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

WP10533

RESOURCE QUALITY OBJECTIVES AND NUMERICAL LIMITS REPORT

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

Resource Quality Objectives and Numerical Limits Report

Executive Summary

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

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

Components of steps 1 and 2 were available from the WRC study to which this RQO determination process was aligned. This report documents the RQOs and associated NLs which give effect to the RQOs for the Upper Vaal Water Management Area. In addition the supplementary information for these RQOs and NLs are provided (Step 5 and 6). The components and sub-components for which RQOs and NLs were provided include:

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

Through this step a total of 354 RQOs were determined for the Upper Vaal WMA:

- A total of 137 RQOs were determined for river resources.
- A total of 60 RQOs were determined for wetlands resources.
- A total of 62 RQOs were determined for dam resources.
- A total of 95 RQOs were determined for groundwater resources.

Table 1 provides a summary of the hydrological nodes, river names and their associated Present Ecological State (PES) and Recommended Ecological Category (REC) within each IUA as well as the management class for the IUA.

Table 2 provides a summary of all the sub-components for which RQOs and NLs were determined for each IUA.

Table 1: Summary of the Integrated Units of Analyses, Management Classes, Hydrological nodes (and Resource Unit (RU) numbers), river names and the associated Present Ecological State (PES) and Recommended Ecological Categories (RECs).

IUA Name	Class for IUA	RU	Hydro Node	River Name	PES	REC
UA. Vaal River upstream of Grootdraai Dam	**II**	1	UA.1	Vaal	B/C	B
		2	UA.2	Vaal	C	C
		3	EWR1RE	Vaal	C	C
		4	UA.3	Rietspruit	C	C
		5	UA.4	Vaal	C	C
		6	UA.5	Vaal	C/D	C/D
		7	UA.6	Vaal	C/D	C/D
		8	EWR1	Vaal	B/C (B)	B/C (B)
		9	UA.7	Vaal	C/D	C/D
		10	UA.8	Vaal	B/C	B/C
		11	UA.9	Vaal	C	C
UB. Klip River (Free State)	**II**	12	UB.1	Vaal	B	B
		13	UB.2	Vaal	B/C	B
		14	UB.3	Vaal	B/C	B
		15	EWR6	Vaal	B/C	B/C
		16	UB.4	Klip	C	C
		17	UB.5	Klip	C	C
		18	UB.6	Klip	B/C	B
		19	UB.7	Vaal	C/D	C/D
		20	UB.8	Klip	C	C
		21	UB.9	Vaal	C/D	C/D
UC1. Upper Wilge River	**II**	22	EWR7	Vaal	A/B	A/B
		23	UC1.1	Vaal	B	B
		24	UC1.2	Vaal	C	C
		25	UC1.3	Wilge	B	B
		26	UC1.4	Wilge	C	C
		27	UC1.5	Wilge	C	C
		28	UC1.6	Wilge	C	C
UC2. Wilge River and tributaries	**II**	29	UC2.1	Vaal	C/D	C/D
		30	UC2.2	Elands	C	C
		31	UC2.3		B	B
		32	UC2.4	Wilge	C	C
		33	UC2.5	Nuwejaarspruit	B/C	B/C
		34	UC2.6	Wilge	C	C
		35	EWR8	Vaal	C	C
		36	UC2.7	Wilge	C	C
UC3. Lower Wilge River	**II**	37	UC3.1	Wilge	C	C
		38	UC3.2	Wilge	B/C	B/C
		39	UC3.3	Wilge	C	C
		40	UC3.4	Vaal	C/D	C/D
UD. Liebenbergsvlei River	**III**	41	UD.1	Liebenbergsvlei	C	C
		42	UD.2	Liebenbergsvlei	C	C
		43	UD.3	Liebenbergsvlei	C	C
		44	UD.4	Liebenbergsvlei	B/C	B
		45	UD.5	Liebenbergsvlei	B/C	B
UE. Waterval River	**III**	46	UE.1	Vaal	C	C
		47	UE.2	Vaal	D	D
		48	UE.3	Waterval	C	C
		49	UE.4	Vaal	D	D
		50	UE.5	Vaal	D	D

IUA Name	Class for IUA	RU	Hydro Node	River Name	PES	REC
UF. Kromspruit and Skulpspruit	II	51	UF.1	Wilge	C	C
		52	UF.2	Vaal	C	C
UG. Vaal River from Grootdraai Dam to Vaal Dam	II	53	EWR2	Vaal	C	C
		54	UG.1	Vaal	C	C
		55	UG.2	Vaal	C	C
		56	EWR3	Vaal	C	C
		57	UG.3	Vaal	C	C
		58	UG.4	Vaal	C	C
UH. Suikerbosrand River	II	59	UH.1	Vaal	B/C	B
		60	EWR9	Vaal	C	B/C
		61	EWR10	Vaal	C/D	C/D
		62	EWR11	Suikerbosrand	D	D
UI. Klip River (Gauteng)	III	63	UI.1	Klip River	E	D
		64	UI.2	Vaal	E	D
		65	UI.3	Vaal	E	D
		66	UI.4	Vaal	D/E	D
UJ. Taaibosspruit	III	67	UJ.1	Vaal	D	D
UK. Kromelmboogspruit	III	68	UK.1	Vaal	C	C
UL. Mooi River	III	69	UL.1	Vaal	C/D	C/D
		70	EWR2RE	Vaal	D	D
		71	UL.2	Mooi	E	D
		72	UL.3	Mooi	E	D
		73	UL.4	Vaal	D	D
		74	EWR4	Vaal	C	B/C
UM. Vaal River reach from Vaal Dam to C23L	III	75	EWR5	Vaal	C/D	C

Table 2: Integrated Units of Analyses (IUAs) for which Resource Quality Objectives (RQOs).

IUA	RIVERS				WETLANDS	DAMS				GROUND WATER
	Quantity	Quality	Habitat	Biota		Quantity	Quality	Habitat	Biota	
UA. Vaal River upstream of Grootdraai Dam	X	X	X	X	X	X		X	X	X
UB. Klip River (Free State)	X	X	X	X	X	X				X
UC1. Upper Wilge River			X	X	X	X				X
UC2. Wilge River and tributaries	X	X	X	X	X	X		X	X	X
UC3. Lower Wilge River	X	X	X		X					X
UD. Liebenbergsvlei River	X		X		X	X				X
UE. Waterval River	X	X	X	X	X					X
UF. Kromspruit and Skulpspruit	X		X	X	X					X
UG. Vaal River from Grootdraai Dam to Vaal Dam	X	X	X	X	X					X
UH. Suikerbosrand River	X	X	X	X	X	X				X
UI. Klip River (Gauteng)	X	X	X	X	X					X
UJ. Taaibosspruit		X	X		X					X
UK. Kromelmboogspruit			X	X	X					X
UL. Mooi River		X	X	X	X	X		X	X	X
UM. Vaal River reach from Vaal Dam to C23L	X	X	X	X	X	X		X	X	X

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Resource Quality Objectives and Numerical Limits 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 Upper Vaal Water Management Area (WMA8) - WP10533

Resource Quality Objectives and Numerical Limits Report

1 INTRODUCTION

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

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

This section of the RQO determination procedure includes the development of the RQOs and associated NLs (Step 5 and 6; DWA, 2011).

Step 5 in the study included the development of the draft RQOs and NLs for the sub-components and indicators that were selected during Step 4. The RQOs are essentially narrative but sometimes broadly quantitative descriptions of the resource and include the requirements necessary for achieving the objectives. Step 6 follows on Step 5 where the outcomes from Steps 3, 4 and 5 are presented to stakeholders in a workshop process. The aim of this step is to verify and refine:

- The prioritisation of Resource Units for RQO determination.
- The selection of sub-components and indicators for RQOs, and the proposed direction of change for these.
- The Draft RQOs and Numerical Limits.

The final RQOs and NLs are then published by way of government notice in the government gazette Step 7.

2 SCOPE OF THE STUDY

The study entails the determination of Resource Quality Objectives (RQOs) for all significant water resources (rivers, wetlands, dams (or lakes) and groundwater ecosystems) in the Upper Vaal Water Management Area (WMA). The RQO determination procedure established by DWA (2011) has been implemented to determine RQOs in this case study. The RQO determination procedure is based on a seven step framework including (DWA, 2011; Figure 1):

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

In 2013 the Department of Water Affairs completed the Water Resource Classification (WRC) study for the Upper Vaal WMA which included the delineation IUAs and established a vision for the catchment and key elements for the IUAs (DWA, 2013). This resulted in the determination of Management Classes for each IUA and Recommended Ecological Categories for biophysical nodes selected to represent the riverine ecosystem in the WMA. These outcomes met the IUA delineation requirements for the study and provided the vision information, including Management Classes for the study. As such this study did not 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 for the development of the RQOs and NLs as set out in Step 5 and 6 of the RQO determination procedure (DWA, 2011).

3 METHODOLOGY

3.1 RESOURCE QUALITY OBJECTIVES METHODOLOGY OVERVIEW

The RQO determination procedure established by DWA (2011) has been implemented in the study. This includes the implementation of a seven step procedural framework (Figure 1), that is repeatable and as such forms allows for an adaptive management cycle with additional steps. Overall the procedure involves defining the resource, setting a vision, determination of RQOs and NLs, gazetting this and then moving to implementation, monitoring and review before starting the process all over again. A summary of the procedural steps established for this case study with some adaptations that were required to include groundwater, dams and wetland resources includes (Figure 1):

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

  The RU delineation procedure initially involved the identification of sub-quaternary reaches of rivers in the WMA for each biophysical node obtained from the WRC study (DWA, 2013; DWA, 2013). The RU delineation process then involved amalgamating the upstream associated sub-quaternary reaches of riverine ecosystems, and their associated catchment areas, for secondary catchments in South Africa to the identified sub-quaternary reaches (DWS, 2013). As a result, the number of RUs selected for the study is identical to and aligned to the information associated with the biophysical nodes from the WRC study. The delineation procedure for ecosystem scale resource assessment involved the use of Geographical Information System (GIS) spatial ecosystem data. Refer to the delineation report (Step 1) for more information (DWA, 2013a).
- **Step 2. Establish a vision for the catchment and key elements for the IUAs:** The stakeholder requirements and their associated outcomes which include the Management Classes for IUAs and RECs for RUs from the WRC study were adopted as the vision for this study (DWA, 2013). No further visioning process was appropriate as this could have conflicted with the WRC process. The WRC outcomes were skewed towards river resources in the WMA which necessitated obtaining additional information for the other resources considered in the study (wetlands, dams and groundwater ecosystems). This additional information is highlighted in the reports where applicable.
- **Step 3. Prioritise and select RUs and ecosystems for RQO determination:** This step involved the use of existing ecosystem (EcoSpecs) and user information (UserSpecs) from the Upper Vaal Reserve and WRC studies (DWA, 2013). 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 case study. Wetland ecosystem prioritisation involved the implementation of a new GIS based prioritisation approach developed for this case study and dam ecosystem prioritisation was based on a desktop assessment of available user- and eco-spec information. During this step in the study RU and ecosystem prioritisation stakeholder participation workshops were carried out during which available information was discussed and amended according to available local information of the protection and use requirements for the WMA. During these RU and ecosystem prioritisation stakeholder participation workshops consensus was reached to select the final lists of prioritised RUs and ecosystems for the RQO determination process. Please consider the RUs and ecosystem prioritisation report for more information (DWA, 2013b).
- **Step 4. Prioritise sub-components for RQO determination, select indicators for monitoring and propose the direction of change:** This step included the hosting of a range of specialist workshops for rivers, dams and groundwater resources where RU Evaluation Tools were used to select sub-

components for RQO determination, select indicators and propose the direction of change. The RU Evaluation Tools used in this section for wetlands, dams and groundwater were developed for this study. This information could then be used to develop draft RQOs and Numerical Limits in the next step. . Please consider the sub-component and indicator selection report for more information (DWA, 2014).

- **Step 5. Develop draft RQOs and Numerical Limits**: This step, which is presented in greater detail in the methodology of this report, is based on the outcomes of the RU and ecosystem prioritisation step (Step 4). From the outcomes of the RU and ecosystem prioritisation step draft RQO were established and then provided to recognised specialists to establish NLs that are generally quantitative descriptors of the different components of the resource such as the water quantity, quality, habitat and biota. These descriptors were designed to give a quantitative measure of the RQOs (DWA, 2011). Although the NLs may have some uncertainty associated with them and were not originally intended for gazetting (DWA, 2011) the will be considered for gazetting in this case study at the request of the Department of Water and Sanitation (DWS) legal services.
- **Step 6. Agree Resource Units, RQOs and Numerical Limits with stakeholders:** This component of the RQO determination process is carried out by the regulators of the WMA, assisted by the project team, and includes the consideration of RQO and NL outcomes with stakeholders, prior to the initiation of the gazetting process.
- **Step 7. Finalise and Gazette RQOs:** This component of the RQO determination process is carried out by the regulators of the WMA assisted by the project team, and includes the development of gazette RQO and NL drafts for submission to legal services of the Department of Water and Sanitation for gazetting.

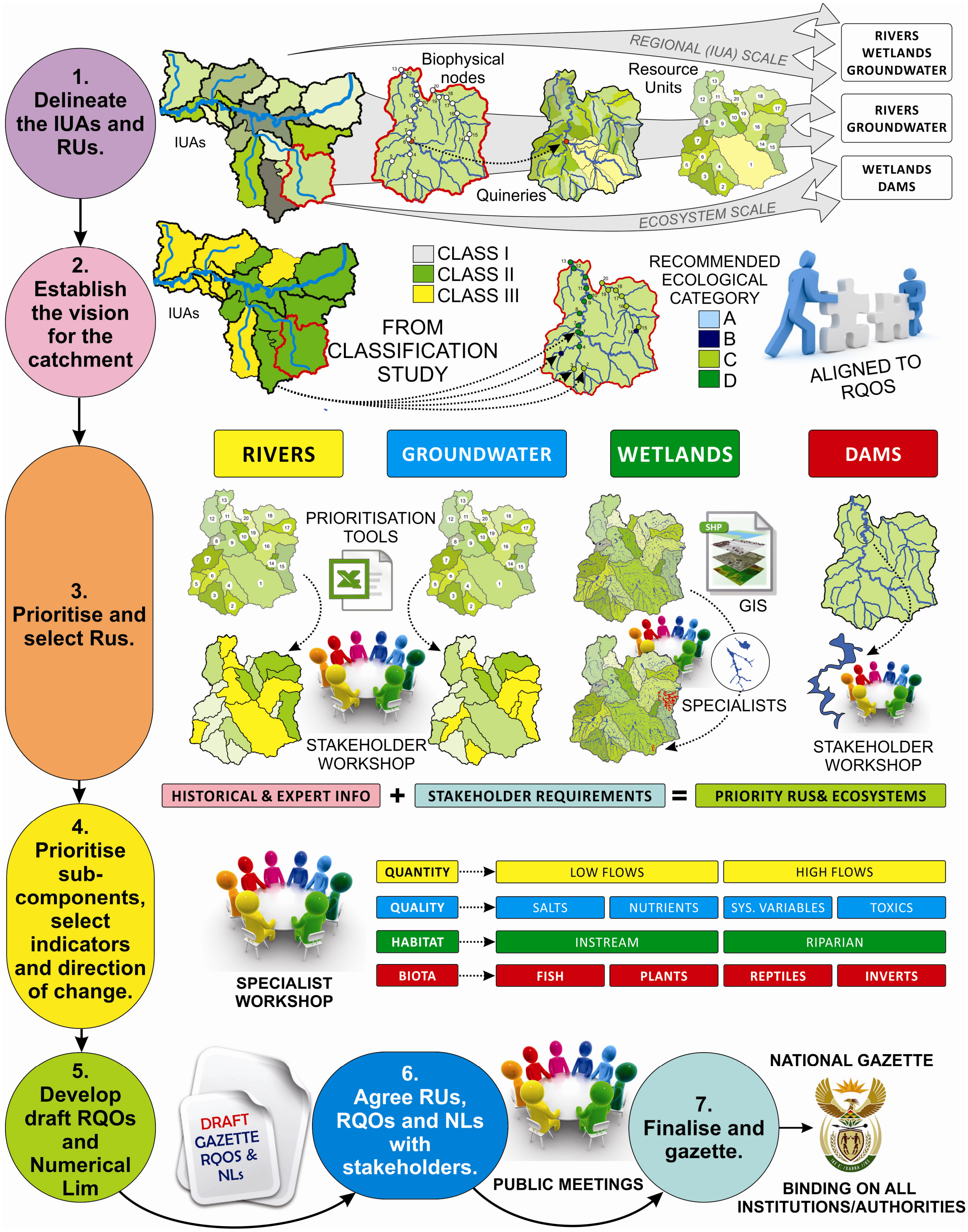

Figure 1: Schematic summary of the RQO determination procedure (adapted from DWA, 2011) which was implemented in this study.

3.2 RESOURCE QUALITY OBJECTIVES AND NUMERICAL LIMITS OVERVIEW AND GAPS

As indicated, following the completion of the sub-component and indicator information phase (Step 4) for all resources considered in the study, the outcomes of the application of the Resource Unit Evaluation Tool (RUET) include a list of sub-components and indicators selected for RQOs and their associated 'EcoSpec', 'UserSpec' or 'Integrated measure' associations which is used for RQO development (Step 5). Following the selection of RQOs, NLs which are generally quantitative descriptors of the different components/sub-components of the resource such as the water quantity, quality, habitat and biota were established. These descriptors were designed to give a quantitative measure of the RQOs and are associated with some uncertainties (DWA, 2011). The RQOs and NLs were established after consideration of the following:

- Available data to evaluate the present state for selected sub-components and indicators for RQO determination.
- Suitability of the data available for RQO and NL selection.
- Determine the level at which to set RQOs
  - Carry over the proposed direction of change from the RUET.
  - Consider the requirements defined by the WRC.
  - Review the stakeholder aspirations and translate into Numerical Limits.

Available data to evaluate the present state for selected sub-components and indicators for RQO determination: Available data which may assist in determining the present state of selected sub-components/indicators has been reviewed prior to RQO determination. This information has been used to determine the level at which to set RQOs, as it relates the present state of each sub-component to reference conditions. The PES of a water resource is expressed in terms of its bio-physical components including:

- Drivers (Physico-chemical, geomorphology, hydrology, instream and riparian habitat) which provide a particular physical habitat template.
- Biological responses (fish, riparian vegetation, aquatic invertebrates, diatoms, amphibians and reptiles for e.g.)

Where available, data has been used to contribute to the development of RQOs and associated NLs. There are however numerous examples of driver and responder components/sub-components that were selected for RQO determination for which no present ecological state and on occasion indicator information is available. This may have occurred for example where an uncommon indicator such as birds and selected as sub-component for the riparian habitat (components) for the study for which no information is available. For these occasions a specialist with local knowledge was commissioned to assess available literature, proposed indicators (if unavailable) and select NLs (Refer to the appendix).

Assess the suitability of the data: In addition, the suitability of available data for sub-components and indicators was considered in the study. Where suitable, the data was used to determine the present state of the selected indicators and select RQOs. Alternatively; specialists with local knowledge were commissioned to carry out desktop evaluations of available information to select PES'. Data suitability considerations incorporated in the study according to DWA (2011) included:

- The age of the data
- The techniques and methods used
- The format of data
- The season in which it was collected
- Whether the data has been extrapolated

To determine the level at which to set RQOs were to be set, the proposed direction of change from the RUET was considered as well as the requirements defined by the WRC for the component so that the outcomes could be synchronised with the WRC. And finally, consideration of the stakeholder aspirations to translate RQO endpoints into NLs was made. The following process was followed:

- Carry over the proposed direction of change from the Resource Unit Evaluation Tool: Step 4 of the RQO process entailed proposing the most appropriate and feasible direction and magnitude of change for each of the selected sub-components. This information should be carried forward to this sub-step as it provides an indication of the level at which to set the respective RQOs.

- Consider the requirements defined by the Water Resource Classification: The REC and MCs available from the WRC were initially considered. During this component REC would be matched with the EcoStatus from the Ecological Reserve and or any other available information.
- Review the stakeholder aspirations and translate into Numerical Limits: During Step 4, the aspirations of stakeholders for management of specific components were identified. These aspirations informed the 'proposed direction of change' for each of the components and also influenced the final selection of sub-components for RQO determination. These aspirations have also been captured, in part, in the rationales for selecting a particular sub-component.

Set appropriate draft RQOs and Numerical Limits in line with the draft RQOs

The established RQOs included contextual information to reflect the direction of change of a particular sub-component and/or indicator. They also included the reason for the selection of component, sub-component and/or indicator and the rationale for the level at which it has been set. This contextual information is available in the supplementary tables provided below. Numerical Limits translate the narrative RQOs into numerical values which can be monitored and assessed for compliance of RQO implementation (DWA, 2011). These NLs considered feasibility assessments undertaken by specialists with local experience in this study (refer to appendix).

3.3 PUBLIC MEETING PROCESS

The draft RQOs and NLs were presented to stakeholders of the study at a public meeting as follows (Appendix 2):

- Public meeting: 11 April 2014, Manhattan Hotel, Pretoria, Gauteng (APPENDIX).

The presentations contained two components including an introductory and background section and a breakaway group discussions section for the RQO and NL considerations. The introduction section included the presentation of the following components:

- Resource Quality Objectives within Water resource management in South Africa
- Introduction to the process of determining Resource Quality Objectives
- Determination of RQOs in the Upper Vaal Water Management Area
- Water resources considered:
- Rivers, Wetlands, Dams & Groundwater
- Components and subcomponents
- Draft RQOs and Numerical limits

The breakaway group discussions considered:

- Catchment orientation, land uses type and water resource location considerations.
- Summary RQO outcome maps for major water resources considered:
- Rivers, Wetlands, Dams & Groundwater
- Draft RQO considerations and recommendations

Stakeholders were provided with an opportunity to query draft RQOs and NLs. All comments were captured, evaluated and where appropriate changes that needed to be made were done. This resulted in some changes to various steps of the RQO determination process and draft RQO and NL outcomes. These changes have been clearly identified in the report.

4 FINDINGS

The RQOs and NLs that were determined for the Upper Vaal WMA as well as the supplementary information are presented per resource considered.

4.1 RIVER RESOURCE QUALITY OBJECTIVES AND NUMERICAL LIMITS FOR THE UPPER VAAL WMA

The outcomes of the RQO and NL determination of the sub-components and indicators for the river component of the RQO determination study for the Upper Vaal WMA, including a summary of additional supplementary information are provided as follows:

- RQOs for regional rivers in the Upper Vaal WMA are presented in Table 3.
- RQOs for the river water quantity component are presented in Table 4.
- RQOs for the river water quality component are presented in Table 5.
- RQOs for the river water habitat component are presented in Table 6.
- RQOs for the river water biota component are presented in Table 7.
- Supplementary information for the river water quantity component is presented in Table 8.
- Supplementary information for the river water quality component is presented in Table 9.
- Supplementary information for the river water habitat component is presented in Table 10.
- Supplementary information for the river water biota component is presented in Table 11.

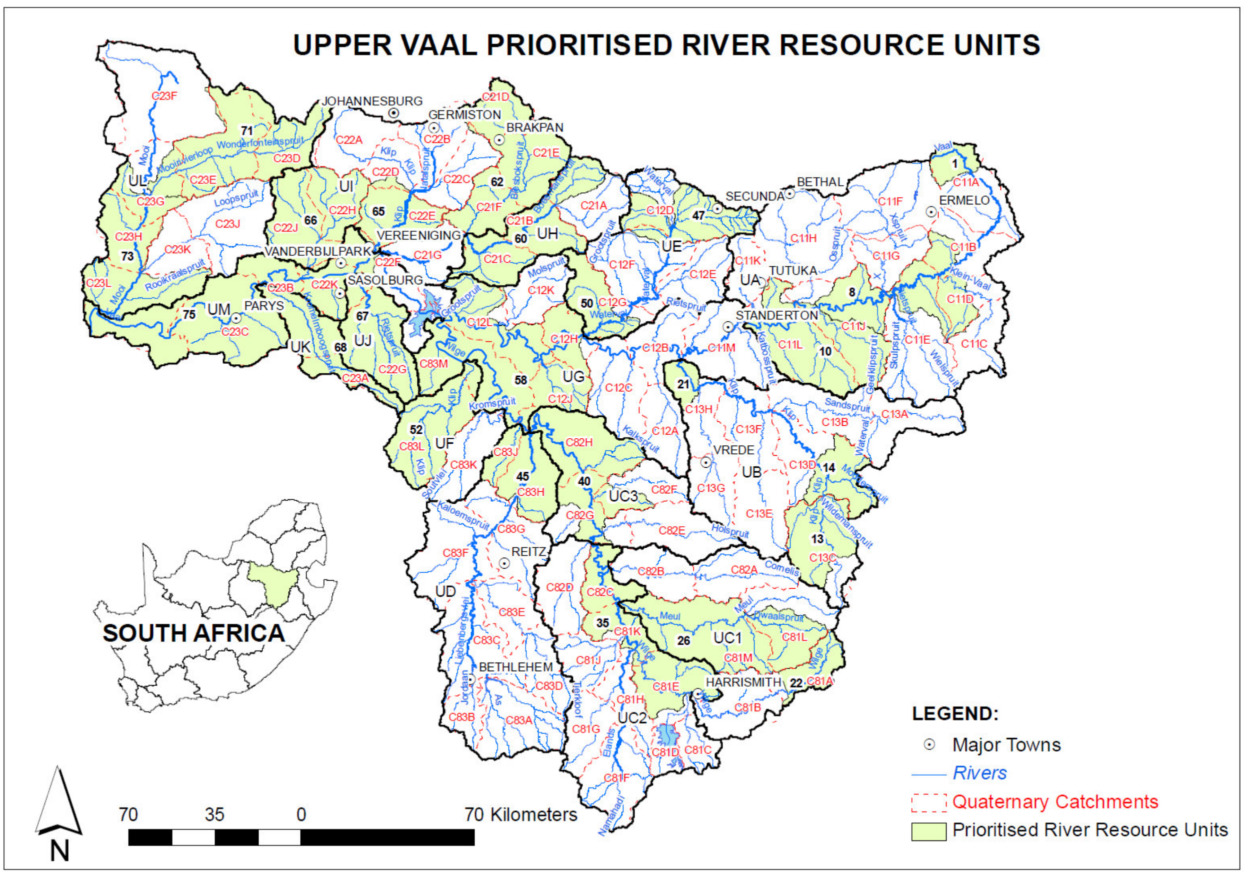

Figure 2: Map of the Integrated Units of Analysis (IUAs), priority River Resource Units (RUs), rivers and quaternary catchments.

4.1.1 RIVER RESOURCE QUALITY OBJECTIVES AND NUMERICAL LIMITS TABLES

Table 3: RQOs for REGIONAL RIVER in the Upper Vaal WMA

REGIONAL RIVERS	
IUA	**RQO**
UA	This IUA contains river reaches which are regarded as being important priority areas (NFEPA). To maintain these systems and to provide water for irrigation, it is necessary to maintain the low flows in the river at present conditions, and simultaneously to improve generally elevated nutrient concentrations to a C or better ecological category. Water quality contamination by salts and other toxins are potentially high and needs careful management to attain a D or better ecological category. The instream habitat quality is presently inadequate which results in a poor fish community, both of which need to be improved to at least a C ecological category. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health. The riparian habitat is in good condition and needs to be maintained as it is valued as an important part of the ecosystem and for riparian users. The recommended ecological category (REC) of any river reach as described in the Classification (Annexure A) must be adhered to unless superseded by the detailed Resource Quality Objectives for the RUs below.
UB	This IUA contains headwater streams which are important ecologically important (National Freshwater Ecosystem Priority Areas) and need to be maintained in current or better ecological states, part of the motivation being that particular species of important fish need to be protected. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health. In some areas low flows are insufficient and need to be improved to at least a D ecological category, as is the case with instream habitat. The riparian habitat is acceptable at its present condition and must be maintained, by controlling alien vegetation in particular. The recommended ecological category (REC) of any river reach as described in the Classification (Annexure A) must be adhered to unless superseded by the detailed Resource Quality Objectives for the RUs below.
UC1	This IUA contains headwater streams which are important ecologically important (National Freshwater Ecosystem Priority Areas) and need to be maintained in current or better ecological states. In order to maintain the required condition, the instream habitat often needs improvement to at least a D ecological category to maintain the important fish species. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health. The recommended ecological category (REC) of any river reach as described in the Classification (Annexure A) must be adhered to unless superseded by the detailed Resource Quality Objectives for the RUs below.
UC2	The headwater characteristics of the rivers in this IUA are being affected by the Sterkfontein Dam as well as by agriculture activities and urban areas. These impacts of these activities must be reduced to low risk levels by improving the ecological state of the flow, habitat and water quality in the IUA to a C or better ecological category. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health. The recommended ecological category (REC) of any river reach as described in the Classification (Annexure A) must be adhered to unless superseded by the detailed Resource Quality Objectives for the RUs below.
UC3	The IUA is dominated by the lower reaches of the Wilge River and its tributaries which been classified for moderate use. Although no validated river protection areas (FEPAs) occur in this IUA, the rivers contain unique habitats and a high diversity of ecologically important biota including fish and macroinvertebrates which must be maintained in a C or better ecological category. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health. The recommended ecological category (REC) of any river reach as described in the Classification (Annexure A) must be adhered to unless superseded by the detailed Resource Quality Objectives for the RUs below.
UD	The use of the rivers in this IUA is dominated by the water transfer from Lesotho Highlands Transfer Scheme (Phase I). Besides the quantity impacts associated with the transfer there are few other stresses in the catchment. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health. The recommended ecological category (REC) of any river reach as described in the Classification (Annexure A) must be adhered to unless superseded by the detailed Resource Quality Objectives for the RUs below.
UE	The impacts of industries and Wastewater Treatment Works are placing strain on the river resources of this IUA. Water quality needs to be improved and toxics and pathogens concentrations pose a threat to users and the ecosystem which must be reduced to a D or better ecological category. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health. The recommended ecological category (REC) of any river reach as described in the Classification (Annexure A) must be adhered to unless superseded by the detailed Resource Quality Objectives for the RUs below.
UF	This small IUA is dominated by the Klip River which flows directly into the Vaal Dam. Limited land use activities within this IUA are having a limited impact on the water quality, quantity and habitat of the Klip River, and its tributaries. The natural flow variability and acceptable water quality and habitat wellbeing of this IUA provide important recruitment services for Vaal River biota that take up refuge in the Vaal Dam and must be maintained in a D or better ecological category state. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health. The recommended ecological category (REC) of any river reach as described in the Classification (Annexure A) must be adhered to unless superseded by the detailed Resource Quality Objectives for the RUs below.
UG	This IUA provides important conduits between the Vaal Dam and the major rivers of the upper Vaal River catchment, including the upper Vaal, Wilge, Liebenburgsvlei, Waterval and Klip Rivers and accordingly needs to be maintained in good condition. The flows in particular need to be improved to support good instream habitat conditions (C or better ecological category state) and the associated fish populations in a C or better ecological category that migrate into and out of the Vaal Dam. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health. Of concern is the quality of the water from the upper Vaal and Waterval Rivers which needs to be improved to acceptable conditions and in particular the risk of toxicity of the water should be reduced to moderate or low levels (maintain D or better ecological category) to maintain the ecosystem and users. The recommended ecological category (REC) of any river reach as described in the Classification (Annexure A) must be adhered to unless superseded by the detailed Resource Quality Objectives for the RUs below.
UH	There are many stresses and user requirements for the water in this IUA. The provision of Reserve flows and the improvement of water quality is important for maintenance of the ecosystem structure

	and in particular of important protected fish species which must be maintained in a C or better ecological category. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health. The recommended ecological category (REC) of any river reach as described in the Classification (Annexure A) must be adhered to unless superseded by the detailed Resource Quality Objectives for the RUs below.
UI	The rivers in this IUA provide critical ecosystem services to the southern portion of Gauteng, South Africa's most economically important urban area. Many of the rivers in this IUA are heavily impacted and it is important that the ecosystem be maintained in an acceptable quality (D or better ecological category) so that there can be a continued supply of ecosystem services. Altered low flows conditions are of particular importance in this IUA. Elevated low flows need to be managed to be sympathetic to the ecosystem. In addition, there are numerous water quality issues that need to be managed so that wellbeing the ecosystem does not deteriorate to unacceptable conditions, below a D category. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health. The recommended ecological category (REC) of any river reach as described in the Classification (Annexure A) must be adhered to unless superseded by the detailed Resource Quality Objectives for the RUs below.
UJ	The rivers in this IUA are not ecologically sensitive and or important but may provide refuge to aquatic biota from the Vaal Barrage. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health. The rivers are potentially impacted on by the releases of partially treated industrial waste water. The recommended ecological category (REC) of any river reach as described in the Classification (Annexure A) must be adhered to unless superseded by the detailed Resource Quality Objectives for the RUs below.
UK	This small IUA is dominated by the Kromelmboogspruit which flows directly into the Vaal River below the Vaal Barrage. The limited agricultural activities within this IUA may be having a limited impact on the water quality and habitat of the river. The natural flow variability and acceptable water quality and habitat wellbeing of this IUA which must be maintained in a D or better ecological state provides important recruitment services for Vaal River biota that take up refuge in the Vaal River and cannot gain access to the Vaal River above the Vaal Barrage. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health. The recommended ecological category (REC) of any river reach as described in the Classification (Annexure A) must be adhered to unless superseded by the detailed Resource Quality Objectives for the RUs below.
UL	This IUA is currently being highly threatened by water quality impacts associated with the acid mine drainage decant into the Wonderfonteinspruit, from the western basin in Gauteng. The high impacts to water resources in this IUA that need to be managed so that the ecosystem can provide ecosystem services. Of particular concern are water quality issues where salts, system variables, toxins and nutrients are all at or have transgressed borderline levels and pose a high risk to downstream users. The water quality in this IUA must not deteriorate below a D ecological category and the consumption of fish harvested from rivers in the IUA must not pose a threat to human health. The recommended ecological category (REC) of any river reach as described in the Classification (Annexure A) must be adhered to unless superseded by the detailed Resource Quality Objectives for the RUs below.
UM	This ecologically important and sensitive part of the Vaal River is influenced by upstream releases from the Vaal Dam and Vaal Barrage and water quality impacts from upstream activities, which is negatively impacting on the quantity and quality of water in this IUA and the habitat of the river. These and other issues such as water hyacinth need to be managed so that the instream habitat continues to be suitable for users (maintain in a D or better state) and the local ecosystem including populations of the threatened Orange-Vaal largemouth yellowfish (*Labeobarbus kimberleyensis*) and the spotted-necked otter (*Lutra maculicollis*) must be maintained. The consumption of fish harvested from rivers in the IUA must not pose a threat to human health. The recommended ecological category (REC) of any river reach as described in the Classification (Annexure A) must be adhered to unless superseded by the detailed Resource Quality Objectives for the RUs below.

Table 4: RQOs for RIVER WATER QUANTITY in priority RUs in the Upper Vaal WMA

RIVER WATER QUANTITY												
IUA	**Class**	**River**	**RU**	**Node**	**REC**	**Component**	**Sub Component**	**RQO**	**Indicator/ measure**	**Numerical Limits**		
										Maintenance low flows (m^3/s) (%ile)		Drought flows (m^3/s) (%ile)
UA	II	Vaal	RU8	EWR1	B/C (B)	Quantity	Low Flows	Low flows need to be maintained in a healthy condition for the ecosystem and for users.	EWR maintenance low and drought flows: Vaal EWR1 in C11J VMAR = 332.3x$10^6 m^3$ REC=B/C category (equivalent to EcoClassification score 70-80)*	Oct	2.9 (50)	0.2 (99)
										Nov	3.7 (70)	0.22 (99)
										Dec	4 (50)	0.25 (99)
										Jan	4.3 (50)	0.26 (99)
										Feb	5.2 (50)	0.265 (99)
										Mar	3.7 (30)	0.04 (99)
										Apr	3 (40)	0.08 (99)
										May	2.6 (50)	0.03 (90)
										Jun	2.5 (50)	0.15 (99)
										Jul	2.4 (50)	0.15 (99)
										Aug	2.4 (50)	0.15 (99)

										Sep	2.6 (50)	0.16 (99)
		Vaal	RU10	UA.8	B/C	Quantity	Low Flows	Low flows need to be maintained in a healthy condition for the ecosystem and for users.	EWR maintenance low and drought flows: EWR for B/C category (equivalent to EcoClassification score 70-80), Kaalspruit in C11L	Use Desktop Reserve Model (DRM) and updated PES/EI/ES data to determine low and drought requirements. This data is not presently available.		
UB	II	Vaal	RU21	UB.9	C/D	Quantity	Low Flows	Low flows: Low flows at this site need to improve to maintain the FEPA status of this important ecosystem. Low flows to be improved to a C category.	EWR maintenance low and drought flows: EWR for C category, Klip in B13H, VMAR = 39.776x106m3	Maintenance low flows (m3/s) (%ile)		Drought flows (m3/s) (%ile)
										Oct	0.310 (40)	0.000
										Nov	0.358 (40)	0.000
										Dec	0.366 (40)	0.000
										Jan	0.401 (40)	0.000
										Feb	0.594 (40)	0.000
										Mar	0.341 (40)	0.000
										Apr	0.199 (50)	0.000
										May	0.102 (50)	0.000
										Jun	0.054 (50)	0.000
										Jul	0.077 (40)	0.000
										Aug	0.071 (50)	0.015 (99)
										Sep	0.092 (50)	0.000
UC2	II	Vaal	RU35	EWR8	C	Quantity	Low Flows	Low flows need to be maintained to support the ecosystem.	EWR maintenance low and drought flows: Wilge EWR8 in C82C, VMAR = 474.3x10^{6}m□, REC=C category*	Maintenance low flows (m□/s) (%ile)		Drought flows (m□/s) (%ile)
										Oct	0.053 (99)	0.011 (99)
										Nov	0.083 (99)	0.236 (99)
										Dec	0.97 (60)	0.274 (99)
										Jan	1.1(60)	0.316 (99)
										Feb	1.4 (60)	0.422 (99)
										Mar	1.25 (60)	0.355 (99)
										Apr	1 (60)	0.27 (99)
										May	0.65 (50)	0.06 (99)
										Jun	0.45 (50)	0.031 (99)
										Jul	0.4 (50)	0.011 (99)
										Aug	0.33 (50)	0.015 (99)
										Sep	0.4 (50)	0.118 (99)

UC3	II	Vaal	RU40	UC3.4	C/D	Quantity	Low Flows	Low flow: There is potential for the low flows in this RU to be negatively impacted by unnatural releases from Sterkfontein Dam. Low flows should be improved to a C/D category	1. EWR maintenance low and drought flows: EWR for C category, Wilge in C82H, VMAR = 591.36x106m3	Maintenance low flows (m□/s) (%ile)		Drought flows (m□/s) (%ile)	
										Oct	1.358 (70)	0.011 (99)	
										Nov	1.977 (99)	0.829 (99)	
										Dec	2.246 (99)	0.992 (99)	
										Jan	2.538 (99)	1.112 (99)	
										Feb	3.297 (99)	1.431 (99)	
										Mar	2.817 (99)	1.226 (99)	
										Apr	2.226 (80)	0.621(99)	
										May	1.606 (70)	0.060 (99)	
										Jun	1.206 (70)	0.031 (99)	
										Jul	1.042 (70)	0.007 (99)	
										Aug	0.974 (70)	0.015 (99)	
										Sep	1.102 (80)	0.321(99)	
UD	III	Liebenbergsvlei	RU45	UD.5	B	Quantity	Low Flows	Flows in this river should be capped and should reflect the flow characteristics of the region.	Dry season capping flows. Liebenbergsvlei in C83H, PES=C	To be determined using an approved approach			
UG	II	Vaal	RU58	UG.4	C	Quantity	Low Flows	Low flows need to be improved to support the ecosystem and provide for irrigation and other users.	EWR maintenance low and drought flows: Vaal in C12H, PES = B/C category (equivalent to EcoClassification score 70-80)*	Maintenance low flows (m□/s) (%ile)		Drought flows (m□/s) (%ile)	
										Oct	1.775 (60)	0.1 (99)	
										Nov	3.591 (60)	0.3 (99)	
										Dec	4.54 (60)	0.4 (99)	
										Jan	5.229 (70)	0.5 (99)	
										Feb	7.501 (70)	0.8 (99)	
										Mar	5.002 (70)	0.5 (99)	
										Apr	3.204 (60)	0.3 (99)	
										May	1.559 (60)	0.1 (99)	
										Jun	0.776 (60)	0.05 (00)	
										Jul	0.687 (60)	0.00	
										Aug	0.4 (60)	0.00	
										Sep	0.554 (60)	0.00	
UH	II	Vaal	RU60	EWR9	B/C	Quantity	Low Flows	Low flows need to be improved to support the ecosystem and provide	EWR maintenance low and high flows and drought flows: Suikerbosrant EWR9 in C21C, VMAR=31.31x10^{6}m□,	Maintenance low flows (m□/s) (%ile)		Drought flows (m□/s) (%ile)	High flows (m□/s)
										Oct	0.12 (60)	0.05 (99)	1.5 for 3 days

								for users.	REC = C category*	Nov	0.177 (60)	0.066 (99)	1.5 for 3 days
										Dec	0.147 (60)	0.06 (99)	1.5 for 3 days
										Jan	0.182 (60)	0.066 (99)	5 for 4 days
										Feb	0.231 (60)	0.079 (99)	1.5 for 3 days
										Mar	0.18 (60)	0.066 (99)	1.5 for 3 days
								High flows need to be maintained to support the ecosystem especially fish		Apr	0.16 (60)	0.064 (99)	
										May	0.143 (60)	0.059 (99)	
										Jun	0.123 (60)	0.057 (99)	
										Jul	0.08 (70)	0.05 (99)	
										Aug	0.065 (70)	0.04 (99)	
										Sep	0.075 (70)	0.04 (99)	
UI	III	Suikerbosrand	RU62	EWR11	D	Quantity	Low Flows	Low flows should be capped to protect the ecosystem.	EWR maintenance and drought flows: Blesbokspruit EWR11 in C21F, VMAR=100.69x10^{6}m^3, REC = D category*	Maintenance low flows (m^3/s) (%ile)			Drought flows (m^3/s) (%ile)
										Oct		0.034 99()	0.034
										Nov		0.3 (99)	0.3
										Dec		0.3 (99)	0.3
										Jan		0.34 (99)	0.34
										Feb		0.37 (99)	0.37
										Mar		0.34 (99)	0.34
										Apr		0.34 (99)	0.34
										May		0.32 (99)	0.32
										Jun		0.3 (99)	0.3
										Jul		0.3 (99)	0.3
										Aug		0.3 (99)	0.3
										Sep		0.3 (99)	0.3
	III	Vaal	RU65	UI.3	D			Low flows should be capped to protect the ecosystem.	Base flows in rivers (consider wetland RESERVE)	D category (equivalent to EcoClassification score >40). This data is not presently available.			
	III	Vaal	RU66	UI.4	D			Low flows must be improved to support the ecosystem.	EWR	C/D category (equivalent to EcoClassification score 50-60) (equivalent to EcoClassification score >40). This data is not presently available.			

UM	III	Vaal	RU75	EWR5	C	Quantity	High Flows	High flows in the river reach upstream of the confluence with the Mooi River need to be provided to support the ecosystem.	EWR high flows: Vaal EWR5 in C23L, MAR=2288.0x10^{6}m□, REC = C category*	Maintenance high flows (m□/s)	
										Oct	
										Nov	50 for 3 days
										Dec	50 for 3 days
										Jan	50 for 3 days
										Feb	180-260 for 3-5 days
										Mar	400-570 for 3-5 days
										Apr	
										May	
										Jun	
										Jul	
										Aug	
										Sep	

**Per Rule Table*

Table 5: RQOs for RIVER WATER QUALITY in priority RUs in the Upper Vaal WMA

RIVER WATER QUALITY											
IUA	**Class**	**River**	**RU**	**Node**	**REC**	**Component**	**Sub Component**	**RQO**	**Indicator/ measure**	**Numerical Limits**	**95th %tile**
UA	II	Vaal	RU8	EWR1	B/C (B)	Quality	Nutrients	The nutrient condition must be improved to provide for users and the ecosystem.	Phosphate(PO_4) *	≤ 0.020 mg/L P	0.121
									Nitrate (NO_3) & Nitrite (NO_2) *	≤ 0.85 mg/L N	0.858
			RU10	UA.8	B/C				Phosphate(PO_4) *	≤ 0.020 mg/L P	0.0085
									Nitrate (NO_3) & Nitrite (NO_2) *	≤ 0.85 mg/L N	0.099
UC2	II	Vaal	RU35	EWR8	C	Quality	Nutrients	The nutrient condition must be maintained to provide for users and the ecosystem.	Phosphate(PO_4) *	≤ 0.025 mg/L P	0.71
									Nitrate (NO_3) & Nitrite (NO_2) *	≤ 1.00 mg/L N	0.655
UC3	II	Vaal	RU40	UC3.4	C/D	Quality	Nutrients	The nutrient condition must be maintained to provide for users and the ecosystem.	Phosphate(PO_4) *	≤ 0.075 mg/L P	0.08
									Nitrate (NO_3) & Nitrite (NO_2) *	≤ 2.50 mg/L N	1.008
UE	III	Vaal	RU47 RU50	UE.2 UE.5	D	Quality	Nutrients	The nutrient condition must be improved to an acceptable level for the ecosystem.	Phosphate(PO_4) *	≤ 0.125 mg/L P	0.08
									Nitrate (NO_3) & Nitrite (NO_2) *	≤ 4.00 mg/L N	1.008
UH	II	Vaal	RU60	EWR9	B/C	Quality	Nutrients	The nutrient condition must be improved to an acceptable level for the ecosystem.	Phosphate(PO_4)*	≤ 0.020 mg/L P	0.6
									Nitrate (NO_3) & Nitrite (NO_2) *	≤ 0.85 mg/L N	1.62
UI	III	Suikerbosrant	RU62	EWR11	D	Quality	Nutrients	The nutrient concentrations must be improved to an acceptable mesotrophic state.	Phosphate(PO_4) *	≤ 0.125 mg/L P	0.5
									Nitrate (NO_3) & Nitrite (NO_2) *	≤ 4.00 mg/L N	1.7
				UI.3					Phosphate(PO_4) *	≤ 0.125 mg/L P	0.5

				UI.4					Nitrate (NO_3) & Nitrite (NO_2) *	≤ 4.00 mg/L N	1.7
UL	III	Mooi	RU71	UL.2	D	Quality	Nutrients	The nutrients should be improved to an acceptable state.	Phosphate(PO_4) *	≤ 0.125 mg/L P	0.4
									Nitrate (NO_3) & Nitrite (NO_2) *	≤ 4.00 mg/L N	1.94
		Vaal	RU73	UL.4				The nutrients should be improved to an acceptable state	Phosphates (RWQO limits 0.4 mg/l) *	≤ 0.125 mg/L P	1.40
UM	III	Vaal	RU75	EWR5	C	Quality	Nutrients	The nutrients should be improved to an acceptable state	Phosphate(PO_4)*	≤ 0.025 mg/L P	0.2
									Nitrate (NO_3) & Nitrite (NO_2) *	≤ 1.00 mg/L N	0.25
									Total Ammonia*	≤ 73 µg/L N	1.5
UA	II	Vaal	RU1	8VF5	B	Quality	Salts	Salt concentrations need to be maintained to meet quality requirements for agriculture and to maintain the ecosystem wellbeing.	Electrical conductivity*	≤ 70 mS/m	51.
			RU8	EWR1	B/C (B)	Quality	Salts	Salt concentrations need to be maintained to meet quality requirements for agriculture and to maintain the ecosystem wellbeing.	Electrical conductivity*	≤ 70 mS/m	51.
			RU10	UA.8	B/C					≤ 70 mS/m	29.4
UE	III	Vaal	RU47	UE.2	D	Quality	Salts	Salts need to be improved to levels that do not threaten the ecosystem and to provide for users.	Electrical conductivity*	≤ 111 mS/m	79.1
UI	III	Suikerbosrant	RU62	EWR11	D	Quality	Salts	Salts need to be improved to levels that do not threaten the ecosystem and to provide for users.	Electrical conductivity*	≤ 111 mS/m	135
		Vaal	RU65	UI.3							90.6
			RU66	UI.4							98.1
UJ	III	Vaal	RU67	UJ.1	D	Quality	Salts	Salts need to be improved to levels that do not threaten the ecosystem and to provide for users.	Electrical conductivity*	≤ 111 mS/m	79.1
UL	III	Mooi	RU71	UL.2	D	Quality	Salts	Salts need to be improved to levels that do not threaten the ecosystem and to provide for users.	Electrical conductivity*	≤ 111 mS/m	87
		Vaal	RU73	UL.4				Salts need to be improved to levels that do not threaten the ecosystem and to provide for users.	Electrical conductivity*	≤ 111 mS/m	90.5
									Sulphates *	≤ 500 mg/L	132
UM	III	Vaal	RU75	EWR5	C	Quality	Salts	Salts need to be improved to levels that do not threaten the ecosystem especially fish and to provide for users.	Electrical conductivity *	≤ 85 mS/m	84
									Sulphates *	≤ 200 mg/L	173
UA	II	Vaal	RU8	EWR1	B/C (B)	Quality	System Variables	Temperature and oxygen should be improved to support the ecosystem.	Temperature *	≤ abs(dev from ambient) abs(dev from ambient) 1 deg C	No data
									Dissolved oxygen *	≥ 7 mg/L O_2	No data

			RU10	UA.8	B/C				Temperature *	≤ abs(dev from ambient) abs(dev from ambient) 1 deg C	No data
									Dissolved oxygen *	≥ 7 mg/L O_2	No data
UE	III	Vaal	RU47	UE.2	D	Quality	System Variables	Oxygen levels must be improved to support the ecosystem.	Dissolved oxygen *	≥ 4 mg/L O_2	No data
UG	II	Vaal	RU58	UG.4	C	Quality	System Variables	Temperatures and oxygen concentrations must not threaten the viability of local aquatic species.	Temperature *	≤ abs(dev from ambient) abs(dev from ambient) 2 deg C	No data
									Dissolved oxygen *	≥ 6 mg/L O_2	No data
UH	II	Vaal	RU60	EWR9	B/C	Quality	System Variables	Temperature and oxygen should be improved to support the ecosystem in a good condition.	Temperature *	≤ abs(dev from ambient) abs(dev from ambient) 1 deg C	No data
									Dissolved oxygen *	≥ 7 mg/L O_2	No data
UI	III	Vaal	RU66	UI.4	D	Quality	System Variables	Dissolved organic carbon concentrations should not cause the ecosystem to become unsustainable.	DOC *	30 day median ± 20% of median background mg/L C	No data
UA	II	Vaal	RU8	EWR1	B/C (B)	Quality	Toxins	Toxics need to be maintained at levels which are non-toxic to the ecosystem.	Endosulfan *	≤ 0.103 µg/L	No data
									Atrazine *	≤ 64 µg/L	No data
			RU10	UA.8	B/C			Toxics need to be maintained at levels which are non-toxic to the ecosystem.	Endosulfan *	≤ 0.103 µg/L	No data

UB	II	Vaal	RU21	UB.9	C/D	Quality	Toxins	Ammonia toxicity must be limited for the sake of the ecosystem.	Total Ammonia *	≤ 86 µg/L N	2.9
UE	III	Vaal	RU47 RU50	UE.2 UE.5	D	Quality	Toxins	The river water should not be toxic to aquatic organisms or be a threat to human health.	F *	≤ 3.0 mg/L	0.39
									Al *	≤ 150 µg/L	No data
									As *	≤ 130 µg/L	No data
									Cd hard *	≤ 5.0 µg/L	No data
									Cr(VI) *	≤ 200 µg/L	No data
									Cu hard *	≤ 8.0 µg/L	No data
									Hg *	≤ 1.70 µg/L	No data
									Mn *	≤ 1300 µg/L	No data
									Pb hard *	≤ 13.00 µg/L	No data
									Se *	≤ 30 µg/L	No data
									Zn *	≤ 36 µg/L	No data
									Chlorine *	≤ 5.0 µg/L free Cl	No data
									Endosulfan *	≤ 0.200 µg/L	No data
									Atrazine *	≤ 100 µg/L	No data
UG	II	Vaal	RU58	UG.4	C	Quality	Toxins	The river water should not be toxic to aquatic organisms or be a threat to human health.	F *	≤ 2.5 mg/L	0.50
									Al *	≤ 105 µg/L	No data
									As *	≤ 95 µg/L	No data
									Cd hard *	≤ 3.0 µg/L	No data
									Cr(VI) *	≤ 121 µg/L	No data
									Cu hard *	≤ 6.0 µg/L	No data
									Hg *	≤ 0.97 µg/L	No data
									Mn *	≤ 990 µg/L	No data
									Pb hard *	≤ 9.50 µg/L	No data
									Se *	≤ 22 µg/L	No data
									Zn *	≤ 25 µg/L	No data
									Chlorine *	≤ 3.1 µg/L free Cl	No data
									Endosulfan *	≤ 0.130 µg/L	No data
									Atrazine *	≤ 79 µg/L	No data
UI	III	Suikerbosrant and Vaal	RU62 RU65 RU66	EWR11 UI.3 UI.4	D	Quality	Toxins	The river water should not be toxic to aquatic organisms or be a threat to human health.	F *	≤ 3.0 mg/L	0.465
									Al *	≤ 150 µg/L	No data

									As *	≤ 130 µg/L	No data
									Cd hard *	≤ 5.0 µg/L	No data
									Cr(VI) *	≤ 200 µg/L	No data
									Cu hard *	≤ 8.0 µg/L	No data
									Hg *	≤ 1.70 µg/L	No data
									Mn *	≤ 1300 µg/L	No data
									Pb hard *	≤ 13.00 µg/L	No data
									Se *	≤ 30 µg/L	No data
									Zn *	≤ 36 µg/L	No data
									Chorine *	≤ 5.0 µg/L free Cl	No data
									Endosulfan *	≤ 0.200 µg/L	No data
									Atrazine *	≤ 100 µg/L	No data
UJ	III	Vaal	RU67	UJ.1	D	Quality	Toxins	The river water should not be toxic to aquatic organisms or be a threat to human health.	F *	≤ 3.0 mg/L	4.95
									Al *	≤ 150 µg/L	No data
									As *	≤ 130 µg/L	No data
									Cd hard *	≤ 5.0 µg/L	No data
									Cr(VI) *	≤ 200 µg/L	No data
									Cu hard *	≤ 8.0 µg/L	No data
									Hg *	≤ 1.70 µg/L	No data
									Mn *	≤ 1300 µg/L	No data
									Pb hard *	≤ 13.00 µg/L	No data
									Se *	≤ 30 µg/L	No data
									Zn *	≤ 36 µg/L	No data
									Chorine *	≤ 5.0 µg/L free Cl	No data
									Endosulfan *	≤ 0.200 µg/L	No data
									Atrazine *	≤ 100 µg/L	No data
UL	III	Mooi	RU71	UL.2	D	Quality	Toxins	The river water should not be toxic to aquatic organisms or be a threat to human health. Uranium concentrations need to be at acceptable levels.	F *	≤ 3.0 mg/L	0.05
									Al *	≤ 150 µg/L	No data
									As *	≤ 130 µg/L	No data
									Cd hard *	≤ 5.0 µg/L	No data
									Cr(VI) *	≤ 200 µg/L	No data

									Cu hard *	≤ 8.0 µg/L	No data
									Hg *	≤ 1.70 µg/L	No data
									Mn *	≤ 1300 µg/L	No data
									Pb hard *	≤ 13.00 µg/L	No data
									Se *	≤ 30 µg/L	No data
									Zn *	≤ 36 µg/L	No data
									Chorine *	≤ 5.0 µg/L free Cl	No data
									Endosulfan *	≤ 0.200 µg/L	No data
									Atrazine *	≤ 100 µg/L	No data
									Uranium *	≤ 15 µg/L	No data
UC2	II	Vaal	RU35	EWR8	C	Quality	Pathogens	Pathogens should be maintained at levels safe for human use (excluding for direct consumption).	*E.coli* *	≤ 130 counts/100 ml	No data
UE	III	Vaal	RU47 RU50	UE.2 UE.5	D	Quality	Pathogens	Pathogens should be maintained at levels safe for human use (excluding for direct consumption).	*E.coli* *	≤ 130 counts/100 ml	No data
UI	III	Suikerbosrant	RU62	EWR11	D	Quality	Pathogens	Pathogens should be maintained at levels safe for human use (excluding for direct consumption).	*E.coli* *	≤ 130 counts/100 ml	No data
		Vaal	RU65	UI.3						≤ 130 counts/100 ml	No data
			RU66	UI.4						≤ 130 counts/100 ml	No data
UM	III	Vaal	RU75	EWRS5	C	Quality	Pathogens	Pathogens should be maintained at levels safe for human use (excluding for direct consumption).	*E.coli* *	≤ 130 counts/100 ml	No data

**as per standard methods of America Water Works Association (www.awwa.org)*

Table 6: RQOs for RIVER HABITAT in priority RUs in the Upper Vaal WMA

RIVER HABITAT										
IUA	**Class**	**River**	**RU**	**Node**	**REC**	**Component**	**Sub Component**	**RQO**	**Indicator/ measure**	**Numerical Limits**
UA	II	Vaal	RU8	EWR1	B/C (B)	Habitat	Instream Habitat	The instream habitat must be maintained to support the ecosystem and for property values and recreation.	State of instream habitat according to Rapid Habitat Assessment Method (RHAM)	EcoStatus (RHAM) ≥B/C category (≥78) and or maintenance of habitat for indicator species in a ≥B/C ecological category
			RU10	UB.9	B/C					
UB		Vaal	RU13	UB.2	B	Habitat	Instream Habitat	Instream habitat should be maintained/improved to a good condition to provide for the ecosystem.	State of instream habitat according to Rapid Habitat Assessment Method (RHAM)	EcoStatus (RHAM) ≥B category (≥82), and or maintenance of habitat for indicator species in a ≥B ecological category.
			RU14	UB.3	C/D					EcoStatus (RHAM) ≥B/C category ((≥78), and or maintenance of habitat for indicator species in a ≥B/C
			RU21	UB.9						

										ecological category.
UC1	II	Vaal	RU22	EWR7	B	Habitat	Instream Habitat	Instream habitat should be maintained/improved to a good condition to provide for the ecosystem.	State of instream habitat according to Rapid Habitat Assessment Method (RHAM)	EcoStatus (RHAM) ≥B category (≥82), and or maintenance of habitat for indicator species in a ≥B ecological category.
		Wilge	RU26	UC1.4	C					
UC2	II	Vaal	RU35	EWR8	C	Habitat	Instream Habitat	Instream habitat should be maintained for the ecosystem.	State of instream habitat according to Rapid Habitat Assessment Method (RHAM)	EcoStatus (RHAM) ≥C category (≥62), and or maintenance of habitat for indicator species in a ≥C ecological category.
UC3	II	Vaal	RU40	UC3.4	C/D	Habitat	Instream Habitat	Instream habitat should be maintained for the ecosystem.	State of instream habitat according to Rapid Habitat Assessment Method (RHAM)	EcoStatus (RHAM) ≥C/D category (≥58), and or maintenance of habitat for indicator species in a ≥C/D ecological category.
UD	III	Liebenbergsvlei	RU45	UD.5	B	Habitat	Instream Habitat	Instream habitat should be maintained for the ecosystem.	State of instream habitat according to Rapid Habitat Assessment Method (RHAM)	EcoStatus (RHAM) ≥D category (≥42), and or maintenance of habitat for indicator species in a ≥D ecological category.
UE	III	Vaal	RU47	UE.2	D	Habitat	Instream Habitat	Filamentous algae must be controlled to improve the instream habitat.	State of instream habitat according to Rapid Habitat Assessment Method (RHAM)	EcoStatus (RHAM) ≥C category (≥62), and or maintenance of habitat for indicator species in a ≥C ecological category.
	III	Vaal	RU50	UE.5	D	Habitat	Instream Habitat	Filamentous algae must be controlled to improve the instream habitat.	State of instream habitat according to Rapid Habitat Assessment Method (RHAM)	EcoStatus (RHAM) ≥D category (≥42), and or maintenance of habitat for indicator species in a ≥D ecological category.
UF	II	Vaal	RU52	UF.2	C	Habitat	Instream Habitat	The instream habitat abundance and diversity should be maintained in a good condition to support the ecosystem.	State of instream habitat according to Rapid Habitat Assessment Method (RHAM)	EcoStatus (RHAM) ≥B category (≥82), and or maintenance of habitat for indicator species in a ≥B ecological category.
UG	II	Vaal	RU58	UG.4	C	Habitat	Instream Habitat	The instream habitat function must be provided to support the fish RQO.	State of instream habitat according to Rapid Habitat Assessment Method (RHAM)	EcoStatus (RHAM) ≥C category (≥62), and or maintenance of habitat for indicator species in a ≥C ecological category.
UH	II	Vaal	RU60	EWR9	B/C	Habitat	Instream Habitat	Instream habitat needs to be improved to a good condition to support fish communities.	State of instream habitat according to Rapid Habitat Assessment Method (RHAM)	EcoStatus (RHAM) ≥B category (≥82), and or maintenance of habitat for indicator species in a ≥B ecological category.
UI	III	Suikerbosrant	RU62	EWR11	D	Habitat	Instream Habitat	The instream habitat should be maintained to a level that sustains this ecosystem.	State of instream habitat according to Rapid Habitat Assessment Method (RHAM)	EcoStatus (RHAM) ≥D category (≥42), and or maintenance of habitat for indicator species in a ≥D ecological category.
		Vaal	RU66	UI.4						
	III		RU65	UI.3				The instream habitat needs to be healthy to ameliorate water quality impacts and to provide for other users.		EcoStatus (RHAM) ≥C category (≥62), and or maintenance of habitat for indicator species in a ≥C ecological category.
UK	III	Vaal	RU68	UK.1	C	Habitat	Instream Habitat	The instream habitat must be maintained to a healthy condition.	State of instream habitat according to Rapid Habitat Assessment Method (RHAM)	EcoStatus (RHAM) ≥C category (≥62), and or maintenance of habitat for indicator species in a ≥C

										ecological category.
UL	III	Mooi	RU71	UL.2	D	Habitat	Instream Habitat	The instream habitat needs to be maintained to a level that sustains the ecosystem.	State of instream habitat according to Rapid Habitat Assessment Method (RHAM)	EcoStatus (RHAM) ≥D category (≥42), and or maintenance of habitat for indicator species in a ≥D ecological category.
		Vaal	RU73	UL.4				The instream habitat needs to be improved to a level that sustains the ecosystem.		EcoStatus (RHAM) ≥C/D category (≥58), and or maintenance of habitat for indicator species in a ≥C/D ecological category.
UM	III	Vaal	RU75	EWRS5	C	Habitat	Instream Habitat	The river should be kept essentially free of water hyacinth and excessive filamentous algae.	State of instream habitat according to Rapid Habitat Assessment Method (RHAM)	EcoStatus (RHAM) ≥D category (≥42), and or maintenance of habitat for indicator species in a ≥D ecological category.
UA	II	Vaal	RU8	EWR1	B/C (B)	Habitat	Riparian	The riparian habitat must be maintained to retain ecological functions, property values and for recreational purposes.	State of riparian habitat according to Riparian Vegetation Response Assessment Index (VEGRAI) III	VEGRAI (Level III) in ≥B category (equivalent to EcoClassification score >80)
			RU10	UA.8	B/C					
UB	II	Vaal	RU 21	UB.9	C/D	Habitat	Riparian	The riparian habitat must be maintained to control impacts in the riparian zone which negatively affect the river system.	State of riparian habitat according to Riparian Vegetation Response Assessment Index (VEGRAI) III	VEGRAI (Level III) in ≥C category (equivalent to EcoClassification score >60)
UE	III	Vaal	RU47	UE.2	D	Habitat	Riparian	The riparian habitat must be maintained to buffer the aquatic ecosystem from land-use impacts.	State of riparian habitat according to Riparian Vegetation Response Assessment Index (VEGRAI) III	VEGRAI (Level III) in ≥D category (equivalent to EcoClassification score >40)
UF	II	Vaal	RU 52	UF.2	C	Habitat	Riparian	The riparian habitat must be maintained to buffer the aquatic ecosystem from land-use impacts.	State of riparian habitat according to Riparian Vegetation Response Assessment Index (VEGRAI) III	VEGRAI (Level III) in ≥B category (equivalent to EcoClassification score >80)
UK	III	Vaal	RU68	UK.1	C	Habitat	Riparian	The riparian habitat must be maintained to buffer the aquatic ecosystem from agricultural activities.	State of riparian habitat according to Riparian Vegetation Response Assessment Index (VEGRAI) III	VEGRAI (Level III) in ≥C category (equivalent to EcoClassification score >60)
UM	III	Vaal	RU 75	EWR5	C	Habitat	Riparian	The riparian habitat must be maintained to stabilise the aquatic ecosystem and meet aesthetic requirements.	State of riparian habitat according to Riparian Vegetation Response Assessment Index (VEGRAI) III	VEGRAI (Level III) in ≥C category (equivalent to EcoClassification score >60)

Table 7: RQOs for RIVER BIOTA in priority RUs in the Upper Vaal WMA

RIVER BIOTA										
IUA	**Class**	**River**	**RU**	**Node**	**REC**	**Component**	**Sub Component**	**RQO**	**Indicator/ measure**	**Numerical Limits**
UA	II	Vaal	RU8	EWR1	B/C (B)	Biota	Fish	Fish communities should be maintained/improved so that they include viable populations of ecologically important species.	State of fish populations according to Fish Response Assessment Index (FRAI) Score.	FRAI Score ≥80 (≥B category (equivalent to EcoClassification score >80))
									State of critical instream habitat	Maintenance of critical habitat for

			RU10	UA.8	B/C				for the Orange-Vaal largemouth yellowfish *(Labeobarbus kimberleyensis)* and the Vaal rock catfish *(Austroglanis sclateri)* according to Rapid Habitat Assessment Method (RHAM).	indicator species in a state equivalent to ≥B/C EcoStatus (≥78 Score).
UB	II	Vaal	RU13 RU14	UB.2 UB.3	B	Biota	Fish	The river must support healthy populations of important fish species.	State of critical instream habitat for the Goldie barb (*Barbus pallidus*) and Chubby head barb (*Barbus anoplus*) according to Rapid Habitat Assessment Method (RHAM).	Maintenance of critical habitat for indicator species in a state equivalent to ≥B/C EcoStatus (≥78 Score).
UC1	II	Vaal	RU22	EWR7	A/B	Biota	Fish	The fish community needs to be maintained to a good condition including important species. The genetic integrity of local cyprinid populations must not be contaminated by non-endemic cyprinids from the Thukela Catchment.	State of fish populations according to Fish Response Assessment Index (FRAI) Score	FRAI Score ≥80 (≥B category (equivalent to EcoClassification score >80))
									State of critical instream habitat for the local populations of Chubby head barb *(Barbus anoplus)* according to Rapid Habitat Assessment Method (RHAM).	Maintenance of critical habitat for indicator species in a state equivalent to ≥B/C EcoStatus (≥78 Score).
									Genetic diversity assessment of local Cyprinids.	Genetic diversity must compare with reference.
UC2	II	Vaal	RU35	EWR8	C	Biota	Fish	The local genetic integrity of fish must be protected.	Genetic diversity assessment of local Cyprinids.	Genetic diversity must compare with reference.
UE	III	Vaal	RU50	UE.5	D	Biota	Fish	The fish community needs to be improved to sustainable levels including important species.	State of fish populations according to Fish Response Assessment Index (FRAI) Score	FRAI Score ≥50 (≥C/D category (equivalent to EcoClassification score 50-60) (equivalent to EcoClassification score >40))
									State of critical instream habitat for the Orange-Vaal largemouth yellowfish (*Labeobarbus kimberleyensis*) according to Rapid Habitat Assessment Method (RHAM).	Maintenance of critical habitat for indicator species in s state equivalent to ≥C EcoStatus (≥62 Score).
UF	II	Vaal	RU52	UF.2	C	Biota	Fish	The fish community needs to be improved to a good condition.	State of fish populations according to Fish Response Assessment Index (FRAI) Score	FRAI Score ≥80 (≥B category (equivalent to EcoClassification score >80))
UG	II	Vaal	RU58	UG.4	C	Biota	Fish	The populations of the Orange-Vaal largemouth yellowfish (*Labeobarbus kimberleyensis*) and Vaal Rock catfish (*Austroglanis sclateri*) need to be maintained in a viable state.	State of critical instream habitat for the Orange-Vaal largemouth yellowfish *(Labeobarbus kimberleyensis)* and the Vaal rock catfish *(Austroglanis sclateri)* according to Rapid Habitat Assessment Method (RHAM).	Maintenance of critical habitat for indicator species in a state equivalent to ≥B/C EcoStatus (≥78 Score).
UH	II	Vaal	RU60	EWR9	B/C	Biota	Fish	The fish community needs to be improved to sustainable levels.	State of fish populations according to Fish Response Assessment Index (FRAI) Score	FRAI Score ≥60 (≥C category (equivalent to EcoClassification score >60))

UI	III	Suikerbosrant	RU62	EWR11	D	Biota	Fish	The fish community needs to be maintained to sustainable levels.	State of fish populations according to Fish Response Assessment Index (FRAI) Score	FRAI Score ≥40 (≥D category (equivalent to EcoClassification score >40))
		Vaal	RU65	UI.3						
UK	III	Vaal	RU68	UK.1	C	Biota	Fish	The fish community needs to be maintained to sustainable levels.	State of fish populations according to Fish Response Assessment Index (FRAI) Score	FRAI Score ≥60 (≥C/D category (equivalent to EcoClassification score 50-60) (equivalent to EcoClassification score >40))
UM	III	Vaal	RU75	EWRS5	C	Biota	Fish	The fish community needs to be maintained to sustainable levels including important species.	State of fish populations according to Fish Response Assessment Index (FRAI) Score	FRAI Score ≥60 (≥C category (equivalent to EcoClassification score >60))
									State of critical instream habitat for the Orange-Vaal largemouth yellowfish *(Labeobarbus kimberleyensis)* according to Rapid Habitat Assessment Method (RHAM).	Maintenance of critical habitat for indicator species in in a state equivalent to ≥C EcoStatus (≥62 Score).
UA	II	Vaal	RU1	8VF5	B	Biota	Aquatic invertebrates	Invertebrates should be maintained in a good condition to support biodiversity.	State of aquatic invertebrates according to Macroinvertebrate Response Assessment Index (MIRAI) Score, using the SASS5 sampling method and maintenance of critical habitat according to Rapid Habitat Assessment Method (RHAM).	MIRAI Score ≥B category (equivalent to EcoClassification score >80) and maintenance of critical habitat for invertebrates in a in a state equivalent to ≥B EcoStatus (≥82 Score).
UB	II	Vaal	RU14	UB.3	B	Biota	Aquatic invertebrates	Invertebrates should be maintained in a good condition to support biodiversity.	State of aquatic invertebrates according to Macroinvertebrate Response Assessment Index (MIRAI) Score, using the SASS5 sampling method and maintenance of critical habitat according to Rapid Habitat Assessment Method (RHAM).	MIRAI Score ≥B category (equivalent to EcoClassification score >80) and maintenance of critical habitat for invertebrates in a in a state equivalent to ≥B EcoStatus (≥82 Score).
			RU21	UB.9	C/D					
UC1	II	Wilge	RU26	UC1.4	C	Biota	Aquatic invertebrates	Invertebrates should be maintained in a good condition to support biodiversity.	State of aquatic invertebrates according to Macroinvertebrate Response Assessment Index (MIRAI) Score, using the SASS5 sampling method and maintenance of critical habitat according to Rapid Habitat Assessment Method (RHAM).	MIRAI Score ≥B category (equivalent to EcoClassification score >80) and maintenance of critical habitat for invertebrates in a in a state equivalent to ≥B EcoStatus (≥82 Score).
UC2		Vaal	RU35	EWR8						
UC3	II	Vaal	RU40	UC3.4	C/D	Biota	Aquatic invertebrates	Invertebrates should be maintained/improved to a sustainable condition to support biodiversity.	State of aquatic invertebrates according to Macroinvertebrate Response Assessment Index (MIRAI) Score, using the SASS5 sampling method and maintenance of critical habitat according to Rapid Habitat Assessment Method (RHAM).	MIRAI Score ≥C/D category (equivalent to EcoClassification score 50-60) (equivalent to EcoClassification score >40) and maintenance of critical habitat for invertebrates in a in a state equivalent to ≥C/D EcoStatus (≥58 Score).
UE			RU47	UE.2	D					

UH	II	Vaal	RU60	EWR9	B/C	Biota	Aquatic invertebrates	Invertebrates should be maintained to a good condition to support biodiversity.	State of aquatic invertebrates according to Macroinvertebrate Response Assessment Index (MIRAI) Score, using the SASS5 sampling method and maintenance of critical habitat according to Rapid Habitat Assessment Method (RHAM).	MIRAI Score ≥B/C category (equivalent to EcoClassification score 70-80) (equivalent to EcoClassification score >60) (equivalent to EcoClassification score 70-80) and maintenance of critical habitat for invertebrates in a in a state equivalent to ≥B/C EcoStatus (≥78 Score).
UI	III	Suikerbosrant	RU62	EWR11	D	Biota	Aquatic invertebrates	Invertebrates should be maintained/improved to a sustainable condition to support biodiversity.	State of aquatic invertebrates according to Macroinvertebrate Response Assessment Index (MIRAI) Score, using the SASS5 sampling method and maintenance of critical habitat according to Rapid Habitat Assessment Method (RHAM).	MIRAI Score ≥D category (equivalent to EcoClassification score >40) and maintenance of critical habitat for invertebrates in a in a state equivalent to ≥D ecological category.
		Vaal	RU65	UI.3						
		Vaal	RU66	UI.4						MIRAI Score ≥C/D category (equivalent to EcoClassification score 50-60) (equivalent to EcoClassification score >40) and maintenance of critical habitat for invertebrates in a in a state equivalent to ≥C/D EcoStatus (≥58 Score).
UJ	III	Vaal	RU67	UJ.1	D	Biota	Aquatic invertebrates	Invertebrates should be improved to a sustainable condition to support biodiversity.	State of aquatic invertebrates according to Macroinvertebrate Response Assessment Index (MIRAI) Score, using the SASS5 sampling method and maintenance of critical habitat according to Rapid Habitat Assessment Method (RHAM).	MIRAI Score ≥D category (equivalent to EcoClassification score >40) and maintenance of critical habitat for invertebrates in a in a state equivalent to ≥D EcoStatus (≥42 Score).
UK	III	Vaal	RU68	UK.1	C	Biota	Aquatic invertebrates	Invertebrates should be maintained to a sustainable condition to support biodiversity.	State of aquatic invertebrates according to Macroinvertebrate Response Assessment Index (MIRAI) Score, using the SASS5 sampling method and maintenance of critical habitat according to Rapid Habitat Assessment Method (RHAM).	MIRAI Score ≥C category (equivalent to EcoClassification score >60) and maintenance of critical habitat for invertebrates in a in a state equivalent to ≥C EcoStatus (≥62 Score).
UL	III	Mooi	RU71	UL.2	D	Biota	Aquatic invertebrates	Invertebrates should be maintained to a sustainable condition to support biodiversity.	State of aquatic invertebrates according to Macroinvertebrate Response Assessment Index (MIRAI) Score, using the SASS5 sampling method and maintenance of critical habitat according to Rapid Habitat Assessment Method (RHAM).	MIRAI Score ≥D category (equivalent to EcoClassification score >40) and maintenance of critical habitat for invertebrates in a in a state equivalent to ≥D EcoStatus (≥42 Score).
		Vaal	RU73	UL.4						
UE	III	Vaal	RU47	UE.2	D	Biota	Diatoms	Diatoms must be maintained in a	Diatom community structure	SPI score ≥D category (equivalent

			RU50	UE.5				condition that reflects a sustainable ecosystem.	according to Specific Pollution sensitivity Index (SPI) Score using sampling method as per Taylor et al (2005)	to EcoClassification score >40).
UH	III	Suikerbosrant	RU62	EWR11	D	Biota	Diatoms	Diatoms must be maintained in a condition that reflects a sustainable ecosystem.	Diatom community structure according to Specific Pollution sensitivity Index (SPI) Score using sampling method as per Taylor et al (2005)	SPI score ≥D category (equivalent to EcoClassification score >40).
UI	III	Vaal	RU66	UI.4	D	Biota	Diatoms	Diatoms must be maintained in a condition that reflects a sustainable ecosystem.	Diatom community structure according to Specific Pollution sensitivity Index (SPI) Score using sampling method as per Taylor et al (2005)	SPI score ≥C/D category (equivalent to EcoClassification score 50-60) (equivalent to EcoClassification score >40)
UJ	III	Vaal	RU67	UJ.1	D	Biota	Diatoms	Diatoms must be maintained in a condition that reflects a sustainable ecosystem.	Diatom community structure according to Specific Pollution sensitivity Index (SPI) Score using sampling method as per Taylor et al (2005)	SPI score D category (equivalent to EcoClassification score >40)
UL	III	Mooi	RU71	UL.2	D	Biota	Diatoms	Diatoms must be maintained in a condition that reflects a sustainable ecosystem.	Diatom community structure according to Specific Pollution sensitivity Index (SPI) Score using sampling method as per Taylor et al (2005)	SPI score ≥D category (equivalent to EcoClassification score >40)
		Vaal	RU73	UL.4						
	III	Vaal	RU73	UL.4	D	Biota	Periphyton	The periphyton must be maintained to a D category.	Diatoms as indicator of water quality impacts on periphyton according to Specific Pollution sensitivity Index (SPI) Score, at least once a year	SPI-Score ≥D category (equivalent to EcoClassification score >40)
UM	III	Vaal	RU75	EWR5	C	Biota	Periphyton	The river should be managed so that the substrate is kept essentially free of excessive filamentous algae.	Periphyton community structures according to Visual Investigation and maintenance of critical habitat according to Rapid Habitat Assessment Method (RHAM).	Filamentous algae must not dominate instream habitat and critical habitat for indicator organisms must be maintained in a ≥C ecological category.

4.1.2 SUPPLEMENTARY INFORMATION FOR THE RIVER RESOURCE QUALITY OBJECTIVES AND NUMERICAL LIMITS TABLES

Table 8: Supplementary information for RIVER QUANTITY RQOs on Resource Unit Scale.

WATER QUALITY									
IUA	**Class**	**River**	**RU**	**Node**	**REC**	**Component**	**Sub Component**	**Context of the RQO**	**Reference**
UA	II	Vaal	RU8	EWR1	B/C (B)	Quantity	Low Flows	Low flows in this RU are important for maintaining the ecosystem of this important NFEPA and to provide irrigation water for agriculture. The low flows should be maintained in a B/C category (equivalent to EcoClassification score 70-80). Percentiles associated with low flows specify duration requirements.	DWA, 2010

		Vaal	RU10	UA.8	B/C	Quantity	Low Flows	Low flows in this RU are important for maintaining the ecosystem of this important NFEPA and to provide irrigation water for agriculture. The low flows should be maintained in a B/C category (equivalent to EcoClassification score 70-80 Percentiles associated with low flows specify duration requirements.	DWA, 2010
UB	II	Vaal	RU21	UB.9	C/D	Quantity	Low Flows	The low flows at this site need to improve to maintain the FEPA status of this important ecosystem. The low flows need to be improved to a C category. Percentiles associated with low flows specify duration requirements.	Comprehensive Ecological Reserve assessment (DWA 2010). Extrapolated from Vaal_EWR6, Klip in C13D
UC2	II	Vaal	RU35	EWR8	C	Quantity	Low Flows	Low flows in this RU are being impacted on by poor water quality releases from Sterkfontien Dam, abstractions by water institution for urban centres and limited agriculture activities. The low flows should be maintained at a C category level. Percentiles associated with low flows specify duration requirements.	DWA, 2010
UC3	II	Vaal	RU40	UC3.4	C/D	Quantity	Low Flows	There is potential for the low flows in this RU to be negatively impacted by unnatural releases from Sterkfontein Dam. Low flows should be improved to a C/D category . Percentiles associated with low flows specify duration requirements.	Desktop Reserve Model with updated PES data from DWA 2013 study. Extrapolated from UV_EWR8 Wilge in C82C
UD	III	Liebenbergsvlei	RU45	UD.5	B	Quantity	Low Flows	The low flows of this river are significantly modified by the interbasin transfer of water from Lesotho. Flow requirements are almost impossible to attain given the volumes being transferred. It is nevertheless necessary for the stability of the river ecosystem to manage these flows to maintain a suitable habitat. This habitat of this river should reflect that of a river larger than natural for the RU but showing the flow and associated hydrological characteristics of the region, including the distribution and variability of flows. Percentiles associated with low flows specify duration requirements.	DWA, 2010
UG	II	Vaal	RU58	UG.4	C	Quantity	Low Flows	Low flows of the upper Vaal River are important in this RU to provide water for local irrigation requirements and for domestic use. It is necessary to improve the low	DWA, 2010

								flows in the upper Vaal in this RU to a B/C category (equivalent to EcoClassification score 70-80). Percentiles associated with low flows specify duration requirements.	
UH	II	Vaal	RU60	EWR9	B/C	Quantity	Low Flows	There are many user requirements for the water in this RU. The provision of low flows is also important for maintenance of ecosystem structure and function thus the Reserve requirement must be met. Low flows must be improved to a C category. Timing and duration of flows is necessary to provide ecological cues for threatened or protected Orange-Vaal largemouth yellowfish (*Labeobarbus kimberleyensis*) to complete life cycle events in this river and to maintain the ecosystem. The high flows should be maintained in a C category. Percentiles associated with low flows specify duration requirements.	DWA, 2010
UI	III	Suikerbosrant	RU62	EWR11	D	Quantity	Low Flows	Low flows in this system are highly impacted on by abnormally high discharges by existing and defunct mines and from Wastewater Treatment Works. The timing and duration of elevated low flows must be managed to minimise the incision of the main channel which is affecting the integrity of the floodplain wetland associated with the river. Low flows should be lowered and improved to a D category. Percentiles associated with low flows specify duration requirements.	DWA, 2010
	III	Vaal	RU65	UI.3	D			Low flows in this system are highly impacted on by abnormally high discharges by existing and defunct mines and from Wastewater Treatment Works. The timing and duration of flows needs to be managed to be sympathetic to the ecosystem as well as the maximum discharge should be capped to not exceed natural base high levels. Low flows should be maintained at a D category. Percentiles associated with low flows specify duration requirements.	DWA, 2010
	III	Vaal	RU66	UI.4	D			Low flows in this RU are negatively altered by upstream activities. For the improvement of the wellbeing of the entire river, the low flows must be improved to a C/D category. Percentiles associated with low flows specify duration requirements.	DWA, 2010
UM	III	Vaal	RU75	EWR5	C	Quantity	High Flows	High flows are necessary for the provision of ecological cues for the protected Orange-Vaal largemouth yellowfish (*Labeobarbus kimberleyensis*) and for the general maintenance of the instream habitat including the flushing of algae and water hyacinths. High flows in the river reach upstream of the confluence with the Mooi River need to be provided to this system in a C category. The high flow requirements include flood and freshet flows and their associated flow duration requirements which are defined by the percentiles associated with the numerical limits of flows.	DWA, 2010

Table 9: Supplementary information for RIVER QUALITY RQOs on Resource Unit Scale.

RIVER WATER QUALITY											
IUA	**Class**	**River**	**RU**	**Node**	**REC**	**Component**	**Sub Component**	**Context of the RQO**	**TPC**		**Reference**
UA	II	Vaal	RU8	EWR1	B/C (B)	Quality	Nutrients	Nutrient concentrations impact negatively on the ecosystem of this NFEPA site, but also negatively on recreation, ecotourism and real estate values. They also reduce the fitness of the water for domestic use. The nutrient condition must be improved to a C category. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Phosphate(PO_4) *	0.015 mg/L P	DWAF, 2008
									Nitrate (NO_3) & Nitrite (NO_2) *	0.70 mg/L N	
			RU10	UA.8	B/C				Phosphate(PO_4) *	0.015 mg/L P	
									Nitrate (NO_3) & Nitrite (NO_2) *	0.70 mg/L N	
UC2	II	Vaal	RU35	EWR8	C	Quality	Nutrients	Nutrients: Wastewater Treatment Works and associated urban centres are contributing to nutrient enrichment in this RU. Nutrient concentrations should be maintained at C category. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Phosphate(PO_4) *	0.020 mg/L P	DWAF, 2008
									Nitrate (NO_3) & Nitrite (NO_2) *	0.85 mg/L N	
UC3	II	Vaal	RU40	UC3.4	C/D	Quality	Nutrients	The presence of Wastewater Treatment Works and associated urban centres are linked to nutrient enrichment in this RU. Concentrations of nutrient should be maintained at a C category. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Phosphate(PO_4) *	0.025 mg/L P	DWAF, 2008
									Nitrate (NO_3) & Nitrite (NO_2) *	1.00 mg/L N	
UE	III	Vaal	RU47 RU50	UE.2 UE.5	D	Quality	Nutrients	This river is stressed by releases from Wastewater Treatment Works which are affecting the eutrophic state of the ecosystem. Nutrient concentrations should be improved to a *D category*. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Phosphate(PO_4) *	0.075 mg/L P	DWAF, 2008
									Nitrate (NO_3) & Nitrite (NO_2) *	2.50 mg/L N	
UH	II	Vaal	RU60	EWR9	B/C	Quality	Nutrients	There is elevation of nutrient concentrations associated with urban centres and other communities which needs to be addressed if the overall ecosystem wellbeing is to be improved. The nutrient concentrations must be improved to a C category. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to	Phosphate(PO_4)*	0.015 mg/L P	DWAF, 2008
									Nitrate (NO_3) & Nitrite (NO_2) *	0.70 mg/L N	

								remove the extreme values considered to represent outliers.			
UI	III	Suikerbosrant	RU62	EWR11	D	Quality	Nutrients	Nutrient loads in this water are affecting the trophic state of the river and other users including irrigated agriculture. The river should be improved to a D category and or mesotrophic state. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Phosphate(PO_4) *	0.075 mg/L P	DWAF, 2008
									Nitrate (NO_3) & Nitrite (NO_2) *	2.50 mg/L N	
		Vaal		UI.3 UI.4					Phosphate(PO_4) *	0.075 mg/L P	
									Nitrate (NO_3) & Nitrite (NO_2) *	2.50 mg/L N	
UL	III	Mooi	RU71	UL.2	D	Quality	Nutrients	There are eutrophic conditions associated nutrient contamination from peri-urban and informal communities and Wastewater Treatment Works of the far West Rand. The nutrients should be improved to a D category. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Phosphate(PO_4) *	0.075 mg/L P	DWAF, 2008
									Nitrate (NO_3) & Nitrite (NO_2) *	2.50 mg/L N	
		Vaal	RU73	UL.4				Upstream activities, especially Wastewater Treatment Works, are introducing nutrients which are causing eutrophic conditions manifesting as excessive filamentous algal growth. To reduce the amount of algae the nutrient concentrations must be reduced so that the nutrient state is improved to a D category. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Phosphates (RWQO limits 0.4 mg/l) *	0.075 mg/L P	DWAF, 2008
UM	III	Vaal	RU75	EWR5	C	Quality	Nutrients	Nutrient concentrations are excessive resulting from upstream activities. Concentrations must be controlled to prevent eutrophication and also to minimise water treatment costs. Nutrient concentrations should be managed to a C category. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Phosphate(PO_4)*	0.020 mg/L P	DWAF, 2008
									Nitrate (NO_3) & Nitrite (NO_2) *	0.85 mg/L N	
									Total Ammonia*	58 µg/L N	
UA	II	Vaal	RU8	EWR1	B/C (B)	Quality	Salts	Salts: Salt concentrations need to be maintained in a C category to meet quality requirements for agriculture and maintain the ecosystem wellbeing. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Electrical conductivity*	55 mS/m	DWAF, 2008
			RU10	UA.8	B/C					55 mS/m	

UE	III	Vaal	RU47	UE.2	D	Quality	Salts	Salt concentrations associated with upstream industry releases are unacceptably high and must be improved to a D category. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Electrical conductivity*	98 mS/m	DWAF, 2008
UI	III	Suikerbosrant	RU62	EWR11	D	Quality	Salts	Salts: Salt contamination is a major issue here with upstream acid mine drainage, which his impacting on peri-urban users who use the water for irrigation, and the cost of water treatment for downstream users. The salt concentrations must be improved to a D category. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Electrical conductivity*	98 mS/m	DWAF, 2008
		Vaal	RU65	UI.3							
			RU66	UI.4							
UJ	III	Vaal	RU67	UJ.1	D	Quality	Salts	Local industrial activities are having a negative impact on the water quality causing salinization of the Taaibosspruit. Salt concentrations should be improved to a D category. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Electrical conductivity*	98 mS/m	DWAF, 2008
UL	III	Mooi	RU71	UL.2	D	Quality	Salts	Salts: Upstream mining activity releases have causes acid mine drainage conditions in the system. The salts need to be returned to a state where it is not having a serious impact on the ecosystem, i.e. a D category. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Electrical conductivity*	98 mS/m	DWAF, 2008
		Vaal	RU73	UL.4				Salt loads associated with acid mine drainage impacts from upstream mining activities are of concern for the ecosystem and also for downstream users. The salt concentrations should be managed to a D category. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Electrical conductivity*	98 mS/m	DWAF, 2008
									Sulphates *	350 mg/L	Golder Associates, 2013.
UM	III	Vaal	RU75	EWR5	C	Quality	Salts	Excessive salt in this system causes salinisation of agricultural land and also fouling of industries. It is also a potential problem for maintenance of the Orange-Vaal largemouth yellowfish population, recruitment of which may be sensitive to high salt	Electrical conductivity *	70 mS/m	DWAF, 2008
									Sulphates *	140 mg/L	Golder Associates, 2013.

								loads. Salt concentrations must be improved to a C category. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.			
UA	II	Vaal	RU8	EWR1	B/C (B)	Quality	System Variables	Excessively low flow conditions are causing water temperatures to increase abnormally and reduce oxygen concentrations, thus threatening the ecosystem. These variables should be improved to a C category. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Temperature *	abs(dev from ambient) 0 deg C	DWAF, 2008
									Dissolved oxygen *	7 mg/L O_2	
			RU10	UA.8	B/C				Temperature *	abs(dev from ambient) 0 deg C	
									Dissolved oxygen *	7 mg/L O_2	
UE	III	Vaal	RU47	UE.2	D	Quality	System Variables	System variables: Low oxygen levels associated with organic matter emanating from upstream industries and Wastewater Treatment Works are negatively impacting on the ecosystem. Oxygen levels should be improved to a D category. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Dissolved oxygen *	5 mg/L O_2	DWAF, 2008
UG	II	Vaal	RU58	UG.4	C	Quality	System Variables	The abnormal increases and temperatures and the associated decreases in oxygen levels of the upper Vaal River in this RU during extremely low flow periods due to excessive abstractions, is concerning. Temperatures and oxygen concentrations in the upper Vaal River in this RU must not threaten the viability of local aquatic species, and or act as a chemical barrier and affect the access to the upper Vaal River or Dam during low flow periods. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Temperature *	abs(dev from ambient) 1 deg C	DWAF, 2008
									Dissolved oxygen *	7 mg/L O_2	
UH	II	Vaal	RU60	EWR9	B/C	Quality	System Variables	Low flows are causing a rise in temperatures and a drop in oxygen levels which are threatening the ecosystem. Temperatures and oxygen levels need to be improved to a B/C category (equivalent to EcoClassification score 70-80). Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Temperature *	abs(dev from ambient) 0 deg C	DWAF, 2008
									Dissolved oxygen *	7 mg/L O_2	

UI	III	Vaal	RU66	UI.4	D	Quality	System Variables	There are high levels of COD and BOD in the river associated with industrial activities, Wastewater Treatment Works and some mines in the catchment. The COD and BOD must be improved to a D category. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	DOC *	30 day median ± 20% of median background mg/L C	DWAF, 2008
UA	II	Vaal	RU8	EWR1	B/C (B)	Quality	Toxins	Pesticides emanating from agriculture activities are potentially threatening the ecosystem maintenance and need to be maintained at levels which are non-toxic to the ecosystem. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Endosulfan *	0.075 µg/L	DWAF, 2008
									Atrazine *	49 µg/L	
			RU10	UA.8	B/C			Pesticides emanating from agriculture activities are potentially threatening the ecosystem maintenance and need to be maintained at levels which are non-toxic to the ecosystem. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Endosulfan *	0.075 µg/L	DWAF, 2008
UB	II	Vaal	RU21	UB.9	C/D	Quality	Toxins	There is an upwards trend in the concentrations of ammonia in this RU. This trend needs to be stopped at present or better levels. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Total Ammonia *	73 µg/L N	DWAF, 2008
UE	III	Vaal	RU47 RU50	UE.2 UE.5	D	Quality	Toxins	There is an upwards trend in the concentrations of ammonia in this RU. This trend needs to be stopped at present or better levels. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	F *	2.8 mg/L	DWAF, 2008
									Al *	128 µg/L	
									As *	113 µg/L	
									Cd hard *	4.0 µg/L	
									Cr(VI) *	161 µg/L	
									Cu hard *	7.0 µg/L	
									Hg *	1.34 µg/L	
									Mn *	1145 µg/L	
									Pb hard *	11.25 µg/L	
									Se *	26 µg/L	
									Zn *	31 µg/L	
									Chlorine *	4.1 µg/L free Cl	
									Endosulfan *	0.165 µg/L	
									Atrazine *	89 µg/L	
UG	II	Vaal	RU58	UG.4	C	Quality	Toxins	Various toxins are likely to occur in this river due to upstream mining, agriculture and Wastewater	F *	2.3 mg/L	DWAF, 2008
									Al *	84 µg/L	

								Treatment Works. The river water should not be toxic to aquatic organisms or pose a threat to human health. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	As * Cd hard * Cr(VI) * Cu hard * Hg * Mn * Pb hard * Se * Zn * Chlorine * Endosulfan * Atrazine *	76 µg/L 2.3 µg/L 94 µg/L 5.4 µg/L 0.75 µg/L 835 µg/L 7.63 µg/L 18 µg/L 20 µg/L 2.4 µg/L free Cl 0.103 µg/L 64 µg/L	
UI	III	Suikerbosrant and Vaal	RU62 RU65 RU66	EWR11 UI.3 UI.4	D	Quality	Toxins	Toxic chemicals in this river (organic and inorganic) are emanating from upstream activities including mines (associated with acid mine drainage), industries and Wastewater Treatment Works. Some communities in the region are dependent on local water resources for irrigation, basic human needs, spiritual rituals, and are at a high risk of human health impacts through direct contact and consumption of water, watered vegetables and fish. Toxic concentrations must be reduced to a D category, not pose a high risk of human health so as to make this water acceptable for human use, and ecosystem wellbeing. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	F * Al * As * Cd hard * Cr(VI) * Cu hard * Hg * Mn * Pb hard * Se * Zn * Chorine * Endosulfan * Atrazine *	2.8 mg/L 128 µg/L 113 µg/L 4.0 µg/L 161 µg/L 7.0 µg/L 1.34 µg/L 1145 µg/L 11.25 µg/L 26 µg/L 31 µg/L 4.1 µg/L free Cl 0.165 µg/L 89 µg/L	DWAF, 2008
UJ	III	Vaal	RU67	UJ.1	D	Quality	Toxins	Toxic chemicals are accumulating in the system due to upstream activities, which is negatively impacting on the fitness for use of the water for the watering of crops and may also be contaminating fish which may be captured and consumed by local communities. Toxic chemicals in the water should be managed in a D category. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	F * Al * As * Cd hard * Cr(VI) * Cu hard * Hg * Mn * Pb hard * Se * Zn * Chorine * Endosulfan * Atrazine *	2.8 mg/L 128 µg/L 113 µg/L 4.0 µg/L 161 µg/L 7.0 µg/L 1.34 µg/L 1145 µg/L 11.25 µg/L 26 µg/L 31 µg/L 4.1 µg/L free Cl 0.165 µg/L 89 µg/L	DWAF, 2008
UL	III	Mooi	RU71	UL.2	D	Quality	Toxins	There are a number of toxic chemicals associated with the mining industry and in this RU uranium is of particular concern and poses a high risk and imminent threat to the human health of downstream users who	F * Al * As * Cd hard *	2.8 mg/L 128 µg/L 113 µg/L 4.0 µg/L	DWAF, 2008

								consume water and or watered vegetables and fish. Uranium concentrations as well as other toxins need to be maintained at a D category. Where available the 95%ile of observed or modelled data has been provided. The 95%ile threshold is a standard procedure which has been selected to remove the extreme values considered to represent outliers.	Cr(VI) *	161 µg/L	
									Cu hard *	7.0 µg/L	
									Hg *	1.34 µg/L	
									Mn *	1145 µg/L	
									Pb hard *	11.25 µg/L	
									Se *	26 µg/L	
									Zn *	31 µg/L	
									Chorine *	4.1 µg/L free Cl	
									Endosulfan *	0.165 µg/L	
									Atrazine *	89 µg/L	
									Uranium *	15 µg/L	
UC2	II	Vaal	RU35	EWR8	C	Quality	Pathogens	Microbial contamination of the river water associated with human waste poses a threat to human health through direct consumption but via fish and vegetable consumption. Pathogens should be maintained at levels safe for human use.	*E.coli* *	130 counts/100 ml	DWAF, 1996
UE	III	Vaal	RU47 RU50	UE.2 UE.5	D	Quality	Pathogens	Pathogens are present in the system due to upstream activities which is negatively impacting on the fitness for use of the water for domestic use, watering of crops and is a risk to human health. Pathogens in the water should be managed in a D category	*E.coli* *	130 counts/100 ml	DWAF, 1996
UI	III	Suikerbosrant	RU62	EWR11	D	Quality	Pathogens	Upstream activities are result in pathogen concentrations that pose a high risk of human health impacts to communities who have contact with the water and consume watered vegetables and fish. Pathogens should be maintained at a D category where they are not a high risk to human health.	*E.coli* *	130 counts/100 ml	DWAF, 1996
		Vaal	RU65	UI.3				Contamination of the river with wastewater from upstream Wastewater Treatment Works and also from urban areas has elevated the risk of infection with pathogens to high levels. Communities in the region are dependent on water resources for irrigation, drinking, spiritual rituals, and are at a high risk of human health impacts through direct contact and consumption of water, watered vegetables and fish.		130 counts/100 ml	DWAF, 1996
			RU66	UI.4				Pathogens are present in the system due to upstream activities which is negatively impacting on the fitness for use of the water for domestic use, watering of crops and is a risk to human health. Pathogens in the water should be managed in a D category		130 counts/100 ml	DWAF, 1996
UM	III	Vaal	RU75	EWRS5	C	Quality	Pathogens	Pathogens that affect people and fish are found in this system and must be limited to protect ecosystem service use by people and the population structures of protected Orange-Vaal largemouth yellowfish. Pathogen concentrations should be limited to a D category.	*E.coli* *	130 counts/100 ml	DWAF, 1996

Table 10: Supplementary information for RIVER HABITAT RQOs on Resource Unit Scale.

River Habitat										
IUA	**Class**	**River**	**RU**	**Node**	**REC**	**Component**	**Sub Component**	**Context of the RQO**	**TPC**	**Reference**
UA	II	Vaal	RU8	EWR1	B/C (B)	Habitat	Instream Habitat	The instream habitat is very important for maintaining the ecosystem wellbeing of this NFEPA site but also for real estate and property values and for recreational angling.	EcoStatus (RHAM) ≥B category (≥82) and or maintenance of habitat for indicator species in a ≥B ecological category.	DWA, 2009
			RU10	UB.9	B/C					
UB		Vaal	RU13	UB.2	B	Habitat	Instream Habitat	The instream habitat of this headwater stream is important part of the FEPA and provides habitat for fish	EcoStatus (RHAM) ≥A/B category (≥88) and or maintenance of habitat for indicator species in a ≥A/B ecological category.	DWA, 2009
			RU14	UB.3	C/D			The instream habitat of this headwater stream is important to provide habitat for fish	EcoStatus (RHAM) ≥B category (≥82) and or maintenance of habitat for indicator species in a ≥B ecological category.	DWA, 2009
			RU21	UB.9				The instream habitat is important for protection of this FEPA site which elevates the importance of this ecosystem. Agricultural activities pose a risk to this instream habitat	EcoStatus (RHAM) ≥B category (≥82) and or maintenance of habitat for indicator species in a ≥B ecological category.	DWA, 2009
UC1	II	Vaal	RU22	EWR7	B	Habitat	Instream Habitat	This headwater stream needs to provide a suitable habitat for important fish populations in keeping with its FEPA status.	EcoStatus (RHAM) ≥A/B category (≥88) and or maintenance of habitat for indicator species in a ≥A/B ecological category.	DWA, 2009
		Wilge	RU26	UC1.4	C			The instream habitat is an important ecosystem component and maintains diverse populations of aquatic biota. To maintain these populations, the instream habitat should be protected from upstream and terrestrial stresses	EcoStatus (RHAM) ≥A/B category (≥88) and or maintenance of habitat for indicator species in a ≥A/B ecological category.	DWA, 2009
UC2	II	Vaal	RU35	EWR8	C	Habitat	Instream Habitat	The instream habitat is stressed by sedimentation from dryland agriculture, livestock farming and poor releases of flows from Sterkfontein Dam.	EcoStatus (RHAM) ≥B/C category (≥78) and or maintenance of habitat for indicator species in a ≥B/C ecological category.	DWA, 2009
UC3	II	Vaal	RU40	UC3.4	C/D	Habitat	Instream Habitat	The instream habitat is impacted on by sedimentation from dryland agriculture and livestock farming as well as excessive algal growth associated with nutrient enrichment.	EcoStatus (RHAM) ≥C category (≥62) and or maintenance of habitat for indicator species in a ≥C ecological category	DWA, 2009
UD	III	Liebenbergsvlei	RU45	UD.5	B	Habitat	Instream Habitat	The instream habitat of this river is significantly modified by the interbasin transfer of water from Lesotho.	EcoStatus (RHAM) ≥C/D category (≥78) and or maintenance of habitat for indicator species in a ≥ C/D ecological category.	DWA, 2009

UE	III	Vaal	RU47	UE.2	D	Habitat	Instream Habitat	The instream habitat is negatively impacted by nutrient levels that promote the excessive growth of filamentous algae.	EcoStatus (RHAM) ≥B/C category (≥78) and or maintenance of habitat for indicator species in a ≥B/C ecological category.	DWA, 2009
	III	Vaal	RU50	UE.5	D	Habitat	Instream Habitat	The instream habitat is negatively impacted by nutrient levels that promote the excessive growth of filamentous algae.	EcoStatus (RHAM) ≥C/D category (≥58) and or maintenance of habitat for indicator species in a ≥ C/D ecological category.	DWA, 2009
UF	II	Vaal	RU52	UF.2	C	Habitat	Instream Habitat	The instream habitat for this RU is an ecologically important component of the regional Vaal River ecosystem, and provides habitats which can regularly be accessed by and facilitate recruitment of aquatic biota from the Vaal Dam.	EcoStatus (RHAM) ≥A/B category (≥88) and or maintenance of habitat for indicator species in a ≥ A/B ecological category.	DWA, 2009
UG	II	Vaal	RU58	UG.4	C	Habitat	Instream Habitat	The instream habitat of the rivers in this RU is an important component of the basic ecosystem structure and is necessary for the migration of fish into the upper reaches of the Vaal and Klip Rivers.	EcoStatus (RHAM) ≥B/C category (≥78) and or maintenance of habitat for indicator species in a ≥ B/C ecological category.	DWA, 2009
UH	II	Vaal	RU60	EWR9	B/C	Habitat	Instream Habitat	The instream habitat is a vital component of the structure of the ecosystem and is required to maintain other ecosystem components in particular populations of the protected Orange-Vaal largemouth yellowfish (*Labeobarbus kimberleyensis*) and the Vaal Rock catfish (Austroglanis sclateri).	EcoStatus (RHAM) ≥A/B category (≥88) and or maintenance of habitat for indicator species in a ≥ A/B ecological category.	DWA, 2009
UI	III	Suikerbosrant	RU62	EWR11	D	Habitat	Instream Habitat	The instream habitat is an important component of the ecosystem and supports water quality amelioration, an ecosystems services which Wastewater Treatment Works, mines, urban communities require of the river.	EcoStatus (RHAM) ≥C/D category (≥58) and or maintenance of habitat for indicator species in a ≥ C/D ecological category.	DWA, 2009
		Vaal	RU66	UI.4				Impacts from agriculture, peri-urban and informal communities and general water quality issues are all negatively impacting on the instream habitat, which is an essential component supporting the ecosystem.	EcoStatus (RHAM) ≥C/D category (≥58) and or maintenance of habitat for indicator species in a ≥ C/D ecological category.	DWA, 2009
	III		RU65	UI.3				The instream habitat is important for maintenance of the ecosystem structure and function and provides a water quality amelioration service for Wastewater Treatment Works and mines. Poor Instream habitat state also affects users and health (safety issues) as well as real-estate and property values.	EcoStatus (RHAM) ≥B/C category (≥78) and or maintenance of habitat for indicator species in a ≥ B/C ecological category.	DWA, 2009
UK	III	Vaal	RU68	UK.1	C	Habitat	Instream Habitat	The instream habitat is an important component of the ecosystem that is being impacted by agricultural activities that disturb the riparian zone and impact on the instream ecosystem.	EcoStatus (RHAM) ≥B/C category (≥78) and or maintenance of habitat for indicator species in a ≥ B/C ecological category.	DWA, 2009
UL	III	Mooi	RU71	UL.2	D	Habitat	Instream	The instream habitat is an important component of the	EcoStatus (RHAM) ≥C/D	DWA, 2009

							Habitat	structure and function of the ecosystem and needs to be improved to contribute to the amelioration of poor water quality and contribute to the integrated (EcoStatus) recommended D category being attained.	category (≥58) and or maintenance of habitat for indicator species in a ≥ C/D ecological category.	
		Vaal	RU73	UL.4				The instream habitat is an important component of the structure and function of the ecosystem and needs to be improved particularly in terms of the amount of filamentous algae that is dominating the instream, and to offset the poor water quality that exists.	EcoStatus (RHAM) ≥C category (≥62) and or maintenance of habitat for indicator species in a ≥C ecological category.	DWA, 2009
UM	III	Vaal	RU75	EWRS5	C	Habitat	Instream Habitat	Periodic congestion by water hyacinth and excessive filamentous algae negatively impacts on the instream habitat and affects use of the river by the yellowfish dependent angling industry.	EcoStatus (RHAM) ≥C/D category (≥58) and or maintenance of habitat for indicator species in a ≥ C/D ecological category.	DWA, 2009
UA	II	Vaal	RU8	EWR1	B/C (B)	Habitat	Riparian	The riparian zone is necessary for maintenance of the ecosystem (including the instream habitat) and also for real estate and property values as well as recreation.	VEGRAI Score A/B category	Kleynhans et al, 2007; DWAF, 2008
			RU10	UA.8	B/C					
UB	II	Vaal	RU 21	UB.9	C/D	Habitat	Riparian	Alien vegetation and land use practices are negatively impacting the riparian zone which forms an important part of the overall river ecosystem.	VEGRAI Score B/C category (equivalent to EcoClassification score 70-80)	Kleynhans et al, 2007; DWAF, 2008
UE	III	Vaal	RU47	UE.2	D	Habitat	Riparian	Alteration of the riparian zone is negatively impacting on the river ecosystem.	VEGRAI Score C/D category	Kleynhans et al, 2007; DWAF, 2008
UF	II	Vaal	RU 52	UF.2	C	Habitat	Riparian	The riparian zone buffers the river from terrestrial land use activities	VEGRAI Score A/B category	Kleynhans et al, 2007; DWAF, 2008
UK	III	Vaal	RU68	UK.1	C	Habitat	Riparian	Agricultural activities need to be separated from the river ecosystem by establishment of a strong riparian zone buffer.	VEGRAI Score B/C category (equivalent to EcoClassification score 70-80)	Kleynhans et al, 2007; DWAF, 2008
UM	III	Vaal	RU 75	EWR5	C	Habitat	Riparian	Parts of the riparian zone of this river are infested with excessive alien trees which negatively impact on the stability of the river ecosystem as well as on users who value the aesthetics of the river.	VEGRAI Score B/C category (equivalent to EcoClassification score 70-80)	Kleynhans et al, 2007; DWAF, 2008

Table 11: Supplementary information for RIVER BIOTA RQOs on Resource Unit Scale.

River Biota										
IUA	**Class**	**River**	**RU**	**Node**	**REC**	**Component**	**Sub Component**	**Context of the RQO**	**TPC**	**Reference**
UA	II	Vaal	RU8	EWR1	B/C (B)	Biota	Fish	Conditions need to be maintained so that there is re-establishment of representative fish populations where tolerant species in particular should prevail, not only for the sake of the ecosystem but also for community use. A viable fish population is an important aspect of the ecosystem and the NFEPA site. The fish community needs to be maintained in a B category and the protected Orange-Vaal largemouth yellowfish (*Labeobarbus*	FRAI Score between 85-95 (category A/B category)	Moulton et al, 2002
			RU10	UA.8	B/C				A/B category	

							kimberleyensis) population must remain viable.		
UB	II	Vaal	RU13 RU14	UB.2 UB.3	B	Biota	Fish	Conditions need to be maintained so that there is re-establishment of representative fish populations where tolerant species in particular should prevail, not only for the sake of the ecosystem but also for community use. A viable fish population is an important aspect of the ecosystem and the NFEPA site. The fish community needs to be maintained in a B category and the population must remain viable for species including Goldie barb (*Barbus pallidus*) and Chubby head barb (*Barbus anoplus*) which are FEPA indicators.	A/B category	Moulton et al, 2002
UC1	II	Vaal	RU22	EWR7	A/B	Biota	Fish	Conditions need to be maintained so that there is re-establishment of representative fish populations where tolerant species in particular should prevail, not only for the sake of the ecosystem but also for community use. A viable fish population is an important aspect of the ecosystem and the NFEPA site. The fish community needs to be maintained in a B category and the population must remain viable for species including Goldie barb (*Barbus pallidus*) and Chubby head barb (*Barbus anoplus*) which are FEPA indicators.	FRAI Score between 85-90 (category A/B category) B category A/B category	Moulton et al, 2002 Moulton et al, 2002 Moulton et al, 2002
UC2	II	Vaal	RU35	EWR8	C	Biota	Fish	There is a threat of genetic contamination of local cyprinids by in the upper Wilge River from contaminations in the Sterkfontein Dam. The local genetic integrity of fish must be protected. This resource unit provides an ecologically important refugia for species which are representative of populations from the Upper Vaal catchment	A/B category	Moulton et al, 2002
UE	III	Vaal	RU50	UE.5	D	Biota	Fish	Conditions need to be maintained so that there is re-establishment of representative fish populations where tolerant species in particular should prevail, not only for the sake of the ecosystem but also for community use. A viable fish population is an important aspect of the ecosystem and the NFEPA site. The fish community needs to be maintained in a B category and the protected Orange-Vaal largemouth yellowfish (*Labeobarbus kimberleyensis*) population must remain viable.	FRAI Score ≥60 (≥C category) C category	Moulton et al, 2002
UF	II	Vaal	RU52	UF.2	C	Biota	Fish	Populations of fish in this river, especially the yellowfishes, form an important part of a sustainable population in the Vaal Dam. The seasonal community structure of the Klip River in this RU must to be improved to a B category and should include a high recruitment of cyprinid young into the Klip River during high flow periods. The fish community needs to be maintained in a B category and the protected Orange-Vaal largemouth yellowfish (*Labeobarbus kimberleyensis*) population and the Orange-Vaal smallmouth yellowfish (*Labeobarbus aeneus*) must remain viable.	FRAI Score 85-95 (A/B category)	Moulton et al, 2002

UG	II	Vaal	RU58	UG.4	C	Biota	Fish	Populations of fish in this river, especially the *Labeobarbus* spp. *and Labeo* spp., form an important part of a sustainable population. The fish community needs to be maintained in a C category and the protected Orange-Vaal largemouth yellowfish (*Labeobarbus kimberleyensis*) population and the Orange-Vaal smallmouth yellowfish (*Labeobarbus aeneus*) must remain viable.	B category	Kleynhans, 2007
UH	II	Vaal	RU60	EWR9	B/C	Biota	Fish	Populations of fish in this river, especially the Labeobarbus spp. and *Labeo spp.*, form an important part of a sustainable population. The fish community needs to be maintained in a C category and the protected Orange-Vaal largemouth yellowfish (*Labeobarbus kimberleyensis*) and Vaal River rock catfish (*Austroglanis sclateri*) must remain viable.	FRAI Score between 70-85 (category B/C)	Moulton et al, 2002
UI	III	Suikerbosrant	RU62	EWR11	D	Biota	Fish	Fish in this river are used by communities as food but there is potential that accumulation of toxics could pose a high risk to human health. The accumulation of toxins in fish tissue should be maintained at a D category level so as not to pose a high risk to consumers. The health of indicator fish populations in the RU should also be maintained so that the viability of the indicator species populations is not threatened.	FRAI Score between 50-70 (category C/D)	Kleynhans, 2007
		Vaal	RU65	UI.3						Kleynhans, 2007
UK	III	Vaal	RU68	UK.1	C	Biota	Fish	This tributary is an important refuge for fish that cannot migrate over the Barrage and potentially provides important spawning habitats for many migrating Vaal River cyprinids, thus contributing to the recruitment of cyprinids in the Vaal River. The fish communities should be maintained in a C/D category, and the adequate requirement of cyprinids must be evident during high flow periods.	FRAI Score between 70-80 (C category)	Kleynhans, 2007
UM	III	Vaal	RU75	EWRS5	C	Biota	Fish	Populations of fish in this river, especially the Labeobarbus spp. and *Labeo* spp., form an important part of a sustainable population. The fish community needs to be maintained in a C category and the protected Orange-Vaal largemouth yellowfish (*Labeobarbus kimberleyensis*) population and the Orange-Vaal smallmouth yellowfish (*Labeobarbus aeneus*) must remain viable.	FRAI Score between 70-85 (category B/C)	Moulton II et al, 2002
									B/C category (equivalent to EcoClassification score 70-80)	
UB	II	Vaal	RU14	UB.3	B	Biota	Aquatic invertebrates	Invertebrates are good ecological indicators of water quality, quantity and habitat state.	MARAI Score A/B category	Taylor et al, 2005; DWAF, 2008
			RU21	UB.9	C/D					
UC1	II	Wilge	RU26	UC1.4	C	Biota	Aquatic invertebrates	The local invertebrate communities contain a high diversity of species. They are also good indicators of the health of the system.	MARAI Score A/B category	Taylor et al, 2005; DWAF, 2008
UC2		Vaal	RU35	EWR8				Macroinvertebrates are a good indicator of water quality and instream habitat.	MARAI Score B/C category (equivalent to EcoClassification score 70-80)	Taylor et al, 2005; DWAF, 2008
UC3	II	Vaal	RU40	UC3.4	C/D	Biota	Aquatic invertebrates	Macroinvertebrates are a good indicator of water quality and instream habitat	MARAI Score C category	Taylor et al, 2005; DWAF, 2008

UE			RU47	UE.2	D			Invertebrates are good indicators of the state of a site especially of its water quality,	MARAI Score C/D category	Taylor et al, 2005; DWAF, 2008
UH	II	Vaal	RU60	EWR9	B/C	Biota	Aquatic invertebrates	Invertebrates are an important component of the ecosystem and the food web, as well as being a good indicator of the state of the water quantity, quality and habitat.	MARAI Score B category	Taylor et al, 2005; DWAF, 2008
UI	III	Suikerbosrant	RU62	EWR11	D	Biota	Aquatic invertebrates	Invertebrates are an important component of the ecosystem and are good indicators of water quality, quantity and habitat.	MARAI Score C/D category	Taylor et al, 2005; DWAF, 2008
		Vaal	RU65	UI.3						
		Vaal	RU66	UI.4				Aquatic invertebrates are an important component of the ecosystem and are indicators of water quality, quantity and habitat condition.	MARAI Score C category	
UJ	III	Vaal	RU67	UJ.1	D	Biota	Aquatic invertebrates	Aquatic invertebrates are an important component of the ecosystem and act as indicators of water quality, quantity and habitat condition.	MARAI Score C/D category	Taylor et al, 2005; DWAF, 2008
UK	III	Vaal	RU68	UK.1	C	Biota	Aquatic invertebrates	Aquatic invertebrates are an important component of the ecosystem and act as indicators of water quality, quantity and habitat condition.	MARAI Score B/C category (equivalent to EcoClassification score 70-80)	Taylor et al, 2005; DWAF, 2008
UL	III	Mooi	RU71	UL.2	D	Biota	Aquatic invertebrates	Aquatic invertebrates are an important component of the ecosystem and act as indicators of water quality, quantity and habitat condition.	MARAI Score C/D category	Taylor et al, 2005; DWAF, 2008
		Vaal	RU73	UL.4						
UE	III	Vaal	RU47 RU50	UE.2 UE.5	D	Biota	Diatoms	Diatoms reflect the presence of elevated nutrient concentrations and also toxic contaminants.	SPI score C/D category	Taylor et al. 2005. DWAF. 2008.
UH	III	Suikerbosrant	RU62	EWR11	D	Biota	Diatoms	Diatoms are good indicators of the presence of toxics in the water	SPI score C/D category	Taylor et al. 2005. DWAF. 2008.
UI	III	Vaal	RU66	UI.4	D	Biota	Diatoms	Diatoms are excellent indicators of water quality especially metals and other toxics.	SPI score C category	Taylor et al, 2005; DWAF, 2008
UJ	III	Vaal	RU67	UJ.1	D	Biota	Diatoms	Diatoms are excellent indicators of water quality especially metals and other toxics.	SPI score C/D category	Taylor et al, 2005; DWAF, 2008
UL	III	Mooi	RU71	UL.2	D	Biota	Diatoms	Diatoms are excellent indicators of water quality especially metals and other toxics.	SPI score C/D category	Taylor et al, 2005; DWAF, 2008
		Vaal	RU73	UL.4						
	III	Vaal	RU73	UL.4	D	Biota	Periphyton	Excessive periphyton is an indicator of excessive nutrient but also of an instream habitat that is compromised by nutrients.	SPI Score C/D category	Taylor et al, 2007a, b, c, d; Harding and Taylor, 2011
UM	III	Vaal	RU75	EWR5	C	Biota	Periphyton	Periphyton algae, in particular excessive filamentous algae, are an indication of excessive nutrient concentrations and a poor instream habitat states.	Substrate free of periphyton (This is as stated in the RQO)	*E.g.: The rapid field-based method of: Stevenson & Balls Accessed May 2014: http://water.epa.gov/scitech/monitoring/rsl/bioassessment/ch06main.cfm*

4.2 WETLAND RESOURCE QUALITY OBJECTIVES AND NUMERICAL LIMITS FOR THE UPPER VAAL WMA

The outcomes of the RQO and NL determination of the sub-components and indicators for the wetland component of the RQO determination study for the Upper Vaal WMA, including a summary of additional supplementary information are provided as follows (Figure 3):

- RQOs for regional wetland in the Upper Vaal WMA are presented in Table 12.
- RQOs for the wetland water quantity component are presented in Table 13.
- RQOs for the wetland water quality component are presented in Table 14.
- RQOs for the wetland water habitat component are presented in Table 15.
- RQOs for the wetland water biota component are presented in Table 16.
- Supplementary information for the wetland water quantity component is presented in Table 17.
- Supplementary information for the wetland water quality component is presented in Table 18.
- Supplementary information for the wetland water habitat component is presented in Table 19.
- Supplementary information for the wetland water biota component is presented in Table 20.

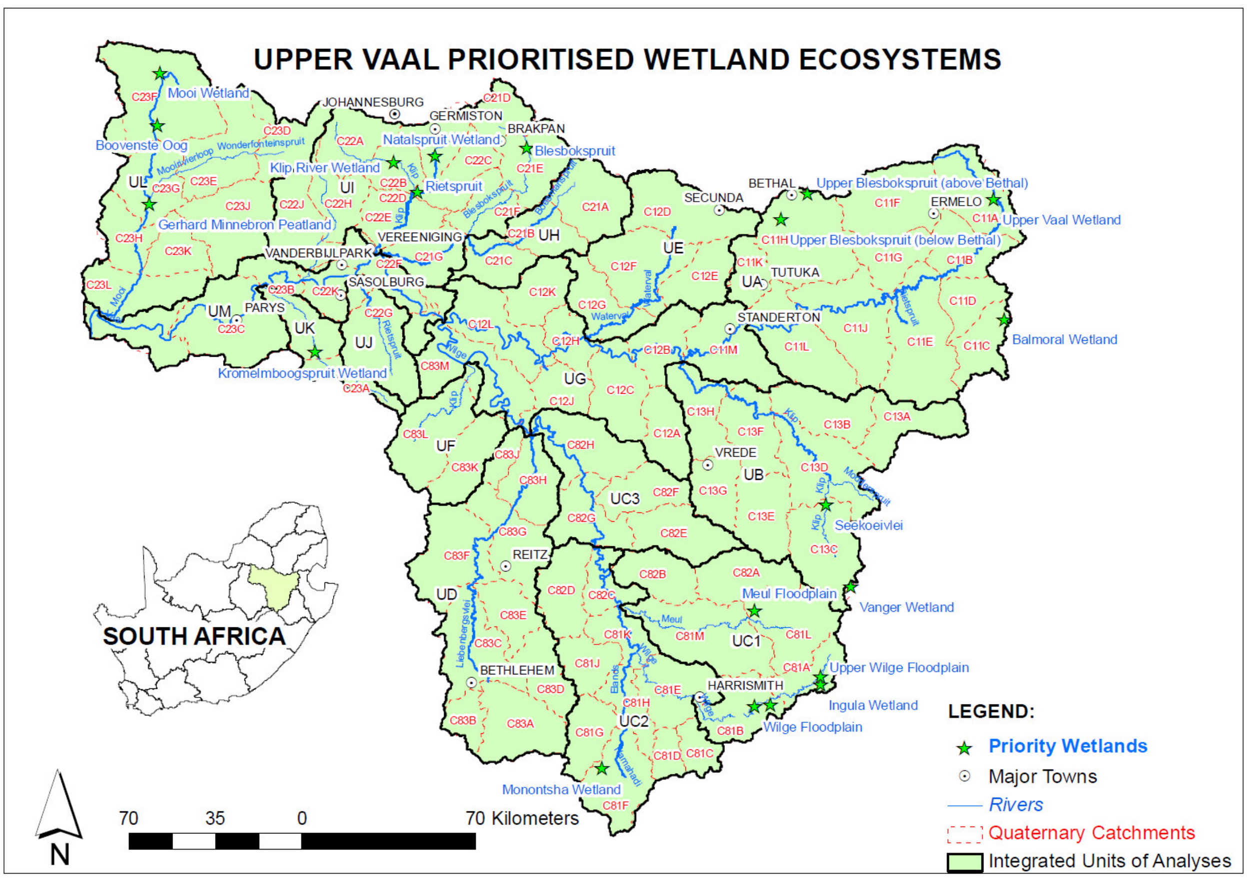

Figure 3: Priority wetland ecosystems considered in the study within Integrated Units of Analyses considered in the study. Quaternary catchments and major rivers also presented.

4.2.1 WETLAND RESOURCE QUALITY OBJECTIVES AND NUMERICAL LIMITS TABLES

Table 12: RQOs for REGIONAL WETLANDS in the Upper Vaal WMA

Regional Wetlands		
RQO	**Indicator/ measure**	**Numerical Limits**
There must be no net loss in wetland functioning within the IUA.	Condition of wetlands in the IUA. IUA level desktop wetland assessment supplemented with a site-level assessment of a subset of indicator wetlands within the IUA. This assessment should be repeated every 5 years.	Hectare equivalents of wetlands in the IUA are unknown. An assessment of the current condition is required. The numerical criteria should equate to the hectare equivalents of the current condition of wetlands.
Validated wetland FEPAs in a good condition (equivalent to an A-B ecological category) must be maintained whilst wetland FEPAs in a modified condition (equivalent to a C-F ecological category) must be improved to their best attainable ecological condition.	Condition of validated wetland FEPAs in the IUA. IUA level desktop assessment of validated wetland FEPAs supplemented with a site-level assessment of a subset of these wetlands within the IUA. This assessment should be repeated every 5 years.	Hectare equivalents of wetlands in the IUA are unknown. An assessment of the current condition is required. The numerical criteria should equate to the hectare equivalents of the current condition of wetlands.
Landuses associated with validated FEPA wetland clusters must be controlled to maintain hydrological linkages that maintain connectivity between wetlands.	Landuse associated with validated FEPA wetland clusters. Desktop assessment of landuse compatibility within a 500m buffer of validated FEPA wetland clusters. This assessment should be repeated every 5 years.	Hectare equivalents of wetlands in the IUA are unknown. An assessment of the current condition is required. The numerical criteria should equate to the hectare equivalents of the current condition of wetlands.
Wetland FEPAs must be formally protected through appropriate protection mechanisms to secure key biodiversity values and meet wetland conservation targets.	Proportion of validated wetland FEPAs that are formally protected. IUA level assessment of protection status based on available protected area coverage's. This assessment should be repeated every 5 years.	Hectare equivalents of wetlands in the IUA are unknown. An assessment of the current condition is required. The numerical criteria should equate to the hectare equivalents of the current condition of wetlands.

Table 13: RQOs for WETLAND WATER QUANTITY in priority RUs in the Upper Vaal WMA

Wetland Water Quantity							
IUA	**Wetlands**	**RU**	**Component**	**Sub Component**	**RQO**	**Indicator/ measure**	**Numerical Limits**
UA UC1 UK UL	1.1 Upper Vaal 1.3 Upper Blesbokspruit (downstream of Bethal) 1.4 Balmoral 3.5 Meul 13.1 Kromelmboogspruit 14.2 Mooi	RU2 RU9 RU3 RU25 RU68 RU69	Quantity	Water distribution and retention patterns	Water distribution and retention patterns within the wetland must be maintained to avoid the loss of wetland hydrological function.	Water distribution & retention patterns score. Water distribution and retention assessment, hydrology module of Wet-Health (Level 2). Every 3-5 years	Present condition is unknown. An assessment of the current condition is required. The numerical criteria should equate to 10% less than the PES score determined.
UI	11.3 Rietspruit	RU63					Water distribution & retention pattern score / Health Category = D (Largely altered: Overall impact score = 4 - 5.9)
UL	14.1 Boovenste Oog	RU69					Water distribution & retention pattern score / Health Category = B (Largely natural: Overall impact score = 1 - 1.9)
UB UC2 UL	2.2 Seekoeivlei 4.1 Monontsha 14.3 Gerhard Minnebron	RU13 and RU14 RU29 RU73	Quantity	Wetland hydrology	The quantity and timing of inputs, and the distribution and retention patterns within the wetland must be maintained to avoid the loss of wetland hydrological function.	Wetland hydrology score. Hydrology module of Wet-Health (Level 2). Every 3-5 years	Present Hydrology State Category = C (Moderately altered: Overall impact score = 2 - 3.9)
UI	11.1 Blesbokspruit 11.2 Klip River	RU62 RU64					Present Hydrology State Category = D (Largely altered: Overall impact score = 4 - 5.9)
UC1	3.2 Ingula	RU22	Quantity	Water inputs	The quantity and timing of inputs, and the distribution and retention patterns within the wetland must be maintained to avoid the loss of wetland hydrological function.	Water inputs, and water distribution & retention patterns within the wetland according to wetland hydrology score. Hydrology module of Wet-Health (Level 2). Every 3-5 years	Present Vegetation State Category = A/B (Natural to largely natural: Overall impact score = 0 - 1.9)
UL	14.1 Boovenste Oog	RU69	Quantity	Water Inputs	Water distribution and retention patterns within the wetland must be maintained to avoid the loss of wetland hydrological function.	Water inputs, and water distribution & retention patterns within the wetland according to wetland hydrology score. Hydrology module of Wet-Health (Level 2). Every 3-5 years	Present condition is unknown. An assessment of the current condition is required.

Table 14: RQOs for WETLAND WATER QUALITY in priority RUs in the Upper Vaal WMA

Wetland Water Quality								
IUA	**Wetlands**	**RU**	**Component**	**Sub Component**	**RQO**	**Indicator/ measure**	**Numerical Limits**	**95th %ile**
UB	2.2 Seekoeivlei	RU 13 and 14	Quality	Nutrients	The nutrient concentrations at the top end of the wetland must be maintained at a level that does not pose a threat to biodiversity and long-term wetland functioning (B/C).	TIN *	≤ 1.00 mg/L N	0.2
						Phosphate (PO_4) *	≤ 0.025 mg/L P	0.1
UC2	4.1 Monontsha	RU29	Quality	Nutrients	The nutrient concentrations at the top end of the wetland must be maintained at a level that does not pose a threat to biodiversity and long-term wetland functioning (B/C).	TIN *	≤ 1.00 mg/L N	1.1
UI	11.1 Blesbokspruit	RU62				Phosphate (PO_4) *	≤ 0.025 mg/L P	0.5
UI	11.1 Blesbokspruit	RU62	Quality	Salts	The salts concentrations at the top end of the wetland must be maintained at a level that does not pose a threat to biodiversity and long-term wetland functioning (B/C).	Electrical conductivity *	≤ 85 mS/m	135
UL	14.3 Gerhard Minnebron	RU73	Quality	Salts	Salt levels thus need to be reduced in order to prevent further decomposition of the peat (B).	Electrical conductivity *	≤ 85 mS/m	71
UB	2.2 Seekoeivlei	RU 13 and 15	Quality	System variables	Sediment loads must be maintained at a level that does not pose a threat to biodiversity and long-term wetland functioning (B/C).	Turbidity *	≤ 10.0 NTU	No data
UI	11.1 Blesbokspruit	RU62	Quality	Toxins	Maintain the levels of toxic contaminants at concentrations acceptable for the ecosystem and users (B).	F *	≤ 2.5 mg/L	0.455
						Al *	≤ 105 µg/L	No data
						As *	≤ 95 µg/L	No data
						Cd hard *	≤ 3.0 µg/L	No data
						Cr(VI) *	≤ 121 µg/L	No data
						Cu hard *	≤ 6.0 µg/L	No data
						Hg *	≤ 0.97 µg/L	No data
						Mn *	≤ 990 µg/L	No data
						Pb hard *	≤ 9.50 µg/L	No data
						Se *	≤ 22 µg/L	No data
						Zn *	≤ 25 µg/L	No data
						Chlorine *	≤ 3.1 µg/L free Cl	No data
						Endosulfan *	≤ 0.130 µg/L	No data
						Atrazine *	≤ 79 µg/L	No data

**as per standard methods of America Water Works Association (www.awwa.org)*

Table 15: RQOs for WETLAND HABITAT in priority RUs in the Upper Vaal WMA

Wetland Habitat							
IUA	**Wetlands**	**RU**	**Component**	**Sub Component**	**RQO**	**Indicator/ measure**	**Numerical Limits**
UA UC1 UI UK UL	1.1 Upper Vaal 1.2 Upper Blesbokspruit (upstream of Bethal) 1.3 Upper Blesbokspruit (downstream of Bethal) 1.4 Balmoral 3.5 Meul 11.4 Natalspruit 13.1 Kromelmboogspruit 14.1 Boovenste Oog 14.2 Mooi	RU2 RU9 RU3 RU25 RU63 RU68 RU69	Habitat	Wetland Vegetation	The wetland vegetation must be maintained to ensure that the ecosystem structure and function are maintained.	Wetland vegetation score. Vegetation module of Wet-Health (Level 2). Every 3-5 years	Present condition is unknown. An assessment of the current condition is required. The numerical criteria should equate to 10% less than the PES score determined.
UB	2.1 Vanger	RU12					Present Vegetation State Category = A (Natural condition: Overall impact score = 0 - 0.9)
UC1	3.2 Ingula 3.3 Wilge 3.4 Upper Wilge	RU22 RU23 RU22					Present Vegetation State Category = A/B (Natural to largely natural: Overall impact score = 0 - 1.9)
	3.1 Murphy's Rust	RU23					Present Vegetation State Category = B (Largely natural: Overall impact score = 1 - 1.9)
UB UC2	2.2 Seekoeivlei 4.1 Monontsha	RU13 and RU14 RU29					Present Vegetation State Category = C (Moderately altered: Overall impact score = 2 - 3.9)
UI	11.1 Blesbokspruit 11.2 Klip River 11.3 Rietspruit	RU62 RU64 RU63					Present Vegetation State Category = D (Largely altered: Overall impact score = 4 - 5.9)
UA UC1 UI UL	1.1 Upper Vaal 1.2 Upper Blesbokspruit (upstream of Bethal) 1.3 Upper Blesbokspruit (downstream of Bethal) 1.4 Balmoral 3.5 Meul 11.3 Rietspruit 11.4 Natalspruit 14.1 Boovenste Oog	RU2 RU9 RU3 RU25 RU63 RU69	Habitat	Wetland Geomorphology	The wetland geomorphology must be maintained to ensure that the ecosystem structure and function are maintained.	Wetland geomorphology score. Geomorphology module of Wet-Health (Level 2). Every 3-5 years	Present condition is unknown. An assessment of the current condition is required. The numerical criteria should equate to 10% less than the PES score determined.
UC1	3.2 Ingula; 3.3 Wilge; 3.4 Upper Wilge	RU22 RU23 RU22					Present Geomorphology State Category = A/B (Natural to largely natural: Overall impact score = 0 - 1.9)
UB UC2 UL	2.2 Seekoeivlei 4.1 Monontsha 14.3 Gerhard Minnebron	RU13 and RU14 RU29 RU73					Present Geomorphology State Category = C (Moderately altered: Overall impact score = 2 - 3.9)
UI	11.1 Blesbokspruit; 11.2 Klip River	RU62 RU64					Present Geomorphology State Category = D

							(Largely altered: Overall impact score = 4 - 5.9)

Table 16: RQOs for WETLAND BIOTA in priority RUs in the Upper Vaal WMA

Wetland Biota							
IUA	**Wetlands**	**RU**	**Component**	**Sub Component**	**RQO**	**Indicator/ measure**	**Numerical Limits**
UB	2.2 Seekoeivlei	RU13 and RU14	Biota	Biodiversity	Overall biodiversity must be maintained and viable populations of Red Data species must be maintained.	Presence of Serval, Little bittern, Yellowbilled Stork, Wattled Crane, Blue Crane, Grey Crowned Crane, Black Stork, Grass Owl, *Nerine bowdenii*, *Nerine platypetala*, *Gladiolus robertsoniae*, and *Crassula tuberella*. Presence of adequate White-winged Flufftail and Rock Barble habitat.	Reporting rates (RR)* in RU 13 and 14: Crowned crane RR 30.0-38.3%; Blue cranes RR 10.0-16.1%; Wattled crane RR 4.3-7.3%; Little bittern RR 6.09-7.46%; Yellowbilled Stork RR <3.85%; Grass Owl RR <2.78%. Presence of adequate habitat for Serval, White-winged Flufftail , Little bittern, Yellowbilled Stork, Wattled Crane, Blue Crane, Grey Crowned Crane, Black Stork, Grass Owl, *Nerine bowdenii*, *Nerine platypetala*, *Gladiolus robertsoniae*, *Crassula tuberella*.
UB	2.1 Vanger	RU12	Biota	Birds	Protection of White-winged Flufftail habitat.	Presence of adequate White-winged Flufftail habitat**	Presence of only one specimen will be adequate, but favourable habitat will be the main indicator.
UC1	3.1 Murphy's Rust	RU23	Biota	Birds	The populations of Grey Crowned Cranes must be maintained at least at current levels to meet conservation targets.	Presence of endangered bird: Grey Crowned Crane. Reporting Rate, or total numbers counted annually**	Reporting rates (RR)* in RU 23: RR 59.7-77.7% Crowned crane.
	3.2 Ingula	RU22			Populations of White-winged Flufftails, Grey Crowned Cranes, Blue Cranes, and Wattled Cranes must be maintained at least at current levels to meet conservation targets.	Presence of endangered birds: White-winged Flufftail, Grey Crowned Crane, Blue Crane, and Wattled Crane. Reporting Rate, or total numbers counted annually.**	Reporting rates (RR)* in RU 22: Crowned crane RR 11.1-18.2%; Blue cranes RR 5.5-11.1%; Wattled crane RR 28.5-40.9%. Presence of adequate White-winged Flufftail habitat.
	3.4 Upper Wilge					Presence of endangered birds: White-winged Flufftail, Grey Crowned Crane, Blue Crane, and Wattled Crane. Reporting Rate, or total numbers counted annually.**	Reporting rates (RR)* in RU 22: Crowned crane RR 11.1-18.2%; Blue cranes RR 5.5-11.1%; Wattled crane RR 28.5-40.9%. Presence of adequate White-winged Flufftail habitat.
UI	11.1 Blesbokspruit	RU62	Biota	Birds	Populations of waterfowl, Lesser Flamingos, and Greater Flamingos must be maintained at least at current levels to meet conservation targets.	Number of observed Lesser Flamingos *(Phoenicopterus minor)* and Greater Flamingos *(Phoenicopterus ruber)* present annually. Reporting Rate, or total numbers counted annually**	Reporting rates (RR)* in RU 62: Greater flamingo, RR 36.3-47.3%; Lesser flamingo, RR 6.8-11.1%.
UC1	3.4 Upper Wilge (Upper Bedford Wetland)	RU22	Biota	Fish	The genetically unique population of Barbus sp. (to be determined) in the upper Bedford Wetland must to be maintained in a viable state.	Maintain barrier to isolate upper reach of Bedford Wetland.	Maintain barrier to restrict access to upper Bedford Wetland by non-endemic fishes.
						State of critical instream habitat for the local populations of genetically unique barb (*Barbus sp.*) according to Rapid Habitat Assessment Method (RHAM).	Maintenance of critical habitat for indicator species in a natural state (equivalent to ≥A category (equivalent to EcoClassification score >90)).

UL	14.1 Boovenste Oog	RU69	Biota	Fish	The unknown population of what was believed to be the Goldie Barb *Barbus sp.* (to be determined) in the wetland must be maintained	State of critical instream habitat for the local populations of *Barbus sp.* according to Rapid Habitat Assessment Method (RHAM).	Maintenance of critical habitat for indicator species in a natural state (equivalent to ≥A category (equivalent to EcoClassification score >90)).
*** Data obtained from bird clubs and conservation authorities. Measured as per methods prescribed by Avian Demography Unit, Department of Statistical Sciences University of Cape Town or Birdlife SA.*							

4.2.2 SUPPLEMENTARY INFORMATION FOR THE WETLAND RESOURCE QUALITY OBJECTIVES AND NUMERICAL LIMITS TABLES

Table 17: Supplementary for WETLAND QUANTITY RQOs on ecosystem scale.

Wetland Water Quantity							
IUA	**Wetlands**	**RU**	**Component**	**Sub Component**	**Context of the RQO**	**TPC**	**Reference**
UA UC1 UK UL	1.1 Upper Vaal 1.3 Upper Blesbokspruit (downstream of Bethal) 1.4 Balmoral 3.5 Meul 13.1 Kromelmboogspruit 14.2 Mooi	RU2 RU9 RU3 RU25 RU68 RU69	Quantity	Water distribution and retention patterns	The integrity of wetland hydrology can be affected by modifications taking place within the wetland that alter the distribution and retention patterns of water. The water distribution and retention patterns must be maintained.	Given that the present condition is unknown, the TPC cannot be determined. Once the numerical criteria has been determined the TPC should be set at 30% more than the lowest score for the present condition score.	Macfarlane et al, 2007
UI	11.3 Rietspruit	RU63			The hydrological regime of the wetland has been affected by urban and agricultural inputs, which have changed water inputs and the pattern of flood peaks considerably. These alterations in the catchment have affected the distribution and retention patterns within the wetland system itself. Flood attenuation is an important service, thus distribution and retention patterns must be maintained in a D Ecological Category (largely modified condition).	Impact score = 5.33	
UL	14.1 Boovenste Oog	RU69			The current excavated canals undermine conservation value. Current water distribution and retention patterns must therefore be improved. Infilling of some of the excavated canals must be undertaken to improve the Ecological Category to a B.	Impact score = 1.63	
UB UC2 UL	2.2 Seekoeivlei 4.1 Monontsha 14.3 Gerhard Minnebron	RU13 and RU14 RU29 RU73	Quantity	Wetland hydrology	An application to prospect for coal to gas processing, which may include the wetlands catchment, has been lodged. This could potentially have a negative impact on the wetlands hydrology, which in turn would affect the quantity and timing of inputs, and thus the distribution and retention patterns within the wetland system itself. Wetland hydrology must thus be maintained in a C Ecological Category (moderately modified condition) or better.	Impact score = 3.33	Macfarlane et al, 2007

UI	11.1 Blesbokspruit 11.2 Klip River	RU62 RU64			The wetlands hydrology has been altered through increased baseflows (due to mine dewatering) and through infrastructure (roads and rail crossings) which have caused backflooding and changing of large areas of wetland from seasonally to permanently flooded. Additional increases to baseflows are proposed. The timing and duration of elevated flows must be managed to minimise further degradation to the ecosystem structure and function. The wetland hydrology must thus be maintained at a D Ecological Category (largely modified condition).	Impact score = 5.33	Macfarlane et al, 2007
UC1	3.2 Ingula	RU22	Quantity	Water inputs	The wetland is directly downstream of the Braamhoek pump storage scheme. The integrity of the wetlands ecosystem is reliant on the release of ecological flow requirements from the dam. The ecological flow requirements must be maintained.	Impact score = 1.33	Macfarlane et al, 2007
UL	14.1 Boovenste Oog	RU69	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 the area. Current water inputs must therefore be maintained.	Given that the present condition is unknown, the TPC cannot be determined. Once the numerical criteria has been determined the TPC should be set at 30% more than the lowest score for the present condition score.	Macfarlane et al, 2007

Table 18: Supplementary information for WETLAND QUALITY RQOs on ecosystem scale.

Wetland Water Quality								
IUA	**Wetlands**	**RU**	**Component**	**Sub Component**	**Context of the RQO**		**TPC**	**Reference**
UB	2.2 Seekoeivlei	RU 13 and 14	Quality	Nutrients	High concentrations of nutrients are placing stress on the top end of the wetland. These nutrients are associated with the Memel WWTWs and solid waste dumpsite. The nutrient concentrations at the top end of the wetland must be maintained at a level that does not pose a threat to biodiversity and long-term wetland functioning.	TIN *	0.85 mg/L N	DWAF, 2008
						Phosphate (PO_4) *	0.020 mg/L P	
UC2	4.1 Monontsha	RU29	Quality	Nutrients	Nutrients entering the wetland are largely the result of overflows or spills from the sewage pipeline running through the wetland, pit latrines located either in or in close proximity to the wetland, and solid waste entering the system. The high concentrations of nutrients are placing stress on the ecosystem and reducing fitness for use. The nutrient concentrations thus need to be improved to a D Ecological Category (largely modified condition).	TIN *	0.85 mg/L N	DWAF, 2008
UI	11.1 Blesbokspruit	RU62				Phosphate (PO_4) *	0.020 mg/L P	
UI	11.1 Blesbokspruit	RU62	Quality	Salts	Elevated salinity is negatively affecting water quality for irrigated agriculture which includes informal and peri-urban communities that water vegetables grown in the floodplain. Salts need to be improved to a D category.	Electrical conductivity *	70 mS/m	DWAF, 2008
UL	14.3 Gerhard Minnebron	RU73	Quality	Salts	Salt loads associated with acid mine drainage impacts from upstream mining activities are of concern for the ecosystem and also for downstream users. The salt concentrations should be managed to a D category.	Electrical conductivity *	70 mS/m	DWAF, 2008
UB	2.2 Seekoeivlei	RU 13 and 15	Quality	System variables	Sedimentation resulting from an increase in informal settlements in the Memel area is placing a stress on the top end of the wetland. Sediment loads must be maintained at a level that does not	Turbidity *	5.5 NTU	DWAF, 2008

					pose a threat to biodiversity and long-term wetland functioning.			
UI	11.1 Blesbokspruit	RU62	Quality	Toxins	Upstream activities are releasing toxic substances that may pose a high risk to human and ecosystem health. . The ecosystem and human health should not be subjected to a high health risk through contact and consumption of watered vegetables and fish. Toxin loads should be maintained in a D category levels where they do not pose a high risk to the ecosystem wellbeing or to human health.	F *	2.3 mg/L	DWAF, 2008
						Al *	84 µg/L	
						As *	76 µg/L	
						Cd hard *	2.3 µg/L	
						Cr(VI) *	94 µg/L	
						Cu hard *	5.4 µg/L	
						Hg *	0.75 µg/L	
						Mn *	835 µg/L	
						Pb hard *	7.63 µg/L	
						Se *	18 µg/L	
						Zn *	20 µg/L	
						Chlorine *	2.4 µg/L free Cl	
						Endosulfan *	0.103 µg/L	
						Atrazine *	64 µg/L	

Table 19: Supplementary information for WETLAND HABITAT RQOs on ecosystem scale.

Wetland Habitat							
IUA	**Wetlands**	**RU**	**Component**	**Sub Component**	**Context of the RQO**	**TPC**	**Reference**
UA UC1 UI UK UL	1.1 Upper Vaal 1.2 Upper Blesbokspruit (upstream of Bethal) 1.3 Upper Blesbokspruit (downstream of Bethal) 1.4 Balmoral 3.5 Meul 11.4 Natalspruit 13.1 Kromelmboogspruit 14.1 Boovenste Oog 14.2 Mooi	RU2 RU9 RU3 RU25 RU63 RU68 RU69	Habitat	Wetland Vegetation	The Upper Vaal wetland is a wetland FEPA that plays a substantial hydrological and ecological role in the natural functioning of the Vaal River. Management of the wetland is important to ensure that the ecosystem structure and function are maintained and that there is ongoing supply of ecosystem services, particularly regulating and supporting services for the downstream river FEPA. The wetland vegetation must be maintained.	Given that the present condition is unknown, the TPC cannot be determined. Once the numerical criteria has been determined the TPC should be set at 30% more than the lowest score for the relevant Present Vegetation State Category.	Macfarlane et al, 2007
UB	2.1 Vanger	RU12			The wetland is considered to be in a natural condition as there are very few alterations in the catchment and the wetland itself. The wetland also provides suitable habitat for a Red Data bird species, White-winged Flufftail (*Sarothrura ayresi*). The wetland vegetation must therefore be maintained in an A Ecological Category (natural condition).	Impact score = 0.63	Macfarlane et al, 2007
UC1	3.2 Ingula 3.3 Wilge	RU22			The wetland habitat provides an important template	Impact score = 1.33	Macfarlane

	3.4 Upper Wilge	RU23 RU22			for the ecosystem, so if this component is maintained it will be beneficial for other responder components including mammals, birds and amphibians/reptiles. Management of the wetland vegetation and geomorphology is important to ensure that the ecosystem structure and function of this wetland FEPA are maintained. The wetland also provides suitable habitat for a number of Red Data bird species. The wetland vegetation must be maintained in an A/B Ecological Category (natural to largely natural condition).		et al, 2007
	3.1 Murphy's Rust	RU23			The wetland is considered to be in a largely natural condition as there are only minor alterations in the catchment and the wetland itself. The wetland vegetation provides an important food source for livestock, an important source of reeds for the local community, suitable habitat for a Red Data bird species, Grey Crowned Crane (*Balearica regulorum*), and a scenic setting for tourism opportunities in the area. The wetland vegetation must therefore be maintained in a B Ecological Category (largely natural condition).	Impact score = 1.63	
UB UC2	2.2 Seekoeivlei 4.1 Monontsha	RU13 and RU14 RU29			The wetland habitat provides an important template for the ecosystem, so if this component is maintained it will be beneficial for other responder components including mammals, birds and amphibians/reptiles. Management of the wetland vegetation and geomorphology is important to ensure that the ecosystem structure and function of this RAMSAR wetland are maintained. The wetland vegetation must be maintained in a C Ecological Category (moderately modified condition) or better.	Impact score = 3.33	Macfarlane et al, 2007
UI	11.1 Blesbokspruit 11.2 Klip River 11.3 Rietspruit	RU62 RU64 RU63			There are multiple stressors associated with land-use activities either in or adjacent to the wetland. These include road infrastructure, impacts from urban and per-urban users, mining activities, agricultural areas, and industrial areas. The management of this RAMSAR wetland is important to ensure that the ecosystem structure and functioning are maintained. The wetland vegetation must be maintained in a D Ecological Category (largely modified condition) and appropriate buffer zone policy must be applied.	Impact score = 5.33	Macfarlane et al, 2007
UA UC1 UI UL	1.1 Upper Vaal 1.2 Upper Blesbokspruit (upstream of Bethal) 1.3 Upper Blesbokspruit (downstream of Bethal) 1.4 Balmoral 3.5 Meul 11.3 Rietspruit 11.4 Natalspruit 14.1	RU2 RU9 RU3 RU25 RU63 RU69	Habitat	Wetland Geomorphology	The Upper Vaal wetland is a wetland FEPA that plays a substantial hydrological and ecological role in the natural functioning of the Vaal River. Management of the wetland is important to ensure that the ecosystem structure and function are maintained and that there is ongoing supply of ecosystem services, particularly	Given that the present condition is unknown, the TPC cannot be determined. Once the numerical criteria has been determined the TPC should be set at 30% more than the lowest score for the	Macfarlane et al, 2007

	Boovenste Oog				regulating and supporting services for the downstream river FEPA. The wetland geomorphology must be maintained.	relevant Present Geomorphology State Category.	
UC1	3.2 Ingula; 3.3 Wilge; 3.4 Upper Wilge	RU22 RU23 RU22			The wetland habitat provides an important template for the ecosystem, so if this component is maintained it will be beneficial for other responder components including mammals, birds and amphibians/reptiles. Management of the wetland vegetation and geomorphology is important to ensure that the ecosystem structure and function of this wetland FEPA are maintained. The wetland also provides suitable habitat for a number of Red Data bird species. The wetland geomorphology must be maintained in an A/B Ecological Category (natural to largely natural condition).	Impact score = 1.33	Macfarlane et al, 2007
UB UC2 UL	2.2 Seekoeivlei 4.1 Monontsha 14.3 Gerhard Minnebron	RU13 and RU14 RU29 RU73			The wetland habitat provides an important template for the ecosystem, so if this component is maintained it will be beneficial for other responder components including mammals, birds and amphibians/reptiles. Management of the wetland vegetation and geomorphology is important to ensure that the ecosystem structure and function of this RAMSAR wetland are maintained. The wetland geomorphology must be maintained in a C Ecological Category (moderately modified condition) or better.	Impact score = 3.33	Macfarlane et al, 2007
UI	11.1 Blesbokspruit; 11.2 Klip River	RU62 RU64			There are multiple stressors associated with land-use activities either in or adjacent to the wetland. These include road infrastructure, impacts from urban and per-urban users, mining activities, agricultural areas, and industrial areas. The management of this RAMSAR wetland is important to ensure that the ecosystem structure and functioning are maintained. The wetland geomorphology must be maintained in a D Ecological Category (largely modified condition).	Impact score = 5.33	Macfarlane et al, 2007

Table 20: Supplementary information for WETLAND BIOTA RQOs on ecosystem scale.

Wetland Biota							
IUA	Wetlands	RU	Component	Sub Component	Context of the RQO	TPC	Reference
UB	2.2 Seekoeivlei	RU13 and RU14	Biota	Biodiversity	The area supports an appreciable assemblage of rare or threatened species or subspecies of plants and animals. Overall biodiversity must be maintained and viable populations of Red Data species must be maintained. One Red Data mammal species, 8 Red Data bird species and four Red Data plant species are partially or wholly dependent on the wetland. These are the serval Felis serval, Little bittern *Ixobrychus minutus*, Yellowbilled stork *Mycteria ibis*, Wattled crane *Bugeranus carunculatus*, Blue crane *Anthropoides paradiseus*, Grey crowned	Crowned crane RR <30.0%; Blue cranes RR <10.08% Wattled crane RR <4.3%.	SA Wetlands Conservation Programme, 1996; Avian Demography Unit, 2011

					crane *Balearica regulorum*, Black stork *Cocinia nigra*, White-winged flufftail *Sarothrura ayresii* and Grass owl *Tyto capensis* respectively. In addition, four Red Data plant species are associated with or dependent on the wetland, these are Nerine bowdenii, *Nerine platypetala*, *Gladiolus robertsoniae*, and *Crassula tuberella*.		
UB	2.1 Vanger	RU12	Biota	Birds	The wetland provides suitable habitat for a Red Data bird species, White-winged Flufftail (*Sarothrura ayresi*). Maintenance of population numbers is desirable given the conservation status of this species.	Essential White-winged Flufftail habitat deteriorated and no birds or signs of birds observed.	Avian Demography Unit, 2011
UC1	3.1 Murphy's Rust	RU23	Biota	Birds	The wetland provides suitable habitat for a Red Data bird species, Grey Crowned Crane (*Balearica regulorum*). Maintenance of population numbers is desirable given the conservation status of this species.	Crowned crane RR <65.0%.	Avian Demography Unit, 2011
	3.2 Ingula	RU22			The area supports more than 270 bird species, which includes a number of Red Data bird species. These species include White-winged Flufftail (Sarothrura ayresi), Grey Crowned Crane (Balearica regulorum), Blue Crane (Anthropoides paradiseus), and Wattled Crane (Bugeranus carunculatus). Overall biodiversity must be maintained and viable populations of Red Data bird species must be maintained.	Crowned crane RR <15.0%; Blue cranes RR <8.0% Wattled crane RR <35.0%.	Avian Demography Unit, 2011
	3.4 Upper Wilge				The wetland is in close proximity to the Ingula wetland and is therefore likely to support a high diversity of bird species, including Red data bird species such as White-winged Flufftail (Sarothrura ayresi), Grey Crowned Crane (Balearica regulorum), Blue Crane (Anthropoides paradiseus), and Wattled Crane (Bugeranus carunculatus). Overall biodiversity must be maintained and viable populations of Red Data bird species must be maintained.	Crowned crane RR <15.0%; Blue cranes RR <8.0% Wattled crane RR <35.0%.	Avian Demography Unit, 2011
UI	11.1 Blesbokspruit	RU62	Biota	Birds	The wetland is home to a wide diversity of bird species and a high abundance of some species, particularly waterfowl. It also supports a number of Red Data species, such as the Lesser Flamingo (*Phoeniconaias minor*) and Greater Flamingo (*Phoenicopterus ruber*). Reduction in bird numbers including threatened species and the reduction in availability and diversity of bird habitat through reed encroachment is of concern. Improved monitoring of bird populations must therefore be undertaken and viable populations of Red Data bird species must be maintained.	Greater flamingo, RR <40%; Lesser flamingo, RR <8.0%.	Avian Demography Unit, 2011
UC1	3.4 Upper Wilge (Upper Bedford Wetland)	RU22	Biota	Fish	The upper Bedford River contains a unique population of Barbus sp. (to be determined) which must be protected to maintain biodiversity.	Risk that non-endemic Barbus anoplus from the Wilge River can access upper Bedford Source.	DWAF, 2009
						Critical habitat for indicator species according to RHAM assessment reduced from reference (equivalent to low A category).	
UL	14.1 Boovenste Oog	RU69	Biota	Fish	The Boovenste Oog contains an ecologically important population of Barbus sp. (to be determined) which must be protected to maintain local biodiversity.	Critical habitat for indicator species according to RHAM assessment reduced from reference (equivalent to low A category).	DWAF, 2009

4.3 DAM RESOURCE QUALITY OBJECTIVES AND NUMERICAL LIMITS FOR THE UPPER VAAL WMA

The outcomes of the RQO and NL determination of the sub-components and indicators for the dam component of the RQO determination study for the Upper Vaal WMA, including a summary of additional supplementary information are provided as follows (Figure 4):

- RQOs for the dam water quantity component are presented in Table 21.
- RQOs for the dam water quality component are presented in Table 22.
- RQOs for the dam water biota component are presented in Table 23.
- Supplementary information for the dam water quantity component is presented in Table 24.
- Supplementary information for the dam water quality component is presented in Table 25.
- Supplementary information for the dam water biota component is presented in Table 26.

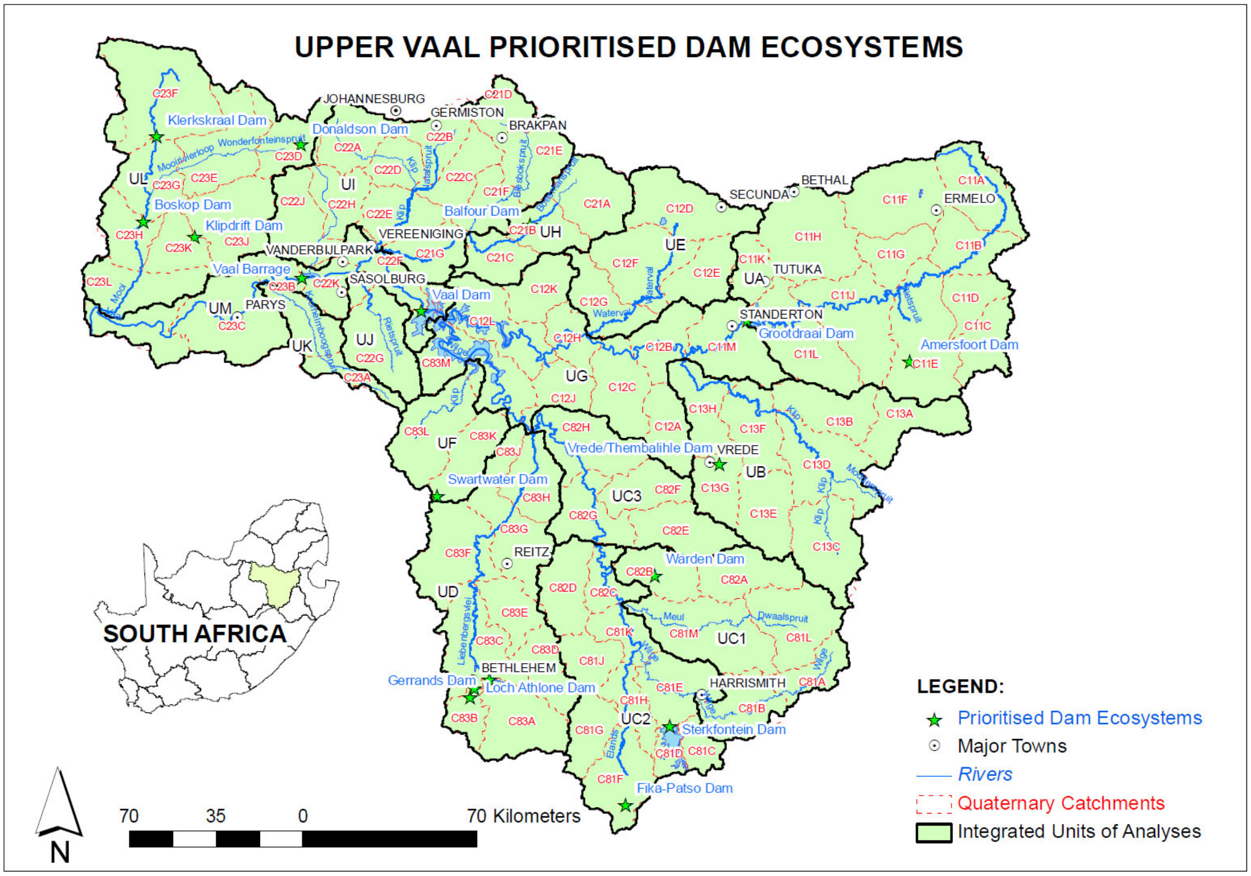

Figure 4: Priority dams considered in the study within Integrated Units of Analyses. Quaternary and major rivers also presented.

4.3.1 DAM RESOURCE QUALITY OBJECTIVES AND NUMERICAL LIMITS TABLES

Table 21: RQOs for DAM WATER QUANTITY IN priority RUs in the Upper Vaal WMA

Dam Water Quantity									
IUA	**Dams**	**RU**	**Component**	**Sub Component**	**RQO**	**Indicator/ measure**	**Numerical Limits**		
UA	Amersfoort Dam (27°4'1"S; 29°53'1"E)	RU4	Quantity	Low Flows	Dam levels must be sufficient for release for domestic supply to Amersfoort and the surrounding small irrigation areas	Flow releases: Skulpspruit in C11E, VMAR = 12.035x$10^6 m^3$, PES=C		Maintenance low flows (m□/s) (%ile)	Drought flows (m□/s) (%ile)
							Oct	0.049 (50)	0.007 (99)
							Nov	0.099 (40)	0.015 (99)
							Dec	0.130 (50)	0.030 (99)
							Jan	0.143 (40)	0.045 (99)
							Feb	0.196 (40)	0.041 (99)
							Mar	0.131 (40)	0.015 (99)
							Apr	0.087 (40)	0.012 (99)
							May	0.051 (40)	0.000
							Jun	0.035 (40)	0.000
							Jul	0.031 (40)	0.000
							Aug	0.024 (50)	0.000
							Sep	0.027 (50)	0.008 (99)
	Grootdraai Dam (26°55'9.2"S; 29°17'41.6"E)	RU10			Dam levels must remain sufficient to provide for municipal and industrial use, as well as releases for ecosystem function downstream.	Flow releases: Vaal EWR2 in C11M VMAR = 457.7x10^6m□ REC=C category*. (Releases from C1R002)		Maintenance low flows (m□/s) (%ile)	Drought flows (m□/s) (%ile)
							Oct	0.7 (50)	0.116 (99)
							Nov	1 (50)	0.219 (99)
							Dec	1.2 (50)	0.281 (99)
							Jan	1.35 (50)	0.309 (99)
							Feb	1.75 (50)	0.422 (99)
							Mar	1.3 (50)	0.285 (99)
							Apr	1 (50)	0.194 (99)
							May	0.8 (50)	0.00
							Jun	0.7 (50)	0.00
							Jul	0.6 (60)	0.00
							Aug	0.55 (60)	0.00
							Sep	0.6 (60)	0.071 (99)
UB	Vrede/Thembalihle Dam (27°26'21.8"S; 29°11'45.1"E)	RU20	Quantity	Low Flows	Dam levels must be sufficient to maintain releases for domestic and industrial use.	Flow releases: Spruitsonderdrif in C13G, PES=C. (Releases - no gauge close by)	Use Desktop Reserve Model (DRM) and updated PES/EI/ES data to determine low and drought requirements for Spruitsonderdrif downstream Vrede Dam. Data not available at present.		
UC1	Warden Dam (27°50'42"S; 28°57'45"E)	RU28	Quantity	Low Flows	During the dry season dam levels must be sufficient for releases for human use and protection of ecosystem function.	Flow releases: Cornelisspruit in C82B, PES=D. (Releases from Warden Dam monitored by C8H003.)	Use Desktop Reserve Model (DRM) and updated PES/EI/ES data to determine low, drought and freshets requirements for Cornelisspruit downstream Warden Dam. Data not available at present.		
				High Flows	During the wet season the dam levels must be maintained such				

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td>that they are able to support releases for ecosystem function and domestic water use.</td><td></td><td></td></tr>
<tr><td rowspan="4">UC2</td><td rowspan="2">Fika-Patso Dam (28°40'19.3"S; 28°51'22.5"E)</td><td rowspan="2">RU29</td><td rowspan="4">Quantity</td><td>Low Flows</td><td>During the dry season dam levels must be sufficient for releases for municipal and industrial use and protection of ecosystem function downstream.</td><td rowspan="2">Release flows: Namahadi River in C81F, PES=C. (Releases from Sterkfontein Dam monitored by C8H032)</td><td rowspan="2">Use Desktop Reserve Model (DRM) and updated PES/EI/ES data to determine low, drought and freshets requirements for Nuwejaarspruit downstream Sterkfontein Dam. No data is available at this time.</td></tr>
<tr><td>High Flows</td><td>During the wet season dam levels must be maintained such that they support ecosystem function and human use.</td></tr>
<tr><td>Swartwater Dam (27°33'15"S; 28°10'24"E)</td><td>RU29</td><td>High Flows</td><td>During the wet season the dam levels must be sufficient for releases that will support ecosystem function as well as domestic and rural use downstream.</td><td>Flow releases: Metsi-Matsho River in C81F, PES=C. (Releases from Fika-Patso Dam monitored by C8R002)</td><td>Use Desktop Reserve Model (DRM) and updated PES/EI/ES data to determine freshets requirements for Metsi-Matsho River downstream Swartwater Dam. No data is available at this time.</td></tr>
<tr><td>Sterkfontein Dam (28°23'15"S; 29°1'1"E)</td><td>RU33 and 34</td><td>Flows</td><td>Dam levels must be sufficient for releases to protect ecosystem function and for municipal and industrial use downstream.

The dam is filled from the Thukela catchment, the increased dam levels from the transfer must be maintained such that they support the protection of ecosystem function within the dam.</td><td>Flow releases: Nuwejaarspruit in C81D, VMAR == 40.089x10^{6}m^3, REC=C/D</td><td>
<table>
<tr><td></td><td>Maintenance low flows (m^3/s) (%ile)</td><td>Drought flows (/m^{3}s) (%ile)</td><td>Maintenance high flows (m^3/s) (%ile)</td></tr>
<tr><td>Oct</td><td>0.125 (50)</td><td>0.011 (99)</td><td>0.114 (99)</td></tr>
<tr><td>Nov</td><td>0.215 (50)</td><td>0.042 (99)</td><td>0.238 (40)</td></tr>
<tr><td>Dec</td><td>0.252 (40)</td><td>0.045 (99)</td><td>0.115 (60)</td></tr>
<tr><td>Jan</td><td>0.324 (50)</td><td>0.134 (99)</td><td>0.115 (99)</td></tr>
<tr><td>Feb</td><td>0.412 (50)</td><td>0.098 (99)</td><td>0.585 (30)</td></tr>
<tr><td>Mar</td><td>0.368 (50)</td><td>0.146 (99)</td><td>0.206 (70)</td></tr>
<tr><td>Apr</td><td>0.246 (50)</td><td>0.042 (99)</td><td>0.056 (90)</td></tr>
<tr><td>May</td><td>0.139 (50)</td><td>0.045 (99)</td><td>0.00</td></tr>
<tr><td>Jun</td><td>0.075 (50)</td><td>0.031 (99)</td><td>0.00</td></tr>
<tr><td>Jul</td><td>0.053 (50)</td><td>0.007 (99)</td><td>0.00</td></tr>
<tr><td>Aug</td><td>0.048 (50)</td><td>0.015 (99)</td><td>0.00</td></tr>
<tr><td>Sep</td><td>0.083 (50)</td><td>0.035 (99)</td><td>0.070 (60)</td></tr>
</table>
</td></tr>
<tr><td rowspan="3">UD</td><td>Gerrands Dam (28°16'55.3"S; 28°17'30.6"E)</td><td>RU43</td><td rowspan="3">Quantity</td><td>Flows</td><td>During the dry season dam levels must be sufficient for release for domestic and industrial use as well as protection of ecosystem function downstream.</td><td>Flow releases: Gerrandsspruit in C83B, PES=D. (Releases from dam - no gauge close by)</td><td>Use Desktop Reserve Model (DRM) and updated PES/EI/ES data to determine drought and low flow requirements for Gerrandsspruit downstream Gerrands Dam. No data is available at this time.</td></tr>
<tr><td rowspan="2">Loch Athlone Dam (28°15'0.9"S; 28°18'31.4"E)</td><td rowspan="2">RU43</td><td>Low Flows</td><td>During the dry season the dam levels must be sufficient levels to protect ecosystem function and to conserve the recreational value of the dam.</td><td rowspan="2">Flow releases: Jordaanspruit in C83C, REC=D. (Releases from Loch Athlone monitored by C8R005.)</td><td rowspan="2">Use Desktop Reserve Model (DRM) and updated PES/EI/ES data to determine drought, low flow and freshets requirements for Jordaanspruit downstream Loch Athlone. No data is available at this time.</td></tr>
<tr><td>High Flows</td><td>During the wet season the dam levels must be maintained at levels that will support the</td></tr>
</table>

					recreational use of the dam.				
	Saulspoort Dam (Sol Plaatjie Dam) (28°13'1.5"S; 28°21'46.9"E)	RU41 and 43		Flows	Dam levels must be sufficient to provide releases for domestic and industrial use as well as protection of ecosystem function downstream. Dam levels must be maintained such that they support ecosystem function.	Capping flows in river. Liebenbergsvlei in C83C, REC=D. (Releases from Saulspoort Dam monitored by C8R004)	To be determined using an approved approach for increased flows.		
UH	Balfour Dam (26°34'25"S; 28°30'37"E)	RU60	Quantity	Flows	Dam levels must be maintained at sufficient levels to provide releases for municipal and industrial use as well as protection of ecosystem function downstream.	Flow releases: Vaal EWR9 in C21C VMAR = 31.31x$10^6 m^3$ REC=C category*. (Daily - no flow gauge close by)		Maintenance low flows (m^3/s) (%ile)	Drought flows (m^3/s) (%ile)
							Oct	0.12 (60)	0.05 (99)
							Nov	0.177 (60)	0.066 (99)
							Dec	0.147 (60)	0.06 (99)
							Jan	0.182 (60)	0.066 (99)
							Feb	0.231 (60)	0.079 (99)
							Mar	0.18 (60)	0.066 (99)
							Apr	0.16 (60)	0.064 (99)
							May	0.143 (60)	0.059 (99)
							Jun	0.123 (60)	0.057 (99)
							Jul	0.08 (70)	0.05 (99)
							Aug	0.065 (70)	0.04 (99)
							Sep	0.075 (70)	0.04 (99)
UL	Klerkskraal Dam (26°15'9"S; 27°9'40"E)	RU69	Quantity	Flows	Dam levels must therefore be maintained at levels sufficient for irrigation releases as well as for protection of ecosystem function downstream.	Flow releases: Vaal RE-EWR2 in C23G VMAR = 37.7x106m³ REC=D*. (Releases from Klerkskraal Dam monitored by C2H006.)		Maintenance low flows (m^3/s) (%ile)	Drought flows (m^3/s) (%ile)
							Oct	0.12 (70)	0.106 (99)
							Nov	0.12 (70)	0.109 (99)
							Dec	0.12 (70)	0.106 (99)
							Jan	0.128 (60)	0.108 (99)
							Feb	0.155 (60)	0.124 (99)
							Mar	0.153 (50)	0.115 (99)
							Apr	0.16 (60)	0.12 (99)
							May	0.154 (60)	0.116 (99)
							Jun	0.154 (60)	0.118 (99)
							Jul	0.146 (60)	0.113 (99)
							Aug	0.143 (60)	0.112 (99)
							Sep	0.137 (70)	0.113 (99)
	Donaldson Dam (26°16'55"S; 27°41'0"E)	RU71			Dam levels must be maintained such that ecosystem function is protected and the recreational value of the dam is retained.	Flow releases: Wonderfonteinspruit in C23D, REC=D. (Releases from Donaldson Dam monitored by C2H025).	Use Desktop Reserve Model (DRM) and updated PES/EI/ES data to determine drought and low flow requirements for Wonderfonteinspruit downstream Donaldson Dam. No data is available at this time.		
	Klipdrift Dam (26°37'0"S; 27°17'52"E)	RU72			The dam must be maintained at sufficient levels for irrigation releases and releases for the protection of ecosystem function downstream.	Flow releases: Loopspruit in C23K, REC=D. (Releases from Klipdrift Dam monitored by C2R005.)	Use Desktop Reserve Model (DRM) and updated PES/EI/ES data to determine drought and low flow requirements for Loopspruit downstream Klipdrift Dam. No data is available at this time.		

	Boskop Dam (26°33'42''S; 27°6'41''E)	RU73			The dam must be maintained at levels sufficient for irrigation releases and releases for protection of ecosystem function downstream.	Flow releases: Mooi River in C23H, REC=D. (Releases from Boskop Dam monitored by C2H273.)	Use Desktop Reserve Model (DRM) and updated PES/EI/ES data to determine drought and low flow requirements for Mooi River downstream Boskop Dam. No data is available at this time.			
UM	Vaal Barrage (26°45'53''S; 27°41'3''E)	RU75	Quantity	Flows	Levels must be maintained at sufficient levels for municipal and industrial releases as well as to provide releases for the protection of ecosystem function downstream.	Flow releases: Vaal River in C23B, VMAR = 2 253.9x10^{6}m^3, REC=C		Maintenance low flows (m^3/s) (%ile)	Drought flows (m^3/s) (%ile)	
							Oct	6.16 (95)	2.55 (99)	
							Nov	8.56 (90)	3.59 (99)	
							Dec	9.36 (95)	4.30 (99)	
							Jan	10.51 (95)	4.79 (99)	
							Feb	13.61 (85)	6.15 (99)	
							Mar	10.97 (90)	4.99 (99)	
							Apr	8.67 (85)	3.76 (99)	
							May	6.19 (85)	2.96 (99)	
							Jun	4.98 (90)	2.45 (99)	
							Jul	4.58 (90)	2.27 (99)	
							Aug	4.29 (95)	2.15 (99)	
							Sep	4.69 (95)	2.33 (99)	
	Vaal Dam (26°52'57''S; 28°6'58''E)	RU74			Dam levels must be maintained such that they are sufficient for municipal, industrial and irrigation releases as well as protection of ecosystem function downstream.	Flow releases: Vaal EWR4 in C22F downstream Vaal Dam MAR = 1977x10^{6}m□ REC=C category*. (Releases from Vaal Dam monitored by C1H122.)		Maintenance low flows (m^3/s) (%ile)	Drought flows (m^3/s) (%ile)	High flows (m□/s)
							Oct	13.05 (70)	3.44 (99)	
							Nov	16.02 (50)	5.04 (99)	15 - 25
							Dec	17.65 (50)	5.58 (99)	15 – 25
							Jan	18.23 (50)	5.98 (90)	15 – 25
							Feb	17.38 (50)	6.63 (95)	40 - 96
							Mar	16.6 (50)	5.58 (95)	15 - 25
					During the wet season dam inflows and levels must be maintained such that they are sufficient for releases for intended use, and release for the protection of ecosystem function downstream.		Apr	13.95 (40)	4.72 (99)	
							May	11.01 (60)	4.14 (99)	
							Jun	10.03 (70)	4.14 (99)	
							Jul	9.54 (95)	3.98 (99)	
							Aug	9.37 (95)	3.98 (99)	
							Sep	9.37 (95)	3.98 (99)	

** Per Rule Table*

Table 22: RQOs for DAM WATER QUALITY in priority RUs in the Upper Vaal WMA

Dam Water Quality								
IUA	**Dams**	**RU**	**Component**	**Sub Component**	**RQO**	**Indicator/ measure**	**Numerical Limits**	**95th %ile**
UA	Grootdraai Dam (26°55'9.2"S; 29°17'41.6"E)	RU10	Quality	Nutrients	The system must be maintained in a mesotrophic state or better.	Phosphate(PO_4) *	≤ 0.025 mg/L P	0.0085
						Nitrate (NO_3) & Nitrite (NO_2) *	≤ 1.00 mg/L N	0.099
UB	Vrede/Thembalihle Dam (27°26'21.8"S; 29°11'45.1"E)	RU20	Quality	Nutrients	The system must be maintained in a mesotrophic state or better.	Phosphate(PO_4) *	≤ 0.025 mg/L P	0.2
						Nitrate (NO_3) & Nitrite (NO_2) *	≤ 1.00 mg/L N	0.4
UD	Gerrands Dam (28°16'55.3"S; 28°17'30.6"E)	RU43	Quality	Nutrients	Nutrients must be maintained at mesotrophic levels.	Phosphate(PO_4) *	≤ 0.025 mg/L P	0.006
						Nitrate (NO_3) & Nitrite (NO_2) *	≤ 1.00 mg/L N	0.025
	Loch Athlone Dam (28°15'0.9"S; 28°18'31.4"E)				Nutrients must be maintained at mesotrophic levels so as to retain the recreational value of the dam.	Phosphate(PO_4) *	≤ 0.025 mg/L P	0.024
						Nitrate (NO_3) & Nitrite (NO_2) *	≤ 1.00 mg/L N	0.05
	Saulspoort Dam (Sol Plaatjie Dam) (28°13'1.5"S; 28°21'46.9"E)	RU41			Nutrients must be maintained at mesotrophic levels to protect the ecosystem and also the fitness for use.	Phosphate(PO_4) *	≤ 0.025 mg/L P	0.022
						Nitrate (NO_3) & Nitrite (NO_2) *	≤ 1.00 mg/L N	0.2
UL	Klipdrift Dam (26°37'0"S; 27°17'52"E)	RU72	Quality	Nutrients	The system is currently in a eutrophic state and must be improved and maintained in a mesotrophic state.	Phosphate(PO_4) *	≤ 0.025 mg/L P	0.031
						Nitrate (NO_3) & Nitrite (NO_2) *	≤ 1.00 mg/L N	0.11
	Boskop Dam (26°33'42"S; 27°6'41"E)	RU73			Nutrient concentrations must be maintained such that the system is in a mesotrophic state	Phosphate(PO_4) *	≤ 0.025 mg/L P	0.006
						Nitrate (NO_3) & Nitrite (NO_2) *	≤ 1.00 mg/L N	0.3
UM	Vaal Barrage (26°45'53"S; 27°41'3"E)	RU75	Quality	Nutrients	The system is currently eutrophic and must be improved and maintained in a mesotrophic state.	Phosphate(PO_4) *	≤ 0.025 mg/L P	0.295
						Nitrate (NO_3) & Nitrite (NO_2) *	≤ 1.00 mg/L N	2.4
	Vaal Dam (26°52'57"S; 28°6'58"E)				The system must be improved and managed in a mesotrophic state.	Phosphate(PO_4) *	≤ 0.025 mg/L P	0.021
						Nitrate (NO_3) & Nitrite (NO_2) *	≤ 1.00 mg/L N	0.2

UB	Vrede/Thembalihle Dam (27°26'21.8"S; 29°11'45.1"E)	RU 20	Quality	Salts	Salt levels must be maintained at concentrations where they do not impact negatively on the ecosystem.	Electrical Conductivity*	≤ 85 mS/m	84.8
UL	Klipdrift Dam (26°37'0"S; 27°17'52"E)	RU 72	Quality	Salts	Salt levels must be maintained at concentrations where they do not impact negatively on the ecosystem.	Electrical Conductivity*	≤ 85 mS/m	102
UM	Vaal Barrage (26°45'53"S; 27°41'3"E)	RU 75	Quality	Salts	Salt levels must be maintained at concentrations where they do not impact negatively on the ecosystem.	Electrical Conductivity*	≤ 85 mS/m	80.4
UL	Boskop Dam (26°33'42"S; 27°6'41"E)	RU 73	Quality	System Variables	The pH of the water in the dam should not negatively impact on ecosystem function.	pH_max *	≥ 8.8	8.7
						pH_min *	≤ 5.9	8.1
UA	Grootdraai Dam (26°55'9.2"S; 29°17'41.6"E)	RU10	Quality	Toxins	Toxicity must be maintained better than concentrations that would pose a threat to human health. The dam must be maintained in a mesotrophic state to avoid cyanobacterial blooms and the associated algal toxins.	Chl-a: phytoplankton*	≤ 20 µg/L	No data
UD	Gerrands Dam (28°16'55.3"S; 28°17'30.6"E)	RU 43	Quality	Toxins	The system must be maintained in a mesotrophic condition to avoid cyanobacteria and the associated algal toxins.	Chl-a: phytoplankton*	≤ 20 µg/L	No data
	Loch Athlone Dam (28°15'0.9"S; 28°18'31.4"E)							
	Saulspoort Dam (Sol Plaatjie Dam) (28°13'1.5"S; 28°21'46.9"E)	RU 41 & 43						
UL	Klipdrift Dam (26°37'0"S; 27°17'52"E)	RU 72	Quality	Toxins	To avoid cyanobacteria blooms, the dam must be maintained in a mesotrophic state.	Chl-a: phytoplankton*	≤ 20 µg/L	No data
UM	Vaal Barrage (26°45'53"S; 27°41'3"E)	RU 75	Quality	Toxins	The system must be maintained in a mesotrophic state to prevent build-up of cyanobacteria blooms and associated algal toxins. The water in the Barrage should not contain toxins including metals at levels that pose a threat to human health.	Chl-a: phytoplankton*	≤ 20 µg/L	No data
	Vaal Dam (26°52'57"S; 28°6'58"E)	RU 74			The system must be maintained in a mesotrophic state to avoid cyanobacterial blooms and associated algal toxins.	Chl-a: phytoplankton*	≤ 20 µg/L	No data

**as per standard methods of America Water Works Association (www.awwa.org)*

Table 23: RQOs for DAM BIOTA in priority RUs in the Upper Vaal WMA

Dam Biota							
IUA	**Dams**	**RU**	**Component**	**Sub Component**	**RQO**	**Indicator/ measure**	**Numerical Limits**
UA	Grootdraai Dam (RU 10, 26°55'9.2"S; 29°17'41.6"E)	RU10	Biota	Fish	The wellbeing of the fish community of this artificial ecosystem must be maintained in a suitable condition to contribute to regional biodiversity (Including maintenance of Orange-Vaal largemouth yellowfish population (*Labeobarbus kimberleyensis*)) and to support local recreational angling industry. Consumption of fish must not pose a health risk to local communities.	Implementation of the Index of Reservoir Habitat Impairment (IRHI) by Miranda and Hunt (2011).	Habitat suitability and fish wellbeing in a state which is equivalent to a C or better ecological category.
						Fish health evaluation	Fish health must not deviate significantly

							from baseline state.
							Toxicants in fish tissue must not exceed guideline thresholds.
UC2	Sterkfontein Dam (RU 33 & 34, 28°23'15"S; 29°1'1"E)	RU33 RU34	Biota	Fish	The wellbeing of the fish community of this artificial ecosystem must be maintained in a suitable condition to contribute to regional biodiversity (Including maintenance of Orange-Vaal largemouth yellowfish population *(Labeobarbus kimberleyensis)* and to support local recreational angling industry. Consumption of fish must not pose a health risk to local communities. The genetic diversity of the cyprinids in the dam must not be contaminated by non-endemic cyprinids.	Implementation of the Index of Reservoir Habitat Impairment (IRHI) by Miranda and Hunt (2011).	Habitat suitability and fish wellbeing in a state which is equivalent to a C or better ecological category.
						Genetic diversity assessment of local Cyprinids.	Genetic diversity must compare with reference.
UL	Donaldson Dam (RU 71, 26°16'55"S; 27°41'0"E)	RU71	Biota	Fish	The fish must not pose a threat to human health if consumed by local communities.	Fish health evaluation	Fish health must not deviate significantly from baseline state.
							Toxicants in fish tissue must not exceed guideline thresholds.
	Boskop Dam (RU 73, 26°33'42"S; 27°6'41"E)	RU73			The wellbeing of the fish community of this artificial ecosystem must be maintained in a suitable condition to contribute to regional biodiversity (Including maintenance of Orange-Vaal largemouth yellowfish population *(Labeobarbus kimberleyensis)* and to support local recreational angling industry. Consumption of fish must not pose a health risk to local communities. The genetic diversity of the cyprinids in the dam must not be contaminated by non-endemic cyprinids.	Implementation of the Index of Reservoir Habitat Impairment (IRHI) by Miranda and Hunt (2011).	Habitat suitability and fish wellbeing in a state which is equivalent to a C or better ecological category.
						Fish health evaluation	Fish health must not deviate significantly from baseline state.
							Toxicants in fish tissue must not exceed guideline thresholds.
UM	RU74 - Vaal Dam (26°52'57"S; 28°6'58"E)	RU74	Biota	Fish	The wellbeing of the fish community of this artificial ecosystem must be maintained in a suitable condition to contribute to regional biodiversity (Including maintenance of Orange-Vaal largemouth yellowfish population *(Labeobarbus kimberleyensis)* and to support local recreational angling industry. Consumption of fish must not pose a health risk to local communities. The genetic diversity of the cyprinids in the dam must not be contaminated by non-endemic cyprinids.	Implementation of the Index of Reservoir Habitat Impairment (IRHI) by Miranda and Hunt (2011).	Habitat suitability and fish wellbeing in a state which is equivalent to a C or better ecological category.
						Fish health evaluation	Fish health must not deviate significantly from baseline state.
							Toxicants in fish tissue must not exceed guideline thresholds.
	Vaal Barrage (RU 75, 26°45'53"S; 27°41'3"E)	RU75			The fish must not pose a threat to human health if consumed by local communities.	Fish health evaluation	Fish health must not deviate significantly from baseline state.
							Toxicants in fish tissue must not exceed guideline thresholds.

4.3.2 SUPPLEMENTARY INFORMATION FOR THE DAM RESOURCE QUALITY OBJECTIVES AND NUMERICAL LIMITS TABLES

Table 24: Supplementary information for DAM QUANTITY RQOs on ecosystem scale.

Dam Water Quantity								
IUA	**Dams**	**RU**	**Component**	**Sub Component**	**RQO**	**Context of the RQO**	**TPC**	**Reference**
UA	Amersfoort Dam (27°4'1"S; 29°53'1"E)	RU4	Quantity	Low Flows	Dam levels must be sufficient for release for domestic supply to Amersfoort and the surrounding small irrigation areas		Not Applicable	DWA, 2013 Extrapolated from Vaal_EWR1 in C11
	Grootdraai Dam (26°55'9.2"S; 29°17'41.6"E)	RU10			Dam levels must remain sufficient to provide for municipal and industrial use, as well as releases for ecosystem function downstream.	The dam supplies water to Standerton for municipal use, to Sasol for industrial use and to Tutuka Power Station for power generation.	Not Applicable	DWA, 2010
UB	Vrede/Thembalihle Dam (27°26'21.8"S; 29°11'45.1"E)	RU20	Quantity	Low Flows	Dam levels must be sufficient to maintain releases for domestic and industrial use.	The dam supplies water for domestic and industrial use to Vrede.	Not Applicable	DWA, 2013
UC1	Warden Dam (27°50'42"S; 28°57'45"E)	RU28	Quantity	Low Flows	During the dry season dam levels must be sufficient for releases for human use and protection of ecosystem function.	There is irrigated and dry-land agriculture upstream of the dam. The dam supplies water for municipal use to the town of Warden.	Not Applicable	DWA, 2013
				High Flows	During the wet season the dam levels must be maintained such that they are able to support releases for ecosystem function and domestic water use.			
UC2	Fika-Patso Dam (28°40'19.3"S; 28°51'22.5"E)	RU29	Quantity	Low Flows	During the dry season dam levels must be sufficient for releases for municipal and industrial use and protection of ecosystem function downstream.	The dam supplies water for municipal and industrial use to Phuthadijhaba, however the dam is large compared to runoff.	Not Applicable	DWA, 2013
				High Flows	During the wet season dam levels must be maintained such that they support ecosystem function and human use.			
	Swartwater Dam (27°33'15"S; 28°10'24"E)	RU29		High Flows	During the wet season the dam levels must be sufficient for releases that will support	The dam supplies water for municipal and industrial use to QwaQwa.	Not Applicable	DWA, 2013

					ecosystem function as well as domestic and rural use downstream.			
	Sterkfontein Dam (28°23'15''S; 29°1'1''E)	RU33 and 34		Flows	Dam levels must be sufficient for releases to protect ecosystem function and for municipal and industrial use downstream. The dam is filled from the Thukela catchment, the increased dam levels from the transfer must be maintained such that they support the protection of ecosystem function within the dam.	Water is transferred into the dam from the Thukela catchment. The dam supplies water for municipal use to Harrismith and when necessary can release water to the Vaal system.	Not Applicable	DWA, 2013 Extrapolated using hydronode at confluence of Wilge and Nuwejaarspruit (C81E)
UD	Gerrands Dam (28°16'55.3''S; 28°17'30.6''E)	RU43	Quantity	Flows	During the dry season dam levels must be sufficient for release for domestic and industrial use as well as protection of ecosystem function downstream.	This dam supplies water for municipal and industrial use to Bethlehem. There are small in-stream dams used for irrigation upstream.	Not Applicable	DWA, 2013
UD	Loch Athlone Dam (28°15'0.9''S; 28°18'31.4''E)	RU43	Quantity	Low Flows	During the dry season the dam levels must be sufficient levels to protect ecosystem function and to conserve the recreational value of the dam.	This dam is used for recreation.	Not Applicable	DWA, 2013
UD	Loch Athlone Dam (28°15'0.9''S; 28°18'31.4''E)	RU43	Quantity	High Flows	During the wet season the dam levels must be maintained at levels that will support the recreational use of the dam.	This dam is used for recreation.	Not Applicable	DWA, 2013
UD	Saulspoort Dam (Sol Plaatjie Dam) (28°13'1.5''S; 28°21'46.9''E)	RU41 and 43	Quantity	Flows	Dam levels must be sufficient to provide releases for domestic and industrial use as well as protection of ecosystem function downstream. Dam levels must be maintained such that they support ecosystem function.	This dam supplies water for municipal and industrial use.	Not Applicable	DWA, 2013
UH	Balfour Dam (26°34'25''S; 28°30'37''E)	RU60	Quantity	Flows	Dam levels must be maintained at sufficient levels to provide releases for municipal and industrial use as well as protection of ecosystem function downstream.	The dam supplies water for municipal and industrial use to Balfour. Currently there are limited releases from the dam into the river.	Not Applicable	DWA, 2010
UL	Klerkskraal Dam	RU69	Quantity	Flows	Dam levels must therefore be	This dam was constructed mainly for irrigation	Not Applicable	DWA, 2010

	(26°15'9"S; 27°9'40"E)				maintained at levels sufficient for irrigation releases as well as for protection of ecosystem function downstream.	releases, but needs to release water for protection of ecosystem functioning downstream.		
	Donaldson Dam (26°16'55"S; 27°41'0"E)	RU71			Dam levels must be maintained such that ecosystem function is protected and the recreational value of the dam is retained.	The main purpose of the dam is recreation. There are a number of in-stream dams upstream which could affect inflow volumes to the dam and therefore water levels.	Not Applicable	DWA, 2013
	Klipdrift Dam (26°37'0"S; 27°17'52"E)	RU72			The dam must be maintained at sufficient levels for irrigation releases and releases for the protection of ecosystem function downstream.	The main purpose of the dam is irrigation.	Not Applicable	DWA, 2013
	Boskop Dam (26°33'42"S; 27°6'41"E)	RU73			The dam must be maintained at levels sufficient for irrigation releases and releases for protection of ecosystem function downstream.	The dam was built mainly for irrigation releases and there is extensive irrigation downstream.	Not Applicable	DWA, 2013
UM	Vaal Barrage (26°45'53"S; 27°41'3"E)	RU75	Quantity	Flows	Levels must be maintained at sufficient levels for municipal and industrial releases as well as to provide releases for the protection of ecosystem function downstream.	The purpose of the Vaal Barrage is to supply water to Rand Water and to industrial users like Eskom, Iscor and Sasol. Water is released from the Vaal Dam through the Vaal Barrage for irrigation and municipal use downstream.	Not Applicable	DWA, 2013 Extrapolated from Vaal_EWR5 in C23L
	Vaal Dam (26°52'57"S; 28°6'58"E)	RU74			Dam levels must be maintained such that they are sufficient for municipal, industrial and irrigation releases as well as protection of ecosystem function downstream. During the wet season dam inflows and levels must be maintained such that they are sufficient for releases for intended use, and release for the protection of ecosystem function downstream.	The purpose of the dam is to release water for municipal, industrial and irrigation use downstream. There are transfers in and out of the dam, and these result in variability in flows. There are increased base-flows due to dam inflow and releases for other users.	Not Applicable	DWA, 2010

Table 25: Supplementary information for DAM QUALITY RQOs on ecosystem scale.

Dam Water Quality								
IUA	**Dams**	**RU**	**Component**	**Sub Component**	**Context of the RQO**	**TPC**		**Reference**
UA	Grootdraai Dam (26°55'9.2"S; 29°17'41.6"E)	RU10	Quality	Nutrients	Nutrient concentrations impact negatively on the ecosystem of this NFEPA site, but also negatively on recreation, ecotourism and real estate values. They also reduce the fitness of the water for domestic use. The nutrient condition must be improved to a C category.	Phosphate(PO_4) *	0.020 mg/L P	DWAF, 2008
						Nitrate (NO_3) & Nitrite (NO_2) *	0.85 mg/L N	
UB	Vrede/Thembalihle Dam (27°26'21.8"S; 29°11'45.1"E)	RU20	Quality	Nutrients	There is potential for agricultural return flows from upstream which may result in an increase in nutrient levels in the dam. The system must be maintained in a mesotrophic state or better.	Phosphate(PO_4) *	0.020 mg/L P	DWAF, 2008
						Nitrate (NO_3) & Nitrite (NO_2) *	0.85 mg/L N	
UD	Gerrands Dam (28°16'55.3"S; 28°17'30.6"E)	RU43	Quality	Nutrients	Nutrients must be maintained at mesotrophic levels.	Phosphate(PO_4) *	0.020 mg/L P	DWAF, 2008
						Nitrate (NO_3) & Nitrite (NO_2) *	0.85 mg/L N	
	Loch Athlone Dam (28°15'0.9"S; 28°18'31.4"E)				There is irrigation and small in-stream dams upstream. There may be irrigation return flows that could impact on the nutrient levels in the dam. Nutrients must be maintained at mesotrophic levels so as to retain the recreational value of the dam.	Phosphate(PO_4) *	0.020 mg/L P	DWAF, 2008
						Nitrate (NO_3) & Nitrite (NO_2) *	0.85 mg/L N	
	Saulspoort Dam (Sol Plaatjie Dam) (28°13'1.5"S; 28°21'46.9"E)	RU41			There are high phosphate concentrations in the dam. Nutrients must be maintained at mesotrophic levels to protect the ecosystem and also the fitness for use.	Phosphate(PO_4) *	0.020 mg/L P	DWAF, 2008
						Nitrate (NO_3) & Nitrite (NO_2) *	0.85 mg/L N	
UL	Klipdrift Dam (26°37'0"S; 27°17'52"E)	RU72	Quality	Nutrients	The system is currently in a eutrophic state and must be improved and maintained in a mesotrophic state.	Phosphate(PO_4) *	0.020 mg/L P	DWAF, 2008
						Nitrate (NO_3) & Nitrite (NO_2) *	0.85 mg/L N	
	Boskop Dam (26°33'42"S; 27°6'41"E)	RU73			Upstream activities, especially Wastewater Treatment Works, are introducing nutrients which are causing eutrophic conditions manifesting as excessive filamentous algal growth. To reduce the amount of algae the nutrient concentrations must be reduced so that the nutrient state is improved to a D category.	Phosphate(PO_4) *	0.020 mg/L P	DWAF, 2008
						Nitrate (NO_3) & Nitrite (NO_2) *	0.85 mg/L N	
UM	Vaal Barrage (26°45'53"S; 27°41'3"E)	RU75	Quality	Nutrients	Nutrient concentrations are excessive resulting from upstream activities. Concentrations must be controlled to prevent eutrophication and also to minimise water treatment costs. Nutrient concentrations should be managed to a C category.	Phosphate(PO_4) *	0.020 mg/L P	DWAF, 2008
						Nitrate (NO_3) & Nitrite (NO_2) *	0.85 mg/L	

							N	
	Vaal Dam (26°52'57"S; 28°6'58"E)				Nutrient concentrations are excessive resulting from upstream activities. Concentrations must be controlled to prevent eutrophication and also to minimise water treatment costs. Nutrient concentrations should be managed to a C category.	Phosphate(PO_4) *	0.020 mg/L P	DWAF, 2008
						Nitrate (NO_3) & Nitrite (NO_2) *	0.85 mg/L N	
UB	Vrede/Thembalihle Dam (27°26'21.8"S; 29°11'45.1"E)	RU 20	Quality	Salts	Irrigation return flows from upstream may contribute to increased salinity. Salt levels must be maintained at a *C category*.	Electrical Conductivity*	70 mS/m	DWAF, 2008
UL	Klipdrift Dam (26°37'0"S; 27°17'52"E)	RU 72	Quality	Salts	Irrigation return flows may result in increased salt concentrations in the dam. There are small urban and mining areas upstream and these may also contribute to changes in the water quality of the dam. Salt levels must be maintained at a *C category* in the dam.	Electrical Conductivity*	70 mS/m	DWAF, 2008
UM	Vaal Barrage (26°45'53"S; 27°41'3"E)	RU 75	Quality	Salts	The water from the dam contains high salt concentrations and is used for potable water supply, thus salt concentrations must be maintained in a *C category* or better.	Electrical Conductivity*	70 mS/m	DWAF, 2008
UL	Boskop Dam (26°33'42"S; 27°6'41"E)	RU 73	Quality	System Variables	The pH of the water in the dam is high and this could negatively impact on ecosystem function. The pH of the water in the dam must be maintained at a *C category*.	pH_max *	8.4	DWAF, 2008
						pH_min *	6.2	
UA	Grootdraai Dam (26°55'9.2"S; 29°17'41.6"E)	RU10	Quality	Toxins	Pesticides emanating from agriculture activities are potentially threatening the ecosystem maintenance and need to be maintained at levels which are non-toxic to the ecosystem.	Chl-a: phytoplankton*	18 µg/L	DWAF, 2008
UD	Gerrands Dam (28°16'55.3"S; 28°17'30.6"E)	RU 43	Quality	Toxins	There is potential of cyanobacterial blooms. The system must be maintained in a mesotrophic condition to avoid cyanobacteria and the associated algal toxins.	Chl-a: phytoplankton*	18 µg/L	DWAF, 2008
	Loch Athlone Dam (28°15'0.9"S; 28°18'31.4"E)							
	Saulspoort Dam (Sol Plaatjie Dam) (28°13'1.5"S; 28°21'46.9"E)	RU 41 & 43						
UL	Klipdrift Dam (26°37'0"S; 27°17'52"E)	RU 72	Quality	Toxins	The eutrophic status of the dam may potentially result in cyanobacterial blooms with the associated toxins. This could have a negative impact on the ecosystem function in the dam. To avoid cyanobacteria blooms, the dam must be maintained in a mesotrophic state.	Chl-a: phytoplankton*	18 µg/L	DWAF, 2008
UM	Vaal Barrage (26°45'53"S; 27°41'3"E)	RU 75	Quality	Toxins	The Vaal Barrage is known for incidents of cyanobacteria blooms. The system must be maintained in a mesotrophic state to prevent build-up of cyanobacteria blooms and associated algal toxins. There is potential for the presence of heavy metals as the barrage receives water from upstream industrial effluent. The water in the Barrage should not contain toxins including metals at levels that pose a threat to human health.	Chl-a: phytoplankton*	18 µg/L	DWAF, 2008
	Vaal Dam (26°52'57"S; 28°6'58"E)	RU 74			There are historical occurrences of cyanobacterial blooms in the dam. The system must be maintained in a mesotrophic state to avoid cyanobacterial blooms and associated algal toxins.	Chl-a: phytoplankton*	18 µg/L	DWAF, 2008

Table 26: Supplementary information for DAM BIOTA RQOs on ecosystem scale.

Dam Biota							
IUA	**Dams**	**RU**	**Component**	**Sub Component**	**Context of the RQO**	**TPC**	**Reference**
UA	Grootdraai Dam (RU 10, 26°55'9.2"S; 29°17'41.6"E)	RU10	Biota	Fish	This dam provides an important refuge area for indigenous fishes and must be managed to maintain suitable populations of the local Orange-Vaal largemouth yellowfish (*Labeobarbue kimberleyensis*) and ecologically important Barbs (*Barbus* spp.).	Habitat suitability and fish wellbeing in a state equivalent to a low C ecological category.	IUCN, 2013
						Fish health must not deviates noticeably (not significant) from baseline state	Du Preez et al, 2003
						Toxicants in fish tissue differ noticeably from base line state (to be determined)	
UC2	Sterkfontein Dam (RU 33 & 34, 28°23'15"S; 29°1'1"E)	RU33 RU34	Biota	Fish	This dam contains an abundant population of the threatened Orange-Vaal largemouth yellowfish (*Labeobarbus kimberleyensis*).The genetic diversity of local cyprinids may be threatened by the relocation of species from the Thukela catchment into the dam through the hydro-electric power generation scheme.	Habitat suitability and fish wellbeing in a state equivalent to a low C ecological category.	IUCN, 2013
						Risk of genetic diversity contamination exists.	
UL	Donaldson Dam (RU 71, 26°16'55"S; 27°41'0"E)	RU71	Biota	Fish	The fish communities within the Donaldson Dam have been severely altered by water quality impacts. In addition the health of the populations that still occur in the dam pose a high risk to human health when consumed.	Fish health must not deviates noticeably (not significant) from baseline state	Du Preez et al, 2003
						Toxicants in fish tissue differ noticeably from base line state (to be determined)	
	Boskop Dam (RU 73, 26°33'42"S; 27°6'41"E)	RU73			The fish communities within the Boskop Dam have been severely altered by water quality impacts. In addition the health of the populations that still occur in the dam pose a high risk to human health when consumed. This dam has a high diversity of indigenous species and provides refuge for the Orange-Vaal largemouth yellowfish. Ecotourism and recreational angling is important in this dam.	Habitat suitability and fish wellbeing in a state equivalent to a low C ecological category.	IUCN, 2013
						Fish health must not deviates noticeably (not significant) from baseline state	Du Preez et al, 2003
						Toxicants in fish tissue differ noticeably from base line state (to be determined)	
UM	RU74 - Vaal Dam (26°52'57"S; 28°6'58"E)	RU74	Biota	Fish	This dam provides an important refuge area for indigenous fishes and must be managed to maintain suitable populations of the local Orange-Vaal largemouth yellowfish (Labeobarbue kimberleyensis) and ecologically important Barbs (Barbus spp.).	Habitat suitability and fish wellbeing in a state equivalent to a low C ecological category.	IUCN, 2013
						Fish health must not deviates noticeably (not significant) from baseline state	Du Preez et al, 2003
						Toxicants in fish tissue differ noticeably from base line state (to be determined)	
	Vaal Barrage (RU 75, 26°45'53"S; 27°41'3"E)	RU75			The fish communities within the Barrage Dam have been severely altered by water quality impacts. In addition the health of the populations that still occur in the dam pose a high risk to human health when consumed.	Fish health must not deviates noticeably (not significant) from baseline state	Du Preez et al, 2003
						Toxicants in fish tissue differ noticeably from base line state (to be determined)	

4.4 GROUNDWATER RESOURCE QUALITY OBJECTIVES AND NUMERICAL LIMITS FOR THE UPPER VAAL WMA

The outcomes of the RQO and NL determination of the sub-components and indicators for the groundwater component of the RQO determination study for the Upper Vaal WMA, including a summary of additional supplementary information are provided as follows (Figure 5):

- RQOs for groundwater presented in Table 27.
- Supplementary information for groundwater is presented in Table 28.

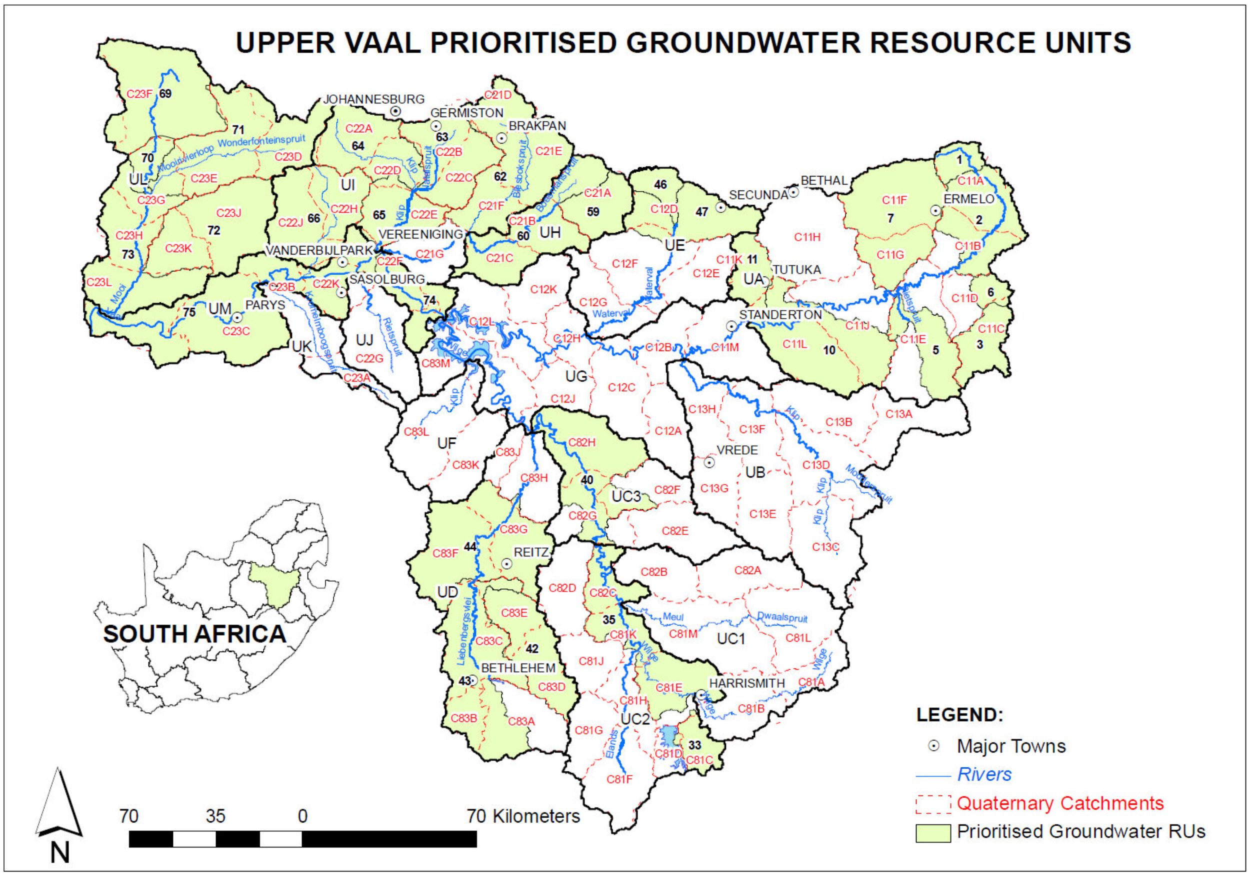

Figure 5: Priority groundwater Resource Units considered in the study within Integrated Units of Analyses. Quaternary catchments and major rivers also presented.

4.4.1 GROUNDWATER RESOURCE QUALITY OBJECTIVES AND NUMERICAL LIMITS TABLES

Table 27: RQOs for GROUNDWATER in priority RUs in the Upper Vaal WMA

GROUNDWATER					
IUA	**RU**	**Component**	**RQO**	**Indicator/ measure**	**Numerical Limits**
All	All Prioritised RUs	Quantity	Where water use is higher than requirements for Reserve, Schedule 1 and General Authorizations, abstraction rates should not exceed the average recharge values of the aquifer based on the area.	Abstraction Volume (Q) per hectare > Reserve, Schedule[1] and General Authorizations.	Q < Average recharge per hectare
All	RU1 RU2 RU3 RU5 RU6 RU7 RU10 RU11 RU33 RU35 RU40 RU42 RU44 RU43 RU46 RU47 RU59 RU60 RU74	Aquifer	Medium to long-term water trends should not show negative decline or deviation from the natural trend	Depth to Groundwater Level using Groundwater Monitoring Guidelines[2].	At least one NGwQI MP monitoring site that is representative of the aquifer. Water level fluctuations in Dolomitic aquifers[6] should not exceed 6m.
	RU69				Water level fluctuations around the average site water level should not exceed 4.05 m
	RU63				Water level fluctuations around the average site water level should not exceed 15.3 m
	RU71				Water level fluctuations around the average site water level should not exceed 13.8 m
	RU64				Water level fluctuations around the average site water level should not exceed 14.8 m
	RU66				Water level fluctuations around the average site water level should not exceed 23.6 m
	RU75				Water level fluctuations around the average site water level should not exceed 9.8 m
	RU70				Water level fluctuations around the average site water level should not exceed 15.4 m
	RU62				Water level fluctuations around the average site water level should not exceed 11.8 m
	RU73				Water level fluctuations around the average site water level should not exceed 4.2 m
	RU65				Water level fluctuations around the average site water level should not exceed 22.9 m
	RU72				Water level fluctuations around the average site water level should not exceed 7.16 m
All	All Prioritised RUs	Quantity	The radius of influence should not intersect any other protection zone. In cases where infringements already exits, the infringements will be used as baseline measurement.	Radius of influence (r)□. r = 1.5*√(T*t/S), T=Transmissivity(m^2/d), t=Time(days), S=Storativity. Annual sampling via GIS algorithm or on introduction of new borehole	r should not overlap with any other radius of influence, cone of depression, protection zone or increase zone infringements
All	All Prioritised RUs	Ecological	A protection zone along a river/stream is required to protect the ecological reserve. In cases where infringements already exits, the infringements will be used as	Distance from river (L)4. L = (T*i)/R, T=Transmissivity(m2/d), i=Groundwater Gradient, R=Recharge(m/d). Annual sampling via GIS algorithm or on introduction of new borehole	L should not overlap with any other radius of influence, cone of depression, protection zone or increase zone infringements

			baseline measurement.		
All	All Prioritised RUs	Ecological	A protection zone along all wetlands is required to protect the ecological reserve. In cases where infringements already exits, the infringements will be used as baseline measurement.	Distance from river (L)[4]. L = (T*i)/R, T=Transmissivity(m²/d), i=Groundwater Gradient, R=Recharge(m/d) W=Wetland Perimeter. Annual sampling via GIS algorithm or on introduction of new borehole (perimeter is based on the Wetland Delineation Guidelines).	L should not overlap with any other radius of influence, cone of depression, protection zone or increase zone infringements
All	All Prioritised RUs	Quality	Boreholes require a protection zone from microbial pollution sources. Minimum requirement of 75m depending on the geohydrological condition of the area.	Microbial radius (r)[4]. r = 2(0.28*T) + 53, T=Transmissivity(m²/d). Annual sampling via GIS algorithm or on introduction of new borehole	Distance to pit latrine > r
All	All Prioritised RUs	Quality	Groundwater quality should be based on the groundwater quality change in water quality should not be allowed to deteriorate significantly from backgroundwater quality	Background water quality per borehole using Groundwater Monitoring Guidelines2²	Water quality should not be allowed to deteriorate significantly form background water quality

[1] *General Authorization for the taking and storage of water, DWAF (2012)*
[2] *A Guideline for the Assessment, Planning and Management of Groundwater Resources in South Africa, DWAF (2008)*
[3] *The radius of influence is time dependent and the RU statistics is based on borehole pumping of 8 hours/day*
[4] *A protection zone is defined as a zone where the groundwater gradient is maintained*
[5] *South African Water Quality Guidelines, DWAF (1996)*
[6] *Groundwater Resource Directed Measures, WRC (2007)*

4.4.2 SUPPLEMENTARY INFORMATION FOR THE GROUNDWATER RESOURCE QUALITY OBJECTIVES AND NUMERICAL LIMITS TABLES

Table 28: Supplementary information for GROUNDWATER on Resource Unit scale.

GROUNDWATER						
IUA	**RU**	**Component**	**Indicator/ measure**	**Context of the RQO**	**TPC**	**Reference**
All	All Prioritised RUs	Quantity	Abstraction Rate (Q) per hectare > Reserve, Schedule¹ and General Authorizations.	In areas where the abstraction per unit area exceeds the recharge per unit area, aquifer failure is likely. Although it is not possible to abstract all recharge from groundwater, the abstraction compared to the recharge gives an indication of the current aquifer stress.	Stress Index = Abstraction / Recharge, Highly Stressed = 0.65 to 0.95, Critically Stressed > 0.95	WRC, 2007
All	RU1 RU2 RU3 RU5 RU6 RU7 RU10 RU11 RU33 RU35 RU40 RU42 RU44 RU43 RU46 RU47 RU59 RU60 RU74	Aquifer	Depth to Groundwater Level using Groundwater Monitoring Guidelines².	Recovery in groundwater levels over time is an indication that over abstraction is not taking place. Although groundwater levels can vary significantly across a resource unit, groundwater monitoring points should be identified which is representative of the overall aquifer response.	N/A	WRC, 2011
	RU69 RU63 RU71 RU64 RU66			Recovery in groundwater levels over time is an indication that over abstraction is not taking place. Although groundwater levels can vary significantly across a resource unit, groundwater monitoring points should be identified which is representative of the overall aquifer response.	Declining water level trend from average level after wet season	WRC, 2011

	RU75					
	RU70					
	RU62					
	RU73					
	RU65					
	RU72					
All	All Prioritised RUs	Quantity	Radius of influence (r)□. r = 1.5*√(T*t/S), T=Transmissivity(m^2/d), t=Time(days), S=Storativity. Annual sampling via GIS algorithm or on introduction of new borehole	The radius of influence of a borehole gives an indication of how far the effect of the borehole drawdown will reach. It should be noted that this is a theoretical estimate and is not dependent on the abstraction rate, but only on the aquifer parameters and the duration of abstraction. The borehole radius of influence should not intersect any other radius of influence or protection zone.	N/A	WRC, 2007
All	All Prioritised RUs	Ecological	Distance from river (L)4. L = (T*i)/R, T=Transmissivity(m2/d), i=Groundwater Gradient, R=Recharge(m/d). Annual sampling via GIS algorithm or on introduction of new borehole	The concept of a river protection zone is to ensure that the average groundwater gradient toward the river is not altered, as this is the driving force of the natural groundwater seepage toward the river. This gradient will stay intact as long as there are no other protection zones infringing on the river protection zone.	N/A	WRC, 2007
All	All Prioritised RUs	Ecological	Distance from river (L)[4]. L = (T*i)/R, T=Transmissivity(m^2/d), i=Groundwater Gradient, R=Recharge(m/d) W=Wetland Perimeter. Annual sampling via GIS algorithm or on introduction of new borehole (perimeter is based on the Wetland Delineation Guidelines).	The concept of a wetland protection zone is to ensure that the average groundwater gradient toward the wetland is not altered, as this is the driving force of the natural groundwater seepage toward the wetland. This gradient will stay intact as long as there are no other protection zones infringing on the wetland protection zone.	N/A	WRC, 2007
All	All Prioritised RUs	Quality	Microbial radius (r)[4]. r = 2(0.28*T) + 53, T=Transmissivity(m^2/d). Annual sampling via GIS algorithm or on introduction of new borehole	Communities dependent on groundwater often don't have sufficient infrastructure for sanitation purposes. The result of this is that houses and pit latrines are often constructed close to the water supply which leads to microbial pollution of the groundwater emanating from the pit latrines. High Nitrate values are a known cause of the “blue baby” syndrome and are fatal to young children. The microbial protection zone aims to protect groundwater from being exposed to high Nitrate values.	N/A	WRC, 2007
All	All Prioritised RUs	Quality	Background water quality per borehole using Groundwater Monitoring Guidelines2[2]	Groundwater should be fit for use e.g. human consumption, stock watering or irrigation purposes. Due to the fact that groundwater quality is related to the underlying geology it is often found that the background water quality exceeds the guideline associated with a particular use. For these cases the groundwater quality should be managed against the natural background values and all other cases should be managed against the specified guideline applicable to the specific use.	Continued declining water quality trend from established background	N/A

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6 APPENDIX

6.1 APPENDIX A: TECHNICAL BRIEF FOR THE JUSTIFICATION OF WATER QUALITY NUMERICAL LIMITS USED IN THE STUDY.

DERIVATION OF WATER QUALITY RESOURCE QUALITY OBJECTIVES

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SCOPE OF THE BRIEF

The brief was to determine water quality RQOs and Numerical Limits i.e. numerical estimates of the values of water quality variables ensuring a balance between ecological functioning and economic use of water resources for the Lower Vaal River.

Variability and uncertainty in the data

The contributors to the indeterminacy of the value of a water quality variable characteristic of a desired state are divided into the two entities, *variability* and *uncertainty*:

- Uncertainty: in a system is partitioned into known elements, the behaviour of which are unknown, and elements interacting with and within systems, which are completely unknown. Known uncertainty is for example the direction and magnitude of climate change, of population migrations, of international commodity markets. Unknown uncertainty is that which is identified and reduced through the application of scientific research and management experience. Thus in order to account for uncertainty, RQOs may be regarded as “best estimates” in the light of current knowledge.
- Variability: in the system is the known or potentially known changing behaviour of elements within the system, such as annual fluctuations in temperature, rainfall, drought cycles and others.

In this assessment an attempt is made to quantify variability in water quality parameters by making the assumption that elements influencing immediate future behaviour of systems impacting on the water quality of a resource are relatively static in the short timeframe of the anticipated lifetime of the RQO. The variability in the water quality of the water resource is taken as the variance in the water quality parameters measured over a stipulated period. The variability embedded in the RQO is expressed as the 95^{th} %ile of the projected range of the water quality variable. In other words, embedded in the philosophy underlying the endeavour of quantifying RQOs for water quality is the knowledge that the Numerical Limits must change in future as understanding of the ecosystem is improved.

Compliance with water quality RQOs and Numerical Limits

Compliance with RQOs and especially Numerical Limits may be confused with compliance with a license condition. The main difference between compliances is that RQOs are *objectives* conceivably unattainable at present. In the present application, the managers of the water resource would be required to demonstrate continual approach towards the RQO, as opposed to the situation of compliance with a license condition, which is strict adherence to an achievable range of water quality values.

Conceived future implementation of water quality RQOs

The expression of RQOs as numerical quantities, albeit with ranges to address variability and embedded uncertainty, is viewed by the author of this document as an interim strategy, pending a more sophisticated approach. It is conceived here that rather than documentation and Gazetting of numerical values of RQOs, a more favourable future approach would be documentation and Gazetting of an accepted, scientifically and technically defensible, *method* of deriving unambiguous RQOs, in the light of the complexity of each system examined. Within complex systems many factors are connected to each other as “trade-offs”, arising naturally and immutably, such that the behaviour of one entity is strongly negatively or positively impacted by another. In these situations the normal logic of fixed entities breaks down. An imperfect but simple example would be the definition of RQOs for Winter and Summer periods, when annual absolutes do not exist.

Bayesian logic handles fractional values of descriptors.

Since systems of interacting elements may be represented as networks of known or hypothesised relationships between known entities, the Bayesian Network Analysis approach is more subtle and dynamic than the approach assumed in the current endeavour. It is anticipated that this or similar instruments may be standardised, as opposed to the uncertain and changing numerical descriptors of a desired state of a water resource.

Sources of information for this study

Site Water Quality Monitoring Data

Water quality monitoring data informing the projected values of water quality parameters was obtained from the DWA WMS database.

Water Quality Standards

The sources of water quality standards were the:

- South African Water Quality Guidelines (second edition). Volume 1: Domestic Use (2006);

METHODS

Origin of the data

The Google Earth WMS templates were used to locate the most appropriate DWA water quality monitoring sites to adequately characterise the water quality status and trends in the resource under investigation. In the case of dams the choice of monitoring point is usually straightforward since for most dams there exists a water quality monitoring point at which samples are taken and analysed and the resultant water quality information is readily available on the WMS site. In the case of rivers the situation is much more complex as water quality monitoring points may fortuitously be located at the lowest point of the region (or Resource Unit) of interest, but often such DWA water quality monitoring points are located elsewhere on the water resource, or completely absent. Various strategies are implemented to estimate what the conditions might be in the water resource under investigation, including inspection of land use and assignment of data from similar water resources relatively close geographically.

Use of the data

Prior to the current determination of numerical values for characterising desired states of the water resources, analysis had been performed of the requirements of various entities within the ambit of the resource and the general RQO expressed in terms of DWA categories "A" to "E". In deriving the current values, an adaptation of the methods for deriving site-specific water use license criteria was implemented. A reference monitoring point, supposedly representing data from a "pre-anthropogenic" impact, was chosen such that the water quality monitoring data represented a state several decades before the present. The "Present Ecological Status" monitoring location was chosen as described above.

Monitoring data points were examined for obvious spurious irregularities, such as those resulting from errors in input to the WMS database. These would typically be manifested as gross "outliers" from the range of the data representing the water quality parameter under investigation. Caution should be exercised, however, in excising these "outliers" from the dataset, as they may represent real occurrences which may be a feature of the system impacting the water resource, and thus should be retained in the analysis. There are methods of cross-checking such apparent anomalies. For instance, if a spike in electrical conductivity is observed in a water resource directly downstream of a coal-mining operation, the corresponding pH of the water sample would be expected to decrease significantly. If not, then traditional statistical outlier analyses may be implemented to test for advisability of deleting the value from the analysis. Water quality monitoring data is often sparse and there is a considerable temptation to use one of the "missing value interpolation" algorithms to yield a larger dataset for analysis. This practice was avoided in this endeavour, but may be considered in future implementations, particularly if a Bayesian analysis is used. The dataset representing the reference condition and the present ecological status were inputted into the Reserve Determination program TEACHA, the use and interpretation being provided in DWA (2008).
The distinct advantages of using this tool include

- Rigorous development of the algorithms
- Extensive implementation of the method for setting guidelines
- Similarity of purpose between the setting of guidelines and derivation of RQOs
- Embedded sophisticated methods for determining the 95th %ile for the numerical limits.

Baseline adjustment of the "reference condition" data was implemented in order to project the output of the TEACHA program into the range of desirability of the water quality parameters. The latter implementation may seem at first glance to add an arbitrary modification to an exact procedure. The justification for this approach lies in the current high indeterminacy of the characteristics of the systems within the regions of interest, mindful of the objective of the exercise, that being to establish a range of values for the RQOs, expressed as a 95th %ile. Workshops were convened and the required medium-term water quality objectives established based on current available information as described above. The outputs of the workshops as regarding water quality were the different levels of protection required for a water resource, including rivers, dams and wetlands. These levels of protection were translated into the well-known and widely implemented water resource classes. In some instances water quality classes have not been derived for water quality constituents of interest and of importance. Variables not currently analysed and graded in terms of the water resource class system include sulphate, uranium, biological oxygen demand (BOD) and Chemical Oxygen Demand (COD).

RQOs as indicators of water quality risk

The water quality RQOs and their associated Numerical Limits function as recommended upper concentrations for the resource to be managed. The RQOs and Numerical Limits thus function as target indicators for management, akin to the “Effects” values employed in an Ecological Risk Assessment (US EPA 1999). The observed concentrations of the water quality variables would function as “Exposure” parameters to be compared to the Effects values. The water quality variable in concern would be referred to as the “Stressor” and the measure of the water quality variable as the “Exposure”. These two measures fit into the Tier I Risk Assessment method which is simply a comparison of the two values, Exposure and Effects values, in a mathematical relationship. More specifically the Tier I Risk Quotient is the value obtained when Exposure concentrations are divided by Effects concentrations. Thus if the Tier I Risk Quotient is less than 1.0 then the Exposure concentrations are less than the Effects concentrations, and one assumes that all is well with respect to that water quality parameter. In the case of the analysis performed in the derivation of the RQOs in the current study, the Tier I Risk Quotient would be less than 1.0 if the concentrations of water quality parameter were below the RQO Numerical Limit for that parameter.

Use of DWA Classifications for water quality RQOs.

The target quality of the water resource under investigation is expressed in the familiar DWA resource classifications expressed in Table A2.1 below. Acceptable resource classes range from A to D and are directly associated with PES ratings which range from 1 to 4. In the case of many water quality variables, the concentrations relate to the classes in a linear fashion, as shown in Figure A2.1.

Table A2.1: DWA resource classifications

Resource ecosystem values	Natural	Good	Upper Fair	Lower Fair
Deviation from reference condition	No change	Small change	Moderate change	Large change
Water Quality category	A	B	C	D
PES Ratings	1	2	3	4

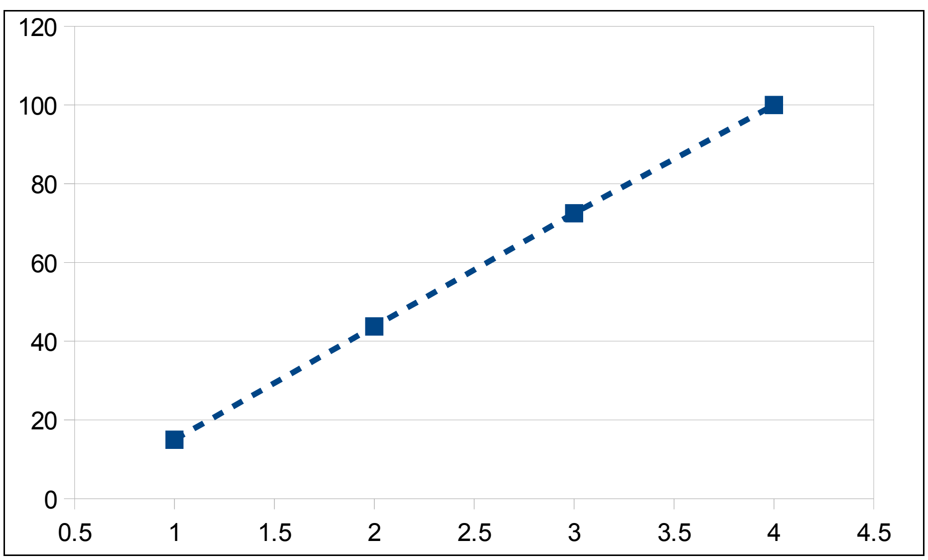

Figure A2:1 Concentrations (y-axis) of ammonia corresponding to DWA categories (x-axis).

The general method for establishing the concentration ratings is to establish the chronic effects concentration of a particular water quality variable on an indicator organism and to set the upper limit of the A category to this value. The acute effects value on the organism is set to the upper limit of the D category. The intervening categories are usually derived by interpolating a straight line through the A value and the D value, with the PES ratings acting as the numerical equivalent of the categories A to D. Fractional ratings are allowed for, given that some of the resource classes are broad in definition and some ecosystem requirements change within the classification. Thus if an ecosystem requirement falls between an A and a B category, the required value of the ecosystem category is designated AB. The numerical equivalent of the fractional ecosystem category is derived by interpolating between the categories on either side. Thus if a concentration value corresponding to an AB category is required, the concentration values of the water quality variable corresponding to A category (PES rating = 1.0) and B category (PES rating = 2.0) are interpolated to a PES rating of 1.5. E.g. for unionised ammonia the concentrations corresponding to the ecological categories are as presented in Table A2.2

Table A2.2 Ammonia (unionised) values at fractional levels of WQ category.

Water Quality category	**A**	**AB**	**B**	**BC**	**C**	**CD**	**D**
PES Ratings	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
Ammonia (µg/L N)	**15.0**	**29.4**	**43.8**	**57.8**	**72.5**	**86.2**	**100**

Thresholds of potential concern (TPCs)

The threshold of potential concern (TPC) is the numerical value which serves as an alert that the ecological system is potentially threatened by approach of the relevant water quality variable to the RQO Numerical Limit value. The TPC is set to the concentration corresponding to the interpolated intermediate fractional value of the ecosystem category. Thus, for example, if the substance in question is ammonia and the Numerical Limit is the AB category, corresponding to a PES rating of 1.5 (mapping onto a concentration of 29.4 µg/L N), the TPC will correspond to a PES rating of 1.0 (mapping onto a concentration of 15.0 µg/L N).

Relationship of RQO Numerical Limits and TPCs with Risk Quotients

If the RQO Numerical Limit is the upper limit of tolerable effects, corresponding to stressor concentrations, a Risk Quotient of a stressor at the RQO is 1.0. Since in the case of a linear relationship of DWA categories with stressor concentrations corresponding to chronic ill effects (upper limit of A category) to acute ill effects (upper limit of D category) the intercept of the extrapolated line is not guaranteed to be zero, there is no clear regularity between TPC and Risk Quotient.

Water Quality Criteria defining risk

Exposure parameters

Water quality exposure parameters as classified in DWAF (2008) are presented below (Table A2.3). This list is incomplete with respect to the study of the catchments in this study, for which local guidelines were derived.

Table A2.3: Water quality indicators for which SA Guidelines exist

Algae	**Cyanide**	**Phenol**
Alkalinity	**Dissolved Organic Carbon**	**Phosphorus**
Aluminium	**Dissolved Oxygen**	**Potassium**
Ammonia	**Endosulfan**	**Protozoan Parasites**
Arsenic	**Enteric Viruses**	**Radionuclides**
Asbestos	**Faecal Streptococci**	**Selenium**
Atrazine	**Fluoride**	**Silica**
Beryllium	**Iron**	**Sodium**
Boron	**Lead**	**Sodium Absorption Rate**
Cadmium	**Lithium**	**Sulphate**
Calcium	**Magnesium**	**Sulphides**
Carbon Dioxide CO	**Manganese**	**Suspended Solids**
Chemical Oxygen Demand	**Mercury**	**Total Dissolved Solids**
Chloride	**Molybdenum**	**Total Hardness**
Chromium(VI)	**Nickel**	**Trihalomethanes**
Cobalt	**Nitrate/Nitrite**	**Turbidity**
Coliforms	**Nitrogen (Inorganic)**	**Uranium**
Coliphages	**Odour**	**Vanadium**
Contents	**Organic Carbon**	**Zinc**
Copper	**pH**	

SUBSTANCES RELEVANT TO THIS STUDY

Consideration of inclusion of WQ variables

The workshops defining the water quality categories of the selected geographical units, water resources, and the water quality constituents of relevance yielded the following comprehensive list for the Olifants, Upper Vaal and Lower Vaal catchments. The water quality constituents easily represent as indicators or measures of water quality in the geographical units. The values corresponding to the indicators or measures are specified in published texts. These are referenced in Table A2.4.

Table A2.4: Present State Rating variables used for the Water Quality RQO components (DWAF (2008)

Target	Type	Indicator
Human & ecosystem	Metal	Al
Human & ecosystem	Metalloid	As
Human & ecosystem	Pesticide	Atrazine
Human & ecosystem	Metal	Cd hard
Human, ecosystem & agriculture	Halogen	Chlorine (free)
Human & ecosystem	Metal	Cr(VI)
Human & ecosystem	Metal	Cu hard

Human & ecosystem	Pesticide	Endosulfan
Human & ecosystem	Halogen	F
Human & ecosystem	Metal	Hg
Wetland biota	Electron donor	Ammonia (unionised)
River and wetland biota	Oxidant	Dissolved oxygen
Human & ecosystem	Metal	Cu hard

Table A2.5: Variables used for the Water Quality RQO components (This study)

Target	Type	Indicator
Human	Algal toxins	Chl-a: phytoplankton
Wetland biota	Reductant	COD
Human & ecosystem	Metal	Mn
Human & ecosystem	Metalloid	Se
Wetland biota	Electron donor & acceptor	TIN-N
River organisms	Electron donor	Total Ammonia
Human & ecosystem	Metal	Uranium
Human & ecosystem	Metal	Zn
River and wetland biota	Oxidant	Dissolved oxygen

Nutrients

Nutrients - general

Total inorganic nitrogen (TIN = $[NO_2^-]$ + $[NO_3^-]$ + $[NH_4^+]$: species specified as concentration of nitrogen) – Note that unionised ammonia is regarded as a toxicant and described under "Toxics". At pH levels below 9.3 most ammonia is in the ionised ammonium (NH_4^+) form.
Phosphate (PO_4^{3-}) – also referred to as SRP (Soluble Reactive Phosphorous) or ortho-phosphate, as distinct from Total Phosphate, designated "TP".

Ammonia (Total)

Total ammonia as a nutrient was used in the context of river water quality.
Within the context of river water quality the total ammonia was specified as a RQO Numerical Limit in order to limit the trophic state of the river to mesotrophic ("good") state, and to prevent nuisance conditions for ecotourism. Ammonia is very readily detected as a smell and is noxious at concentrations below that of many other naturally emitted gases.

Chl-a: phytoplankton

Chl-a: phytoplankton is used as an indicator for the presence of nutrients in a water resource. The indicator is useful because chlorophyll-a is readily and inexpensively measured by spectrophotometry. Care has to be used in using Chl-a as an indicator where there is additional turbidity not due to algal biomass. If significant turbidity is a result of inorganic particle suspension the particles may occlude the chlorophyll and result in a measurement lower than actual.

Nitrate (NO_3) & Nitrite (NO_2)

Nitrate (NO_3) & Nitrite (NO_2) is a direct measure of nutrient concentration, the NOx being utilised by algae, high levels of which nutrient result in high levels of problematic algal biomass.

Total Inorganic Nitrogen (TIN)

Total Inorganic Nitrogen (TIN) is a useful measure of nutrient concentration.

Care must be taken, however, in systems in which ammonia is in high concentration. Ammonia will report to TIN, whilst it is not directly used as a nutrient by macroscopic organisms.

The assumption that ammonia is a useful component of TIN as describing nutrient status may not be valid. The conversion of ammonia to the actual nutrients NOx is slow and in many systems may be regarded as a “spectator ion”.

Phosphate (PO_4)

Phosphate (PO_4) is a nutrient, being readily absorbed by organisms and used to make DNA and cell-wall phospholipids. *The ratio of phosphate to NOx is an important factor in predicting the undesirable growth of algal biomass, being important to a number of algal species.*

Pathogens

E. coli

E. coli is an important indicator of pathogens in water resources. Whilst active as a pathogen on its own, it is usually present concomitant with other water-borne pathogens utilising or being emitted through the digestive tract. *Cholera vibrii* is one such pathogen. Whilst ingestion of any water containing *E. coli* and associated pathogens is discouraged, the water in the resources under study are deemed as being non-potable, the RQO of *E. coli* defaulting to the agricultural limit. Support for the RWQO set at the limit of 150 counts/100 mL comes also from a study commissioned by the Australian Government Department of Sustainability, Environment, Water, Population and Communities (ANZECC/ARMCANZ, 2000) (cit. in: Sinclair et al., 2011). This study quotes objectives relating to water quality as:

Good:	**<=150 CFU /100mL**
Fair:	**>150 and <500 CFU /100mL**
Poor:	**>500 and <1000 CFU /100mL**
Very poor:	**>1000 CFU /100mL**

Salts

“Salts” is a term describing dissolved solids. Dissolved solids impact biota by influencing the ionic strength of the environment in which aquatic biota function. Ionic strength is an important determinant of the natural extent of biochemical reactions. Aquatic organisms usually have the ability to "osmoregulate", being the capacity to pump ions into, or out of the local environment through membranes. These reactions are frustrated if the concentrations of ions are too high or too low.

Electrical conductivity (EC)

Electrical conductivity has long been known to be an indicator of bulk ionic strength of aqueous solutions. Electrical conductivity is readily measured on-site using relatively inexpensive equipment.

Care must be taken in applying blanket values for RQOs using EC. In naturally saline systems organisms are adapted to the ambient salinity and high EC readings may not indicate a problem for the ecosystems. Default trigger values for key water quality variables for ecosystems in Australia (ANZECC/ARMCANZ 2000) are presented in the following table:

Region	**Upper riverine (µS/cm)**	**Lower riverine (µS/cm)**	**Dams and lakes**
South-east Australia	**30-350**	**125-2200**	**20-30**
Tropical Australia	**20-250**	**20-250**	**90-900**
South-west Australia	**120-300**	**120-300**	**300-1500**
South central Australia	**n/d**	**100-5000**	**300-1000**

Thus there may be a great regional disparity in EC values to which local biota are conditioned and a more sensitive approach is required. Whilst studies on particular organisms form the basis of many water quality guidelines, broader concerns such as biodiversity have been studied. The relationship between stream macroinvertebrates and measures of conductivity in Queensland river systems was examined to assess if there were any broad patterns in community composition that were attributable to salinity. Family level presence/absence stream macroinvertebrate data from edge (2580 samples) and riffle (1367 samples) habitats collected throughout Queensland in spring and autumn from 1994 to 2002 was used in this analysis. Salinity Sensitivity Scores (SSS) were e derived for individual macroinvertebrate families in Queensland. SSS were derived from the results of a sensitivity analysis using predictive Artificial Neural Network (ANN) models. After establishing the SSS for individual macroinvertebrates, A Salinity Index (SI) was proposed to reflect changes in macroinvertebrate communities caused by changes in conductivity. The SI was calculated using a formula including presence/absence of taxa and number of taxa in the samples. (Dunlop et al, 2005). The results show that as conductivity increases, sensitive taxa are being replaced by tolerant taxa, and this is reflected in decreasing values of SI with increasing conductivity (Figure A2.2). This trend is obvious in both habitats but appears to be more prominent in riffles. Figure 10 shows changes in the percentage of sensitive and very tolerant taxa with increasing conductivity (12 equal intervals). With reference to riffle data, sites having an EC in the range of 800 and 1500 µS cm -1 were observed to have a decrease in the mean percent of sensitive taxa from 33 to 16.7 relative to the low conductivity category (22-99 µS cm -1) and percent of very tolerant taxa increased accordingly from 9.4% to 32%. The following figures (Figure A2.2 and Figure A2.3) indicate a possible method of evaluating site-specific RWQOs in important catchments .

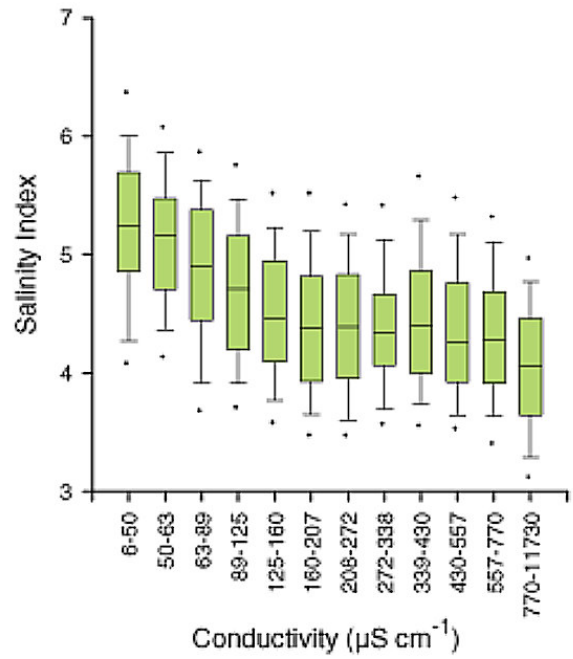

Figure A2.2: Salinity index along increasing conductivity gradient for edge habitats. Median values with boxes corresponding to 80th and 20th percentiles and horizontal bars to maximum and minimum.

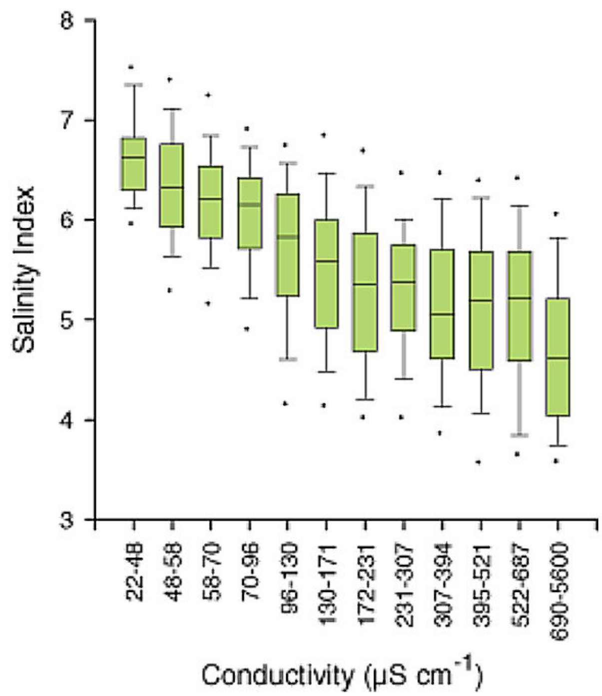

Figure A2.3. Salinity index along increasing conductivity gradient for riffle habitats. Median values with boxes corresponding to 80th and 20th percentiles and horizontal bars to maximum and minimum.

Sulphate (SO_4)

Sulphate is not usually considered a "Salt". It is an anion, and usually a minor component of environmental water resources. In the regions of concern, however, acid mine drainage (AMD) is a significant concern downstream of large formal coal-mining operations, and intense informal coal-mining operations. Sulphate a good indicator, in combination with EC values, of the origin of water pollution contributing to adverse environmental conditions. Sulphate is also involved in problematic behaviour in anaerobic sediments. Sulphate is converted to sulphide, which interferes with the iron-phosphorous cycles. In addition, sulphate may competitively bind to anion-adsorption sites in sedimentary organic matter. By both mechanisms phosphate is expelled from sediments and becomes a problem in eutrophication (Smolders et al, 2006; E. Tamis & C.C. Karman, 2008).

System variables

pH

The concentration of the hydrogen ion (H^+) is particularly important in the regulation of various biochemical reactions, and is measured as pH = -log[H^+]. All organisms operate within a range of pH values typical to their ability to regulate internal and external concentrations of hydrogen ion. This parameter is one of the most important parameters dictating limits on survival of species.

Alkalinity

Alkalinity is a "second-order" system variable, often correctly related to the capacity of the aqueous system to buffer bulk pH levels from small impacts by acidic or alkaline inputs. Usually carbonate anion, represented dominantly by bicarbonate anion at pH values about neutral (pH = 7), is the major factor in alkalinity of a system.

Dissolved oxygen

Dissolved oxygen is important for respiration of aquatic organisms. The levels of dissolved oxygen may be depleted by chemical reactions with organic matter, (reaction product being carbon dioxide). Dissolved oxygen may also be depleted by rapid, transient rise in temperature.

Temperature

Temperature is akin to pH in that all biochemical reactions are governed by temperature. Temperature governs the rate of reactions, and all organisms function within a range of temperature values, beyond which the different changes in rates of reactions leads to imbalances of biochemicals and ultimately to the collapse of the biochemical system that is an organism. Thermal impacts include outputs from power stations, outputs from dams which buffer temperature at levels that may differ from downstream rivers, and likewise changes in flow rates of rivers, impacting the rate of gain or loss of heat from the environment. Whilst it is recommended that water temperature be modelled from ambient air temperatures (DWAF, 2002; DWAF, 2008), it may be preferable to measure temperature directly to eliminate unaccounted confounding factors influencing model estimates. Temperature requirements of organisms are site-specific. Thus there is no universal baseline for temperature data as a measure of ecological impact. The expedient of using temperature *deviations* from optimal/natural conditions is effectively used.

Turbidity and/or water clarity

Turbidity/water clarity is the result of suspended particles in the river. The suspended particles may influence the river system by excluding light (implied by the "water clarity" description), or by directly occluding gill membranes of aquatic organisms. As with temperature and salinity, turbidity/water clarity is site-specific. Most aquatic scientists prefer to use clarity measures as opposed to turbidity measures. The advantage of this choice is that rapid measurements may be made under field conditions. The disadvantage is that measurements are related to individual observer optical functionality, and thus clarity is not a repeatable, fixed measure. Thus in this document turbidity is recommended as a measure, being reliably and accurately measurable in an analytical laboratory.

Toxic substances

Toxic Substances currently regulated by DWS. Toxic substances are chosen as those listed in the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996) (Table A2.6). This category includes unionised ammonia, toxic metal ions and toxic organic substances. Toxic substances identified as relevant to the current study are listed in Table A2.7.

Table A2.6: Toxic Substances (ecological) regulated by DWAF (1996)

Aluminium	Lead
Ammonia	Manganese
Arsenic	Mercury
Atrazine	Nitrogen (Inorganic)
Cadmium	pH (Acidity and Alkalinity)
Chlorine	Phenol
Chromium	Phosphorus (Inorganic)
Copper	Selenium
Cyanide	Temperature
Dissolved Oxygen	Total Dissolved Salts/Solids
Endosulfan	Total Suspended Solids
Fluoride	Zinc
Iron	

Table A2.7: Toxic Substances relevant to this study

Target	Type	Indicator	Reference
Human & ecosystem	Metal	Al	DWAF (2008) (Tables below)
Human & ecosystem	Metalloid	As	
Human & ecosystem	Pesticide	Atrazine	
Human & ecosystem	Metal	Cd hard	
Human	Algal toxins	Chl-a: phytoplankton	
Human, ecosystem & agriculture	Halogen	Chlorine (free)	
Wetland biota	Reductant	COD	
Human & ecosystem	Metal	Cr(VI)	
Human & ecosystem	Metal	Cu hard	
Human & ecosystem	Pesticide	Endosulfan	
Human & ecosystem	Halogen	F	
Human & ecosystem	Metal	Hg	
Human & ecosystem	Metal	Mn	
Wetland biota	Electron donor	Ammonia (unionised)	
Human & ecosystem	Metal	Cu hard	
Human & ecosystem	Metalloid	Se	This study
Wetland biota	Electron donor & acceptor	TIN-N	This study
River organisms	Electron donor	Total Ammonia	This study
Human & ecosystem	Metal	Uranium	This study
Human & ecosystem	Metal	Zn	This study

Selected toxic substances will be discussed in this section.

Ammonia (unionised)

Unionised ammonia is toxic. It readily enters cells through lipid cell walls (hydrophobic) due to being neutrally charged, not excluded as would be hydrophilic charged ions. Once within the cell, ammonia may ionise and change internal pH values, or it may overwhelm the mechanisms of excretion of toxic metabolic by-products. Ammonia is the principle form of nitrogenous excretion by fishes. At 25 degrees C at pH values of above 9.3, ammonia exists predominantly in the unionised form. The pH at which ammonia exists in the unionised form is dependent on temperature. Lookup tables may be used to determine the concentration of unionised ammonia from the concentration of total ammonia. This process is laborious and it is here recommended that total ammonia be analysed for as a screening value.

Hardness-sensitive toxic transition metals

As regulated as toxins, the toxic transition metals Cu, Cd and Pb have differential effects on biota as a function of water hardness. In the current study the RQOs corresponding to these toxic metals refer to the levels in hard water. This assumption was initially motivated by hardness levels appropriate to systems in which dolomite was dissolved by AMD, as occurs in the gold-mining areas of the Western

Basin. At low levels of ambient hardness, high-hardness RQOs for these metals will be somewhat under-protective of aquatic life. It is a topic for future discussion as to whether the RQO values for the metal ions be adapted for current levels of hardness in the resource waters, or for future levels of hardness extrapolated by chemical speciation calculation from all RQOs for the resource under investigation.

Toxic ions of Mn, Se and Zn

Categorical concentration criteria for the toxic ions of Mn, Se and Zn are absent from the DWAF (1999) and DWAF (2008) guideline documents. Thus the levels of concentrations of these entities corresponding to resource water classes were derived using the method of assigning chronic toxicity values to the upper limit of "natural" class A, and acute toxicity values to the upper limit of "natural" class D.

Cyanobacterial blooms; algal toxins

Cyanobacterial blooms and other algal toxins are extremely dangerous if ingested. The toxins emitted by these organisms are very expensive to measure directly. Thus a useful surrogate is used, being measurements of Chl-a: phytoplankton.

Uranium

≤ 10 µg/L (Irrigation),
≤ 15 µg/L (this study)
Canadian Council of Ministers of the Environment. 2011. Canadian water quality guidelines for the protection of aquatic life: Uranium. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg. Pp 1-9. Not much work has been done to establish uranium water quality guidelines for ecosystems. A notably conscientious study of this matter was conducted in British Columbia (CCME. 2011 in: CCME, 2011a). The method of determining Canadian Water Quality Guidelines for Uranium (Total recoverable, Unfiltered) for the Protection of Aquatic Life in ecological systems was the Species Sensitivity Distribution (SSD). The long-term water quality criteria were based on the SSD 5th percentile, as opposed to the SSD 5th percentile, 90% LFL (5%) = 9 µg/L, or the SSD 5th percentile, 90% UFL (95%) = 130 µg/L. Toxicity endpoints were lethality. Long-term exposure guidelines identify benchmarks in the aquatic ecosystem that are intended to protect all forms of aquatic life for *indefinite* exposure periods (≥ 7d exposures for fish and invertebrates, ≥ 24h for aquatic plants and algae). Long-term exposure levels toxic to a range of species was determined to be 15 µg/L uranium. "Long-term" exposure ranged from exposure periods of 7 days (*C. dubia*; reproduction) to 141d (*S. namaycush*; survival). The short-term water quality criteria were based on the SSD 5th percentile, as opposed to the SSD 5th percentile, 90% LFL (5%) = 8.5 µg/L, or the SSD 5th percentile, 90% UFL (95%) = 25 µg/L. Toxicity endpoints were non-viable embryos, survival and growth. "Short-term" exposure ranged from exposure periods of 24h (*C. latipinnis*) to 96h (*O. mykiss*). Short-term exposure levels toxic to species was determined to be 33 µg/L uranium. Toxicity endpoints were lethality. An example plot of long-term SSD is presented in Figure A2.4.

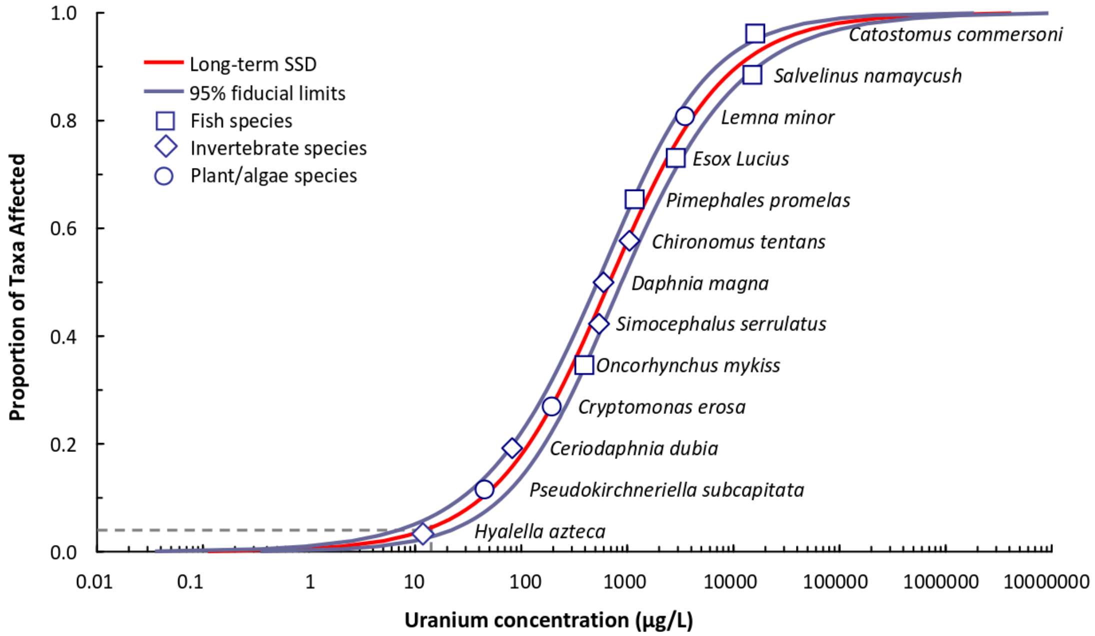

Figure A2.4: Long-term SSD for Uranium (Total recoverable, Unfiltered)

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SA RESERVE GUIDELINES

Water quality ranges corresponding to resource classifications are presented in Table A2.8 below:

Table A2.8: Water quality ranges corresponding to resource classifications

Natural – Poor categories		Natural	Good	Upper Fair	Lower Fair	Poor
PES rating		0	1	2	3	4
Deviation from reference condition		No change	Small change	Moderate change	Large change	Serious change
Water quality indicator	Units	Values				
EC	mS/m	0	30.1	55.1	85	-
pH	5th percentile Min	6.5	5.9	5.6	5	4
pH	95th percentile Max	6.5	6.5	5.9	5.6	5
pH	95th percentile Min	8	8	8.8	9.2	10
pH	5th percentile Max	8	8.8	9.2	10	11
Al	µg/L	20	62.5	105	150	192.5
Ammonia	µg/L	15	43.75	72.5	100	128.75
As	µg/L	20	57.5	95	130	167.5
Atrazine	µg/L	19	48.75	78.5	100	129.75
Cd soft	µg/L	0.2	0.7	1.2	1.8	2.3
Cd mod	µg/L	0.2	0.95	1.7	2.8	3.55
Cd hard	µg/L	0.3	1.63	2.95	5	6.33
Chorine (free)	µg/L	0.4	1.75	3.1	5	6.35
Cr(III)	µg/L	24	115	206	340	431
Cr(VI)	µg/L	14	67.5	121	200	253.5
Cu soft	µg/L	0.5	1.03	1.55	1.6	2.13
Cu mod	µg/L	1.5	3.03	4.55	4.6	6.13
Cu hard	µg/L	2.4	4.88	7.35	7.5	9.98
Cyanide	µg/L	4	32.5	61	110	138.5
Endosulfan	µg/L	0.02	0.08	0.13	0.2	0.26
Fluoride	µg/L	1500	2510	3520	2540	3550
Pb soft	µg/L	0.5	1.63	2.75	4	5.13
Pb mod	µg/L	1	3	5	7	9
Pb hard	µg/L	2	5.75	9.5	13	16.75
Hg	µg/L	0.08	0.53	0.97	1.7	2.15
Phenol	µg/L	60	200	340	500	640
DO	mg/L	8	8	6	6	4
PO4-P	mg/L P	0	0.01	0.02	0.03	0.13
TIN-N	mg/L N	0	0.25	0.7	1	4
Chl-a: periphyton (mg/m2)	mg/m^2	0	10	15	20	30
Chl-a: phytoplankton (µg/L)	µg/L	0	1.7	12	21	84

Data taken from DWAF (2008)

6.2 APPENDIX B: ADDITIONAL JUSTIFICATION OF SULPHATE SPECIFIC WATER QUALITY NUMERICAL LIMITS USED IN THE STUDY.

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There are a number of different guidelines or trigger values for sulphate concentration published by various regulatory agencies. Most of the guidelines and trigger values are based on species sensitivity distributions which are the "toxicology state-of-the-art" at the time of writing of this document. Many propose a guideline value for aquatic health in terms of sulphate concentration as around 500 mg/L sulphate. The current study assumes that the EC guideline values for aquatic health have been in use for a long period and are thus assumed to be provisionally non-contentious. Thus setting a sulphate guideline value as guided by EC relationships in a highly sulphate-polluted catchment would be appropriate until more site-specific methods were applied, such as whole effluent toxicity tests. Sulphate and EC values that were measured in tandem by DWA and published on WMS were downloaded and submitted to a rigorous data verification regime. The paired values were then plotted and a very large scatter was observed in the data. This scatter was enhanced when a log-log transformation was applied. Cluster analysis was applied to the dataset and three main clusters emerged. The most relevant cluster was fortunately the most linear. From this linear cluster of paired SO4 and EC values a direct least squares linear interpolation was performed, yielding a result with a high correlation coefficient. The interpolation of the least squares relationship to the EC value corresponding to a "D" class river water quality yielded a value of approximately 500 mg/L sulphate for a "D" class river. This value was set at the "D" level for sulphate concentrations and the "C", "B" and "A" values derived as were the values derived for use in the DWA Reserve Determination process.

INTRODUCTION

Sulphate is not usually considered a “Salt”. It is an anion, and usually a minor component of environmental water resources. In the regions of concern, however, acid mine drainage (AMD) is a significant concern downstream of large formal coal-mining operations, and intense informal coal-mining operations. In regions such as these, sulphate a good indicator, in combination with EC values, of the origin of water pollution contributing to adverse environmental conditions. In setting resource quality objectives for the Olifants and Upper Vaal catchments, the problem was encountered that there are no non-contentious guidelines available in South Africa for sulphate concentrations in highly impacted rivers. The problem reared its head in the above catchments in particular due to the great levels of sulphate loading emanating from coal- and gold-mining activities. There are no coherent internationally developed guidelines for sulphate concentrations in rivers, for the protection of aquatic communities. The procedure-based guidelines derived for sulphate utilised the techniques of Species Sensitivity Distributions, current "state of the art" for aquatic toxicology studies. In the absence of such studies in South Africa for sulphate and in particular for the catchments under study, in an explicitly site-specific undertaking such as resource quality objectives, an empirical approach was assumed. In the current study, guided by large values of internationally accepted guidelines, monitoring data were obtained from the DWA water quality monitoring programme database (WMS). This data was analysed with a view to establishing a provisional objective guideline based on sulphate/EC relationships. This current documentary is a summary of the above efforts.

Sulphate: Direct or indirect toxicity?

Sulphate toxicity as a direct phenomenon is somewhat contentious. The reason for the above is the fact that adverse health effects observed in organisms manifest at relatively high concentrations of sulphate. The contention is introduced at high sulphate concentrations due to concomitant high concentrations of the coupled cations, and of ionic strength, measured as electrical conductivity. Influences of these specific ions and system variables confound interpretation of laboratory toxicity tests, upon which most substance-specific guidelines are based.

Indirect toxicity: Chemically reducing environments.

Sulphate loading on a water resource containing a substantial reducing phase such as a wetland or a dam may exert indirect toxicity effects that are important to consider. Sulphate is also involved in problematic behaviour in anaerobic sediments. Sulphate is converted to sulphide, which interferes with the iron-phosphorous cycles. In addition, sulphate may competitively bind to anion-adsorption sites in sedimentary organic matter. By both mechanisms phosphate is expelled from sediments and becomes a problem in eutrophication. Indirect effects on these water resources originate from the conversion of sulphate to sulphide within sediments or other phases rich in organic matter. Sulphate reducing bacteria (SRBs) use the organic matter to reduce the sulphate. Sulphide is extremely toxic to oxygen-metabolising organisms. It binds to, and inactivates respiratory enzymes containing iron and copper several orders of magnitude stronger than does cyanide, a more charismatic toxin. The effect of concomitant increase of sulphate and organic matter has been observed to result in hyper-abundance of hydrogen sulphide in the sediments of the Loskop dam. Estimation of the loading of sulphate to create sulphide problems involves models more sophisticated than the ambit of the current study.

Confounding effects of other WQ variables

As mentioned above, specific coupled cations and system variables such as electrical conductivity may make assignation of toxicity to sulphate problematic. Some factors, e.g. hardness (concentrations of calcium and magnesium) and chloride concentrations confounding the establishment of direct sulphate toxicity have been recognised as persuasive enough to include in local water management legislation in the state of Iowa, USA.

Some sulphate guidelines implemented internationally

Many guideline values have been proposed and published and embedded as trigger values by various governing bodies. Much of the reasoning behind the derivation of the guidelines is opaque. Where the reasoning is not opaque, there is great discrepancy between values recommended. The following high guideline levels are presented in this light.

- USA: In the state of Wyoming, USA, the current level of permissible sulphate concentrations in fresh water resources is 3,000 mg/L SO4, and there is a petition underway to reduce this value to 500 mg/L. In the state of Iowa, based on toxicity test data and available toxicity data from a total of 11 species, to achieve aquatic life protection and livestock watering uses, concentrations for sulphate from 500 mg/L to 2,000 mg/L are not to be exceeded except in receiving waters for which mixing is allowed.
- Canada: In a Chronic Effects Benchmark study for the British Columbia (BC) government by Golder Canada (2013) based on toxicity test data, the hardness-level-adjusted sulphate environmental guideline for “moderately soft/hard to hard” water (76-180 mg/L $CaCO_3$) is between 309 mg/L sulphate and 743 mg/L sulphate. Meays and Nordin (2013) proposed a BC sulphate water quality guideline for moderately hard to hard water conditions, and recalculated benchmarks for hard water conditions, based on model-averaged sulphate toxicity endpoints from three direct investigations of sulphate toxicity in relation to water hardness. In a site-specific assessment for medium hard waters, sulphate concentrations were proposed to be set by TOTAL E&P Canada Ltd (2013) at alert levels of 309 to 430 mg/L.
- Australia: In a study involving actual site-specific toxicity testing and using the ANZECC guidelines “the concentrations of sulphate that would protect 95% of species would be 341 mg/L sulphate and the concentration predicted to be protective of 99% of species would be 123 mg/L” (Hydrobiology, 2012).

ESTIMATION OF SITE-SPECIFIC SULPHATE TARGET VALUES FOR THE OLIFANTS CATCHMENT

Method for estimating sulphate trigger values

The method for deriving interim target sulphate trigger values for the Olifants catchment and extrapolated to the Vaal catchments involves recognition of the high range of water quality standard values, and the operational assumption that electrical conductivity recommendations may guide estimations for a maximum value of sulphate recommended for various water quality classes.

Datamining: Clarifying EC-SO4 relationship

The main objective of analysing monitoring data for the Olifants River catchment is to derive a sulphate Resource Quality Indicator measurement. Sulphate was identified as an indicator of resource quality specific to sub-catchments of the Olifants River catchment. Managing operations such that sulphate concentrations fall below certain trigger values implies managing for sulphate toxicity, or managing for other environmental stressors for which sulphate may be a surrogate. Since EC is managed in the catchments, and SO4 is a contributor to EC, any "toxicity" of SO4 above the possible total contribution to EC by SO4 would be a useless endeavour.

Hazard Class risk method

The regions of the Olifants catchment under consideration are heavily impacted or soon to be heavily impacted by coal mining activities. When setting a RQO regulators are balancing long-term ecological health against short-term and necessary economic growth. Whilst in individual publications river classes are proposed correlated with percent species protected (as is the approach used in most first-world countries), this method has not as yet been comprehensively applied. In the current analysis it is estimated that a "D" class would represent a preservation of between 90% and 95% of the species in the ecosystem. The modifications are presented below (Table B1).

Table B1: Proposed hazard class values corresponding to water quality categories

HC_p	Water condition	Classification	Natural – Poor categories	Water Quality category	PES rating
<HC_1 (50)	Natural	Unmodified, or approximates natural condition.	Natural	A	0
HC_5 (5-25)	Good	Largely natural with few modifications.	Good	B	1
HC_5 (25-35)	Upper Fair	Moderately modified.	Upper Fair	C	2
HC_5 (36-50)	Lower Fair	Large change	Lower Fair	D	3
>HC_5 (50)	Poor	Largely modified.	Poor	E	4

In the absence of better information on the distribution of the sulphate concentrations and protection levels, an operational assumption was made in the current study that for a Level D ecosystem one may tolerate of the order of 10% of the data variance unassigned in the description of the HC5. This approximates to a sulphate concentration of 500 mg/L, as will be demonstrated below. It has been noted in many publications that the toxicity of sulphate to aquatic life is strongly dependent on water chemistry, not only hardness but chloride concentration and concentration of other constituents. It may well be that site-specific toxicity testing is required in the future.

ANALYSIS OF OLIFANTS WQ DATA

Considering the difficulty in finding coherent water quality guidelines from literature, the following operational approach was employed:

- The fundamental assumption was that sulphate may be acting in concert with other water quality constituents in a synergistic manner, possibly contributing to exhaustion of target organisms in their battles with metals or simple osmotic stress. Electrical conductivity (EC) was chosen as an indicator of osmotic shock for which there are already guideline values published (DWAF, 2008).
- Since EC values are not published for recommended limits to a D category water resource, the value of 110 mS/m was extrapolated to a PES of 3.0 from values published that corresponded to lower PES values and lower DWA classes.

UPPER LIMIT OF SULPHATE TRIGGER VALUE

Based on a limiting condition of 110 mS/m electrical conductivity, the maximum sulphate concentration recommended is calculated from limiting ionic conductivities. From CRC Handbook of Chemistry, and Physics, 91st Edition, Weast, R. C.,Ed., CRC Press, Boca Raton, FL, 1989 (Table B2).

Table B2: Electrical conductivity of sodium sulphate solutions

Mass % Sodium sulphate	0.5	1.0	2.0	5.0
EC (mS/m)	590	1120	1970	4270

Fitting curve of the form $-10\ x^3\ -105\ x2\ +1235\ x$

Thus for a pure sodium sulphate solution in water, interpolation yields the mass fraction of 0.09% (m/m) to effect an EC of 110 mS/m.

A mass fraction of 0.09% corresponds to a concentration of 900 mg/L of sodium sulphate, which equals 6.34 mmoles/L of sodium sulphate. This equates to 6.34 mmoles/L of sulphate ion which corresponds to 608 mg/L sulphate.

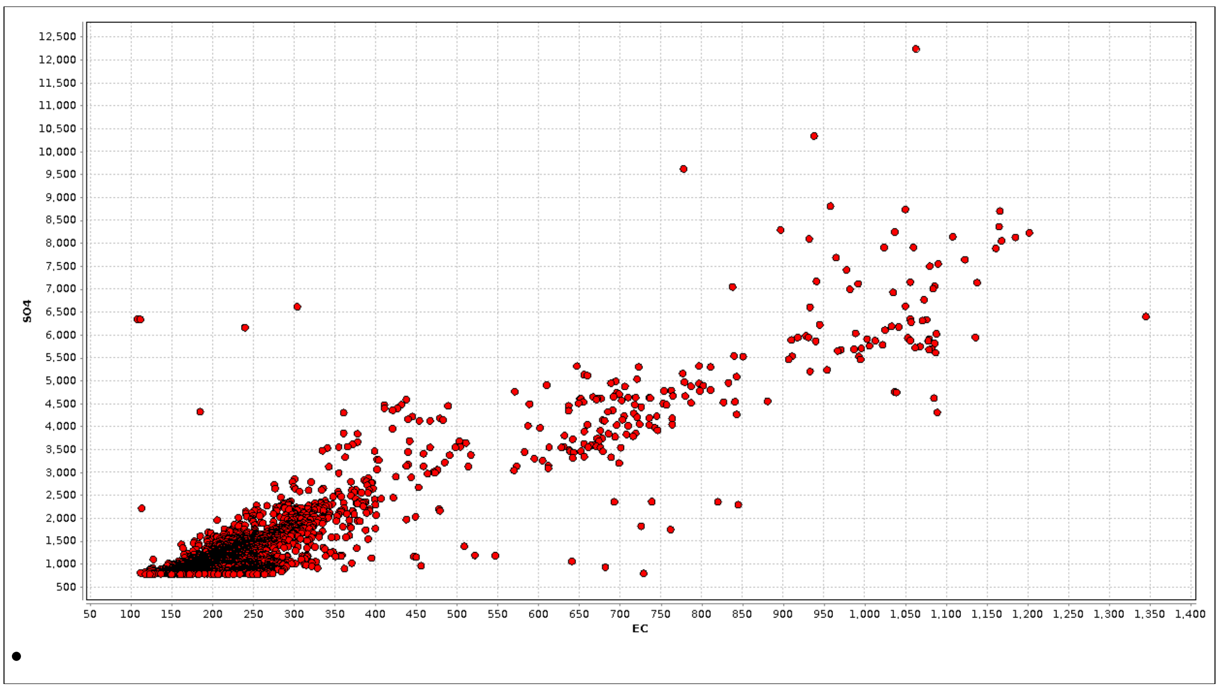
This therefore is the maximum concentration of sulphate as a trigger to be derived in this study.

Please note that the above analysis only works for sodium sulphate in a pure solution because the electrical conductivities were *measured* for this system.

DERIVATION OF SULPHATE TRIGGER VALUE FROM WQ MONITORING DATA

All water quality monitoring data for all stations in the Olifant River catchment (Region B) were retrieved from WMS. There were 69,388 records retrieved. Of these data, records where both EC and sulphate were present were extracted and the highest 20% of EC value data retained (13,898 records). Within this data set the highest 10% of sulphate concentrations were retained, yielding 2,360 records. If there were some regularity between EC and SO4 at elevated concentrations of both, it would mean that SO4 dominates the ionic composition of the water and that some value of SO4 trigger may be derived from the EC regulation value. The figure below (Figure B1) shows the relationships between SO4 and EC in the dataset as derived above. A direct plot shows a great deal of scatter in the relationship between SO4 and EC in the Olifants River catchment which is expected.

In order to reveal more of the detail in the scatter at lower SO4 and EC values a log-log plot is used (Figure B1).



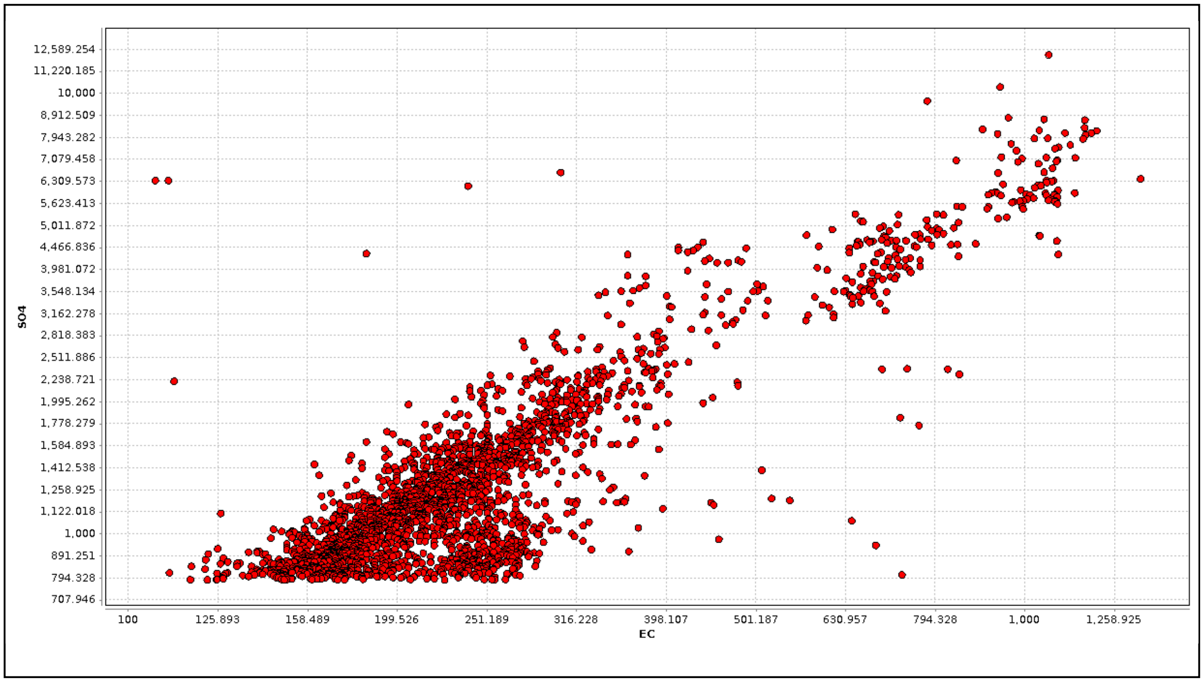


Figure B1 (a) Direct plot of SO4 vs EC; (b) log-log plot of SO4 vs EC

A direct linear regression on the EC and SO4 data produces the relationship:

[SO4 (mg/L)] = 6.4 x [EC (mS/m)] -190.

There is considerable scatter in the diagram. The intercept of the regression line is negative, implying that in the absence of sulphate the EC in general would be about 30 mS/m. This at least checks logically – were there to be a positive intercept it would imply that a non-zero concentration solution of sulphate could have zero EC. When the SO4-EC relationship is explored in detail in the log-log plot (Figure (b)), three clusters appear. In order to find a useful relationship between EC and SO4 to base some limiting value on, a clearer picture needs to be formed describing the entire dataset. Simply stated, if one expects (or desires) a simple relationship between e.g. EC and SO4 and complexity arises in the projected relationship between the variables, it means that there is some additional factor or combination of factors that is causing the complexity. It is a useful assumption that the aforementioned factor(s) would be chemical in nature. Identifying the factor(s) would allow for their contribution to the complexity to be removed, yielding a clearer relationship between EC and SO4 in this case. The methods of data mining are used for this objective. Since the driving force of all chemical and biochemical reactions, the free energy, is directly proportional to the logarithms of concentrations, all water quality variables were represented as logarithms. The above statement is not strictly true, since it is the “activities” of the chemical constituents that are thus related to the free energy, and the activities vary with increasing concentration of salts in solution. There are in the system of interest considerably higher concentrations of salts than the “infinite dilution” that is required for use of concentrations as activities without transformation. Concentrations are presented as the molar form of the chemical constituent, as opposed to the mass per unit volume form most often used in water quality management. This transformation is performed in order to compare magnitudes of chemical constituents on the same level, the level at which the constituents would behave as molecular or atomic entities. It is noted that pH is already in a log form, being the negative logarithm of the concentration of free hydrogen ion. In order to compare pH with the other variables in the data mining exercise, it was used as the negative value of pH, denoted pH_neg. The reason to use data mining is to understand macro-dynamics in the higher salinity parts of the Olifants River system. Thus initially all water quality data are used in analysis.

Cluster analysis

To return to the original objective of the datamining activity, the monitoring data in the Olifants River catchment was analysed to establish workable relationships between the concentrations of sulphate and the physical water quality parameter Electrical Conductivity, the latter for which there exist trigger values for management of water quality to environmental and human health targets. The upper limit of EC characterising a water resource as a D-category resource in terms of water quality is 110 mS/m. A relationship between EC and the conductivity of a pure sodium sulphate solution was explored in a previous section. The work in this section aims to determine a relationship relating to the unique additional background salts of the region such that a water quality trigger value for sulphate may be provisionally established.

K-means clustering

The objective of cluster analysis is to establish similarities and difference between data points as viewed in groups. Thus clustering aims to group together points that are most similar, and to distinguish between groups so determined. K-means clustering is an *exclusive* method in that each point is assigned to one cluster only. The default analysis in Rapidminer was used, being clustering by squared Euclidean distances between points, and discrimination between clusters measured by this divergence parameter by the technique of Bregman Divergences.

Data integrity verification

Chemical analytical data is subject to the occasional mishap, such as entry into a database involving the misplacement of a decimal point, or in cases of high concentrations of a particular constituent, errors in dilution of the sample to levels acceptable to the analytical instruments. Whilst it is expected that the data used in the exercise of determining a convincing relationship between EC and SO4 will have significant scatter, modelling procedure of data verification is followed.

Mass balance calculations

The first test that should be applied to a chemical analysis is the mass-balance calculation. In the case of waters not heavily polluted and thus coming more under the heading of industrial water, an effective screen for bulk errors in chemical analyses takes the form of the mass balance. Mass balance involves adding up the individual concentrations per litre (usually expressed in milligrams per litre) and comparing the total to the “total dissolved solids” or TDS. The technique is relatively simple but has some minor problems associated with it. Carbonate and bicarbonate concentrations are not usually reported directly and need to be calculated from the Total Alkalinity and the pH values. There is the risk of making errors in calculating carbonate species concentrations in this way. In addition, TDS is often (usually) not determined directly, owing to the high costs of determining by dehydration. Usually TDS is derived from the EC measurement by multiplying by a scalar factor. This method may not be valid if the ionic composition of the samples deviates significantly from “natural”, which would be the case in the Olifants and Vaal River catchments. In many cases, as appears to be the case with the WMS data, the TDS is actually derived as the sum of the analysed dissolved constituents. The WMS database explicitly quotes the DMS = “Dissolved mineral solids”. A caution with respect to the concern of calculation of carbonate species mentioned above: The mass balance is much better effected after submitting the total analytical data to a chemical speciation calculation. This technique was used to verify the database of chemical analyses at the requisite coarse level.

Charge balance calculations

The program Phreeqci was used to calculate charge imbalances. A charge imbalance detected by a proper chemical speciation analysis refers to uncertainty in the concentrations of one or more of the water quality constituents analysed for, or in the worst case, a chemical species not analysed for. Chemical analyses featuring charge imbalances of less than 5% are acceptable for interpretation according to the ASTM “Standard Methods” (APHA), 1998). The dataset derived to represent resource waters of D-category or better was subjected to filtering by charge balance calculation.

DATA FILTERING

Sulphate data cleaning

All data points with sulphate concentrations less than 0.032 mmol/L SO4 were removed. The reason for this was that this is the maximum of the “instrumental detection limit” concentrations. Inclusion of these values in the analysis would skew the analysis towards unrealistically low concentrations of sulphate.

Sulphate data reduction

During exploratory clustering analysis the dataset clustered according to sulphate concentrations as seen in the figure below (Figure B2):

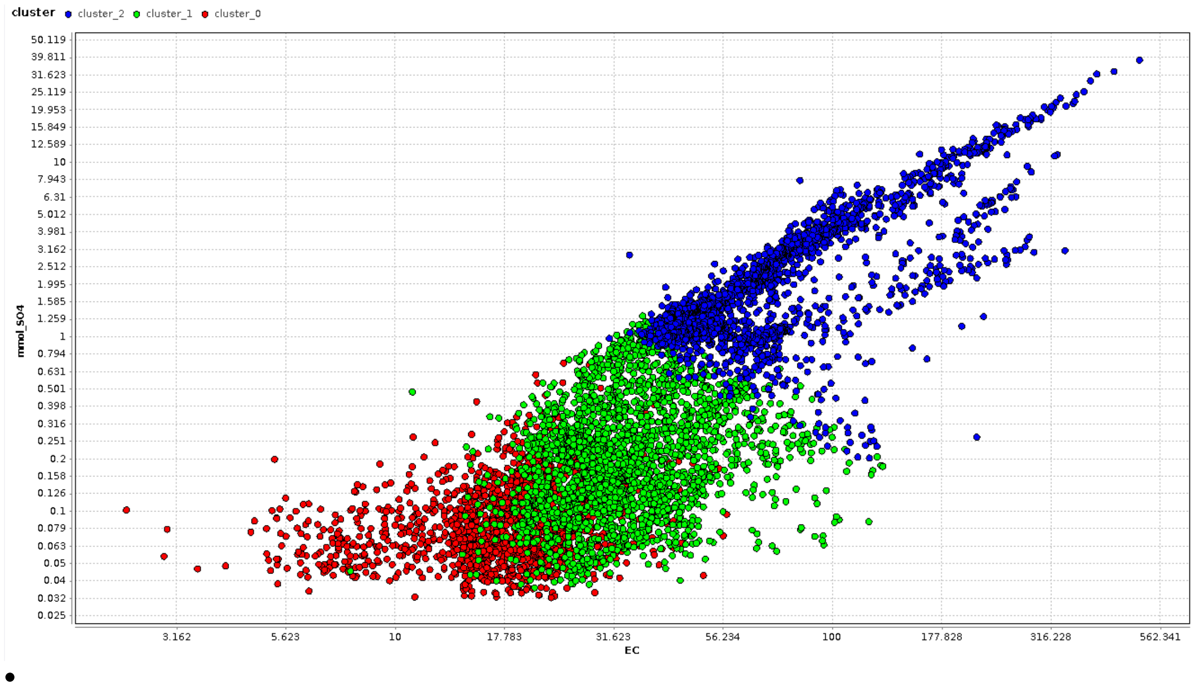


Figure B2 Preliminary cluster analysis of SO4-EC data for Olifants catchment

This was not a meaningful clustering as it did not achieve a linearity of a single cluster for analysis by linear regression. Thus all SO4 values below a concentration of 1 mmol/L were removed and the following clustering obtained (Figure B3).

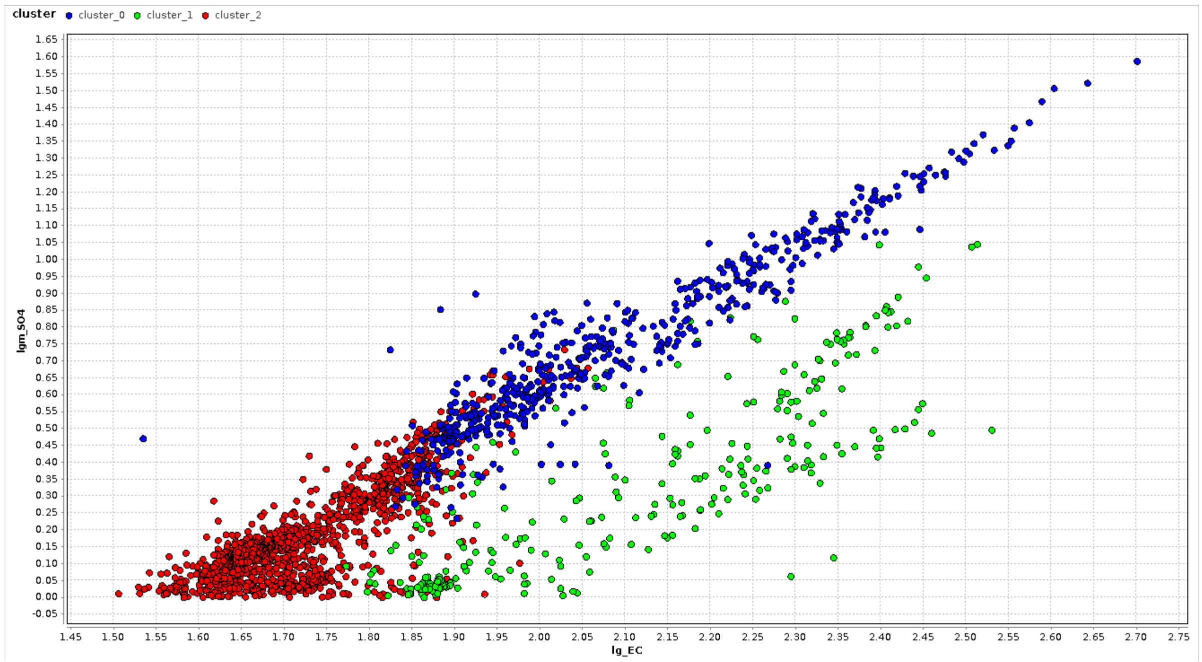


Figure B3: Cluster analysis of SO4-EC data with low values removed

The centroid plot of the clusters (Figure B4) shows the clustering driven mainly by the concentrations of chloride, sodium, phosphate, and then sulphate.

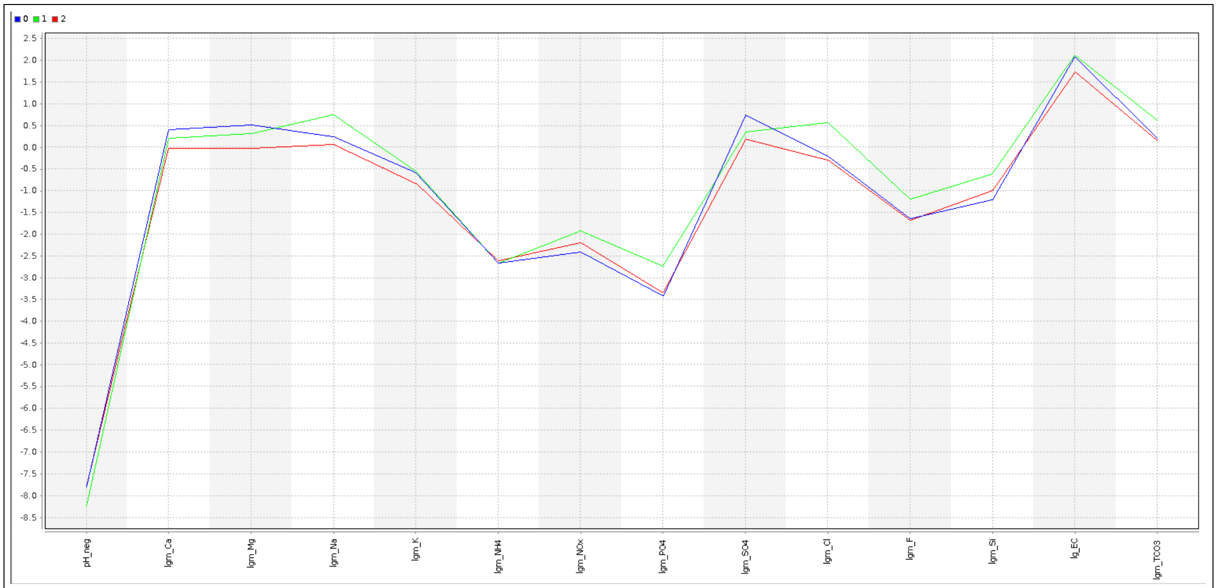


Figure B4: Centroid plot of clusters presented in Figure.

A parallel plot (Figure B5) demonstrates this separation.

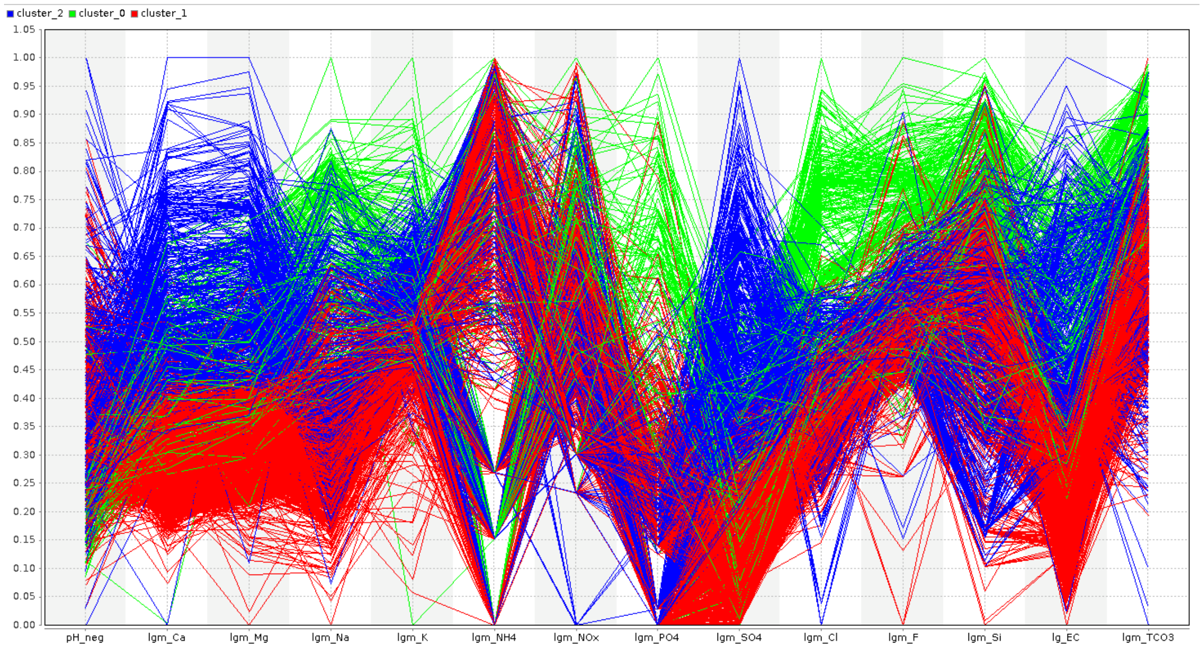


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Figure B5: Parallel plot of clusters presented in Figure.

The separation of the clusters does reveal a relatively linear relationship between SO4 and EC in the combination of clusters 1 and 2. However the fact that clusters 1 and 2 still contain a sulphate-concentration component may be problematic. On the other hand, it may not. A further test was implemented in data exploration. The analysis was repeated with all data featuring SO4 concentrations less than 3 mmol/L removed (Figure B6).

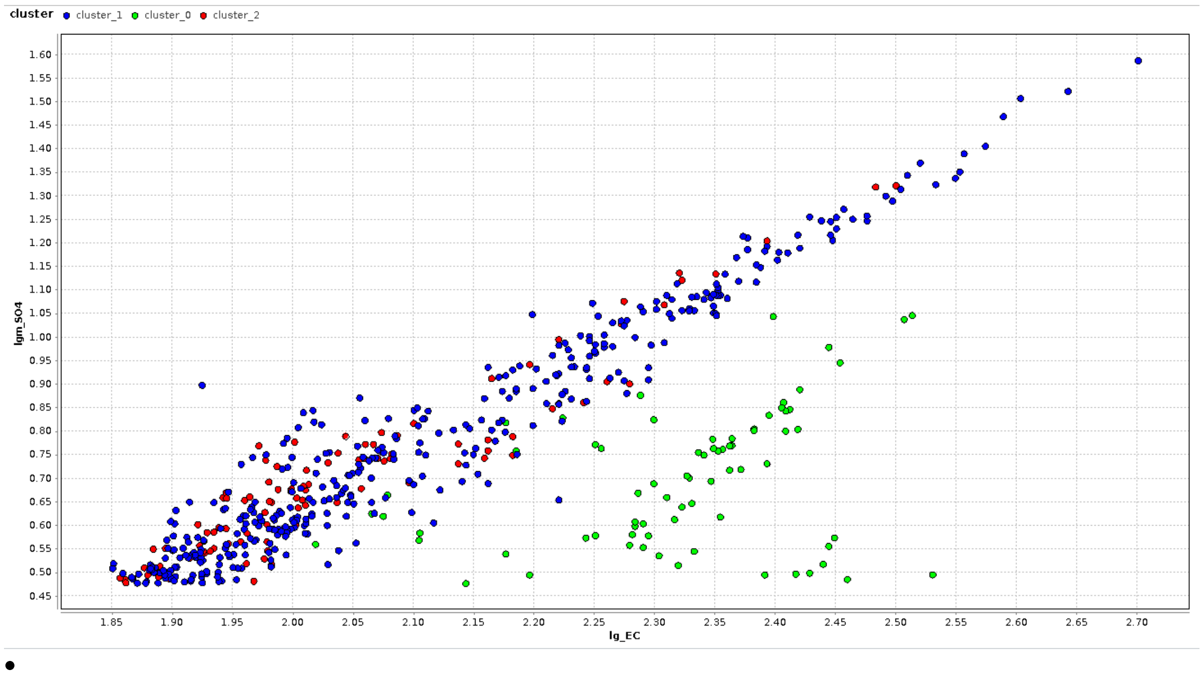

Figure B6: Cluster analysis of SO4-EC data above 3 mmol/L.

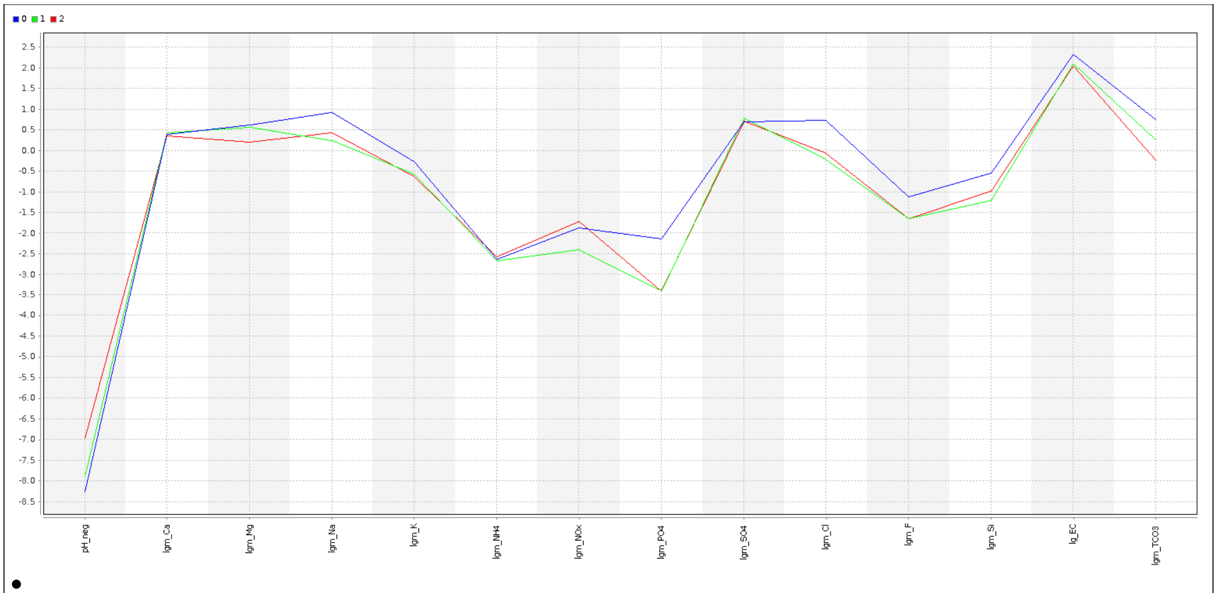

Figure B7 Centroid plot of SO4-EC data above 3 mmol/L.

The linear regression on the lgm_SO4 vs lg_EC set defined by the combination of Clusters 1 and 2 reveal the following statistics:

lgm_SO4 = 1.28 x lg_EC -1.93; r^2 = 97%.

Interpolation of the maximum limit of EC for a water resource of Class D yields the information in the following table (Linear correlation = 96.5%):

EC (mS/m)	lg_EC	lgm_SO4	m_SO4 (mmol/L)	SO4 (mg/L)
110	2.04	0.70	5.05	495

FINAL RECOMMENDATIONS OF TRIGGER VALUES FOR SULPHATE

The value of 500 (“rounded up” from 495 mg/L) was set at the "D" level for sulphate concentrations and the "C", "B" and "A" values derived as were the values derived for use in the DWA Reserve Determination process (Table B3).

Table B3: Sulphate trigger values recommended

Water Quality category	Natural – Poor categories	PES rating	SO4 (mg/L)
A	Natural	0	50
AB		0.5	65
B	Good	1	80
BC		1.5	140
C	Upper Fair	2	200
CD		2.5	350
D	Lower Fair	3	500

CONCLUSION

The current study assumes that the EC guideline values for aquatic health have been in use for a long period and are thus assumed to be provisionally non-contentious. Thus setting a sulphate guideline value as guided by EC relationships in a highly sulphate-polluted catchment would be appropriate until more site-specific methods were applied, such as whole effluent toxicity tests. Sulphate and EC values that were measured in tandem by DWA and published on WMS were downloaded and submitted to a rigorous data verification regime. The paired values were then plotted and a very large scatter was observed in the data. This scatter was enhanced when a log-log transformation was applied. Cluster analysis was applied to the dataset and three main clusters emerged. The most relevant cluster was fortunately the most linear. From this linear cluster of paired SO4 and EC values a direct least squares linear interpolation was performed, yielding a result with a high correlation coefficient. The interpolation of the least squares relationship to the EC value corresponding to a "D" class river water quality yielded a value of approximately 500 mg/L sulphate for a "D" class river. This value was set at the "D" level for sulphate concentrations and the "C", "B" and "A" values derived as were the values derived for use in the DWA Reserve Determination process.

REFERENCES

APHA (1998): American Public Health Association (APHA), 1998. Standard Methods for the Examination of Water and Wastewater, 20th ed. American Public Health Assoc., Washington, DC.

DWAF (2008): Department of Water Affairs and Forestry, South Africa. 2008. Methods for determining the Water Quality component of the Ecological Reserve. Prepared by Scherman Consulting.

Golder Canada (2013): Golder Canada (2013, Project Number: 13-1346-0001) Appendix 3.6: “Chronic Effects Benchmarks”.

Hydrobiology (2012): Hydrobiology Pty Ltd, 2012. “Sulphate Trigger Value for MRM mine”.

TOTAL E&P Canada Ltd (2013): Joslyn North Mine Project Modifications Amendment Application Appendix J: Water Quality Supporting Information. November 2013. TOTAL E&P Canada Ltd.

6.3 APPENDIX B: WATER QUANTITY RULE TABLES INCLUDING MONTHLY FLOW PERCENTILES FOR APPLICABLE RQOS.

Amersfoort Dam (Skulpspruit)
IUA UA
RU 4
EWR1 Low flows

Desktop Version 2, Generated on 2/6/2011

Summary of EWR rule curves (Desktop Version 2) for:
Total Runoff: Runoff: UUV9- C11E
Regional Type: Vaal

Ecological Category = C

Data are given in m^3 * 10^6 monthly flow volume

Total Ecological Flows
% Points

Oct	0.102	0.099	0.093	0.082	0.066	0.047	0.030	0.018	0.012	0.011
Nov	0.373	0.313	0.258	0.202	0.129	0.087	0.054	0.035	0.027	0.019
Dec	0.294	0.260	0.224	0.182	0.127	0.087	0.058	0.042	0.036	0.036
Jan	0.313	0.279	0.242	0.198	0.142	0.101	0.072	0.057	0.051	0.051
Feb	0.881	0.729	0.593	0.457	0.283	0.190	0.121	0.084	0.069	0.066
Mar	0.225	0.216	0.197	0.166	0.124	0.081	0.048	0.029	0.021	0.020
Apr	0.138	0.134	0.126	0.110	0.088	0.063	0.039	0.023	0.015	0.012
May	0.071	0.069	0.064	0.056	0.044	0.029	0.016	0.006	0.002	0.000
Jun	0.049	0.047	0.044	0.039	0.031	0.021	0.012	0.005	0.001	0.000
Jul	0.042	0.041	0.039	0.034	0.027	0.019	0.011	0.005	0.001	0.000
Aug	0.033	0.032	0.030	0.026	0.021	0.014	0.008	0.003	0.001	0.000
Sep	0.046	0.044	0.042	0.035	0.031	0.024	0.017	0.012	0.009	0.008

Reserve Flows without High Flows

Oct	0.068	0.066	0.062	0.054	0.044	0.031	0.020	0.012	0.009	0.008
Nov	0.136	0.131	0.120	0.102	0.077	0.052	0.033	0.022	0.017	0.016
Dec	0.179	0.173	0.158	0.134	0.103	0.072	0.049	0.036	0.031	0.031
Jan	0.198	0.191	0.176	0.151	0.118	0.086	0.063	0.050	0.046	0.046
Feb	0.273	0.263	0.240	0.203	0.154	0.106	0.070	0.051	0.043	0.043
Mar	0.181	0.174	0.159	0.133	0.100	0.066	0.039	0.023	0.017	0.016
Apr	0.121	0.117	0.110	0.096	0.077	0.055	0.034	0.020	0.014	0.012
May	0.071	0.069	0.064	0.056	0.044	0.029	0.016	0.006	0.002	0.000
Jun	0.049	0.047	0.044	0.039	0.031	0.021	0.012	0.005	0.001	0.000
Jul	0.042	0.041	0.039	0.034	0.027	0.019	0.011	0.005	0.001	0.000
Aug	0.033	0.032	0.030	0.026	0.021	0.014	0.008	0.003	0.001	0.000
Sep	0.037	0.036	0.034	0.031	0.026	0.020	0.014	0.010	0.008	0.008

Natural Duration curves

Oct	0.971	0.190	0.161	0.108	0.086	0.063	0.049	0.030	0.019	0.011
Nov	1.775	1.146	0.637	0.428	0.313	0.204	0.162	0.123	0.042	0.019
Dec	2.412	1.516	0.956	0.777	0.597	0.388	0.291	0.153	0.097	0.045
Jan	1.673	1.120	0.821	0.717	0.504	0.467	0.340	0.243	0.164	0.078
Feb	3.299	0.934	0.806	0.488	0.393	0.289	0.252	0.165	0.128	0.066
Mar	1.008	0.635	0.474	0.310	0.239	0.202	0.138	0.090	0.045	0.030
Apr	0.486	0.297	0.181	0.154	0.104	0.081	0.058	0.046	0.035	0.012
May	0.235	0.116	0.086	0.060	0.045	0.034	0.026	0.026	0.019	0.004
Jun	0.116	0.073	0.054	0.042	0.035	0.031	0.027	0.023	0.012	0.000
Jul	0.082	0.063	0.049	0.037	0.034	0.026	0.026	0.022	0.015	0.004
Aug	0.063	0.052	0.041	0.037	0.030	0.026	0.022	0.019	0.015	0.007
Sep	0.104	0.066	0.054	0.035	0.031	0.027	0.023	0.019	0.012	0.008

Vaal River

IUA	UA
RU	8
EWR1	Low flows

Desktop Version 2, Printed on 2008/07/02

Summary of EWR rule curves for: EWR1 based on Present Day Monthly Flow in C11J

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: Vaal

REC = B/C

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	3.798	3.719	3.559	3.274	2.827	2.222	1.532	0.893	0.443	0.239
Nov	8.618	7.940	7.289	6.586	5.396	4.522	3.388	2.146	1.076	0.490
Dec	8.894	8.230	7.583	6.873	5.672	4.754	3.563	2.258	1.134	0.519
Jan	15.998	14.248	12.685	11.174	8.589	7.219	5.441	3.493	1.815	0.898
Feb	10.866	10.114	9.364	8.519	7.092	5.932	4.426	2.777	1.355	0.405
Mar	5.291	5.204	5.037	4.736	4.243	3.514	2.568	1.532	0.640	0.112
Apr	3.964	3.900	3.775	3.551	3.171	2.577	1.809	1.165	0.501	0.116
May	3.403	3.328	3.179	2.912	2.492	1.925	1.278	0.680	0.258	0.067
Jun	3.274	3.205	3.066	2.819	2.431	1.905	1.306	0.752	0.361	0.184
Jul	3.143	3.077	2.944	2.707	2.335	1.832	1.258	0.727	0.352	0.183
Aug	3.143	3.077	2.944	2.707	2.335	1.832	1.258	0.727	0.352	0.183
Sep	3.405	3.333	3.189	2.932	2.529	1.983	1.361	0.785	0.379	0.195

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	3.798	3.719	3.559	3.274	2.827	2.222	1.532	0.893	0.443	0.239
Nov	4.891	4.813	4.663	4.394	3.953	3.300	2.453	1.525	0.726	0.289
Dec	5.288	5.204	5.042	4.752	4.276	3.572	2.658	1.658	0.795	0.324
Jan	5.684	5.594	5.420	5.107	4.594	3.836	2.853	1.776	0.847	0.340
Feb	6.873	6.764	6.551	6.170	5.546	4.622	3.424	2.111	0.980	0.362
Mar	4.888	4.808	4.652	4.373	3.914	3.237	2.358	1.395	0.565	0.111
Apr	3.964	3.900	3.775	3.551	3.171	2.577	1.809	1.165	0.501	0.116
May	3.403	3.328	3.179	2.912	2.492	1.925	1.278	0.680	0.258	0.067
Jun	3.274	3.205	3.066	2.819	2.431	1.905	1.306	0.752	0.361	0.184
Jul	3.143	3.077	2.944	2.707	2.335	1.832	1.258	0.727	0.352	0.183
Aug	3.143	3.077	2.944	2.707	2.335	1.832	1.258	0.727	0.352	0.183
Sep	3.405	3.333	3.189	2.932	2.529	1.983	1.361	0.785	0.379	0.195

Natural Duration curves

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	20.848	7.288	6.489	5.977	5.556	5.205	4.854	3.711	1.557	0.814
Nov	41.651	25.104	15.278	11.508	8.260	7.114	5.598	4.938	2.604	0.899
Dec	53.364	34.088	22.431	17.533	14.483	9.424	7.183	6.392	5.141	1.396
Jan	38.460	26.579	18.869	16.947	12.410	10.170	8.471	6.179	5.126	2.882
Feb	66.791	25.149	18.295	11.359	8.908	7.941	6.089	4.245	1.885	0.405
Mar	21.991	16.234	10.010	6.952	5.600	5.175	3.939	2.535	1.128	0.112
Apr	9.576	6.894	5.741	4.429	3.171	2.577	1.809	1.470	0.768	0.116
May	5.365	5.149	4.981	4.626	3.640	2.841	1.583	1.042	0.721	0.302
Jun	5.340	5.208	5.096	5.046	4.568	3.661	2.465	1.331	0.891	0.667
Jul	5.518	5.257	5.126	5.037	4.969	4.394	3.465	1.206	0.971	0.631
Aug	5.395	5.272	5.134	5.040	4.962	4.876	3.483	1.501	0.986	0.750
Sep	5.907	5.532	5.147	5.069	5.000	4.892	3.808	2.967	1.100	0.779

Klip River
IUA UB
RU 21
EWR1 Low flows

Desktop Version 2, Generated on 2011/02/07

Summary of EWR rule curves (Desktop Version 2) for:
Total Runoff: Runoff: C13H
Regional Type: Vaal
Ecological Category = C

Data are given in m^3 * 10^6 monthly flow volume

Total Ecological Flows
% Points

Oct	0.623	0.603	0.561	0.487	0.381	0.257	0.143	0.065	0.027	0.000
Nov	1.171	0.993	0.822	0.639	0.401	0.250	0.132	0.064	0.036	0.000
Dec	0.832	0.733	0.622	0.488	0.315	0.186	0.091	0.038	0.018	0.000
Jan	0.880	0.778	0.661	0.516	0.330	0.192	0.091	0.037	0.017	0.000
Feb	2.800	2.304	1.853	1.402	0.820	0.504	0.269	0.141	0.000	0.000
Mar	0.673	0.645	0.585	0.484	0.352	0.217	0.111	0.050	0.000	0.000
Apr	0.337	0.326	0.303	0.262	0.204	0.089	0.039	0.015	0.000	0.000
May	0.141	0.137	0.127	0.111	0.086	0.058	0.031	0.013	0.000	0.000
Jun	0.076	0.074	0.069	0.060	0.048	0.033	0.019	0.008	0.002	0.000
Jul	0.107	0.104	0.097	0.085	0.068	0.048	0.028	0.012	0.004	0.000
Aug	0.099	0.096	0.091	0.082	0.068	0.051	0.035	0.024	0.017	0.015
Sep	0.201	0.195	0.182	0.159	0.125	0.086	0.049	0.023	0.010	0.000

Reserve Flows without High Flows

Oct	0.431	0.417	0.387	0.335	0.259	0.171	0.090	0.035	0.008	0.000
Nov	0.494	0.473	0.428	0.352	0.252	0.150	0.071	0.025	0.006	0.000
Dec	0.504	0.481	0.432	0.351	0.245	0.141	0.063	0.021	0.004	0.000
Jan	0.552	0.526	0.471	0.380	0.262	0.148	0.064	0.020	0.004	0.000
Feb	0.826	0.789	0.709	0.575	0.402	0.231	0.103	0.034	0.000	0.000
Mar	0.471	0.450	0.407	0.335	0.240	0.143	0.068	0.024	0.000	0.000
Apr	0.277	0.268	0.249	0.215	0.167	0.089	0.039	0.015	0.000	0.000
May	0.141	0.137	0.127	0.111	0.086	0.058	0.031	0.013	0.000	0.000
Jun	0.076	0.074	0.069	0.060	0.048	0.033	0.019	0.008	0.002	0.000
Jul	0.107	0.104	0.097	0.085	0.068	0.048	0.028	0.012	0.004	0.000
Aug	0.099	0.096	0.091	0.082	0.068	0.051	0.035	0.024	0.017	0.015
Sep	0.132	0.128	0.119	0.103	0.081	0.054	0.029	0.012	0.003	0.000

Natural Duration curves

Oct	4.387	1.777	0.683	0.553	0.429	0.261	0.179	0.093	0.037	0.000
Nov	5.285	3.414	2.585	1.532	0.802	0.621	0.421	0.266	0.139	0.000
Dec	6.709	3.524	2.628	1.725	1.452	0.743	0.392	0.224	0.056	0.000
Jan	5.186	3.457	2.274	1.729	1.404	1.023	0.706	0.414	0.116	0.000
Feb	13.529	4.307	2.468	1.591	1.195	0.806	0.587	0.190	0.000	0.000
Mar	4.910	1.837	1.064	0.792	0.549	0.407	0.321	0.093	0.000	0.000
Apr	1.794	1.019	0.644	0.394	0.274	0.089	0.039	0.015	0.000	0.000
May	0.728	0.329	0.258	0.202	0.142	0.086	0.037	0.015	0.000	0.000
Jun	0.382	0.235	0.185	0.127	0.073	0.042	0.027	0.019	0.015	0.000
Jul	0.586	0.385	0.306	0.228	0.164	0.142	0.078	0.030	0.019	0.000
Aug	0.620	0.508	0.388	0.306	0.243	0.194	0.157	0.101	0.049	0.019
Sep	0.899	0.548	0.440	0.301	0.239	0.193	0.100	0.050	0.031	0.000

Wilge River
IUA UC2
RU 35
EWR8 Low flows

Desktop Version 2, Printed on 2008/07/04

Summary of IFR rule curves for: EWR8 based on Natural Monthly Flows in C82C
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal

REC = C

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.403	1.373	1.314	1.208	1.042	0.817	0.560	0.323	0.156	0.080
Nov	2.430	2.178	1.947	1.712	1.343	1.101	0.825	0.569	0.389	0.308
Dec	5.997	5.119	4.372	3.690	2.625	2.131	1.568	1.047	0.679	0.513
Jan	16.141	13.419	11.161	9.186	6.100	4.918	3.570	2.323	1.444	1.045
Feb	7.104	6.124	5.282	4.499	3.276	2.672	1.982	1.344	0.894	0.690
Mar	1.777	1.745	1.682	1.570	1.393	1.154	0.881	0.629	0.451	0.370
Apr	1.421	1.396	1.345	1.253	1.110	0.917	0.696	0.492	0.348	0.283
May	0.922	0.903	0.865	0.796	0.689	0.544	0.379	0.226	0.118	0.069
Jun	0.638	0.625	0.598	0.550	0.474	0.372	0.256	0.148	0.072	0.038
Jul	0.567	0.555	0.530	0.486	0.417	0.323	0.217	0.118	0.049	0.017
Aug	0.468	0.458	0.438	0.402	0.346	0.269	0.183	0.102	0.046	0.020
Sep	0.569	0.559	0.539	0.503	0.447	0.371	0.285	0.205	0.148	0.123

Reserve flows without High Flows

Oct	0.751	0.735	0.702	0.643	0.551	0.427	0.285	0.154	0.061	0.019
Nov	1.180	1.159	1.117	1.042	0.925	0.766	0.585	0.418	0.300	0.246
Dec	1.379	1.354	1.305	1.218	1.081	0.895	0.683	0.487	0.349	0.286
Jan	1.564	1.536	1.481	1.382	1.227	1.017	0.778	0.556	0.400	0.330
Feb	1.990	1.956	1.886	1.762	1.567	1.303	1.002	0.724	0.528	0.439
Mar	1.777	1.745	1.682	1.570	1.393	1.154	0.881	0.629	0.451	0.370
Apr	1.421	1.396	1.345	1.253	1.110	0.917	0.696	0.492	0.348	0.283
May	0.922	0.903	0.865	0.796	0.689	0.544	0.379	0.226	0.118	0.069
Jun	0.638	0.625	0.598	0.550	0.474	0.372	0.256	0.148	0.072	0.038
Jul	0.567	0.555	0.530	0.486	0.417	0.323	0.217	0.118	0.049	0.017
Aug	0.468	0.458	0.438	0.402	0.346	0.269	0.183	0.102	0.046	0.020
Sep	0.569	0.559	0.539	0.503	0.447	0.371	0.285	0.205	0.148	0.123

Natural Duration curves

Oct	29.977	14.064	10.286	5.903	3.689	2.755	1.747	1.512	0.862	0.452
Nov	60.980	35.972	22.635	15.926	9.973	7.589	5.810	4.201	1.439	0.737
Dec	58.330	35.510	28.103	22.166	16.502	11.354	8.094	4.540	2.080	0.952
Jan	63.064	42.813	31.761	25.299	18.836	15.636	10.924	9.577	5.164	1.647
Feb	81.911	49.463	31.341	25.107	22.330	17.551	14.687	10.904	6.465	3.580
Mar	35.880	29.570	24.197	18.963	13.803	11.540	9.013	6.119	3.707	1.900
Apr	18.233	13.870	11.532	9.483	6.362	5.502	4.360	2.955	1.968	0.621
May	9.453	6.153	4.757	3.368	2.744	2.169	1.568	1.228	0.814	0.299
Jun	6.134	3.584	2.716	2.373	1.890	1.358	1.096	0.887	0.559	0.197
Jul	5.626	3.237	2.221	1.826	1.576	1.277	0.963	0.874	0.545	0.019
Aug	5.208	3.047	2.177	1.807	1.385	1.273	1.049	0.945	0.448	0.022
Sep	9.194	4.375	3.044	2.238	1.647	1.350	1.038	0.938	0.760	0.521

Wilge River
IUA UC3
RU 40
EWR8 Low flows

Desktop Version 2, Printed on 2013/07/17

Summary of EWR rule curves for: C82H WR90 Cumulative flows
Determination based on site specific parameters from SPATSIM database.
Regional Type: Vaal

REC = C

Data are given in m^3 * 10^6 monthly flow volume

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	10.143	9.823	9.150	7.971	6.271	4.292	2.485	1.240	0.634	0.518
Nov	32.761	26.609	21.388	16.572	10.319	7.433	5.188	3.886	3.342	2.390
Dec	21.171	17.934	14.975	11.991	8.142	6.025	4.448	3.587	3.254	3.210
Jan	22.254	18.968	15.905	12.751	8.703	6.424	4.766	3.889	3.562	3.562
Feb	73.196	58.436	46.043	34.818	20.354	14.230	9.668	7.177	6.214	6.163
Mar	20.437	19.735	18.245	15.743	12.448	9.087	6.472	4.955	4.321	4.233
Apr	10.488	10.201	9.599	8.543	7.020	5.249	3.630	2.515	1.972	1.820
May	5.994	5.806	5.413	4.722	3.721	2.545	1.452	0.679	0.287	0.197
Jun	4.359	4.227	3.954	3.475	2.775	1.936	1.131	0.534	0.208	0.107
Jul	3.890	3.774	3.533	3.112	2.493	1.746	1.018	0.465	0.154	0.045
Aug	3.636	3.526	3.296	2.893	2.305	1.600	0.924	0.421	0.148	0.060
Sep	6.915	6.727	6.335	5.646	4.647	3.474	2.383	1.612	1.221	1.131

Reserve flows without High Flows

Oct	5.067	4.900	4.551	3.938	3.053	2.025	1.085	0.437	0.122	0.062
Nov	7.113	6.899	6.446	5.684	4.682	3.659	2.863	2.402	2.209	2.182
Dec	8.349	8.091	7.541	6.621	5.429	4.249	3.370	2.889	2.704	2.694
Jan	9.433	9.133	8.490	7.419	6.045	4.704	3.728	3.212	3.020	3.020
Feb	11.170	10.822	10.079	8.838	7.231	5.638	4.452	3.804	3.554	3.541
Mar	10.475	10.165	9.509	8.406	6.953	5.471	4.318	3.650	3.370	3.331
Apr	8.065	7.852	7.404	6.618	5.484	4.166	2.962	2.132	1.728	1.651
May	5.994	5.806	5.413	4.722	3.721	2.545	1.452	0.679	0.287	0.197
Jun	4.359	4.227	3.954	3.475	2.775	1.936	1.131	0.534	0.208	0.107
Jul	3.890	3.774	3.533	3.112	2.493	1.746	1.018	0.465	0.154	0.045
Aug	3.636	3.526	3.296	2.893	2.305	1.600	0.924	0.421	0.148	0.060
Sep	4.129	4.023	3.803	3.416	2.855	2.196	1.584	1.151	0.931	0.881

Natural Duration curves

Oct	98.450	46.780	34.180	19.890	12.330	9.230	5.850	4.920	2.900	1.520
Nov	196.260	115.100	73.570	51.460	32.360	24.640	18.850	13.650	4.620	2.390
Dec	194.980	117.620	93.930	74.110	54.860	38.180	27.160	15.270	6.970	3.210
Jan	211.960	143.740	106.830	83.690	63.150	51.410	36.690	31.870	17.360	5.490
Feb	247.580	146.020	95.140	76.280	67.090	53.230	44.060	32.300	19.610	10.880
Mar	118.340	97.480	81.340	63.790	46.360	37.520	30.280	20.160	12.430	6.370
Apr	59.030	45.120	37.070	30.410	20.680	17.910	14.130	9.580	6.150	1.820
May	31.690	20.620	15.970	11.270	9.160	7.220	5.220	4.120	2.720	0.980
Jun	19.910	11.680	8.840	7.690	6.110	4.400	3.540	2.890	1.810	0.620
Jul	18.840	10.880	7.350	6.120	5.300	4.250	3.230	2.920	1.840	0.050
Aug	17.290	10.240	7.320	5.860	4.650	4.260	3.530	3.190	1.510	0.060
Sep	29.400	14.230	9.870	7.220	5.340	4.360	3.360	3.040	2.460	1.670

Vaal River
IUA UG
RU 58
EWR3 Low flows

Desktop Version 2, Printed on 2008/09/10

Summary of EWR rule curves for: EWR3 based on Natural Monthly Flows in C12H
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal

REC = C

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	2.556	2.513	2.430	2.280	2.033	1.670	1.205	0.710	0.306	0.115
Nov	5.172	5.087	4.922	4.625	4.135	3.414	2.492	1.510	0.708	0.331
Dec	10.112	9.435	8.757	7.988	6.690	5.620	4.232	2.711	1.400	0.683
Jan	11.063	10.527	9.981	9.358	8.565	7.298	5.950	4.188	2.262	0.873
Feb	25.785	23.670	21.735	19.831	17.762	14.439	11.818	8.393	4.649	1.950
Mar	9.529	9.422	9.226	8.879	8.293	7.363	6.001	4.222	2.277	0.875
Apr	4.615	4.540	4.394	4.130	3.696	3.058	2.242	1.371	0.661	0.327
May	2.245	2.208	2.135	2.004	1.788	1.471	1.065	0.633	0.280	0.114
Jun	1.117	1.099	1.063	0.998	0.890	0.732	0.530	0.315	0.139	0.057
Jul	0.989	0.971	0.938	0.878	0.778	0.632	0.445	0.245	0.083	0.006
Aug	0.576	0.566	0.546	0.511	0.453	0.368	0.259	0.143	0.048	0.004
Sep	0.797	0.783	0.756	0.708	0.628	0.510	0.359	0.198	0.067	0.005

Reserve flows without High Flows

Oct	2.556	2.513	2.430	2.280	2.033	1.670	1.205	0.710	0.306	0.115
Nov	5.172	5.087	4.922	4.625	4.135	3.414	2.492	1.510	0.708	0.331
Dec	6.540	6.438	6.241	5.887	5.307	4.449	3.335	2.116	1.065	0.490
Jan	7.752	7.665	7.505	7.220	6.740	5.979	4.864	3.407	1.815	0.667
Feb	11.121	10.998	10.769	10.364	9.682	8.598	7.011	4.938	2.672	1.038
Mar	7.416	7.333	7.180	6.909	6.451	5.725	4.662	3.273	1.754	0.659
Apr	4.615	4.540	4.394	4.130	3.696	3.058	2.242	1.371	0.661	0.327
May	2.245	2.208	2.135	2.004	1.788	1.471	1.065	0.633	0.280	0.114
Jun	1.117	1.099	1.063	0.998	0.890	0.732	0.530	0.315	0.139	0.057
Jul	0.989	0.971	0.938	0.878	0.778	0.632	0.445	0.245	0.083	0.006
Aug	0.576	0.566	0.546	0.511	0.453	0.368	0.259	0.143	0.048	0.004
Sep	0.797	0.783	0.756	0.708	0.628	0.510	0.359	0.198	0.067	0.005

Natural Duration curves

Oct	70.923	22.095	10.928	8.834	6.687	4.857	4.096	3.230	1.333	0.605
Nov	106.412	72.728	50.000	31.354	27.022	16.084	10.301	8.291	4.402	2.778
Dec	146.677	99.754	66.368	48.006	38.620	24.474	19.486	12.269	6.623	2.834
Jan	116.275	83.057	59.741	47.547	37.115	30.907	25.310	15.248	10.114	4.850
Feb	165.332	83.569	50.132	34.540	28.336	22.499	18.895	16.171	11.103	3.344
Mar	70.105	47.715	35.129	31.239	19.153	13.945	11.757	8.453	4.712	1.941
Apr	34.290	19.796	15.000	12.361	9.070	7.361	5.224	3.665	2.596	0.702
May	12.407	8.382	5.933	4.648	3.726	3.006	2.348	1.885	1.165	0.534
Jun	8.796	6.022	3.989	3.063	2.674	2.292	1.775	1.586	0.772	0.505
Jul	6.575	4.607	3.663	3.237	2.688	2.337	1.964	1.658	1.344	0.538
Aug	5.821	4.626	3.506	2.976	2.490	2.277	1.960	1.635	1.355	1.042
Sep	11.038	5.285	3.700	3.318	2.820	2.431	2.014	1.690	1.107	0.629

Grootdraai Dam (Vaal River)
IUA UA
RU 10
EWR2 Low flows

Desktop Version 2, Printed on 2008/07/03

Summary of EWR rule curves for: EWR2 based on Natural Monthly Flows in C11L
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal

REC = C

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.133	1.111	1.066	0.987	0.862	0.693	0.500	0.321	0.196	0.139
Nov	2.925	2.620	2.339	2.051	1.599	1.297	0.952	0.633	0.408	0.306
Dec	3.223	2.863	2.523	2.163	1.642	1.273	0.903	0.610	0.434	0.364
Jan	19.261	15.221	11.969	9.174	5.492	3.982	2.651	1.732	1.246	1.066
Feb	10.577	8.637	7.017	5.544	3.593	2.636	1.792	1.209	0.901	0.787
Mar	2.594	2.529	2.397	2.166	1.824	1.404	0.983	0.650	0.450	0.370
Apr	1.398	1.363	1.292	1.168	0.985	0.759	0.534	0.355	0.248	0.205
May	1.134	1.108	1.058	0.968	0.828	0.637	0.419	0.218	0.077	0.012
Jun	0.992	0.970	0.926	0.847	0.724	0.557	0.367	0.191	0.067	0.000
Jul	0.864	0.849	0.822	0.772	0.690	0.569	0.413	0.241	0.094	0.013
Aug	0.792	0.779	0.753	0.707	0.633	0.522	0.378	0.221	0.086	0.012
Sep	0.865	0.851	0.826	0.780	0.705	0.594	0.450	0.293	0.157	0.083

Reserve flows without High Flows

Oct	0.994	0.974	0.935	0.866	0.757	0.609	0.441	0.285	0.175	0.126
Nov	1.420	1.394	1.341	1.245	1.096	0.894	0.664	0.451	0.300	0.232
Dec	1.678	1.638	1.556	1.412	1.199	0.937	0.675	0.468	0.343	0.294
Jan	1.871	1.814	1.696	1.496	1.220	0.913	0.643	0.457	0.358	0.321
Feb	2.426	2.353	2.202	1.945	1.590	1.197	0.851	0.611	0.485	0.438
Mar	1.818	1.774	1.684	1.525	1.292	1.005	0.717	0.490	0.353	0.299
Apr	1.398	1.363	1.292	1.168	0.985	0.759	0.534	0.355	0.248	0.205
May	1.134	1.108	1.058	0.968	0.828	0.637	0.419	0.218	0.077	0.012
Jun	0.992	0.970	0.926	0.847	0.724	0.557	0.367	0.191	0.067	0.000
Jul	0.864	0.849	0.822	0.772	0.690	0.569	0.413	0.241	0.094	0.013
Aug	0.792	0.779	0.753	0.707	0.633	0.522	0.378	0.221	0.086	0.012
Sep	0.865	0.851	0.826	0.780	0.705	0.594	0.450	0.293	0.157	0.083

Natural Duration curves

Oct	36.466	7.236	5.813	4.096	2.875	2.404	1.747	1.165	0.650	0.362
Nov	67.438	43.499	23.476	16.300	10.795	7.778	6.076	4.684	1.184	0.694
Dec	84.528	57.658	34.819	29.574	20.975	14.740	9.692	5.839	3.297	1.635
Jan	61.675	42.525	31.228	27.319	18.873	17.805	11.776	9.256	6.101	3.047
Feb	108.999	35.553	28.356	18.531	14.509	11.004	8.470	6.242	4.477	2.538
Mar	37.138	24.175	15.898	11.835	8.979	7.676	5.190	3.457	1.676	1.109
Apr	16.211	11.254	6.883	5.883	3.912	3.009	2.176	1.809	1.254	0.459
May	8.789	4.443	2.838	2.285	1.512	1.221	1.023	0.926	0.732	0.209
Jun	4.298	2.805	2.029	1.644	1.350	1.111	1.003	0.849	0.320	0.000
Jul	2.953	2.356	1.844	1.400	1.236	1.049	0.922	0.848	0.508	0.127
Aug	2.378	1.968	1.609	1.415	1.198	0.971	0.851	0.747	0.560	0.239
Sep	3.600	2.442	1.906	1.331	1.142	1.011	0.880	0.683	0.498	0.313

Sterkfontein Dam (Nuwejaarspruit)
IUA UC2
RU 33&34
EWR2 Low and high flows

Desktop Version 2, Generated on 2011/02/08

Summary of EWR rule curves (Desktop Version 2) for:
Total Runoff: Runoff: CC8NUW- C81E
Regional Type: Vaal
Ecological Category = C/D

Data are given in m^3 * 10^6 monthly flow volume

Total Ecological Flows
% Points

Oct	0.338	0.328	0.306	0.268	0.212	0.148	0.089	0.048	0.028	0.025
Nov	0.922	0.772	0.635	0.498	0.318	0.217	0.137	0.091	0.072	0.066
Dec	0.670	0.587	0.501	0.400	0.270	0.179	0.111	0.074	0.060	0.059
Jan	0.781	0.698	0.608	0.501	0.365	0.269	0.199	0.163	0.149	0.138
Feb	2.106	1.739	1.411	1.088	0.670	0.452	0.290	0.201	0.167	0.165
Mar	0.819	0.791	0.731	0.631	0.499	0.365	0.260	0.199	0.174	0.149
Apr	0.453	0.439	0.411	0.362	0.291	0.208	0.133	0.081	0.055	0.051
May	0.215	0.210	0.198	0.178	0.149	0.115	0.083	0.060	0.049	0.046
Jun	0.117	0.115	0.109	0.099	0.085	0.068	0.052	0.040	0.033	0.031
Jul	0.083	0.080	0.076	0.067	0.055	0.041	0.027	0.016	0.010	0.008
Aug	0.074	0.073	0.069	0.062	0.052	0.041	0.030	0.021	0.017	0.015
Sep	0.217	0.212	0.200	0.139	0.116	0.089	0.077	0.057	0.046	0.035

Reserve Flows without High Flows

Oct	0.195	0.188	0.176	0.153	0.121	0.084	0.050	0.026	0.015	0.012
Nov	0.327	0.315	0.289	0.245	0.188	0.129	0.083	0.057	0.046	0.044
Dec	0.382	0.367	0.334	0.280	0.209	0.139	0.087	0.059	0.048	0.047
Jan	0.494	0.477	0.441	0.382	0.305	0.230	0.176	0.147	0.137	0.137
Feb	0.632	0.607	0.556	0.470	0.358	0.248	0.166	0.121	0.104	0.103
Mar	0.561	0.543	0.505	0.442	0.358	0.272	0.205	0.167	0.151	0.148
Apr	0.382	0.371	0.347	0.306	0.246	0.177	0.114	0.070	0.049	0.045
May	0.215	0.210	0.198	0.178	0.149	0.115	0.083	0.060	0.049	0.046
Jun	0.117	0.115	0.109	0.099	0.085	0.068	0.052	0.040	0.033	0.031
Jul	0.083	0.080	0.076	0.067	0.055	0.041	0.027	0.016	0.010	0.008
Aug	0.074	0.073	0.069	0.062	0.052	0.041	0.030	0.021	0.017	0.015
Sep	0.129	0.126	0.119	0.108	0.092	0.073	0.055	0.043	0.037	0.035

Natural Duration curves

Oct	2.606	1.172	0.765	0.526	0.329	0.205	0.142	0.097	0.063	0.034
Nov	5.853	3.596	1.686	1.073	0.644	0.475	0.394	0.320	0.123	0.066
Dec	4.697	2.748	2.360	1.759	1.206	0.698	0.493	0.287	0.205	0.060
Jan	5.959	4.014	2.927	2.251	1.938	1.213	0.848	0.568	0.329	0.138
Feb	7.044	4.787	2.724	2.294	1.794	1.381	1.071	0.694	0.384	0.203
Mar	5.160	2.834	2.012	1.325	0.982	0.848	0.638	0.463	0.321	0.149
Apr	2.184	1.250	0.756	0.694	0.559	0.359	0.324	0.235	0.189	0.093
May	0.866	0.414	0.332	0.243	0.202	0.168	0.134	0.101	0.071	0.052
Jun	0.559	0.320	0.201	0.158	0.135	0.108	0.085	0.069	0.058	0.031
Jul	0.407	0.258	0.153	0.127	0.108	0.093	0.082	0.067	0.052	0.019
Aug	0.482	0.205	0.153	0.119	0.108	0.090	0.078	0.067	0.049	0.022
Sep	0.625	0.309	0.231	0.139	0.116	0.089	0.077	0.066	0.054	0.035

Suikerbosrant and Balfour Dam
IUA UH
RU 60
EWR9 Low flows (river and dam) and high flows (river)

Desktop Version 2, Printed on 2009/10/11

Summary of EWR rule curves for: EWR9 based on Natural Monthly Flows in C21C
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal

REC = C

Data are given in m^3/s mean monthly flow

% Points										
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.276	0.271	0.261	0.244	0.217	0.181	0.139	0.100	0.073	0.061
Nov	0.453	0.412	0.373	0.332	0.269	0.224	0.173	0.126	0.093	0.077
Dec	0.404	0.364	0.328	0.292	0.234	0.196	0.152	0.112	0.084	0.071
Jan	1.015	0.871	0.748	0.636	0.460	0.377	0.282	0.195	0.133	0.105
Feb	0.759	0.674	0.598	0.523	0.405	0.334	0.254	0.179	0.127	0.103
Mar	0.256	0.252	0.243	0.228	0.205	0.173	0.136	0.103	0.079	0.068
Apr	0.228	0.224	0.217	0.204	0.184	0.156	0.125	0.096	0.075	0.066
May	0.204	0.200	0.194	0.182	0.165	0.140	0.112	0.087	0.069	0.061
Jun	0.175	0.173	0.167	0.158	0.143	0.123	0.101	0.080	0.065	0.058
Jul	0.116	0.115	0.113	0.109	0.103	0.093	0.081	0.068	0.057	0.051
Aug	0.094	0.093	0.091	0.088	0.083	0.076	0.066	0.055	0.046	0.041
Sep	0.109	0.107	0.105	0.101	0.095	0.085	0.073	0.059	0.047	0.041
Reserve flows without High Flows										
Oct	0.171	0.168	0.163	0.153	0.138	0.118	0.095	0.073	0.058	0.051
Nov	0.252	0.248	0.239	0.225	0.202	0.170	0.135	0.102	0.079	0.068
Dec	0.209	0.206	0.199	0.187	0.169	0.144	0.115	0.089	0.070	0.062
Jan	0.259	0.255	0.246	0.231	0.207	0.174	0.137	0.103	0.079	0.068
Feb	0.329	0.323	0.312	0.292	0.261	0.219	0.171	0.127	0.096	0.082
Mar	0.256	0.252	0.243	0.228	0.205	0.173	0.136	0.103	0.079	0.068
Apr	0.228	0.224	0.217	0.204	0.184	0.156	0.125	0.096	0.075	0.066
May	0.204	0.200	0.194	0.182	0.165	0.140	0.112	0.087	0.069	0.061
Jun	0.175	0.173	0.167	0.158	0.143	0.123	0.101	0.080	0.065	0.058
Jul	0.116	0.115	0.113	0.109	0.103	0.093	0.081	0.068	0.057	0.051
Aug	0.094	0.093	0.091	0.088	0.083	0.076	0.066	0.055	0.046	0.041
Sep	0.109	0.107	0.105	0.101	0.095	0.085	0.073	0.059	0.047	0.041
Natural Duration curves										
Oct	1.090	0.736	0.564	0.470	0.332	0.254	0.202	0.149	0.108	0.093
Nov	3.287	1.389	1.057	0.868	0.694	0.629	0.421	0.266	0.147	0.077
Dec	1.676	1.273	0.956	0.795	0.661	0.541	0.396	0.310	0.224	0.138
Jan	3.424	1.236	0.915	0.833	0.691	0.597	0.489	0.355	0.235	0.161
Feb	6.320	1.724	0.922	0.847	0.707	0.612	0.475	0.430	0.298	0.203
Mar	2.808	1.198	0.948	0.814	0.668	0.575	0.470	0.414	0.287	0.202
Apr	1.597	0.999	0.837	0.718	0.625	0.509	0.432	0.367	0.266	0.181
May	1.314	0.717	0.582	0.478	0.414	0.370	0.310	0.235	0.205	0.127
Jun	0.856	0.617	0.440	0.363	0.340	0.297	0.243	0.220	0.177	0.143
Jul	0.642	0.489	0.377	0.310	0.280	0.246	0.231	0.209	0.183	0.149
Aug	0.482	0.358	0.310	0.265	0.235	0.209	0.194	0.183	0.172	0.138
Sep	0.536	0.332	0.282	0.239	0.201	0.197	0.166	0.147	0.131	0.112

Blesbokspruit
IUA UI
RU 62
EWR11 Low flows

Desktop Version 2, Printed on 2008/09/12

Summary of EWR rule curves for: EWR11 based on Present Day Flows in C21F
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal

REC = D

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.406	0.400	0.387	0.364	0.327	0.272	0.201	0.126	0.065	0.036
Nov	0.603	0.598	0.588	0.569	0.539	0.494	0.436	0.375	0.325	0.302
Dec	1.031	1.019	0.995	0.951	0.879	0.774	0.639	0.495	0.377	0.322
Jan	2.018	1.998	1.960	1.892	1.778	1.596	1.331	0.990	0.631	0.409
Feb	2.928	2.897	2.840	2.738	2.565	2.290	1.889	1.373	0.832	0.495
Mar	1.767	1.750	1.718	1.660	1.562	1.406	1.179	0.887	0.580	0.389
Apr	1.048	1.036	1.012	0.969	0.897	0.793	0.659	0.516	0.399	0.344
May	0.951	0.940	0.919	0.880	0.817	0.724	0.604	0.477	0.373	0.324
Jun	0.777	0.769	0.753	0.723	0.676	0.605	0.515	0.418	0.340	0.303
Jul	0.603	0.598	0.588	0.569	0.539	0.494	0.436	0.375	0.325	0.302
Aug	0.410	0.408	0.404	0.398	0.387	0.370	0.349	0.327	0.309	0.301
Sep	0.410	0.408	0.404	0.398	0.387	0.370	0.349	0.327	0.309	0.301

Reserve flows without High Flows

Oct	0.406	0.400	0.387	0.364	0.327	0.272	0.201	0.126	0.065	0.036
Nov	0.603	0.598	0.588	0.569	0.539	0.494	0.436	0.375	0.325	0.302
Dec	0.777	0.769	0.753	0.723	0.676	0.605	0.515	0.418	0.340	0.303
Jan	1.124	1.114	1.096	1.063	1.008	0.920	0.791	0.626	0.453	0.345
Feb	1.249	1.238	1.217	1.181	1.119	1.020	0.876	0.691	0.496	0.376
Mar	1.145	1.135	1.116	1.082	1.026	0.935	0.803	0.634	0.456	0.345
Apr	1.048	1.036	1.012	0.969	0.897	0.793	0.659	0.516	0.399	0.344
May	0.951	0.940	0.919	0.880	0.817	0.724	0.604	0.477	0.373	0.324
Jun	0.777	0.769	0.753	0.723	0.676	0.605	0.515	0.418	0.340	0.303
Jul	0.603	0.598	0.588	0.569	0.539	0.494	0.436	0.375	0.325	0.302
Aug	0.410	0.408	0.404	0.398	0.387	0.370	0.349	0.327	0.309	0.301
Sep	0.410	0.408	0.404	0.398	0.387	0.370	0.349	0.327	0.309	0.301

Natural Duration curves

Oct	3.170	2.688	2.412	2.263	2.106	2.065	1.945	1.859	1.815	1.744
Nov	4.653	3.769	3.326	2.940	2.623	2.58	2.265	2.060	1.694	1.512
Dec	4.898	4.264	3.890	3.498	3.207	2.748	2.449	2.162	1.863	1.564
Jan	6.713	4.368	3.853	3.416	3.162	3.017	2.726	2.348	2.068	1.785
Feb	6.672	4.638	4.171	3.650	3.187	3.001	2.877	2.575	2.025	1.703
Mar	5.563	4.469	4.017	3.364	3.058	2.867	2.662	2.404	1.990	1.736
Apr	4.853	4.225	3.785	3.414	2.990	2.770	2.654	2.411	2.257	1.929
May	4.398	3.468	3.132	2.894	2.647	2.535	2.445	2.352	2.221	2.091
Jun	3.275	2.785	2.627	2.519	2.423	2.326	2.249	2.211	2.188	2.141
Jul	2.737	2.576	2.464	2.397	2.341	2.307	2.285	2.255	2.233	2.214
Aug	2.681	2.348	2.300	2.277	2.251	2.221	2.210	2.192	2.180	2.169
Sep	2.585	2.365	2.280	2.242	2.207	2.164	2.145	2.130	2.110	2.083

Vaal River
IUA UL
RU 75
EWR5 High flows

VAAL RIVER, EWR5												
OBSERVED FLOW, REC=C/D												
Array	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.10%	560.41	1774.97	645.53	175.93	360.29	247.30	264.34	46.30	590.28	673.91	483.41	323.70
1.00%	560.41	1774.97	645.53	175.93	360.29	247.30	264.34	46.30	590.28	673.91	483.41	323.70
5.00%	421.52	1338.87	323.33	125.00	161.29	39.35	38.46	41.07	115.35	100.06	182.87	268.07
10.00%	307.27	430.31	214.31	86.81	33.64	26.97	28.19	36.22	49.38	60.48	96.06	241.94
15.00%	193.77	183.74	154.94	76.39	30.09	26.62	27.52	33.27	43.21	49.66	76.77	156.81
20.00%	131.05	139.30	130.68	50.54	28.56	25.27	24.34	29.12	39.35	45.55	55.17	143.37
30.00%	75.04	50.84	58.99	36.50	26.81	21.72	20.87	26.66	32.95	36.25	42.05	71.68
40.00%	49.28	43.82	38.46	27.04	23.52	19.65	19.75	24.53	30.48	29.61	34.95	39.20
50.00%	38.46	37.24	33.23	22.18	17.66	14.70	18.11	19.60	23.03	27.07	26.27	32.89
60.00%	31.92	31.58	28.64	17.82	13.22	11.57	14.64	17.25	19.25	23.41	20.49	27.93
70.00%	28.79	26.46	21.58	14.08	9.37	9.68	10.57	15.08	14.81	17.14	15.51	19.49
80.00%	25.46	17.44	17.29	11.34	7.24	6.40	6.80	7.17	8.95	10.53	12.81	15.72
85.00%	20.50	13.60	12.69	8.26	5.97	5.56	5.71	6.50	8.14	9.18	10.73	13.63
90.00%	11.20	11.20	9.93	5.44	4.52	5.29	5.00	5.68	6.60	8.55	8.64	11.91
95.00%	9.89	7.23	6.83	4.36	3.18	3.22	3.57	3.66	4.51	6.16	7.66	8.92
99.00%	5.90	5.08	4.41	3.62	2.80	2.65	3.24	3.09	3.76	5.64	4.67	6.12
99.90%	5.11	4.75	4.29	3.39	2.43	2.03	2.79	3.08	2.92	2.33	3.83	5.26

- Requirements in table has been produced by the Fish Flow Habitat Assessment model (FFHA)

Klerkskraal Dam (Mooi River)
IUA UL
RU 69
RE-EWR2 Low flows

Desktop Version 2, Printed on 2008/09/12

Summary of EWR rule curves for: RE-EWR2 based on Natural Monthly Flows in C23G
Determination based on site specific parameters from SPATSIM database.
Regional Type: Vaal

REC: D

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.222	0.218	0.210	0.196	0.176	0.153	0.132	0.118	0.110	0.109
Nov	0.430	0.370	0.318	0.267	0.202	0.168	0.142	0.127	0.120	0.119
Dec	0.300	0.270	0.240	0.209	0.168	0.144	0.126	0.116	0.112	0.112
Jan	0.304	0.273	0.243	0.211	0.170	0.145	0.127	0.117	0.114	0.114
Feb	1.233	0.992	0.792	0.613	0.383	0.290	0.220	0.183	0.168	0.167
Mar	0.416	0.404	0.378	0.334	0.277	0.218	0.173	0.146	0.135	0.133
Apr	0.385	0.377	0.359	0.329	0.284	0.232	0.185	0.153	0.137	0.134
May	0.206	0.203	0.197	0.186	0.171	0.153	0.136	0.124	0.118	0.116
Jun	0.210	0.208	0.202	0.191	0.176	0.158	0.141	0.128	0.121	0.118
Jul	0.202	0.200	0.194	0.185	0.170	0.153	0.136	0.124	0.116	0.114
Aug	0.201	0.198	0.192	0.182	0.168	0.151	0.134	0.122	0.115	0.113
Sep	0.230	0.227	0.219	0.205	0.186	0.162	0.141	0.125	0.118	0.116

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.189	0.187	0.181	0.171	0.156	0.139	0.124	0.113	0.108	0.107
Nov	0.187	0.184	0.176	0.164	0.149	0.132	0.120	0.112	0.109	0.109
Dec	0.183	0.180	0.172	0.160	0.144	0.128	0.116	0.109	0.107	0.107
Jan	0.187	0.183	0.175	0.162	0.145	0.129	0.117	0.111	0.109	0.109
Feb	0.213	0.209	0.200	0.186	0.167	0.148	0.135	0.127	0.124	0.124
Mar	0.199	0.195	0.188	0.175	0.158	0.141	0.127	0.120	0.116	0.116
Apr	0.213	0.210	0.204	0.192	0.176	0.157	0.139	0.127	0.121	0.120
May	0.206	0.203	0.197	0.186	0.171	0.153	0.136	0.124	0.118	0.116
Jun	0.210	0.208	0.202	0.191	0.176	0.158	0.141	0.128	0.121	0.118
Jul	0.202	0.200	0.194	0.185	0.170	0.153	0.136	0.124	0.116	0.114
Aug	0.201	0.198	0.192	0.182	0.168	0.151	0.134	0.122	0.115	0.113
Sep	0.202	0.199	0.193	0.182	0.167	0.149	0.133	0.121	0.115	0.114

Natural Duration curves

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.770	1.131	0.881	0.758	0.676	0.605	0.549	0.526	0.482	0.392
Nov	1.736	1.296	0.976	0.934	0.768	0.691	0.625	0.575	0.486	0.386
Dec	1.990	1.430	1.086	0.963	0.866	0.721	0.635	0.560	0.459	0.370
Jan	2.289	1.542	1.314	1.086	0.960	0.810	0.717	0.635	0.504	0.306
Feb	2.956	1.951	1.459	1.257	1.058	0.909	0.773	0.678	0.562	0.417
Mar	2.759	1.882	1.572	1.284	1.049	0.896	0.792	0.698	0.609	0.437
Apr	2.789	2.157	1.674	1.354	1.076	0.957	0.860	0.760	0.679	0.529
May	2.042	1.688	1.370	1.146	0.963	0.885	0.821	0.706	0.657	0.541
Jun	2.253	1.574	1.188	1.046	0.899	0.802	0.741	0.683	0.640	0.556
Jul	1.945	1.381	1.030	0.960	0.892	0.788	0.698	0.650	0.616	0.571
Aug	1.949	1.232	1.012	0.874	0.803	0.736	0.665	0.620	0.586	0.534
Sep	1.952	1.088	0.961	0.810	0.756	0.702	0.617	0.590	0.559	0.494

Vaal Dam (Vaal River)

IUA UM
RU 74
EWR4 Low and high flows

VAAL RIVER, EWR4												
OBSERVED FLOWS, REC=C												
Array	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
0.10%	361.41	1292.58	528.67	183.64	221.40	208.72	32.44	36.22	125.39	77.66	162.81	306.90
1.00%	361.41	1292.58	528.67	183.64	221.40	208.72	32.44	36.22	125.39	77.66	162.81	306.90
5.00%	361.41	1292.58	528.67	183.64	221.40	208.72	32.44	36.22	125.39	77.66	162.81	306.90
10.00%	250.90	449.32	327.81	54.40	19.38	20.41	28.15	32.74	40.51	41.07	54.01	139.64
15.00%	144.49	338.54	193.40	40.51	16.50	17.63	22.59	32.11	37.04	39.95	37.65	105.29
20.00%	115.74	79.37	140.38	21.99	16.13	17.63	20.05	30.24	35.80	36.96	33.56	76.16
30.00%	63.47	37.66	48.16	16.01	15.23	14.81	18.07	21.06	21.84	24.53	22.45	43.31
40.00%	20.98	20.42	24.64	14.74	13.37	14.54	16.76	19.27	21.06	20.91	21.03	33.27
50.00%	17.70	16.00	17.25	12.92	12.25	13.93	15.31	16.80	16.63	17.17	15.93	19.12
60.00%	13.96	13.81	14.93	12.35	11.24	11.92	13.70	15.53	16.17	15.68	13.62	11.46
70.00%	13.07	12.28	13.59	12.23	10.01	10.26	13.18	15.20	15.16	13.63	13.04	10.42
80.00%	8.33	10.33	10.86	7.83	8.18	9.30	11.69	11.61	12.85	12.96	10.22	9.33
85.00%	7.17	9.84	9.89	7.48	8.10	9.26	11.13	10.45	12.27	12.84	8.41	8.85
90.00%	6.83	8.97	7.80	7.48	7.88	8.49	10.68	10.01	11.57	12.73	8.29	7.06
95.00%	3.48	7.85	7.58	7.06	7.69	7.52	9.97	9.71	10.76	10.12	7.41	4.93
99.00%	0.51	3.62	2.68	6.83	6.98	2.45	7.02	6.83	6.64	7.65	6.29	1.08
99.90%	0.51	3.62	2.68	6.83	6.98	2.45	7.02	6.83	6.64	7.65	6.29	1.08

Requirements in table has been produced by the Fish Flow Habitat Assessment model (FFHA)

Vaal Barrage (Vaal River)
IUA UM
RU 75
EWR4 Low flows

Desktop Version 2, Printed on 2013/07/17

Summary of EWR rule curves for: C23B WR90 Cumulative flows
Determination based on site specific parameters from SPATSIM database.
Regional Type: Vaal

ERC = C

Data are given in m^3 * 10^6 monthly flow volume

% Points										
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	42.780	41.647	39.267	35.093	29.073	22.071	15.674	11.265	9.119	8.670
Nov	130.314	106.349	85.884	66.854	42.140	30.481	21.411	16.151	13.951	13.644
Dec	84.542	71.928	60.334	48.565	33.383	24.922	18.619	15.178	13.848	13.778
Jan	88.813	76.012	64.006	51.572	35.612	26.525	19.910	16.412	15.110	15.110
Feb	287.342	229.881	181.565	137.705	81.192	57.113	39.176	29.382	25.597	25.397
Mar	69.526	67.213	62.305	54.061	43.206	32.131	23.516	18.519	16.430	16.138
Apr	39.690	38.724	36.693	33.132	27.997	22.023	16.566	12.805	10.974	10.627
May	23.253	22.759	21.724	19.910	17.280	14.189	11.317	9.285	8.256	8.019
Jun	18.124	17.762	17.011	15.695	13.770	11.465	9.253	7.611	6.716	6.438
Jul	17.201	16.867	16.176	14.965	13.188	11.040	8.950	7.362	6.467	6.153
Aug	16.109	15.791	15.130	13.970	12.275	10.245	8.297	6.851	6.062	5.818
Sep	23.868	23.312	22.147	20.104	17.144	13.664	10.431	8.143	6.985	6.718

Reserve flows without High Flows

Oct	23.111	22.574	21.444	19.463	16.607	13.283	10.247	8.155	7.136	6.943
Nov	30.799	29.873	27.909	24.611	20.267	15.836	12.389	10.390	9.553	9.437
Dec	34.795	33.740	31.489	27.728	22.858	18.031	14.436	12.473	11.714	11.674
Jan	39.072	37.850	35.238	30.886	25.300	19.851	15.884	13.787	13.006	13.006
Feb	46.127	44.716	41.705	36.674	30.158	23.702	18.892	16.266	15.251	15.197
Mar	40.807	39.625	37.118	32.908	27.363	21.707	17.307	14.755	13.687	13.538
Apr	31.472	30.754	29.246	26.602	22.788	18.351	14.298	11.505	10.146	9.888
May	23.253	22.759	21.724	19.910	17.280	14.189	11.317	9.285	8.256	8.019
Jun	18.124	17.762	17.011	15.695	13.770	11.465	9.253	7.611	6.716	6.438
Jul	17.201	16.867	16.176	14.965	13.188	11.040	8.950	7.362	6.467	6.153
Aug	16.109	15.791	15.130	13.970	12.275	10.245	8.297	6.851	6.062	5.818
Sep	17.032	16.677	15.935	14.633	12.747	10.529	8.469	7.011	6.273	6.103

Natural Duration curves

Oct	505.490	211.250	95.020	69.220	56.540	45.630	32.860	25.680	13.980	8.670
Nov	826.210	418.900	316.100	237.830	178.870	119.500	88.040	60.180	32.160	22.970
Dec	910.730	572.320	369.620	305.140	244.730	184.400	132.560	87.660	43.610	26.190
Jan	799.560	513.120	390.710	329.050	300.600	236.680	177.190	137.930	78.980	28.530
Feb	1087.380	602.120	327.070	242.330	202.860	174.470	152.650	123.340	66.780	32.960
Mar	560.540	402.640	247.440	193.710	156.800	118.580	101.060	79.930	49.550	23.910
Apr	255.050	173.870	108.380	98.120	79.560	68.860	53.360	43.600	25.100	11.240
May	108.230	80.640	52.130	47.260	34.810	31.720	26.300	23.980	13.950	11.210
Jun	65.240	49.420	36.570	31.400	23.860	22.330	18.650	16.450	12.360	9.160
Jul	60.030	42.080	33.350	28.390	25.280	22.440	20.280	17.730	15.710	9.880
Aug	50.150	40.360	32.330	29.540	26.280	23.980	20.000	18.280	15.130	11.660
Sep	73.990	51.790	35.760	29.650	25.610	22.880	18.460	16.110	12.890	8.370