DETERMINATION OF RESOURCE QUALITY OBJECTIVES IN THE OLIFANTS WATER MANAGEMENT AREA (WMA4)

WP10536

SUB-COMPONENT PRIORITISATION AND INDICATOR SELECTION REPORT

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Determination of Resource Quality Objectives in the Olifants Water Management Area (WMA4) - WP10536

Sub-Component Prioritisation and Indicator Selection Report

Executive Summary

The Resource Quality Objectives (RQOs) determination procedure for the Olifants Water Management Area (WMA) involved the application of the seven step framework established by the Department of Water Affairs in 2011 (DWA, 2011). Some of these steps were achieved in the Water Resource Classification Study and were 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 Olifants Water Management Area (Step 4). These components and sub-components include:

- Quantity component including low and high flow sub-components.
- Quality component including nutrients, salts, system variables, toxicants and pathogen sub-components.
- Habitat component including instream and riparian habitat sub-components.
- Biota component 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 212 sub-components were selected to represent river resources from 32 prioritised RUs.
- A total of 133 sub-components were selected to represent groundwater resources from 30 prioritised RUs.
- A total of 69 sub-components were selected to represent dam resources from 28 prioritised RUs.
- A total of 80 sub-components were selected to represent wetlands resources from 32 prioritised RUs.

Determination of Resource Quality Objectives in the Olifants Water Management Area (WMA4) - WP10536

Sub-Component Prioritisation and Indicator Selection Report

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ABBREVIATIONS

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

O_2	Oxygen
Pb	Lead
PES	Present Ecological State
pH	power of hydrogen
PO_4	Phosphate
RDM	Resource Directed Measures
REC	Recommended Ecological Category
REC	Recommended ecological category
RHAM	Rapid Habitat Assessment Method
RHP	River Health Programme
RO	Regional Office
RQOs	Resource Quality Objectives
RR	Reporting rates
RU / RUs	Resource Unit/s
RUET	Resource Unit Evaluation Tool
RUPT	Resource Unit Prioritisation Tool
SASS5	South African Scoring System version 5
Se	Selenium
SPI	Specific Pollution sensitivity Index
TDS	Total Dissolved Solids
TIN	Total Inorganic Nitrogen
TPC	Threshold of Probable Concern
VEGRAI	Vegetation Response Assessment Index
VMAR	Virgin Mean Annual Runoff
WE	Water Ecosystems
WMA	Water Management Area
WRC	Water Resource Classification
WWTW	Waste Water Treatment Works
Zn	Zinc

DEFINITION OF PROJECT SPECIFIC ACRONYMS:

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

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

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

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

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

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

Determination of Resource Quality Objectives in the Olifants Water Management Area (WMA4) - WP10536

Sub-Component Prioritisation and Indicator Selection 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 produces 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 procedure includes the prioritisation of sub-components for RQOs, the select indicators for monitoring and proposes and the direction of change of these indicators (Step 4; DWA, 2011). 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,
- to select 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

The study entails the determination of Resource Quality Objectives (RQOs) for all significant water resources including rivers, wetlands, lakes and groundwater in the Olifants 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 Olifants WMA which included the delineation IUAs and established a vision for the catchment and key elements for the IUAs (DWA, 2013). 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, 2013). 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 METHODOLOGY 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:
    1. Regional (IUA) scale assessments were considered for rivers, wetlands and groundwater resources in the study.
    2. 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.
    3. 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 Olifants 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. 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.

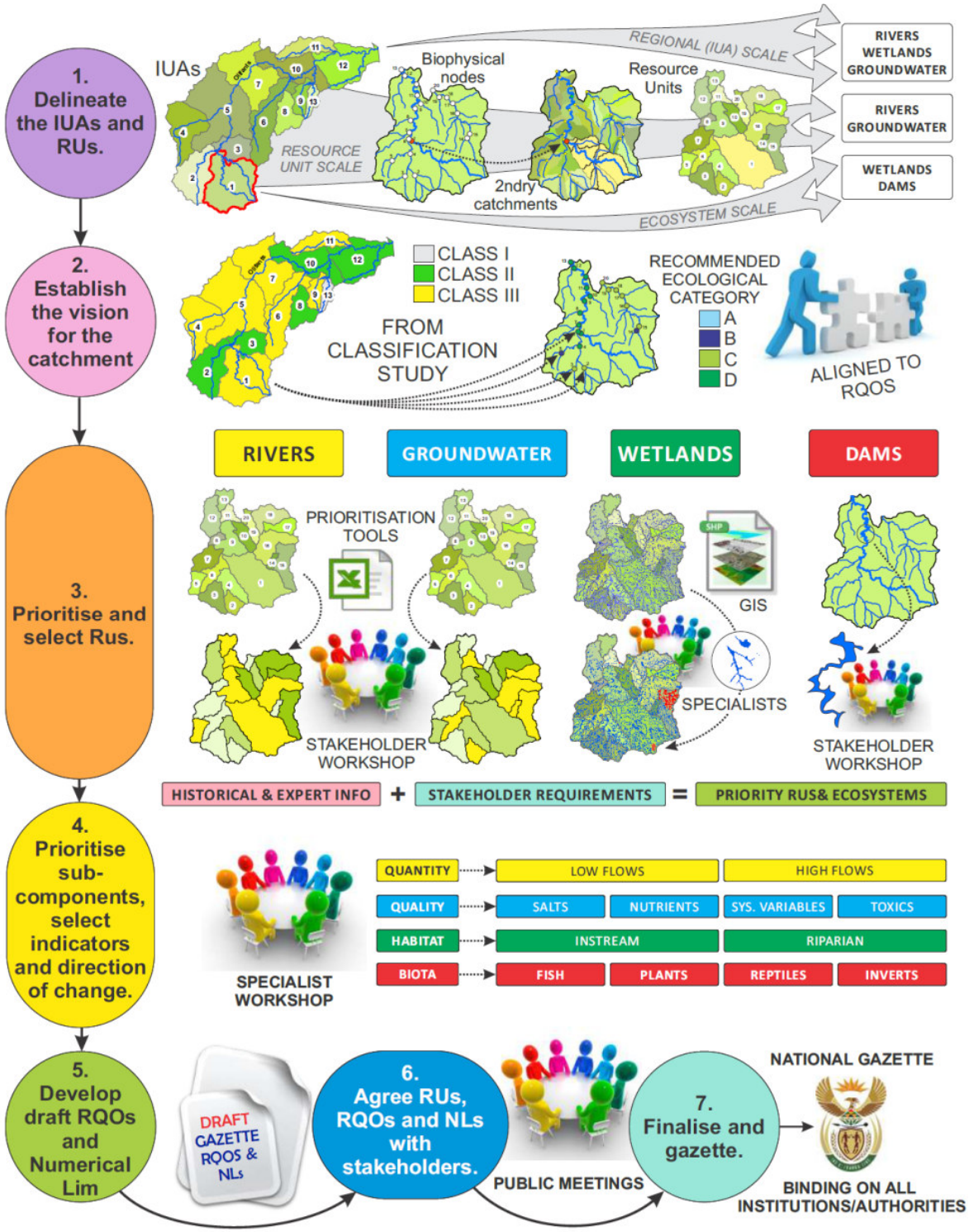

Figure 1: Schematic summary of the RQO determination procedure (adapted from DWA, 2011) which was implemented in this study.

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:

- determine the level of threat posed to each of the sub-components by impacting activities in the catchment and secondly,
- 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.

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 (Appendix 1). 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 (Kleynhans, 2013) 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 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 'UserSpecs', '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 'UserSpecs', '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 the 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 35 RUs in the Olifants 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 or 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.

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

IUA	Resource Unit	Workshop	Desktop	Extrapolated	Protection
1	RU9	X			
	RU11	X			
	RU12		X		
	RU13			X	
2	RU24		X		
	RU27				X
	RU31	X			
3	RU34		X		
	RU35				X
	RU40	X			
4	RU46			X	
5	RU47	X			
	RU49		X		
	RU52	X			
	RU53			X	
6	RU54		X		
	RU57		X		
	RU62		X		
	RU66		X		
7	RU72			X	
8	RU82		X		
9	RU83			X	
	RU86		X		
10	RU88				X
	RU93				X
	RU95	X			
	RU96			X	
	RU97		X		
	RU98	X			
11	RU103			X	
	RU104		X		
12	RU105			X	
	RU116	X			
13	RU117				X
	RU121		X		

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.

3.4 WETLAND COMPONENT

The process established in the study to select sub-components and indicators for wetlands differed between a regional scale and wetland ecosystem scale i.e. for individual wetlands and wetland systems. At a regional scale, selection of appropriate indicators was guided by emerging policy goals that include the need to meet conservation targets for wetland ecosystems and to secure critical ecosystem goods and services that wetlands provide. Potential indicators were initially selected by the target team and then discussed with DWA and key wetland experts at a meeting on 9th September 2013 to obtain input on the most appropriate approach to be followed. Once selected, this provided a basis for setting regional Scale RQOs as part of the next step in the study. For wetland ecosystems a Wetland Ecosystem Evaluation Tool was specifically developed for prioritised wetland ecosystems to assist in the rationalisation process. This tool can be compared to the river RU Evaluation Tool which similarly 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.

In order to apply this tool, available spatial information regarding catchment landuse and potential impacting activities such as mining, waste water works, urban areas and dams was collated. This information was then used together with available supporting information (including that already collated for river ecosystems) and Google Earth imagery to systematically evaluate the impact of current and anticipated future use on each of the prioritized wetlands within the Olifants catchment. This process was undertaken at a workshop attended by key stakeholders with knowledge of the catchment on 27th and 28th November 2013. In this manner, the cumulative level of impact to each sub-component was evaluated for each of the prioritized wetland ecosystems. Once an understanding of key impacts driving current and future impacts had been assessed, this was used to assess the anticipated consequences of impacting activities on water resource quality. This was captured as a projected trajectory of change for each sub-component in the Wetland Ecosystem Evaluation Tool.

The Wetland Ecosystem Evaluation Tool was then used to identify requirements of important user groups. In the case of wetland ecosystems, the rationale for wetland selection provided an important starting point. Where wetlands had been specifically selected based on conservation attributes, the focus was strongly on identifying specific sub-components that were important for meeting conservation objectives at an ecosystem level. In other instances, wetlands had been selected based on their functional importance in the catchment. In this case, the GIS datasets used to prioritize wetlands from a functional perspective were interrogated to better understand the demand for specific services. A rapid screening of local and downstream users was then undertaken to identify important user groups. Sub-components were then rated based on the anticipated importance of wetland attributes in maintaining or enhancing important ecosystem goods and services. So, in instances where water quality enhancement was identified as a key function for example, maintenance of water distribution and retention patterns and wetland vegetation was prioritized as these sub-components are particularly important for assimilating pollutants. It is important to note here that while the RQO guidelines recommend that present state information be reviewed, this was typically not available at a level that could be used for the assessment. The tool was therefore modified to exclude this aspect from the assessment together with the desired magnitude and direction of change.

Once the importance of sub-components for the ‘protection of the water resource’ and ‘water resource dependent activities’ had been rated, the aspirations of each of the important user groups were briefly summarised. These aspirations effectively provided a justification for assigning the ratings to each of the sub-components for the different wetland systems.

Based on the outcomes of this assessment, specific sub-components were selected for RQO determination. The rationale for the choice of different sub-components was then documented in the Wetland Ecosystem Evaluation Tool together with the desired direction of change. Once drafted, these outcomes were considered

together with those for river, dam and groundwater components as part of a synchronization process. Given that a decision had been taken to set objectives for wetlands that were independent but supportive of the classification outcomes, no changes to the desired direction of change were regarded as necessary. The selection of sub-components for individual wetlands was therefore finalised in preparation for the drafting of RQOs and associated numeric limits.

3.5 DAM COMPONENT

The dams considered for sub-component and indicator selection were based on the ecosystems prioritised for the Olifants WMA in step 3 of the RQO process (Table 2). This included a total of 23 dams which 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.

Table 2: Prioritised dams considered in this sub-component and indicator phase of the RQO determination procedure for the Olifants Water Management Area.

IUA	Resource Unit	Dam Name	Quaternary	River	Year Established	FSC (Mm^3)	Why it was built (Purpose)
1	9	Witbank	B11G	Olifants	1971	104.0	Domestic (urban), industrial use
	9	Doornpoort	B11J	Olifants	1925	9.2	Recreation, domestic (urban)
	18	Middelburg	B12C	Klein Olifants	1978	48.4	Domestic (urban), industrial
2	24	Bronkorstspruit	B20C	Bronkhorstspruit	1950	57.9	Industrial, domestic (urban)
	27	Wilge Dam (Premier Mine)	B20F	Wilge	1909	1.7	Domestic (urban), industrial, mining
3	37	Loskop	B32A	Olifants	1939	374.3	Irrigation, domestic (rural), recreation
	38	Roodepoort	B32B	Selons	1968	1.8	Irrigation
4	41	Rust De Winter	B31C	Elands	1934	27.2	Irrigation
	45	Mkhombo/ Weltevreden Weir	B31F	Elands	1980	205.8	Domestic (urban & rural), industrial, irrigation
5	48	Rooikraal	B32F	Bloed	1921	2.1	Irrigation
	52	Flag Boshielo	B51B	Olifants	1987	103.0	Irrigation, industrial, domestic (urban & rural)
6	54	Belfast	B41A	Langspruit	1973	4.4	Domestic (urban)
	56	Tonteldoos	B41C	Tonteldoos	1954	0.6	Irrigation
	56	Vlugkraal	B41C	Vlugkraal	1959	0.4	Irrigation
	62	Der Bruchen	B41G	Groot Dwars	1989	7.3	Irrigation, mining

	64	De Hoop	B41H	Steelpoort	2012	347.4	Domestic (urban & rural), mining, industrial
8	74	Lydenburg Dam	B42B	Sterk	1977	1.1	Domestic (urban), industrial
	79	Buffelskloof	B42F	Watervals	1972	5.4	Irrigation
9	83	Ohrigstad Dam	B60E	Ohrigstad	1955	14.4	Irrigation
10	88	Blyderivierpoort	B60D	Blyde	1974	56.5	Irrigation, domestic (urban), recreation
11	99	Tours	B72E	Ngwabitsi	1988	5.5	Domestic
12	114	Phalaborwa Barrage	B72D	Olifants	1966	5.7	Domestic (urban), industrial
	106	Klaserie	B73A	Klaserie	1959	5.8	Irrigation

To determine and select subcomponents to be included per priority dam for which RQOs should be determined, the 'Dams 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 that 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:

- 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.
- Trajectory of change – These are indicated by arrows to show a positive (↑), negative (↓) or stable (→**)** trajectory.
- Confidence in the scoring indicated as 'very low' to 'high'.
- 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.
- 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.
- 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 UserSpecs and will form part of the final set of RQOs for that specific dam.

3.6 GROUNDWATER COMPONENT

Unlike surface water where biota exist 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 "types" that may occur currently or in future in the study area. Suggestions on groundwater "types" originating from the groundwater sub-component workshop are listed in Table 3. All examples given were classified according to a site type which relates to the sub-components used in the RQO's

Table 3: 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 3 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 3 was extended to include parameters that can be measured for each of the site types and the resultant table is presented in Table 4.

Table 4: 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 4. Various reasons exist for this and justification is provided in the next section.

4 FINDINGS

The findings of the prioritisation of sub-components for RQO determination and indicator selection for monitoring and propose the direction of change are presented per resource considered. Note that these tables represent the outcome of the selection process, but at times the indicators selected were found to be inappropriate for various reasons, and have been replaced with others.

4.1 RIVER COMPONENT

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

- River sub-component and indicator selection for IUA1 is presented in Table 5.
- River sub-component and indicator selection for IUA2 is presented in Table 6.
- River sub-component and indicator selection for IUA3 is presented in Table 7.
- River sub-component and indicator selection for IUA4 is presented in Table 8.
- River sub-component and indicator selection for IUA5 is presented in Table 9.
- River sub-component and indicator selection for IUA6 is presented in Table 10.
- River sub-component and indicator selection for IUA7 is presented in Table 11.
- River sub-component and indicator selection for IUA8 is presented in Table 12.
- River sub-component and indicator selection for IUA9 is presented in Table 13.
- River sub-component and indicator selection for IUA10 is presented in Table 14.
- River sub-component and indicator selection for IUA11 is presented in Table 15.
- River sub-component and indicator selection for IUA12 is presented in Table 16.
- River sub-component and indicator selection for IUA13 is presented in Table 17.

Table 5: River sub-component and indicator selection for IUA1: Olifants Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
1	RU9	Quality	Nutrients	Important to minimise cost per unit volume of water being treated. Eutrophication will also negatively impact on the ecosystem	X	X		Phosphate, nitrate nitrite, ammonium
			Salts	Progressive increase in salts especially sulphate due to upstream mines - selected intolerant species need to be protected.	X	X		Sulphate, electrical conductivity
			System variables	pH and alkalinity and acidity are critical in this catchment - lack of alkalinity is potentially reaching tipping point where there would be no buffering and pH would then drop dramatically and acidity would rise.	X	X		Alkalinity, pH, turbidity, dissolved oxygen
			Toxics	There is sufficient circumstantial evidence to suggest that there will be toxics emitted from agricultural activities which are untreatable by conventional water - but also metals from mines and other biological toxins	X	X		Toxicity testing (bioassay), diatoms
		Habitat	Instream habitat	Linked to response components	X			RHAM
		Biota	Fish	Trajectory is down and already an E category thus needs to be improved	X			FRAI
			Aquatic Invertebrates	Trajectory is down and already an E category thus needs to be improved	X			MIRAI
			Diatoms	Indicate all negative impacts especially toxics			X	Diatoms
	RU11	Quantity	Low Flows (Maintenance Flows)	PES for RU "D/E", REC "D", MC III. Low flow (PES D - maintain) is necessary to maintain river habitat for ecotourism. Poor releases from Doringpoort Dam and Witbank Dam stressors. Recreation/tourism and ecosystem requirements.	X	X		EWR low flows
		Quality	Nutrients	Increase in nutrients (PES "C" - maintain) would cause super abundance of organisms that would negatively affect ecosystem and appearance of river. Would also increase health risk. Ecosystem and recreation/tourism have requirements. Stressors from upstream of dams.	X	X		Phosphate, nitrate, nitrite, ammonium

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
			Salts	Salts (PES "D" - maintain) will negatively impact salinity sensitive organisms. Stressors upstream - mines, users include ecosystem.	X			Sulphate, electrical conductivity
		Habitat	Instream habitat	Instream (PES "C" - maintain) important for wellbeing of the aquatic ecosystem but will also be important for the users who consider it to be aesthetically pleasing (ecotourism - game farming). Stressors associated with upstream flows.	X			RHAM
			Riparian Habitat	Riparian (PES "B/C" - maintain), important for aesthetics for tourism and also habitat for charismatic fauna. Stressors minimal cause of game farming. Alien veg identified.	X	X		VEGRAI or alternative aesthetic indicator
		Biota	Aquatic Invertebrates	Inverts (PES "D" - maintain) indication of the ecosystem condition and also a source of food for fish etc. Stressors upstream water quality and flow impacts. Indicator of ecosystem wellbeing.			X	MIRAI
	RU12	Quantity	Low Flows (Maintenance Flows)	PES "E" REC "D", MC III. LF (PES "D" maintain) Low flows (dry period) affected by mines, industrial and urban users. Important for the ecosystem and users who release (dilution issues) into the Klip River. Ecosystem functioning seriously modified.	X	X		EWR
		Quality	Nutrients	Nutrients (PES "E" improve to "D") High loads issues for ecosystem and fitness for use. Stressors associated with Emalahleni communities and WWTWs. Eutrophic state of ecosystem concerning.	X	X		Phosphates
			Salts	Salts (PES "D/E" - improve to "D"). Salinity associated with industries and mines excessive - impacting on ecosystem function and suitability of water for domestic use by informal communities for basic human needs and vegetable/livestock watering.	X	X		EC, SO4
			System variables	System variables (PES "D" - maintain) Industrial releases and abstraction affect temperatures and DO levels as well as alkalinity associated with AMD, threshold may be reached.	X	X		Dissolved oxygen, temperature, alkalinity

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
			Toxics	Toxics (Although largely unknown considered to be in PES "D" - maintain). Linked to industrial uses releases and peri-urban areas water use requirements as well as ecosystem function impacts.	X	X		DEEEP
		Habitat	Instream habitat	Instream habitat (PES "D/E" - Improve to "D"). Important aspect for ecosystem structure and associated function, linked to current state. Stressors associated with land use activities, road and other infrastructure impacts, urban and peri-urban communities. Water abstraction.	X			RHAM
			Riparian Habitat	Riparian zone (PES "D/E" - improve to "D") Important aspect for ecosystem structure and associated function linked to current state. Riparian zone affected by land use and local communities, flow issues. Important for ecosystem (incl. ecotone or buffer between urban and peri-urban/terrestrial systems and river) and users.	X			VEGRAI
		Biota	Aquatic Invertebrates	Inverts (PES "D/E" - improve to "D") Ecological indicator of ecosystem integrity, important component of ecosystem structure and function. Stressors affecting inverts include water quality, quantity and habitat modifications.			X	MIRAI
	RU13	Quantity	Low Flows (Maintenance Flows)	PES for RU "D/E", REC "D", MC III. Low flow (PES D - maintain) is necessary to maintain river habitat for ecotourism. Poor releases from Doringpoort Dam and Witbank Dam stressors. Recreation/tourism and ecosystem requirements.	X	X		EWR low flows
		Quality	Nutrients	Increase in nutrients (PES "C" - maintain) would cause super abundance of organisms that would negatively affect ecosystem and appearance of river. Would also increase health risk. Ecosystem and recreation/tourism have requirements. Stressors from upstream of dams.	X	X		Phosphate, nitrate, nitrite, ammonium
			Salts	Salts (PES "D" - maintain) will negatively impact salinity sensitive organisms. Stressors upstream - mines, users include ecosystem.	X			Sulphate, electrical conductivity

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
		Habitat	Instream habitat	Instream (PES "C" - maintain) important for wellbeing of the aquatic ecosystem but will also be important for the users who consider it to be aesthetically pleasing (ecotourism - game farming). Stressors associated with upstream flows.	X			RHAM
			Riparian Habitat	Riparian (PES "B/C" - maintain), important for aesthetics for tourism and also habitat for charismatic fauna. Stressors minimal cause of game farming. Alien veg identified.	X	X		VEGRAI or alternative aesthetic indicator
		Biota	Aquatic Invertebrates	Inverts (PES "D" - maintain) indication of the ecosystem condition and also a source of food for fish etc. Stressors upstream water quality and flow impacts. Indicator of ecosystem wellbeing.			X	MIRAI

Table 6: River sub-component and indicator selection for IUA2: Olifants Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
2	RU24	Habitat	Instream habitat	PES "C", REC to maintain "C", MC III. Instream habitat (PES "C" - maintain) important component of the ecosystem template and supports local biodiversity used for ecotourism and recreation. Threats to instream habitat include flow impacts associated with dams and urban informal settlements and agriculture related land use practices.	X	X		RHAM
			Riparian Habitat	Riparian habitat (PES "D/E" improve to "C/D") important component of the ecosystem template and supports local biodiversity used for ecotourism and recreation. Threats from agriculture important sources.	X	X		VEGRAI

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
		Biota	Fish	Fish (PES "C/D" - improve to "C") local source of food for local communities and important part of recreation and ecosystem functioning. Ecologically important species which are representative of possible populations from the Olifants and Klein-Olifants occur within the Wilge River. Wilge River should provide refuge for fish from upper Olifants Catchment monitor population structures of indicator Bushveld Smallscale yellowfish (*Labeobarbus polylepis*) and Stargazer mountain catfish (*Amphilius uranoscopus*) populations.	X	X		FRAI
			Aquatic Invertebrates	Invertebrates ("PES" - improve to "C") Important part of the ecosystem functioning and used as ecological indicator for state of ecosystem health, indicator of water quality impacts from mines!			X	MIRAI
	RU27	Biota	Fish	This Resource Unit is needed to support and maintain local fish community structures including stable populations structures of the Bushveld smallscale yellowfish (*Labeobarbus polylepis)* and Stargazer mountain catfish (*Amphilius uranoscopus*).				Maintenance of critical habitat for indicator species
	RU31	Quantity	Low Flows (Maintenance Flows)	PES "C" REC "B" CLASS II. Low flows (PES "C" - improve to "B/C") are important to ecosystem and users even though current impacts are low. Users include ecosystem and irrigation. Minimal stressors from agriculture and urban areas.	X	X		EWR
		Quality	Salts	Salts (PES "D/E" - improve to "C/D") episodic spikes if sulphates must be addresses. NB EcoSpec and moderately NB UserSpecs (agriculture).	X	X		Sulphate
			Toxics	Experts suspect that toxics (PES unknown - improve) occur and are in excess causing ecological impacts. Sources include WWTW and agriculture - pesticides. Users include ecosystem and irrigation.	X	X		DEEEP
		Habitat	Instream habitat	Instream habitat (PES "C/D" - maintain) Important template for ecosystem, if this component is managed the improvement will be beneficial for other responder components including mammals, birds and amphibians/reptiles. Stressors flow alterations, and local impacts from agriculture. Users include	X			RHAM

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
				ecosystem.				
			Riparian Habitat	Riparian (PES "C" - maintain) Important template for ecosystem, if this component is managed the improvement will be beneficial for other responder components including mammals, birds and amphibians/reptiles. Users include ecosystem, stressors from alien veg and local agriculture.	X			VEGRAI
		Biota	Fish	Fish (PES "D" - improve to "C") Ecologically important species which are representative of possible populations from the Olifants and Klein-Olifants occur within the Wilge River. Wilge River should provide refuge for fish from upper Olifants Catchment monitor population structures of indicator Bushveld Smallscale yellowfish (*Labeobarbus polylepis*) and Stargazer mountain catfish (*Amphilius uranoscopus*) populations.	X			Fish
			Aquatic Invertebrates	Invertebrates (PES "D" - Improve to "C") Ecologically important species which are representative of possible populations from the Olifants and Klein-Olifants occur within the Wilge River. Stressors include water quality and quantity impacts.	X			MIRAI

Table 7: River sub-component and indicator selection for IUA3: Olifants Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
3	RU34	Quantity	Low Flows (Maintenance Flows)	PES "C", REC "C". Low flow (PES "D/E" - Improve "C/D") is necessary to maintain river habitat for ecotourism and ecosystem functioning, flow alterations by poor dam releases, abstractions for agriculture activities compounds issues.	X	X		EWR low flows

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
		Quality	Nutrients	Increase in nutrients (PES "C" - maintain) would cause dominance of tolerant species, alter community structure of species, and appearance of river. Would also increase health risks. Stressors associated with WWTW.	X	X		Phosphate, nitrate, nitrite, ammonium
			Salts	Salts (PES "D" - improve to "C/D") caused by mine releases, negatively impact salinity sensitive organisms.	X			Sulphate, electrical conductivity
			System variables	System variables (PES "D" - improve "C/D"), AMD and associated alkalinity levels are concerning, tipping point for pH may be approaching,	X			Alkalinity
		Habitat	Instream habitat	Instream habitat (PES "C" - maintain) for the wellbeing of the aquatic ecosystem but will also be important for the users who consider it to be aesthetically pleasing.	X	X		RHAM
			Riparian Habitat	Riparian habitat (PES "B/C" - maintain) important for aesthetics for tourism (Game farms) and also habitat for charismatic fauna.		X		VEGRAI or alternative aesthetic indicator
		Biota	Aquatic Invertebrates	Inverts (PES "D" - improve to "C/D") indication of the ecosystem condition and also a source of food for fish etc.			X	MIRAI
	RU35	Biota	Fish	This Resource Unit provides an important refuge for fish. It is thus important to maintain local fish community structures including state population structures of the endemic Hyphen barb (*Barb sp.*) and the Stargazer mountain catfish (*Amphilius uranoscopus*).				Maintenance of critical habitat for indicator species
	RU40	Quantity	Low Flows (Maintenance Flows)	Management class III, REC "C" (MC REPORT HAS "B") low flows currently in "E" (Improve to "C/D") state and are important to maintain ecosystem functioning and use demand which is high in this RU. Stressors associated with poor releases from Loskop and local abstraction by agriculture industries. Users include ecosystem.	X	X		EWR
			High Flows (Floods)	High flows currently in "D" state (maintain) but are important to maintain ecosystem functioning especially recovery from low flow impacted state (dilution) and provision of ecological cues for fish.	X			EWR, ecological cues for fishes

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
		Quality	Salts	Salinisation (PES "D" - maintain) of river from upstream impacts concerning for irrigation and downstream users. Salts associated with AMD (SO4) particularly concerning. Users - ecosystem and agriculture.		X		Electrical conductivity, sulphate
			System variables	Considering REC "C/D" water quality variables including DO and alkalinity NB for protection of ecosystem. Impacts associated with dam releases and upstream impacts. Users - ecosystem, recreation and irrigation.	X			Dissolved oxygen, temperature, alkalinity
			Toxics	The potential for toxics associated with agricultural activities (pesticides), eutrophication of Loskop Dam (blue-green algae) and toxics from upstream users particularly if assimilative capacity of Loskop reduces due to low alkalinity on river of great concern. Users NB ecosystem		X		DEEEP
		Habitat	Instream habitat	Instream habitat in a "D" (improve to a C) state. Largely attributed to flow alterations which is indirectly affecting structure and function of ecosystem.	X			RHAM
		Biota	Fish	Fish (PES D/E - improve to C/D) Loskop acts as major barrier to more tropical diversity of fishes which have their distribution cut off due to Loskop. This reach now acts as an important refugia and spawning area for many migrating species. Provision of suitable flows, water quality, habitat and ecological cues to maintain species is required in consideration of "C" REC.	X			FRAI
			Aquatic Invertebrates	Macroinvertebrates (currently in "D/E" state) is an important indicator of ecosystem state and can be used to evaluate management success to achieve REC "C".			X	MIRAI

Table 8: River sub-component and indicator selection for IUA4: Olifants Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
4	RU46	Quantity	Low Flows (Maintenance Flows)	**PES "D-E" REC "D", MC III.** LF (PES "E/F" - improve to "D") present low flows are inadequate to maintain the ecosystem and to meet basic human needs and also timing of flows is contrary to ecosystem needs. Upstream impacts include agriculture, urban and informal communities.	X	X		EWR
			High Flows (Floods)	HF (PES "E/F" - improve to "D") high flows will ensure better ecosystem maintenance and will also charge storage systems. Ecosystem and users require EWR. Upstream impacts include agriculture, urban and rural communities.	X	X		EWR
		Quality	Pathogens	Pathogens (PES "C/D" but largely unknown - maintain). Large numbers of unserved communities producing waste and water resources being used by downstream communities. Users include local communities dependent on abstraction of water directly from resource.		X		E.coli
		Habitat	Instream habitat	Instream habitat (PES "E" improve to "D") rehabilitation of the instream habitat is necessary for the whole aquatic ecosystem to begin to working. Stressors include flows, water quality and land use (agriculture and urban and informal communities upstream).	X	X		RHAM
		Biota	Fish	Fish (PES "E" improve to "D") are presently not important in the system but must be improved to worst allowable category and for community use abundance of tolerant species including indigenous and alien cyprinids (*Cyprinis carpio*, *Labeo spp.* and *Labeobarbus spp.*), tilapians (*Oreochromis mossambicus* and *Tilapia rendalii*) and the sharp tooth catfish (*Clarius gariepinus*).	X	X		FRAI
			Aquatic Invertebrates	Invertebrates (PES "D/E" improve to "D") will integrate the assessment of health of the ecosystem for both ecosystem and user needs.	X			MIRAI

Table 9: River sub-component and indicator selection for IUA5: Olifants Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
5	RU47	Quantity	Low Flows (Maintenance Flows)	**PES "D-E" REC "D", MC III.** LF (PES "E/F" - improve to "D") present low flows are inadequate to maintain the ecosystem and to meet basic human needs and also timing of flows is contrary to ecosystem needs. Upstream impacts include agriculture, urban and informal communities.	X	X		EWR
			High Flows (Floods)	HF (PES "E/F" - improve to "D") high flows will ensure better ecosystem maintenance and will also charge storage systems. Ecosystem and users require EWR. Upstream impacts include agriculture, urban and rural communities.	X	X		EWR
		Quality	Pathogens	Pathogens (PES "C/D" but largely unknown - maintain). Large numbers of unserved communities producing waste and water resources being used by downstream communities. Users include local communities dependent on abstraction of water directly from resource.		X		E.coli
		Habitat	Instream habitat	Instream habitat (PES "E" improve to "D") rehabilitation of the instream habitat is necessary for the whole aquatic ecosystem to begin to working. Stressors include flows, water quality and land use (agriculture and urban and informal communities upstream).	X	X		RHAM
		Biota	Fish	Fish (PES "E" improve to "D") are presently not important in the system but must be improved to worst allowable category and for community use abundance of tolerant species including indigenous and alien cyprinids (*Cyprinis carpio*, *Labeo spp.* and *Labeobarbus spp.*), tilapias (*Oreochromis mossambicus* and *Tilapia rendalii*) and the sharp tooth catfish (*Clarius gariepinus*).	X	X		FRAI
			Aquatic Invertebrates	Invertebrates (PES "D/E" improve to "D") will integrate the assessment of health of the ecosystem for both ecosystem and user needs.	X			MIRAI

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
	RU49	Quantity	Low Flows (Maintenance Flows)	PES "C", REC "C", MC III. Low flows (PES "E/F" - improve "C/D") are important to maintain ecosystem structure and function and demand for users is very high. Impacts associated with excessive abstraction for agriculture.	X	X		EWR
		Quality	Nutrients	High nutrient enrichment may be affecting the ecological processes and fitness for use. Source from WWTW, agriculture activities.	X			Phosphates
			Toxics	Pesticides and toxics (PES "D" improve to "C") associated with mines may be excessive in this RU.		X		DEEEP
			Pathogens	Pathogens (Proposed to be in a "D" improve to "C") malfunctioning WWTW cause a human health risk which is threatening recreational activities and informal settlement use of instream habitat in RU.				Not available
		Habitat	Instream habitat	Instream (PES "E" improve to "C/D") Important for ecosystem and affecting ability of users to sustainably use resources, impacts associated with land use "agriculture NB".	X			RHAM
		Biota	Fish	Fish (PES "E" improve to "C/D") historical diversity high and EI and ES high, current state of "E" unacceptable impacts associated with water quality, quantity and habitat must be addressed.	X	X		FRAI
			Aquatic Invertebrates	Inverts (PES "D/E" improve to "C/D") historical diversity high and EI and ES high, impacts associated with water quality, quantity and habitat must be addressed.	X			MIRAI
	RU52	Quantity	Low Flows (Maintenance Flows)	PES "D" REC "D", MC III, some components below D state. Low flows (PES E/F - improve to "D") are important for maintenance of the ecosystem and for provision of water for users especially in the dry season. Stressors associated with Flag Boshelo releases.	X	X		Provision of low flows to EWR requirements
		Quality	Salts	Salts (PES "D " maintain) are deteriorating and are causing problems to users of water and contribute to corrosion, SO4 associated with EC's very concerning. Upstream impacts include agriculture activities, WWTW, mines etc.		X		Electrical conductivity and occasional samples of sulphate/chloride ratio

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
		Habitat	Riparian Habitat	Riparian (PES "D" - improve to C/D) habitat is important for the entire ecosystem, for fauna and stability of the banks. Exotic invasions are a threat. Also a useful resource for communities. Stressors include upstream flow issues and agriculture issues.	X	X		VEGRAI
		Biota	Fish	Fish (PES "E" improve to C/D) important part of food chain especially for crocodiles and also a human food source. Must improve to at least "D" but some important species use RU to breed in/recruit as Flag Boshielo acts as a barrier which forces congregations below dam wall. Population structures of migrating mudfish and yellowfish (*Labeo spp* and *Labeobarbus spp*) which may use river below dam for important recruitment must be maintained. Recruitment success of dominance of cyprinid young of year (0-1) fishes must occur. Threats include local harvesting "illegal gill netting" and water quality and habitat quality.	X	X		FRAI
			Birds	Birds (PES "C/D" maintain) riparian and aquatic birds are important part of the food chain and biodiversity of this ecologically important area "transition" zone between ecoregions.	X			Bird transect monitoring
			Amphibians & reptiles	Crocodiles and pythons (PES "D" maintain) are important in this area. Population must be viable and include suitable population structures. Habitat and food availability may be affecting these species too.	X			Population structure of crocodiles
			Diatoms	Diatoms (PES "D" maintain) diatoms are suitable indicators of water quality and an important part of base of food chain.			X	Diatom index
	RU53	Quantity	Low Flows (Maintenance Flows)	PES "D" REC "D", MC III, some components below D state. Low flows (PES E/F - improve to "D") are important for maintenance of the ecosystem and for provision of water for users especially in the dry season. Stressors associated with Flag Boshelo releases.	X	X		Provision of low flows to EWR requirements

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
		Quality	Salts	Salts (PES "D" maintain) are deteriorating and are causing problems to users of water and contribute to corrosion, SO4 associated with EC's very concerning. Upstream impacts include agriculture activities, WWTW, mines etc.		X		Electrical conductivity and occasional samples of sulphate/chloride ratio
		Habitat	Riparian Habitat	Riparian (PES "D" - improve to C/D) habitat is important for the entire ecosystem, for fauna and stability of the banks. Exotic invasions are a threat. Also a useful resource for communities. Stressors include upstream flow issues and agriculture issues.	X	X		VEGRAI
		Biota	Fish	Fish (PES "E" improve to C/D) important part of food chain especially for crocodiles and also a human food source. Must improve to at least "D" but some important species use RU to breed in/recruit as Flag Boshielo acts as a barrier which forces congregations below dam wall. Population structures of migrating mudfish and yellowfish (*Labeo spp* and *Labeobarbus spp*) which may use river below dam for important recruitment must be maintained. Recruitment success of dominance of cyprinid young of year (0-1) fishes must occur. Threats include local harvesting "illegal gill netting" and water quality and habitat quality.	X	X		FRAI
			Birds	Birds (PES "C/D" maintain) riparian and aquatic birds are important part of the food chain and biodiversity of this ecologically important area "transition" zone between ecoregions.	X			Bird transect monitoring
			Amphibians & reptiles	Crocodiles and pythons (PES "D" maintain) are important in this area. Population must be viable and include suitable population structures. Habitat and food availability may be affecting these species too.	X			Population structure of crocodiles
			Diatoms	Diatoms (PES "D" maintain) diatoms are suitable indicators of water quality and an important part of base of food chain.			X	Diatom index

Table 10: River sub-component and indicator selection for IUA6: Olifants Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
6	RU54	Quantity	Low Flows (Maintenance Flows)	Current PES ranges from C to D while REC is "C" and MC is III. Category of flows is "C/D" while REC is "C". Trajectory of change is "improve". Excessive abstraction by agriculture & forestry predominantly has resulted in high threat score to low flows which are considered to be insufficient to maintain ecosystem functioning and local trout industry which is the major local tourism/recreational activity.	X	X		EWR
		Quality	Nutrients	PES for nutrients is a "C" and desired trajectory of change is to "maintain". Nutrient stressors associated with WWTWs in this relatively intolerant area of the Steelpoort have been identified. These stressors are negatively impacting on ecosystem structure and function and local trout fishing industry and associated ecotourism.	X	X		Phosphate, nitrate, nitrite, ammonium
			System variables	PES for system variables is a C/D and desired trajectory of change is to "improve to a C". Temperatures and DO in particular are important to maintain ecosystem and trout industry in particular in this RU. Stressors associated with WWTWs, urban areas, forestry and flow impacts in this relatively intolerant area of the Steelpoort have been identified.	X	X		Temperatures and Dissolved Oxygen
		Habitat	Instream habitat	PES for instream habitat is "C/D" and desired trajectory of change is to "maintain". Instream habitat should be maintained in a C/D state for the maintenance of local aquatic biodiversity and trout for fly-fishing industry.	X			RHAM
		Biota	Fish	PES for fish is "C" and desired trajectory of change is to "maintain". High diversity of local fish communities must be protected and abundances maintained to provide food for trout industry.				FRAI
			Aquatic Invertebrates	PES for Invertebrates is "C" and desired trajectory of change is to "maintain". Inverts used as integrated measure of water quality state and macro invertebrate state. Abundances of invertebrates must be maintained to provide food for trout				MIRAI

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
				industry.				
	RU57	Quantity	Low Flows (Maintenance Flows)	PES "C", REC "C" MC III. Low flows (PES "D" - improve to "C") Low flows are important for maintenance of ecosystem structure and function and mines and irrigated agriculture.	X	X		EWR
		Habitat	Instream habitat	Instream habitat (PES "C/D" - improve to "C") Habitat quality important to maintain ecosystem in suitable state.	X			RHAM
		Biota	Aquatic Invertebrates	Aquatic inverts (PES "D" - Improve to "C") indicator selected to represent response of ecosystem to altered water quality, quantity and habitat alterations.			X	MIRAI
	RU62	Quantity	Low Flows (Maintenance Flows)	PES "C (WRC) & D (PESEIS) REC "C". MC III. Low flow "C/D" improve to "C". Low flows important for maintaining ecosystem structure and function and for peri-urban users.	X	X		EWR
		Quality	Salts	PES "C/D" improve to "C". Salt loads associated with mining activities in elevated state. Improve to allow EC to remain in moderately modified state.	X			Electrical conductivity
		Habitat	Instream habitat	PES "C/D" improve to "C" instream habitat NB for structure and function of ecosystem. Main impact linked to flow alterations.	X	X		RHAM
		Biota	Aquatic Invertebrates	PES "D" improve to "C" important component of ecosystem and indicator of water quality and quantity impacts.			X	MIRAI
	RU66	Quantity	Low Flows (Maintenance Flows)	PES "D" REC "D". EI low but ES high. Low flows NB for ecosystem structure and function and for irrigated agriculture, rural and peri-urban communities who harvest water. Upstream dams and abstraction for agriculture causing main issues.	X	X		EWR
		Quality	Nutrients	PES "D" maintain in D state. Excessive nutrient enrichment from WWTW issues. Maintain ecosystem in mesotrophic state.	X			Phosphate

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
			Toxics	Current toxicity of water unknown, threat of metals, organic contaminants and EDCs evident. Toxics must be minimised to reduce risk of human health and ecosystem impairment.	X	X		DEEEP
		Habitat	Instream habitat	Instream habitat (PES "D/E" improve to "D") important component of ecosystem template.	X			RHAM, monitor periphyton abundance.
			Riparian Habitat	PES "E" improve to "D". Riparian zone important component of aquatic ecosystem including buffering from terrestrial ecosystem and associated land use. Provides cover for aquatic species and contributes to assimilation of wastes.	X			VEGRAI
		Biota	Fish	PES "D/E" improve to "D". Important component of ecosystem and provides food for rural and peri-urban community.				FRAI
			Aquatic Invertebrates	PES "D/E" improve to "D". Important component of the ecosystem and indicator of water quality and quantity and habitat alterations.			X	MIRAI

Table 11: River sub-component and indicator selection for IUA7: Olifants Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
7	RU72	Quantity	Low Flows (Maintenance Flows)	Low flows are essential for ecosystem and users	X	X		EWR
			High Flows (Floods)	Low flows are essential for ecosystem	X			EWR
		Quality	System variables	Sedimentation of habitat and difficulty of removing sediment from water for water institutions.	X	X		Clarity tube or Secchi tube readings and Total Dissolved Solids
		Habitat	Instream habitat	Template for ecosystem, NB for biota and ecosystem functioning and moderating flows and sediment impacts downstream. Harvesting clay for pottery etc.	X	X	X	RHAM

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
			Riparian Habitat	Template for ecosystem, NB for biota and ecosystem functioning and preventing sediment loss from terrestrial ecosystem, important for bank stability and meeting user needs.	X	X	X	VEGRAI
		Biota	Fish	Important to protect local diversity, related to uniqueness of middle veld habitat types and important source of food for people.	X	X		FRAI
			Aquatic & riparian plant species	Rare endemic plants contributing to biodiversity and supply of plants for food, medicinal values and mats etc. for people.	X	X		Population wellbeing of endemics
			Birds	Corridor for birds, unique habitat and species and important part of the food chain.	X			Bird population wellbeing

Table 12: River sub-component and indicator selection for IUA8: Olifants Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
8	RU82	Quantity	Low Flows (Maintenance Flows)	PES "B-C" REC "B" MC II. RU FEPA Fish support area which requires suitable low flows to provide refugia for fish during low flow period. Upstream urban centres and irrigated agriculture causing flow issues. Increasing irrigated agriculture also requires water during low flow periods.	X			EWR
		Quality	Toxics	Current toxic levels unknown, risk of pesticide contaminations in river associated with irrigated agriculture. Toxicity levels must be minimised for FEPA support fish plan. Rural communities also consume water and fish from rivers.	X	X		DEEEP
		Habitat	Instream habitat	PES "C/D" must improve to "B" for ecosystem and FEPA fish support area. Drivers of poor state include flow alterations and land use practices associated with agriculture.	X			RHAM

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
		Biota	Fish	PES "C" Improve to "B". NB component of the FEPA fish support area and used by rural communities. Maintain population structure of *Opsaridium peringueyi* (indicator spp).	X	X		FRAI and population structure of Opsaridium peringueyi

Table 13: River sub-component and indicator selection for IUA9: Olifants Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
9	RU83	Quantity	Low Flows (Maintenance Flows)	Low flows are essential for ecosystem and users	X	X		EWR
			High Flows (Floods)	Low flows are essential for ecosystem	X			EWR
		Quality	Nutrients	Maintain in D state. Maintain ecosystem in mesotrophic state.	X			Nitrates & Phosphate
		Habitat	Instream habitat	PES must improve to "D" for ecosystem for fish.	X			RHAM
		Biota	Fish	PES improve to "D". State of critical instream habitat for the *Barbus sp*. "Ohrigstad" according to Rapid Habitat Assessment Method (RHAM).	X	X		FRAI and RHAM
			Diatoms	Diatoms (PES "D" maintain) diatoms are suitable indicators of water quality and an important part of base of food chain.			X	Diatom index
	RU86	Quantity	Low Flows (Maintenance Flows)	Low flows are essential for ecosystem and users	X	X		EWR
			High Flows (Floods)	Low flows are essential for ecosystem	X			EWR
		Quality	Nutrients	Maintain in C/D state. Maintain ecosystem in mesotrophic state.	X			Nitrates & Phosphate
		Habitat	Instream habitat	PES must improve to "C/D" for ecosystem for fish.	X			RHAM
		Biota	Fish	PES improve to "C/D". State of critical instream habitat for the Barbus sp. "Ohrigstad" according to Rapid Habitat	X	X		FRAI and RHAM

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
				Assessment Method (RHAM).				
			Diatoms	Diatoms (PES "C/D" maintain) diatoms are suitable indicators of water quality and an important part of base of food chain.			X	Diatom index

Table 14: River sub-component and indicator selection for IUA10: Olifants Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
10	RU88	Biota	Fish	This RU contains a unique fish species that requires protection in terms of protection of the overall water resource. Thus the local fish community structures including viable populations of the endemic Southern dwarf minnow (*Opsaridium peringueyi*) should be maintained.				Fish communities should be maintained so that they include viable populations of ecologically important species
	RU93	Biota	Fish	This RU contains unique fish species that requires protection in terms of protection of the overall water resource. Thus the local fish community structures including viable populations of the endemic Shortspine catlet (*Chiloglanis pretoriae*) and the Southern dwarf minnow (*Opsaridium peringueyi*) should be maintained				Fish communities should be maintained so that they include viable populations of ecologically important species
	RU95	Quantity	Low Flows (Maintenance Flows)	Low flows are essential for ecosystem and users	X	X		EWR
			High Flows (Floods)	Low flows are essential for ecosystem	X			EWR
		Quality	System variables	Sedimentation of habitat and difficulty of removing sediment from water for water institutions.	X	X		Clarity tube or Secchi tube readings and Total Dissolved Solids

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
		Habitat	Instream habitat	Template for ecosystem, NB for biota and ecosystem functioning and moderating flows and sediment impacts downstream. Harvesting clay for pottery etc.	X	X	X	RHAM
			Riparian Habitat	Template for ecosystem, NB for biota and ecosystem functioning and preventing sediment loss from terrestrial ecosystem, important for bank stability and meeting user needs.	X	X	X	VEGRAI
		Biota	Fish	Important to protect local diversity, related to uniqueness of middle veld habitat types and important source of food for people.	X	X		FRAI
			Aquatic & riparian plant species	Rare endemic plants contributing to biodiversity and supply of plants for food, medicinal values and mats etc. for people.	X	X		Population wellbeing of endemics
			Birds	Corridor for birds, unique habitat and species and important part of the food chain.	X			Bird population wellbeing
	RU96	Quantity	Low Flows (Maintenance Flows)	Low flows are essential for ecosystem and users	X	X		EWR
			High Flows (Floods)	Low flows are essential for ecosystem	X	X		EWR
		Quality	System variables	Sedimentation of habitat and difficulty of removing sediment from water for water institutions.		X		Clarity tube or Secchi tube readings and Total Dissolved Solids
		Habitat	Instream habitat	Template for ecosystem, NB for biota and ecosystem functioning and moderating flows and sediment impacts downstream. Harvesting clay for pottery etc.	X	X	X	RHAM
			Riparian Habitat	Template for ecosystem, NB for biota and ecosystem functioning and preventing sediment loss from terrestrial ecosystem, important for bank stability and meeting user needs.	X	X	X	VEGRAI
		Biota	Fish	Important to protect local diversity, related to uniqueness of middle veld habitat types and important source of food for people.	X		X	FRAI

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
			Mammals	Hippos need to be monitored and managed - maybe done by nature conservation	X	X		Hippos and other riparian mammals
			Birds	Corridor for birds, unique habitat and species and important part of the food chain.	X	X		Bird population wellbeing
	RU97	Quantity	Low Flows (Maintenance Flows)	PES "C" maintain "C" MC II. Highly seasonal river with few developments but upstream peri-urban communities depend highly on the low flows. Maintain EWR	X	X		EWR
		Habitat	Instream habitat	PES "C/D" improve to "C" instream habitat important component of ecosystem structure and function. Sedimentation associated with upper land use activities (peri-urban communities) negatively affecting ecosystem state.				RHAM
	RU98	Quantity	Low Flows (Maintenance Flows)	Low flows are essential for ecosystem and users	X	X		EWR
			High Flows (Floods)	Low flows are essential for ecosystem	X	X		EWR
		Quality	System variables	Sedimentation of habitat and difficulty of removing sediment from water for water institutions.		X		Clarity tube or Secchi tube readings and Total Dissolved Solids
		Habitat	Instream habitat	Template for ecosystem, NB for biota and ecosystem functioning and moderating flows and sediment impacts downstream. Harvesting clay for pottery etc.	X	X	X	RHAM
			Riparian Habitat	Template for ecosystem, NB for biota and ecosystem functioning and preventing sediment loss from terrestrial ecosystem, important for bank stability and meeting user needs.	X	X	X	VEGRAI
		Biota	Fish	Important to protect local diversity, related to uniqueness of middle veld habitat types and important source of food for people.	X		X	FRAI
			Mammals	Hippos need to be monitored and managed - maybe done by nature conservation	X	X		Hippos and other riparian mammals

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
			Birds	Corridor for birds, unique habitat and species and important part of the food chain.	X	X		Bird population wellbeing

Table 15: River sub-component and indicator selection for IUA11: Olifants Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
11	RU103	Quantity	Low Flows (Maintenance Flows)	EI&ES in "E" improve to "D". All divers of ecosystem in severely impacted state. EWR not being maintained. Major contributors include agriculture and mining industry.	X	X		EWR, mining requirements
		Quality	Salts	PES "F" improve to "D". Salinisation associated with mining industry severe.	X			Electrical conductivity, sulphates and TIMS
			System variables	PES "F" Improve to "D", management of sedimentation and river oxygen levels important.	X			Alkalinity, clarity, temperatures and dissolved oxygen
			Toxics	Presence of and threat of toxins from mining industry unknown. Risk of regional ecosystem (Olifants River) being impacted on by these toxics relatively high.	X			DEEEP
		Habitat	Instream habitat	PES "E" improve to "D". Flow alterations, water quality and land use practices negatively impacting on instream habitat which is important to maintain ecosystem functioning.	X			RHAM and Periphyton
			Riparian Habitat	PES "E" Improve to "D". Riparian Vegetation important component of ecosystem negatively impacted on by water quality, quantity and habitat alterations.	X			VEGRAI
		Biota	Fish	PES "E/F" Improve to "D". Fish important component of ecosystem negatively impacted on by water quality, quantity and habitat alterations.	X			FRAI
			Aquatic Invertebrates	PES "E/F" Improve to "D". Inverts important component of ecosystem negatively impacted on by water quality, quantity and habitat alterations.			X	MIRAI

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
	RU104	Quantity	Low Flows (Maintenance Flows)	EI&ES in "E" improve to "D". All divers of ecosystem in severely impacted state. EWR not being maintained. Major contributors include agriculture and mining industry.	X	X		EWR, mining requirements
		Quality	Salts	PES "F" improve to "D". Salinisation associated with mining industry severe.	X			Electrical conductivity, sulphates and TIMS
			System variables	PES "F" Improve to "D", management of sedimentation and river oxygen levels important.	X			Alkalinity, clarity, temperatures and dissolved oxygen
			Toxics	Presence of and threat of toxins from mining industry unknown. Risk of regional ecosystem (Olifants River) being impacted on by these toxics relatively high.	X			DEEEP
		Habitat	Instream habitat	PES "E" improve to "D". Flow alterations, water quality and land use practices negatively impacting on instream habitat which is important to maintain ecosystem functioning.	X			RHAM and Periphyton
			Riparian Habitat	PES "E" Improve to "D". Riparian Vegetation important component of ecosystem negatively impacted on by water quality, quantity and habitat alterations.	X			VEGRAI
		Biota	Fish	PES "E/F" Improve to "D". Fish important component of ecosystem negatively impacted on by water quality, quantity and habitat alterations.	X			FRAI
			Aquatic Invertebrates	PES "E/F" Improve to "D". Inverts important component of ecosystem negatively impacted on by water quality, quantity and habitat alterations.			X	MIRAI

Table 16: River sub-component and indicator selection for IUA12: Olifants Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
12	RU105	Quantity	Low Flows (Maintenance Flows)	Low flows are essential for ecosystem and users	X	X		EWR

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
			High Flows (Floods)	Low flows are essential for ecosystem	X	X		EWR
		Quality	System variables	Sedimentation of habitat and difficulty of removing sediment from water for water institutions.		X		Clarity tube or Secchi tube readings and Total Dissolved Solids
		Habitat	Instream habitat	Template for ecosystem, NB for biota and ecosystem functioning and moderating flows and sediment impacts downstream. Harvesting clay for pottery etc.	X	X	X	RHAM
			Riparian Habitat	Template for ecosystem, NB for biota and ecosystem functioning and preventing sediment loss from terrestrial ecosystem, important for bank stability and meeting user needs.	X	X	X	VEGRAI
		Biota	Fish	Important to protect local diversity, related to uniqueness of middle veld habitat types and important source of food for people.	X		X	FRAI
			Mammals	Hippos need to be monitored and managed - maybe done by nature conservation	X	X		Hippos and other riparian mammals
			Birds	Corridor for birds, unique habitat and species and important part of the food chain.	X	X		Bird population wellbeing
	RU116	Quantity	Low Flows (Maintenance Flows)	Crucial diver of ecosystem	X			EWR
			High Flows (Floods)	Crucial diver of ecosystem	X			EWR
		Quality	System variables	Sediment negatively driving whole system process, negatively impacting on all habitats etc.	X			Total dissolved solids and Clarity tube etc.
			Toxics	Suspected influence of toxics need to be addressed	X			DEEEP
			Pathogens	Suspected influence of pathogens need to be addressed	X			DEEEP

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
		Habitat	Instream habitat	Crucial template for KNP conservation area	X			Periodic geomorphology, RHAM assessments and hydraulic modelling. Consider event response modelling.
			Riparian Habitat	Crucial template for KNP conservation area	X			VEGRAI IV
		Biota	Fish	Important components of KNP biodiversity and contribute to ecosystem wellbeing	X			FRAI other LoEs if FRAI not reached
			Aquatic & riparian plant species	Important components of KNP biodiversity and contribute to ecosystem wellbeing	X			VEGRAI
			Mammals	Important components of KNP biodiversity and contribute to ecosystem wellbeing & ecotourism for KNP	X			Indicator population wellbeing studies
			Birds	Important components of KNP biodiversity and contribute to ecosystem wellbeing & ecotourism for KNP	X			Indicator population wellbeing studies
			Amphibians & reptiles	Important components of KNP biodiversity and contribute to ecosystem wellbeing & ecotourism for KNP	X			Indicator population wellbeing studies
			Periphyton	Important components of KNP biodiversity and contribute to ecosystem wellbeing	X			Periphyton torch
			Aquatic Invertebrates	Important components of KNP biodiversity and contribute to ecosystem wellbeing	X			MIRAI
			Diatoms	Important components of KNP biodiversity and contribute to ecosystem wellbeing	X			Diatom index

Table 17: River sub-component and indicator selection for IUA13: Olifants Water Management Area

IUA	RU	Component	Sub-component	Rationale for sub-component choice	EcoSpec	UserSpecs	Integrated Measure	Indicator selection
13	RU117	Biota	Fish	This RU contains species of fish that are important to maintain for the state of the overall water resource. Thus the local fish community structures should be maintained including stable population structures of the endemic Treur River barb (Barbus treurensis).				Fish communities should be improved so that they include viable populations of ecologically important species
	RU121	Quantity	Low Flows (Maintenance Flows)	PES "B" REC "B" MC I. Protection prioritised. Provision of EWR during low flows critical for maintenance of protected area.	X			EWR
			High Flows (Floods)	PES "B" REC "B" Provision of EWR including ecological cue flows from Blydepoort dam during high flows critical for maintenance of protected area.	X			EWR
		Quality	System variables	PES "B/C" improve to "B" turbidity associated with upstream forestry activities must be minimised to ensure ecosystem maintained in "B" state.	X			Clarity converted to turbidity (NTUs)
		Habitat	Instream habitat	Instream habitat must be maintained in current "B" category to maintain ecosystem	X			RHAM
		Biota	Fish	Fish important component of the ecosystem and selected as indicator for conservation "FEPA" maintain existing fish community structures and population structures of indicator water quality and flow indicator species including protected Barbus treurensis and Knerian sp.	X			FRAI, community structures and population structure of Barbus treurensis and Knerian sp

4.2 WETLAND COMPONENT

Regional-level components and indicators selected for RQO determination

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.

Wetland sub-components and indicators selected for prioritized wetland ecosystems

Selection of sub-components for prioritized wetland ecosystems was based on an evaluation of the relevance of each sub-component in light of protection requirements and water resource dependant activities. While details of the assessment outcome are documented in the Resource Unit Evaluation Tools for each wetland, a summary of the indicators selected is presented in Table 18, below.

Table 18: Wetland sub-component and indicator selections for prioritised wetlands in the Olifants Water Management Area

IUA	RU	Wetland	Component	Sub-component	Rationale for sub-component choice	Indicator selection
1	RU5	1.1 Blesbokspruit wetland	Quantity	Water distribution and retention patterns	Diffuse water distribution is required to optimise the water quality enhancement function of the wetland. While an improvement in water distribution and retention patterns is desirable, this is likely to be unachievable in this particular wetland. Existing water distribution and retention patterns should therefore be maintained to ensure no loss in functional value of the system occurs.	Alteration of water distribution & retention patterns within the wetland
			Habitat	Geomorphology	Erosion & drainage can undermine the water quality enhancement functions of this wetland. Maintenance of the existing geomorphic template is required to prevent further loss in wetland functioning.	Geomorphic impacts: Erosional features
				Wetland Vegetation	Wetland vegetation plays a key role in improving water quality for downstream users. It also provides habitat for wetland-dependant biota. Maintenance of vegetation attributes is therefore required to prevent loss in biodiversity maintenance and water quality enhancement functions.	Wetland vegetation
	RU6	1.2 Rietspruit wetland	Quantity	*Water distribution and retention patterns*	Diffuse water distribution is required to optimise the water quality enhancement function of this wetland. Headward erosion threatens to reduce this functionality. Existing water distribution and retention patterns should therefore be maintained to ensure no loss in the functional value of the system.	Alteration of water distribution & retention patterns within the wetland
			Habitat	Geomorphology	Erosion & drainage can undermine the water quality enhancement functions of this wetland. Maintenance of the existing geomorphic template is required to prevent further loss in wetland functioning.	Geomorphic impacts: Erosional features

IUA	RU	Wetland	Component	Sub-component	Rationale for sub-component choice	Indicator selection
				Wetland Vegetation	Wetland vegetation plays a key role in improving water quality for downstream users. It also provides habitat for wetland-dependant biota. Maintenance of wetland vegetation in its present state is therefore required to secure existing biodiversity and functional values	Wetland vegetation
	RUs 3 and 4	1.3 Kriel wetland	Quantity	Water distribution and retention patterns	: Diffuse water distribution is required to optimise the water quality enhancement function of this wetland. Headward erosion threatens to reduce this functionality. Existing water distribution and retention patterns should therefore be maintained to ensure no loss in the functional value of the system.	Alteration of water distribution & retention patterns within the wetland
			Habitat	Geomorphology	Erosion & drainage threaten to undermine the water quality enhancement functions of this wetland. Rehabilitation is required to halt erosion and prevent further loss in water quality enhancement functions.	Geomorphic impacts: Erosional features
				Wetland Vegetation	Wetland vegetation plays a key role in improving water quality. Rehabilitation is required in order to maintain existing wetland vegetation cover necessary to prevent further loss in water quality enhancement functions.	Wetland vegetation
	RU 7	1.4 Klippoortjiespruit wetland	Habitat	Wetland vegetation:	Wetland vegetation plays a key role in improving water quality for downstream users. It also provides habitat for wetland-dependant biota with extensive cutgrass (*Leersia sp*.) beds occurring in this wetland. Maintenance of vegetation attributes is therefore required to ensure that existing wetland habitat is not undermined within this heavily transformed catchment.	Wetland vegetation

IUA	RU	Wetland	Component	Sub-component	Rationale for sub-component choice	Indicator selection
	RU1	1.5 Koringspruit wetland	Quantity	*Water distribution and retention patterns*	Diffuse water distribution is required to optimise water quality enhancement functions provided by this wetland. Current erosion threatens to undermine wetland functioning. Rehabilitation is therefore required to safeguard the current water quality enhancement functions provided by this wetland	Alteration of water distribution & retention patterns within the wetland
			Habitat	Geomorphology	Erosion & drainage threaten to undermine the water quality enhancement functions of this wetland. Rehabilitation is therefore required to halt erosion and prevent further loss in water quality enhancement functions.	Geomorphic impacts: Erosional features
				Wetland Vegetation	Wetland vegetation plays a key role in improving water quality for downstream users. Rehabilitation is required in order to maintain existing wetland vegetation cover and prevent further loss in water quality enhancement functions.	Wetland vegetation
	RU12	1.6 Klipspruit wetland	Quantity	Water distribution and retention patterns	Diffuse water distribution is required to optimise water quality enhancement functions provided by this wetland. The wetland is however located in an urban context where drainage is a common threat. Elevated peak flows may also contribute to erosion and incision. Given the importance of water quality enhancement functions, existing water distribution and retention patterns must be maintained to ensure no loss in functional value.	Alteration of water distribution & retention patterns within the wetland
			Habitat	Wetland vegetation	Wetland vegetation plays a key role in improving water quality and buffering the impacts of mining and urban areas on downstream water resources. Maintenance of wetland vegetation cover is therefore required to prevent further loss in wetland functioning	Wetland vegetation

IUA	RU	Wetland	Component	Sub-component	Rationale for sub-component choice	Indicator selection
	RU15	1.7 Klein Olifants tributary	Quantity	Water distribution and retention patterns	Changes in landuse are likely to accelerate erosion which could alter water distribution and retention patterns in this wetland. This would result in a loss of wetland habitat, important for wetland-dependant plant & animal species. Maintenance of the existing geomorphic template is therefore required to ensure that biodiversity maintenance functions are not undermined	Alteration of water distribution & retention patterns within the wetland
			Habitat	Wetland vegetation	Wetland vegetation is a good indicator of the habitat and biodiversity value of a wetland and provides foraging & breeding habitat for crane species. Maintenance of wetland vegetation is required to ensure that existing biodiversity values are not undermined.	Wetland vegetation
	RU15	1.8 Matla wetland	Quantity	Water distribution and retention patterns	Changes in landuse are likely to accelerate erosion which could alter water distribution and retention patterns in this wetland. This would result in a loss of wetland habitat, important for wetland-dependant plant & animal species. Maintenance of the existing geomorphic template is required to ensure that biodiversity maintenance functions are not undermined.	Alteration of water distribution & retention patterns within the wetland
			Habitat	Wetland vegetation	Wetland vegetation is a good indicator of the habitat and biodiversity value of a wetland and provides foraging & breeding habitat for crane species. Maintenance of wetland vegetation attributes is therefore required to ensure that existing biodiversity values are not undermined.	Wetland vegetation
	RU16	1.9 Woes-Alleenspruit wetland	Quantity	Water distribution and retention patterns	Diffuse water distribution is required to optimise water quality enhancement functions provided by this wetland. Existing water distribution and retention patterns should therefore be maintained to ensure no loss in functional value.	Alteration of water distribution & retention patterns within the wetland

IUA	RU	Wetland	Component	Sub-component	Rationale for sub-component choice	Indicator selection
			Habitat	Wetland vegetation	Wetland vegetation plays a key role in improving water quality and buffering the impacts of mining and urban areas on downstream water resources. Maintenance of wetland vegetation cover is therefore required to prevent further loss in wetland functioning	Wetland vegetation
	RU16	1.10 Bosmanspruit wetland	Quantity	Water distribution and retention patterns	Diffuse water distribution is required to optimise water quality enhancement functions provided by this wetland. Existing water distribution and retention patterns should therefore be maintained to ensure no loss in functional value.	Alteration of water distribution & retention patterns within the wetland
			Habitat	Wetland vegetation	Wetland vegetation plays a key role in improving water quality and buffering the impacts of mining and urban areas on downstream water resources. Maintenance of wetland vegetation cover is therefore required to prevent further loss in wetland functioning	Wetland vegetation
	RU17	1.11 Kopermyn wetland	Quantity	Water distribution and retention patterns	Diffuse water distribution is required to optimise water quality enhancement functions provided by this wetland. Existing water distribution and retention patterns should therefore be maintained to ensure no loss in functional value.	Alteration of water distribution & retention patterns within the wetland
			Habitat	Wetland vegetation	Wetland vegetation provides habitat for wetland-dependant biota and plays a key role in improving water quality. Maintenance of wetland vegetation is therefore required in order to secure existing habitat values and prevent further loss in wetland functioning.	Wetland vegetation

IUA	RU	Wetland	Component	Sub-component	Rationale for sub-component choice	Indicator selection
2	RU23	2.1 Elandsvlei pan system	Quantity	Water inputs	Water inputs are important in shaping habitat characteristics of pan systems. Afforestation and abstraction poses a threat to natural hydrological functioning. No further increase in abstraction or stream flow reduction activities should therefore be permitted to reduce potential hydrological impacts on these pan systems	Water input
			Habitat	Wetland vegetation	Wetland vegetation and associated buffer zone areas provides important habitat for grass owls and other wetland-dependant species. Maintenance of wetland vegetation and associated untransformed habitat is therefore required to ensure that these pans continue to provide important refuge for biodiversity within an agricultural matrix.	Wetland vegetation and associated buffer zone habitat
			Biota	Birds	This pan system provides a particularly important refuge for grass owl populations. Maintenance of population numbers is desirable given the importance of this area for grass owl populations.	African Grass-Owl (*Tyto capensis*)
	RU22	2.2 Koffiespruit tributary	Habitat	Wetland vegetation	Wetland vegetation is a good indicator of the habitat and biodiversity value of a wetland. Maintenance of wetland vegetation is therefore necessary to ensure that these values are not undermined.	Wetland vegetation
	RU21	2.3 Delmas wetland	Quantity	Water distribution and retention patterns	Diffuse water distribution is required to optimise water quality enhancement functions provided by this wetland. Existing water distribution and retention patterns should therefore be maintained to ensure no loss in functional value.	Alteration of water distribution & retention patterns within the wetland

IUA	RU	Wetland	Component	Sub-component	Rationale for sub-component choice	Indicator selection
			Quality	Pathogens	Elevated pathogen levels are associated with discharges from the waste water treatment works and pose a health risk for local community members. A reduction in E. Coli levels to within an acceptable state is required to reduce the risk of water borne diseases associated with faecal contamination emanating from the upstream waste water treatment works.	*E. coli*
			Habitat	Wetland vegetation	Assimilation of toxics and uptake of nutrients requires good vegetation cover. Maintenance of wetland vegetation is therefore required to ensure that optimal conditions for water quality enhancement are maintained.	Wetland vegetation
		2.4 Bronkhorstspruit tributary	Quantity	Water distribution and retention patterns	Water distribution and retention patterns are important in defining the habitat template for wetland-dependant biota. Maintenance of diffuse flows is also important for maintaining water quality enhancement functions. Water distribution and retention patterns must therefore be maintained to ensure that habitat structure and variability is not negatively affected and that water quality	Alteration of water distribution & retention patterns within the wetland
			Habitat	Wetland vegetation	Wetland vegetation (particularly areas of tall grass habitat) is important for African Grass Owls and plays a key role in water quality amelioration. Maintenance of wetland vegetation characteristics is therefore required to ensure that these functions are not undermined	Wetland vegetation
	RU27	2.5 Wilge tributary	Quantity	Water distribution and retention patterns	Diffuse water distribution is required to optimise water quality enhancement functions. Existing water distribution and retention patterns should therefore be maintained to ensure no loss in functional value.	Alteration of water distribution & retention patterns within the wetland

IUA	RU	Wetland	Component	Sub-component	Rationale for sub-component choice	Indicator selection
			Habitat	Wetland vegetation	Water quality enhancement functioning is dependent on good vegetation cover and is likely to increase in importance in response to growing mining pressure. Maintenance of wetland vegetation is therefore required to ensure that water quality enhancement functions provided by this wetland are not undermined.	Wetland vegetation
	RU28	2.6 Zaalklap wetland	Quantity	Water distribution and retention patterns	Diffuse flows are important for maintaining habitat diversity and water quality enhancement functions. Historic drainage has canalised flows, reducing the ability of the wetland to provide this service. Rehabilitation is therefore required to improve habitat value and to enhance water quality enhancement functions provided by the wetland.	Alteration of water distribution & retention patterns within the wetland
			Habitat	Wetland vegetation	Wetland vegetation provides a useful surrogate for habitat value and is essential for water quality enhancement functions. An improvement in wetland vegetation structure and composition is therefore required to ensure that habitat values, plant species composition and existing water quality enhancement functions are improved	Wetland vegetation
		2.7 Saalboomspruit wetland	Quantity	Water distribution and retention patterns	Diffuse flows are important for maintaining habitat diversity and water quality enhancement functions provided by this wetland. Historic drainage has impacted negatively on the wetland with headcut advancement threatening to cause further loss in functional values. Rehabilitation is therefore required to halt headcut advancement and improve both habitat and water quality enhancement values	Alteration of water distribution & retention patterns within the wetland

IUA	RU	Wetland	Component	Sub-component	Rationale for sub-component choice	Indicator selection
			Habitat	Wetland vegetation	Wetland vegetation provides a useful surrogate for habitat value and is essential for water quality enhancement functions. An improvement in wetland vegetation structure and composition is therefore required to ensure that habitat values and water quality enhancement functions are improved.	Wetland vegetation
IUA	**RU**	**Wetland**	**Component**	**Sub-component**	**Rationale for sub-component choice**	**Indicator selection**
3	RU34	3.1 Klein Olifants Tributary	Quantity	Water distribution and retention patterns	Water distribution and retention patterns are important in defining the habitat template for wetland-dependant biota. Drainage / erosion would undermine habitat value and should be avoided. Maintenance of water and distribution and retention patterns is therefore required to ensure that habitat suitable for cranes and other wetland-dependant biota is maintained.	Alteration of water distribution & retention patterns within the wetland
			Habitat	Wetland vegetation	Wetland vegetation provides foraging & breeding habitat for cranes and other wetland-dependant species. Wetland vegetation characteristics must therefore be retained to support biota utilizing the wetland.	Wetland vegetation
IUA	**RU**	**Wetland**	**Component**	**Sub-component**	**Rationale for sub-component choice**	**Indicator selection**
4	RU41	4.1 Elands tributary wetland	Quantity	Water distribution and retention patterns	Water distribution and retention patterns are important in defining the habitat template for wetland-dependant biota. Drainage / erosion would undermine habitat value and should be avoided. Maintenance of water and distribution and retention patterns is therefore required to ensure that habitat suitable for cranes and other wetland-dependant biota is maintained.	Alteration of water distribution & retention patterns within the wetland

IUA	RU	Wetland	Component	Sub-component	Rationale for sub-component choice	Indicator selection
			Habitat	Wetland vegetation	Wetland vegetation provides foraging & breeding habitat for cranes and other wetland-dependant species. Wetland vegetation characteristics must therefore be retained to support biota utilizing the wetland.	Wetland vegetation
IUA	**RU**	**Wetland**	**Component**	**Sub-component**	**Rationale for sub-component choice**	**Indicator selection**
6	RU54	6.1 Lakenvlei wetland complex	Quantity	Water inputs	Maintenance of water inputs is critical for peat formation and to prevent oxidation. Any increase in stream flow reduction or abstraction activities could threaten the integrity of these areas. Current water inputs must therefore be maintained.	Water input
				Water distribution and retention patterns	Parts of the wetland remain affected by drainage which needs to be improved to further support conservation objectives. Rehabilitation of degraded areas is therefore required to improve the existing conservation values of the site.	Alteration of water distribution & retention patterns within the wetland
			Habitat	Geomorphology	Peat is susceptible to desiccation and erosion. No further impacts to wetland geomorphology should therefore be permitted to ensure that the integrity of the peatland is not compromised.	Geomorphic impacts: Erosional features
				Wetland vegetation	Wetland vegetation provides habitat which is critical to wetland-dependant biota including a range of threatened bird species that utilize wetlands in this complex. Rehabilitation of areas affected by drainage is required to enhance existing habitat values.	Wetland vegetation

IUA	RU	Wetland	Component	Sub-component	Rationale for sub-component choice	Indicator selection
			Biota	Plant species	Species such as Carex and Phragmites are peat forming and desirable in this system. There are however indications that the extent of *Typha capensis* is increasing which could affect peat creation. An increase in *Typha capensis* is regarded as undesirable for peat creation and needs to be carefully monitored.	Increase in the extent Typha dominated plant communities
				Birds	The wetland is home to a range of threatened bird species and this is one of a handful of wetlands where there is an opportunity to stabilise and improve the population status of crane populations. Populations of Grey Crowned Cranes and Wattled Cranes must therefore be maintained or improved to meet conservation targets for these important species.	Grey Crowned Cranes (*Balearica regulorum*) Wattled Cranes (*Bugeranus carunculatus*)
	RU57	6.2 Welgevonden wetland	Quantity	Water inputs	Maintenance of water inputs is critical for peat formation and to prevent oxidation. Any increase in stream flow reduction or abstraction activities could threaten the integrity of these areas. Current water inputs must therefore be maintained.	Water input
				Water distribution and retention patterns	Any drainage or erosion would undermine conservation value. Current water distribution and retention patterns must therefore be maintained.	Alteration of water distribution & retention patterns within the wetland
			Habitat	Geomorphology	Peat is susceptible to desiccation and erosion. No further impacts to wetland geomorphology should therefore be permitted to ensure that the integrity of the peatland is not compromised.	Geomorphic impacts: Erosional features
				Wetland vegetation	Wetland vegetation provides habitat which is critical to wetland-dependant biota including threatened bird species. Maintenance of vegetation is therefore required to maintain existing conservation values.	Wetland vegetation

IUA	RU	Wetland	Component	Sub-component	Rationale for sub-component choice	Indicator selection
	RU58	6.3 Draaikraal wetland 1	Quantity	Water inputs	Maintenance of water inputs is critical for peat formation and to prevent oxidation. Any increase in stream flow reduction or abstraction activities could threaten the integrity of these areas. Current water inputs must therefore be maintained.	Water input
				Water distribution and retention patterns	Any drainage or erosion would undermine the wetlands conservation value. Current water distribution and retention patterns must therefore be maintained.	Alteration of water distribution & retention patterns within the wetland
			Habitat	Wetland vegetation	Wetland vegetation provides habitat which is critical to wetland-dependant biota including threatened bird species. Maintenance of vegetation is therefore required to maintain existing conservation values.	Wetland vegetation
	RU59	6.4 Draaikraal wetland 2	Quantity	Water inputs	Maintenance of water inputs is critical for peat formation and to prevent oxidation. Any increase in stream flow reduction or abstraction activities could threaten the integrity of these areas. Current water inputs must therefore be maintained to maintain this important peatland system.	Water input
				Water distribution and retention patterns	Any drainage or erosion would undermine the wetlands conservation value. Current water distribution and retention patterns must therefore be maintained.	Alteration of water distribution & retention patterns within the wetland
			Habitat	Geomorphology	Peat is susceptible to desiccation and erosion. No further impacts to wetland geomorphology should therefore be permitted to ensure that the integrity of the peatland is not compromised.	Geomorphic impacts: Erosional features

IUA	RU	Wetland	Component	Sub-component	Rationale for sub-component choice	Indicator selection
				Wetland vegetation	Wetland vegetation provides habitat which is critical to wetland-dependant biota including threatened bird species. Maintenance of vegetation is therefore required to maintain existing conservation values.	Wetland vegetation
	RU59	6.5 Draaikraal wetland 3	Quantity	Water distribution and retention patterns	Water distribution & retention patterns are important in ensuring that peatland areas remain saturated and that appropriate foraging and breeding habitat is available for biota including threatened crane species. Maintenance of water distribution & retention patterns is therefore required to ensure that the existing peatland areas and habitat for crane species is not undermined	Alteration of water distribution & retention patterns within the wetland
			Habitat	Wetland vegetation	Wetland vegetation provides the basic habitat template on which wetland-dependant biota including threatened crane species depend. Maintenance of vegetation characteristics is required to ensure that habitat is retained for cranes and other wetland-dependant biota.	Wetland vegetation
	RU54	6.6 Belfast wetland 1	Quantity	Water distribution and retention patterns	Maintenance of diffuse flows is essential in order to maintain the water quality enhancement functions of this wetland. Maintenance of diffuse flow patterns (already improved through rehabilitation efforts) is therefore required to ensure that water quality enhancement functions are not undermined.	Alteration of water distribution & retention patterns within the wetland
			Habitat	Wetland vegetation	Water quality enhancement functioning is dependent on good vegetation cover. Maintenance of wetland vegetation is therefore required to ensure that water quality enhancement functions provided by this wetland are not undermined.	Wetland vegetation

IUA	RU	Wetland	Component	Sub-component	Rationale for sub-component choice	Indicator selection
	RU54	6.7 Belfast wetland 1	Quantity	Water distribution and retention patterns	Diffuse flows provide optimal conditions for water quality enhancement. Maintenance of flow patterns is therefore required to ensure that there is not a reduction in the capacity of the wetland to provide this service.	Alteration of water distribution & retention patterns within the wetland
			Habitat	Wetland vegetation	Assimilation of nutrients and other contaminants from the upstream waste water treatment works and mining activities requires good vegetation cover. Maintenance of wetland vegetation is therefore required to ensure that existing water quality enhancement functions are not undermined.	Wetland vegetation
IUA	**RU**	**Wetland**	**Component**	**Sub-component**	**Rationale for sub-component choice**	**Indicator selection**
9	RU83	9.1 Krankloofspruit tributary	Quantity	Water distribution and retention patterns	Diffuse water distribution is required to optimise water quality enhancement functions. Maintenance of water distribution & retention patterns is therefore required to ensure that water quality enhancement functions provided by this wetland are not further undermined	Alteration of water distribution & retention patterns within the wetland
			Habitat	Wetland vegetation	Wetland vegetation plays a key role in improving water quality. Maintenance of wetland vegetation is therefore required to ensure that water quality enhancement functions are not further undermined.	Wetland vegetation
	RU85	9.2 Ohrigstad wetland	Quantity	Water distribution and retention patterns	Diffuse water distribution is required to optimise water quality enhancement functions. Maintenance of water distribution & retention patterns is therefore required to ensure that water quality enhancement functions provided by this wetland are not further undermined.	Alteration of water distribution & retention patterns within the wetland

IUA	RU	Wetland	Component	Sub-component	Rationale for sub-component choice	Indicator selection
			Habitat	Wetland vegetation	Wetland vegetation plays a key role in improving water quality. Maintenance of wetland vegetation is therefore required to ensure that water quality enhancement functions provided by this wetland are not further undermined.	Wetland vegetation
IUA	**RU**	**Wetland**	**Component**	**Sub-component**	**Rationale for sub-component choice**	**Indicator selection**
13	RU120	13.1 Treur wetland	Quantity	Water inputs	Maintaining water inputs are critical to prevent oxidation of peatland systems. Any further expansion in SFR activities would serve to exaggerate impacts on this important wetland system and must be avoided.	Water input
			Habitat	Wetland vegetation	Vegetation condition provides a useful surrogate measure for habitat value. Maintenance of wetland vegetation is therefore required to ensure that biodiversity values are retained	Wetland vegetation
			Biota	Fish	This is an important peatland system. The associated river supports the endemic Treur River Barb (*Barbus treurensis*) which has an extremely limited distribution. The wetland and associated biota are threatened by existing forestry & proposed future mining activities.	FRAI with special reference to Treur River barb (*Barbus treurensis*)

4.3 DAM COMPONENT

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

- Dam sub-component and indicator selection for IUA1 presented in Table 19
- Dam sub-component and indicator selection for IUA2 presented in Table 20
- Dam sub-component and indicator selection for IUA3 presented in Table 21
- Dam sub-component and indicator selection for IUA4 presented in Table 22
- Dam sub-component and indicator selection for IUA5 presented in Table 23
- Dam sub-component and indicator selection for IUA6 presented in Table 24
- Dam sub-component and indicator selection for IUA8 presented in Table 25
- Dam sub-component and indicator selection for IUA9 presented in Table 26
- Dam sub-component and indicator selection for IUA10 presented in Table 27
- Dam sub-component and indicator selection for IUA11 presented in Table 28
- Dam sub-component and indicator selection for IUA11 presented in Table 29

NOTE: A high flow requirement for the protection of the downstream ecosystem was selected for most of the priority dams during the selection of indicators. However, due to a decision taken by DWA during the development of the Reconciliation Strategy for the Olifants river, no high flow releases from dams in order to provide for the EWR were allowed during the determination of the management classes (MC) for the various catchments. The following dams required high flow releases from an ecological and user perspective, but high flow releases were eventually only included in the development of RQOs for Loskop Dam.

- Witbank Dam
- Middelburg Dam
- Wilge Dam
- Loskop Dam
- Mkhombo Dam
- Flag Boshielo Dam

Table 19: Dam sub-component and indicator selection for IUA1: Olifants Water Management Area

IUA	RU	Dam Name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
1	RU9	Witbank Dam	Quantity	Low Flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users.	EWR
			Quality	Nutrients	The system must be maintained in a mesotrophic state to avoid cyanobacterial blooms and the associated algal toxins.	Phosphates
				Salts	Salt concentrations must be maintained at levels where they allow for a sustainable ecosystem in the dam and downstream and do not compromise users.	Sulphates, Electrical conductivity
				System variables	The pH in the dam must be improved and maintained at levels where it does not compromise the ecosystem or users.	pH
				Toxins	The system must be maintained in a mesotrophic state to avoid cyanobacterial blooms and the associated algal toxins. Metal concentrations in the dam must be maintained at levels which allow for a sustainable ecosystem.	Toxins
			Biota	Fish	The wellbeing of the fish community of this artificial ecosystem must be maintained in a suitable condition to contribute to regional biodiversity 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).
		Doornpoort Dam	Quantity	Low Flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users.	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 to avoid cyanobacterial blooms and the associated algal toxins.	TIN
				Salts	Salt concentrations must be maintained at levels where they allow for a sustainable ecosystem in the dam and downstream and do not compromise users.	Sulphates, Electrical conductivity
			Habitat	System variables	The pH in the dam must be improved and maintained at levels where it does not compromise the ecosystem or users.	pH
				Toxins	The system must be maintained in a mesotrophic state to avoid cyanobacterial blooms and the associated algal toxins. Metal concentrations in the dam must be maintained at levels which allow for a sustainable ecosystem.	Toxins
	RU18	Middleburg Dam	Quantity	Low Flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users.	EWR
			Quality	Nutrients	The system must be maintained in a mesotrophic state to avoid cyanobacterial blooms and the associated algal toxins.	Chl-a: phytoplankton
				Salts	Salt concentrations must be maintained at levels where they allow for a sustainable ecosystem in the dam and downstream and do not compromise users.	Sulphates, Electrical conductivity
				System variables	The pH in the dam must be improved and maintained at levels where it does not compromise the ecosystem or users.	pH

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 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).

Table 20: Dam sub-component and indicator selection for IUA2: Olifants Water Management Area

IUA	RU	Dam Name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
2	RU23	Bronkhorstspruit Dam	Quantity	Low Flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users.	EWR
			Quality	Nutrients	Nutrient concentrations in the dam must be maintained at mesotrophic levels.	Phosphates, TIN, 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 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).
	RU26	Wilge Dam	Quantity	Low flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users.	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 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).

Table 21: Dam sub-component and indicator selection for IUA3: Olifants Water Management Area

IUA	RU	Dam Name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
3	RU37	Loskop dam	Quantity	Low flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users. Freshets are important for the downstream ecosystem and should be released.	EWR
			Quality	Nutrients	The dam must be maintained in a mesotrophic state to avoid cyanobacterial blooms and the associated algal toxins.	Phosphates, TIN, Chl-a: phytoplankton
				Salts	Salt concentrations must be maintained at levels where they allow for a sustainable ecosystem in the dam and downstream and do not compromise users.	Sulphates, Electrical conductivity *
				Toxins	Toxicity of metals must be maintained at concentrations that would not pose a threat to human or ecosystem health. The dam must be maintained in a mesotrophic state to avoid cyanobacterial blooms and the associated algal toxins.	Toxins
			Biota	Fish	The wellbeing of the fish community of this artificial ecosystem must be maintained in a suitable condition to contribute to regional biodiversity 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).
	RU38	Roodepoort Dam	Quantity	Low flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users.	EWR

Table 22: Dam sub-component and indicator selection for IUA4: Olifants Water Management Area

IUA	RU	Dam Name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
4	RU41	Rust De Winter Dam	Quantity	Low flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users.	EWR
			Quality	Nutrients	Nutrients must be maintained at mesotrophic levels.	Phosphates, TIN, 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 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).
	RU45	Mkhombo Dam	Quantity	Low flows	Release pattern is important and should be based on the natural flow pattern to ensure the protection of ecosystem function downstream.	EWR
			Quality	System variables	The pH in the dam must be improved and maintained at levels where it does not compromise the ecosystem or users.	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 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).

Table 23: Dam sub-component and indicator selection for IUA5: Olifants Water Management Area

IUA	RU	Dam Name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
5	RU48	Rooikraal Dam	Quantity	Low flows	Releases of drought requirements is at least required to maintain ecosystem function downstream.	EWR
	RU52	Flag Boshielo Dam	Quantity	Low flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users.	EWR
			Quality	Nutrients	Nutrients must be maintained at mesotrophic levels.	Phosphates, TIN, Chl-a: phytoplankton
				Salts	Salt concentrations must be maintained at levels where they allow for a sustainable ecosystem in the dam and downstream and do not compromise users.	Sulphates, Electrical conductivity *
			Biota	Fish	The wellbeing of the fish community of this artificial ecosystem must be maintained in a suitable condition to contribute to regional biodiversity 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).

Table 24: Dam sub-component and indicator selection for IUA6: Olifants Water Management Area

IUA	RU	Dam Name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
6	RU54	Belfast Dam	Quantity	Low flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users.	EWR
	RU56	Tonteldoos Dam	Quantity	Low flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users.	EWR
			Quality	Nutrients	Nutrient concentrations must be maintained such that the system is in a mesotrophic state or better.	Phosphates, TIN, Chl-a: phytoplankton
	RU56	Vlugkraal Dam	Quantity	Low flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users.	EWR
	RU62	Der Bruchen Dam	Quantity	Low flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users.	EWR
	RU64	De Hoop Dam	Quantity	Low flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users.	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 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).

Table 25: Dam sub-component and indicator selection for IUA8: Olifants Water Management Area

IUA	RU	Dam Name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
8	RU74	Lydenburg Dam	Quantity	Low flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users.	EWR
	RU79	Buffelskloof Dam	Quantity	Low flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users.	EWR
			Quality	Nutrients	Nutrients must be maintained at mesotrophic levels so as to retain the recreational value of the dam.	Phosphates, TIN, Chl-a: phytoplankton
				Salts	Salt concentrations must be maintained at levels where they allow for a sustainable ecosystem in the dam and downstream and do not compromise users.	Sulphates, Electrical conductivity *

Table 26: Dam sub-component and indicator selection for IUA9: Olifants Water Management Area

IUA	RU	Dam Name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
9	RU83	Ohrigstad Dam	Quantity	Low flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users.	EWR
			Quality	Nutrients	Nutrients must be maintained at mesotrophic levels so as to avoid eutrophication.	Phosphates, TIN
			Biota	Fish	The wellbeing of the fish community of this artificial ecosystem must be maintained in a suitable condition to contribute to regional biodiversity 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).

Table 27: Dam sub-component and indicator selection for IUA10: Olifants Water Management Area

IUA	RU	Dam Name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
10	RU88	Blyderivierpoort Dam	Quantity	Low flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users.	EWR

Table 28: Dam sub-component and indicator selection for IUA11: Olifants Water Management Area

IUA	RU	Dam Name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
11	RU99	Tours Dam	Quantity	Low flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users.	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 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).

Table 29: Dam sub-component and indicator selection for IUA12: Olifants Water Management Area

IUA	RU	Dam Name	Component	Sub-component	Rationale for sub-component choice	Indicator selection
12	RU106	Klaserie Dam	Quantity	Low flows	The dam must be managed to provide sufficient releases for the protection of ecosystem function downstream as well as for other users.	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 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).
	RU114	Phalaborwa Barrage	Quantity	Low flows	Releases from the weir are important to maintain and protect the ecosystem function downstream, especially in the KNP.	EWR

4.4 GROUNDWATER COMPONENT

Complexities in Site Types

Having considered the measurable parameters as listed in Table 4, some complexities were identified and can be summarised as follows (Table 30):

Table 30: 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 detailed 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 measurement 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.

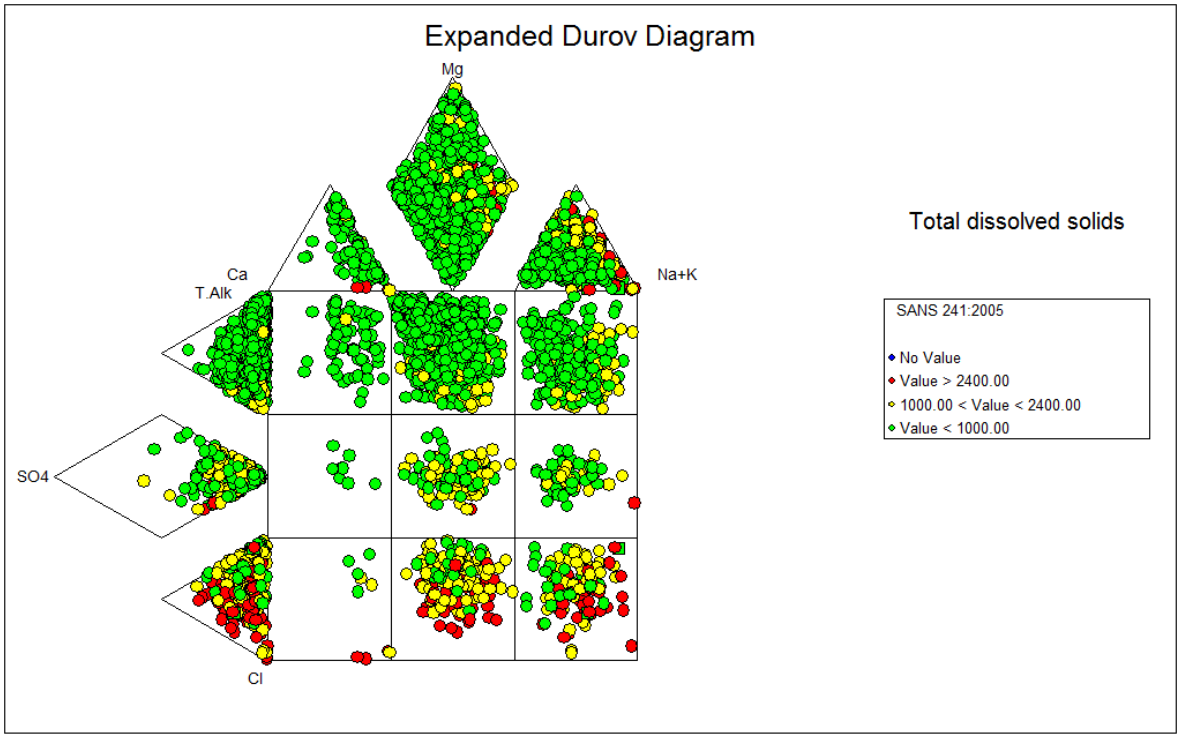

Figure 2: Expanded Durov diagram of available quality data

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 infringement, 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 on 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.

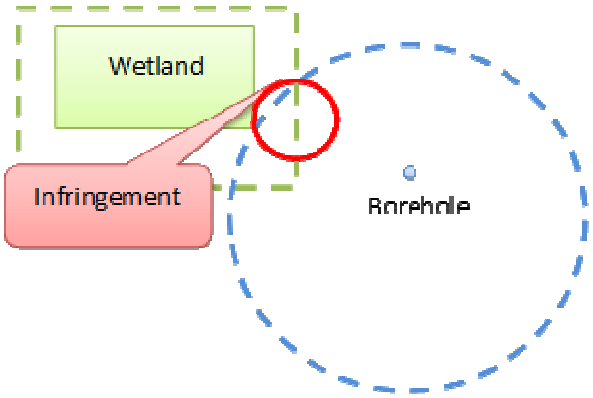

Figure 3: Graphical representation of an infringement area where the influence radius associated with use of a groundwater ecosystem is potentially impacting on a wetland ecosystem.

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 (see Figure 4) 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.

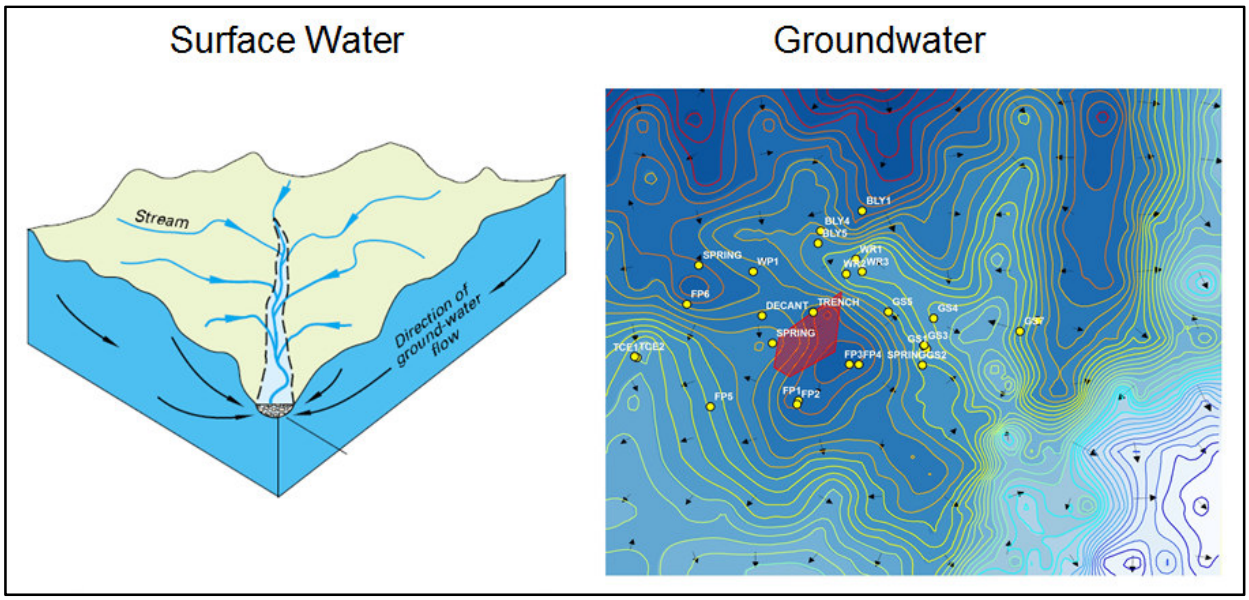

Figure 4: Surface water catchment flow dynamics and groundwater flow dynamics.

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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