DETERMINATION OF RESOURCE QUALITY OBJECTIVES IN THE LOWER VAAL WATER MANAGEMENT AREA (WMA10)

WP10535

RESOURCE UNIT PRIORITISATION REPORT

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Bold type indicates this report.

Title: *Resource Unit Prioritisation Report*

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Determination of Resource Quality Objectives in the Lower Vaal Water Management Area (WMA10) - WP10535

Inception Report

Executive Summary

The Resource Quality Objectives (RQOs) determination procedures for the Lower Vaal Water Management Area (WMA) involved the application of the seven step framework established by the Department of Water Affairs in 2011 (DWA, 2011). Although the procedures involve defining the resource, setting a vision, determination of RQOs and Numerical Limits (NLs), gazetting this and then moving to implementation, monitoring and review before starting the process all over again, some of these steps were achieved in the Water Resource Classification (WRC) Study and not repeated in this study. The procedural steps established for this case study to determine RQOs for rivers, groundwater, dams and wetland resources in the WMA include:

- Step 1. Delineate the Integrated Units of Analyses (IUAs) and Resource Units (RUs).
- Step 2. Establish a vision for the catchment and key elements for the IUAs.
- Step 3. Prioritise and select RUs and ecosystems for RQO determination.
- Step 4. Prioritise sub-components for RQO determination, select indicators for monitoring and propose the direction of change.
- Step 5. Develop draft RQOs and NLs.
- Step 6. Agree Resource Units, RQOs and NLs with stakeholders.
- Step 7. Finalise and Gazette RQOs.

Components of steps 1 and 2 were available from the WRC study to which this RQO determination process was aligned. This report documents the prioritisation and selection of RUs and ecosystems for RQO determination in the Lower Vaal WMA (Step 3).

The prioritisation process resulted in the selection of the number of resources as indicated in Table 1, for each IUA, for which sub-components and indicators would be selected in Step 4:

Table 1: Summary of results of the prioritisation process for the Lower Vaal WMA

IUA	Rivers	Wetlands	Dams	Groundwater
Total	5	8	6	10
LA1		4		2
LA2	1		1	1
LA3		1		1
LA4	2	1	2	1
LB	2	2	3	4

Determination of Resource Quality Objectives in the Lower Vaal Water Management Area (WMA10) - WP10535

Resource Unit Prioritisation Report

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ABBREVIATIONS

Acronym	Meaning
Al	Aluminium
As	Arsenic
$CaCO_3$	Calcium Carbonate
Cd	Cadmium
Chl-a	Chlorophyll a
Cl	Chlorine
Cr(VI)	Hexavalent chromium
Cu	Copper
DOC	Dissolved organic carbon
DRM	Desktop Reserve Model
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
F	Fluorine
FEPA	Freshwater Ecosystem Priority Areas
FRAI	Fish Response Assessment Index
GIS	Geographical Information Science
Hg	Mercury
g/l	Micrograms per litre
IBA	Important Bird Areas
IRHI	Index of Reservoir Habitat Impairment
IUA	Integrated Unit of Analysis
IWRM	Integrated Water Resource Management
IWRMP	Integrated Water Resources Management Plan
KNP	Kruger National Park
m^3/s	Cubic meters per meter (cumecs)
MAR	Mean Annual Runoff
MC	Management Class
mg/l	Milligrams per litre
MIRAI	Macroinvertebrate Response Assessment Index
Mn	Manganese
NFEPA	National Freshwater Ecosystem Priority Areas
NL	Numerical Limit
NO_2	Nitrite
NO_3	Nitrate
NTU	Turbidity
NWA	National Water Act
NWRS	National Water Resource Strategy
O_2	Oxygen
Pb	Lead

PES	Present Ecological State
pH	power of hydrogen
PO_4	Phosphate
RDM	Resource Directed Measures
REC	Recommended Ecological Category
REC	Recommended ecological category
RHAM	Rapid Habitat Assessment Method
RHP	River Health Programme
RO	Regional Office
RQOs	Resource Quality Objectives
RR	Reporting rates
RU / RUs	Resource Unit/s
RUET	Resource Unit Evaluation Tool
RUPT	Resource Unit Prioritisation Tool
SASS5	South African Scoring System version 5
Se	Selenium
SPI	Specific Pollution sensitivity Index
TDS	Total Dissolved Solids
TIN	Total Inorganic Nitrogen
TPC	Threshold of Probable Concern
VEGRAI	Vegetation Response Assessment Index
VMAR	Virgin Mean Annual Runoff
WE	Water Ecosystems
WMA	Water Management Area
WRC	Water Resource Classification
WWTW	Waste Water Treatment Works
Zn	Zinc

DEFINITION OF PROJECT SPECIFIC ACRONYMS:

EWR – Ecological Water Requirements is synonymous with the ecological component of the Reserve as defined in the Water Act (1998).

IUA – Integrated Unit of Analysis or spatial units that will be defined as significant resources (as prescribed by the NWA).They are finer-scale units aligned to watershed boundaries, in which socio-economic activities are likely to be similar.

MC – The Management Class is set by the WRC and describes the degree of alteration that resources may be subjected to.

REC – Recommended Ecological Category – this is a recommendation purely from the ecological perspective designed to meet a possible future state.

RU – Resource Unit is a stretch of river that is sufficiently ecologically distinct to warrant its own specification of Ecological Water Requirements

WRC – Water Resources Classification is a procedure required by the Water Act 1998 that produces a MC per IUA for all water resources.

Determination of Resource Quality Objectives in the Lower Vaal Water Management Area (WMA10) - WP10535

Resource Unit Prioritisation Report

1 INTRODUCTION

The rationale for requiring RQOs, their components, their applicability and implementation procedures emanate from the National Water Act of South Africa (NWA, 1998). The Water Act (1998) requires that all water resources are protected in order to secure their future and sustainable use. It lays out a plan where each significant water resources (surface water, wetlands, groundwater and estuaries) are classified according to a WRC System. In the process, the Reserve is also determined for the water resource, i.e. the amount of water, and the quality of water, that is required to sustain both the ecosystem and provide for basic human needs. This Reserve then contributes to the Classification of the resource. This classification results in a Management Class and associated RQOs for water resources, which gives direction for future management activities in the WMA. According to the Water Act (NWA, 1998), the purpose of RQOs are to establish clear goals relating to the quality of the relevant water resources and stipulates that in determining RQOs a balance must be sought between the need to protect and sustain water resources and the need to use them (sensu DWA, 2011). Thus the "working part" of the Classification of water resources, is the RQOs that are produced. These are numerical and narrative descriptors of conditions that need to be met in order to achieve the required management scenario as provided during the resource classification. Such descriptors relate to the:

(a) quantity, pattern, timing, water level and assurance of instream flow
(b) water quality including the physical, chemical, and biological characteristics of the water
(c) character and condition of the instream and riparian habitat; and
(d) characteristics, condition and distribution of the aquatic biota (DWA, 2011).

This section of the RQO determination procedure includes the prioritisation and selection of RUs and ecosystems RQO determination in the Lower Vaal WMA (Step 3; DWA, 2011).

Step 3: Prioritise and select RUs and ecosystems for RQO determination

The Water Resource Classification System proposes that RQOs are set for each RU. In reality however, this may not be possible as there may be a large number of RUs within a selected catchment. A rationalisation process is necessary to prioritise and select the most useful RUs for RQO determination. The objective of Step 3 is therefore to prioritise and select preliminary RUs which will then be discussed and agreed with stakeholders during Step 6.

2 SCOPE OF THE STUDY

The study entails the determination of Resource Quality Objectives (RQOs) for all significant water resources (rivers, wetlands, dams (or lakes) and groundwater ecosystems) in the Lower Vaal Water Management Area (WMA). The RQO determination procedure established by DWA (2011) has been implemented to determine RQOs in this case study. The RQO determination procedure is based on a seven step framework including (DWA, 2011;

Figure 1):

- Step 1. Delineate the Integrated Units of Analysis (IUAs) and define the Resource Units (RUs)
- Step 2. Establish a vision for the catchment and key elements for the IUAs
- Step 3. Prioritise and select preliminary Resource Units for RQO determination
- Step 4. Prioritise sub-components for RQO determination, select indicators for monitoring and propose the direction of change
- Step 5. Develop draft RQOs and Numerical Limits
- Step 6. Agree Resource Units, RQOs and Numerical Limits with stakeholders
- Step 7. Finalise and Gazette RQOs

In 2013 the Department of Water Affairs (DWA) completed the Water Resource Classification (WRC) study for the Lower Vaal WMA which included the delineation IUAs and established a vision for the catchment and key elements for the IUAs (DWA, 2012). This resulted in the determination of Management Classes for each IUA and Recommended Ecological Categories (REC) for biophysical nodes selected to represent the riverine ecosystem in the WMA. These outcomes met the IUA delineation requirements for the study and provided the vision information, including Management Classes for the study. As such this study did not duplicate these components but rather adopted the outcomes from the WRC study (DWA, 2012). Apart from these components that were obtained from the WRC study, some developments/adaptations were made to the DWA (2011) RQO determination procedure to the groundwater, wetland and dam components of the study in particular. This report documents the approach adopted and the outcomes of the implementation of Step 3 of the RQO determination procedure (DWA, 2011).

3 METHODOLOGY

3.1 RESOURCE QUALITY OBJECTIVES METHODOLOGY OVERVIEW

The RQO determination procedure established by DWA (2011) has been implemented in the study. This includes the implementation of a seven step procedural framework (

Figure 1), that is repeatable and as such forms allows for an adaptive management cycle with additional steps. Overall the procedure involves defining the resource, setting a vision, determination of RQOs and NLs, gazetting this and then moving to implementation, monitoring and review before starting the process all over again. A summary of the procedural steps established for this case study with some adaptations that were required to include groundwater, dams and wetland resources includes (

Figure 1):

- **Step 1. Delineate the IUAs and RUs:** In this case study IUAs were obtained from the WRC (DWA, 2012) and applied to all water resources considered in the study (rivers, wetlands, dams and groundwater ecosystems). Three spatial levels for resources were considered for RQO determination in this case study including:
    - Regional (IUA) scale assessments were considered for rivers, wetlands and groundwater resources in the study.
    - Resource Unit scale assessments that were aligned to biophysical nodes obtained from the WRC study (DWA, 2012) were considered for river and groundwater resources alone.
    - Ecosystem scale assessments were considered for wetland and dam ecosystems/resources in the study.

  The RU delineation procedure initially involved the identification of sub-quaternary reaches of rivers in the WMA for each biophysical node obtained from the WRC study (DWA, 2012; DWA, 2013a). The RU delineation process then involved amalgamating the upstream associated sub-quaternary reaches of riverine ecosystems, and their associated catchment areas, (DWA, 2013a). As a result, the number of RUs selected for the study is identical to and can later be aligned to the information associated with the biophysical nodes from the WRC study. The delineation procedure for ecosystem scale resource assessment involved the use of Geographical Information System (GIS) spatial ecosystem data. Refer to the delineation report (Step 1) for more information (DWA, 2013a).

- **Step 2. Establish a vision for the catchment and key elements for the IUAs:** The stakeholder requirements and their associated outcomes which includes the Management Classes for IUAs and RECs for RUs from the WRC study were adopted as the vision for this study (DWA, 2012). No further visioning process was appropriate as this could have conflicted with the WRC process. The WRC outcomes were skewed towards river resources in the WMA which necessitated obtaining additional information for the other resources considered in the study (wetlands, dams and groundwater ecosystems). This additional information is highlighted in the reports where applicable.

- **Step 3. Prioritise and select RUs and ecosystems for RQO determination:** Within this case study only 11 IUAs were delineated, as such the RU Prioritisation Tool for rivers (DWA, 2011) was not implemented. Priority RUs were selected during the following step (STEP 4) (DWA, 2013b).

- **Step 4. Prioritise sub-components for RQO determination, select indicators for monitoring and propose the direction of change:** This step included the hosting of a range of specialist workshops for rivers, dams and groundwater resources where RU Evaluation Tools were used to select sub-components for RQO determination, select indicators and propose the direction of change. The RU Evaluation Tools used in this section for wetlands, dams and groundwater were developed for this study. This information could then be used to develop draft RQOs and Numerical Limits in the next step (DWA, 2014). The relevant activities of this step are:

4.1 Identify and assess the impact of current and anticipated future use on water resource components
4.2 Identify requirements of important user groups
4.3 Selection of sub-components for RQO determination
4.4 Establish the desired direction of change for selected sub-components
4.5 Complete the information sheet for the Resource Unit Evaluation Tool.

- **Step 5. Develop draft RQOs and Numerical Limits**: This step is based on the outcomes of the RU and ecosystem prioritisation step (Step 4). From the outcomes of the RU and ecosystem prioritisation step draft RQO were established and then provided to recognised specialists to establish NLs that are generally quantitative descriptors of the different components of the resource such as the water quantity, quality, habitat and biota. These descriptors were designed to give a quantitative measure of the RQOs (DWA, 2011). Although the NLs may have some uncertainty associated with them and were not originally intended for gazetting (DWA, 2011) the will be considered for gazetting in this case study at the request of the Department of Water and Sanitation (DWS) legal services. Consider the RQO and NL reports for more information. The relevant activities of this step are:

5.1 Carry over sub-component and indicator information from the Resource Unit Evaluation Tool
5.2 Extract available data to determine the present state for selected sub-components and indicators
5.3 Assess the suitability of the data
5.4 Where necessary, collect data to determine the Present State for selected indicators
5.5 Determine the level at which to set RQOs
5.6 Set appropriate draft RQOs
5.7 Set appropriate draft Numerical Limits in line with the draft RQO
5.8 Determine confidence in the RQOs and process

- **Step 6. Agree Resource Units, RQOs and Numerical Limits with stakeholders:** This component of the RQO determination process is carried out by the regulators of the WMA, assisted by the project team, and includes the consideration of RQO and NL outcomes with stakeholder, prior to the initiation of the gazetting process. The relevant activities of this step are:

6.1 Notify stakeholders and plan the workshop
6.2 Present and refine the Resource Unit selection with stakeholders
6.3 Present the sub-components and indicators selected for the RQO determination
6.4 Present the proposed direction of change and associated rationale
6.5 Present and revise RQOs and Numerical Limits

- **Step 7. Finalise and Gazette RQOs:** This component of the RQO determination process is carried out by the regulators of the WMA assisted by the project team, and includes the development of gazette RQO and NL drafts for submission to legal services of the Department of Water and Sanitation for gazetting

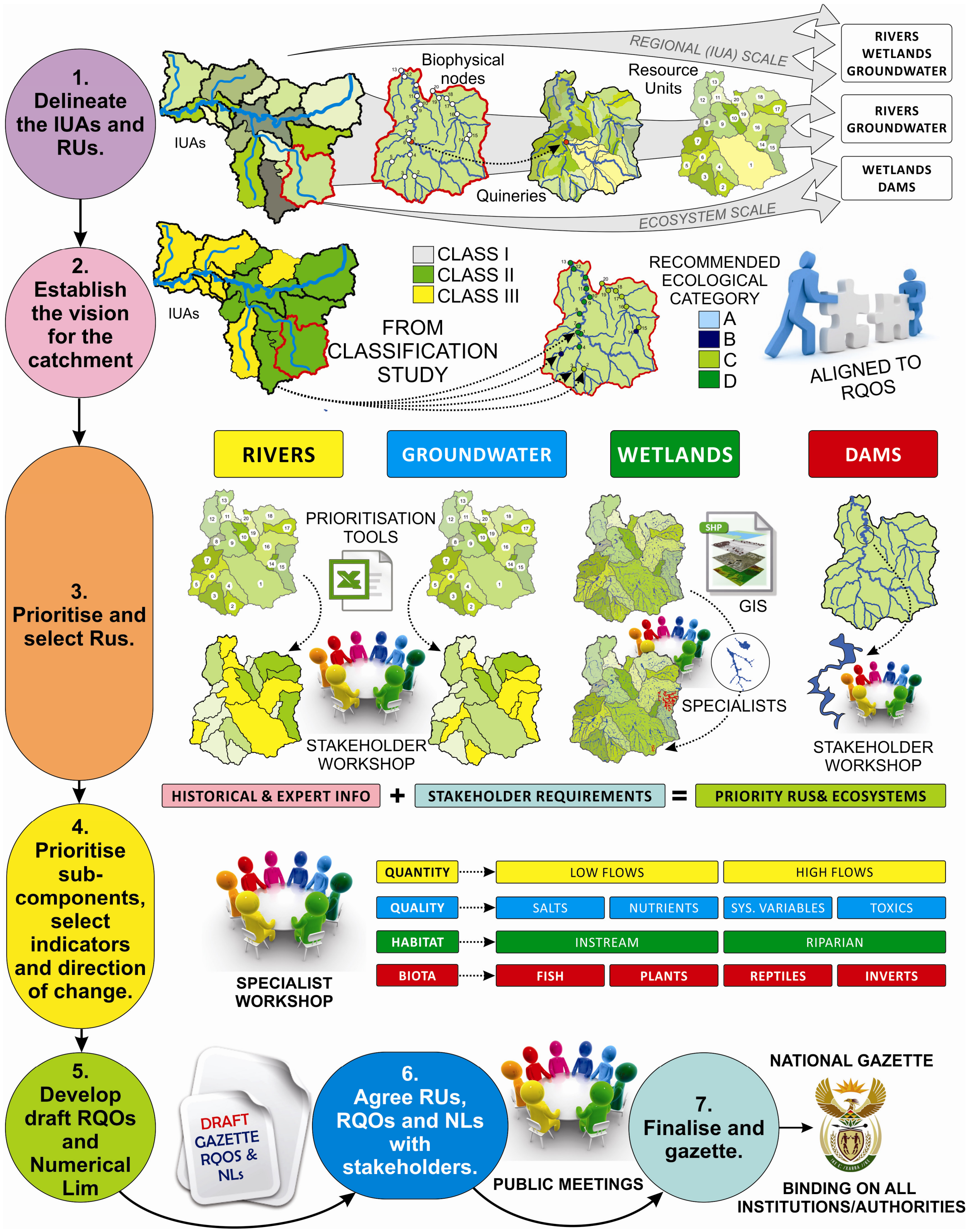

Figure 1: Schematic summary of the RQO determination procedure (adapted from DWA, 2011) which was implemented in this study.

3.2 RESOURCE UNIT PRIORITISATION OVERVIEW AND GAPS

The Water Resource Classification System proposes that RQOs are set for each RU. In reality however, this is not practical as there are a large number of RUs within the WMA and it would be expensive to set RQOs to monitor them all. A rationalisation process is therefore necessary to prioritise and select the most useful RUs for RQO determination. The objective of Step 3 was therefore to prioritise and select preliminary RUs which were discussed and agreed with stakeholders. Different approaches were used to prioritise the river, wetland, groundwater and dam resources within the Lower Vaal WMA. Each of these respective approaches is discussed below.

3.3 STAKEHOLDER WORKSHOPS

A stakeholder engagement workshop to contribute to the prioritisation of RUs for Rivers, Groundwater and dams in the Lower Vaal WMA study was held from 24-26 July 2013 (held from 24-26 July at Thornbirds, Johannesbur) stakeholders with local knowledge of the use and protection scenarios of the study area were invited to comment and if needed amend the desktop score.

3.4 STEP 3: RIVER RESOURCE UNIT PRIORITISATION FOR LOWER VAAL WMA

While, the RQO methodology provides a decision support tool, the Resource Unit Prioritisation Tool (RUPT), to guide the selection process (DWA, 2011), this tool was not applied in the current study as there are so few RUs. Data for some of the criteria detailed in the RUPT was however gathered, processed and presented to stakeholders at a workshop held on 24-26 July 2013 (This information is detailed in Appendix A).

The outcomes of this workshop resulted in the selection of five priority RUs for the Lower Vaal WMA. The rationale for selecting these RUs is detailed in Table 2.

Table 2: RUs selected by stakeholders and the associated rationale for their selection

RU	Rationale for selection by stakeholders
Due to the limited abundance of RUs in the Lower Vaal case study the use of the Resource Unit Prioritisation Tool for this case study was considered not to be necessary. Stakeholders were however involved in selecting RUs for RQO determination that would address the vision established for the study (achieve the class and recommended ecological categories). Considerations of available resources for RQO implementation and having adopted the requisite simplicity approach (as few RUs to achieve the objective of RQOs as necessary) five of the 11 (45%) of the River RUs were selected for RQO determination.	
3	This RU is located on the upper Harts River (IUA LA2) and was prioritised to allow RQOs to regulate use of riverine ecosystems in the upper Harts River Catchment where a range of EcoSpecs and UserSpecs were considered.
6	This RU is located on the lower Harts River (IUA LA4) and was prioritised to allow RQOs to regulate use of riverine ecosystems associated with the Vaalharts River Irrigation Scheme UserSpecs in particular were considered.
7	This RU is located on an ecologically important but unnamed tributary of the Harts River (IUA LA4). This RU was prioritised to allow RQOs to address the EcoSpecs associated with the lower Harts River Catchment.
8	This RU is located on the Vaal River below the Bloemhof Dam in IUA LB. This RU was prioritised to allow use of the Middle Vaal River WMA to be regulated at the point of entry into the Lower Vaal WMA.
11	This RU is located on the Vaal River at the base of IUA LB and was prioritised to allow use of the Lower Vaal River WMA to be regulated at the point of exit from the Lower Vaal WMA.

3.5 WETLAND ECOSYSTEM PRIORITISATION FOR THE LOWER VAAL WMA

Selection of wetland ecosystems is important as monitoring of these wetlands over the long-terms is intended to provide an indication as to how well wetlands in the catchment are being managed and how they are responding to water resource management at both a catchment and IUA level[1]. A three-pronged approach was used to help prioritize wetland ecosystems for RQO determination in the Lower Vaal catchment, which included:

- A desktop based prioritization process aimed at flagging priorities based on available spatial datasets;
- A comparison of the desktop findings with the findings from a wetland prioritization undertaken for the comprehensive reserve determination study of the integrated Vaal River System (DWA, 2009a). This report identified possible priority wetlands within the Lower Vaal catchment according to broad conservation importance, social importance, and/or threats from proposed developments; and
- Engagement with key stakeholders to identify potential priority wetlands based on local knowledge of the study area. The final set of wetlands selected was then reviewed and finalised with stakeholders as part of Step 6 of the RQO process.

While prioritizing individual wetland ecosystems for RQO determination is regarded as useful, it is important to note that wetlands are highly variable systems and are not linearly connected in the same manner that rivers are. As such monitoring of a sub-set of wetlands is likely to provide very little information on how other wetlands within the catchment are responding to site and catchment-level activities. As such, a decision was taken to also set regional-scale RQOs which are designed to provide general resource quality objectives for all wetlands in the Lower Vaal catchment. This also allows for monitoring to be undertaken at a broader level which can be used to obtain a more holistic picture of wetland management. The approach and process followed in setting regional-scale RQOs is outlined in the RQO Subcomponent and subsequent reports.

A different approach to that used to prioritize wetlands in the Lower Vaal was used for the Lower Vaal. The change in approach was largely due to the Lower Vaal only comprising of five IUAs. With so few IUAs throughout the catchment a more simplified approach was required. The initial prioritization approach included:

- Developing a consolidated wetland map for the catchment;
- Identifying the distribution of different wetland types throughout the catchment; and
- Identifying the top ranked FEPA wetlands (Rank 1 – 3) throughout the catchment.

The NFEPA wetland coverage of the Lower Vaal was used as the primary basis for delineating wetlands RUs (Figure 2). The NFEPA wetland layer was also used to identify the different wetland types through the catchment (Figure 2). This wetland coverage comprises both mapped and modelled wetlands, and is thus only a broad indicator of wetland distribution throughout the catchment.

[1]Bredin *et al*., in prep. Lower Vaal case study: selecting wetland ecosystems for long-term monitoring to provide an indication as to how well wetlands in the catchment are being managed and how they are responding to water resource management at both a catchment and IUA level.

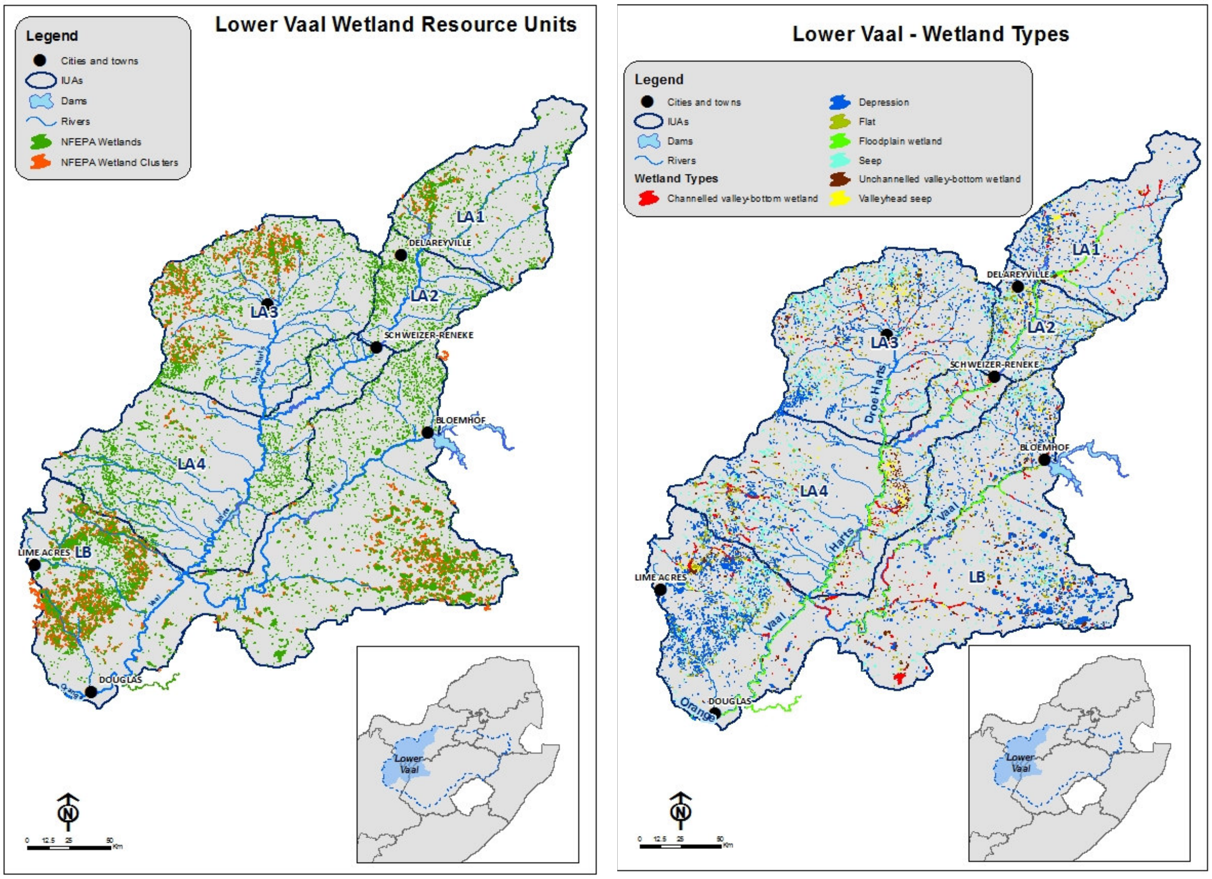

Figure 2: Lower Vaal wetland resource units (NFEPA wetlands and wetland clusters) (LEFT) and Lower Vaal wetland types (RIGHT).

The NFEPA rank for wetland importance (i.e. 1=most important to 6=least important), provided a useful surrogate for indicating where important wetlands are likely to occur within the catchment (Figure 3).

3.6 DAMS ECOSYSTEM PRIORITISATION FOR THE LOWER VAAL WMA

Step 4 of the RQO determination procedure uses the information that was gathered during the previous steps, especially step 3 to determine those priority areas or resource units where RQOs should be determined for the protection of the resource quality. The purpose of the development of RQOs for dams is to ensure adequate releases from the priority dams to provide the quantity and quality of water required for the protection of the aquatic ecosystems downstream of the dams.

The dams that were identified from the various sources of information (DWA database, Water Situation Assessment Model (WSAM) database, Internal Strategic Perspective (ISP) documents, reconciliation strategy documents and any other relevant studies' reports) were used and the following criteria was used to select the final priority dams:

- All dams from the DWA Hydrological Information System (HIS) database
- Additional dams identified through any other study or by stakeholders
- Other dams constructed with the specific purpose to provide water for urban and/or rural water use
- Where a dam was specifically built for irrigation water supply (mainly some of the smaller dams).

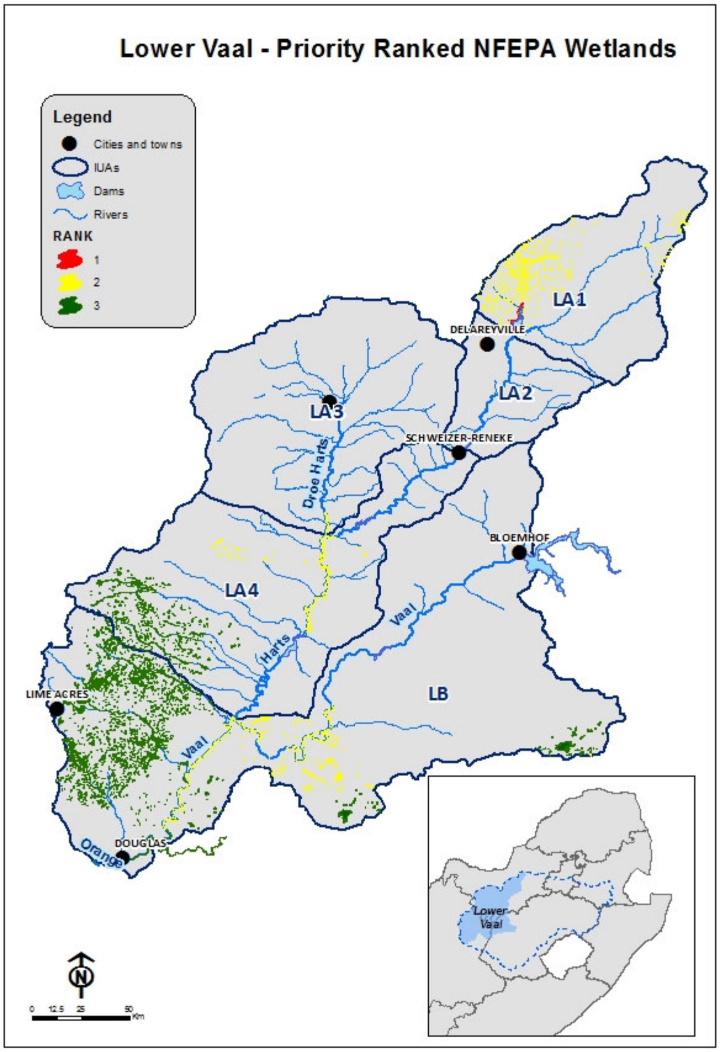

Figure 3: Priority NFEPA ranked wetlands

3.7 GROUNDWATER RESOURCE UNIT AND ECOSYSTEM PRIORITISATION FOR THE LOWER VAAL WMA

The framework selected for the purpose of groundwater RU prioritisation, was based on the RQO determination procedures for river RUs (DWA, 2011). The approach requires a set of criteria and sub-criteria to be weighted and rated to calculate a priority rating which is then normalised.

The set of criteria and sub-criteria that were selected for the groundwater prioritisation process was largely dictated by available datasets as well as input from the public participation process. The resultant table with the selected criteria as and the relative weights applied is shown in Table 3.

Table 3: Groundwater prioritisation criteria

Criterion	Relative weighting	Sub-criteria	Relative weighting
Importance for users (Current & anticipated future use)	30	Water character of a high quality	30
		Major aquifers	40
		Activities that contribute to economy	30
Threat posed to users	30	Aquifers which are highly stressed	40
		Water quality is currently threatened	40
		Vulnerable aquifers	20
Ecological Importance	30	Groundwater importance to wetlands	45
		Ground-surface water interactions	50
		Important groundwater fauna	5
Management Considerations	10	Management plans already exist	100

Sub-criteria can have a spatial variability across the resource unit extent, but any sub-criteria can only have one rating in the proposed prioritisation model. To address this constraint the following rule set was applied:

a) The sub-criteria category which covers the largest part of the resource unit is assigned.
b) Rule (a) can be overridden through public participation if consensus was reached among the relevant role players.

3.7.1 IMPORTANCE FOR USERS

The sections that follow discuss the sub-criteria linked to the importance for users and the rating guideline that applies to each of the sub-criteria.

3.7.1.1 Water character of high quality

All available water quality data was obtained from the NGA for each of the RUs and the water quality data for these sites were used in generating an expanded Durov diagram which utilises the major anions and cations to produce a plot that characterises water in nine different regions. The plotting procedure of the expanded Durov diagram is available in Appendix B. A water quality score was assigned (Figure 4) to each of the nine regions to assist in evaluating the status of each RU. Since a Durov diagram only gives information about the character of the water, the EC parameter was also displayed to give an indication of the salinity of the water in question. The average values for the Lower Vaal sites are displayed in Figure 5 and were evaluated against the SANS 241:2005 drinking water guidelines.

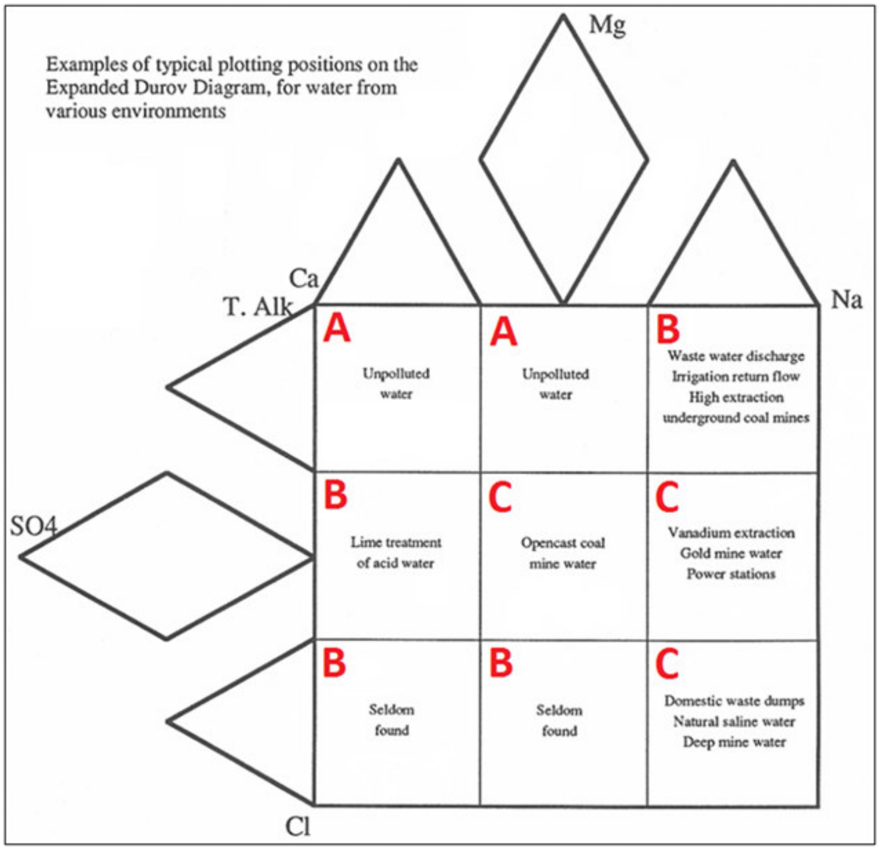

Figure 4: Class assignment of expanded Durov diagram

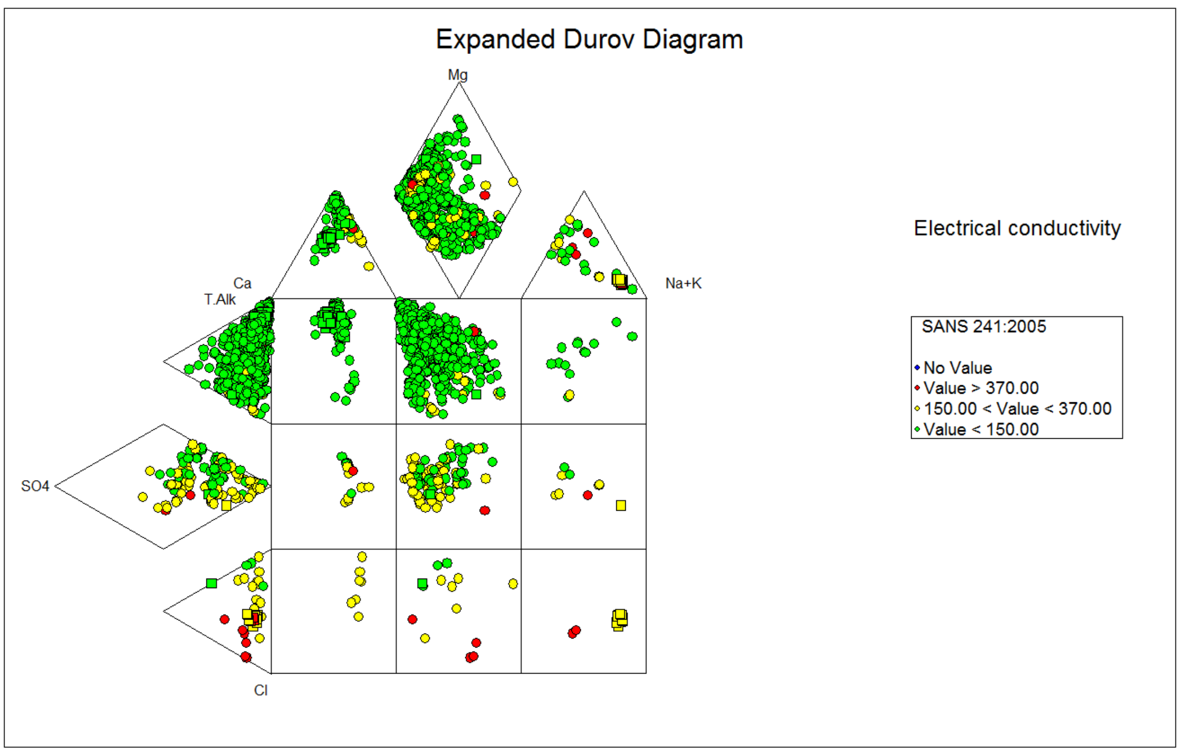

Figure 5: Expanded Durov diagram with evaluation of EC

It should be noted that the chemistry data used, span over the entire time line available in the database. Applied date filters resulted in little or no data for various areas.

The rating guideline applied to each RU for evaluating the water character is presented in Table 4 and the spatial distribution of the final ratings is shown in Figure 6.

Table 4: Water character rating guideline

Rating	Guideline
0.0	RUs which contain a C water quality score
0.5	RUs which contain a B water quality score
1.0	RUs which contain an A water quality score

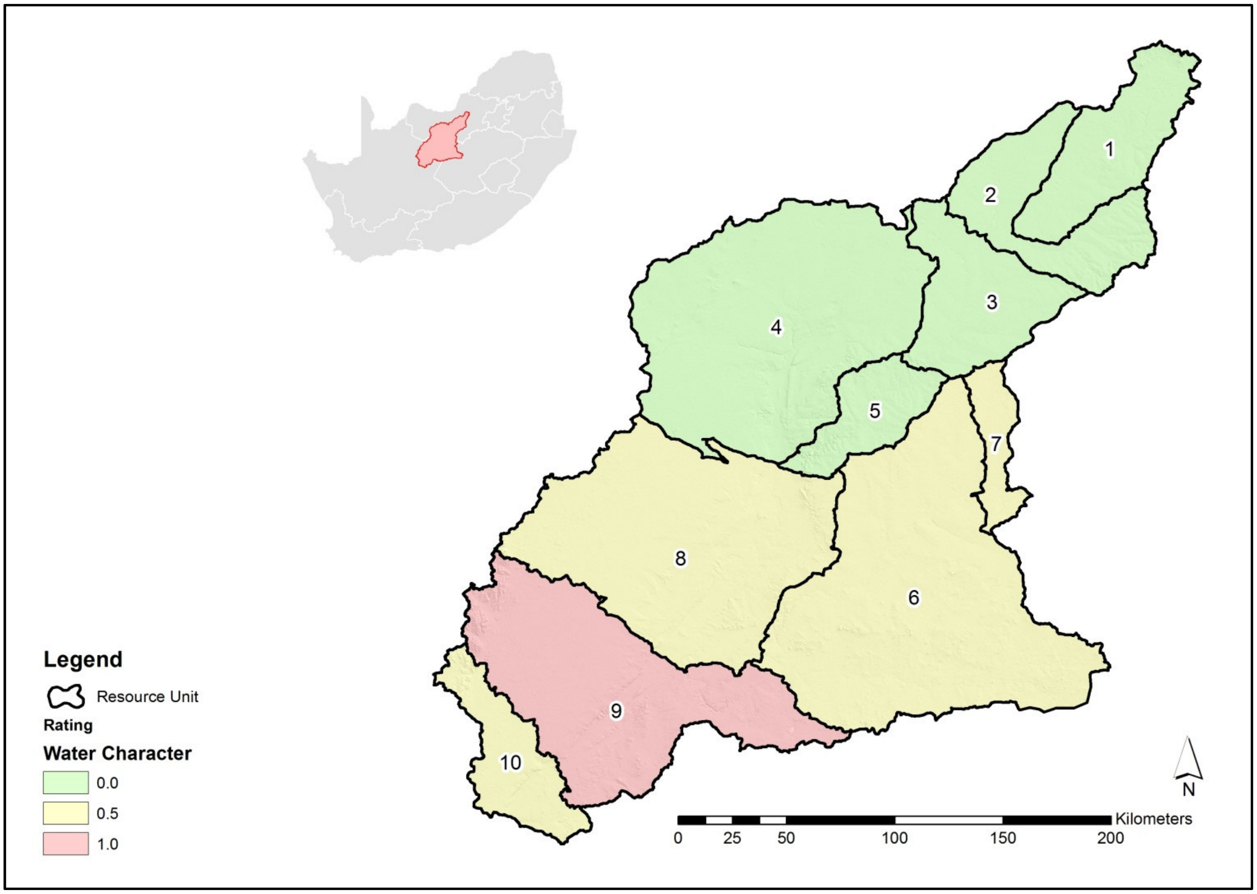

Figure 6: Spatial distribution of water character rating. ***Please note that the spatial distribution of 10 RUs were used in this assessment prior to the splitting of RU 8 into two RUs.***

3.7.1.2 Major aquifers

Groundwater occurrence was identified using the Geohydrological Yield map (DWAF, 2009b) obtained from DWA. Three aquifer yield classes were defined as high, medium and low irrespective of the aquifer type as shown in Table 5. The resultant yield classification map is shown in Figure 7.

Table 5: Aquifer yield class

Aquifer Yield Class	Aquifer Yield Range
High	2.0 – 5.0 L/s

Medium	0.5 – 2.0 L/s
Low	0.0 – 0.5 L/s

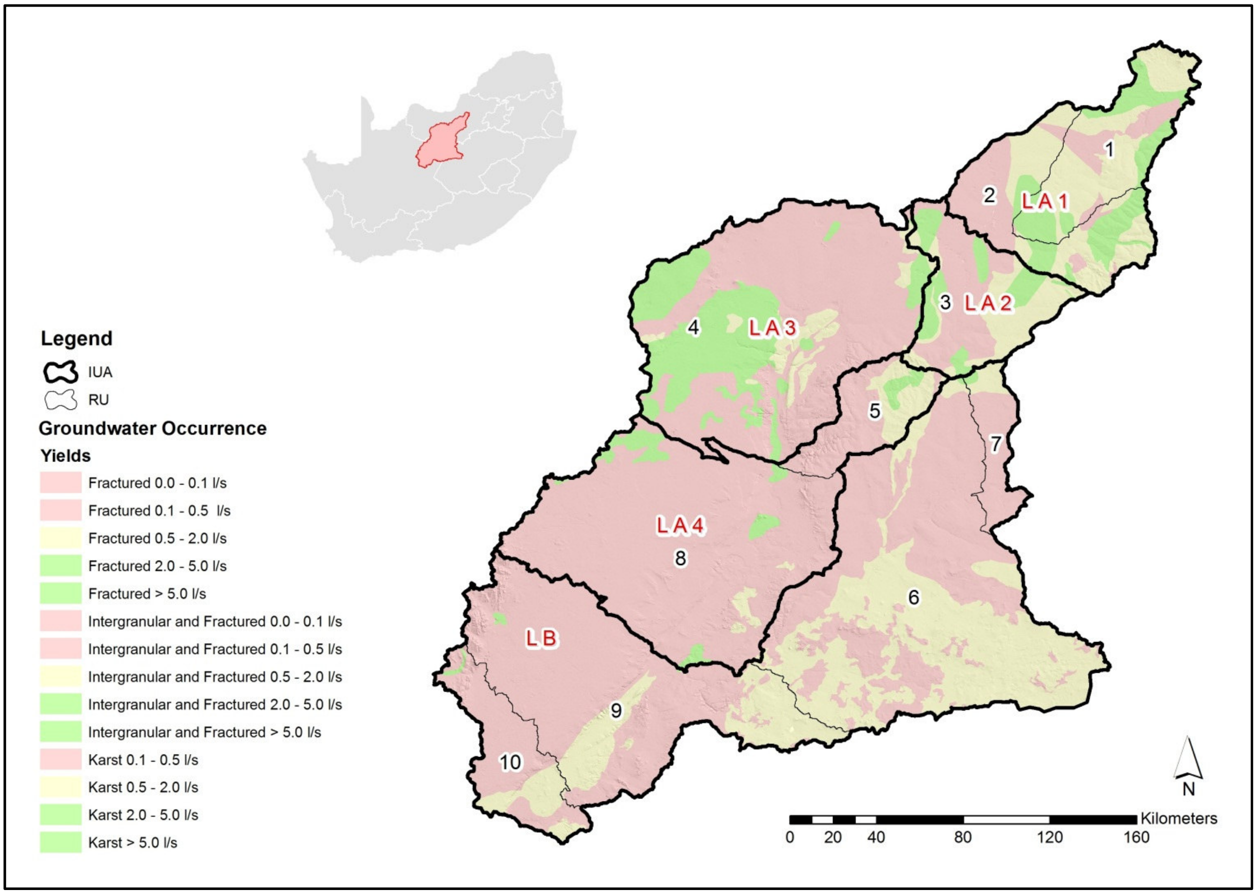

Figure 7: Major aquifer classification map. ***Please note that the spatial distribution of 10 RUs were used in this assessment prior to the splitting of RU 8 into two RUs.***

The rating guideline applied to each RU for evaluating major aquifers are presented in Table 6 and the spatial distribution of the final ratings is shown in Figure 8.

Table 6: Major aquifer rating guideline

Rating	Guideline
0.0	RUs which contain or are dominated by poor aquifers (< 0.5 L/s)
0.5	RUs which contain or are dominated by minor aquifers (0.5 - 2 L/s)
1.0	RUs which contain or are dominated by major aquifers (> 2L/s)

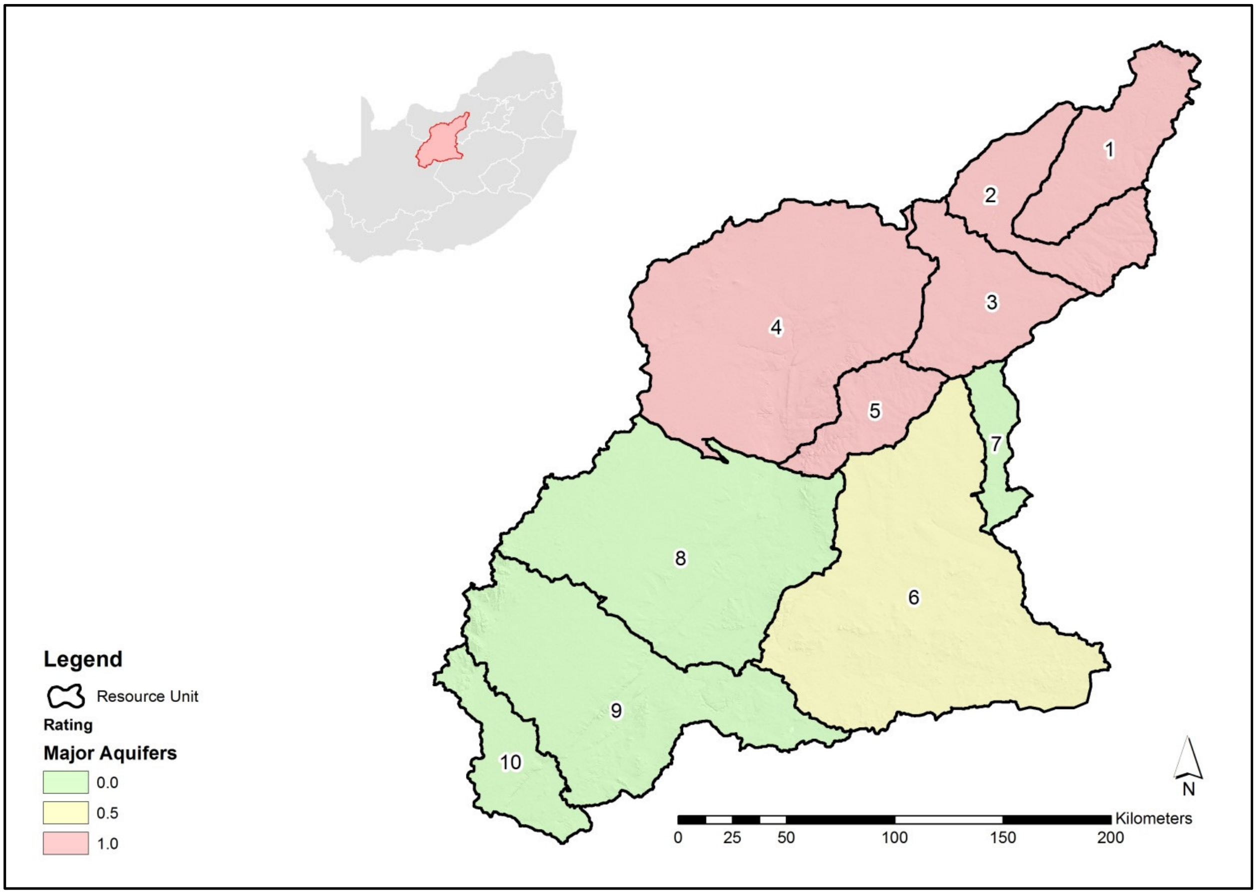

Figure 8: Spatial distribution of major aquifers rating. ***Please note that the spatial distribution of 10 RUs were used in this assessment prior to the splitting of RU 8 into two RUs.***

3.7.1.3 Activities that contribute to the economy

Activities that contribute to the economy that could be dependent on groundwater were identified as farming, parks and mines. The datasets used to depict the aforementioned activities is as follows:

- Protected Areas (DWAF Groundwater Resource Assessment Phase 2, 2006)
- Cultivated Lands (SANBI Land Cover, 2009)
- Registered Groundwater Use (WARMS Data, 2013)
- High Yielding Aquifers as discussed in previous section

The resulting map of the aforementioned covers is shown in Figure 9. The mining activities are not explicitly shown due to the fact that if they utilise groundwater it should be included in the registered use as obtained from the WARMS database.

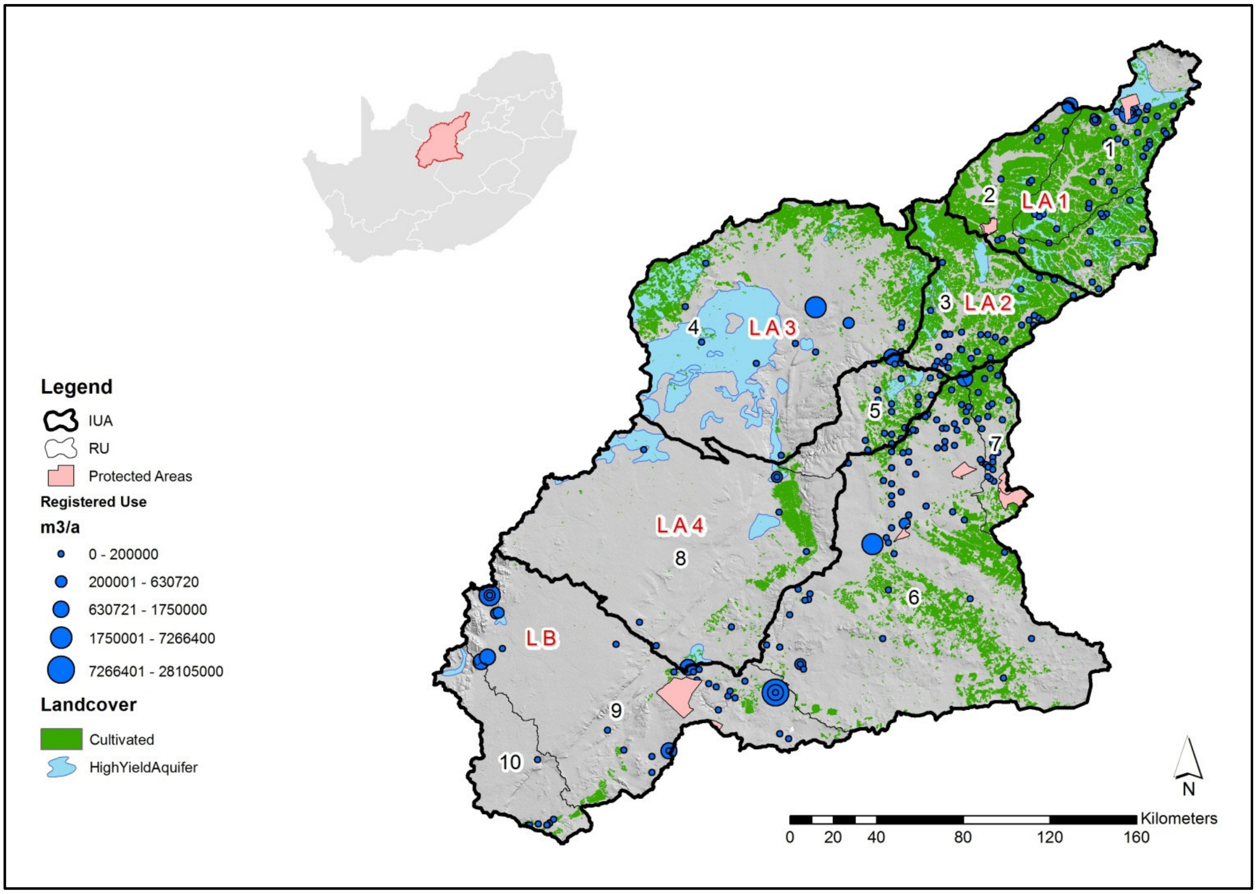

Figure 9: Activities that contribute to the economy. ***Please note that the spatial distribution of 10 RUs were used in this assessment prior to the splitting of RU 8 into two RUs.***

The rating guideline applied to each RU for evaluating the activities that contribute to the economy is presented in Table 7 and the spatial distribution of the final ratings is shown in Figure 10.

Table 7: Contribution to economy rating guideline

Rating	Guideline
0.0	RUs which do not directly support any activities which contribute to the economy
0.5	RUs which support activities which provide a moderate contribution to the economy
1.0	RUs which support activities which contribute significantly to the economy

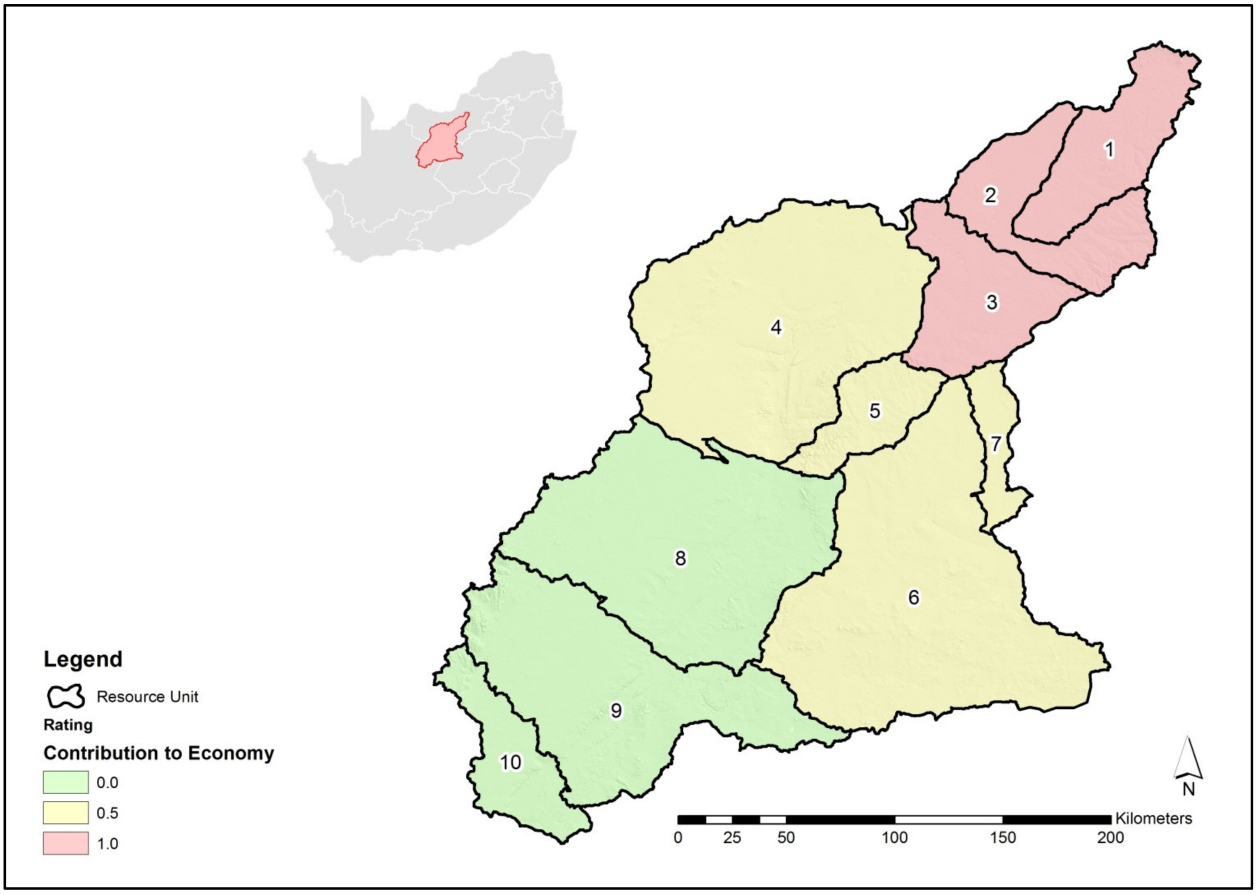

Figure 10: Spatial distribution of contribution to the economy rating. *Please note that the spatial distribution of 10 RUs were used in this assessment prior to the splitting of RU 8 into two RUs.*

3.7.2 THREAT POSED TO USERS

The sections that follow discuss the sub-criteria linked to the threat posed to users and the rating guideline that applies to each of the sub-criteria.

3.7.2.1 Aquifers which are highly stressed (relative aquifer stress)

The AFYM (Murray *et al*, 2011) was used to calculate the aquifer firm yield per quaternary catchment that comprises the various RUs. The existing use was expressed as a percentage of the firm yield to calculate a stress index. It is important to note that the firm yield model is very conservative. The default values for the quaternaries were used that was supplied with the model, which was sourced through the GRAII project. The stress indices were classified as high, medium and low and the class breaks were chosen by selecting the highest and lowest stress index and assigning the high class low class respectively. The remainder of the remainder of the indices were scaled accordingly.

The rationale behind the approach outlined above is to highlight quaternaries that are more stressed than others, even though they may not currently be stressed. There is a huge uncertainty in the current groundwater use figures and therefore it is not possible to calculate high confidence stress indices. The purpose of the prioritisation tool is only to highlight differences between RUs to assist in the prioritisation process and the relative stress index calculation allows for the generation of contrasts between the RUs.

The resulting aquifer stresses are shown in Figure 11.

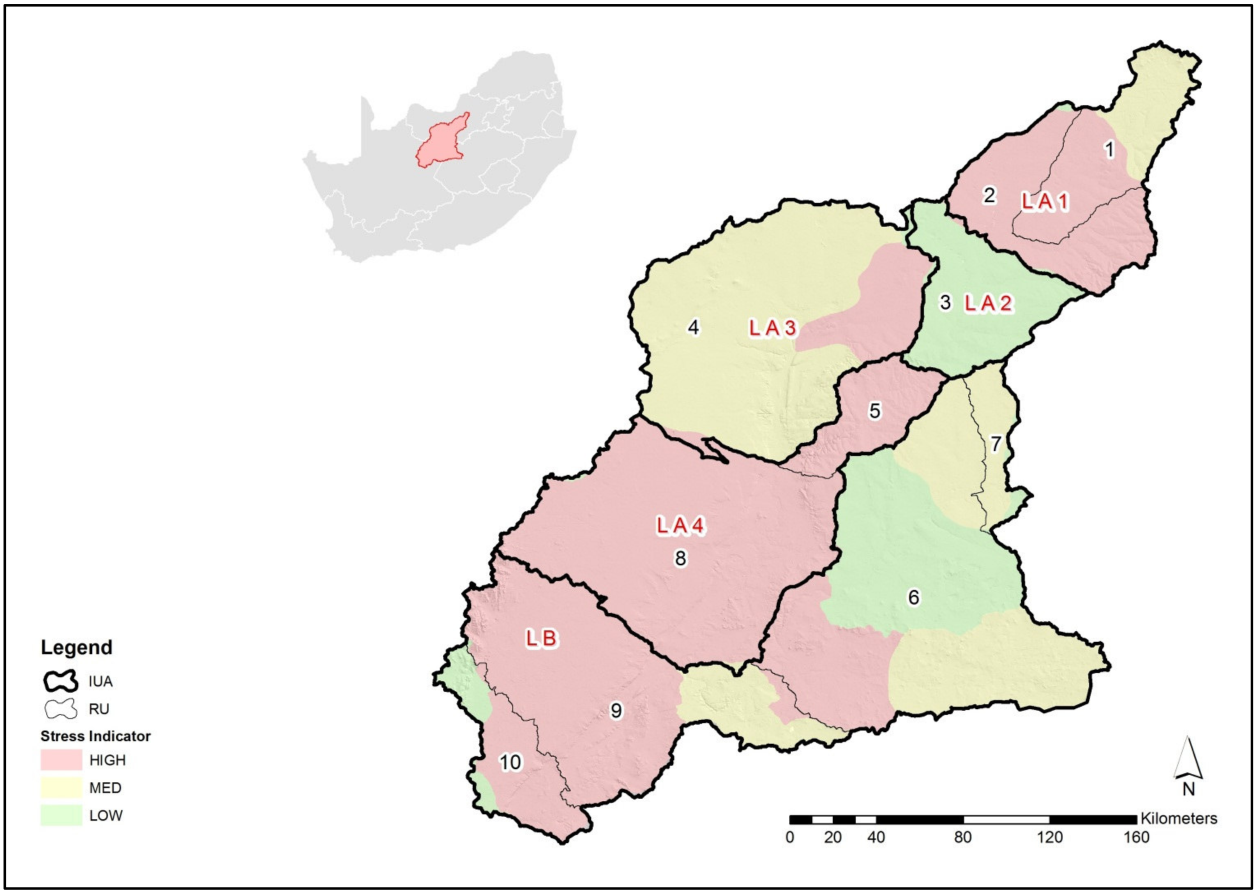

Figure 11: Relative aquifer stress. ***Please note that the spatial distribution of 10 RUs were used in this assessment prior to the splitting of RU 8 into two RUs.***

The rating guideline applied to each RU for evaluating the relative aquifer stress is presented in Table 8 and the spatial distribution of the final ratings is shown in Figure 12.

Table 8: Relative aquifer stress rating guideline

Rating	Guideline
0.0	RUs which contain or are dominated by aquifers which are not stressed
0.5	RUs which contain or are dominated by aquifers which are moderately stressed
1.0	RUs which contain aquifers which are highly stressed

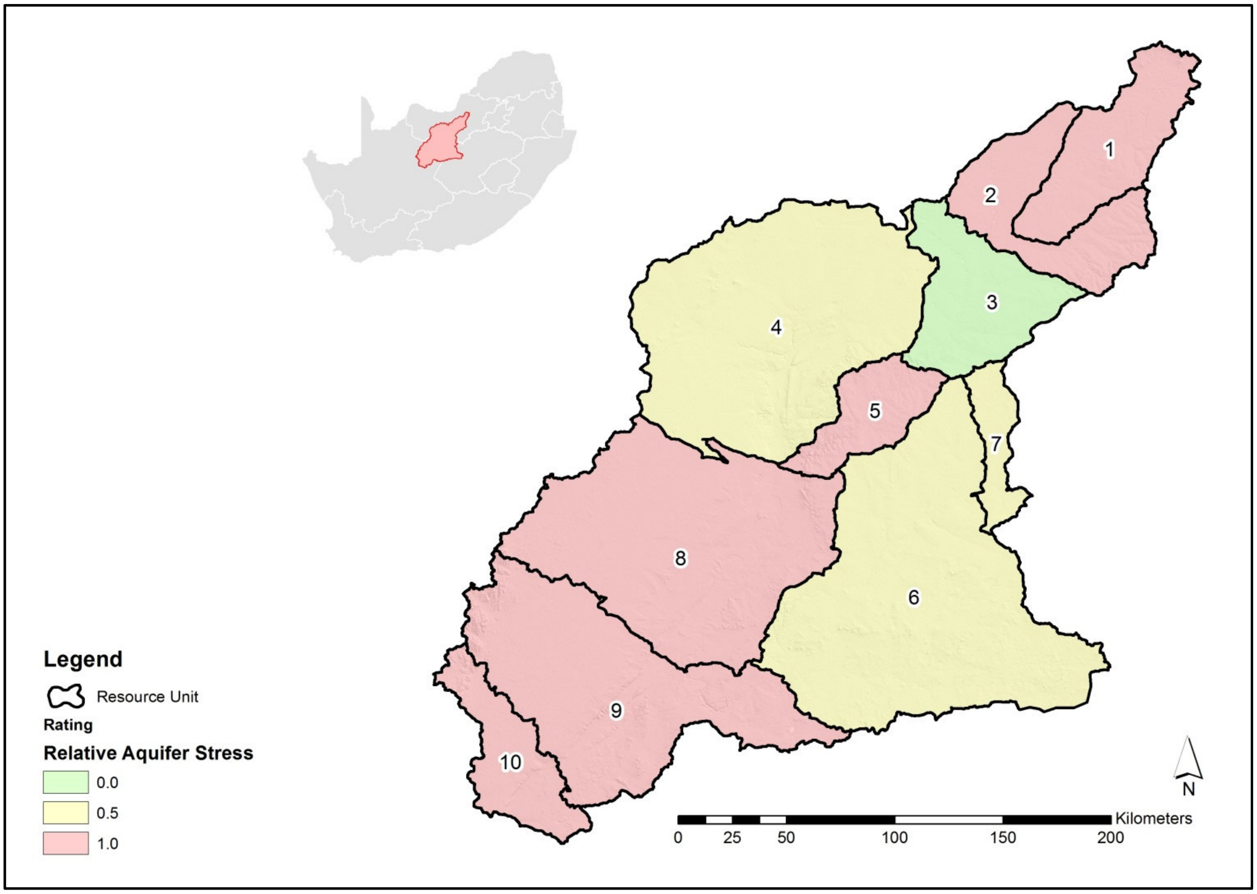

Figure 12: Spatial distribution of relative aquifer stress rating. ***Please note that the spatial distribution of 10 RUs were used in this assessment prior to the splitting of RU 8 into two RUs.***

3.7.2.2 Water quality currently threatened

There is not enough historic data available with good distribution across the study area to allow for the generation of a detailed groundwater quality map. The datasets used to visually show the current water quality across the area are:

- The TDS map to give indication of the regional groundwater salinity levels (DWAF Vegter Map, 1995)
- Current and Abandoned Mines (NWU Geography Department, author unknown)

Background groundwater quality is inherently related to the host geology and can be spatially highly variable depending on the geological and physical setting. Although mining operations can be indicative of potential groundwater quality issues, the evaluation of this sub-criterion relies heavily on the public participation process. The resultant map produced is shown in Figure 13.

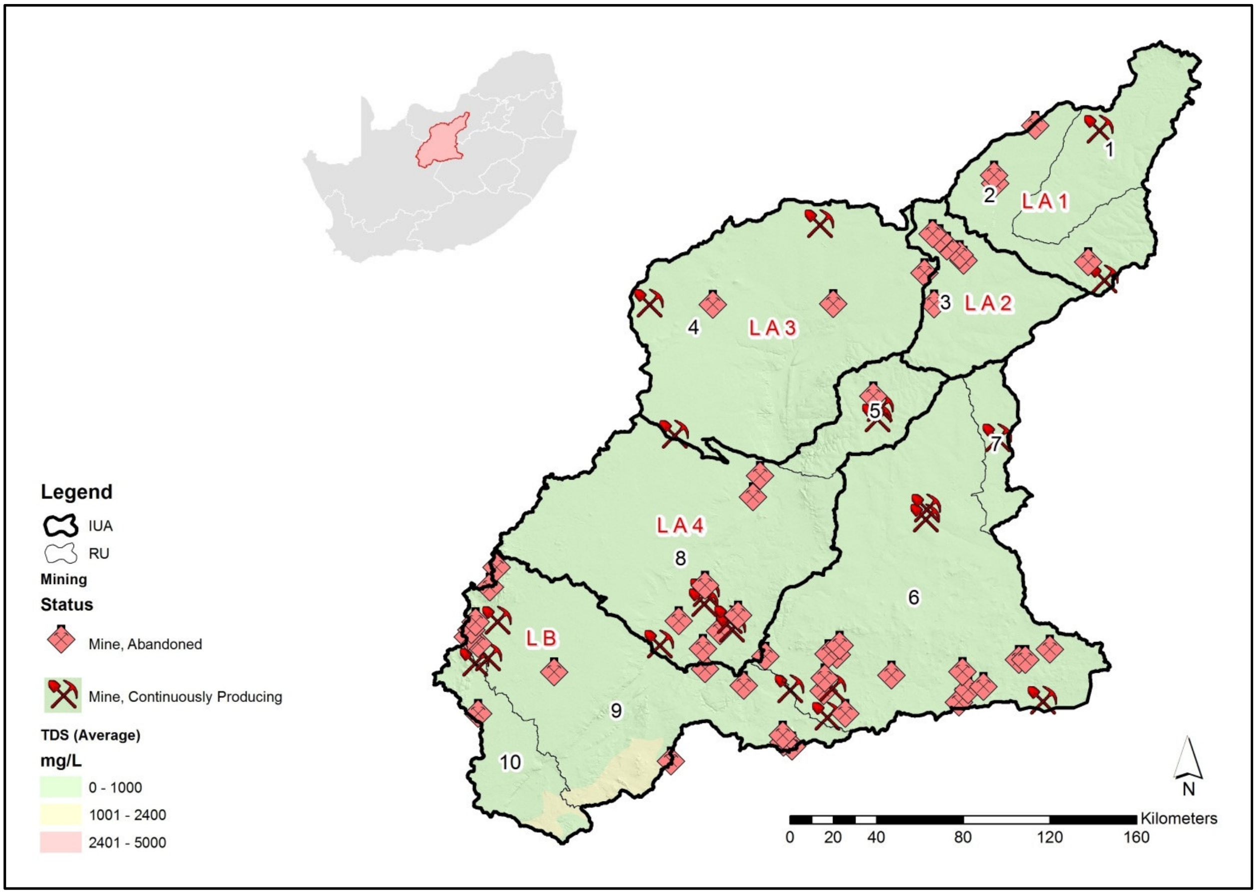

Figure 13: Groundwater quality distribution map. ***Please note that the spatial distribution of 10 RUs were used in this assessment prior to the splitting of RU 8 into two RUs.***

The rating guideline applied to each RU for evaluating water qualities that are currently threatened is shown in Table 9 and the spatial distribution of the final ratings is shown in Figure 14.

Table 9: Water quality that is threatened rating guideline

Rating	Guideline
0.0	RUs where potential threat to water quality is low
0.5	RUs where potential threat to water quality is moderate
1.0	RUs where potential threat to water quality is high

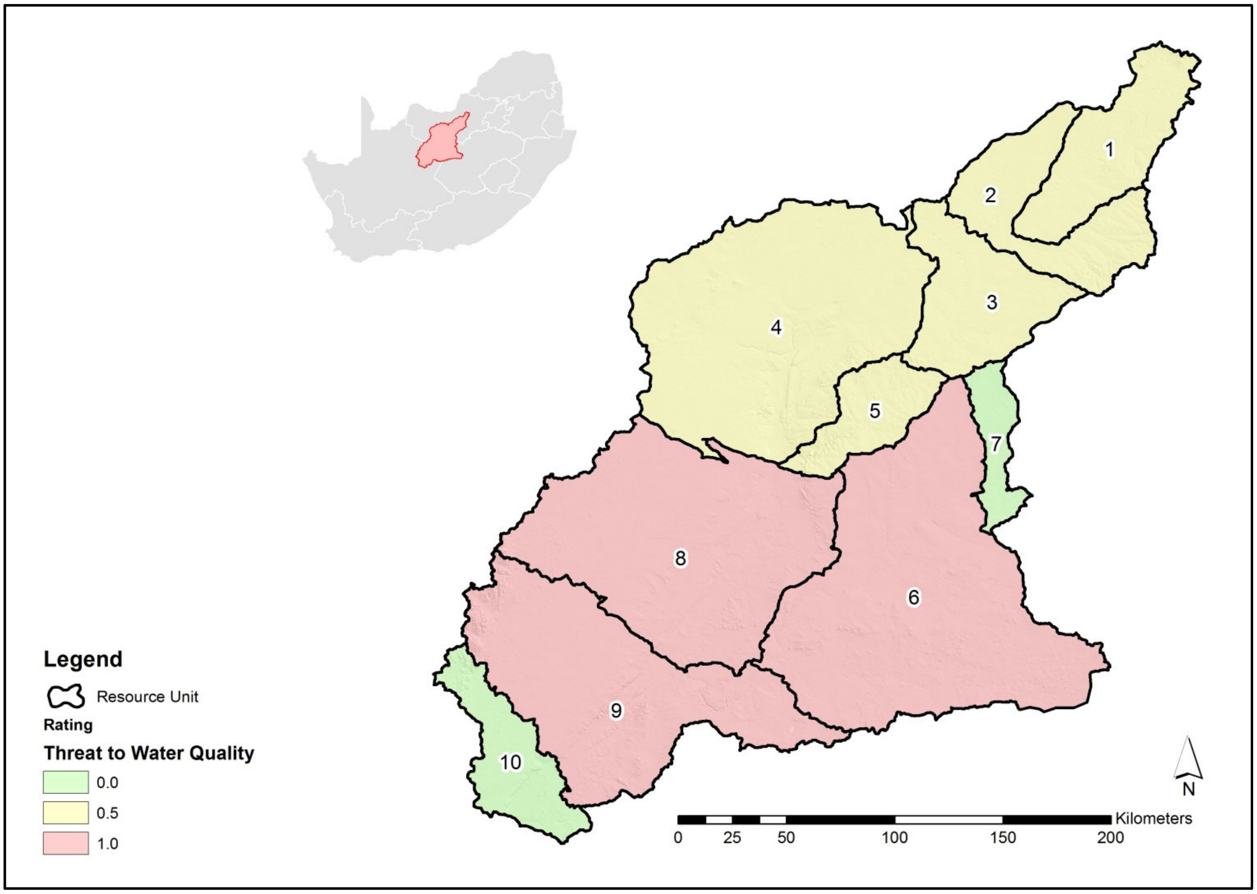

Figure 14: Spatial distribution of threat to water quality rating. ***Please note that the spatial distribution of 10 RUs were used in this assessment prior to the splitting of RU 8 into two RUs.***

3.7.2.3 Vulnerable aquifers

Aquifer vulnerability is addressed through the DRASTIC map (DWAF, 2011). The map comprise of the following parameters:

Table 10: DRASTIC Parameters

Parameter	Input dataset
Depth to water table (D)	126 263 groundwater levels from the NGDB (for 4 280 of these, the mean groundwater level was calculated from time-series data) were interpolated to a groundwater level grid.
Recharge (R)	Recharge calculated as part of GRAII-3 project.
Aquifer material (A)	1:1 million Geology from CGS
Soils (S)	WR90 soils data set
Topography and slope (T)	DWAF 20m DTM resampled to 1X1km
Impact of the vadose (unsaturated) zone (I)	1:1 million Geology from CGS
Hydraulic conductivity (C)	1:1 million Geology from CGS

The DRASTIC index has a maximum index of 200 which represents the highest aquifer vulnerability with respect to pollution. For the purpose of the prioritisation tool the following classes of DRASTIC index were adopted based on the index range for the study area:

- High Vulnerability (152-179)
- Medium Vulnerability (113-151)

- Low Vulnerability (56-112)

The resulting map is shown in Figure 15.

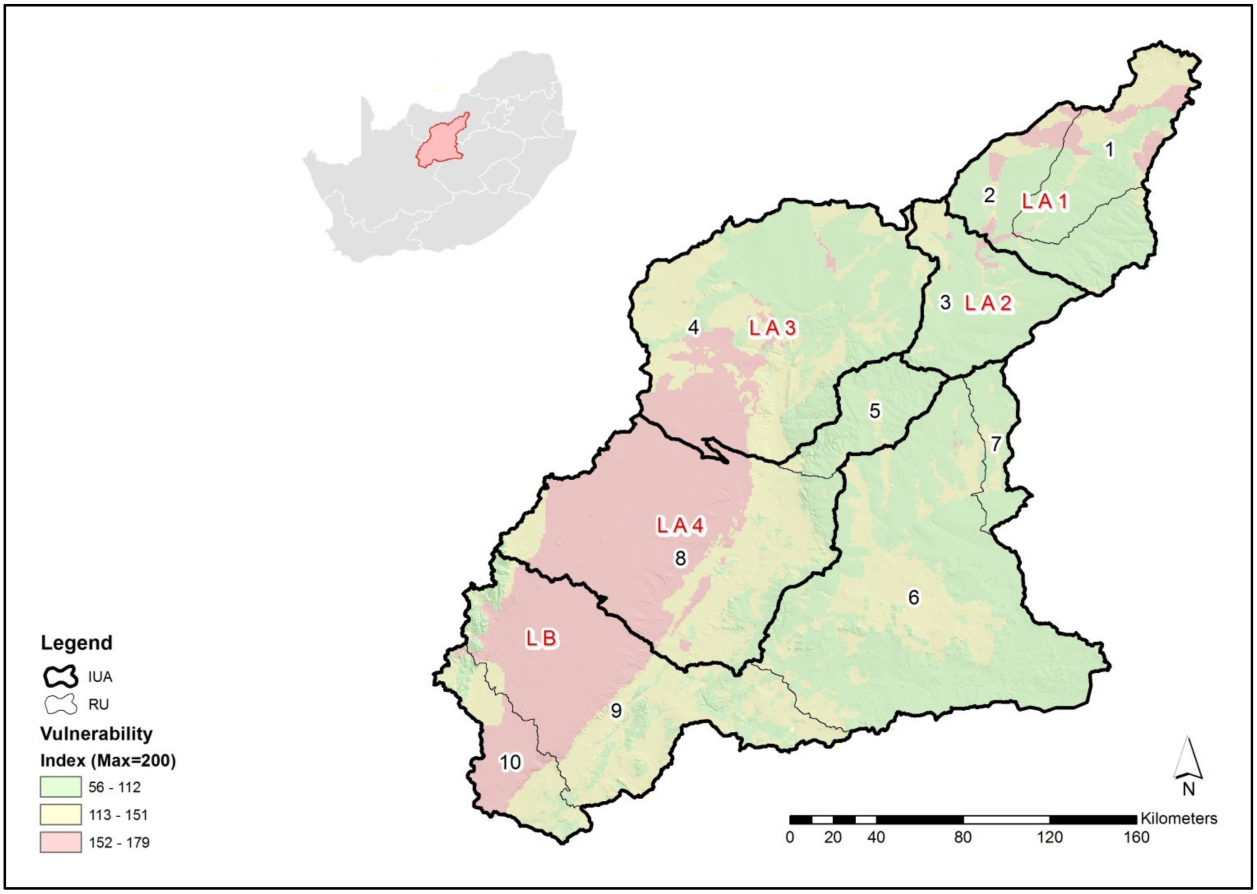

Figure 15: DRASTIC aquifer vulnerability. ***Please note that the spatial distribution of 10 RUs were used in this assessment prior to the splitting of RU 8 into two RUs.***

The rating guideline applied to each RU for evaluating aquifer vulnerabilities are shown in Table 11 and spatial distribution of the final ratings is shown in Figure 16.

Table 11: Aquifer vulnerability rating guideline

Rating	Guideline
0.0	RUs that are not vulnerable to pollution
0.5	RUs that are moderately vulnerable to pollution
1.0	RUs that are highly vulnerable to pollution

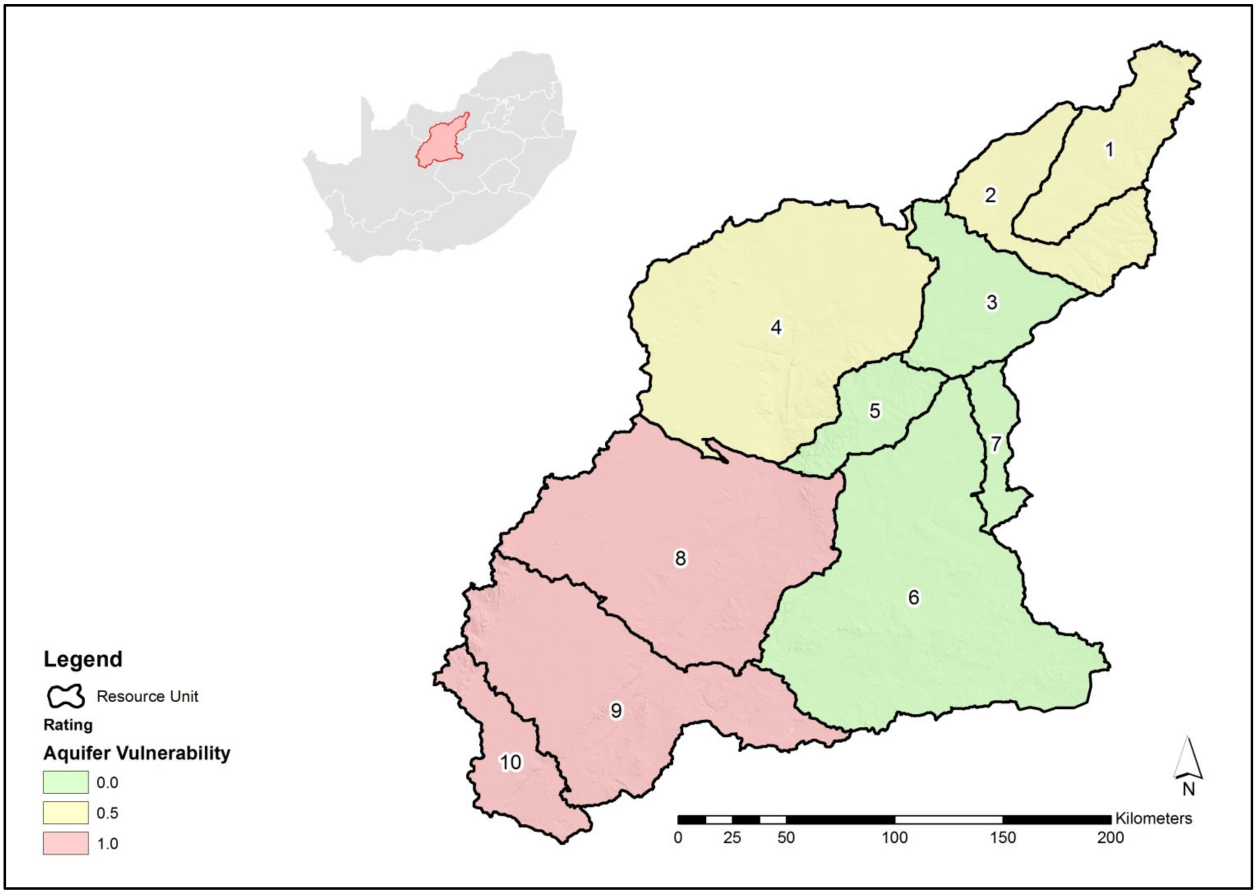

Figure 16: Spatial distribution of aquifer vulnerability rating. ***Please note that the spatial distribution of 10 RUs were used in this assessment prior to the splitting of RU 8 into two RUs.***

3.7.3 ECOLOGICAL IMPORTANCE

The sections that follow discuss the sub-criteria linked to the ecological importance and the rating guideline that applies to each of the sub-criteria.

3.7.3.1 Groundwater importance to wetlands

The wetland cover generated for the study area was used and only wetlands associated with possible groundwater dependence were considered. The spatial distribution of the wetlands directly affected by groundwater are shown in Figure 17.

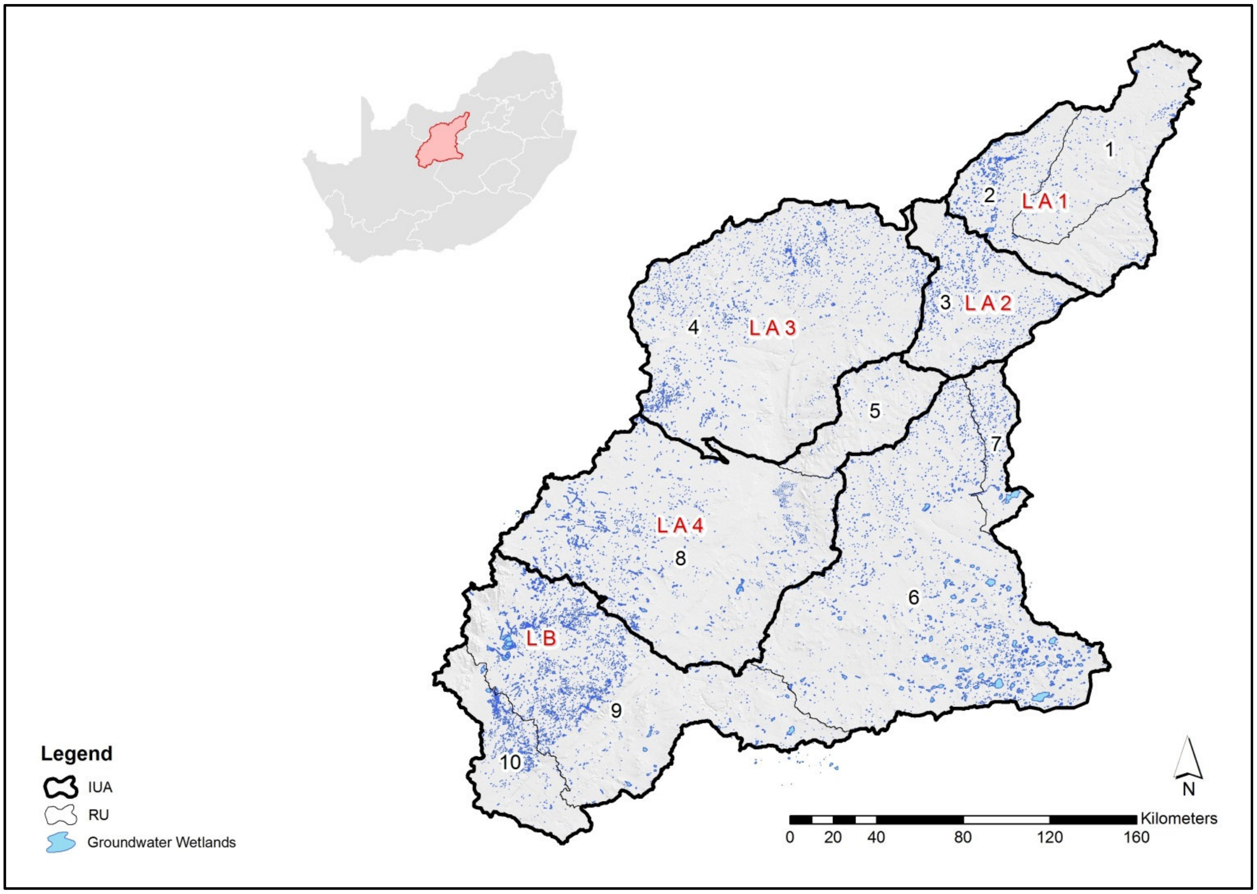

Figure 17: Wetlands affected directly by groundwater. ***Please note that the spatial distribution of 10 RUs were used in this assessment prior to the splitting of RU 8 into two RUs.***

Evaluation of the wetlands posed difficult due to the large number and the uncertainty with regard to groundwater, therefore the wetland densities per RU was used in the evaluation. The rating guideline applied to each RU for evaluating groundwater importance to wetlands is shown in Table 12 and the spatial distribution of the final rating is shown in Figure 18.

Table 12: Groundwater importance to wetlands rating guideline

Rating	Guideline
0.0	RUs which contain wetlands with low groundwater importance
0.5	RUs which contain wetlands with moderate groundwater importance
1.0	RUs which contain wetlands with high groundwater importance

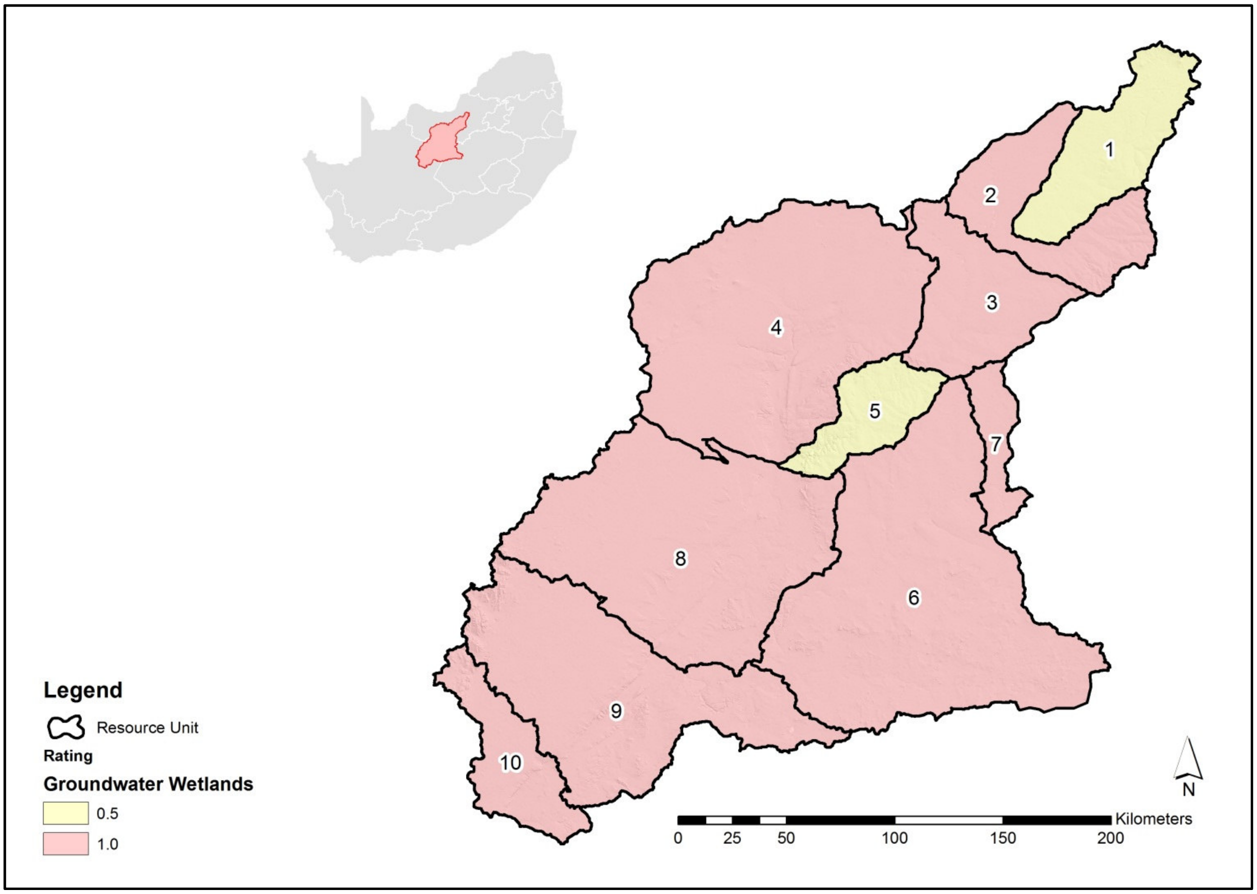

Figure 18: Spatial distribution of wetlands affected by groundwater rating. ***Please note that the spatial distribution of 10 RUs were used in this assessment prior to the splitting of RU 8 into two RUs.***

3.7.3.2 Surface-groundwater water interaction

Surface-groundwater interaction is an on-going field of research and this component is very expensive to measure. This has resulted in models being used to predict the groundwater contribution to baseflow. For the purpose of the prioritisation tool the estimated groundwater contribution to baseflow (GRDM, Van Tonder, 2000) was expressed as a percentage of the MAR. The resultant map is shown in Figure 19.

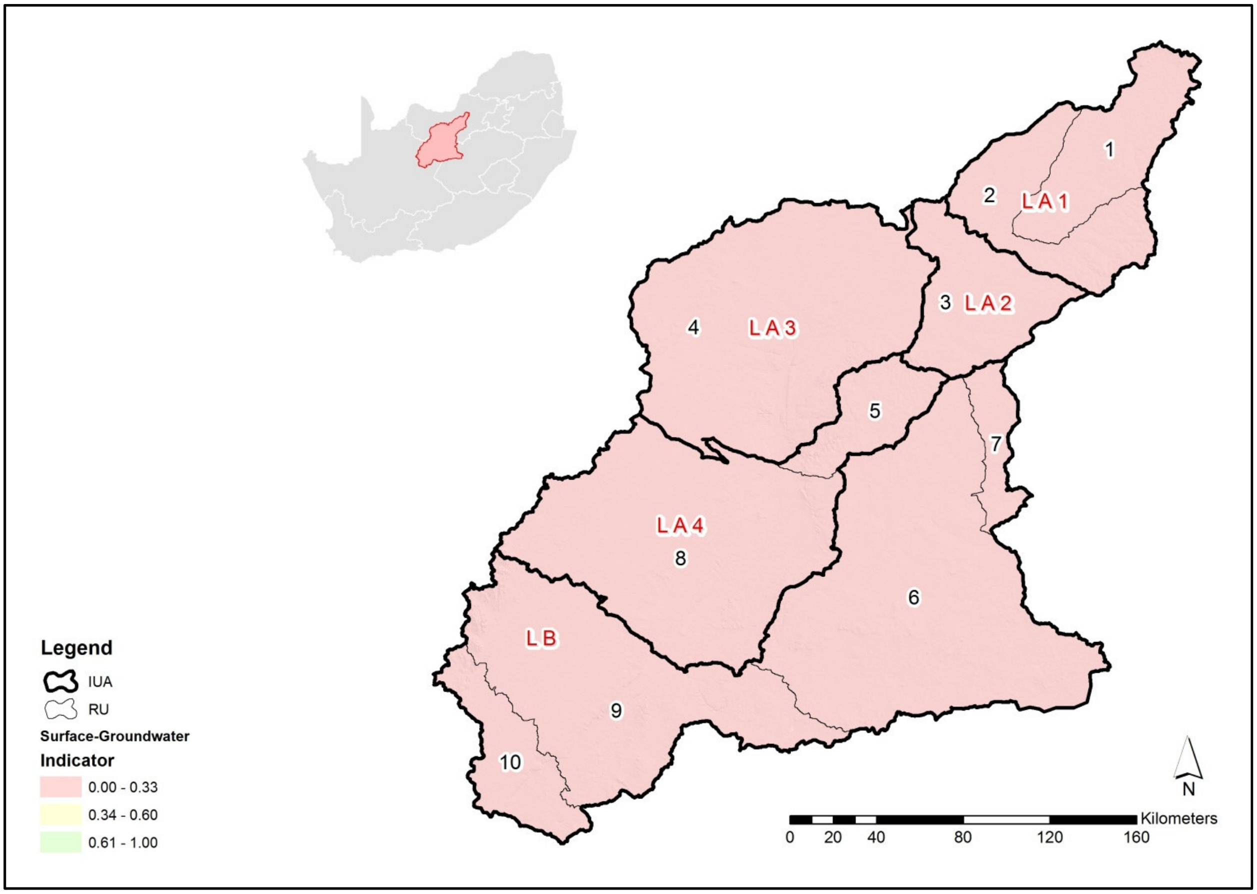

Figure 19: Surface-groundwater interaction. ***Please note that the spatial distribution of 10 RUs were used in this assessment prior to the splitting of RU 8 into two RUs.***

The rating guideline applied to each RU for evaluating the surface-groundwater interaction is shown in Table 13 and the spatial distribution of the final ratings is shown in Figure 20.

Table 13: Surface-groundwater interaction rating guideline

Rating	Guideline
0.0	RUs which contain insignificant GW-SW interaction
0.5	RUs which contain moderate GW-SW interaction
1.0	RUs which contain significant GW-SW interaction

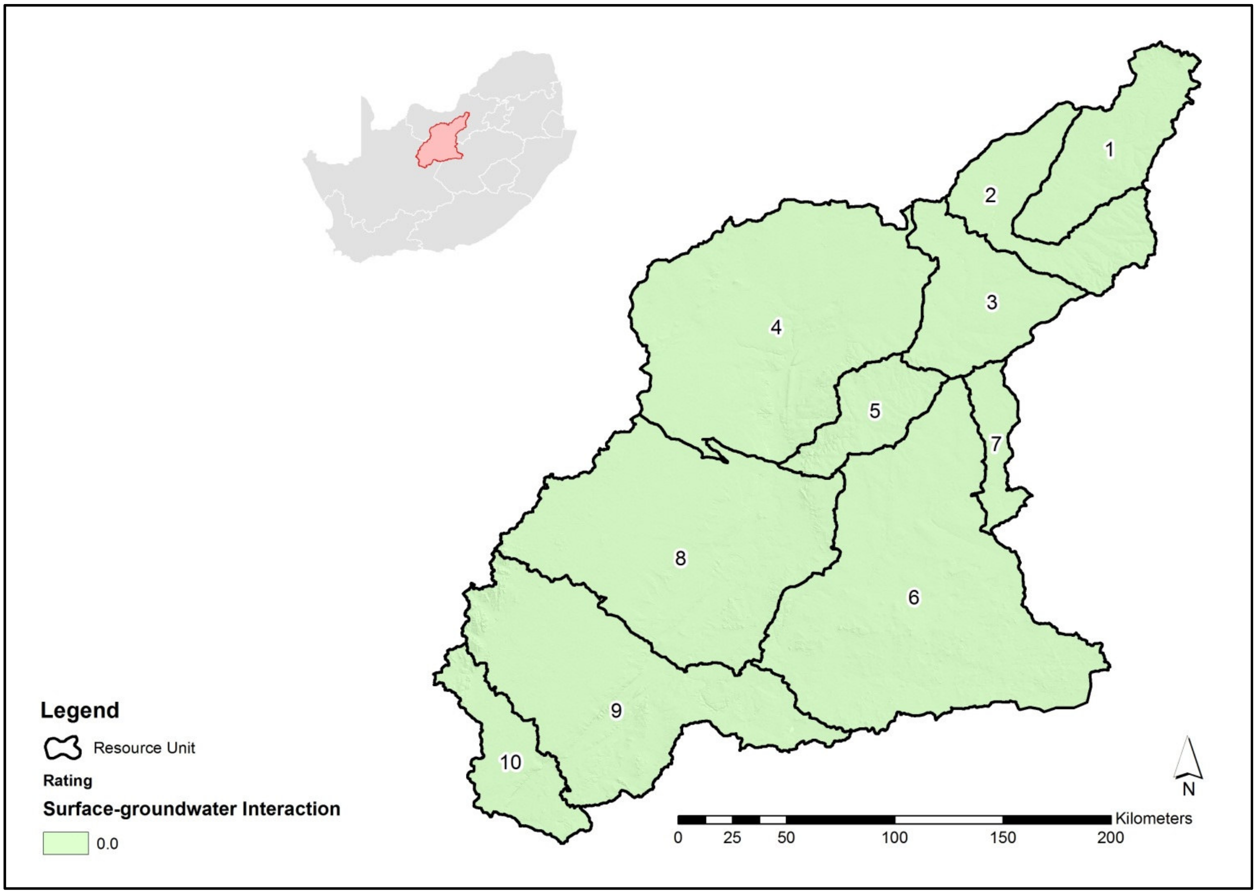

Figure 20: Spatial distribution of surface-groundwater interaction rating. *Please note that the spatial distribution of 10 RUs were used in this assessment prior to the splitting of RU 8 into two RUs.*

3.7.3.3 Important groundwater fauna

This sub-criteria has been included for the sake of completeness, but no database exist that can be used to apply this specific sub-criteria. Table 14 shows the rating guideline to be used once this type of data is available.

Table 14: Important groundwater fauna rating guideline

Rating	Guideline
0.0	RUs which contain little groundwater fauna
0.5	RUs which contain moderate groundwater fauna
1.0	RUs which contain major groundwater fauna

3.7.4 MANAGEMENT CONSIDERATIONS

A dataset that shows the existence of management plans is not available and this criterion relies heavily on the inputs from the public participation. It is assumed that existing mines will have management plans and therefore existing mining locations is used as secondary indicator to where management plans might exist. Figure 21 shows existing mining positions (reference of dataset is unknown, obtained from the NWU Geography Department).

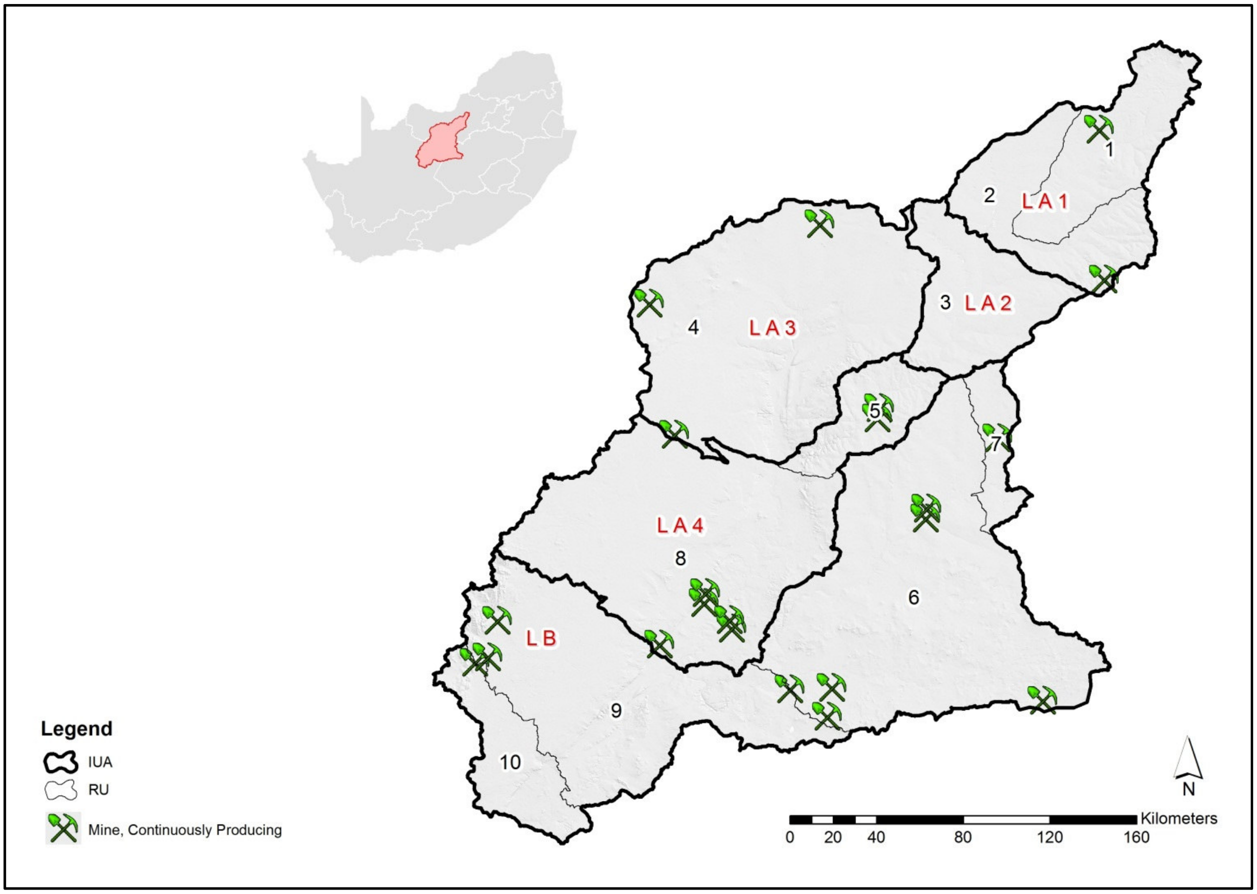

Figure 21: Current mining positions assumed to have management plans. ***Please note that the spatial distribution of 10 RUs were used in this assessment prior to the splitting of RU 8 into two RUs.***

Table 15 shows the rating guideline to be applied to the selected RUs and the spatial distribution of the final ratings is shown in Figure 22.

Table 15: Contribution to economy rating guideline

Rating	Guideline
0.0	RUs which do not contain groundwater resources for which management plans exist
1.0	RUs which contain groundwater resources for which management plans exist

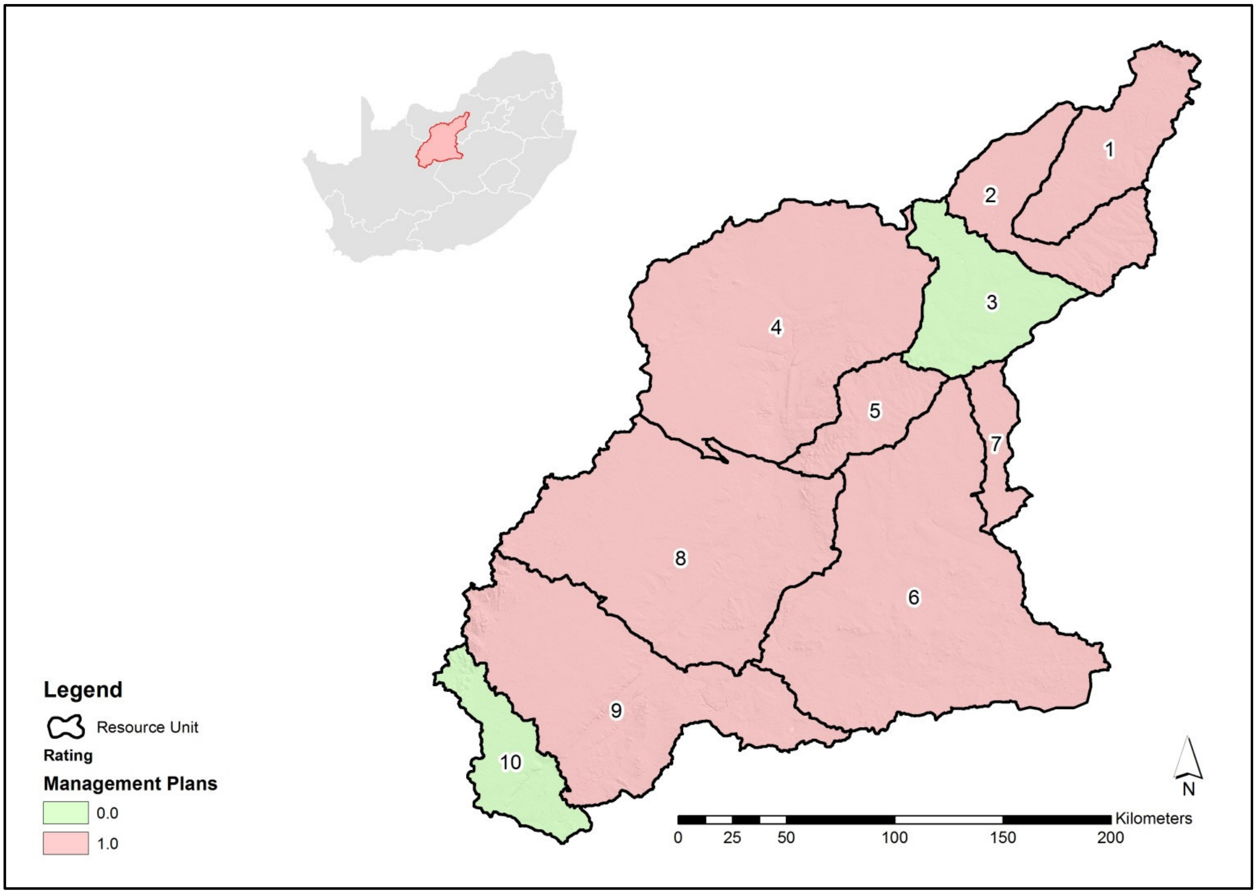

Figure 22: Spatial distribution of management plans rating. ***Please note that the spatial distribution of 10 RUs were used in this assessment prior to the splitting of RU 8 into two RUs.***

4 FINDINGS

4.1 PRIORITY RIVER RESOURCE UNITS FOR THE LOWER VAAL WMA

A total of 5 priority RUs were selected for the Lower Vaal WMA. These RUs and associated IUAs and Secondary catchment reach, and WRC study node name is detailed in Table 16. The location of these RUs is shown in Figure 23.

Table 16: Priority River Resource Units selected for the Lower Vaal WMA

RU	IUA	SQ Reach	Original Node name (WRC)	New Node Name (WRC)	EWR site
3	LA2. Middle Harts River	C31E-02045	VC57	LA2.1	N
6	LA4. Lower Harts River	C33C-02836	EWR 17	EWR17	Y
7		C33C-02746	VC59	LA4.2	N
8	LB. Vaal River from downstream of Bloemhof Dam to Douglas Weir	C91A-02391	EWR 16	EWR16	Y
11			IFR1	Douglas EWR	Y

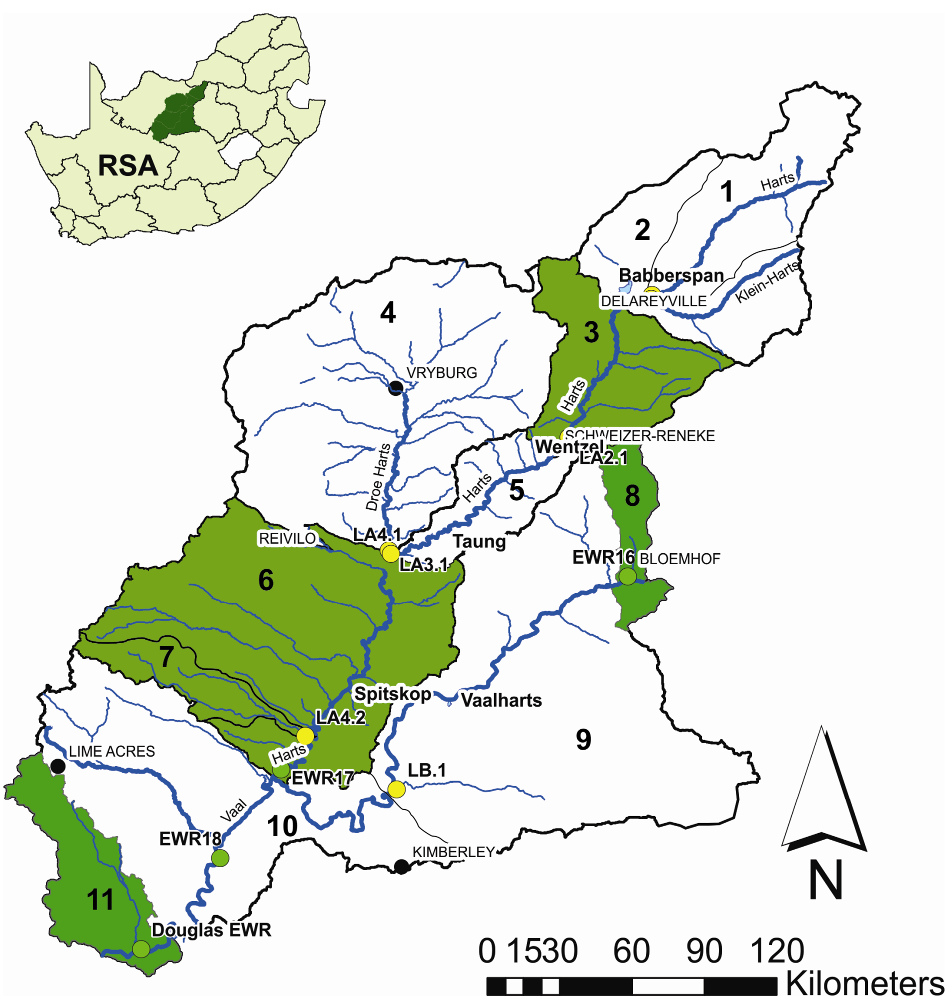

Figure 23: Location of the prioritised RUs in the Lower Vaal WMA

4.2 PRIORITY WETLAND ECOSYSTEMS FOR THE LOWER VAAL WMA

The approach adopted for identifying priority wetlands allowed for a structured step-by-step process to be followed[2]. Through this process key aspects / criteria were taken into consideration and scored / weighted appropriately during the desktop assessment phase. Through the use of available spatial datasets, the desktop assessment allowed for the prioritization of wetland systems.

Candidate wetlands from this initial assessment of priority wetlands were then selected based on existing recommendations for priority wetlands (DWA 2009), and a stakeholder consultation process. The four wetland systems that were identified as part of the comprehensive reserve determination study (DWA 2009), which corresponded to the 'surrogate' priority GIS layer, were taken into consideration. These include:

- Lower Vaal Barberspan (Ramsar site and important bird sanctuary);
- Harts River Floodplain (unique feature and birdlife);
- Kamferpan (lesser flamingo breeding site); and
- SA Lombard NR (important floodplain system).

A range of key stakeholders were consulted to help identify candidate wetlands for RQP determination, based primarily on biodiversity value, and / or functional importance. A list of these stakeholders, together with brief notes on the inputs obtained is summarized in Appendix C and D.

Once potential candidate wetlands had been identified, a stakeholder workshop was arranged to finalise the list of priority sites and to continue with the sub-component and indicator selection process. This was held on 20th and 21st of November 2013 and was attended by the following stakeholders:

- Jacqueline Jay (DWA);
- Paul Meulenbeld (DWA);
- Marc De Fontaine (Rand Water);
- Gary Marneweck (Wetland Consulting Services);
- Douglas Macfarlane (Eco-Pulse Environmental Consulting Services); and
- Ian Bredin (INR).

In addition, a meeting with Nacelle Collins (DETEA FS) was held on the 22nd of November.

Through stakeholder / specialist consultation it was determined that eight wetlands be considered as priority wetlands in the Lower Vaal. The location of each of these wetland ecosystems were then mapped as a final output of the prioritization process (Figure 24). Table 18 provides a summary of the eight priority wetlands selected for the Lower Vaal catchment.

[2] Bredin *et al*., in preparation.

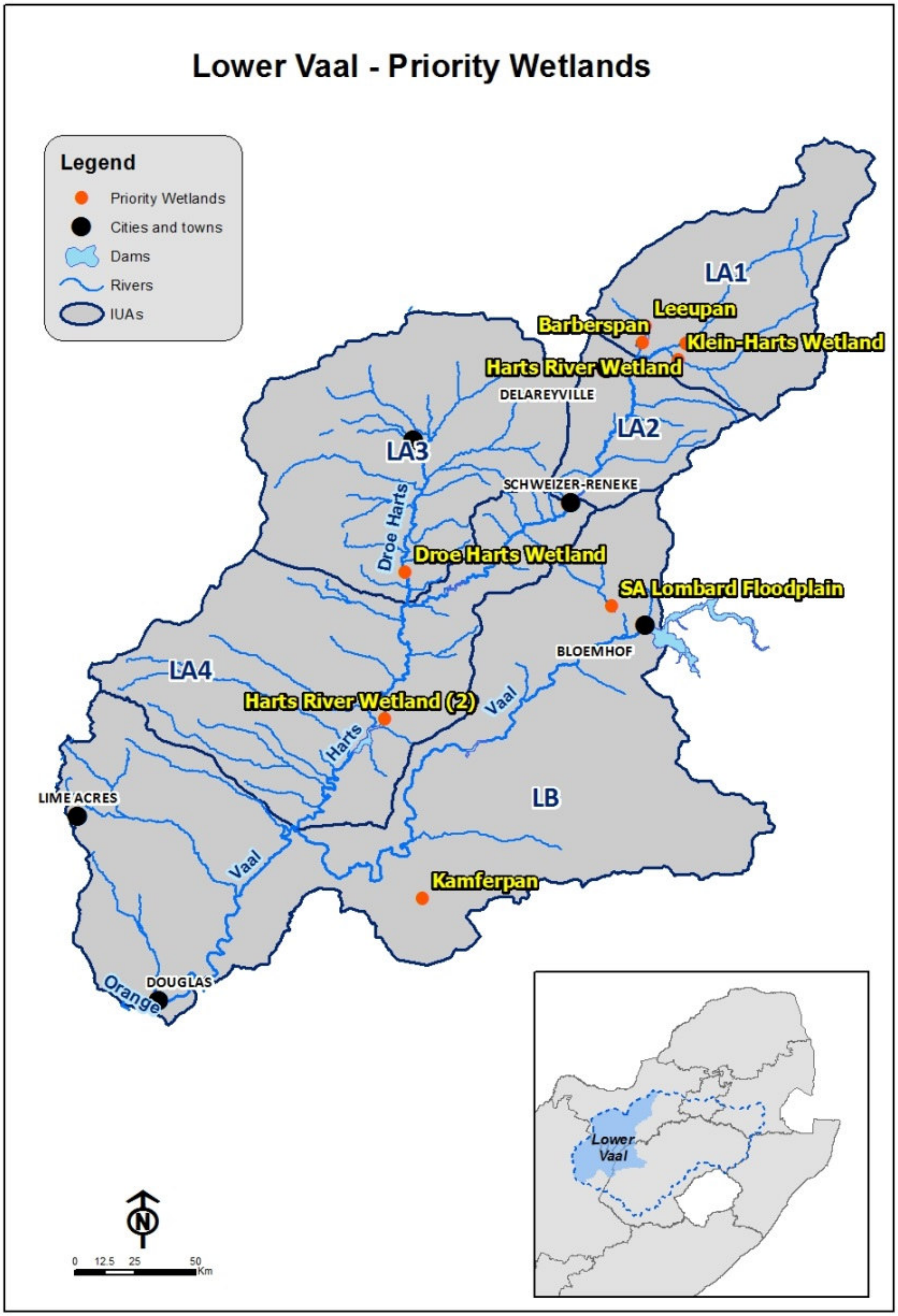

Figure 24: Lower Vaal catchment priority wetlands

Table 17: Lower Vaal catchment priority wetlands

IUA	Wetland Name / Code	Coordinates	River RU	Rationale
LA1	Leeupan	26°31'35.26"S 25°36'4.73"E	2	Important bird sanctuary.
LA1	Barberspan	26°35'13.01"S 25°35'28.41"E	2	Ramsar site and important bird sanctuary.
LA1	Klein-Harts Floodplain	26°39'10.54"S 25°43'24.13"E	2	High functional value.
LA1	Harts River Floodplain	26°35'18.13"S 25°45'14.63"E	1	Unique features and birdlife. High functional value.
LA3	Droe Harts Floodplain	27°26'59.92"S 24°41'52.73"E	4	High functional value.
LB	SA Lombard Floodplain	27°34'24.21"S 25°28'19.44"E	9	Important floodplain system.
LB	Kamferpan	28°40'24.08"S 24°45'48.91"E	10	Lesser flamingo breeding site.
LA4	Harts River Floodplain_2	28° 0'1.01"S 24°37'25.60"E	6	Unique features and birdlife. High functional value.

4.3 PRIORITY DAM ECOSYSTEMS FOR THE LOWER VAAL WMA

The application of the above criteria resulted in the selection of 6 priority dams for the Lower Vaal catchment. The final selected priority dams are presented in Table 18 below.

Table 18: Selected priority dam for the Lower Vaal WMA

IUA	Resource Unit	Dam Name	Quaternary	Dam number	River	Year Established	FSC Mm³	Why it was built (Purpose)
LA2	3	Wentzel	C31E	C3R001	Harts	1988	6.58	Irrigation, municipal - Schweizer Reineke
LA4	5	Taung	C31F	C3R006	Harts	1993	58.9	Irrigation
	6	Spitskop	C33B	C3R002	Harts	1992	56.6	Irrigation
LB	8	Bloemhof	C91A	C9R002	Vaal	1987	1269	Irrigation
	9	Vaalharts Weir	C91B	C9R001	Vaal	1987	48.7	Municipal, industrial, irrigation - Hartswater, Vryburg
	11	Douglas Weir	C92B	C9R003	Vaal	1987	16.1	Irrigation, municipal - Douglas

The selection of sub-components (quantity, quality, habitat and biota) to determine specific RQOs will be undertaken during step 5 of the process.

4.4 PRIORITY GROUNDWATER RESOURCE UNITS AND ECOSYSTEMS FOR THE LOWER VAAL WMA

One of the most important findings to highlight was the fact that a lot of intimate knowledge about the areas represented by the RUs resides with the public. The available datasets however fail to address some of the critical issues in certain areas and this highlights the importance of the public participation process.

Although public participation can address gaps in the data, it can also skew the prioritisation process if not all areas are equally represented.

The final results of the prioritisation tool are shown in Figure 25.

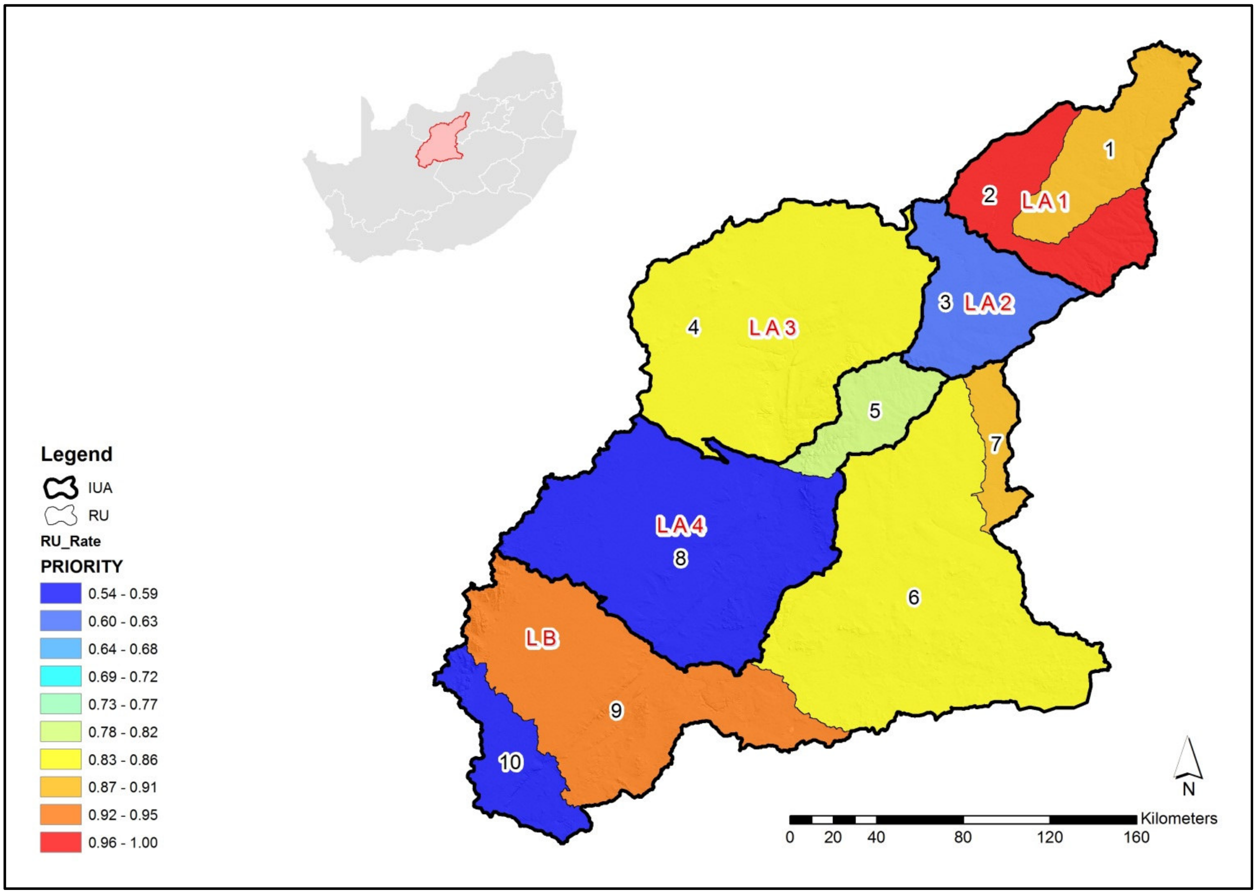

Figure 25: Lower Vaal groundwater prioritization. ***Please note that the spatial distribution of 10 RUs were used in this assessment prior to the splitting of RU 8 into two RUs.***

5 LIMITATIONS AND UNCERTAINTIES

SOME OF THE KEY LIMITATIONS WHICH MAY INFLUENCE THE CONFIDENCE OF THE OUTCOMES OF THE RESOURCE UNIT AND ECOSYSTEM PRIORITISATION PROCESS WHICH SHOULD BE CONSIDERED WHEN IMPLEMENTING THESE PRIORITY RUS AND ECOSYSTEMS INCLUDE:

5.1 RIVERS

- Quantitate data availability was limited which necessitated the use of qualitative data and specialist solicitations. This limitation was particularly evident in the moderately to minimally impacted areas of the Water Management Area. Through the implementation of RQOs real data would be generated to evaluate the accuracy of RU prioritisation process.
- The requisite simplicity principal was adopted in the study to prioritise RUs. In addition, stakeholders considered the capacity and resource availability of the regional regulators to prioritise RUs for RQO determination. These may result in the prioritisation of insufficient RUs for RQO determination which may inadequately address the protection requirement of the vision of the RQO determination process (available from the WRC study).

5.2 WETLANDS

- It should be noted that available datasets used, were either datasets generated at a national scale or surrogate datasets. Therefore, the prioritisation of wetlands is based on broad scale datasets.
- The number of specialist / stakeholders who were able to attend the final stakeholder / specialist workshops.
- The requisite simplicity principal was adopted in the study to prioritise wetlands. In addition, stakeholders considered the capacity and resource availability of the regional regulators to prioritise wetlands for RQO determination. These may result in the prioritisation of insufficient RUs for RQO determination which may inadequately address the protection requirement of the vision of the RQO determination process (available from the WRC study).

5.3 DAMS

- Quantitate data availability was limited which necessitated the use of qualitative data and specialist solicitations. This limitation was particularly evident in the moderately to minimally impacted areas of the Water Management Area. Through the implementation of RQOs real data would be generated to evaluate the accuracy of RU prioritisation process.
- Stakeholder representation of some IUAs were limited which may have resulted in these areas being neglected during the prioritisation process.

5.4 GROUNDWATER

- Quantitate data availability was limited which necessitated the use of qualitative data and specialist solicitations. This limitation was particularly evident in the moderately to minimally impacted areas of the Water Management Area. Through the implementation of RQOs real data would be generated to evaluate the accuracy of RU prioritisation process.
- Stakeholder representation of some IUAs were limited which may have resulted in these areas being neglected during the prioritisation process.

- The requisite simplicity principal was adopted in the study to prioritise groundwater RUs. In addition, stakeholders considered the capacity and resource availability of the regional regulators to prioritise groundwater RUs for RQO determination. These may result in the prioritisation of insufficient RUs for RQO determination which may inadequately address the protection requirement of the vision of the RQO determination process (available from the WRC study).

6 WAY FORWARD

Step 4 of the RQO methodology entails prioritising sub-components for RQO determination and the selection of indicators for monitoring. Each of the prioritised RUs (detailed in this report) will therefore by subjected to more detailed analyses to identify which sub-components present in these RUs should be protected in order to support water resource dependent activities and/or maintain the integrity and ecological functioning of the water resource. This information is then used to prioritise sub-components for RQO determination.

Wetlands were prioritized for RQO determination through a systematic desktop GIS process and supplemented with priorities identified by key local stakeholders. A final subset of wetlands was then selected at a focussed stakeholder meeting based on their importance for biodiversity conservation and / or their functional importance. The focus during subsequent steps will be to select sub-components and indicators for RQO determination for these prioritised wetlands. Regional-level RQOs will also be developed to cater for the plethora of other wetland ecosystems not catered for through this resource unit based approach.

7 ACKNOWLEDGEMENTS

We would like to acknowledge the contributions made by the stakeholders of the Upper Vaal Water Management Area who participated in the stakeholder workshop to the RQO determination process. The information and direction provided by these stakeholders has made a noticeable contribution to the study. In addition we acknowledge the contributions made by scientists and consultants who provided information to the study team.

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9 APPENDICES

APPENDIX A: SUMMARY OF THE DATA AND ASSOCIATED PROCESSING METHODS USED TO SCORE SOME OF THE CRITERIA AND SUB-CRITERIA IN THE RUPT FOR PRESENTATION TO STAKEHOLDERS.

1. Importance to users

a) Presence of cultural services

Cultural services are defined as the non-material benefits that people obtain from contact with ecosystems. They include recreational, aesthetic and spiritual benefits (TEEB, 2010). Resource Units which provide these benefits should be protected as they contribute to the wellbeing of society. The WRC study for the Vaal WMAs undertook an ecosystem services assessment in which they assessed the following ecosystem services:

- Recreational fishing
- Subsistence fishing
- Other recreational aspects associated with the rivers
- Riparian vegetation usage
- Waste water dilutions
- Floodplain agricultural usage of subsistence purposes.

This information was generated via site visits and available literature and converted into a socio-cultural importance score (SCI). The SCI provides an indication of the river resource dependence by those who rely directly on such aspects for their survival. The SCI for each Resource Unit was converted into a relative percentage. These percentages were then converted into three classes namely 0-33%, 34-66% and 67-100% and scored as 0, 0.5 and 1 respectively within the RUPT.

b) Presence of significant vulnerable communities

Many poor communities are directly reliant on water resources for domestic water use, food, grazing, medicine, and building materials. Rivers provide an important source of water for many vulnerable communities in the Lower Vaal WMA. The Census 2011 data identifies the source of water for households across the country and classifies the source according to 11 categories. Two of these categories, namely dam/pool/stagnant water and rivers/streams have been used to identify the location of vulnerable communities who are dependent on natural surface water resources in the Lower Vaal WMA

All categories provided in Statistics South Africa 2011 Census data	Categories used as indicators of vulnerable communities
Piped water inside dwelling	Dam/pool/stagnant water River/stream
Piper water inside yard	
Piped water on community stand: distance less than 200m from dwelling	
Piped water on community stand: distance greater than 200m from dwelling	
Borehole	
Spring	
Rain-water tank	
Dam/pool/stagnant water	
River/stream	
Water vendor	
Other	

The number of households within each of the selected categories was calculated per ward. Households were assumed to be uniformly distributed across each ward. Where a ward was located across two Resource Units, an area percentage was used to calculate the number of households within the portion of the ward occurring in each Resource Unit. The total number of households for all wards occurring within a Resource Unit was then summed to give an indication of the total number of households dependent on natural surface water resources within each Resource Unit.

In order to identify Resource Units which include more vulnerable communities than another, quantiles were used. This method divides the total number of Resource Units into three equal categories. All Resource Units occurring in the category with the highest number of vulnerable households were scored as a 1, while all Resource Units falling into the middle category were scored as 0.5. All Resource Units falling into the category containing the least number of vulnerable households were scored as 0.

c) Use in meeting strategic requirements

The economic component of the WRC study undertook an assessment of the contribution of different sectors to the GDP per IUA. The values for the "power generation" sector were used in the current prioritisation process. No power generation was listed as taking place in the Lower Vaal WMA and thus all RUs were scored as 0.

d) Presence of important regulating and supporting services

The only regulating and supporting service that was assessed for this criterion was the waste treatment function. A spatial layer was generated based on the physic-chemico metric from PES-EIS study to indicate demand whilst a supply layer was generated using stream order (assuming that bigger streams have greater capacity to assimilate waste). These two layers were then combined. Areas with both high supply and high demand were considered important for current use and scored as 1 whilst areas with high supply and low demand were considered important for future use and scored as 0.5.

e) Presence of activities supporting the economy

The economic component of the WRC study undertook an assessment of the contribution of different sectors to the GDP per IUA. The contribution of mining, manufacturing and irrigation was used to assess the presence of activities supporting the economy. These values were converted into relative percentages, categorised according to three classes namely 0-33%, 34-66% and 67-100% and scored as 0, 0.5 and 1 respectively. All Resource Units occurring in the specified IUA were scored the same.

2. Level of threat posed to users

The data used to assess the threat posed to users of the resource unit was sourced from Dr Neels Kleynhans at the Department of Water and Sanitation. This data forms part of the 2011/2012 desktop assessment of the PES/EIS of the WMA. For the purposes of the RUPT, three metrics were considered based on their potential to alter the in-stream condition of rivers within the resource unit. These included:

- Potential Instream Modification Activities
- Potential Flow Modification Activities
- Potential Physico-Chemical Modification Activities

Each of these metrics was scored as follows:

Threat description	Rating
None	0
Small	1
Moderate	2
Large	3
Serious	4
Critical	5

The maximum score from any of the three metrics was incorporated into the RUPT.

3. Ecological importance

a) Resource units with a high or very high EIS category

The Management Class report of the Water Resource Classification for the Vaal WMAs details the category for Ecological Importance and Sensitivity of each biophysical node in the study area. These categories range from "very high" to "very low". These categories were converted to scores for with "very high" assigned a score of 1, "high" assigned a score of 0.5 and the remainder of the categories scored as 0. The resulting scores for each Resource Unit were included in the prioritisation tool.

b) Resource units which have an A/B NEC and / or PES

The Water Resource Classification for the Vaal WMAs details both Present Ecological State information as well as the proposed ecological category for each biophysical node which must be met if the recommended Management Class is to be attained. This information was interrogated to identify those RUs which are currently or required to be in an A or B state. These categories were converted to a score with an A or A/B category scored as 1, a B category scored as 0.5 and the remainder of the categories scored as 0. The maximum score of either the PES or REC was included for the respective Resource Units within the prioritisation tool.

c) Resource units identified as National Freshwater Ecosystem Priority Areas

The National Freshwater Ecosystem Priority Areas (NFEPA) project identifies a number of freshwater ecosystem priority areas necessary to meet national biodiversity goals for freshwater ecosystems. River FEPAs achieve biodiversity targets for river ecosystems and threatened/near-threatened fish species, and were identified in rivers that are currently in a good condition (A or B ecological category) (Nel *et al*., 2011). Resource Units which contained a FEPA were scored as 1 in the prioritisation tool. The NFEPA project also identified Phase 2 FEPAs. Phase 2 FEPAs are located in moderately modified (C) rivers and their condition should not be degraded further, as they may in future be considered for rehabilitation once good condition FEPAs (in an A or B ecological category) are considered fully rehabilitated (Nel *et al*., 2011). Resource Units containing a Phase 2 FEPA were scored as 0.5 in the prioritisation tool.

d) Resource units identified as a priority in provincial / fine scale aquatic biodiversity plans

Aquatic biodiversity plans have been developed for a number of provinces. These plans incorporate NFEPA data which has already been considered as a separate sub-criterion in the Resource Unit prioritisation tool. To avoid double accounting, these plans were excluded from the assessment. However, the presence of conservancies and both formally and informally protected areas was interrogated. The National Protected Areas coverage was overlaid with the study area in a GIS environment to identify the location of protected areas relative to each Resource Unit. Resource Units which contained a formally protected area were scored as 1 while Resource Units which contained an informally protected area or conservancy were scored as 0.5. The protected areas considered during the assessment are detailed below:

- Barberspan Bird Sanctuary
- S.A. Lombard Nature Reserve
- Sandveld Nature Reserve
- Mokala National Park
- Lichtenburg Game Breeding Centre

4. Level of threat posed to ecological components of the resource unit

The same scores as those reflected under the "Level of threat posed to users" criterion were used for this criterion.

5. Management considerations

a) Resource Units with PES lower than a D category or lower than the accepted Gazetted Category

The Resource Directed Measures Integrated Manual (1999) sets out a default rule which states that "the management class is determined in relation to the present state, but at a level which represents a goal of no further degradation for water resources which are largely modified, and at least a move toward improvement for water resources which are critically modified". Similarly, the National Water Resources Strategy (2002) states that "any water resource which demonstrates 'Unacceptable' conditions is deemed to be unsustainable. In these cases the management class will be determined as a minimum of 'Heavily used/impacted' (the lowest management class), and management will aim to rehabilitate the water resources to this state". In line with this thinking, the Water Resource Classification for the Vaal WMAs considers that an E category is unsustainable and cannot be recommended as an ecological condition. This principle was also adopted in the RQO methodology. Consequently, any Resource Units with a PES lower than a D category must be prioritised for management action. No Resource Units in the Lower Vaal WMA had a PES of a "D/E" or "E". However, one RU had a PES lower than the accepted Gazetted Category. This RU was therefore scored as 1 in the prioritisation tool.

6. Practical considerations

a) Monitoring points

The Department of Water and Sanitation undertakes a number of national monitoring programmes including the National Chemical Monitoring Programme (NCMP), the National Microbiological Monitoring Programme (NMMP) and the River Health Programme (RHP). In addition, the Department has a number of routine water quality monitoring sites and Ecological Water Requirement (EWR) sites. The location of these monitoring sites relative to each of the Resource Units was identified. Resource Units which contained either a EWR or RHP site were scored as 1 while those Resource Units which contained any other monitoring site received a score of 0.5. The maximum score assigned to each Resource Unit was included as the final score for this sub-criterion in the Resource Unit prioritisation tool.

b) Accessibility

No desktop data was available to score this sub-criterion and it was therefore excluded from the initial prioritisation process.

c) Safety risk

No desktop data was available to score this sub-criterion and it was therefore excluded from the initial prioritisation process.

APPENDIX B – PLOTTING PROCEDURE FOR EXPANDED DUROV DIAGRAM

Data Interpretation with Piper and Durov Diagrams

Many facilities for the interpretation of water quality monitoring data exist. Some of these are well-known methodologies, such as statistical evaluations, line and bar charts, or plots of borehole and water-level information. Other methodologies are less known. These are, for instance, the so-called specialized chemical diagrams. Of these, only the Piper and Expanded Durov Diagrams will be discussed.

Piper and Expanded Durov Diagrams

The Piper and Expanded Durov Diagrams allow the plotting of eight chemical parameters for a single water sample. Either surface or ground-water chemistries may be plotted.

The procedure is as follows:

- Calculate concentrations for Ca, Mg, Na, K, Cl, SO_4, NO_3, T. Alk. in units of milli-equivalents per litre.
- Calculate relative percentages for the cations and anions.
- Plot the percentages cations in the bottom left triangle.
- Plot the percentages anions in the bottom right triangle.
- Project the two points to the central block on the Piper or Durov Diagrams and make a mark where the two projections cross.

Interpretation is as follows:

- It is a matter of personal preference whether the Piper or Durov Diagrams are used.
- Both diagrams should primarily be used as visual displays, summarizing the chemistry of all samples taken at a site, or at many sites.
- Of particular value is the identification of pollution trends, through the aid of these diagrams. A comparison between plots of successive sampling exercises, will clearly show whether or not trends in the chemistry of the water are developing. Trends to observe are:

1) Sodium enrichment - typical of processes such as waste water discharge, chemical extraction of minerals from ore, dewatering of deep mines, return flow from irrigation or natural deterioration of the ground-water quality by ion exchange within the aquifer.

2) Sulphate enrichment - typical of most mining environments.

3) Calcium enrichment - typical of lime dosing to neutralize acid water.

4) Chloride enrichment - typical of leachate from domestic waste and dewatering of deep mines.

A word of caution though: the ground-water chemistry is one of the most complex natural systems to predict, because of the many natural processes/parameters that could affect it. The following are but a few examples of chemical changes which could occur within an aquifer:

- Dissolution of soluble elements, such as Na, K, Cl and HCO_3.
- Precipitation of oversaturated species.
- Ion exchange and adsorption onto clays, such as Ca-adsorption and Na-release.
- Chemical reaction between two waters mixing.
- Natural decay of substances, such as modern pesticides.
- Bacterial oxidation/reduction, such as pyrite oxidation and sulphate reduction.
- Dispersion of pollutants through the aquifer.
- Convection during flow of pollutants through the aquifer.
- The aquifer hydraulic constants, such as transmissivity, storativity, gradients and boundary conditions.

The specialized diagrams and other techniques for the interpretation of the data, included within WasteBase and WasteManager, should therefore be used with circumspection. The identification of trends should be done by all waste disposal managers. However, if undesirable pollution trends develop, which cannot obviously be linked to operations, it should best be left to the geohydrologist to suggest remedial action.

PIPER DIAGRAM

The chemical composition of ground water reflects the processes which are responsible for the different constituents it contains: Wind blowing over the ocean carries mainly sodium chloride landwards. Oxygen, nitrogen and carbon dioxide dissolve when the humidity in the air condenses. Additional carbon dioxide and humic acids dissolve when water percolates through the soil containing organic matter.

The ground water changes its composition as the water moves through the aquifer. Minerals dissolve and release salts; sulphides may oxidize; cations are exchanged; sulphides and nitrates can be reduced through bacterial action; evaporation leads to concentration; and once the solubility products are exceded minerals are precipitated. Mixing with water of different origin also influences the composition.

Trilinear diagrams are used for the investigation of ions or groups of ions as a function of the concentration. On these diagrams the milli-equivalent percentages of the major cations and anions are plotted; and it has been found that the point at which an analysis plots is of considerable diagnostical value.

The Piper diagram is a combination of two trilinear diagrams and a central diamond field. In the diamond field the cations Ca^{2+}, Mg^{2+}, $Na^{+} + K^{+}$; and the anions SO_4^{2-}, Cl^{-} and $HCO_3^{-} + CO_2^{2-}$ are represented by a point, in the trilinear diagrams cat- and anions each separately.

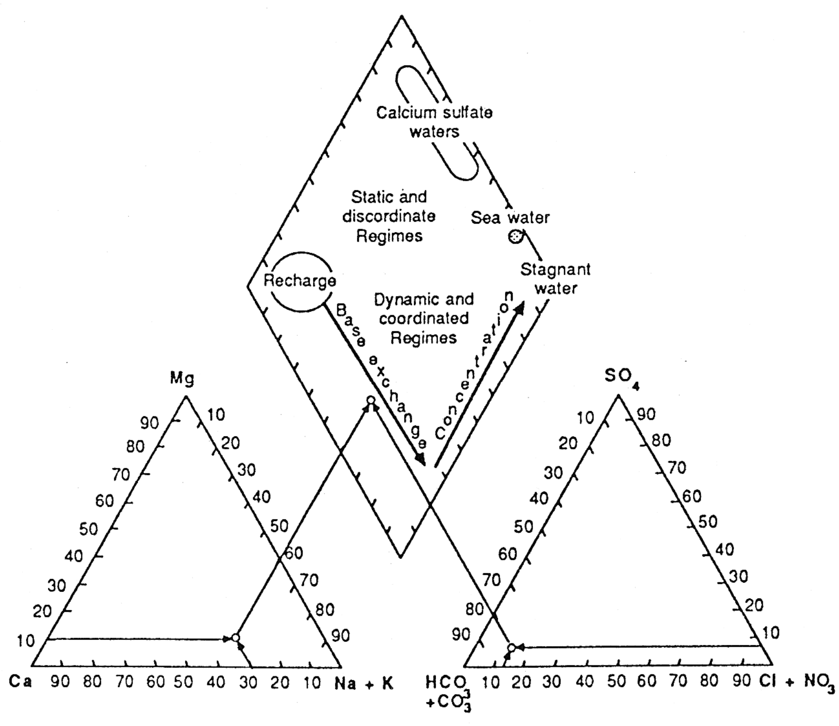
To convert the units mg/L normally given in an analysis to milliequivalents the determined quantities must be divided by the molecular weight of the respective ion and its valence. The constants for the conversion of the different ions are:

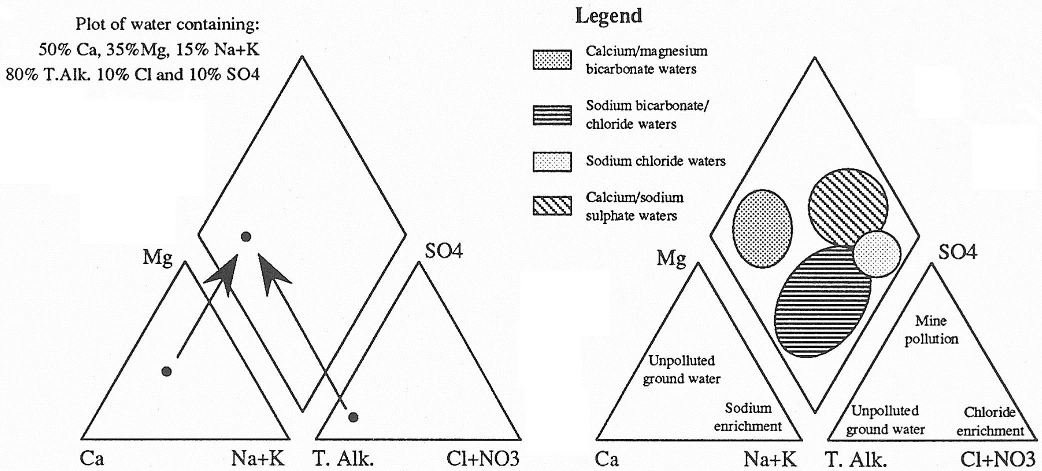
Cations		Anions	
Ca	1/20	HCO_3	1/61
Mg	1/12	CO_3	1/30
Na	1/23	Cl	1/35.5
K	1/39	NO_3	1/62
		SO_4	1/48

The percentage milli-eqivalents for the different cations are calculated by dividing the respective milli-equivalent values by the sum of the milli-equivalents of the cations. The percentage milli-equivalents for the anions are calculated accordingly.

After the cat- and anions are plottes in the trilinear fields their position is projected in the central diamond field. Based on the position in the diamond field ground water can be divided into four categories, nl.:

- Recently recharged ground water rich in calcium and/or magnesium and bicarbonate.
- A dynamic regime with water rich in bicarbonate with increasing sodium (and potassium) concentrations.
- "Stagnant" or relatively old ground water at the end of the cycle with high sodium, chloride and/or sulphate values. It plots near the point for sea water.
- Calcium sulfate water as well as other relatively seldom encountered water which plots in the upper half of the diamond field.

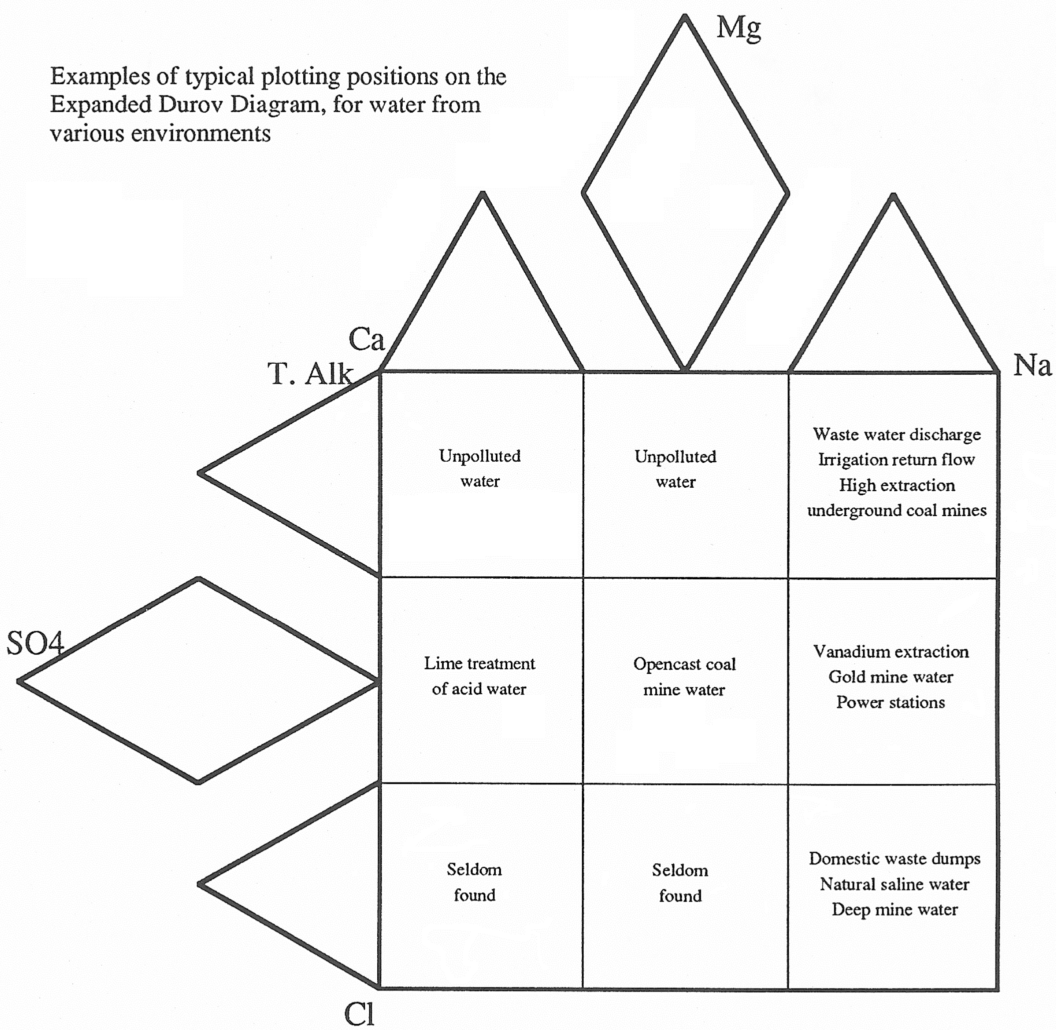


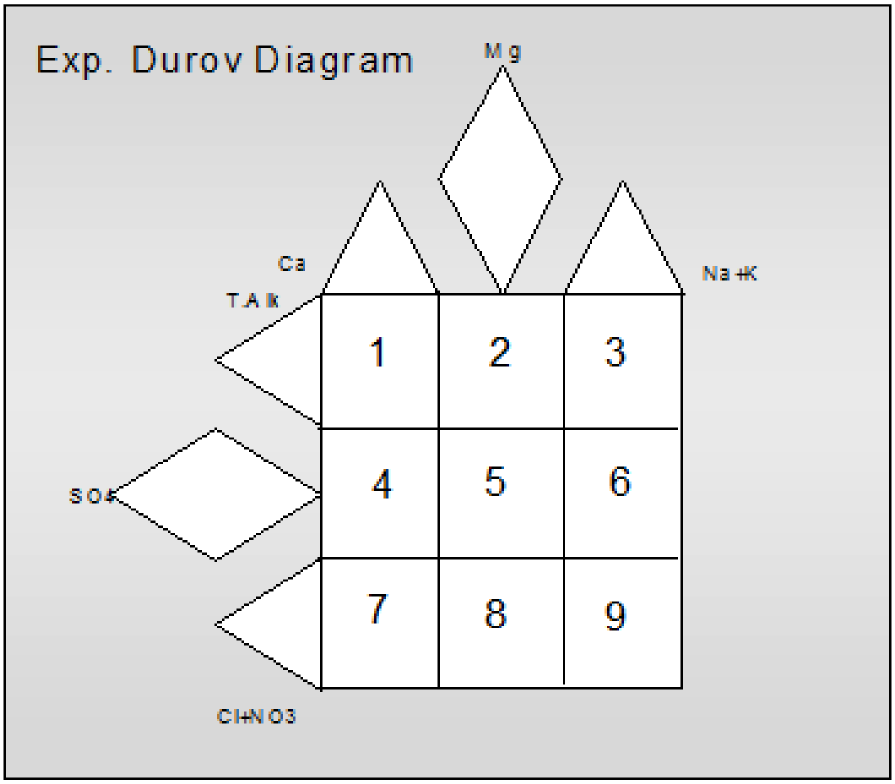


Plotting procedure on the Piper Diagram

Examples of typical plotting positions on the Piper Diagram, for water from various environments

Examples of typical plotting positions on the Expanded Durov Diagram, for water from various environments





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

APPENDIX C - LIST OF KEY STAKEHOLDERS CONTACTED AND SUMMARY OF FEEDBACK OBTAINED

Stakeholder	Organization	Input provided
Hermien Roux	North West DEDECT	Could not provide any specific data. Suggested a number of contacts to follow up with further.
Jacqueline Jay	DWS	Highlighted the importance of a number of wetlands and activities within IUAs.
Malaika Koali-Lebona	Provincial Coordinator: North West SANBI	Highlighted the importance of a number of wetlands.
Marc De Fontaine	Rand Water	Highlighted the importance of a number of wetlands and activities within IUAs.
Mark Rountree	Fluvius Consulting Services	Highlighted the importance of a number of wetlands. Suggested a number of contacts to follow up with further.
Anton Linström	Wet-earth eco-specs	Could not provide any specific data. Suggested a number of contacts to follow up with further.
Martin Ferreira	Jeffares & Green (Pty) Ltd	Highlighted the importance of a number of wetlands, primarily pan systems.
Paul Meulenbeld	DWS	Highlighted the importance of a number of wetlands and activities within IUAs.
Nacelle Collins	DETEA FS	Highlighted the importance of a number of wetlands. Provided data on a number of priority wetlands.
Vukosi Ndlopfu	GDARD	Highlighted the importance of some wetlands in Gauteng section of the catchment.
Retief Grobler	Imperata Consulting	Highlighted the importance of a number of wetlands, particularly the Meul floodplain.
Terence McCarthy	WITS	Provided data on the Klip River wetland.
Gary Marneweck	Wetland Consulting Services	Highlighted the importance of a number of wetlands.
Piet-Louis Grundling	Ixhaphozi Enviro Services CC (I.E.S)	No feedback obtained.
Andre Beetge	Working for Wetlands and head of Mpumalanga Wetland Forum	No feedback obtained.
Frank Winder	North West University	No feedback obtained. Used available reports and presentations compiled by Frank on priority wetlands.
Doug Macfarlane	Eco-Pulse Consulting	Highlighted the importance of a number of wetlands.
Wynand Malherbe	University of Johannesburg	Could not provide any specific data.
Heidi Nieuwoudt	SANBI	Could not provide any specific data. Suggested a number of contacts to follow up with further.

APPENDIX D - KEY NOTES FROM THE SPECIALIST WORKSHOP

Wetland	Key Notes
Barberspan	Good candidate wetland.
SA Lombard	Quite a unique floodplain. Threatened by alluvial diamond mining.
Kamfer pan	NB wetland for flamingos (Breeding population). Need to ensure that water levels are maintained at appropriate levels. Consider excluding land based activities around breeding sites. OK
Hartswater River floodplain (2 sections)	Nice sections of wetlands.
Droe Harts Floodplain	Irrigation upstream, nice wetland floodplain
Leeupan	Good candidate wetland.
Klein-Harts Floodplain	Important from a user perspective. High functional value.

APPENDIX E: GIS WORKSHOP EVALUATION QUESTIONNAIRE.RESOURCE QUALITY OBJECTIVES DETERMINATION STUDY FOR THE LOWER VAAL WMA – Resource Unit Prioritisation Workshop (24 -26 July)

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RESOURCE UNIT PRIORITISATION TRAINING WORKSHOP FOR THE LOWER VAAL WMA

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