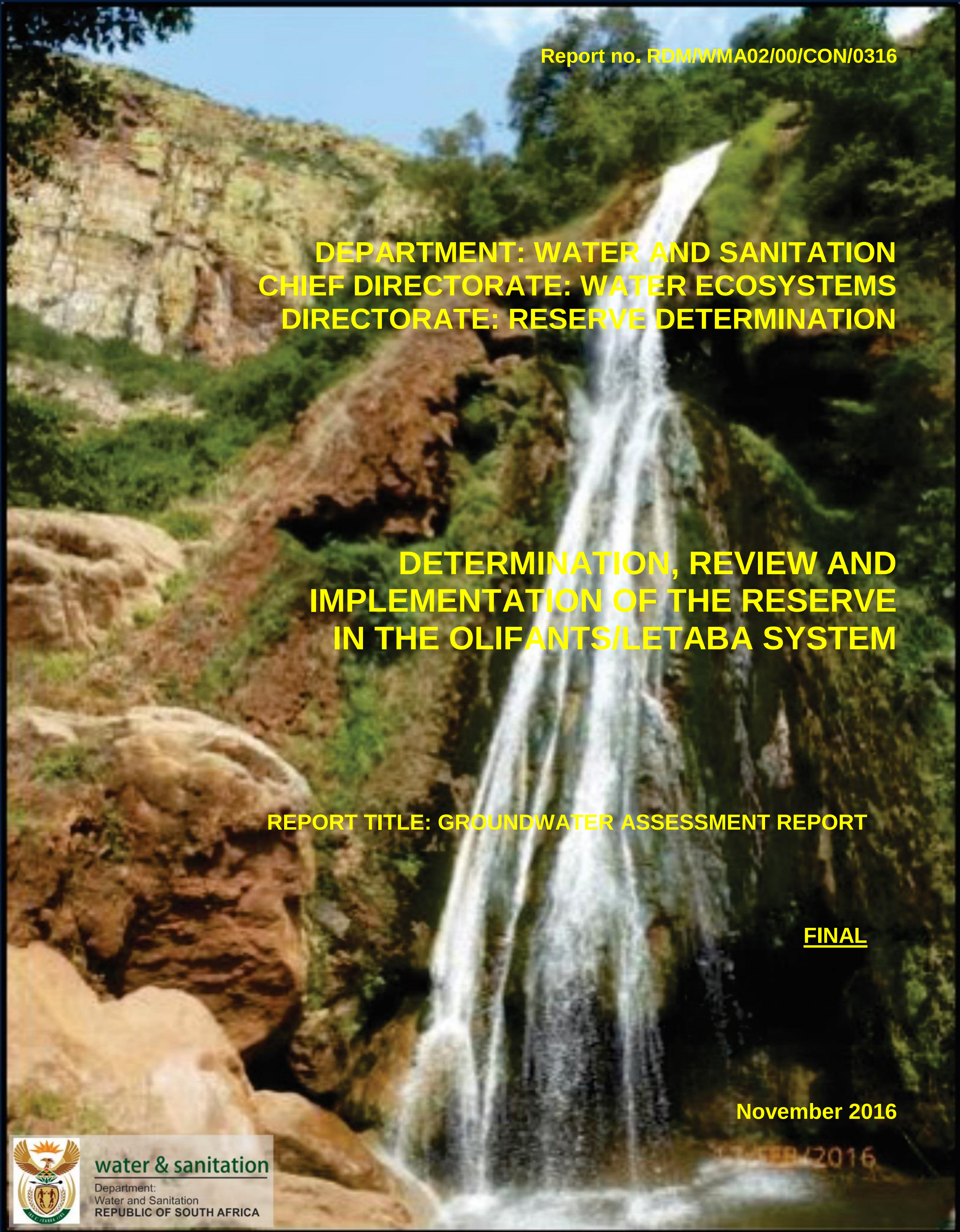

Report no. RDM/WMA02/00/CON/0316

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CHIEF DIRECTORATE: WATER ECOSYSTEMS
DIRECTORATE: RESERVE DETERMINATION

DETERMINATION, REVIEW AND IMPLEMENTATION OF THE RESERVE IN THE OLIFANTS/LETABA SYSTEM

REPORT TITLE: GROUNDWATER ASSESSMENT REPORT

FINAL

November 2016

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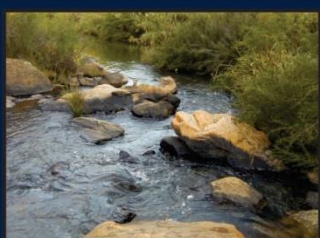


DEPARTMENT: WATER AND SANITATION

Directorate: Reserve Determination

DETERMINATION, REVIEW AND IMPLEMENTATION

OF THE

RESERVE IN THE OLIFANTS / LETABA SYSTEM

WP10940

Groundwater Assessment Report

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4.0	RDM/WMA02/00/CON/0116	Eco-Classification Report
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LIST OF ABBREVIATIONS

AMD	Acid Mine Drainage
CD: WE	Chief Directorate: Water Ecosystems
DLMT	Dolomite (rock or karst aquifer systems)
DWS	Department of Water Affairs (presently DWS)
DWAF	Department of Water Affairs and Forestry (presently DWS)
DWS	Department of Water and Sanitation
EC	Electrical Conductivity (mS/m)
ER	Ecological Requirement (from regional aquifer system)
Gwater	Groundwater
IUA	Integrated Unit of Analysis
IWRM	Integrated Water Resource Management
IWRMP	Integrated Water Resources Management Plan
KCA	Karoo Coal Aquifers
mbgl	Metres below ground (surface) level
MC	Management Class
NFEPA	National Freshwater Ecosystem Priority Areas
NGwQlMP	National Groundwater Quality Monitoring Programme
NWA	National Water Act
Ql	Quality (of water source/resource)
Qn	Quantity (of water source/resource)
QC	Quaternary Catchment
RC	Resource Classification
RDM	Resource Directed Measures
RHP	River Health Programme
RQOs	Resource Quality Objectives
RQS	Resource Quality Services
SA	South Africa
SFKA	Springbok Flats Karoo Aquifer
STW	Sewage Treatment Works
Swater	Surface Water
TC	Tertiary Catchment
TDS	Total Dissolved Solids (mg/l)
WMA	Water Management Area
WULC	Water use licence conditions (volumes allocated)
WWTW	Waste Water Treatment Works

EXECUTIVE SUMMARY

A groundwater assessment of the Olifants – Letaba System in support of determining, review and implementing of the reserve based on existing groundwater studies, is presented in this chapter.

Very limited physical field work were conducted; thus the process followed was to review the existing datasets, which were unfortunately based on different processing in the Olifants and Letaba respectively. A procedure was therefore followed to combine the two datasets to produce a listing of the quaternary catchments based on the groundwater quantities, quality, and potential groundwater support to the surface water resources.

Other important aspects of the groundwater assessment in support of the reserve determination was the interaction between the groundwater and surface water components – in this case a significant number of quaternary catchments were identified during previous studies where groundwater resources are effectively supporting the groundwater part of the baseflow. Four levels of interaction have been proposed by previous study teams and this has been used and updated where “modern” information was available. It has been noted that impacts in the upper parts of quaternary catchments have a substantial impact on the surface water baseflow support to the ecology in the far field downstream quaternary catchments – a phenomenon noted in the Letaba River.

The groundwater resources in the study area varies from insignificant (<0.1 l/s) to significant (>5 l.s), however, the sustainability is a factor of rainfall recharge (recurrence rate of 5 to 10 yrs depending on the geographical setting).

Groundwater contribution of baseflow in rivers (so-called Groundwater water Baseflow) plays an important role in the head waters regions of the Letaba River System, as well as the head waters catchments (viz. QC’s) of the Olifants River System (i.e. Klein Olifants River, Blyde River, Elands River, Wilge River (Grootspruit and Saalboomspruit tributaries) and Steelpoort River (viz. Grootspruit and Dwars tributaries)). Significant agricultural developments in the upper Elands River (QC’s B31E, –F and –J) has probably depleted any baseflow generation due to agricultural developments (Groundwater Reserve is <<0.25 MCM/a).

The groundwater quality in the study area varies significantly; from Ideal/Good in the recharge areas (high relief QC’s) to Marginal throughout the study area. Groundwater quality in certain areas such as the Upper Olifants Coal Area are deteriorating due to AMD development which has a serious impact on the local surface water resources due to interflow decanting into drainages. What is, however, a concern throughout the study area is the steady increase of nitrates in the groundwater and is directly linked to irrigation practices (i.e. The Springbok Flats) and high-density populated areas – three specific areas have been identified where regional nitrate pollution as the result of sanitary practices (pit latrines) are probably the cause. Local groundwater resources in the Giyani Region (QC B82G –Little Letaba River) are significantly impacted by nitrate pollution and the effect is probably irreversible.

The groundwater reserves in the dolomite water areas vary from highly impacted (reserve criteria for Ql, Qn and ER) in the Delmas Area (B20A and–B), the Zebediela-Mogoto Mountains Area to a lesser degree of impact in the Groblersdal Area. The groundwater reserve for Wolkberg "Escarpment" is still in a manageable order (RC and RQO's specifications are in the moderate to natural categories for Ql, Qn and ER) except for QC's B52D (24% of area), B52G (36% of area), B60C (17% of area), and B60H (46% of area) where Qn is impacted.

Over all, the following areas have been identified as significantly impacted, thus the groundwater reserve is in a status where strict measure will have to be considered to improve the current status (high-level control of all water use practices), they are (updated from Ages Group selection (Ages Group, 2009):

1. The Delmas Dolomite Aquifer (B20A and B20B) due to significant abstractions for irrigation and domestic water supplies. The risks are sinkhole formation and direct recharge of poorly treated sewer water into the aquifer system.

2. Similar to Delmas case is the Zebediela Dolomite Aquifer (B51E and B51G), although over-abstraction is the main concern here;

3. The Springbok Flats Karoo Aquifer (B51E) where 10-12 Mm^3/a is abstracted for irrigation. The concern here is that abstractions are focussed on specific areas, i.e. not a diffused abstraction pattern. Secondly, nitrate pollution due to the application of artificial fertilizers is polluting the shallow aquifer systems;

4. Upper Olifants Coal Area mining at Witbank-Middelburg-Kriel poses a significant water quality on the underlying Karoo Coal Aquifers (B11K, B11J, B11H and B12D) where water quality is more affected than quantity – interflow interaction with local surface water systems becomes more of a reality;

5. Steelpoort mining and community water supply aquifer areas (B41J and B41K) where groundwater quantity and quality is affected;

6. Kruger National Park and Bushbuckridge Catchments (B73J, B73H, and B73F) where groundwater sustains community water and riparian vegetation;

7. The upper Letaba River catchments (i.e. B81D and –E) where the groundwater baseflow contribution to the lower, downstream QC's are impacted by surface water abstractions and afforestation.

To conclude, one of the most manageable parameters of the resource directed measures protocols is groundwater abstraction figures. This aspect needs to be addressed as part of the groundwater reserve measures and can only be achieved by auditing of groundwater use licenses and limitation of further groundwater developments in a group of quaternary catchments identified in this study.

In addition, the whole hydrological monitoring programme of the study area needs to be updated and maintained. Recommendations have been made by previous study teams and include several surface water gauging weirs along the Olifants River main stem which are crucial for the new bulk water supply scheme from the Wolkberg Escarpment dolomite aquifer systems. The surface water – groundwater interaction on this area is regarded as significantly high.

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1. INTRODUCTION

This section of the Assessment Report deals with the groundwater component of a reserve for the Olifants / Letaba System (herein referred as the Study Area) and specifically focus on the quality and quantity aspects of the groundwater resources which is used for a wide range of water uses, including mining activities where the groundwater is removed to allow deeper mining activities.

The groundwater resources in the Study Area occurs in wide range of hydrogeological units (viz. aquifers systems) – which will be discussed in section 4.1 below. Although the intergranular and fractured aquifer type is dominant in the Study Area, high-yielding aquifer type such as the (i) intergranular (river valleys) and (ii) the karst aquifer types are regarded as important specifically for specifying protocols in order to limit the impact on the total reserve (viz. including the surface water resource).

Groundwater use in the Study Area varies from local, small supplies to stock water and domestic users (< 3 000 $m^3/km^2/a$ or ~2.3 l/s, rural areas), to large scale bulk users (>1 $Mm^3/km^2/a$, ~32 l/s, Springbok Flats area).There are therefore areas where the magnitude of groundwater abstractions could impact on smaller users and/or surface water resources.

Land use activities varies from rural type stock farming with isolated stock kraals (local nitrate pollution if borehole is situated <50 m from stock kraals) to large scale mining activities (acid mine drainage, sulphate pollution, elevated metals, salinity (Total Dissolved Solids (TDS) impacts and destruction of natural geo-ecological sites such as wet lands and even surface drainages.

The third important aspect of the study is a review of the interaction between groundwater and surface water resources in order to sufficiently address the groundwater component of the reserve (herein referred as the groundwater reserve). However, the surface water-groundwater interaction is not well understood on the scale of the Olifants / Letaba System and requires further research in identified areas (related to the quaternary catchment).

2. APPROACH – METHODOLOGY

The assessment of the groundwater reserve in the Study Area is based on reviews of investigations and reviews done by independent research teams in the period between 2001 and 2013. In all cases the Olifants Riverand Letaba River Catchments were not addressed as one water management area, therefore, this assessment will focus on submitting a combined assessment of the groundwater reserve.

The Shingwedzi River Catchment (TC B90) has not been studied in terms of any resource directed measures (RDM) assessment yet. The Tertiary Catchment (TC) B90 will therefore be addressed on a desktop level assessment instead (as with the surface component).

In short, the methodology followed will be based on the results presented by the research teams involved with the Olifants and Letaba catchments respectively.

As mentioned previously, the understanding of the surface water – groundwater interaction needs tobe improved for the Olifants River Catchment. Two aspects that need further site specific attention is the time series trends of the groundwater quality and aquifer saturation levels (i.e. water levels) and the water use figures. In the first case, the groundwater monitoring networks and programmes needs to be refined to areas where the groundwater Stress Indexes are >0.65 (i.e. 65%) and should be implemented through the water use license application/review/audit processes. In the second case, audits of the groundwater use volumes should be done by the regulators based on the stress index indicator as well. A final list of critical quaternary catchments where the water resource in terms of the groundwater component will be presented in this report. Due to the differentiation of the aquifer systems in a quaternary catchment, zoned areas will be mapped based on the work done by Ages (May, 2009). This work has unfortunately covered the Olifants catchment only, however, the methodology used (*viz*. the groundwater yield model) will be applied to the Letaba and Shingwedzi River Catchments at a later stage.

To conclude, specifying the groundwater contribution to base flow and "calculating" the impact of evapo-transpiration losses in the riparian zone still haunts a realistic/representative convergence of analytical results between the groundwater study teams in South Africa (SA). The importance of surface water gauging in this regard is of extreme importance and a protocol for combined monitoring of surface and groundwater at specific sites should be developed/implemented.

3. DISCUSSION OF RESULTS NOTES IN PREVIOUS STUDIES

Figures indicating the groundwater component of water balances in demarcated groundwater regions hydrological flow balances in quaternary catchment were produces since the Harvest Potential estimations by DWAF (DWAF, 1996).

National level reports by the Department of Water and Sanitation (former Water Affairs & Forestry), were:

1. Groundwater Harvest Potential (Map of RSA) by DWAF 1998;
2. Water Resources Situation Assessment (Groundwater Resources of SA) by WSM, 2001; and
3. Groundwater Resources Assessment Phase II by DWAF, 2006.

The above-mentioned reports provide bulk estimates of groundwater recharge, base flows, water uses, exploitation potential, normal and dry cycle volumes, and estimates of non-factorised/factorised groundwater supplies per quaternary catchments.

The Water Systems Management (WSM, 2001) report provides an estimate of the *Exploitation Potential* per quaternary catchment (QC), thus including the impacts on the water resources. The QC's have been categorisedaccording to (i) Potential Impact of Surface Water Resources according to a High (n=21 QC's), Moderate (n=23 QC's), Low (n=35 QC's) and Insignificant (16 QC's), and (ii) *Groundwater Utilisation Status* per quaternary catchment and has grouped the QC's according to an Over Utilised (n=2 QC's), Heavily-Stressed (n=5 QC's) and Moderately Stressed (n=3 QC's) category.

Updates of the groundwater balances in the Olifants-Letaba System have been done during intermediate reserve assessments (2009, Olifants WMA, by SRK) and a scoping of the groundwater component in a comprehensive level reserve (2006, Letaba WMA by WSM).

The important reports that are available and used in this assessment are as follows:

1. 2003: Olifants Water Management Area: Water Resources Situation Assessment – Main Report (DWAF Rep No P/04000/00/0101, by WSM). Includes a chapter on groundwater resources and a 1: 50 year supply assurance. The exploitable groundwater potential in five (5) tertiary catchments were already over exploited at that time and they are:
    1. B11, B32, B41, B60, and B71.

2. 2006: Letaba Catchment Reserve Determination Study – Groundwater Report (Report: RDM/B800/02/CON/COMP/0504, by WSM) addresses the groundwater contribution to baseflow /ecosystems and degree of groundwater stress. It includes a draft terms of reference for a comprehensive groundwater component of the reserve investigation. Nitrate pollution in the rural water supply areas and overriding (due to abstraction) of the ecological reserve in the following quaternary catchments:

1. B81B, B81D, B82A, B82D, and B82E.

3. 2009: Olifants River Water Management Area: Groundwater Assessment (AG–R–2009-05-20 by the Ages Group for SSI Engineers and Environmental Consultants) includes an evaluation of the groundwater component of the WMA, integration of the groundwater and surface water components in terms of base flow volumes and identified stressed aquifers (in QC context). Certain groundwater sub-units have been identified as significantly stressed and falls within the following QC's:

   1. B20A, B20B, B51E (DLMT), B51G (DLMT), B51E (SFKA), B11K (KCA), B11J (KCA), B11H (KCA), B12D (KCA), B41J, B41K, B73J, B73H and B73F.

   This report further, has identified specific groundwater aquifer systems where groundwater is over-utilised on local scale, and they are:

   1. The Delmas Dolomite Aquifer (B20A and B20B);
   2. The Zebediela Dolomite Aquifer (B51E and B51G);
   3. The Springbok Flats Karoo Aquifer (B51E);
   4. Witbank-Middelburg-Kriel Karoo Coal Aquifers (B11K, B11J, B11H and B12D) (water quality deterioration);
   5. Steelpoort mining and community water supply aquifer areas (B41J and B41K);
   6. Kruger National Park and Bushbuckridge Catchments (B73J, B73H, and B73F); and
   7. The Olifants River Alluvium Aquifer (downstream of the Flag Boshielo Dam, although a local investigation by the Ages Group in 2008 did not specifically indicated this system to be over-utilised; in fact utilised at all).

4. 2009: Groundwater Reserve Determination for the Olifants River Catchment (Report: RDM/WMA4/02/CON/INT/0109, by SRK) is a full scale hydrogeological study of the Olifants WMA including the RDM components (classification, resource quality objectives and reserve). A groundwater status indicator, based on a stress index factor has been used to select quaternary catchments where the groundwater status is largely, seriously and critically modified (utilised) and they are:

   1. B20A, B20B, B31J, and B51G.
   It should be noted though, there has been some critic on the outcome of this report. WSMLeshika did a review of this report and the AGES report (Ages, 2009) and the results will be discussed below (WSMLeshika, 2013).

5. 2011: Development of a Reconciliation Strategy for the Olifants River Water Supply System (DWS Project WP10197, by Aurecon). It includes a chapter on groundwater use and potential based on the Ages 2009 report (as noted above).

6. 2013: Review of the Groundwater Options for Reconciliation Strategy of the Olifants River Water Supply Strategy (WSMLeshika) is a review of the 2009 SRK and 2009 AGES

groundwater assessment reports. The main discrepancies between the two reports seem to be the SRK recharge (2015 MCM/a) and AGES baseflow (45 MCM/a), although the AGES assessment included a substantial value for evapotranspiration (viz. 646 MCM/a). The author did a refinement of the groundwater reserve allocations, based on the GRDM Manual, but only recharge to the regional groundwater system is accounted. The following QC's were identified as stressed (groundwater reserve is zero or already a negative value):

1. B11C, B11D, B11E, and B11J;
2. B12B, and B12D;
3. B20A, B20B, and B20E;
4. B31A, B31H, and B31J;
5. B32C, B32D, and B32F;
6. B32J;
7. B42A;
8. B51E, B51F, and B51G;
9. B52F;
10. B60F, B60G, and B60H;
11. B71H;
12. B72G; and
13. B73G.

7. 2014: Review of the Groundwater Options for Reconciliation Strategy of the Olifants River Water Resources Development Project Phase 2 (the so-called Escarpment Dolomites) (WSM Leshika for Aurecon Ndodana Joint Venture). The Malmani Dolomites in this region has been assessed as "under-developed" earmarked for bulk water supply to support (as per DWAF ISP, 2004).

8. 2014: Classification of Water Resources and Determination of the Resource Quality Objectives in the Letaba Catchment– Resource Quality Objectives (Report: RDM/WMA02/00/CON/CLA/0314 by Rivers for Africa eFlows Consulting and WSMLeshika). The report indicates that the following QC's are Seriously modified (Category E)", to Critically Modified (Category F):
   1. B81E, and B81F; and
   2. B82B, and B82C.

9. The report indicates that the following QC's are "Largely Modified" (Category C):
   1. B81F, and B81G; and
   2. B82D.

3.1 Data Availability

Assessment of the coverage of the groundwater data (quality and quantity) is contained in the groundwater related studies listed in Section 2. Unfortunately, due to deterioration of the operational and maintenance of the water monitoring infrastructure.

Hydrological monitoring, in the sense of monitoring the interaction between groundwater and surface water resources, is not functional and should be addressed in specified terrains, for example the Wolkberg Escarpment arch where the Olifants System (incl. the Steelpoort and Motse Rivers) and Blyde River passes. The report by WSMLeshika (2014) specifically noted that the following actions are required to improve the confidence in quantification of the available groundwater resources and impacts (*viz*. abstraction from groundwater) on baseflow:

10. Gauging stations at B5H002 and B7H009 need to be reopened to measure flows upstream and downstream of the dolomites to quantify the contribution from the dolomite aquifer system; and
11. The gauging station at B7H027 (Havercroft weir) needs to be monitored to determine the flows upstream of B71F and –G where the Olifants flows over dolomites possible (i.e. transmission loses/recharge to the groundwater system).

In the Letaba and Shingwedzi Systems, the recently updated Kruger National Park Hydrological Monitoring Programme (DWS, 2014) represents probably the most recently updated area where a monitoring programme is conducted on a scientific and planned basis.
The groundwater quality data is limited to once-off analyses taken over a period of several decades which could give a skew background of the groundwater hydrochemistry characteristics. The time series data from the National Groundwater Quality Monitoring Programme (ZQM Stations) could be used to establish long-term water quality trends.

High-level studies to address specific aspects of the hydrogeological regime of the study area is required and will be listed in the recommendations section of this report.

3.2 Data coverage

The available groundwater source data has been captured by previous study teams and reworked several times – unfortunately high-level input attributes such as the actual groundwater use figures are still based on assumptions using dated input values.

The WARMS dataset is a great help, but the actual water use figures need to be verified according to the water license conditions. It is therefore not the purpose of this study to perform another round of water balance assessments and evaluations, but rather present a summary of the findings (as discussed is Section 2 above).

It is, however, required that a verification process for those QC's identified as categories D to F (i.e. Largely, Seriously and critically).

4. HYDROGEOLOGICAL BACKGROUND

This section is a summary of the geological and hydrogeological settings and characteristics contained in the literature and presented as a review only. For detail, the reader is referred to the following reports:

1. 2006: Letaba Catchment Reserve Determination Study – Groundwater Report (Report: RDM/B800/02/CON/COMP/0504, by WSM, for the Letaba WMA; and
2. 2009: Olifants River Water Management Area: Groundwater Assessment (AG–R–2009-05-20 by the Ages Group for SSI Engineers and Environmental Consultants).

4.1 Geology

The geology of the study area represents the basis for the aquifer types as well as mining activities for gold (Murchison Sequence) base metals (Rustenburg Layered Suite), coal (Ecca Group), and alkali base metals (Phalaborwa Alkaline Complex).

The important geology formations and features are discussed in detail in the following reports:

1. 2006: Letaba Catchment Reserve Determination – Groundwater Report by WSM describes the geology as follows:
   1. Goudplaats and Makhutsi Gneiss consisting of grey biotite gneiss and migmatite. The gneisses form the Lowveld valley in the east and underlay >50% of the Letaba WMA;
   2. Murchison Sequence – north (an east\north-east trending linear schist belt consisting of greenstone formations preserved in the basement gneisses) consisting of three occurrences in the catchment, (i) Giyani Group (variety of volcano-sedimentary rocks), (ii) Gravelotte Group (links to the Olifants WMA), (iii) the Pietersburg Group (metamorphic rocks), and (iv) the Rooiwater Complex (as described below linked to the Gravelotte Group);
   3. Bandelierskop Complex (highly metamorphosed unit infolded in to the basement gneisses);
   4. Transvaal Group – Wolkberg Group (quartzites, shale and basalt);
   5. Karoo Supergroup – consisting of (i) Letaba Formation (basalts) which shields most of the eastern parts of the Letaba WMA overlying (ii) the Tshipise Formation (aeolian sandstone) occurring on the western margin of the basalts, and on the eastern boundary of the catchment, (iii) the Tshokwane and Jozini Formations (granophyre and rhyolite respectively) forming the catchment boundary (high land area).

2. 2009: Groundwater Reserve Determination by SRK Consulting (Olifants WMA) includes a well-defined summary of the geological formations which comprises of multiplicity of formations and ages. A short summary of the geology is as follows (oldest to youngest) and a tabulated summary is listed in **Figure 1** below (*viz*.**Table 2** of the SRK 2009 Report):

   1. Basement gneisses, comprising the Goudplaats and Makhutsi Gneiss representing the southern part of the basement gneisses.

2. Murchison Sequence – south(an east\north-east trending linear schist belt consisting of greenstone formations) comprises the Gravelotte Group (volcano-sedimentary sequence, folded and metamorphosed to green schist facies) and Rooiwater Igneous Complex (layered intrusive gabbro norites, magnetite seams, and diorite);

3. Basement Granites – a number of granite suites have intruded the basement gneisses and include the following (i) Nelspruit Suite, (ii) Voster Granite, and (iii) Moshimole Suite;

4. Transvaal Supergroup – outcrops in three main areas, namely: along the Drakensburg Mountain Range (escarpment), in the Delmas area, and west of Groblersdal and Marble Hall. The sequence is divided into the following groups: (i) Wolksburg Group (clastic sediments, and andesitic lavas), (ii) Chuniespoort Group (alternating layers of dolomitic, banded iron formation and chert), (iii) Pretoria Group (thick sequence of interlayered shale, lavas and quartzites), and (iv) Rooiberg Group (feldspathic quartzites, arkose and shales with interbeddedrhyolites);

5. Bushveld Complex – a massive layered igneous complex (Rustenburg Layered Suite consisting of intrusive ultramafic rocks, overlain by the Rashoop Granophyre Suite (acidic rocks) and Lebowa Granite;

6. Karoo Supergroup outcrops in the Witbank, Kriel and Hendrina areas, the Springbok Flats area, and within the north eastern portion of the WMA situated in the Kruger National Park. This sedimentary sequence is capped by a basaltic lava and comprises the following groups: (i) Dwyka Formation (glacial tillite), (ii) Ecca Group (shales and sandstone layers and coal deposits); (iii) Irrigasie Formation (sandstone, shales and mudstones) (iv) Clarens Formation (sandstone, grit and mudstone), and (v) Letaba Formation (basaltic cap lava);

Lithostratigraphic unit		Era	Characteristics	Hydrogeological Significance
Intrusions and extrusions			Dolerites, gabbros, pyroxenite, dunite and syenite	Structural features are important for siting of boreholes
Quaternary Deposits		Cenozoic	Clayey silts to gravels	High yielding, recharge from streams.
Karoo Supergroup	Letaba Formation	Palaeozoic	Basalt	Moderate yielding aquifer, structural feature usually higher yielding.
	Clarens Formation		Sandstone, grit and mudstone	
	Irrigasie Formation		Sandstone, shales and mudstones	
	Ecca Group		Shales, sandstone and coal deposits	
	Dwyka Formation		Tillite	
Waterberg Group		Paleo –proterozoic (Mokolian)	Sandstone and quartzites	Moderate to highly jointed, but produce unreliable groundwater sources.
Bushveld Complex	Lebowa Granite Suite	Paleo –proterozoic (Vaalian)	Granite	Shallow weathering, <10m. Poor borehole yields
	Rashoop Granophyre Suite		Granophyre, quartz porphery,	
	Rustenburg Layered Suite		Mafic intrusive, eg. Norites, gabbros, anorthosites.	Deep weathering which stores water and recharges underlying aquifer.
Transvaal Supergroup	Rooiberg Group	Vaalian	Rhyolites, quartzites and conglomerate	Felsites – resistant to weathering. Groundwater associated with lineaments
	Pretoria group		Shales, lavas,quartzite	Fairly high yielding particularly along lineaments
	Chuniespoort group		Dolomite and chert	High yield potential, important aquifer
	Wolksburg group		Quartzites, lavas and shales	Fairly, high yielding particularly along lineaments
Basement Gneisses and Granites	Moshimole Suite	Radian and Swazian	Gneisses and granites	Limited. Lithological contacts, faults, folds and dykes within unit that could be exploited
	Vorster Grainte Suite			
	Nelspruit Suite			
	Murchison Sequence			
	Goudplaats and Makhutsi Gneissess			

Figure 1: Stratigraphy of the Olifants WMA (SRK, 2009)

1. Intrusions and extrusions – These include dykes and sills which are prevalent particularly in the central regions. These generally trend in a north easterly direction but occasionally have a perpendicular orientation. Some of the intrusive complexes that are younger than the Bushveld are (i) Timbavati Gabbro, (ii) Phalaborwa alkaline complex, and (iii)- Spitshoop Complex.

2. 2009: Groundwater Assessment by the Ages Group (Olifants catchment) provides a brief summary of the geology in the Olifants catchment:

“The entire region is underlain by fractured hard rock aquifers developed in secondary features associated with weathering pockets, structures (fracturing, jointing and faulting) and, in dolomite areas, karst features (have developed representing significant aquifer systems). Structural and karst features are important because higher borehole yields are generally associated with these features. The most abundant groundwater resources are associated with the dolomite aquifer, especially around the Delmas area. The dolomite of the escarpment area is not developed and significant development potential is likely to be associated with the dolomite in this area".

Several younger granite intrusions of Randium to Vaalian ages have intruded the basement complexes.

Secondary geological features have a significant high presence in the study area and is consists of a wide range of (i) structural features (trust faulting, folding, fracturing and normal faulting) and (ii) younger dyke-like intrusives (diabase, dolerite, etc.). These features are quite abundant and several (20 to 30) occurrences have been mapped per quaternary catchment (e.g. Letaba WMA).

In the central part of the study area, i.e. Steelpoort, Motse and Blyde Rivers' catchments, regional geological features mapped as Karoo Dolerite dykes and aeromagnetic lineaments occurs.

Quaternary Deposits – alluvial clayey silts, sand, river terrace and gravels are present along most major rivers, such as the Olifants River (alluvium deposits below the Flag Boshielo Dam), and Letaba River (sand and gravel originating from the upstream basement gneiss).

4.2 Important Hydrogeological Aspects

The hydrogeology, based on the aquifer types and borehole yield classification is illustrated in **Figure 2** below.

In the Letaba WMA, the rock formations can be classified as (i) crystalline igneous (granites) and (ii) metamorphic basement (gneisses); thus the aquifer type (intergranular and fractured) are "*predominantly secondary or fractured"* with yields varying in the low to moderate ranges (i.e. 0.5 to 2.0 l/s).

In the Olifants catchment, the rock formations can be classified as (i) crystalline igneous (gabbro, norite, granites, rhyolite, granophyre, and felsite) (ii) sedimentary (clastic shales, mudrock& sandstones, arenites, quartzites and lava), and (iii) chemical precipitates (dolomite and chert). The aquifer tyoes are (i) Intergranular and Fractured (BYC from insignificant to significant, 0.0 to >5.0 l/s), (ii) Karst (BYC from high to significant, 2.0 to >5.0 l/s), and (iii) Fractured (BYC from low to significant, 0.1 to >5.0 l/s).

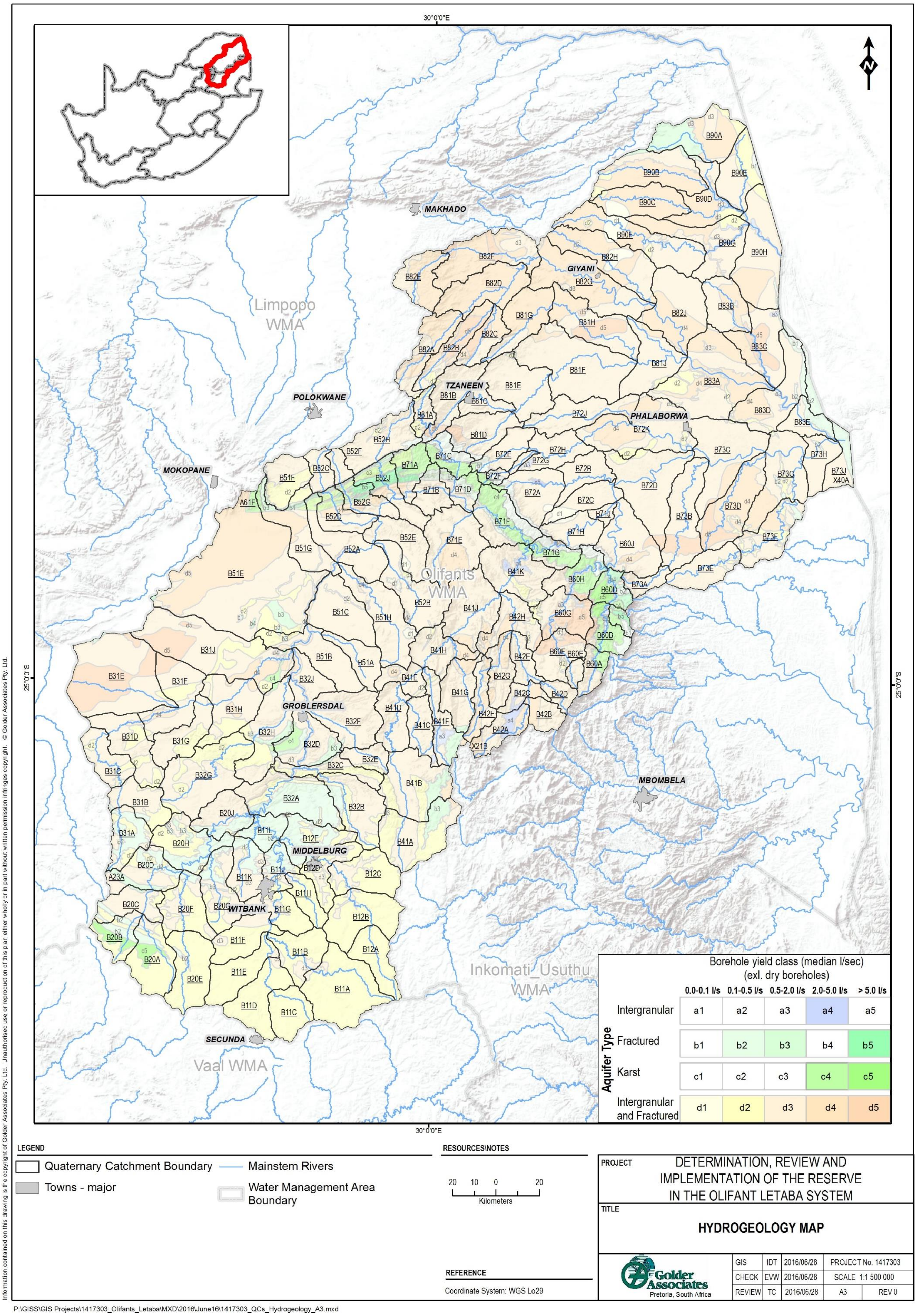

Figure 2: The borehole yield classification in the study area

Intergranular aquifers, consisting of semi to unconsolidated media of primary porosity nature, occurs in the lower parts of the major drainages on the (i) Lowveld rivers on the Letaba basalts in the NKP (i.e. Shingwedzi, Tsende, Letaba, and Olifants Rivers), (ii) Wolkberg Escarpment (Blyde, Ohrigstad, and Mohlapitse Rivers), (iii) Eastern Bankeveld (Steelpoort and Motse Rivers), and (iv) Eastern Bushveld Complex (a section of the Olifants River between Flag Boshielo Dam and the discharge area of QC B52A).

The interaction between the surface and groundwater components of the water resources in the study area have been addressed based on assessments of the water balances of each quaternary catchments (WSM, SRK, AGES Group and WSMLeshika in 2006, 2009, 2009, and 2014 respectively). These assessments are not always converging towards the same order of figures for example for the groundwater component of baseflow, nor the so-called groundwater reserve allocation for a specific quaternary catchment. Authenticated values for surface water-groundwater interaction is not well understood in the Olifants–Letaba System River Catchment and should be based on representative baseflow monitoring programmes.

4.3 Groundwater Reserve

This assessment of the groundwater component of the reserve will be based on the research that has been done in the past and discussed to some detail above and will focus on (i) groundwater quality trends/status, (ii) groundwater quantification (allocable volumes), and (iii) potential impact(s) on the surface water component as an indicator for the ecological requirement status.

5. PRIORITISED QUATERNARY CATCHMENTS

5.1 Integrated Units of Assessment/Groundwater Management Units

The status of classification of the groundwater resources into IUAs and/or groundwater management units at this stage of the project is not viable due to the fact that such classification has been done in the past (viz. the SRK 2009 and WSM 2006 studies). It was noted by users (i.e. Governmental Regulators) of the existing groundwater reserve dataset that this action tends to complicate the actual application of the calculated data and that in several cases the data can't be applied as guidance for supporting/guiding local assessments.

The assessment results are there strictly compiled up to quaternary catchment level based on the tabulated datasets available and scrutinising between the different study results.

5.2 Groundwater quality

For the Olifants catchment, the SRK (SRK, 2009) assessment, is significant compilation of the groundwater quality was done based in the following "*Chemical Parameters"*:

3. Total Dissolved Solids (TDS in mg/l);
4. Nitrate (NO3 as N in mg/l);
5. Sulphate (SO_4 in mg/l); and
6. Fluoride (F in mg/l).

Changes in groundwater quality under natural conditions response on a rather long-term cycle and is generally observed after several months, even years. The important aspect is that any abnormal pollutant will "enrich" on a local scale in an aquifer system before the hydraulic migration starts according to the natural groundwater flow pattern. Resetting the pollution once a migrating plume has mobilised is complicated and in many cases, depending on the hydrogeological characteristics of the aquifer system, impossible to remediate.

The discussion on the groundwater quality in terms of setting a threshold on specific hydrochemical constituents for the groundwater component of the water resources reserve in the Olifants – Letaba System, will be based on groundwater quality assessments done by study teams in the last decade (say 2006 to 2016). The SRK study produced a good assessment of the groundwater quality in the Olifants catchment but, unfortunately, groundwater quality has not been significantly assessed in Letaba and Shingwedzi Catchments and will have to be based on the NGA dataset and the DWS NGwQlMP.

Potential groundwater contamination sites have been mapped by SRK (SRK, 2009) and consists of (i) agricultural practices (i.e. nitrates, phosphates and salinity: fertilizers and pesticides required for cultivated land, and feedlots for livestock), (ii) sanitation management (i.e. poor application of pit latrine systems in formal and informal settlements), (iii) mining and power stations (viz. active and inactive mines for coal, rare metals, gold and stone quarries and associated waste sites incl.

pollution control dams, tailings dams). Several quarries in the study area have been mapped where "*groundwater"* is actually discharging into local surface water drainages, (iv) waste disposal and land fill sites (mostly General Waste-Commercial Land Fill-Insignificant Leachate Produced), but most power station sites are classified as "Hazardous Waste with Hazard Rating – III to IV), (v) Waste Water Treatment Works (WWTW) and Sewage Treatment Works (STW) are a concern as the land use assessment done for this study indicated that "*treated water*" are discharged into local surface water drainages.

The discussion on the groundwater quality in terms of setting a threshold on specific hydrochemical constituents for the groundwater component of the water resources reserve in the Olifants – Letaba System, will be based on groundwater quality assessments done by study teams in the last decade (say 2006 to 2016). The SRK study produced a good assessment of the groundwater quality in the Olifants WMA but, unfortunately, groundwater quality has not been significantly assessed in Letaba and Shingwedzi Catchments and will have to be based on the NGA dataset and the Department of Water and Sanitation's NGwQIMP.

The results from two of DWS's NGwQIMP sites are illustrated in **Figure 3** (Station ZQMTZN2) and **Figure 4** (Station ZQMTSH2) below and portray the concern of nitrate pollution. In the case of the groundwater quality in terms of ensuring that a usable reserve is protected, the nitrate concentration level is slightly increasing over the monitoring period. Unfortunately, a "modern" (<2006) update of the groundwater quality of the total study area, is not available. The EC-values for the respective period in ZQMTZN2 and ZQMTSH2, 1997 to 2014 and 1997 to 2015, respectively, increased from 16.4 to 20.0 mS/m and 132 to 170 mS/m respectively – thus indicating virtually no definite trend over ~18 years, except in the case of ZQMTSH2, which since 2006 has increased from 130 to 170 mS/m. The pH-values for the same period has stayed within the measurable ranges, i.e. ~7.0 to ~7.8 (ZQMTZN2) and ~8.1 to ~8.5 (ZQMTSH2). Close inspection of the graphs in **Figure 3** and **Figure 4** illustrates for example the slight positive trend in the Na (sodium) and CL (chloride) concentration levels which in addition to NO_3–N (nitrate) indicates a small, but constant positive trend in the case of ZQMTZN2 and sporadic, high positive trend in the case of ZQMTSH2. This phenomenon indicates a decreasing water quality condition at these two sites. The coverage of the NGwQIMP sites is illustrated in **Figure 5**.

The SRK study (SRK, 2009) referenced "pre-1980" water quality data which is probably not a representative time frame as a reference status for the study area considering the significant mining, agricultural and industrial developments that have taken place in the last 2 decades in the study area – and in addition, acknowledge the impact of a changing groundwater recharge mechanism due to land surface conditions (viz. de-vegetating) and climate variations.

Nitrate pollution of the groundwater resources in the study area is becoming a serious conditions in terms of its health related risk to infants. In the Letaba catchment, the concentration levels of nitrate is generally low (viz. ~0.65 mg/l NO_3-N in 1997), but has also increased to 1.11 mg/l in 2015. 20% of the local groundwater resources in the Giyani area (QC B82G) have elevated nitrate levels and poses a health risk. It has been noted that long-term, background nitrate increases occurs over large areas, as for example indicated in **Figure 3** below.

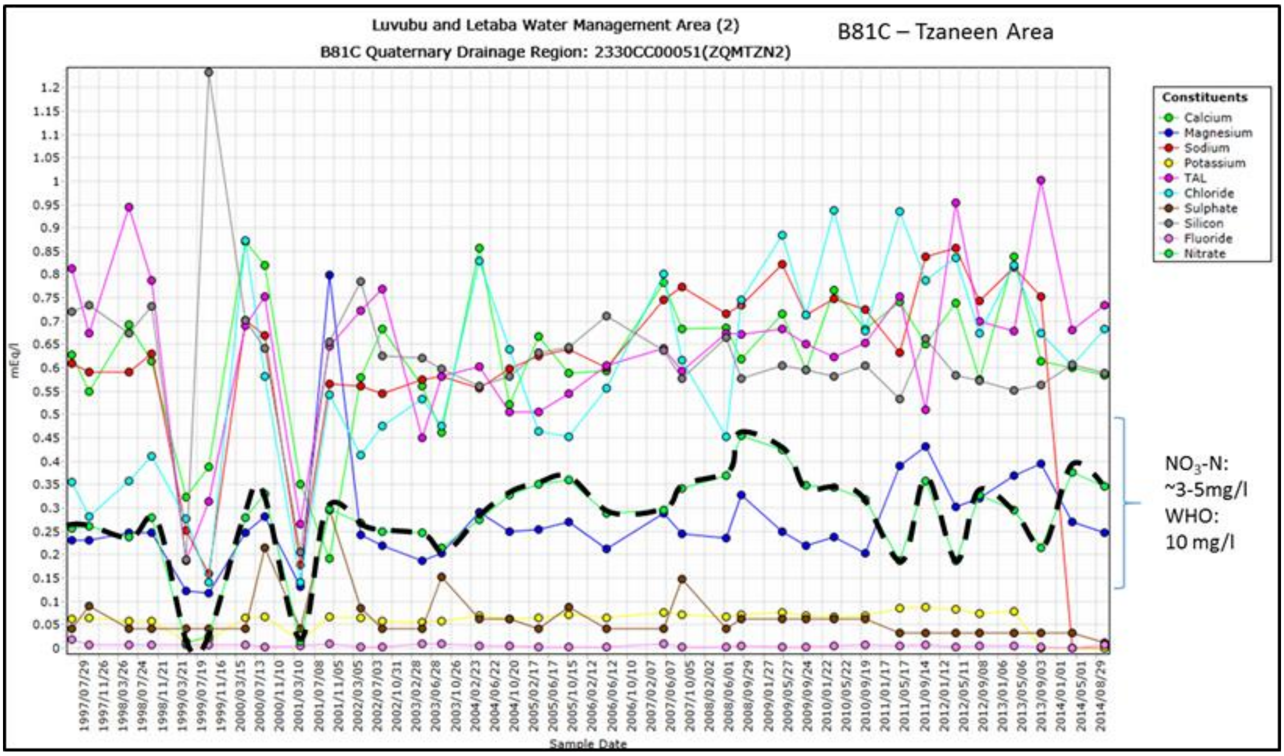

Figure 3: Raw hydrochemical analysis data from DWS's NGwQlMP in QC B81C high-lighting the nitrate values (NO3-N, meq/l).

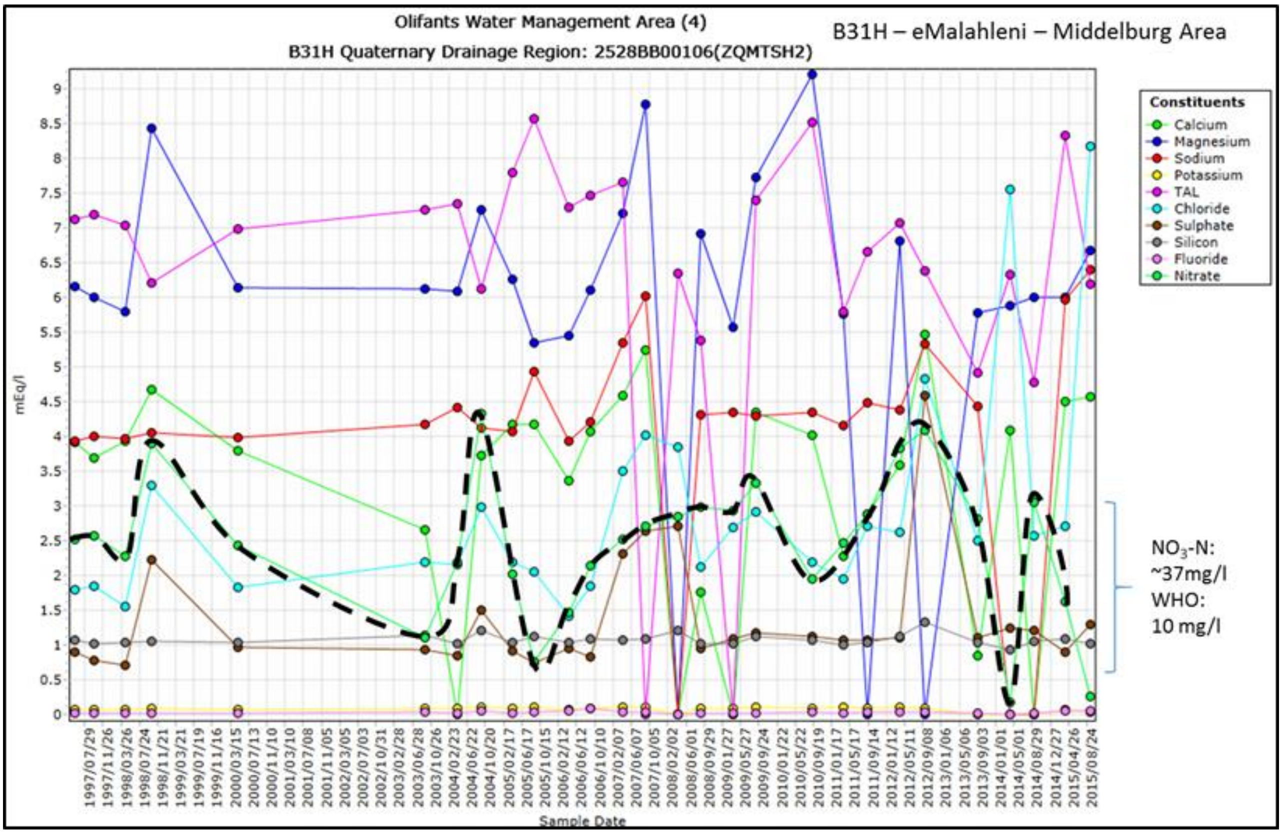

Figure 4: Raw hydrochemical analysis data from DWS's NGwQlMP in QC B31H high-lighting the nitrate values (NO3-N, meq/l).

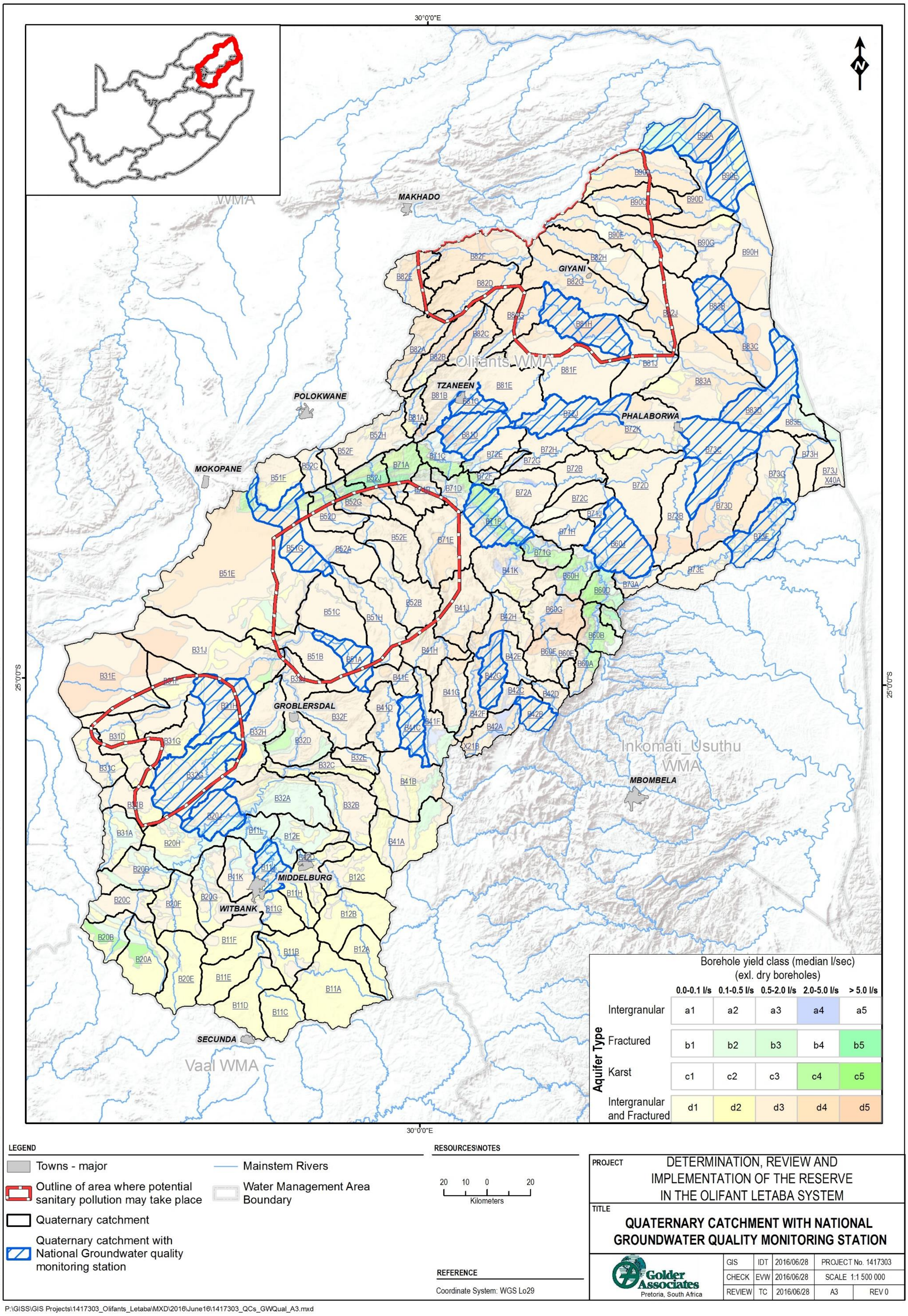

Figure 5: Quaternaries where long-term groundwater quality monitoring is taking place

The largest occurrence of elevated nitrate concentrations occur in the Olifants catchment. For example, the monitoring site in QC B31H (Upper Elands River) area, a rural settlement/agricultural area has elevated nitrate values (from 1997 to 2015:~37 mg/l NO_3-N). Although regarded as "historical values", i.e. pre 1980's (SRK, 2009) elevated nitrate concentrations (viz. >20 mg/l NO_3-N) in the Springbok Flats (viz. QC's B31B, B31J and B51E) has been noted.

To conclude, areas where land use activities (specifically sanitation) could in the long-term impact on the groundwater quality, are indicated as per legend. This will affect the water quality reserve requirements/specifications in terms of microbial and nitrate concentrations. In many cases, groundwater is the sole-source supply and treatment facilities on this scale would be difficult. In addition, the other land use activities, as indicated above, i.e. mining, large scale agricultural practises, waste sites, and discharges from water treatment works are more localised and will be addressed in tabular format.

5.3 Groundwater Quantity and Impacts on Ecological Requirements

The quantification of the groundwater quantity component of the reserve is based on the assessment done by previous studies and will be summarised in a tabular format below. Limited field work were done in the lower Letaba and Shingwedzi Rivers (most KNP area) and focussed on the interaction between surface water and groundwater resources and wetlands (specifically along the Nshawu Vleiland System).

One of the most basic hydrological datasets required for the assessment of the groundwater quantity component, is through long-term (viz. time series) aquifer saturation levels which are not frequently available in the study area. However, a recent upgrade of the groundwater level monitoring programme in the KNP by DWS have produced a set of good, long-term water level data of which examples is illustrated in **Figure 6** and **Figure 7** below.

The time series water level charts portrays the aquifer saturation levels in an area where the utilisation of groundwater is low; thus according the water resource quantification category, insignificantly impacted. One of the water level time series (viz. Baanbreker) shown in **Figure 6**, illustrates the effect of over abstraction on local scale which was corrected by stopping the abstraction and the aquifer saturation levels returned to the normal background response.

In terms of specifying the water resource reserve based on these water level time series data, one could for example use the Baanbreker case and specify a maximum operational water level depth of -9 m.

In terms of assessing groundwater as the driver of wetlands in the Nshawu Vleiland System, the time series water level chart of monitoring site Shawu No 5 indicates a water level depth which is most of the time below 2 mbgl. However, isolated waterholes, such as the one portrayed in Error!

Reference source not found. below, deepened by elephants for example, may intercept the groundwater table and allow groundwater supporting a local wetland system.

To conclude, long-term groundwater level datasets are therefore required in the study area to specify operational levels for aquifer systems to secure a sustainable supply to meet the groundwater component of the reserve, *viz*. BHN and allowing effective groundwater baseflow support.

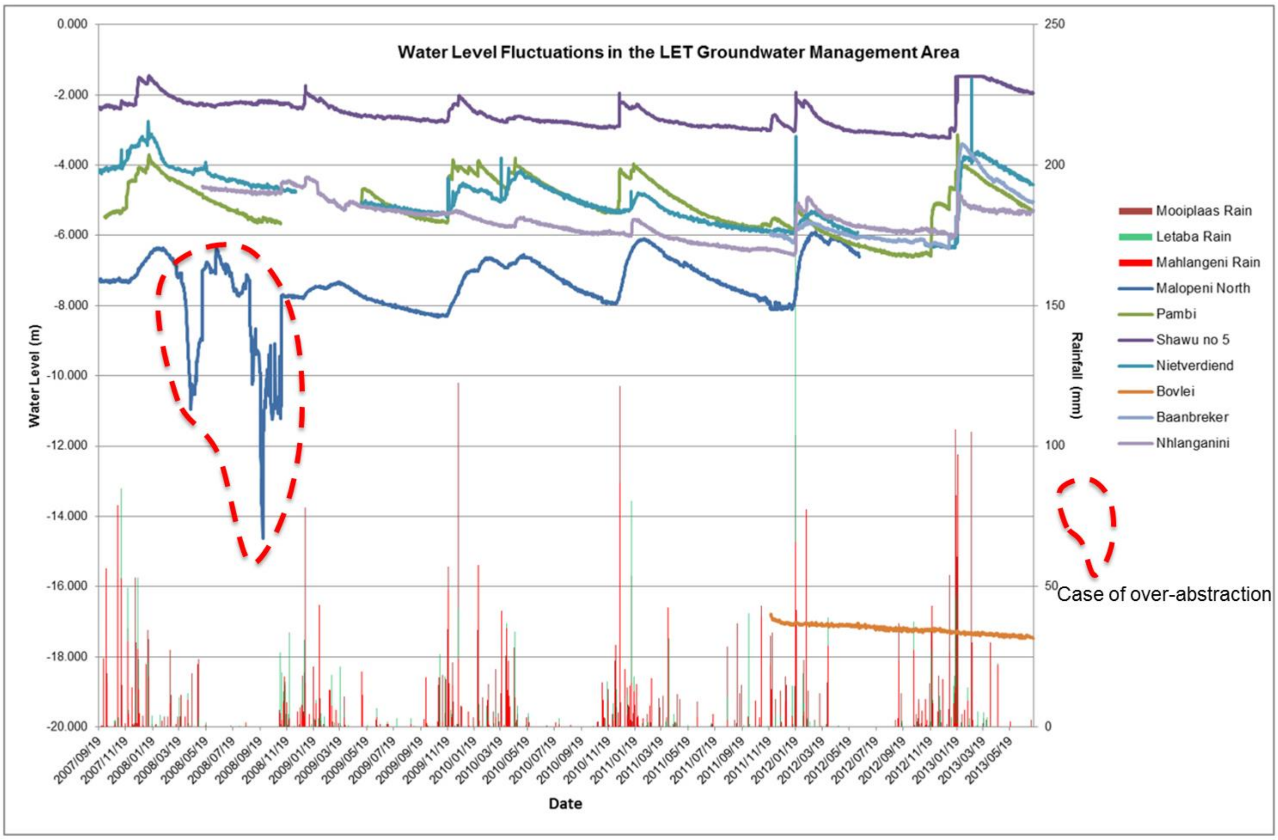

Figure 6: Groundwater level time series dataset for Lower Letaba River area

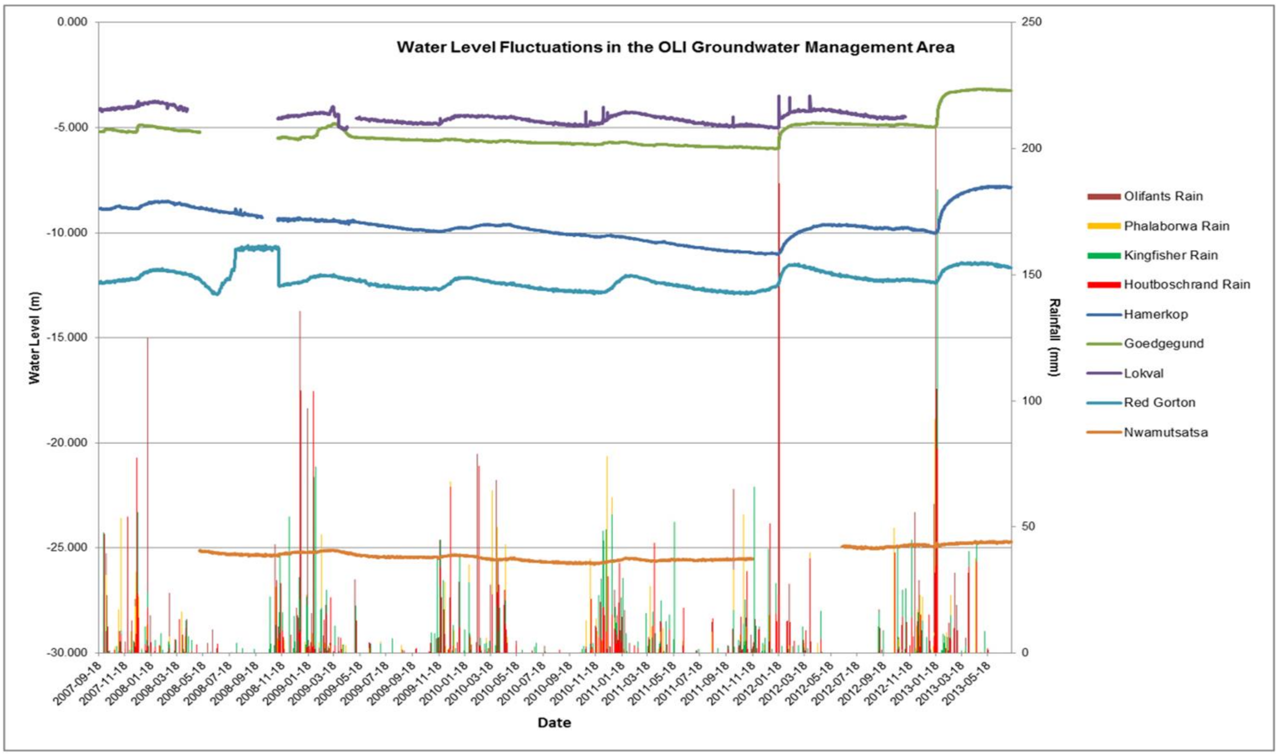

Figure 7: Groundwater level for the Olifants River WMA, Lowveld Area.

Figure 8: A "waterhole" in the Nshawu River Vleiland System, Kruger National Park, probably driven by a shallow groundwater table.

The different prioritised categories is illustrated in **Figure 8** below. The illustration also indicates those quaternary catchments where groundwater is supporting the surface water component through groundwater dependant baseflow discharges. Obviously, the allocable groundwater "reserve" in these quaternary should be protected). The level of surface water dependence when groundwater is abstracted from the larger part of the quaternary catchment is based on the following category rating (WSM, 2006):

1. Insignificant (indicated as "Negligible" on figure): (<1% baseflow reduction);
2. Low (grey areas on figure): <10% baseflow reduction);
3. Moderate: 10% to 30% baseflow reduction; and
4. High: >30% baseflow reduction.

A summary of the prioritised QC's in the Olifants– Letaba System is listed in **Table 1** below. Those quaternary catchments where dolomite aquifer systems are present is indicated, DLMT.

Table 1: Listing of priority quaternary catchment in terms of setting a groundwater component of the water resource reserve

Quaternary Catchment.	Status utilisation (SRK, 2009 and Ages Group, 2009)	Preliminary Groundwater Reserve Allocation (MCM/a) (WSMLeshika, 2014)	Supporting groundwater baseflow
B11F	High/Over (SI>1.0)	1.08[1]	Insignificant/negligible
B11G	Moderately (SI <0.65)	1.17[1]	Insignificant/negligible
B11J	Insignificant (SI <0.30 – 0.10)	0.00	Moderate
B11K	High/Over (SI >1.0)	2.25[1]	Moderate
B11L	Insignificant (SI <0.30 – 0.10)	1.21	Moderately
B12D	High/Over (SI >1.0)	0.00	Insignificant/negligible
B12E	Insignificant (SI <0.30 – 0.10)	2.21	Moderate
B20A (DLMT)	High/Over (SI >1.0)	0.00	High
B20B (DLMT)	High/Over (SI >1.0)	0.00	High
B20C	Insignificant (SI <0.30 – 0.10)	1.59	High
B20D	Insignificant (SI <0.30 – 0.10)	1.70	Moderate
B20E	Moderately (SI <0.65)	0.00	Moderate
B20F	Insignificant (SI <0.30 – 0.10)	2.62	Moderate
B20G	Insignificant (SI <0.30 – 0.10)	1.04	Moderate
B20H	Moderately (SI <0.65)	0.87	Moderate
B20J	Insignificant (SI <0.30 – 0.10)	1.14	Moderate
B31A	Moderately (SI <0.65)	0.00	Insignificant/negligible
B31C	Heavily (SI 0.65 – 1.00)	1.59[1]	Insignificant/negligible
B31D	High/Over (SI >1.0)	1.19[1]	Insignificant/negligible

Quaternary Catchment.	Status utilisation (SRK, 2009 and Ages Group, 2009)	Preliminary Groundwater Reserve Allocation (MCM/a) (WSMLeshika, 2014)	Supporting groundwater baseflow
B31G	Moderately (SI <0.65)	0.95	Insignificant/negligible
B31F	Moderately (SI <0.65)	1.59[1]	Insignificant/negligible
B32A	Insignificant (SI <0.30 – 0.10)	4.36	Moderate
B32B	Insignificant (SI <0.30 – 0.10)	3.59	Moderate
B32C	Insignificant (SI <0.30)[1]	0.00	Moderate
B32F	Moderately (SI <0.65)	0.00	Insignificant/negligible
B32G	Moderately (SI <0.65)	0.07	Insignificant/negligible
B32F	Moderately (SI <0.65)	0.00	Insignificant/negligible
B32J	Moderately (SI <0.65)	0.00	Insignificant/negligible
B41A	Insignificant (SI <0.30 – 0.10)	3.47	Moderate
B41B	Insignificant (SI <0.30 – 0.10)	2.45	Moderate
B41C	High/Over (SI >1.0)	0.90	Insignificant/negligible
B41D	Insignificant (SI <0.30 – 0.10)	0.59	Moderate
B41F	Insignificant (SI <0.30 – 0.10)	1.03	High
B41G	Moderately (SI <0.65)	0.88	High
B41J	Moderately (SI <0.65)	3.26[1]	Insignificant/negligible
B42A	Insignificant (SI <0.30 – 0.10)	0.00	High
B42B	Insignificant (SI <0.30 – 0.10)	1.29	High
B42D	Insignificant (SI <0.30 – 0.10)	0.99	High
B51A	Moderately (SI <0.65)	1.76	Insignificant/negligible
B51E	Heavily (SI 0.65 – 1.00)	0.00	Insignificant/negligible
B51F	Insignificant (SI <0.30 – 0.10)	0.00	Insignificant/negligible
B51G	Heavily (SI 0.65 – 1.00)	0.00	Insignificant/negligible
B52A	Moderately (SI <0.65)	1.82	Insignificant/negligible
B52B	Moderately (SI <0.65)	3.94[1]	Insignificant/negligible
B52C	Moderately (SI <0.65)	0.58	Insignificant/negligible
B52D	Moderately (SI <0.65)	0.17	Insignificant/negligible
B52H	Heavily (SI 0.65 – 1.00)	1.95	Insignificant/negligible
B60A	Insignificant (SI <0.30 – 0.10)	2.23	Insignificant/negligible
B60B	Insignificant (SI <0.30 – 0.10)	3.83	Insignificant/negligible
B60C	Insignificant (SI <0.30 – 0.10)	0.97	Insignificant/negligible
B60D	Insignificant (SI <0.30 – 0.10)	2.52	Insignificant/negligible
B60E	High/Over (SI >1.0)	1.00[1]	High
B60F	Moderately (SI <0.65)	0.00	Moderate

Quaternary Catchment.	Status utilisation (SRK, 2009 and Ages Group, 2009)	Preliminary Groundwater Reserve Allocation (MCM/a) (WSMLeshika, 2014)	Supporting groundwater baseflow
B60G	Moderately (SI <0.65)	0.00	Moderate
B60H	Insignificant (SI <0.30 – 0.10)	0.00	Insignificant/negligible
B60J	Insignificant (SI <0.30 – 0.10)	5.21	Moderate
B71B	Heavily (SI 0.65 – 1.00)	1.85	Insignificant/negligible
B71C	Insignificant (SI <0.30 – 0.10)	3.78	High
B71D	Moderately (SI <0.65)	1.77	High
B71E	High/Over (SI >1.0)	3.90[1]	Moderate
B71F	Insignificant (SI <0.30 – 0.10)	3.84	High
B71G	Insignificant (SI <0.30 – 0.10)	2.87	High
B72A	Insignificant (SI <0.30 – 0.10)	0.56	Moderate
B72E	Heavily (SI 0.65 – 1.00)	2.48[1]	Insignificant/negligible
B72F	Heavily (SI 0.65 – 1.00)	1.07	Insignificant/negligible
B72G	Insignificant (SI <0.30 – 0.10)	2.47	Insignificant/negligible
B73A	Heavily (SI 0.65 – 1.00)	1.04	High
B73B	Insignificant (SI <0.30 – 0.10)	0.00	Insignificant/negligible
B73E	High/Over (SI >1.0)	2.16	Insignificant/negligible
B81A	Insignificant (SI <0.30 – 0.10)	2.62	High
B81B	Insignificant (SI <0.30 – 0.10)	16.58[2]	High
B81C	Moderately (SI <0.65)	0.26	High
B81D	Heavily (SI 0.65 – 1.00)	7.12[2]	Moderate
B81E	High/Over (SI >1.0)	2.41	Insignificant/negligible
B81F	Moderately (SI <0.65)	10.47[2]	Insignificant/negligible
B81G	Moderately (SI <0.65)	7.39[2]	Insignificant/negligible
B81H	Moderately (SI <0.65)	6.17[2]	Insignificant/negligible
B82A	Insignificant (SI <0.30 – 0.10)	1.98	
B82B	High/Over (SI >1.0)	0.00	Insignificant/negligible
B82C	High/Over (SI >1.0)	0.00	Insignificant/negligible
B82D	Heavily (SI 0.65 – 1.00)	5.07[2]	Insignificant/negligible

[1] Required detailed assessment.

[2] Calculation of Reserve Allocation to be checked (DWA, 2014).

Table 1 above indicates that 54 of the quaternary catchments assessed have limited (<1 MCM/a) groundwater reserve allocations; thus meaning that all future allocations should be evaluated using a scientific screening process considering the Category A, B and C requirements by the water users for water use license applications. A summary of the water balance on each property where a new water use is required should be required as part of the water use license application. In addition, a groundwater management plan, based on a representative monitoring programme is required.

The table lists those quaternary catchments where groundwater discharging from the aquifer systems is supporting the surface water resources. This level of information should be applied from a GIS perspective when future water use allocations are assessed. Typically, where the proposed groundwater abstraction would be within a certain distance (for argument sake 1000 m) from a perennial stream, a high-level hydrogeological investigation should be conducted.

The general requirement for groundwater monitoring has been highlighted in the previous reports and should be of the standards as illustrated in **Figure 6** and **Figure 7** *above.*

A selection of critically aquifer systems in shown in **Figure 9** from the 2009 Ages Group assessment (Ages, 2009). The main concern in these aquifer units is over abstraction, however, in the case of the "*Upper Olifants Coal Area*" the impact is also on the groundwater quality, and subsequently AMD discharges from mine workings into local surface water streams.

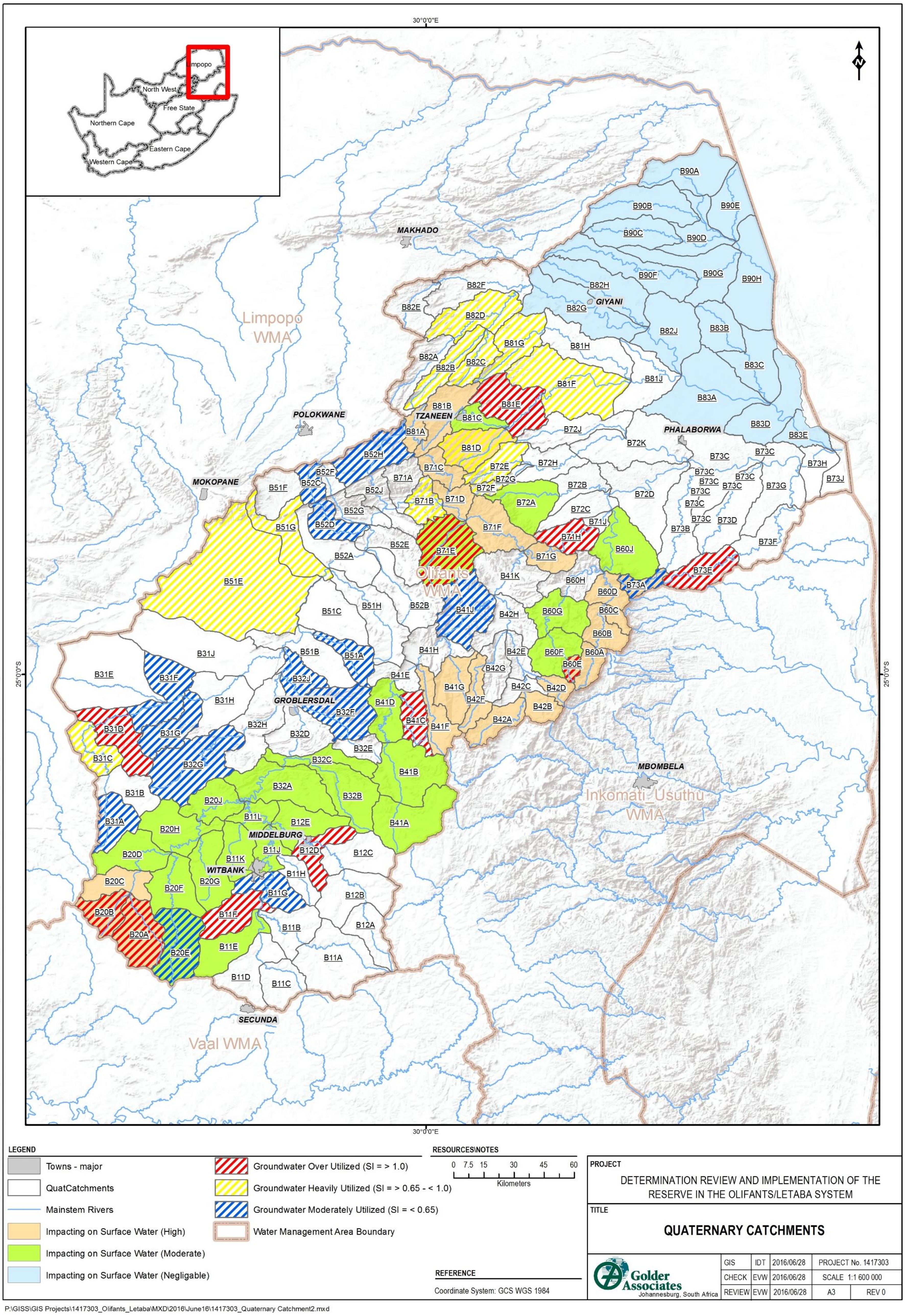

Figure 8: Illustration of thequaternary catchments where the groundwater component of the reserve is categorised according to supporting surface water and utilization.

6. CONCLUSIONS

The following conclusions have relevance:

1. The groundwater quality in the study area varies from Ideal Quality (<450 mg/l TDS) to Marginal Quality (>2 400 mg/l TDS), however elevated/rising nitrate values is a serious concern and could significantly impact on the utilisable portion of the groundwater component of the reserve.

2. The dependence between groundwater and surface water in the study area varies from Insignificant (<1% groundwater baseflow reduction when utilised) to High (>30% groundwater baseflow reduction when utilised).

There are 6 hotspot areas that need immediate intervention (updated based on the selection proposed in the Agres Group, 2009 report):

1. The Delmas Dolomite Aquifer (B20A and B20B) where irrigation in the order of 6 Mm^3/a, is abstracted from a spatially limited aquifer. The risks aresinkhole formation and direct recharge of poorly treated sewer water into the aquifer system.

2. Similar to Delmas is the Zebediela Dolomite Aquifer (B51E and B51G), although over-abstraction is the concern here;

3. The Springbok Flats Karoo Aquifer (B51E) where 10-12 Mm^3/a, is abstracted for irrigation. Historic abstractions were much higher, i.e. 43 MCM/a (estimated aquifer recharge was ~40 MCM/a). The concern here is that abstractions are focussed on specific areas, i.e. not a diffused abstraction pattern;

4. Highveld coal mining area at Witbank-Middelburg-Kriel Karoo Coal Aquifers (B11K, B11J, B11H and B12D) where water quality is more affected than quantity.

5. Steelpoort mining and community water supply aquifer areas (B41J and B41K) where groundwater quantity and quality is affected; and

6. Kruger National Park and Bushbuckridge Catchments (B73J, B73H, and B73F) where groundwater sustains community water and riparian vegetation; and

7. The upper Letaba River catchments (i.e. B81D and –E) where the groundwater baseflow contribution to the lower, downstream QC’s are impacted by surface water abstractions and afforestation.

The groundwater quality in the study area varies significantly; from Ideal/Good in the recharge areas (high relief QC’s) to Marginal throughout the study area. Groundwater quality in certain areas such as the Upper Olifants Coal Area are deteriorating due to AMD development which has a serious impact on the local surface water resources due to interflow decanting into drainages. What is, however, a concern throughout the study area is the steady increase of nitrates in the groundwater and is directly linked to irrigation practices (i.e. The Springbok Flats) and high-density populated areas – three specific areas have been identified where regional nitrate pollution as the result of sanitary practices (pit latrines) are probably the cause. Local groundwater resources in the Giyani Region (QC B82G –Little Letaba River) are significantly impacted by nitrate pollution and the effect is probably irreversible.

To conclude, the previous studies concludes that although certain aquifers in the quaternary catchments are significantly used, the overall groundwater balance in the study area is still significantly high (at least > 100 MCM/a).

From a management perspective, and specifically the groundwater component of the reserve, groundwater is a diffused resource and should be allocated for use in this manner. A positive water balance for a certain quaternary catchment may exists, but over utilisation in certain parts of the quaternary catchment could impact significantly on a local aquifer unit, and for that matter intercepting a surface water resource as well.

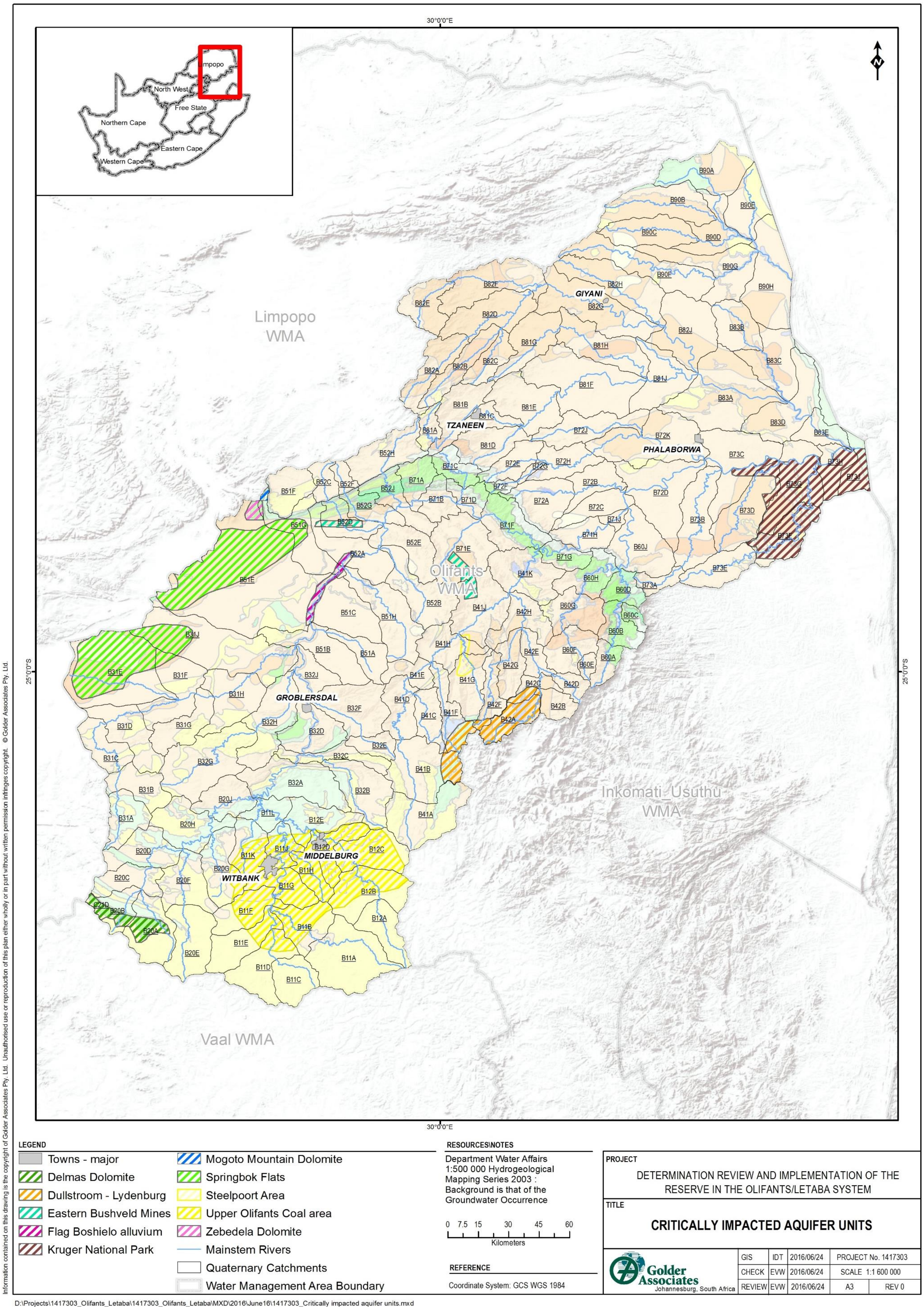

Figure 9: Critically impacted aquifer units (after Ages Group, 2009)

7. RECOMMENDATIONS

The following recommendations have relevance to the study and include those made by previous study teams as well:

1. Implementation of a groundwater accounting system so that the regulatory authority can keep track of the groundwater allocations and surplus or deficits in each quaternary catchment (Ages Group, 2009);

2. A groundwater management plan should be developed for the stressed quaternary catchments. Water users will have to cut back on groundwater volumes used to ensure sustainability of the resources. The groundwater management plans should be developed in co-operation with the local water users associations (Ages Group, 2009);

3. The listed stressed catchments (see **Table 1**) should be reviewed and more detailed water balance models developed to support management protocols;

4. Validation of groundwater use. Although a large dataset is available, the reliability and accuracy of the NGDB and WARMS dataset is limited and incorrect in terms of actual water use locations. The information is not validated before it is entered and errors are promulgated in the co-ordinates, position, and status of the borehole. GRIP type programme should be implemented to address this aspect. Previous studies noted that not all groundwater users are registered on the WARMS database and a catchment scale initiative should be undertaken to register and licence (where required, SRK, 2009);

5. Monitoring: At least 5 regionally representative aquifers should be selected and equipped with automated monitoring systems to verify groundwater recharge volumes. This information can then be used throughout the catchment (Agres Group, 2009).

6. In order to increase the confidence level in calculation of the reserve and allocatable groundwater components for each of the delineated resource units, additional water quality and usage information as well as data specific to recharge calculations and base flow estimates needs to be collected and incorporated with the current findings (SRK, 2009);

7. The impacts relating to opencast and underground mines, decant and generation of acid mine drainage needs to be assessed (SRK, 2009);

8. Groundwater monitoring at heavy industries, feedlots, landfills, cemeteries, waste sites, sewerage and waste water treatment plants etc. needs to be regularly undertaken to quantify the impact arising from these operations (SRK, 2009);

9. Surface water flow and quality records needs to be assessed to exclude discharges into the main streams arising from operations in the catchment and thereafter, hydrograph separation needs to be done to increase confidence in base flow estimates (SRK, 2009, and recommended by WSMLeshika, 2014).

10. Resource quality objectives to be developed near the riparian zones where there is likely impact from farmers abstracting groundwater. Abstraction from boreholes within close proximity of streams need to be regulated so that the groundwater contribution to base flow in the streams is not affected 9SRK, 2009).

11. On the whole, the relationship between surface and groundwater needs to be studied in greater detail and understood so that improved conceptual models are derived and hence improved ecological requirements determined (SRK, 2009);

8. REFERENCES

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Comments and Responses

Page Number and DWS Comment		**Response**
4	Incomplete sentence	The groundwater quality data is limited to once-off analyses taken over a period of several decades which could give a skew background of the groundwater hydrochemistry characteristics. The time series data from the National Groundwater Quality Monitoring Programme (ZQM Stations) could be used to establish long-term water quality trends.
4	Incomplete sentence	
9	Include the pH and EC	The results from two of DWS's NGwQIMP sites are illustrated in Figure 3 (Station ZQMTZN2) and Figure 4 (Station ZQMTSH2) below and portray the concern of nitrate pollution. In the case of the groundwater quality in terms of ensuring that a usable reserve is protected, the nitrate concentration level is slightly increasing over the monitoring period. Unfortunately, a "modern" (<2006) update of the groundwater quality of the total study area, is not available. The EC-values for the respective period in ZQMTZN2 and ZQMTSH2, 1997 to 2014 and 1997 to 2015, respectively, increased from 16.4 to 20.0 mS/m and 132 to 170 mS/m respectively – thus indicating virtually no definite trend over ~18 years, except in the case of ZQMTSH2, which since 2006 has increased from 130 to 170 mS/m. The pH-values for the same period has stayed within the measurable ranges, i.e. ~7.0 to ~7.8 (ZQMTZN2) and ~8.1 to ~8.5 (ZQMTSH2). Close inspection of the graphs in Figure 3 and Figure 4 illustrates for example the slight positive trend in the Na (sodium) and CL (chloride) concentration levels which in addition to NO3–N (nitrate) indicates a small, but constant positive trend in the case of ZQMTZN2 and sporadic, high positive trend in the case of ZQMTSH2. This phenomenon indicates a decreasing water quality condition at these two sites. The coverage of the NGwQIMP sites is illustrated in Figure 5. The SRK study (SRK, 2009) referenced "pre-1980" water quality data which is probably not a representative time frame as a reference status for the study area considering the significant mining, agricultural and industrial developments that have taken place in the last 2 decades in the study area – and in addition, acknowledge the impact of a changing groundwater recharge mechanism due to land surface conditions (viz. de-vegetating) and climate variations.