DETERMINATION OF RESOURCE QUALITY OBJECTIVES IN THE UPPER VAAL WATER MANAGEMENT AREA (WMA8)

WP10533

SUB-COMPONENT PRIORITISATION AND INDICATOR SELECTION REPORT

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Determination of Resource Quality Objectives in the Upper Vaal Water Management Area (WMA8) - WP10533

Sub-Component Prioritisation and Indicator Selection Report

Executive Summary

The Resource Quality Objectives (RQOs) determination procedures for the Upper Vaal Water Management Area (WMA) involved the application of the seven step framework established by the Department of Water Affairs in 2011. Some of these steps were achieved in the Water Resource Classification 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 Numerical Limits.
- Step 6. Agree Resource Units, RQOs and Numerical Limits 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 selection of and prioritisation of sub-components and indicators for the Upper Vaal Water Management Area (Step 4). These components and sub-components include:

- Quantity components including low and high flow sub-components.
- Quality components including nutrients, salts, system variables, toxicants and pathogen sub-components.
- Habitat components including instream and riparian habitat sub-components.
- Biota components including fish, plants, mammals, birds, amphibians and reptiles, periphyton, invertebrates and diatom sub-components.

Through this step a total of 494 sub-components were selected for RQO determination including:

- A total of 137 sub-components were selected to represent river resources from 21 prioritised RUs.
- A total of 95 sub-components were selected to represent groundwater resources from 19 prioritised RUs.
- A total of 62 sub-components were selected to represent dam resources from 17 prioritised RUs.
- A total of 60 sub-components were selected to represent wetlands resources from 18 prioritised RUs.

Determination of Resource Quality Objectives in the Upper Vaal Water Management Area (WMA8) - WP10533

Sub-Component Prioritisation and Indicator Selection Report

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WETLAND HYDRO-GEO-MORPHIC TYPE	REGULATORY BENEFITS POTENTIALLY PROVIDED BY WETLAND							
	Flood attenuation		Stream flow regulation	Enhancement of water quality				
	Early wet season	Late wet season		Erosion control	Sediment trapping	Phos-phates	Nitrates	Toxicants[2]
1. Floodplain	++	+	0	++	++	++	+	+
2. Valley-bottom - channelled	+	0	0	++	+	+	+	+
3. Valley-bottom - unchannelled	+	+	+?	++	++	+	+	++
4. Hillslope seepage connected to a stream channel	+	0	+	++	0	0	++	++
5. Isolated hillslope seepage	+	0	0	++	0	0	++	+
6. Pan/ Depression	+	+	0	0	0	0	+	+

Notes: [1] The rationale for the rating of benefits is given in Section 3.6
[2] Toxicants are taken to include heavy metals and biocides.

Rating: 0 Benefit unlikely to be provided to any significant extent
+ Benefit likely to be present at least to some degree
++ Benefit very likely to be present (and often supplied to a high level)

LIST OF FIGURES

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
µg/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 Upper Vaal Water Management Area (WMA8) - WP10533

Inception 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 significant water resources (surface water, wetlands, groundwater and estuaries) are classified according to a WRC System. In the process, the Reserve (i.e. the amount and the quality of water required to sustain both the ecosystem and provide for basic human needs) is also determined for the water resource. This Reserve then contributes to the Classification of the resource. This classification procedure in a Management Class and associated RQOs for water resources, which then 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). RQOs 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 procedures includes the prioritisation of sub-components for RQOs, the selected indicators for monitoring and proposes and the direction of change of these indicators (Step 4; DWA, 2011).

Step 4. Sub-component prioritisation, indicator selection and direction of change

Step 3 in the study included the prioritisation and selection preliminary Resource Units (RUs) and or ecosystems for the relevant resources for RQO determination. This sub-component prioritisation, indicator selection and direction of change step (Step 4) follows on from Step 3 and consists of two key objectives including:

- identification and prioritisation of sub-components that may be important to either users or the environment and,
- selection of those sub-components and associated indicators for which RQOs and Numerical Limits (NLs) should be developed.

This step in the RQO process bears particular relevance to the consideration of the impacts of land-based activities on the water resource and involves specialist water resource scientists, practitioners and water resource regulators.

2 SCOPE OF THE STUDY

This study entails the determination of Resource Quality Objectives (RQOs) for all significant water resources (rivers, wetlands, dams (or lakes) and groundwater) in the Upper 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 completed the Water Resource Classification (WRC) study for the Upper 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 (MC) for each IUA and Recommended Ecological Categories (REC) for biophysical nodes selected to represent the riverine ecosystem in the WMA. As such this study did not include 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 4 of the RQO determination procedure (DWA, 2011).

3 METHODOLOGY

3.1 RESOURCE QUALITY OBJECTIVES OVERVIEW

The Resource Quality Objectives determination procedures established by DWA (2011) were implemented in this study. This included the implementation of the seven-step procedural framework which is repeatable and as such allows for an adaptive management cycle with additional steps (Figure 1). Overall the procedure involved defining the resource, setting a vision, determining RQOs and Numerical Limits (NLs), gazetting the RQOs and NLs and then moving to implementation, monitoring and review of these RQOs and NLs 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 include:

- **Step 1. Delineate the IUAs and RUs:** In this case study IUAs were obtained from the Water Resource Classification (WRC) study (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:
    - 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. The RU delineation process then involved amalgamating the upstream associated sub-quaternary reaches of riverine ecosystems, and their associated catchment areas. As a result, the number of RUs selected for the study was identical to and could 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.
- **Step 2. Establish a vision for the catchment and key elements for the IUAs:** The stakeholder requirements and their associated outcomes, which include 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 (i.e. wetlands, dams and groundwater ecosystems). This additional information is highlighted in the applicable reports.
- **Step 3. Prioritise and select RUs and ecosystems for RQO determination:** This step involved the use of existing ecological specifications (EcoSpecs) and user specifications (UserSpecs) information from the Upper Vaal Reserve and WRC studies. This information was used to implement the RU Prioritisation Tool for rivers (DWA, 2011) and the new RU Prioritisation Tools developed for groundwater RUs as part of this study. Wetland ecosystem prioritisation involved the implementation of a new GIS based prioritisation approach developed for the study and dam ecosystem prioritisation was based on a desktop assessment of available user- and eco-spec information. During this step, RU and ecosystem prioritisation stakeholder participation workshops were carried out during which available information was discussed and amended according to available local information regarding the protection and use requirements for the WMA. During these RU and ecosystem prioritisation stakeholder workshops, consensus was reached to select the final lists of prioritised RUs and ecosystems for the RQO determination process.
- **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, wetlands 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 for wetlands, dams and groundwater were developed for the study. This

information was then used to develop draft RQOs and Numerical Limits in the next step. The relevant activities of this step were:

- 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 was based on the outcomes of the RU and ecosystem prioritisation step (Step 4). From the outcomes of the RU and ecosystem prioritisation step, draft RQOs were established and provided to recognised specialists to establish NLs that were 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 measures of the RQOs (DWA, 2011). Although the NLs may have had some uncertainty associated with them and were not originally intended for gazetting (DWA, 2011), they were considered for gazetting in the study at the request of the Department of Water and Sanitation (DWS) Chief Directorate: Legal Services. Refer to the RQO and NL reports for more information (REF). The relevant activities of this step were:
  - 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 on Resource Units, RQOs and Numerical Limits with stakeholders:** This component included the consideration of RQO and NL outcomes with stakeholders prior to the initiation of the gazetting process. The relevant activities of this step were:
  - 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 still to be carried out. A Legal Notice was developed as a part of this study for submission to Chief Directorate: Legal Services of the DWS for gazetting.

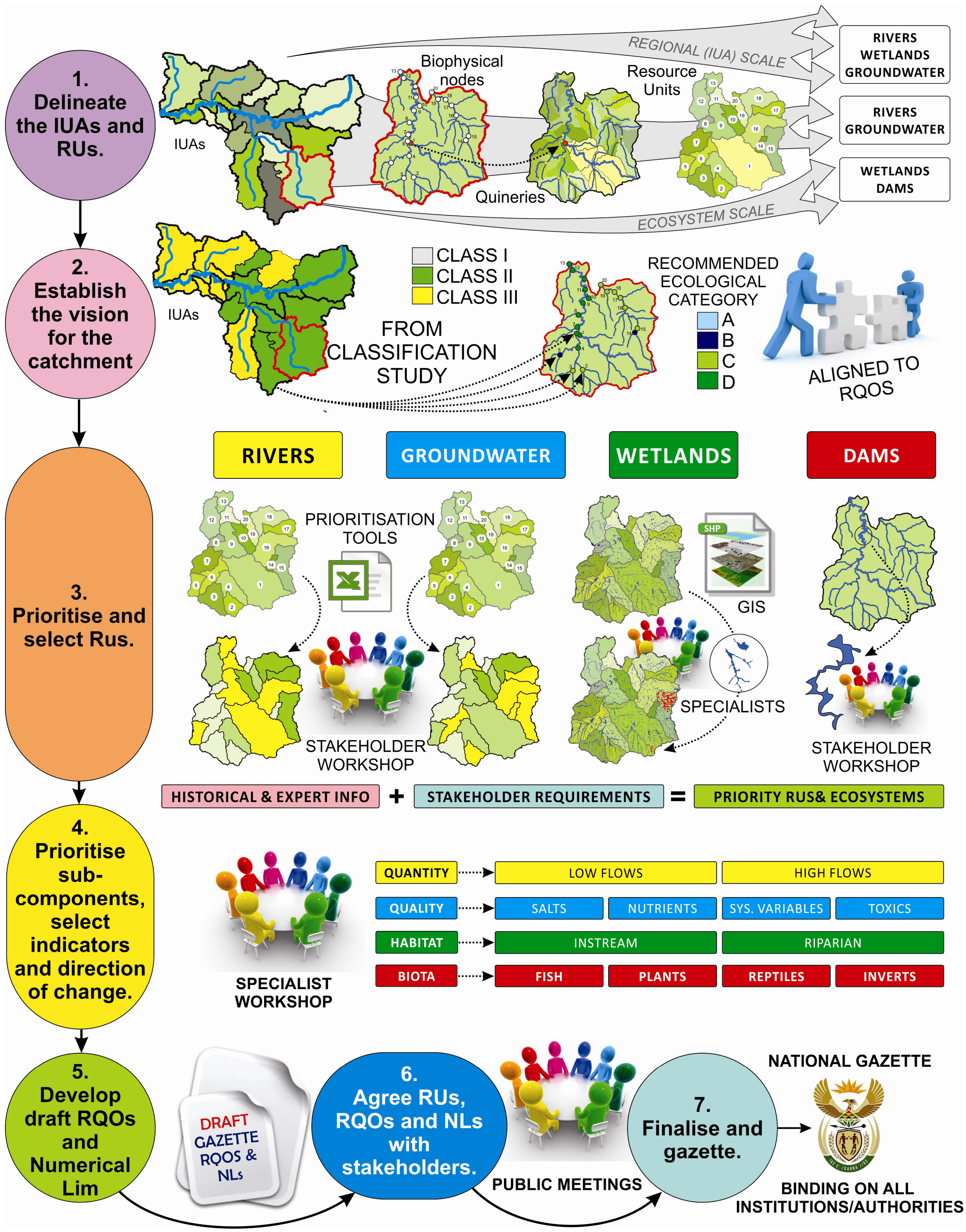

Figure 1: Schematic summary of the RQO determination procedure (adapted from DWA, 2011) which was implemented in this study.

3.2 SUB-COMPONENT AND INDICATOR SELECTION OVERVIEW

The prioritisation of sub-components for RQO determination and selection of indicators forms the fourth step of the RQO determination process (Figure 1). This step included 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.

3.3 RIVER COMPONENT

The river component of the prioritisation of sub-components for RQO determination and selection of indicators component involved the use of the existing Resource Unit Evaluation Tool for rivers that was developed by DWA (2011). The river Resource Unit Evaluation Tool has two primary functions including:

- determining the level of threat posed to each of the sub-components by impacting activities in the catchment and secondly,
- identifying which sub-components should be protected in order to support water resource dependent activities and/or maintain the integrity and ecological functioning of the water resource.

In this case study the river Resource Unit Evaluation Tool was implemented at a specialist workshop which included the relevant catchment managers and other key individuals with a good understanding of the area and also the ecosystem. The procedures involved in applying the tool are available in detail in the RQO determination procedure (DWA, 2011) and are summarised here.

Identify and assess the impact of current and anticipated future use on water resource components: The first sub-step in prioritising sub-components for RQO determination involves building an understanding of current impacts and future pressures on the RU using available data and specialist knowledge. This sub-step was undertaken using the ‘Impacting activities’ worksheet in the river Resource Unit Evaluation Tool.

Assess the importance of activities in driving resource change: Consideration was given to current users (existing and authorised water use) and anticipated future use (within next 5 years) within and upstream of each RU being evaluated. Those activities which were considered to have a considerable impact were rated as very important users irrespective of their contribution to the economy. The economic contribution of activities was then assessed in terms of their contribution to GDP, the number of jobs that they provide and whether they are a strategic water user. A brief description and rationale for the rating assigned to each user was provided.

Determine the anticipated level of impact on each sub-component: Each of the listed activities (*e.g.* irrigated agriculture, urban areas, rehabilitation, *etc.*) has the potential to impact the components and sub-components of the water resource in a variety of different ways. The purpose of this sub-step was to identify those sub-components which are threatened as a result of high levels of impact as such sub-components should be prioritised over those sub-components which are experiencing a low level of impact. The assessment was based on the scale, location and intensity of the current and future activities in the Resource Unit and/or catchment.

Determine the cumulative level of impact on each sub-component: The purpose of this step was to identify the cumulative effect of all of the impacting activities on each sub-component. Cumulative effects are commonly understood as the impacts which combine from different activities and which result in significant change, which is larger than the individual impacts. Based on a review of impact scores, a ‘cumulative level of impact’ score for each sub-component was selected using the impact rating guidelines. This information was used to automatically determine an Impact Class for each sub-component.

Determine the anticipated consequences of the impacting activities on each sub-component: Once an understanding of key impacts driving current and future impacts to the RU was assessed, this was used to help inform an assessment of the anticipated consequences of impacting activities on water resource quality. This is expressed as a projected trajectory of change for each sub-component and is informed by the 'cumulative level of impact' score.

Identify requirements of important user groups: The second sub-step in prioritising sub-components for RQO determination entails identifying which groups are using the resource, classifying the importance of these groups and determining which sub-components are important to them. This sub-step was undertaken using the 'User requirements' worksheet in the river Resource Unit Evaluation Tool.

Identify important user groups within the 'protection of the water resource' and 'water resource dependent activity' user group types: The purpose of this sub-step was to identify water users that need to be considered when setting RQOs. The relative importance of user groups was therefore assessed and recorded with a supporting rationale in the river Resource Unit Evaluation Tool.

Rate the importance of sub-components for the 'protection of the water resource' and 'water resource dependent activities: The purpose this sub-step was to determine which sub-components are important and / or of concern to different user groups. This was determined by rating the importance of sub-components for users who were identified as important or very important and was used to calculate an importance score for each sub-component. This helps to highlight sub-components of primary concern to different user groups, thus reflecting aspects of the water resource that they feel need to be closely monitored.

Summarise the aspirations of each important user group: Opportunity was provided to summarise relevant aspirations of conservation agencies and users dependent on the water resource. In the case of conservation agencies and users dependent on the water resource, stakeholders highlighted specific components or attributes of the water resource which are of concern to them. These aspirations effectively provide a justification for assigning a particular rating or score in the previous importance assessment.

Review Present State information: In this step the Present State information from the Reserve, WRC and from the recently completed assessment of the Present Ecological State, Ecological Importance and Ecological Sensitivity for the whole country (DWA, 2013c) was used. This information was used to inform the desired direction of change for users and also informed the situation from a protection perspective. For water resource dependent activities, the present state was expressed in terms of 'fitness for use' for those activities. When completing the information for the 'protection of the water resource' user group, the Ecological Category was recorded separately for each sub-component. The 'fitness for use' category for each sub-component for the 'water resource dependent activities' user group was then be recorded. The current trajectory of change for each component was also estimated. This was informed by the assessment of impacting activities but was sometimes over-written based on more reliable information.

Propose the desired direction and magnitude of change for each sub-component for important user-groups: For 'water resource dependent activities' and organisations responsible for protecting the natural environment, an assessment of the desired direction of change was undertaken to provide an indication of whether stakeholders would like a particular sub-component of the water resource to be improved or whether some level of degradation may be acceptable. Both the importance ratings for each of the sub-components and present state / fitness for use information was used to guide this assessment.

Selection of sub-components for RQO determination: In this sub-step the key sub-components for RQO determination and appropriate indicators to monitor them were selected.

Review the Ecosystem and User Prioritisation ratings: Two prioritisation ratings, one for the ecosystem and the other for users, are then automatically calculated in the Rivers RU Evaluation Tool. These prioritisation ratings are based on how important a sub-component is from an ecological or user perspective and whether this sub-component is threatened by anthropogenic activities occurring in the catchment. The overall prioritisation ratings range from very low to very high. Very high ratings highlight those sub-components which are both important from an ecological and/or user perspective and which are threatened by anthropogenic activities. This information was used to select the indicators and identify the 'UserSpec', 'EcoSpec' reason for the selection.

Select sub-components and associated indicators for RQO determination
The overall priority ratings were used to guide the selection of sub-components for RQO determination. Sub-components with high scores were selected first. A rationale for selecting each sub-component was provided. Based on the rationale for sub-component selection, the selection of a sub-component as a 'UserSpec', 'EcoSpec' and/or 'Integrated measure' was documented as this was later used to provide context information for the RQOs and to direct the NLs and monitoring requirements

Once sub-components have been selected, suitable indicators for monitoring should be identified. This was informed by the Ecosystem and User Prioritisation rating and the associated aspirations of the user group. The rationale for selecting the indicator was captured in the appropriate column in the Resource Unit Evaluation Tool.

Establish the desired direction of change for selected sub-components: Once sub-components and relevant indicators were selected, the level at which RQOs will be set were established. In this study the outcomes of the WRC were considered. Here the Recommended Ecological Category (REC) scores were used to ensure that the RQO process and the classifications processes are aligned.

The process of prioritisation ranked all of the RUs from high to low priority. Thereafter a decision had to be made on how many RUS to include in the list of priority RUs. This decision was based on the ability of the regulator (DWA) to manage the monitoring and implementation of RQOs in the selected priority RUs. In the absence of a detailed budgetary and capability assessment of DWA, the decision was made in conjunction with DWA staff who estimated how many RUs could be managed. This was partly driven by an estimation of the minimum number of RUs that would need to be monitored to ensure that there was adequate coverage of the entire WMA.

There are 21 RUs in the Upper Vaal WMA that were prioritised for the allocation of RQOs. The methods described above were used to determine the sub-components and indicators for these RUs. Although it would have been ideal to workshop all of these RUs with stakeholders to select the sub-components and indicators, due to time constraints this could not be achieved. The sub-components and indicators were therefore determined using the following processes (Table 1):

- Workshop: Priority RUs were selected and the sub-components and indicators were selected during the workshop involving the specialists who attended the workshop and applied the Rivers Resource Unit Evaluation Tool.
- Desktop: For other RUs, sub-components and indicators were determined at a desktop level by the study team with the guidance and comments from stakeholders who attended the sub-component workshop using the Rivers Resource Unit Evaluation Tool.
- Extrapolated: For other RUs that were immediately upstream of downstream of evaluated RUs, sub-components and indicators were extrapolated but based on the known differences between the RUs. The River Resource Unit Evaluation Tool was not completed for the selection of sub-components and indicators for these RUs. Outcomes were evaluated by stakeholders who attended the sub-component workshop.
- Protection: The stakeholders who attended the sub-component workshop justified the identification of additional RUs that were prioritised during the workshop for specific ecosystem protection components. Specialist knowledge of these protection requirements for these components nullified the need to use the Rivers Resource Unit Evaluation Tool.

After the completion of the sub-component and indicator identification phase the outcomes were aligned between RUs. The purpose of this alignment procedure at this stage of the study was to ensure that management decisions that affect downstream water resources were appropriate.

Table 1: Sub-components and indicator selection procedures for the prioritised RUs considered in the study.

IUA	Resource Unit	Workshop	Desktop	Extrapolated	Stakeholder meetings
UA	RU1				X
	RU8			X	
	RU10	X			
UB	RU13			X	
	RU14		X		
	RU21	X			
UC1	RU22				X
	RU26		X		
UC2	RU35		X		
UC3	RU40	X			
UD	RU45	X			
UE	RU47		X		
	RU50	X			
UF	RU52		X		
UG	RU58	X			
UH	RU60		X		
UI	RU62		X		
	RU65	X			
	RU66		X		
UJ	RU67		X		
UK	RU68		X		
UL	RU71			X	
	RU73	X			
UM	RU75	X			

3.4 WETLAND COMPONENT

Wetland indicator selection for regional scale RQOs

At a regional level, selection of appropriate indicators was guided by the need to meet conservation targets for wetland ecosystems and to secure vital ecosystem goods and services that wetlands provide. Potential indicators were initially selected by the project team and then discussed with DWA and key wetland experts at a workshop held on the 20th and 21st of November 2013 to obtain input on the most appropriate approach to be followed. Additional wetland specialists who were not able to attend the workshop were also consulted.

The DWA (2011) resources unit evaluation tool developed for determining subcomponents and indicators was not designed to cater for regional scale RQOs. However we were able to adapt the tool in order to determine the potential indicators for the regional evaluation. The components and subcomponents were replaced with ecosystem services provided by wetlands (Table 2). The assessment of current and potential future impacts and the requirements of important users groups, with regards to ecosystem services highlighted the demand for services, under threat, at an IUA level.

Table 2: Ecosystem goods and services provided by wetlands

Regulating & Supporting Benefits									**Provisioning Benefits**			**Cultural Benefits**		
		Water Quality Enhancement												
Flood attenuation	Stream flow regulation	Sediment trapping	Phosphate assimilation	Nitrate assimilation	Toxicant assimilation	Erosion control	Carbon storage	Biodiversity maintenance	Provision of water for human use	Provision of harvestable resources	Provision of cultivated foods	Cultural heritage	Tourism and recreation	Education

Kotze, *et al.* (2007) preliminary rating of the hydrological benefits likely to be provided by a wetland based on its particular hydro-geomorphic type, was used to identify probable important wetland types at an IUA level (Table 3).

Table 3: Preliminary ratings of the hydrological benefits likely to be provided by a wetland based on its particular hydro-geomorphic type (Kotze, et al., 2007)

WETLAND HYDRO-GEO-MORPHIC TYPE	REGULATORY BENEFITS POTENTIALLY PROVIDED BY WETLAND							
	Flood attenuation		Stream flow regulation	Enhancement of water quality				
	Early wet season	Late wet season		Erosion control	Sediment trapping	Phos-phates	Nitrates	Toxicants[2]
1. Floodplain	++	+	0	++	++	++	+	+
2. Valley-bottom - channelled	+	0	0	++	+	+	+	+
3. Valley-bottom - unchannelled	+	+	+?	++	++	+	+	++
4. Hillslope seepage connected to a stream channel	+	0	+	++	0	0	++	++
5. Isolated hillslope seepage	+	0	0	++	0	0	++	+
6. Pan/ Depression	+	+	0	0	0	0	+	+

Notes: [1] The rationale for the rating of benefits is given in Section 3.6
[2] Toxicants are taken to include heavy metals and biocides.

Rating: 0 Benefit unlikely to be provided to any significant extent
\+ Benefit likely to be present at least to some degree
++ Benefit very likely to be present (and often supplied to a high level)

The outcomes from the specialist workshops provided the basis for determining ecosystem services in demand, and under threat, at an IUA level. The findings of this process informed the development of regional scale RQOs, which is part of the next step in the study.

Wetland subcomponents and indicator selection for ecosystem scale RQOs

Within this component of the study a Wetland Evaluation Tool was specifically developed for prioritised wetland ecosystems to assist in the rationalisation process. This tool has two primary functions (i) to determine the level of threat posed to each of the sub-components by impacting activities in the catchment and secondly (ii) to identify which sub-components 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.

While the prescribed Wetland Evaluation Tool was used, not all of the attributes of the evaluation tool were used. Completing the entire tool was found to be cumbersome and time-consuming. Instead, the evaluation of sub-components and indicators focused primarily on the:

- Identification and assessment of current and potential future impacts (only cumulative impacts were scored); and
- Identification of the requirements of important users groups, both from a protection perspective and water resource dependent activity perspective.

This information provided suitable evidence to identify subcomponents. Potential subcomponents and indicators were initially selected by the project team and then discussed with DWA and key wetland experts at the workshop held on the 20th and 21st of November 2013 to obtain input on the most appropriate approach to be followed. Additional wetland specialists who were not able to attend the workshop were also consulted. The outcomes from the specialist workshops provided the basis for determining the subcomponents and indicators for priority wetlands. The findings of this process informed the development of ecosystem scale RQOs, which is part of the next step in the study.

3.5 DAM COMPONENT

The dams for the Upper Vaal catchment was prioritised in step 4 of the RQO procedures. A total number of 18 dams were seen as priority dams based on the criteria for selection. These criteria included (i) all DWA listed dams, (ii) smaller dams that are used for urban or community water supply, (iii) any request from stakeholders to include a specific dam. The following table shows the output of step 4 with some information on the selected dams (Table 4).

Although Driekloof Dam was selected as a priority Dam, no RQOs will be established as it is an off-channel dam associated with water transfer from the Thukela River and hydro power generation.

Table 4: Prioritised dams considered in this sub-component and indicator phase of the RQO determination procedure for the Upper Vaal Water Management Area.

IUA	Resource Unit	Dam Name	Quaternary	River	Year Established	FSC Mm³	Why it was built (Purpose)
UA	4	Amersfoort	C11E	Skulpspruit	1987	0.993	Municipal, industrial - Amersfoort
	10	Grootdraai	C11L	Vaal	1986	382.5	Municipal, industrial - Standerton, Sasol II&III, Tutuka Power Station
UB	20	Vrede/ Thembalihle	C13G	Spruitsonderdrift	1998	2.44	Municipal, industrial - Vrede
UH	60	Balfour	C21B	Suikerbosrant	1998	0.424	Municipal, industrial - Balfour
UM	75	Vaal Barrage	C22K	Vaal	1996	55.4	Municipal, industrial - Rand Water, Lethabo Power Station, Iscor, Sasol I
UL	71	Donaldson	C23D	Wonderfontein-spruit	1986	0.46	Recreation
	69	Klerkskraal	C23F	Mooi	1987	8.25	Irrigation
	73	Boskop	C23G	Mooi	1987	20.85	Irrigation
	72	Klipdrift	C23J	Loopspruit	1918	13.6	Irrigation
UC2	33, 34	Sterkfontein	C81D	Nuwejaarspruit	1987	2616.0	Municipal, industrial - Harrismith, Rand Water
	-	Driekloof	C81D	Off-channel	1986	32.2	Hydro-electric, off-channel
	29	Fika-Patso	C81F	Namahadi	1996	28.0	Municipal, industrial - Witsieshoek, Phuthadijhaba
	29	Swartwater	C81F	Metsi-Matsho	1976	4.38	Municipal, industrial - QwaQwa
UC1	28	Warden	C82B	Cornelisspruit	No date	0.10	Municipal - Warden
UD	41	Saulspoort	C83A	Liebenbergvlei	1986	16.87	Municipal, industrial - Bethlehem
	43	Loch Athlone	C83B	Jordaanspruit	1925	3.74	Recreation
	43	Gerrands	C83B	Gerrandsspruit	1905	1.35	Municipal, industrial - Bethlehem
UM	74	Vaal Dam	C83M	Vaal		2609.8	Municipal, industrial, irrigation - Rand Water, Grootvlei Power Station, Deneysville, Sasolburg

To determine the subcomponents to be included per priority dam for which Resource Quality Objectives should be determined, the 'Resource Unit Evaluation' tool was developed. Evaluation criteria were included for quantity, quality, habitat and biotic requirements associated with dams. The specific indicators for each of these include:

- Quantity – low flows or maintenance flows and high flows, including freshets and 1:2 year floods. Note this includes releases of water to the downstream river
- Quality – nutrients, salts, system variables, toxics, pathogens
- Habitat – riparian and in-dam habitats

- Biota – fish, aquatic and riparian plants, mammals, birds, amphibians, phytoplankton and aquatic invertebrates/zooplankton

The evaluation criteria for each of the above indicators are:

i. Cumulative level of impact - This is the anticipated level of impact of current and future use/activities in the upstream catchments on the inflows to the dam and the quality, habitat and biota in the dam. The 'impact rating' can be Very High: -1; High: -0.75; Moderate: -0.5; Low: -0.25; None: 0. Positive scores can be used where a positive impact on the resource quality is expected.
ii. Trajectory of change – These are indicated by arrows to show a positive (↑), negative (↓) or stable (→) trajectory.
iii. Confidence in the scoring indicated as 'very low' to 'high'.
iv. Rating of importance of components for the protection of the water resource, i.e. importance to releases water for downstream EWRs. Scores given are Very High: 1; High: 0.75; Moderate: 0.5; Low: 0.25; Not important: 0.
v. Rating of importance of components for protection of the water resource for in-dam activities and releases of water for downstream use (irrigation, domestic/rural supply, etc.). Scores given are Very High: 1; High: 0.75; Moderate: 0.5; Low: 0.25; Not important: 0.
vi. Components with importance scores of 0.5 and higher for the 'importance for protection' or 'importance for other water use' are then selected to be included as an EcoSpec and/or UserSpec and will form part of the final set of RQOs for that specific dam.

3.6 GROUNDWATER COMPONENT

Unlike surface water where biota exists in the water and can be used as indicators, groundwater is very isolated in this regard. Very few records exist of groundwater biota, simply because this has not been studied extensively and because groundwater is a "hidden resource" that can only be accessed where a borehole has been drilled. Therefore only water quality, water level and abstraction could be used in the formulation of RQOs. The approach taken to identify measurable sub-components and indicators for groundwater was to list groundwater related sites that may occur currently or in future in the study area. Suggestions on groundwater related sites originating from the groundwater sub-component workshop are listed in Table 5. All examples given were classified according to a site type which relates to the sub-components used in the RQO's

Table 5: List of potential groundwater sites that could occur in the study area

Site Type	Example
Quantity	Production Borehole Well Fields Mines (Dewatering) Afforestation
Ecological	Springs Wetlands Baseflow (Groundwater)
Aquifer	Aquifer Dolomites Trans-boundary Aquifer
Quality	Mines (Decant, Fracking) Irrigation Water, WWTW Waste Sites / Landfill Burial Sites / Cemeteries Feedlots / Animal Dip Agricultural Areas (Pesticides / Fertilizer) Petrol Stations Sanitation Systems / Pit Latrines

Table 5 demonstrates that the examples are scale dependent, and for the purposes of this document the following definitions of scale were adopted:

- Local Scale – defines a site or point source e.g. a borehole or TSF
- Regional Scale – can be defined as the aquifer extent or that of the RU

All the components and examples that referred to aquifer were associated with the regional scale. The next step was to identify sub-components with associated indicators. Table 5 was extended to include parameters that can be measured for each of the site types and the resultant table is presented in Table 6.

Table 6: Site type with measurable parameters

Site Type (Components)	Example	Scale	Abstraction	Water Quality	Water Level
Quantity	Production Borehole	Local	X	X	X
	Well Fields	Local	#	#	#
	Mines (Dewatering)	Local	#	#	#
	Afforestation	Local	#	#	#
Ecological	Springs	Local		X	
	Wetlands	Local		X	
	Baseflow (Groundwater)	Local		#	#
Aquifer	Aquifer	Regional	#	#	#
	Dolomites	Regional	#	#	#
	Trans-boundary Aquifer	Regional	#	#	#
Quality	Mines (Decant, Fracking)	Local		X	
	Irrigation Water, WWTW	Local		X	
	Waste Sites / Landfill	Local		X	
	Burial Sites / Cemeteries	Local		X	
	Feedlots / Animal Dip	Local		X	
	Agricultural Areas (Pesticides / Fertilizer)	Local		X	
	Petrol Stations	Local		X	
	Sanitation Systems / Pit Latrines	Local		X	

Although, in theory, all the parameters marked with an X or # should be measurable or at least good estimates should be obtainable, however it is not practical to measure those situations marked with # as shown in Table 6. Various reasons exist for this and justification is provided in the next section.

4 FINDINGS

4.1 RIVER COMPONENT

The outcomes of the determination of the sub-component and indicator process for the RQO determination study for the Upper Vaal WMA includes a summary of the component, sub-component, rationale for sub-component choice, EcoSpec, UserSpec and Integrated Measure consideration and Indicator selection per RU within each IUA as follows:

- River sub-component and indicator selection for IUA UA is presented in Table 7
- River sub-component and indicator selection for IUA UB is presented in Table 8
- River sub-component and indicator selection for IUA UC.1 is presented in Table 9
- River sub-component and indicator selection for IUA UC.2 is presented in Table 10
- River sub-component and indicator selection for IUA UC.3 is presented in Table 11
- River sub-component and indicator selection for IUA UD is presented in Table 12
- River sub-component and indicator selection for IUA UE is presented in Table 13
- River sub-component and indicator selection for IUA UF is presented in Table 14
- River sub-component and indicator selection for IUA UG is presented in Table 15
- River sub-component and indicator selection for IUA UH is presented in Table 16
- River sub-component and indicator selection for IUA UI is presented in Table 17
- River sub-component and indicator selection for IUA UJ is presented in Table 18
- River sub-component and indicator selection for IUA UK is presented in Table 19
- River sub-component and indicator selection for IUA UL is presented in Table 20
- River sub-component and indicator selection for IUA UM is presented in Table 21

Table 7: River sub-component and indicator selection for IUA UA: Upper Vaal Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
UA	RU1	Quality	Salts	Salt PES unknown but NB to maintain ecosystem state in a "B" state.			**Y**	Electrical conductivity
		Biota	Aquatic Invertebrates	PES "B" maintain "B". Invertebrate good ecological indicator of water quality, quantity and habitat state. Maintain inverts in "B" state for local biodiversity and use inverts as indicator.			**Y**	MIRAI Score
	RU8	Quantity	Low Flows (Maintenance Flows)	MC II, PES B/C REC B/C for RU. LF PES unknown, importance of maintaining ecosystem in B/C ecologically important (FEPA site) and but also to ensure provision of water for irrigation	**Y**	**Y**		EWR
		Quality	Nutrients	Nutrient PES in "D", improve to "C" for ecosystem (FEPA) recreation, ecotourism and real estate and excessive nutrients impact negatively on water treatment costs.	**Y**	**Y**		Phosphate and TIN
			Salts	Salt PES unknown but NB to maintain ecosystem state in a "C" state, salts cause negative impact on irrigation agric.		**Y**		Electrical conductivity
			System variables	SV PES unknown but must improve to "C", elevated temperatures and low DO associated with low flows and elevated turbidity issues for irrigation.	**Y**			Temperature
			Pathogens	PES unknown, pesticides emanating from agriculture concerning for ecosystem maintenance.		**Y**		*E. coli*
		Habitat	Instream habitat	Instream habitat PES "D", improve to "B/C" for maintenance of ecosystem (FEPA) and also for real estate and property and recreational angling.	**Y**	**Y**		RHAM with consideration of periphyton
			Riparian Habitat	Riparian PES "B" maintain in "B" state to maintain ecosystem (habitat and provides cover for fish) and also for Real Estate and property as well as recreation	**Y**	**Y**		VEGRAI but check for use of metrics
		Biota	Fish	Fish PES "C" improve to "B" for FEPA and recreational angling (maintenance of target species for angling and consumption).		**Y**		Population structure of target species

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
	RU10	Quantity	Low Flows (Maintenance Flows)	MC II, PES B/C REC B/C for RU. LF PES unknown, importance of maintaining ecosystem in B/C ecologically important (FEPA site) and but also to ensure provision of water for irrigation	**Y**	**Y**		EWR
		Quality	Nutrients	Nutrient PES in "D", improve to "C" for ecosystem (FEPA) recreation, ecotourism and real estate and excessive nutrients impact negatively on water treatment costs.	**Y**	**Y**		Phosphates and TIN
			Salts	Salt PES unknown but NB to maintain ecosystem state in a "C" state, salts cause negative impact on irrigation agric.		**Y**		Electrical conductivity
			System variables	SV PES unknown but must improve to "C", elevated temperatures and low DO associated with low flows and elevated turbidity issues for irrigation.	**Y**			Temperature
			Pathogens	PES unknown, pesticides emanating from agriculture concerning for ecosystem maintenance.		**Y**		*E. coli*
		Habitat	Instream habitat	Instream habitat PES "D", improve to "B/C" for maintenance of ecosystem (FEPA) and also for real estate and property and recreational angling.	**Y**	**Y**		RHAM with consideration of periphyton
			Riparian Habitat	Riparian PES "B" maintain in "B" state to maintenance of ecosystem (habitat and provides cover for fish) and also for Real Estate and property as well as recreation	**Y**	**Y**		VEGRAI but check for use of metrics
		Biota	Fish	Fish PES "C" improve to "B" for FEPA and recreational angling (maintenance of target species for angling and consumption).		**Y**		Population structure of target species

Table 8: River sub-component and indicator selection for IUA UB: Upper Vaal Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
UB	RU13	Habitat	Instream habitat	MC II PES "B/C" maintain "B/C". Instream PES "C" improve to "B/C". Habitat important template for ecosystem structure and function. Must be protected to maintain desired largely natural ecosystem state.	Y			RHAM
		Biota	Aquatic Invertebrates	PES "B" maintain "B". Invertebrate good ecological indicator of water quality, quantity and habitat state. Maintain inverts in "B" state for local biodiversity and use inverts as indicator.				MIRAI
	RU14	Habitat	Instream habitat	MC II PES "B/C" maintain "B/C". Instream PES "C" improve to "B/C". Habitat important template for ecosystem structure and function. Must be protected to maintain desired largely natural ecosystem state.				RHAM
		Biota	Aquatic Invertebrates	PES "B" maintain "B". Invertebrate good ecological indicator of water quality, quantity and habitat state. Maintain inverts in "B" state for local biodiversity and use inverts as indicator.				MIRAI
	RU21	Quantity	Low Flows (Maintenance Flows)	MC II PES "C", maintain "C". LF "C/D" (from EWR site upstream) improve to "C" FEPA site so requires protection of ecosystem NB, concerns that if EWR implemented agricultural use conflicts so illegal use must be addressed.	Y	Y		EWR, manage alien vegetation in Riparian zone to increase water runoff.
		Quality	Toxics	WQ PES "B/C", ammonia levels concerning. Upward trend in median and associated variability observed. Although currently in an acceptable state trend must addressed.	Y			TIN and pH (affects ratio of NH3 vs NH4).
		Habitat	Instream habitat	PES "C" improve to "B/C" for FEPA and ecosystem. Important driver component for ecosystem structure and function. Maintenance of habitat state NB. Impacts associated with agriculture activities.	Y			RHAM maintain in a moderately modified state.

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
			Riparian Habitat	PES "C" maintain. Maintenance of the integrity of the riparian zone NB. Alien vegetation and land use practices must be addressed. Buffer zone must be implemented to keep terrestrial activities away from riparian zone.	**Y**			Establish and maintain buffer zone for riparian zone to remove land use practices from riparian zone and manage trampling of banks by livestock.
		Biota	Aquatic Invertebrates	PES "B" maintain. Inverts good indicator of integrated ecosystem health. Useful for quality, quantity and habitat monitoring.			**Y**	MIRAI "C"

Table 9: River sub-component and indicator selection for IUA UC1: Upper Vaal Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
UC1	RU22	Habitat	Instream habitat	This headwater stream needs to provide a suitable habitat for important fish populations in keeping with its FEPA status. The instream habitat must be improved to a B category.	**Y**	**Y**		**RHAM**
		Biota	Fish	The community structure of fishes should be maintained in a B category and include stable populations of the indicator fishes Goldie barb (*Barbus pallidus*) and Chubby head barb (*Barbus anoplus*).	**Y**			Community structure evaluation method
	RU26	Habitat	Instream habitat	MC II PES WRC "C" REC maintain "C" PESEIS "B", new REC (RQO) maintain "B". Instream important ecosystem component on which response components live in/on. To maintain "B" component must be protected from upstream and terrestrial impacts.	**Y**			RHAM
		Biota	Aquatic Invertebrates	PES "B" maintain. Important component of ecosystem and reach may contain high diversity of spp. Inverts also good indicator of water quality, quantity and habitat.	**Y**	**Y**		MIRAI

Table 10: River sub-component and indicator selection for IUA UC2: Upper Vaal Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
UC2	RU35	Quantity	Low Flows (Maintenance Flows)	MC II PES "C" maintain "C". LF PES "D" improve to "C" quantity issues associated with abstractions by water institutions for urban centres and limited agriculture activities. If Vaal Dam drops below 40% (potentially during low flows) emergency releases from Sterkfontien into Wilge occur. These incorrect timing flood releases in winter must be managed - gradual increase maintenance and reduction of flows for Vaal dam. Impact of releases should be monitored.	**Y**			EWR
		Quality	Nutrients	Nutrients (PES "C" - maintain) WWTW and associated urban centres linked to nutrient enrichment. Affecting water quality in Wilge.	**Y**	**Y**		Nitrates, Phosphates, Ammonium
			Pathogens	Pathogens largely unknown in close proximity to Harrismith WWTW risk of human health impacts linked to contact and consumption of water and other products (fish and veg) must be maintained in "safe" state.	**Y**	**Y**		Microbial contaminant indicators
		Habitat	Instream habitat	Instream habitat (PES "C" - maintain) minimise sedimentation from dryland agriculture, livestock farming and poor releases of flows from Sterfontein.	**Y**	**Y**		RHAM
		Biota	Fish	PES "C" maintain. Threat of genetic contamination by KZN cyprinids in upper Wilge due to IBT concerning, particularly during emergency releases. Local genetic integrity must be protected.	**Y**			Appropriate genetic evaluation techniques
			Aquatic Invertebrates	Macroinvertebrates (PES "C" - maintain) Good indicator of water quality and instream habitat state.			**Y**	MIRAI

Table 11: River sub-component and indicator selection for IUA UC3: Upper Vaal Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
UC3	RU40	Quantity	Low Flows (Maintenance Flows)	MC II PES "C/D" improve "C" (biophysical node REC "C/D" but upstream EWR "C"). LF PES "D" improve to "C/D", limited LF issues but during drought if Vaal dam drops below threshold (40% - check this limit) then releases from Sterkfontien will occur. If these release flows will be abnormally high this may negatively impact on ecosystem.			**Y**	Dry season capping flows.
		Quality	Nutrients	Nutrients (PES "C" - maintain) WWTW and associated urban centres linked to nutrient enrichment. Affecting water quality in lower Wilge.	**Y**	**Y**		Phosphates and Nitrates.
		Habitat	Instream habitat	Instream habitat (PES "C/D" - maintain) potentially linked to sedimentation from dryland agriculture and livestock farming upstream and algal growth associated with nutrient enrichment.	**Y**	**Y**		RHAM
		Biota	Aquatic Invertebrates	Macroinvertebrates (PES "D" - improve to "C/D") Good indicator of water quality and instream habitat state.			**Y**	MIRAI

Table 12: River sub-component and indicator selection for IUA UD: Upper Vaal Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
UD	RU45	Quantity	Low Flows (Maintenance Flows)	MC III PES "D/E" REC "D" (associated with PES) no biophysical nodes on Liebenbergsvlei in WRC. PES LF "E" maintain sub-component but improve overall state to "D". User requirement for volumes released from Lesotho Phase I into Ash for IBT should be established as RQOs so that the flows reach JHB. No net loss from discharge point to Gauteng, consider natural river losses. PES possibly lower than a D must be improved to a D. Consider "resetting" reference conditions to include the transfer as a part of "natural" ecosystem so that existing ecosystem components which are not comparable to natural conditions can be maintained. Seasonality of flows may be major driver. Consider maintaining stable flows and reducing flow fluctuations - consider treaties with Lesotho. Muela should be managed as an attenuation facility. Do not allow sudden no-flow conditions to occur in South Africa associated with IBT maintenance; this can cause massive negative impacts to ecosystem.			**Y**	EWR
			High Flows (Floods)	PES "E" maintain sub-component to "E" but improve overall PES to "D”, volumes released from Lesotho Phase I into Ash for IBT should be established as RQOs so that the flows reach JHB. No net loss from discharge point to Gauteng, consider natural river losses. Also consider "resetting" reference conditions to include the transfer as a part of "natural" ecosystem so that existing ecosystem components which are not comparable to natural conditions can be maintained. Seasonality of flows may be major driver. Consider maintaining stable flows and reducing flow fluctuations - consider treaties with Lesotho. Muela should be managed as an attenuation facility.			**Y**	EWR

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
		Habitat	Instream habitat	PES "D", improve to "C/D" to offset impact associated with flow alterations. Assess habitat suitability for the maintenance ecosystem structure and function. Target to maintain a high diversity of habitat types. Ecosystem in an artificial state, maintain current diversity.	Y	Y		RHAM

Table 13: River sub-component and indicator selection for IUA UE: Upper Vaal Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
UE	RU47	Quantity	Low Flows (Maintenance Flows)	MC III, PES "C" (WRC) REC "C", PES EIS Suggests PES "D/E". Low flows excessively impacted on by releases from industrial areas associated with Secunda. EWR must be attained.			Y	EWR
		Quality	Nutrients	Nutrients PES "E" improve to "D". Obvious WWTW inputs and changing eutrophic state of ecosystem. Most WWTW are not functional.	Y	Y		Nitrates, Phosphate, Ammonia
			Salts	PES "E" salinization associated with Secunda. Improve salinity to "D" state.		Y		Electrical conductivity
			System variables	PES “E/F" improve to "D" low O2 levels associated with COD and BOD from WWTW and Secunda major limiting factor for ecosystem.				Oxygen levels
			Toxics	Toxics "PES" unknown but source "Secunda" is a complex chemical industry and produces toxic waste so metals, OC s and EDCs NB. Also consider toxics from WWTW.			Y	Toxicant levels
			Pathogens	PES unknown but suspected to be an issue linked to irrigated agriculture presuming that people are coming into contact with water and eating vegetables that are being consumed (non-cooked).		Y		Microbial indicators
		Habitat	Instream habitat	PES "E" improve to "D" WQ impacting negatively on the instream habitat (nutrients NB) particularly through growth of filamentous algae.	Y			RHAM

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
			Riparian Habitat	PES "E/F" improve to "D" Removal/alteration of riparian zone major concern. Rehabilitate riparian zone to attain "D" state.	Y			VEGRAI
		Biota	Aquatic Invertebrates	PES "E" improve to "D" Invertebrates good indicator of WQ state.			Y	RHAM
			Diatoms	PES "E" improve to "D" diatoms good indicator of nutrient and toxic contaminants		Y		RHAM
	RU50	Quality	Nutrients	MC III, PES "D" REC "D". Nutrients PES "D/E" improve to "D". Obvious WWTW inputs and changing eutrophic state of ecosystem. Most WWTW are not functional.	Y			Phosphate and TIN
			Toxics	Toxics "PES" unknown but source "Secunda" is a complex chemical industry and produces toxic waste so metals, OC s and EDCs NB. Also consider toxics from WWTW.		Y		DEEEP
			Pathogens	PES unknown but suspected to be an issue linked to irrigated agriculture presuming that people are coming into contact with water and eating vegetables that are being consumed (non-cooked).		Y		*E. coli*
		Habitat	Instream habitat	PES "E" improve to "D" WQ impacting negatively on the instream habitat (nutrients NB) particularly through growth of filamentous algae.	Y			RHAM
		Biota	Fish	PES "D" improve to "C/D" for FEPA. Maintenance of indicator species - yellowfish NB.				FRAI
			Diatoms	PES "E" improve to "D" diatoms good indicator of nutrient and toxic contaminants			Y	Diatom index

Table 14: River sub-component and indicator selection for IUA UF: Upper Vaal Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
UF	RU52	Habitat	Instream habitat	MC II, PES "C" REC "C" EI & ES very high. Instream PES "B" maintain. Connectivity with Vaal Dam NB for species abundance and diversity of habitat in Klip NB.	Y			RHAM

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
			Riparian Habitat	PES "B/C" maintain. Riparian zone buffers river from terrestrial land use activities must be maintained for high EI and ES. Also maintain good marginal vegetation which provides cover for recruited cyprinid young of year.	**Y**			VEGRAI
		Biota	Fish	PES "C" improve to "B". Access to Klip by endemic migrating cyprinids during high flow period NB, contributes to recruitment of regional catchment for population which takes up refugia in Vaal Dam. Ensure high recruitment of cyprinid young of year (>1) in Klip during high flow periods.	**Y**			FRAI, additional appropriate techniques

Table 15: River sub-component and indicator selection for IUA UG: Upper Vaal Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
UG	RU58	Quantity	Low Flows (Maintenance Flows)	MC II, PEC "C" REC maintain "C". LF PES "C". Important indicator component affecting ecosystem state. Improve to "B/C" required to maintain ecosystem (no FEPA). LF required for irrigation and water institution (Villiers).			**Y**	EWR & minimum flows
		Quality	System variables	System variables PES "C", maintain. Temperatures and oxygen levels concerning during extremely low flow periods to maintain fish and invertebrate response components in "C" state.	**Y**			Temperature and Oxygen
			Toxics	Toxics PES unknown but upstream impacts associated with mining, agriculture and WWTW may be contaminating ecosystem with pesticides, metals and EDCs.			**Y**	DEEEP
		Habitat	Instream habitat	Instream PES "C" maintain. Important driver component of ecosystem. Access for fishes to migrate to upper reaches of Vaal and Klip River important.	**Y**	**Y**		RHAM

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
		Biota	Fish	PES "D" improve to "C". Ecologically importance of reach high associated with access of species taking refuge in Vaal Dam that migrate into upper Vaal and Klip.	Y			FRAI

Table 16: River sub-component and indicator selection for IUA UH: Upper Vaal Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
UH	RU60	Quantity	Low Flows (Maintenance Flows)	MC II PES "C" REC "B/C". LF PES "E" improve to "C". Maintenance of ecosystem structure and function important. EWR must be attained. Conflict between users (agriculture) and water availability.	Y			EWR
			High Flows (Floods)	PES "D" improve to "C". Timing and duration of flows to provide ecological cues for threatened or protected Orange-Vaal largemouth yellowfish Labeobarbus kimberleyensis, maintain ecosystem in an overall "B/C" state and provide for agriculture user requirements.	Y			EWR
		Quality	Nutrients	PES "C/D" improve to "C". Elevation of nutrient levels associated this urban centre Balfour and other communities concerning to maintain REC "B/C".	Y	Y		Nitrates, Phosphates, Ammonia
			System variables	PES "C/D" improve to "B/C" temperatures associated with flow issues and oxygen levels must be maintained in a "B/C" state for ecosystem and protected largemouth yellowfish LKIM.	Y			Oxygen Levels
		Habitat	Instream habitat	PES "C" improve to "B" to attain overall "B/C" REC. Important component of structure of ecosystem maintains ecosystem components. Maintain habitat requirements of protected LKIM population prioritised in PES/EIS study.	Y			RHAM
		Biota	Fish	PES "D" improve to "B/C" to attain REC 'B/C" includes protection of local population structure of Orange-Vaal largemouth yellowfish (Labeobarbus kimberleyensis).	Y			FRAI

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
			Aquatic Invertebrates	PES "D" improve to "B/C" to attain REC "B/C". Important component of ecosystem and food web linked to protected predator LKIM. Good indicator of state of water quantity, quality and habitat.	Y			MIRAI

Table 17: River sub-component and indicator selection for IUA UI: Upper Vaal Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
UI	RU62	Quantity	Low Flows (Maintenance Flows)	MC III PES "D" REC "D" LF PES "D/E" improve to "D" timing and duration of elevated flows must be managed to minimise incision of main channel which is affecting the integrity of the floodplain wetland associated with the river.	Y			EWR
		Quality	Nutrients	PES "D/E" improve to "D" maintain mesotrophic state. Nutrient loads are affecting irrigated agriculture. Quality of crops.		Y		Nitrates, Phosphate, Ammonia
			Salts	PES "D/E" improve to "D" elevated salinity affecting water quality treatment costs for irrigated agriculture. Includes informal and peri-urban communities that water vegetables grown in floodplain.		Y		Electrical conductivity
			Toxics	PES "D/E" possibly worse because many toxic substances apart from metals are not monitored. Presence of metals, OS c incl. EDCs must be monitored. Human health should not be affected through contact and consumption of watered vegetables.		Y		Toxicants
			Pathogens	PES'D/E" improve to "D" pathogens associated with WWTW releases threatening communities who have contact with and consume water and watered vegetables.		Y		Microbial contamination indicators
		Habitat	Instream habitat	PES "D/E" improve to "D" important component of ecosystem and supports water quality amelioration ecosystems services which WWTW, mines, urban		Y		RHAM

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
				communities require of the river.				
		Biota	Fish	PES "D/E" improve to "D" important component of ecosystem, contributes to local recreation and fish consumed by local communities.	Y			FRAI
			Aquatic Invertebrates	PES "D/E" improve to "D" important component of ecosystem and good indicator of water quality, quantity and habitat states.	Y			MIRAI
			Diatoms	PES unknown must be in "D" state. Good indicator of state of toxics in water quality.			Y	Diatom index, SPI scores
	RU65	Quantity	Low Flows (Maintenance Flows)	MC III, PES "E" improve to "D". LF "D" maintain. Flow timing and duration currently altered and due to worsen when short term intervention plan for AMD initiated. LFs must not be exceeded by additional releases from WWTWs etc. Attenuation of capping flows (above existing base highs) must be implemented.	Y			Base flows in rivers (consider wetland RESERVE)
			High Flows (Floods)	PES "D" maintain "D". HF affected by current high base flows (exacerbated by short term intervention plan for AMD) must not be exceeded by additional releases from WWTWs etc. Attenuation of capping flows (above existing base highs) must be implemented.	Y			Base flows in rivers (consider wetland RESERVE)
		Quality	Nutrients	PES "E/F" improve to "D". WQ main impact RU exposed to management of metals and salts NB but contribution of high nutrient loads unnecessary. Ecosystems must be maintained in a mesotrophic state.	Y			Nitrates, Phosphates, Ammonia
			Salts	PES "E" improve to "D", current state excessively poor. Main drivers linked to current mine decant and planned AMD intervention plan. Peri-urban users require water with suitable salt levels, levels are already high. Salt concentrations important for irrigation, mines (Require DWA industrial category I) and industrial users.	Y	Y		Electrical conductivity

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
			Toxics	PES unknown but presence of metal, EDC, OC and ammonia toxics known. Data availability is very limited. Communities exist that are dependent on resources for drinking, spiritual rituals, and contact NB through recreation & consumption of fish. Potential, metals (Cd, Co, As, Cu, Zn, Al, Mn, Ur, EDCs & OCs). Other users incl. irrigation NB and bioaccumulation considered. Toxics must be removed to avoid human risks.		**Y**		DEEEP & loads (NB for what is there and for toxicity). Bioaccumulation.
			Pathogens	Current pathogen levels unknown but issues associated with WWTW identified and unnecessary. Communities exist that are dependent on resources for drinking, spiritual rituals, and contact NB through recreation. Microbes, viruses, bacteria? Cryptosporidium. Giardia.		**Y**		*E. coli*, HPC, Tot Col.
		Habitat	Instream habitat	PES "D" improve to "C" to offset poor water quality and flows for overall PES to improve to "D". Habitat NB for ecosystem structure and function, template for responder components. Habitat quality affects users and health (drowning). Also NB for real-estate and property values. Instream habitat important to assimilate waste.	**Y**	**Y**		RHAM,
		Biota	Fish	PES "D" maintain in "D" but monitor accumulation of toxics in fish that can affect local communities that consume fish and commercially supply to informal communities.	**Y**	**Y**		FRAI
			Aquatic Invertebrates	PES "E/F" Improve to "D". Aquatic invertebrates are important component of the ecosystem and as indicators useful to monitor quality, quantity and habitat states.			**Y**	MIRAI
	RU66	Quantity	Low Flows (Maintenance Flows)	MC III. PES "D/E" REC "D". LF PES "D" but to improve PES to "D" must improve to "C/D".	**Y**			EWR

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
		Quality	Nutrients	Nutrients PES "E" improve to "D". Impacts associated with Orangefarm, Sebokeng WWTW and directly from peri-urban and informal communities associated with Grasmere, Evaton, Sebokeng, Lenasia South, Orange Farm, Ennerdale, Vlakfontein and numerous large peri urban settlements. Maintain in mesotrophic state		**Y**		Nitrates, Phosphates, Ammonia
			Salts	PES "E" improve to "D" impacts associated with industrial activities of Vanderbijlpark NB and some mines in the catchment.		**Y**		Electrical conductivity, Sulphates
			System variables	PES "E" improve to "D" NB COD and BOD levels impacts associated with WWTW and industries Vanderbijlpark NB and some mines in the catchment.		**Y**		Oxygen levels
			Toxics	PES unknown threat of OC s, EDCs metals and ammonia exists. Must all be addressed to limit impacts to communities consuming fish and watered vegetables and contact with water.		**Y**		Toxicants
			Pathogens	PES unknown microbial contamination potentially very high, cases of Hepatitis also observed. Minimise pathogens for communities who consume water, watered vegetables and fish.		**Y**		Appropriate techniques
		Habitat	Instream habitat	PES "D" maintain "D" important component of ecosystem that must be managed to reach overall REC "D". Impacts from agriculture, peri-urban and informal communities and WQ issues.			**Y**	RHAM
		Biota	Aquatic Invertebrates	PES "D/E" improve to "C/D" to attain REC "D". Good indicator of water quality impacts for RU	**Y**			MIRAI
			Diatoms	PES "unknown" improve to "C/D" to attain REC "D". Good indicator of toxics for RU			**Y**	Diatom index, SPI score.

Table 18: River sub-component and indicator selection for IUA UJ: Upper Vaal Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
UJ	RU67	Quality	Salts	MC III PES "D", REC "D". PES "D/E" improve to "D" local industrial activities having a negative impact on the water quality causing salinization of Taaibosspruit.		Y		Electrical conductivity
			Toxics	PES unknown, suspected impacts of metals, OC and EDCs in water related to industrial activities must be addressed.		Y		Toxicant concentrations
		Biota	Aquatic Invertebrates	PES "D" maintain "D". Important component of ecosystem and indicator of water quality, quantity and habitat state.			Y	MIRAI
			Diatoms	PES "unknown" maintain "D". Indicator of toxicity.				Diatom index, SPI score.

Table 19: River sub-component and indicator selection for IUA UK: Upper Vaal Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
UK	RU68	Habitat	Instream habitat	MC III PES "C", REC "C". Instream habitat PES "D" improve to "C". Important component of ecosystem impacted by dryland agricultural activities that remove riparian zone and impact on instream ecosystem.	Y	Y		RHAM
			Riparian Habitat	Riparian habitat PES "D" improve to "C". Establish riparian zone to buffer impacts of agriculture on instream channel.		Y		VEGRAI
		Biota	Fish	PES "C/D" (RHP results). Maintain in "C/D" state tributary providing refugia for recruiting cyprinids (they try and gain access above Barrage but can't so use this tributary) in Vaal mainstem where competition with aliens and other adult fish is high.	Y			FRAI
			Aquatic Invertebrates	PES "C" maintain. Important component of ecosystem and indicator of water quantity, quality and habitat state.			Y	MIRAI

Table 20: River sub-component and indicator selection for IUA UL: Upper Vaal Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
UL	RU71	Quality	Nutrients	MC III, PES "D" REC "D". Nutrient PES "E" improve to "D", Eutrophic conditions are manifested with filamentous algal growth. River should be maintained in a Mesotrophic state - consider RWQOs. Causes WWTWs	Y			Phosphates (RWQO limits 0.4 mg/l)
			Salts	PES "D" maintain "D". Salt loads associated with upstream mining activities concerning. Return to suitable state.		y		Electrical conductivity, sulphates (RWQO "75mg/l)
			Toxics	PES unknown but concerning. Associated with the mining industry in the upper reaches of the sub-catchment, Uranium loads are excessive and pose an imminent threat to user health. NB for user perspective - water institutions already supplying potable water to urban centres (Potchefstroom). High costs to link Rand Water line from Vereeniging necessary due to contamination.		Y		DEEEP and Uranium concentrations.
		Habitat	Instream habitat	PES "D" improve to "C/D". Instream habitat important component of structure and function of ecosystem. Improvement required to offset poor WQ state.	y			RHAM
		Biota	Periphyton	PES unknown but excessive periphyton problematic and indicator of nutrient levels and negatively impacting on instream habitat state.	y			Periphyton abundance
			Aquatic Invertebrates	Invertebrates PES "D" maintain. important component of ecosystem response component. Good indicator of water quality	y	y		MIRAI
			Diatoms	PES "D" maintain, important component of ecosystem response component. Good indicator of water quality	y			Diatom index
	RU73	Quality	Nutrients	MC III, PES "D" REC "D". Nutrient PES "E" improve to "D", Eutrophic conditions are manifested with filamentous algal growth. River should be maintained in a Mesotrophic state - consider RWQOs. Causes WWTWs	Y			Phosphates (RWQO limits 0.4 mg/l)
			Salts	PES "D" maintain "D". Salt loads associated with upstream mining activities concerning. Return to		y		Electrical conductivity, sulphates (RWQO "75mg/l)

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
				suitable state.				
			Toxics	PES unknown but concerning. Associated with the mining industry in the upper reaches of the sub-catchment, Uranium loads are excessive and pose an imminent threat to user health. NB for user perspective - water institutions already supplying potable water to urban centres (Potchefstroom). High costs to link Rand Water line from Vereeniging necessary due to contamination.		Y		DEEEP and U concentrations.
		Habitat	Instream habitat	PES "D" improve to "C/D". Instream habitat important component of structure and function of ecosystem. Improvement required to offset poor WQ state.	y			RHAM
		Biota	Periphyton	PES unknown but excessive periphyton problematic and indicator of nutrient levels and negatively impacting on instream habitat state.	y			Periphyton abundance
			Aquatic Invertebrates	Invertebrates PES "D" maintain. important component of ecosystem response component. Good indicator of water quality	y	y		MIRAI
			Diatoms	PES "D" maintain, important component of ecosystem response component. Good indicator of water quality	y			Diatom index

Table 21: River sub-component and indicator selection for IUA UM: Upper Vaal Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
UM	RU75	Quantity	High Flows (Floods)	MC III, PES "C/D" WRC improve to "C". WQ PES "D" improve to "C/D". Monitoring site located on Vaal upstream of confluence with Mooi. High flows are necessary for yellowfish ecological cues and for the general maintenance of the instream habitat including the flushing of algae and water hyacinths.	Y	Y		EWR
		Quality	Nutrients	Nutrient PES "D" improve to "C" nutrient loads must be controlled to prevent eutrophication and also to minimise water treatment costs.	Y	Y		Phosphate, nitrate, nitrite, ammonium

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpec	Integrated Measure	Indicator selection
			Salts	Salts PES "C/D" improve to "C". salinization of agricultural land and also fouling of industries and cause problems to some types of water treatment (RO). Salinity concentrations must also be controlled to attain response component in "C" state. Important to maintain TOPS largemouth yellowfish population, recruitment of which may be sensitive to high salt loads	**Y**	**Y**		Sulphate, electrical conductivity
			Toxics	Toxics "C/D" but largely unknown but EDCs, metals and OC s identified in Vaal, toxicity is unacceptable to the ecosystem and also for users esp. recreation and domestic users and for irrigators and real estate.	**Y**	**Y**		Toxicity testing (bioassay) diatoms
			Pathogens	Pathogens PES "E", pathogen that affect people and fish identified and must be maintained to protect ecosystem service use by people and population structures of protected yellowfish.		**Y**		Microbial contaminant indicators
		Habitat	Instream habitat	This will be monitored under periphyton				
			Riparian Habitat	Riparian habitat "D" improve to "C", excessive alien tree infestation negatively impacts state of riparian zone and negatively impact on the ecosystem, and users who value the aesthetics of the RV.			**Y**	VEGRAI
		Biota	Fish	Fish PES "D" improve to "C" and protect the indicator and TOPS (protected) Orange-Vaal Largemouth yellowfish populations and yellowfishes (includes Orange-Vaal smallmouth yellowfish) recruitment to maintain yellowfish dependent angling industry.	**Y**			FRAI, appropriate methods
			Periphyton	PES unknown but suspected to be in a severely impacted state >D, improve condition by keeping instream habitat essentially free of hyacinth and excessive filamentous algae	**Y**			Appropriate methods

4.2 WETLAND COMPONENT

The findings of an assessment of DWA (2011a) and DWA (2012), undertaken to determine the demand for wetland benefits and services at an IUA level, are included in APPENDIX A. This information was used to determine the key wetland benefits and services that are under threat at an IUA level (Table 22).

Table 22: Key wetland benefits and services that are under threat at an IUA level

IUA	Regulating & Supporting benefits									Provisioning Benefits			Cultural Benefits		
			Water Quality Enhancement												
	Flood attenuation	Stream flow regulation	Sediment trapping	Phosphate assimilation	Nitrate assimilation	Toxicant assimilation	Erosion control	Carbon storage	Biodiversity maintenance	Provision of water for human use	Provision of harvestable resources	Provision of cultivated foods	Cultural heritage	Tourism and recreation	Education
UA		**Y**	**Y**				**Y**		**Y**						
UB		**Y**			**Y**				**Y**					**Y**	
UC1	**Y**	**Y**	**Y**				**Y**		**Y**						
UC2				**Y**	**Y**	**Y**									
UC3			**Y**				**Y**								
UD			**Y**				**Y**								
UE				**Y**	**Y**	**Y**									
UF			**Y**												
UG			**Y**	**Y**	**Y**	**Y**									
UH		**Y**		**Y**	**Y**	**Y**			**Y**						
UI	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**		**Y**						
UJ	**Y**	**Y**	**Y**	**Y**	**Y**										
UK				**Y**	**Y**	**Y**									
UL			**Y**	**Y**	**Y**	**Y**									
UM	**Y**		**Y**	**Y**	**Y**	**Y**			**Y**					**Y**	

Taking into consideration the findings from the above assessment, and following discussions with the project team and key stakeholders, a decision was taken to use the following indicators when setting regional scale RQOs:

- **Wetland condition:** Wetland condition is regarded as an appropriate surrogate and indicator for wetland functioning at a regional scale. This is also a useful measure against which management of priority wetland FEPAs can be evaluated.
- **Landuse compatibility:** In the case of FEPA wetland clusters, landuses that negatively affect hydrological or terrestrial connectivity are regarded as undesirable. As such the compatibility of landuses within a 500m buffer zone around these clusters was selected as an appropriate indicator.
- **Levels of wetland protection:** While maintaining wetland condition (and landuse compatibility in the case of FEPA wetland clusters) is regarded as important, it is essential that a sub-set of wetlands are formally protected to meet conservation targets. For this reason, levels of protection of wetland FEPAs (a sub-set of wetlands selected to meet conservation targets) was selected as an indicator to assess progress made towards meeting biodiversity protection objectives.

Selection of subcomponents for prioritized wetland ecosystems was based on an evaluation of the relevance of each subcomponent in light of protection requirements and water resource dependant activities. A summary of the indicators selected per priority wetland and IUA is presented in Table 23.

Table 23: Summary of subcomponents and indicators selected for prioritized wetlands

IUA	Wetland Code / Name	Quantity		Quality					Habitat		Biota								Indicators selected
		Water inputs	Water distribution and retention patterns	Nutrients	Salts	System variables	Toxics	Pathogens	Geomorphology	Wetland Vegetation	Fish	Plant species	Mammals	Birds	Amphibians & reptiles	Periphyton	Aquatic Invertebrates	Diatoms	
UA	**1.1 Upper Vaal**		**Y**						**Y**	**Y**									• Water distribution & retention patterns Wetland vegetation • Wetland geomorphology
UA	**1.2 Upper Blesbokspruit (upstream of Bethal)**		**Y**						**Y**	**Y**									• Water distribution & retention patterns Wetland vegetation • Wetland geomorphology
UA	**1.3 Upper Blesbokspruit (downstream of Bethal)**								**Y**	**Y**									• Wetland vegetation • Wetland geomorphology
UA	**1.4 Balmoral**								**Y**	**Y**									• Wetland vegetation • Wetland geomorphology
UB	**2.1 Vanger**									**Y**				**Y**					• Wetland vegetation • Adequate White-winged Flufftail habitat
UB	**2.2 Seekoeivlei**	**Y**	**Y**	**Y**		**Y**			**Y**	**Y**		**Y**	**Y**	**Y**	**Y**				• Water inputs, and water distribution & retention patterns within the wetland • Wetland vegetation • Wetland geomorphology • Biodiversity
UC1	**3.1 Murphy's Rust**									**Y**				**Y**					• Wetland vegetation • Grey Crowned Crane population
UC1	**3.2 Ingula**	**Y**							**Y**	**Y**				**Y**					• Water inputs • Wetland vegetation

IUA	Wetland Code / Name	Quantity		Quality					Habitat		Biota								Indicators selected
		Water inputs	Water distribution and retention patterns	Nutrients	Salts	System variables	Toxics	Pathogens	Geomorphology	Wetland Vegetation	Fish	Plant species	Mammals	Birds	Amphibians & reptiles	Periphyton	Aquatic Invertebrates	Diatoms	
																			• Wetland geomorphology • White-winged Flufftail, Grey Crowned Crane, Blue Crane, and Wattled Crane populations
UC1	**3.3 Wilge**								**Y**	**Y**									• Wetland vegetation • Wetland geomorphology
UC1	**3.4 Upper Wilge**								**Y**	**Y**				**Y**					• Wetland vegetation • Wetland geomorphology • White-winged Flufftail, Grey Crowned Crane, Blue Crane, and Wattled Crane populations
UC1	**3.5 Meul**		**Y**						**Y**	**Y**									• Water distribution & retention patterns Wetland vegetation • Wetland geomorphology
UC2	**4.1 Monontsha**	**Y**	**Y**	**Y**					**Y**	**Y**									• Water inputs, and water distribution & retention patterns within the wetland • Nutrients • Wetland vegetation • Wetland geomorphology
UI	**11.1 Blesbokspruit**	**Y**	**Y**	**Y**	**Y**		**Y**		**Y**	**Y**				**Y**					• Water inputs, and water distribution & retention patterns within the wetland • Nutrients • Salts

IUA	Wetland Code / Name	Quantity		Quality					Habitat		Biota								Indicators selected
		Water inputs	Water distribution and retention patterns	Nutrients	Salts	System variables	Toxics	Pathogens	Geomorphology	Wetland Vegetation	Fish	Plant species	Mammals	Birds	Amphibians & reptiles	Periphyton	Aquatic Invertebrates	Diatoms	
																			• Toxics • Wetland vegetation • Wetland geomorphology • Populations of waterfowl and Red Data species such as the Lesser and Greater Flamingos
UI	**11.2 Klip River Wetland**	**Y**	**Y**						**Y**	**Y**									• Water inputs, and water distribution & retention patterns within the wetland • Wetland vegetation • Wetland geomorphology
UI	**11.3 Rietspruit**		**Y**						**Y**	**Y**									• Water distribution & retention patterns Wetland vegetation • Wetland geomorphology
UI	**11.4 Natalspruit**								**Y**	**Y**									• Wetland vegetation • Wetland geomorphology
UK	**13.1 Kromelmboogspruit**		**Y**							**Y**									• Water distribution & retention patterns Wetland vegetation
UL	**14.1 Boovenste Oog**	**Y**	**Y**						**Y**	**Y**	**Y**								• Water inputs, and water distribution & retention patterns within the wetland • Wetland vegetation • Wetland geomorphology • FRAI with special reference to Goldie barb (*Barbus pallidus*)

IUA	Wetland Code / Name	Quantity		Quality					Habitat		Biota								Indicators selected
		Water inputs	Water distribution and retention patterns	Nutrients	Salts	System variables	Toxics	Pathogens	Geomorphology	Wetland Vegetation	Fish	Plant species	Mammals	Birds	Amphibians & reptiles	Periphyton	Aquatic Invertebrates	Diatoms	
UL	**14.2 Mooi**		**Y**							**Y**									• Water distribution & retention patterns Wetland vegetation
UL	**14.3 Gerhard Minnebron**	**Y**	**Y**		**Y**				**Y**										• Water inputs, and water distribution & retention patterns within the wetland • Salts • Wetland geomorphology

4.3 DAM COMPONENT

The following tables provide a summary of the findings for each of the priority dam for which numerical limits will be determined during step 6 of the RQO determination process.

- Dam sub-component and indicator selection for IUA UA presented in Table 24
- Dam sub-component and indicator selection for IUA UB presented in Table 25
- Dam sub-component and indicator selection for IUA UC.1 presented in Table 26
- Dam sub-component and indicator selection for IUA UC.2 presented in Table 27
- Dam sub-component and indicator selection for IUA UD presented in Table 28
- Dam sub-component and indicator selection for IUA UH presented in Table 29
- Dam sub-component and indicator selection for IUA UL presented in Table 30
- Dam sub-component and indicator selection for IUA UM presented in Table 31

Although most of the dams had high flows specified as an indicator, this is mainly to maintain dam levels for the release of water for irrigation, rural and domestic purposes. The only dams that had a high flow release requirement for ecological purposes are:

- Grootdraai Dam
- Fika-Patso Dam
- Klipdrift Dam
- Vaal Dam

Table 24: Dam sub-component and indicator selection for IUA UA: Upper Vaal Water Management Area

IUA	RU	Dam name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
UA	RU4	Amersfoort Dam	Quantity	Low flows	Dam levels must be sufficient for release for domestic supply to Amersfoort and the surrounding small irrigation areas	EWR
	RU10	Grootdraai Dam	Quantity	Low flows	Dam levels must remain sufficient to provide for municipal and industrial use, as well as releases for ecosystem function downstream.	EWR
			Quality	Nutrients	The system must be maintained in a mesotrophic state or better.	Phosphate, nitrate, nitrite
				Toxins	Toxicity must be maintained better than concentrations that would pose a threat to human health. The dam must be maintained in a mesotrophic state to avoid cyanobacterial blooms and the associated algal toxins.	Chl-a: phytoplankton
			Biota	Fish	The wellbeing of the fish community of this artificial ecosystem must be maintained in a suitable condition to contribute to regional biodiversity (Including maintenance of Orange-Vaal largemouth yellowfish population (Labeobarbus kimberleyensis)) and to support local recreational angling industry. Consumption of fish must not pose a health risk to local communities.	Implementation of the Index of Reservoir Habitat Impairment (IRHI) by Miranda and Hunt (2011), fish health evaluation

Table 25: Dam sub-component and indicator selection for IUA UB: Upper Vaal Water Management Area

IUA	RU	Dam name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
UB	RU20	Vrede/Thembalihle Dam	Quantity	Low flows	Dam levels must be sufficient to maintain releases for domestic and industrial use.	EWR

IUA	RU	Dam name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
			Quality	Nutrients	The system must be maintained in a mesotrophic state or better.	Phosphate, nitrate, nitrite
				Salts	Salt levels must be maintained at concentrations where they do not impact negatively on the ecosystem.	Electrical conductivity

Table 26: Dam sub-component and indicator selection for IUA UC1: Upper Vaal Water Management Area

IUA	RU	Dam name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
UC1	RU28	Warden Dam	Quantity	Low flows	During the dry season dam levels must be sufficient for releases for human use and protection of ecosystem function.	EWR
			Quantity	High flows	During the wet season the dam levels must be maintained such that they are able to support releases for ecosystem function and domestic water use.	EWR

Table 27: Dam sub-component and indicator selection for UC2: Upper Vaal Water Management Area

IUA	RU	Dam name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
UC2	RU29	Fika-Patso Dam	Quantity	Low flows	During the dry season dam levels must be sufficient for releases for municipal and industrial use and protection of ecosystem function downstream.	EWR
			Quantity	High flows	During the wet season dam levels must be maintained such that they support ecosystem function and human use.	EWR
	RU29	Swartwater Dam	Quantity	High flows	During the wet season the dam levels must be sufficient for releases that will support ecosystem function as well as domestic and rural use downstream.	EWR

IUA	RU	Dam name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
	RU33 and 34	Sterkfontein Dam	Quantity	Flows	Dam levels must be sufficient for releases to protect ecosystem function and for municipal and industrial use downstream.	EWR
			Quantity		The dam is filled from the Thukela catchment, the increased dam levels from the transfer must be maintained such that they support the protection of ecosystem function within the dam.	EWR
			Biota	Fish	The wellbeing of the fish community of this artificial ecosystem must be maintained in a suitable condition to contribute to regional biodiversity (Including maintenance of Orange-Vaal largemouth yellowfish population (Labeobarbus kimberleyensis) and to support local recreational angling industry. Consumption of fish must not pose a health risk to local communities. The genetic diversity of the cyprinids in the dam must not be contaminated by non-endemic cyprinids.	Implementation of the Index of Reservoir Habitat Impairment (IRHI) by Miranda and Hunt (2011), genetic diversity assessment of local Cyprinids.

Table 28: Dam sub-component and indicator selection for IUA UD: Upper Vaal Water Management Area

IUA	RU	Dam name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
UD	RU43	Gerrands Dam	Quantity	Flows	During the dry season dam levels must be sufficient for release for domestic and industrial use as well as protection of ecosystem function downstream.	EWR
			Quality	Nutrients	Nutrients must be maintained at mesotrophic levels.	Phosphate, nitrate, nitrite

IUA	RU	Dam name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
				Toxins	The system must be maintained in a mesotrophic condition to avoid cyanobacteria and the associated algal toxins	Chl-a: phytoplankton
	RU43	Loch Athlone Dam	Quantity	Low Flows	During the dry season the dam levels must be sufficient levels to protect ecosystem function and to conserve the recreational value of the dam.	EWR
				High Flows	During the wet season the dam levels must be maintained at levels that will support the recreational use of the dam.	EWR
			Quality	Nutrients	Nutrients must be maintained at mesotrophic levels so as to retain the recreational value of the dam.	Phosphate, nitrate, nitrite
				Toxins	The system must be maintained in a mesotrophic condition to avoid cyanobacteria and the associated algal toxins	Chl-a: phytoplankton
	RU41 and 43	Saulspoort Dam (Sol Plaatjie Dam)	Quantity	Flows	Dam levels must be sufficient to provide releases for domestic and industrial use as well as protection of ecosystem function downstream.	EWR
					Dam levels must be maintained such that they support ecosystem function.	EWR
			Quality	Nutrients	Nutrients must be maintained at mesotrophic levels to protect the ecosystem and also the fitness for use.	Phosphate, nitrate, nitrite
				Toxins	The system must be maintained in a mesotrophic condition to avoid cyanobacteria and the associated algal toxins	Chl-a: phytoplankton

Table 29: Dam sub-component and indicator selection for IUA UH: Upper Vaal Water Management Area

IUA	RU	Dam name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
UH	RU60	Balfour Dam	Quantity	Flows	Dam levels must be maintained at sufficient levels to provide releases for municipal and industrial use as well as protection of ecosystem function downstream.	EWR

Table 30: Dam sub-component and indicator selection for IUA UL: Upper Vaal Water Management Area

IUA	RU	Dam name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
UL	RU69	Klerkskraal Dam	Quantity	Flows	Dam levels must therefore be maintained at levels sufficient for irrigation releases as well as for protection of ecosystem function downstream.	EWR
	RU71	Donaldson Dam	Quantity	Flows	Dam levels must be maintained such that ecosystem function is protected and the recreational value of the dam is retained.	EWR
			Biota	Fish	The fish must not pose a threat to human health if consumed by local communities.	Fish health evaluation
	RU72	Klipdrift Dam	Quantity	Flows	The dam must be maintained at sufficient levels for irrigation releases and releases for the protection of ecosystem function downstream.	EWR
			Quality	Nutrients	The system is currently in a eutrophic state and must be improved and maintained in a mesotrophic state.	Phosphate, nitrate, nitrite
				Salts	Salt levels must be maintained at concentrations where they do not impact negatively on the ecosystem.	Electrical conductivity
				Toxins	To avoid cyanobacterial blooms, the dam must be maintained in a mesotrophic state	Chl-a: phytoplankton

IUA	RU	Dam name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
	RU73	Boskop Dam	Quantity	Flows	The dam must be maintained at levels sufficient for irrigation releases and releases for protection of ecosystem function downstream.	EWR
			Quality	Nutrients	Nutrient concentrations must be maintained such that the system is in a mesotrophic state	Phosphate, nitrate, nitrite
				System variables	The pH of the water in the dam should not negatively impact on ecosystem function	pH
			Biota	Fish	The wellbeing of the fish community of this artificial ecosystem must be maintained in a suitable condition to contribute to regional biodiversity (Including maintenance of Orange-Vaal largemouth yellowfish population (Labeobarbus kimberleyensis) and to support local recreational angling industry. Consumption of fish must not pose a health risk to local communities. The genetic diversity of the cyprinids in the dam must not be contaminated by non-endemic cyprinids.	Implementation of the Index of Reservoir Habitat Impairment (IRHI) by Miranda and Hunt (2011), fish health evaluation

Table 31: Dam sub-component and indicator selection for IUA UM: Upper Vaal Water Management Area

IUA	RU	Dam name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
UM	RU75	Vaal Barrage	Quantity	Flows	Levels must be maintained at sufficient levels for municipal and industrial releases as well as to provide releases for the protection of ecosystem function downstream.	EWR

IUA	RU	Dam name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
			Quality	Nutrients	The system is currently eutrophic and must be improved and maintained in a mesotrophic state.	Phosphate, nitrate, nitrite
				Salts	Salt levels must be maintained at concentrations where they do not impact negatively on the ecosystem.	Electrical conductivity
				Toxins	The system must be maintained in a mesotrophic state to prevent build-up of cyanobacteria blooms and associated algal toxins. The water in the Barrage should not contain toxins including metals at levels that pose a threat to human health.	Chl-a: phytoplankton
			Biota	Fish	The fish must not pose a threat to human health if consumed by local communities.	Fish health evaluation
	RU74	Vaal Dam	Quantity	Flows	Dam levels must be maintained such that they are sufficient for municipal, industrial and irrigation releases as well as protection of ecosystem function downstream.	EWR
					During the wet season dam inflows and levels must be maintained such that they are sufficient for releases for intended use, and release for the protection of ecosystem function downstream.	EWR
			Quality	Nutrients	The system must be improved and managed in a mesotrophic state.	Phosphate, nitrate, nitrite
				Toxins	The system must be maintained in a mesotrophic state to avoid cyanobacterial blooms and associated algal toxins.	Chl-a: phytoplankton

IUA	RU	Dam name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
			Biota	Fish	The wellbeing of the fish community of this artificial ecosystem must be maintained in a suitable condition to contribute to regional biodiversity (Including maintenance of Orange-Vaal largemouth yellowfish population (Labeobarbus kimberleyensis) and to support local recreational angling industry. Consumption of fish must not pose a health risk to local communities. The genetic diversity of the cyprinids in the dam must not be contaminated by non-endemic cyprinids.	Implementation of the Index of Reservoir Habitat Impairment (IRHI) by Miranda and Hunt (2011), fish health evaluation

4.4 GROUNDWATER COMPONENT

Complexities in Site Types

Having considered the measurable parameters as listed in Table 6, some complexities were identified and can be summarised as follows (Table 32):

Table 32: Complexities with measurable parameters

Site Type	Description
Well Fields	Well fields are a collection of boreholes which can have a wide distribution in space leading to boreholes intersecting different geologies which may result in different water chemistries. In some instances it will be difficult to determine a representative water quality and water level for a well field. Furthermore abstractions rates of boreholes are not readily available and the WRMS database only reflects registered use.
Dewatering of mines	Mines need to pump to keep the workings dry. Pumping rates (if available) change with time as the mine develops and the groundwater ingress through various geologies can also lead major differences in chemistry especially considering oxidation that can take place. Groundwater levels can vary substantially in and around a mine lease area making it impossible to associate one water level with the mine.
Afforestation	Abstraction can be measured per tree using techniques such as sapflow, but in general abstractions are estimated through the use of a model and it is dependent on the age of the plantation. Water quality and groundwater level can be measured if boreholes are available, and could also vary spatially around the plantation footprint.
Groundwater contribution to baseflow	Water quality and groundwater level can only be measured at a point where a monitoring borehole intersects the groundwater contribution to baseflow and these parameters will vary significantly along a water course due to geological, streambed and topography differences. Hence a single point cannot be used to characterise the groundwater contribution to baseflow.
Aquifer Types	Due to the distributed and geological nature of aquifers, they cannot be characterised by a single water level and water quality. At best an estimation of available water can be done through modelling the system. Abstraction figures relate back to registered use and estimations from cultivated land can also be done through the use of crop models.

The methodologies to be used in setting up the RQO's as well as monitoring them should be practical and easily implementable; therefore detail modelling of complex systems is not an option. Cost implications should also be considered where specialist studies and borehole development are expensive.

The measurable parameters that can be used as sub-components are given as follows:

- *Quantity (Abstraction)* – this is done through metering, however a vast number of production boreholes are not metered and the WARMS database is not updated.
- *Aquifer (Water Level)* – groundwater water levels can be easily measured when access is available to a borehole
- *Quality (Water Quality)* – field measurements of EC and pH is easy to carry out, but lab analysis of physical chemistry is costly. Due to the variations of geology in a RU and the fact that the water character of the groundwater will be associated with the geology through which it moves (see Figure 2),

no specific chemical constituent can be used as a general indicator of the water quality for a particular RU

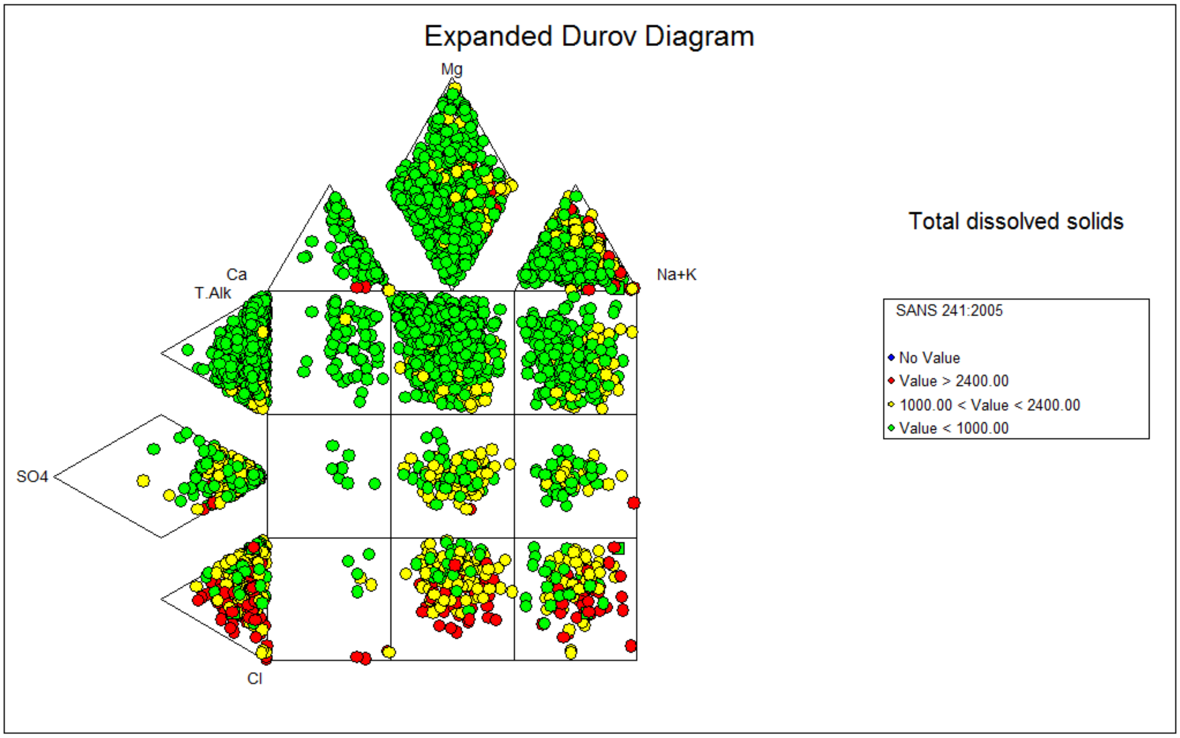

Figure 2: Expanded Durov diagram of available quality data

Protection Zones

According to The National Water Act (NWA) (Act No. 36 of 1998) there is a need to protect basic human needs and the ecological reserve; therefore it is necessary to introduce RQO measures to do this. Due to a lack of information of sub-components in the groundwater system, protection zones have been introduced as a means of protecting the basic human need and ecological reserve. The four protection zones suggested with the concept of infringements are detailed in the following sections.

Radius of Influence:

The protection zone around a borehole (radius of influence) is calculated as follows (Parsons and Wentzel, 2005):

$$r = 1.5\sqrt{\frac{Tt}{S}}$$

where,

r	=	Radius of influence (m)
t	=	Time of pumping (days)
T	=	Transmissivity (m^2/d)
S	=	Storativity

Note: for wellfields a wellfield model is required to verify if protection zone are violated due to the cumulative effect of multiple boreholes.

Microbial Protection Zone:
Groundwater quality is for use and boreholes must be protected from microbial pollution. The protection zone around a borehole to avoid microbial pollution is calculated as follows (Parsons and Wentzel, 2005):

$$r = 2(0.28T) + 53$$

where,

r = Protection radius (m)
T = Transmissivity (m^2/d)

Wetland Protection Zone:
To protect ecological systems that are groundwater fed, it is important to maintain the groundwater gradient to these features. The groundwater gradient can be protected by specifying appropriate protection zones around wetlands (Parsons and Wentzel, 2005).

$$d = \sqrt{\frac{TiL\pi}{R/_{1000}}}$$

where,

d = Distance from wetland (m)
i = Groundwater gradient towards wetland
T = Transmissivity (m^2/d)
L = Wetland perimeter (m)
R = Groundwater recharge (mm/d)

River Protection Zone:
To protect ecological systems that are groundwater fed, it is important to maintain the groundwater gradient to these features. The groundwater gradient can be protected by specifying appropriate protection zones around rivers (Parsons and Wentzel, 2005).

$$d = \frac{Ti}{R/_{1000}}$$

where,

d = Distance from river (m)
i = Groundwater gradient towards wetland
T = Transmissivity (m^2/d)
R = Groundwater recharge (mm/d)

Zone Infringements:
The concept of RQOs based on infringements of a protection zone is proposed for existing infrastructure that will not comply due to their physical position. The RQO will be implemented including the protection zone, but will allow existing infringements. Monitoring of the protection zone will be done to ensure no further infringements are incurred with the introduction of new infrastructure.

Consider the wetland below where the protection zone of the wetland and the borehole overlap. The wetland RQO will be implemented allowing one infringement on the protection zone.

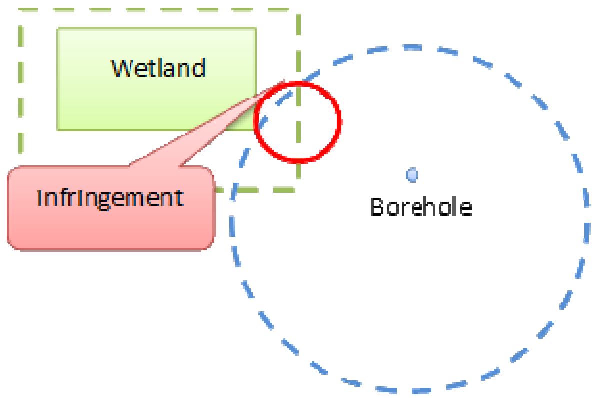

Figure 3: Graphical representation of an infringement area where the influence radius associated with use of a groundwater ecosystem is potentially impacting on a wetland ecosystem.

5 LIMITATIONS AND UNCERTAINTIES

5.1 RIVERS COMPONENT

The following limitations and uncertainties are relevant to the outcomes of this assessment:

- This assessment is largely based on the probability that the sub-components and indicators selected will be suitable indicators of the protection and or use requirements of the water resources considered. This probability consideration is largely based on qualitative information and expert solicitations. These outcomes should be monitored and updated using quantitative data where possible.
- Whilst a range of key stakeholders were involved in this assessment, there were a number of instances where the assessment was based purely on desktop information. There is therefore a risk that some important sub-components could have been omitted from the assessment.

5.2 DAMS COMPONENT

The following limitations and uncertainties are relevant to the outcomes of this assessment:

- This assessment is largely based on the probability that the sub-components and indicators selected will be suitable indicators of the protection and or use requirements of the water resources considered. This probability consideration is largely based on qualitative information and expert solicitations. These outcomes should be monitored and updated using quantitative data where possible.
- Whilst a range of key stakeholders were involved in this assessment, there were a number of instances where the assessment was based purely on desktop information. There is therefore a risk that some important sub-components could have been omitted from the assessment.

5.3 WETLAND COMPONENT

The following limitations and uncertainties are relevant to the outcomes of this assessment:

- The inaccuracy of the current NFEPA data is a concern that will need to be addressed if using this information for setting RQOs. As such, it is recommended that this information to reviewed and/or validated prior to being used to set specific RQOs.
- Stakeholders highlighted the fact that the diversity of pans is not adequately catered for in wetland typing used to set conservation targets for wetlands at a national level. As such, selection of wetland FEPAs does not adequately cater for this diversity and should be re-considered in future.
- Whilst a range of key stakeholders were involved in this assessment, there were a number of instances where the assessment was based purely on desktop information. There is therefore a risk that some important sub-components could have been omitted from the assessment.
- The implication of setting RQO's for groundwater is that individual sites will have to be considered together with prioritized Resource Units that can contain multiple sites. The purpose of this report is to identify sub-components and indicators for the groundwater RQO's while considering the complexity of the groundwater system. There will be a challenge implementing RQO's based on sub-components and indicators with respect to protection zones as each site will have its own parameters which cannot be expressed as regional RQOs. The associated numerical limits will need to be expressed in terms of the formulation of the protection zone, rather than the calculated protection zone.

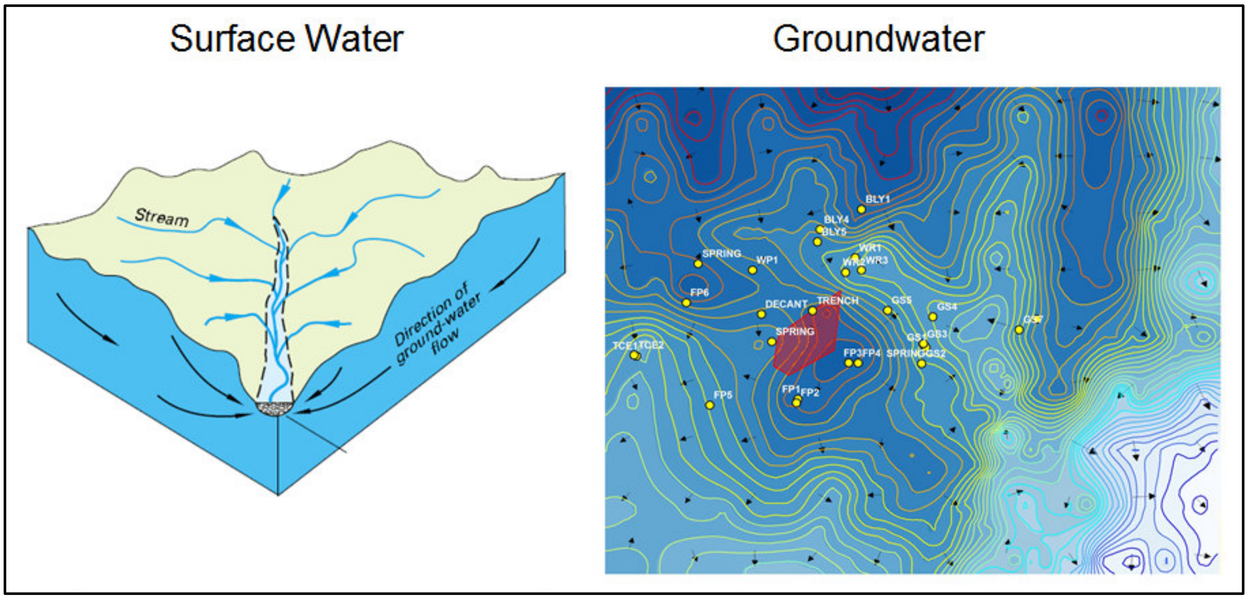

Figure 4: Surface water catchment flow dynamics and groundwater flow dynamics.

6 WAY FORWARD

The prioritisation of sub-components for RQO determination, selection of indicators for monitoring and proposal for the direction of change (Step 4), has been successfully completed and has provided the information required to develop the next report in this series which is the RQO and Numerical Limits report (DWS 2014b).

7 ACKNOWLEDGEMENTS

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8.1 APPENDIX A: UPPER VAAL – DETERMINING DEMAND FOR WETLAND GOODS AND SERVICES

IUA	DESCRIPTION OF RESOURCES	ECOLOGICAL ASSESSMENT	SOCIO-ECONOMIC ASSESSMENT	GOODS AND SERVICES ASSESSMENT
UA	**Vaal River Upstream of Grootdraai Dam** This IUA is situated in the Upper Vaal above Grootdraai Dam. The dominant land use is agriculture, mining and some small towns (Bethal, Ermelo, Amersfoort and Morgenzon) occur. This area is part of the integrated system of water supply to Eskom Power Stations and the Sasol Secunda Complex and is therefore strategically critical to the county's economy.	N/A	This area is part of the integrated system of water supply to most of the Eskom Power Stations and the Sasol Secunda Complex and is, therefore, strategically critical to the county's economy. The area includes the urban centres of Bethal, Ermelo, Amersfoort and Morgenzon. The main contributor to GDP and household income in the area is power generation. The main contributor to employment is the manufacturing sector.	Recreational fishing is important in certain areas with the emphasis on the river and farm dams while subsistence fishing is limited to farm workers. The area offers a limited set of recreational opportunities associated with the riverine system but some bird watching is important in areas associated with wetlands. Although there are floodplains in the area and they are utilised, it is part of the commercial agricultural utilisation sector rather than direct use for livelihoods. Land use is primarily commercial agriculture.
UB	**Klip River (Free State)** This IUA consists of the Klip River with its source and most of the length of the river in the Free State Province. The Klip River catchment contributes a large portion of the incremental runoff to Vaal Dam and is an important tributary of the Vaal River. The area is dominated by agriculture and the flow in the river is influenced by numerous small dams.	The area includes Seekoeivlei, a Ramsar wetland, which gives an indication of its ecological importance.	The area is mainly rural with the urban centre, Memel. The main contributor to GDP, employment and household income is the manufacturing sector. The Klip River UIA is the only catchment area where possible economic implications could occur if the REC is implemented.	Recreational fishing is important in certain areas with the emphasis on the river and farm dams while subsistence fishing is limited to farm workers. The area offers an important set of recreational opportunities associated with bird watching, specifically the Seekoeivlei Ramsar wetland. The upper reaches of the IUA offer important recreational opportunities as it is of a pleasing aesthetic nature. Usage is however relatively

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				low. The floodplains that occur are utilised as part of the commercial agricultural utilisation sector rather than direct use for livelihoods (DWA, 2011c). Land use is primarily commercial agriculture.
UC1	**Upper Wilge River and tributaries (Meul and Cornelius)** This IUA consists of the Wilge River with a very large wetland in the upper area as well as, amongst others, the Meul and Cornelius River tributaries. The proposed Braamhoek Pump-storage Scheme will result in the construction of a dam in the upper part of quaternary C81A. The Wilge River System is largely unregulated with only small dams for water supply to local users. Water users within this catchment comprise of both urban (Harrismith and Warden) and irrigation user groups. The IUA is dominated by agriculture.	EWR 7 is the only node that represents the wetland and its A/B EC is representative of the wetland. It is recommended that the development and operation of the proposed Braamhoek pump-storage scheme, which could impact on the wetland, should therefore accommodate and maintain the integrity of the wetland at an EC of A/B.	The area is to a large extent rural in nature and includes the urban centres of Witsieshoek, Harrismith, Kestell and Phuthaditjhaba. The main contributor to GDP, employment and household income is the manufacturing sector. Irrigation agriculture offers the most direct employment opportunities in the area. **MC II is recommended**	Recreational fishing is important in certain areas with the emphasis on the river and farm dams while subsistence fishing is limited to farm workers. The upper reaches of the IUA offer important recreational opportunities as it is of a pleasing aesthetic nature. Usage is however relatively low. The floodplains that occur are utilised as part of the commercial agricultural utilisation sector rather than direct use for livelihoods. Land use is primarily commercial agriculture.
UC2	**Wilge River and tributaries (Nuwejaarspruit and Namahadi – Elands)** This IUA is situated in the middle Wilge River and tributaries include Nuwejaarspruit and Nahamadi to Elands Rivers. Golden Gate is also part of this IUA and the land use in the remainder of the IUA can be categorised as commercial and mixed farming. Urban areas of note are Phuthaditjhaba surrounding by communal grazing on tribal land. The Wilge River *via* the Nuwejaarspruit receives the transfer from Sterkfontein Dam (located in C81D). In the upper	N/A	Same as UC1.	G&S is important within the Phuthaditjhaba area to provide part of livelihoods. Recreational fishing is important in certain areas with the emphasis on the river and farm dams while subsistence fishing is important with respect to residents of Phuthaditjhaba. Golden Gate National Park also forms part of this IUA and provides an important recreational resource. Waste water

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	portion of quaternary C81F water is abstracted from Fika Patso and Metsi Matso dams to supply the Phuthaditjhaba area. This is an important area with respect to reliance on resources as a part of livelihoods. G&S are particularly important in the upper part of the catchment as this is made up of the areas that were the former homeland of QwaQwa around the town of Phuthaditjhaba and includes some of the most marginal areas of the country			dilution from Phuthaditjhaba is also important. Riparian vegetation is an important component of the livelihoods strategies of people in the Phuthaditjhaba area. Resources are however highly utilised and sustainability of utilisation is questionable.
UC3	**Lower Wilge River** This IUA is situated in the lower Wilge River which is sparsely populated with scattered mixed farming and some irrigation. The river is infested with alien willows resulting in bank erosion.	N/A	Same as UC1.	There is negligible livelihood usage but fishing may be important, particularly closer to the area around Frankfort. Other small-scale recreation is probably important upstream of Frankfort. Subsistence fishing is limited to farm workers and some usage from the dams. Land use is primarily commercial agriculture.
UD	**Liebenbergsvlei River** The area is sparsely populated with scattered mixed farming enterprises the most prominent land form with scattered irrigation along the tributary river reaches. The flow in the Liebenbergsvlei River is highly influenced by the transfer from the LHWP. The LHWP water is discharged into the river system upstream of Saulspoort Dam. There are significant irrigation abstractions along the Liebenbergsvlei River, of which a significant portion is considered to be unlawful.	N/A	The area is to a large extent rural and includes the urban centres of Bethlehem and Reitz. Irrigation agriculture is by far the biggest employment generator in the area.	There is negligible livelihood usage but fishing may be important. Recreational fishing is important in certain areas with the emphasis on the river and farm dams while subsistence fishing is limited to farm workers and some usage from the dams. Some of the higher flows from the transfer may promote other recreational aspects such as canoeing. Although there are floodplains in the area and they are

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				utilised it is part of the commercial agricultural utilisation sector rather than direct use for livelihoods. Land use is primarily commercial agriculture.
UE	**Waterval River** The area includes the industrial centres of Secunda (which includes the Sasol complex), Evander, Kinross and Sasolburg and, in the upper reaches of this IUA; most impacts are associated with deteriorated water quality due to primarily mining, industry, urban and sewage runoff. Agriculture occurs in other parts of the IUA and unlawful irrigation water use occurs in this catchment.	N/A	The area includes the industrial centres of Secunda, Evander and Kinross. The main contributor to GDP, employment and household income in the area is manufacturing.	Aside from the urban nodes the population is sparse and usage in terms of G&S is highly limited. Some recreational fishing and other recreational activities is limited to the lower reaches close to the Vaal River confluence. Some subsistence fishing occurs around the urban areas of Sasolburg.
UF	**Krom and Klip flowing into Vaal Dam** These two relatively small rivers both flow directly into the Vaal Dam and the land use is mainly commercial agriculture. The IUA is relatively sparsely populated.		This IUA includes no significant urban main centres. The main contributor to GDP, employment and household income in the area is irrigation agriculture.	Some recreational fishing and other recreational activities is limited to the lower reaches close to the Vaal Dam confluence. Subsistence fishing is limited to some farm workers. Overall the G&S does not play a significant contributing role to the final MC.
UG	**Vaal River reach upstream of Vaal Dam and downstream of Grootdraai Dam** The area is mainly rural, includes the urban centres of Standerton and Villiers with substantial agricultural activities. The yield balance of Grootdraai Dam is such that most available yield is used to supply Sasol (Secunda Complex) and Eskom Power Stations.	N/A	The economic base of the area is small with irrigation agriculture being the largest contributor to GDP, employment and household income in the area. This reach is influenced by the regulating storage of Grootdraai Dam and the associated abstractions that are of key strategic	The IUA is sparsely populated. Recreation fishing is important in reaches close to the Vaal Dam confluence. Subsistence fishing is relatively important given the town of Villiers and its population, some of whom rely on fish for part of their diet. Picnic spots in the lower reaches close to the Vaal Dam

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			importance to the economy of the country. Even though the economic and water resource importance of this area are high and the flow regime significantly modified, the Vaal River is still within a C EC.	confluence are of importance. Floodplain usage is important but this is restricted to commercial utilisation. Land use is primarily commercial agriculture.
UH	**Suikerbosrand River upstream of confluence with Blesbokspruit** Balfour Dam, situated on the main stem of the Suikerbosrand River, regulates the flow to some extent and is used for supplying water to the town of Balfour. There are extensive areas of commercial agriculture as well as urban development including Nigel and Heidelberg. There are many farm dams and abstractions often result in the river flowing at very low levels.		The area includes the industrial centres of Nigel and Heidelberg. The main contributor to GDP, employment and household income in the area is manufacturing.	The Suikerbosrand catchment is sparsely populated and G&S utilisation is negligible. Given that land use is primarily commercial agriculture the function of the river in terms of waste water assimilation and dilution is of some importance.
UI	**Blesbokspruit, Riet and Klip River (Gauteng)** The IUA is highly urbanized and includes the Rietspruit and Klip rivers in Gauteng as well as the Blesbokspruit River. Urban areas include Johannesburg, Soweto, Boksburg, Brakpan, Benoni, Springs and Sebokeng. The IUA is characterised by water quality related problems due to pollution from gold mining slimes dams, industrial effluent run-off, mine dewatering, run-off from urban areas, leaking sewers, effluent from WWTW, and agricultural return flows.	N/A	The area includes the industrial centres and densely populated area of Johannesburg, Soweto, Boksburg, Brakpan, Benoni, Springs and Sebokeng. The main contributor to GDP, employment opportunities and household income in the area is manufacturing.	There are a broad range of communities present but most are urbanised and dependence on the G&S is likely to be limited. There are a number of poor urban and informal communities that have been observed making use of the fish and living in the vegetation in areas around the river banks. The area offers a relatively limited set of recreational opportunities but the nature of the area means that these are utilised Riparian vegetation: Although some

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				species were deemed to be important in this regard the actual utilisation is low given the nature of restrictions on access to the river and associated area. However there is a population of people living "rough" in the area for whom the shelter offered by riverine trees is important. Waste Water Dilution and Assimilation: Waste water dilution from the urban conglomerate is important. Also given that land use is primarily commercial agriculture the function of the river in this regard is of importance.
UJ	**<u>Taaibosspruit</u>** This catchment contains the Sasolburg industrial complex including coal-mining areas. Extensive agricultural activities occur (dryland and irrigation using pivots), with highly elevated levels of nutrients and salts.		The area includes the manufacturing areas of Vereeniging, Vanderbijlpark, Sasolburg and Parys. The main contributor to GDP, employment opportunities and household income in the area is the manufacturing sector.	G&S utilisation is likely to be practically non-existent however, waste water dilution and assimilation as a function of the river is of some importance given that land use is primarily commercial agriculture.
UK	**<u>Kromelmboogspruit</u>** This reach covers the entire Kromelmboogspruit, a tributary of the Vaal River entering the Vaal upstream of Parys and downstream of Vaal Barrage. Catchment development in the area is mostly agricultural, with numerous road crossings and	N/A	Same as UJ.	G&S utilisation is likely to be practically non-existent however, waste water dilution and assimilation as a function of the river is of some importance given that land use is primarily

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	pivots in the lower reaches. There are no significant abstractions or discharges influencing the river flow. Elevated salts, nutrients and toxics are expected.			commercial agriculture.
UL	**Mooi River up to confluence with Vaal River** The area includes the mining areas of Westonaria, Carletonville and Potchefstroom. This IUA is characterised by water quality problems originating from physical disturbance and changes to the river especially the channel, urban runoff, sewage and mining. The IUA includes the Mooi River of which the major tributary Wonderfonteinspruit is adversely impacted by uranium-laden effluent originating from mining, industrial and urban runoff. In the upper reaches of the Mooi River, commercial farming is also an important land use and the Boskop and Klerkskraal Dams supply water to the irrigation schemes. Loopspruit, another tributary of the Mooi River in the lower reaches of the IUA receives significant mine dewatering upstream of Klipdrift Dam.	N/A	The area includes the mining areas of Westonaria, Carletonville and Potchefstroom. The main contributor to GDP, employment opportunities and household income in the area is the mining industry. Under present conditions, the river does not comply even with the Management Class III criteria and fails.	Given the industrial nature as well as the water quality issues there are few opportunities for communities to make use of G&S. As such any utilisation is negligible.
UM	**Vaal River from downstream of Vaal Dam** The area includes the urban areas of Vereeniging, Vanderbijlpark, Sasolburg and Parys. In the reach between Vaal Dam and the Vaal Barrage the three main tributaries (Suikerbosrand, Klip and Rietspruit rivers) discharge into the Vaal Barrage, each conveying significant volumes of treated waste water and mine discharge water. Management of the flow entering this reach is from Vaal Dam and is influenced by the water users in and downstream of the Vaal Barrage,		The in-stream water quality often does not comply with recreational acceptable standards in areas such as Parys. This means that even though the Ecological Status is still above a D EC, other human related water quality aspects might be unacceptable. Considering the importance of the Vredefort Dome, these should be improved to acceptable standards. It should be	G&S utilisation is likely to be practically non-existent on the tributaries but of high importance in the main Vaal River stem. Recreational fishing is highly important and it includes some of the prime yellow fish and carp fishing areas in the country while subsistence fishing is relatively important. Other recreational usage is of high importance including

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	the urban return flows and mine dewatering discharges as well as the releases form Vaal Dam to maintain the TDS concentration at 600 mg/l. Downstream of the Vaal Barrage the flow is influence by return flows from mine dewatering and treated urban wastewater entering this reach and upstream of the Vaal Barrage as well as a flow dilution operating rule applied to Vaal Dam releases. The Vredefort Dome World Heritage Site is situated in this reach.		noted that many of these issues relate to inadequacy of municipalities to manage sewage in accordance with current discharge licences/permits.	boating, canoeing and utilisation of the area as an aesthetic resource. The river is also a key feature in the Vredefort Dome World Heritage Site.