	0.121	0.01	0.13	2.81	8.23	25%
		A63D	1319	412	13.59	4816	0.088	0.00	0.09	4.68	8.83	34%
Limpopo Tributaries	A63/71-3	A63E	1992	358	13.67	3103	0.057	0.06	0.12	12.18	1.37	89%
		A71L	1765	288	9.62	2673	0.049	0.04	0.09	11.35	-1.81	118%
Upper Sand	A71-1	A71A	1144	468	40.16*	23585	0.430	0.20	0.63	43.88	-4.36	109%
		A71B	882	450	14.38*	10147	0.185	0.12	0.30	10.36	3.72	72%
Middle Sand	A71-2	A71C	1331	418	19.69*	18235	0.333	0.09	0.42	28.39	-9.12	144%
		A71D	892	390	4.64	2620	0.048	0.12	0.17	6.51	-2.04	140%
		A71H	1012	491	16.97	16244	0.296	0.16	0.46	4.83	11.69	28%
Hout	A71-3	A71E	893	421	8.66	4895	0.089	0.32	0.41	7.87	0.37	91%

Description	GRU	Quat	Area	MAP	Recharge	Population	BHN	GW Cont. BF	Total Reserve	GW Use	Balance (i.e. Allocable GW)	Stress Index/factor
Unit			(km²)	mm	Mm³/a	GW Based	Mm³/a	Mm³/a	Mm³/a	Mm³/a	Mm³/a	
		A71F	683	400	4.38	16147	0.295	0.31	0.60	7.30	-3.52	166%
		A71G	875	427	9.23*	4531	0.083	0.06	0.14	13.84	-4.75	150%
		A72A	1908	465	21.69*	17744	0.324	0.07	0.40	23.63	-2.34	109%
Sandbrak	A71-4	A71J	1162	396	11.88	2972	0.054	0.40	0.45	16.49	-5.06	139%
		A72B	1554	344	8.81	3167	0.058	0.28	0.34	5.47	3.00	62%
	A71-5	A71K	1668	305	9.44	2787	0.051	0.20	0.25	13.97	-4.78	148%
Upper Nzhelele	A80-1	A80A	287	938	26.68	4627	0.084	7.64	7.72	1.64	17.31	6%
		A80B	251	659	11.87	4802	0.088	4.40	4.49	1.84	5.54	16%
		A80C	294	576	10.95	3413	0.062	2.90	2.97	1.84	6.14	17%
		A80D	128	622	4.70	336	0.006	1.49	1.50	0.06	3.13	1%
		A80E	247	622	9.91	4980	0.091	2.46	2.56	1.29	6.06	13%
		A80F	630	388	7.77	1669	0.030	0.34	0.37	3.08	4.32	40%
Lower Nzhelele	A80-2	A80G	1230	333	10.44	3439	0.063	0.12	0.18	5.72	4.55	55%
Nwanedi	A80-3	A80H	266	621	10.41	2272	0.041	2.16	2.20	2.28	5.93	22%
		A80J	870	292	4.10	7073	0.129	0.58	0.71	2.07	1.32	51%
Upper Luvuvhu	A91-1	A91A	232	696	10.04	748	0.014	3.41	3.42	9.16	-2.54	91%
		A91B	275	620	17.96*	4043	0.074	3.14	3.21	8.22	6.53	46%
		A91C	250	866	22.59*	5985	0.109	5.34	5.45	29.21	-12.07	129%
		A91D	132	1287	22.99	2476	0.045	4.71	4.76	6.96	11.27	30%
		A91E	223	1078	28.17	6259	0.114	7.97	8.08	0.80	19.28	3%
		A91F	580	662	19.80*	9016	0.165	6.63	6.79	1.44	11.56	7%
		A91G	406	950	51.83	11144	0.203	10.21	10.41	0.86	40.56	2%
Mutale/Luvuvhu	A91-2	A91H	450	722	17.17	4030	0.074	1.58	1.65	1.21	14.30	7%
		A91J	570	450	7.02	151	0.003	0.81	0.82	0.21	5.99	3%
		A91K	669	373	3.66	92	0.002	1.50	1.50	0.00	2.15	0%
		A92A	329	997	51.34	7505	0.137	1.76	1.90	0.50	48.94	1%
		A92B	565	711	28.07	1973	0.036	3.55	3.59	0.64	23.85	2%
		A92C	455	423	5.94	1399	0.026	0.15	0.18	1.07	4.69	18%
		A92D	805	301	2.46	4237	0.077	0.24	0.32	1.29	0.86	52%
Shingwedzi	B90-1	B90A	693	465	7.06	93	0.002	0.03	0.04	0.04	6.99	1%
		B90B	754	470	8.56	1966	0.036	0.09	0.12	0.69	7.76	8%
		B90C	535	498	6.32	2897	0.053	0.08	0.14	0.79	5.39	13%
		B90D	447	471	4.60	10	0.000	0.05	0.05	0.00	4.55	0%
		B90E	474	466	4.48	10	0.000	0.02	0.02	0.00	4.45	0%
		B90F	819	539	11.28	8561	0.156	0.11	0.27	0.75	10.26	7%
		B90G	698	535	12.46	292	0.005	0.07	0.08	0.07	12.32	1%
		B90H	890	538	14.93	92	0.002	0.13	0.13	0.00	14.80	0%

Note 1: Quaternary catchments with no allocable groundwater are highlighted.

Note 2: Quaternary catchments with high to critical (>65 %) groundwater use indexes are highlighted. Further allocation should consider current stressed status.

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