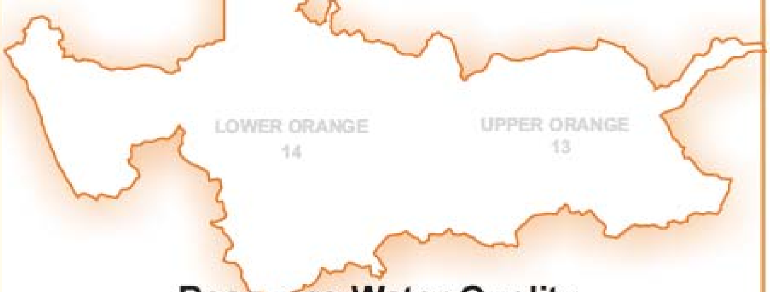
Water Resource Planning Systems

Water Quality Planning

Orange River: Assessment of Water Quality Data Requirements for Water Quality Planning Purposes



Resource Water Quality Objectives (RWQOs): Upper and Lower Orange Water Management Areas (WMAs 13 and 14)

Report No:. 5

June 2009

Final

water & forestry
Department:
Water Affairs & Forestry
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

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5**	Resource Water Quality Objectives (RWQOs): Upper and Lower Orange Water Management Areas (WMAs 13 and 14)
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* Reports produced by the Directorate, Water Resource Planning Systems, Sub-Directorate Water Quality Planning as part of the study titled *"Development of an Integrated Water Quality Management Strategy for the Upper and Lower Orange River Water Management Areas".*

** Reports produced by Zitholele Consulting on behalf of the Department of Water Affairs and Forestry as part of the study titled *"Assessment of Water Quality Data Requirements for Water Quality Planning Purposes in the Upper and Lower Orange Water Management Areas".*

APPROVAL

TITLE:	Orange River: Assessment of water quality data requirements for planning purposes: Resource Water Quality Objectives (RWQOs): Upper and Lower Orange Water Management Areas (WMAs 13 and 14)
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EXECUTIVE SUMMARY

The Orange-Senqu catchment spans four southern African countries (Botswana, Lesotho, Namibia and South Africa) and is one of the largest river basins in southern Africa. The relatively scarce surface and groundwater resources in the Orange-Senqu catchment are critical for the sustainable social and economic development of each country. Existing patterns of land and water use have reached the point where great care is needed to ensure that the scarce and vulnerable water resources are not over-exploited.

The aim of this study was to undertake a water quality assessment of the Orange River (Upper and Lower Orange Water Management areas) to determine the current status, establish in-stream water quality management objectives and to provide recommendations for future planning and strategy development activities.

The purpose of this task (Report No. 5) as part of the study is to determine preliminary resource water quality objectives (RWQOs) for the Orange River System. RWQOs are a mechanism through which a balance between sustainable and optimal water use and protection of the water resource can be achieved.

The scope of work for this task included:

- The determination of any existing RWQOs for the Orange River;
- Collating and assessing this information to understand what is available;
- Determination and identification of gaps that exist and understanding what/where further RWQOs are required (strategic sites), and
- Based on current information available, status quo assessment, water users, water use impacts, expert knowledge and experience from the Regional Offices and DWAF Directorates set preliminary RWQOs for the Orange River System (Desktop level) using the RWQOs Model Version 4.1 developed by DWAF.

Having undertaken the above sub-tasks the following were arrived at with respect to RWQOs for the Orange River (WMAs 13 and 14):

The whole Upper Orange River (from Oranjedraai to Marksdrift) is fairly natural and homogenous in terms of water chemistry, but is divided into two river reaches, *i.e.* (1) from Oranjedraai (Lesotho border) to Gariep Dam and (2) from Gariep Dam to Marksdrift to correspond with the proposed Visioning areas for the upper Orange WMA (UOWMA).

The major tributaries to the Orange River in the UOWMA differ significantly to justify different RWQOs. The Kraai River with a good ecological state is considered to be unique with a high conservation status, therefore, separate RWQOs with more stringent levels of protection.

The water chemistry of Kornetspruit is largely natural and show small changes over the past 35 years. The dissolved salt concentration in Sterkspruit was fairly low, but the high nutrient concentrations are a matter of concern, thus different RWQOs from Kornetspruit.

The Stormbergspruit and Seekoei River are ionic rich systems, but Stormbergspruit is contaminated by sewage and Seekoei River contains naturally high background salt values, therefore, different RWQOs.

The Caledon River and its tributaries are considered as one Visioning area (Area 3, DWAF, 2009a). However, the water quality in the lower end of the Caledon River is significantly different (especially because of the high salt concentrations). Therefore, the Caledon River was divided in 2 river reaches, *i.e.* (1) From the Little Caledon River confluence to Maseru and (2) from Maseru to the confluence with the Orange River. The RWQOs determined for Ficksburg are recommended as the representative site for the upper section of the river and Kommissiedrift are recommended as the representative site for the lower river reach 2.

The Little Caledon River at Golden Gate is a natural (pristine) site with a different and more stringent set of RWQOs. The Little Caledon River (at the confluence with the Caledon River) has been moderately modified, therefore a different set of RWQOs.

The other four tributaries to the Caledon River (Groot, Meul, Moperi and Leeu) show moderate differences therefore different preliminary RWQOs. However, more data is needed to increase the confidence levels of the RWQOs based on 1 or 2 determinations.

The default concentrations for most of the metals (User: Aquatic Ecosystems, DWAF, 1996) are impracticably low for the Orange River, especially for Al, Cd, Cu, Pb and Zn, and 'new' rating concentrations for the Orange River and tributaries are proposed (see **Table 83**).

The lower Orange WMA is divided in 4 river reaches or management unit (very similar to the visioning areas), *i.e.*: (1) Marksdrift to Boegoeberg Dam; (2) Boegoeberg Dam to Neusberg weir (Kakamas); (3) Neusberg weir to Pella and (4) Pella to Alexander Bay.

As one progress downstream in the Orange River, the RWQOs become less stringent for the salts, partially ascribed to a natural build-up of salts. In contrary, the RWQOs for nitrogen (DIN) becomes more stringent downstream because the lower reaches of the river is apparently nitrogen limited and increased N concentrations could lead to excessive algal growth.

The RWQO Model 4.1 should be upgraded and small errors corrected.

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LIST OF ACRONYMS

Chl-*a*	Chlorophyll-a
EC	Electrical Conductivity
EISC	Ecological Importance and Sensitivity Category
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved inorganic phosphorus
DMS	Dissolved major salts
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DTEC	Department of Tourism, Environment and Conservation
DWAF	Department of Water Affairs and Forestry
GGP	Gross Geographic Product
Kjel N	Kjeldahl Nitrogen
LOR	Lower Orange River
Mm^3	Million cubic metres
NCMP	National Chemical Monitoring Programme
NMMP	National Microbial Monitoring Programme
NTU	Nephelometic turbidity units
PES	Present Ecological State
REC	Recommended Ecological Category
RHP	River Health Programme
RWQO	Resource Water Quality Objective
RQS	Resource Quality Services
SA	South Africa
SAR	Sodium Adsorption ratio
Si	Silica
SPI	Specific pollution sensitivity index
TAL	Total Alkalinity
TDS	Total dissolved solids
TIN	Total inorganic nitrogen
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total suspended solids
TWQR	Target Water Quality Range
UOWMA	Upper Orange Water Management Area
WMA	Water Management Area
WMS	Water Management System

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1 INTRODUCTION

Water is one of the most important natural resources for human and ecosystem needs, as well as economic development. Sustained growth in human population and economic activity in South Africa, has led to increasing demand for water. South Africa, being a largely arid country, is fast approaching the limits of its water supply. Innovative approaches are required to ensure that the social, economic and environmental needs of South Africans can be met into the future, within the constraints of available water resources.

The promulgation of the National Water Act, 1998 (Act No. 36 of 1998) (NWA 36:1998), various other acts, policies and White Papers gave new direction to water resources management and specifically management of water quality in South Africa. In terms of the NWA 36:1998, the most important management functions are protection, conservation, development, use, control, management and equitable allocation.

In order to give effect to the interrelated objectives of sustainability and equity an approach to managing water resources has been adopted by the Department of Water Affairs and Forestry (DWAF) that introduces measures to protect water resources by planning and setting objectives for the desired condition of resources, and putting measures in place to control water use to limit impacts to sustainable levels, thereby ensuring a healthy functioning aquatic ecosystem together with water that is fit for use for recognised water users. Resource water quality objectives (RWQOs) constitute planning objectives that apply to the water quality component of resource quality. RWQOs form the basis for management of the water quality of water resources and support various activities such as scenario analysis, water quality allocations and strategy development.

The RWQOs are the water quality component of the Resource Quality Objectives (RQOs), defined by the NWA 36:1998, "as clear goals relating to the quality of the relevant water resources." The integrated RDM manual (DWAF, 1999) defines RQOs as "a numerical or descriptive statement of the conditions which should be met in the receiving water resource… in order to ensure that the water resource is protected." Thus, the RWQOs outline both water user needs with respect to water quality, as well as their needs with respect to the disposal of water containing waste to the resource (a water use need). The process of determining RWQOs is consultative, but requires strong technical support" (DWAF, 2003).

RWQOs provide the basis for determining the allocatable water quality. This is defined as the maximum worsening change in any water quality attribute away from the present value that maintains it within a predetermined range reflecting the desired future state (typically defined by a RWQO/RQO).

RWQOs are descriptive or quantitative, spatial or temporal, and ultimately allows realisation of the catchment vision by giving effect to the water quality component of the gazetted (RQOs). RWQOs are typically set at a finer resolution than RQOs to provide greater detail upon which to base the management of water quality. The RWQOs form part of the strategy to attain the catchment vision, which is a collective statement from all stakeholders of their future aspirations of the relationship between the stakeholders (in particular their quality of life) and the water resources in the catchment.

RWQOs are aimed at ensuring that local priorities are appropriately balanced with broader spatial and temporal perspectives (WMA and national level). They incorporate stakeholder needs, give effect to the Resource Directed Measures (RDM) and dictate the tolerable level of impact collectively produced by upstream uses. RWQOs forms part of the mechanism to make the definition of pollution in terms of the NWA 36:1998 operational in the current context of resource directed water quality management (DWAF, 2006a). As such, this allows for different levels of impact for different water resources though aligned with catchment visions. Particular emphasis is given to effective stakeholder participation in the development of RWQOs.

The levels at which RWQOs are set demand that they are practical and cost-effective if possible. This approach recognises that water has a definable assimilative capacity for pollutants, *i.e.* water has a limited capacity to absorb, degrade and/or transform pollutants without deterioration of water quality to the extent that the fitness for use of the water body becomes impaired.

It is important to note that South Africa's water policy does not aim to, at all costs, prevent impacts to the water environment as this will not allow the country to achieve much-needed social and economic growth. However, the NWA 36:1998 states that "*In determining resource quality* objectives *a balance must be sought between the need to protect and sustain water resources on the one hand, and the need to develop and use them on the other.* Thus the key is to balance long-term protection of water resources with short- and medium-term demands for using them. The challenge is to obtain the right balance with respect to equity and sustainability.

In setting RWQOs, the Department strives to achieve a balance between protecting the water resource for the downstream users and allowing use and development of the water resource upstream of the determined RWQOs. For the downstream water users, the focus is on protecting the water quality in order to ensure a healthy functional aquatic ecosystem, while also meeting the water quality requirements of the other recognised water user groups (domestic, agricultural, industrial, and recreation) downstream of the RWQOs point. However, the selected RWQO might also restrict the type and extent of water use upstream of the point.

Water uses refer to those described in Section 21 of the NWA 36:1998 and includes uses such as the discharge of water containing waste (using some of the allocatable water quality) or taking water from a water resource (using some of the dilution capacity) (DWAF, 2006a). Pollutant loads which can be discharged to a water body, therefore, depend on the total number of polluters and on the ambient water quality.

It must also be borne in mind that in terms of DWAF policy the RQOs (and related RWQOs) will be used as the basis for the setting of waste discharge charges in each catchment. Thus, the setting of RQOs and RWQOs become central to balancing the needs of the upstream "impactors" with downstream user requirements.

The determination of RWQOs is underpinned by the principle of sustainable development – informed by the following principles (DWAF, 2006):

- The Precautionary Principle:

A risk averse and cautious approach that recognizes the limits of current knowledge about the environmental consequences of decisions or actions.

- The default rule : No 'Backsliding'

The management class is determined in relation to the present state, but at a level which represents a goal of no further degradation for water resources which are slightly to largely modified, and at least a move toward improvement for water resources which are critically modified.

In order that the water resources in the Orange River System are effectively managed into the future, sound strategies for water quality management supported by suitable RWQOs, in the WMAs are needed to appropriately address the threats and problems that currently prevail. The determination of RWQOs and their adoption will assist in meeting the water quality management priorities in the Orange River and provide a benchmark against which water quality management actions can be measured to determine if the goals of management are being achieved.

However, the RWQOs developed for this study is only preliminary because it has been developed at a desktop level, with limited or no public participation in the determination process *per se* and no detailed modelling or assessments were undertaken to cater for the cascading effects. Some public input was obtained through the Catchment Visioning process. Next iterations are necessary to refine these preliminary RWQOs. The NWA 36:1998 makes specifically provision for preliminary RQOs "*Provision is made for preliminary determinations of the class and resource quality objectives of water resources before the formal classification system is established. Once the class of a water resource and the resource quality objectives have been determined they are binding on all authorities and institutions when exercising any power or performing any duty under this Act."*

2 AIM AND OBJECTIVES

The aim of this project was to undertake a water quality assessment of the Orange River (Upper and Lower Orange Water Management areas) to:

- Determine the current status;
- Undertake a desktop assessment of the water quality of Lesotho;
- Develop a monitoring programme if necessary;
- Provide future monitoring requirements and preliminary RWQOs, and
- Provide recommendations for future planning and strategy development activities.

The overall objective of the project is to:

Create a clearer picture of the current water quality status and data requirements of the Orange River and in doing so identify the potential water quality problem areas and issues/aspects that have an impact on the overarching planning and management of the system.

The study includes seven tasks, with this report forming the deliverable for task 5 (**Figure 1**).

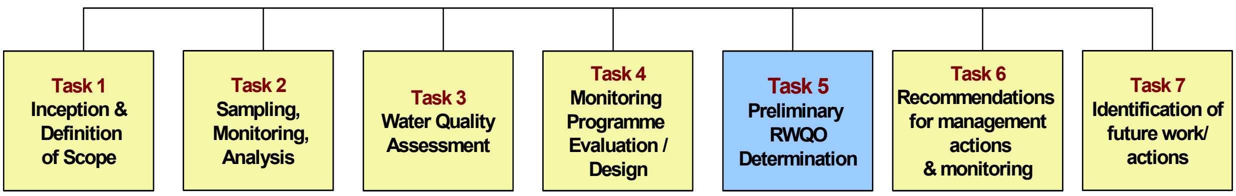

Figure 1: **Study tasks**

2.1 Preliminary RWQO determination

As part of DWAF's approach to the management of water quality, RWQOs are used. The purpose of this task as part of the study is to determine preliminary RWQOs for the Orange River (WMAs 13 and 14).

The scope of work for this task included:

- Determination of any existing RWQOs for the Orange River, and collating and assessing this information to understand what is available;

- Assessment of the appropriateness, applicability and alignment of the existing RWQOs;
- Determination and identification of gaps that exist and understanding what/where RWQOs are required (Level 1 & 2 RWQO sites);
- Determination of/understanding the upstream catchment impact/water quality;
- Setting preliminary RWQOs for the Orange River based on current information available, status quo assessment, water users, water use impacts, expert knowledge and experience from the Regional Offices and DWAF Directorates.

Task Deliverable:

- Preliminary RWQOs for the Orange River at the monitoring sites selected.

3 STUDY AREA

The study area includes the entire length of the Orange River (within South Africa's borders), *i.e*. from Oranjedraai in the east (close to the Lesotho border) to the river mouth in the west at Alexander Bay (Atlantic Ocean) – a total distance of approximately 1 900 km. Also included in the study are the main tributaries of the Orange River, including the Caledon River and some of its tributaries (see summary of sites in **Tables 2, 4 & 6** and **Figures 2, 3 & 4**). More detail on the Orange River and tributaries are provided in the water quality and status quo assessment report of the study (Report No. 3).

The river is managed by the DWAF in terms of two management areas, namely the Upper Orange Water Management area (WMA 13) and Lower Orange Water Management Area (WMA 14).

The WMAs were divided into smaller catchment visioning areas. This was done to ensure that the vision captires the diversity of interest of the stakeholders in a specific area that may not relate to the entire WMAs. The extent of the study area and due to the high level nature of the analysis to be conducted also necessitated the identification of RWQO sites within the Upper and Lower Orange WMAs that would be strategically located and sufficiently widespread to provide effective management of the river that would cater for the interest of all users.

3.1 Upper Orange Water Management Area (UOWMA 13):

The UOWMA was divided into three sub-catchments (visioning areas) for the purpose to formulate the visions during the visioning process (DWAF, 2009a). The three visioning areas are:

Area 1: Orange River from Lesotho border to Gariep Dam, including the Kraai River, Sterkspruit (Herschell) and Stormbergespruit and consist of tertiary catchments D12, D13, D14, D15 and D35.

Area 2: Orange River from Gariep Dam to Marksdrift Weir, including the Seekoei River. The tertiary catchments are D31, D32, D33 and D34.

Area 3: Caledon River and its tributaries, consisting of tertiary catchments D21, D22, D23 and D24.

The Upper Orange River includes 8 RWQO sites (including the two major impoundments) on the main stem (level 1) and 5 sites on the major tributaries (level 2) – See **Figure 2** and **Table 2**.

The Caledon River includes 5 RWQO sites on the main stem (level 1) and 6 sites from tributaries (level 2) (**Table 4**).

3.1.1 RWQO – Sites

3.1.1.1 Upper Orange WMA – Orange River and tributaries

The Level 1 and 2 RWQO sites for the Upper Orange WMA were proposed and discussed during a meeting with DWAF Free State Regional Office, Bloemfontein on the 17 January 2008 – see minutes in **Appendix B**. The following RWQO sites were proposed (**Table 1**):

Table 1: **Proposed** RWQO sites on Orange River and tributaries in Upper Orange management area – WMA 13.

Site	Description/motivation
OS1 Orange River before confluence with Kornetspruit	Orange River just before confluence with Kornetspruit. Good quality water from Lesotho. However, the final location of OS1 (Oranjedraai) was about 4 km downstream of the confluence with Kornetspruit because the Orange River before the confluence is inside Lesotho. Oranjedraai is also a DWAF flow gauging station.
OSL2/1 Kornetspruit	Decision was made to include a level 2 RWQO site on the Kornetspruit as it brings good quality water from Lesotho. The flow gauging station (D1H006) is at the South African-Lesotho border at Maghaleen.
OSL2/2 Sterkspruit	Decision taken to include as a level 2 RWQO site due to farming, communities and sewage impacts in the catchment. An appropriate site was identified within the town of Sterkspruit.
OS20	Orange River between Sterkspruit and Kraai confluences. Impacts of Sterkspruit and good quality water from Kornetspruit. This site was finally rejected because this site was combined with OS3 – proposed new site.
OSL2/3 Kraai River	Good quality water with little impacts. One level 2 site just before confluence with Orange River. A second level 2 RWQO site in the vicinity of Barkley East might be considered in the future.
OS2 Orange at Aliwal North	Aliwal North sewage works discharges into river and the location of this RWQO site should be below the STW.
OSL2/4 Stormberge	Relatively drier than the other upstream tributaries. Only small tanneries and stock farming in the upstream catchment, thus good quality water.
OS3 Orange River	Orange River upstream Caledon confluence. This RWQO site should be close to Gariep Dam. This is a proposed new site. The final site identified was on the farm Saamwerk, just downstream of the confluence of Stormbergspruit with the Orange River.

OS4 Orange River	Orange River downstream of Gariep Dam. Agreed to keep this site. The site was identified as Roodepoort (D3H013), a gauging station.
OSL2/5 Seekoei River	Quite dry but a rather large catchment. Regular sampling is done. The Seekoei River confluence with the Orange River is close to Vanderkloof Dam. The site is at a gauging weir at De Eerste Poort (D3H015).
OS5 Orange River	Orange River downstream Vanderkloof Dam. Agreed to keep this site. The gauging weir and monitoring station (D3H012) is known as Dooren Kuilen approximately 700 m downstream of the dam wall.
OS6 Orange River at Marksdrift	Orange River at Marksdrift. Some irrigation between OS5 and OS6. Agreed to keep this site, but responsibility of Kimberley Office. This site represents runoff from the Orange River catchment upstream of the Vaal River confluence. This is also included in the SA-Gems monitoring network. SA Hydro site ID No.: D3H008Q01.

The Gariep Dam and Vanderkloof Dam were not initially included as part of the RWQO sites, however, it was decided to include the dams as they are strategic points in the system and are important from a regulation and system management point of view. In addition to their importance good historical data exists for these sites and they include very important algal data (Chlorophyll-*a* concentrations and algal composition) not available for the river sites. Vanderkloof Dam is the first site with metal concentrations. Gariep Dam was also proposed for inclusion in SA-Gems/Water monitoring network (Van Niekerk, 2005). In addition, the said two impondments also serve as receiving water bodies for extensive up-stream parts of the Orange River, from where water is transferred to other catchments and/or used by various water user sectors.

In fact the water reaching the lower reaches of the Orange River is controlled to a large extent by releases from Vanderkloof Dam, supported by water released from Gariep Dam. Thus, these dams play a major role in the storage and regulation of irrigation water for downstream use in the Orange River.

The final RWQO sites on Orange River and tributaries in Upper Orange management area (WMA 13) are indicated in **Table 2,** also indicating the Present Ecological State (PES), the Recommended Ecological Category (REC) and Ecological Importance and Sensitivity Category (EISC). Information obtained from the RWQO Model 4.1 (DWAF, 2006b). See **Tables 14** and **15** for an explanation of the different categories.

Table 2: Summary of the final RWQO sites on Orange River and tributaries in Upper Orange Water Management Area – WMA 13. Also indicated are the PES, Present Ecological State; REC, Recommended Ecological Category; EISC, Ecological Importance and Sensitivity Category.

Site Code	Hydro ID	Location	Co-ordinates	Qua-ternary	PES	REC	EISC
Main stem – level 1							
OS1	D1H009 (101793)	Orange River (OR) at **Oranjedraai**	S30.33772 E27.36277	D12A	B	B	High
OS2	D1H003 (101789)	Orange River at **Aliwal North**	S30.68612 E26.70600	D14A	C	B	Moderate
OS3	New site	Orange River at **Saamwerk**	S30.57622 E26.45638	D14J	D	C	High
OSD1	D3R002 (101834)	**Gariep Dam**	S30.60794 E25.50465	D35K	E/F	E or F	Low/ marginal
OS4	D3H013	Orange River at **Roodepoort**	S30.58487 E25.42084	D34A	D	B	Moderate
OSD2	D3R003	**Vanderkloof Dam**	S29.99447 E24.73524	D31E	E/F	E or F	Low/ marginal
OS5	D3H012	Orange River at **Dooren Kuilen**	S29.99141 E24.72414	D33A	D	B	High
OS6	D3H008 (101824)	Orange River **at Marksdrift**	S29.16201 E23.69447	D33K	D	B	High
Tributaries – level 2							
OSL2/1	D1H006	**Kornetspruit** at Maghaleen	S30.16003; E27.40145	D15H	C	B	High
OSL2/2	New site	**Sterkspruit** (at R382 crossing)	S30.52694; E27.37484	D12C	-	-	-
OSL2/3	D1H011 (101795)	**Kraai River** at Roodewal	S30.73707; E26.78440	D13M	C	B	High
OSL2/4	D1H001	**Stormbergspruit** at Burgersdorp	S31.00109; E26.35314	D14F	D	B	Moderate
OSL2/5	D3H015	**Seekoei River** at De Eerste Poort	S30.53480; E24.96250	D32K	D	C	Moderate

3.1.1.2 Upper Orange WMA – Caledon River and tributaries

It was agreed at the meeting with the DWAF Free State Regional Office to change the Caledon River main stem to level 1 and the major tributaries of the Caledon River to level 2 Proposed RWQO sites identified are indicated in **Table 3** and the final sites selected are indicated in **Table 4**. (see **Appendix B**).

Table 3: Proposed RWQO sites on Orange River and tributaries in Upper Orange management area – WMA 13.

Site	Description/motivation
CSL2/1 Little Calendon River at Golden Gate	Little Calendon River at Golden Gate. Site to be situated just downstream of Golden Gate. This site is considered to be largely natural.
CSL2/2 Little Caledon at Oorlogspoort	***CSL2/2*** Little Caledon at Oorlogspoort. Move site further upstream due to possible backwater from main Caledon River. The site finally used was at the gauging station (D2H012 at the Poplars) at the border post with Lesotho.
CS1 Caledon River at Little Caledon confluence	Caledon River at Little Caledon confluence. This site will provide information as to impacts upstream of the confluence from both Lesotho and SA. This is a proposed new site – thus historical data.
CSL2/3 Groot River	Groot River. RWQO site to be included for the snap shot monitoring. If impacts are significant, this will stay as a level 2 RWQO site.
CS2 Caledon at Ficksburg	Caledon at Ficksburg. RWQO site should be situated after the sewage treatment works. Lesotho's industrial impacts to Caledon (material dying).
CSL2/4 Meulspruit	A number of farm dams for irrigation purposes in the upstream catchment. Sediment problems in the catchment. Meulspruit Dam results in river largely being dry. RWQO site to be situated upstream of the dam, perhaps at the Roosendal road bridge.
CSL2/5 Moperi River	Some irrigation in the catchment. Sediment might be a problem. Snap shot monitoring to determine if a RWQO site is really necessary.
CS3 Caledon River at Maseru	This RWQO site should be situated after Maseru to monitor the impacts. A RWQO site should also be considered at Ladybrand. Snap shot monitoring to determine if a second RWQO site is needed.
CSL2/6 Leeuspruit at Hobhouse	A number of large dams (Armenia, Newberry, Lovedale) for irrigation are situated in the upstream catchment. Possible location of RWQO site is at the Hophouse Road bridge.
CS4 Caledon River at Welbedacht Dam	General water quality dam is good, although sediment a huge problem, hence move RWQO site above dam to Tienfontein pump station (abstraction point to Knellpoort Dam). This is a new site and the accessibility is poor because of steep slopes.
CS5 Caledon upstream of Gariep Dam	Agreed to keep this RWQO site. The suitable site was selected at Kommissiedrift (D2H036) at the N6 road crossing.

Table 4: Summary of the final RWQO sites on Caledon River and tributaries in Upper Orange management area – WMA 13 (See Figures 2 & 4). Also indicated are the PES, Present Ecological State; REC, Recommended Ecological Category; EISC, Ecological Importance and Sensitivity Category.

Site Code	Hydro ID	Location	Co-ordinates	Qua-ternary	PES	REC	EISC
CS1	New site	**Caledon River** at **confluence** (with Little Caledon)	S28.69363; E28.23445	D21H	D	C	High
CS2	D2H035	**Caledon River** at **Ficksburg**	S28.90409; E27.83084	D22D	C	B	High
CS3	New site (Old D2H011)	**Caledon** at **Maseru (**Lesotho)	S29.38042; E27.41203	D23A	D	C	Moderate
CS4	New Site (Old D2H001)	**Caledon River** at **Tienfontein** pump station	S29.78357; E26.90998	D23J	C	B	Moderate
CS5	D2H036	Caledon River at **Kommissiedrift** at N6 crossing	S30.27994; E26.65427	D24J	D	C	Moderate
			Tributaries – level 2				
CSL2/1	New site	**Little Caledon River** at Golden Gate	S28.49980; E28.58196	D21E	C	B	High
CSL2/2	D2H012	**Little Caledon River** at The Poplars (confluence)	S28.69477; E28.23486	D21G	D	C	High
CSL2/3	New site	**Grootspruit** at R26 road bridge	S28.68026; E28.13996	D21H	-	-	-
CSL2/4	New site	**Meulspruit** at Ficksburg	S28.83528; E27.83340	D22D	-	-	-
CSL2/5	New site	**Moperispruit** at Clocolan	S28.96011; E27.56664	D22G	D	C	High
CSL2/6	New site	**Leeu River** at Hobhouse	S29.52155; E27.13577	D23E	-	-	-

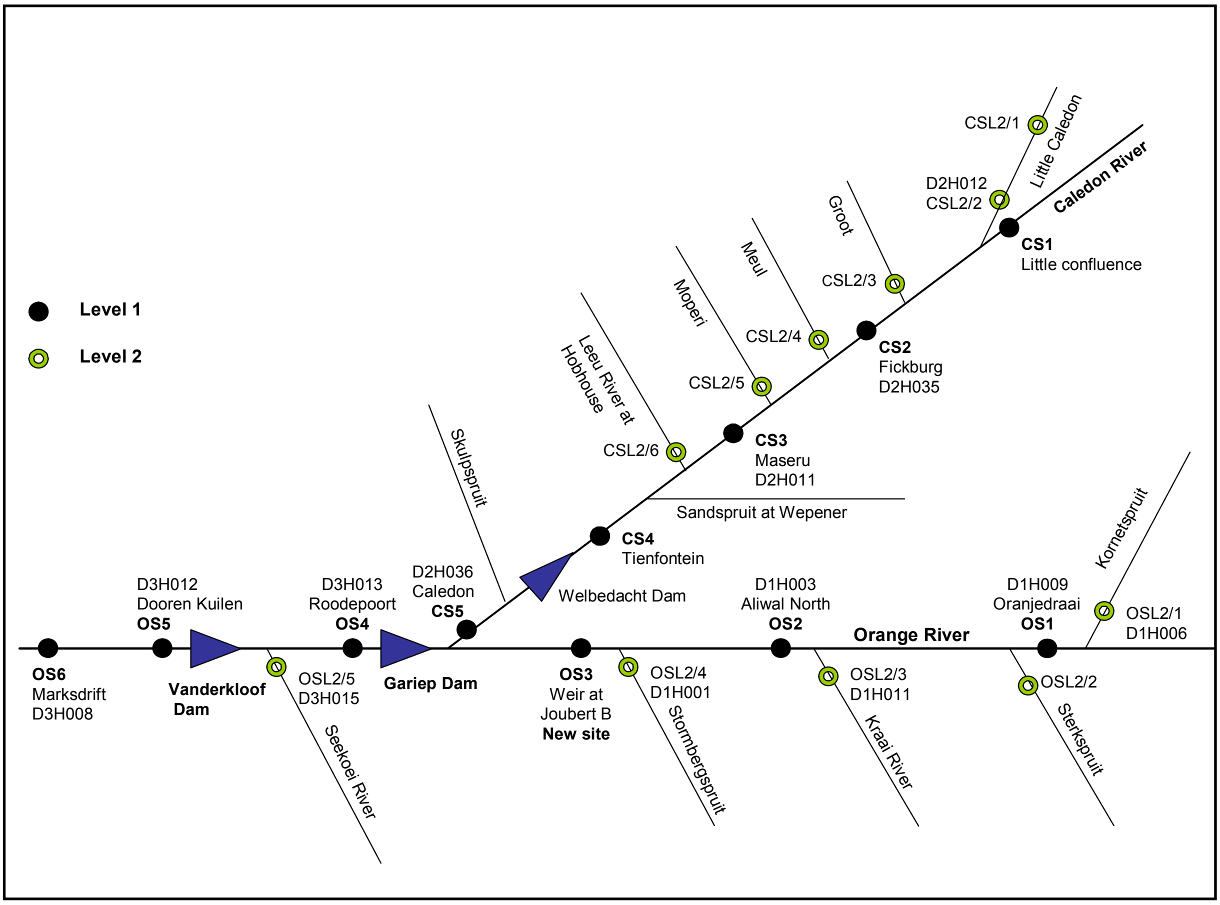

Figure 2: Line diagram of the Upper Orange WMA – RWQO sites (level 1 and 2).

3.2 Lower Orange Water Management Area (WMA 14):

The Lower Orange WMA (LOWMA) stretches from Douglas (Orange-Vaal Rivers' confluence) to Alexander Bay, a distance of approximately 1 200 km.

The LOWMA was divided into four visioning areas (DWAF, 2009b):

Area 1: Douglas (just upstream of the confluence of the Orange with the Vaal River) to Boegoeberg Dam.

Area 2: From Boegoeberg Dam to Kanoneiland.

Area 3: Kanoneiland to Pella.

Area 4: From Pella to Alexander Bay.

Fifteen potential RWQO sites were identified during a meeting that was held with DWAF regional Office, Upington, on 20 November 2006 and the following RWQO sites were proposed (**Table 5**). See **Appendix A**.

Table 5: Potential RWQO sites on Orange River and tributaries in Lower Orange management area – WMA 13.

Site	Description/motivation
OS6 – Marksdrift	This is an important and suitable point because it is located just before the confluence of the Vaal and Upper Orange Rivers. Use existing D3H008Q01 monitoring station.
OS7 – Irene	B Conradie mentioned that there are currently no observers and that the site is used as a flood section only. She suggested that the site be moved closer to the confluence of the Vaal and Upper Orange Rivers and that farmers (W Bruwer) nearby be requested to take the samples. Other sites, such as Katlani were considered, but the accessibility to the river here is poor. Finally, a site (approximately 21 km downstream of Orange Vaal confluence) on the farm De Hoek was identified as an alternative site.
OS8 – Prieska	There is a reliable observer for this site. There is currently no data at this site (D7H002Q01). The impact from the Ongers River (irrigation) will also be included at this site.
0S9 Boegoeberg	The point was accepted, but it was suggested that it should be moved to Boegoeberg Dam (D7H008). This will include the impacts of the irrigation upstream of the dam.

New site: Gifkloof	B Conradie suggested a site between OS9 and OS10 because of the impacts from irrigation (algae). This site is about 17 km upstream of Upington and the accessibility to the river is poor.
OS10 – Upington	This point was accepted, but should be moved to the intake at Upington Water Works. This point will include objectives for Upington domestic supply, international obligations (Nakop border post) and Kalahari West pipeline for domestic and stock watering purposes.
New site: Islands	A new site should be added between OS10 and OS11 to monitor the impacts of the irrigation on the Islands. Blue-green algae have been observed. Finally, Kanon Island (D7H004) was selected as a potential RWQO site.
OS11 – Neusberg	The point was accepted, data from D7H014Q01 monitoring site will be used. The site includes abstractions for domestic, irrigation and industrial use at Kakamas (wine cellars and raisin companies).
OS12 –	This point was taken out due to little impact from the Hartbees River (irregular flow).
OS13 – Blouputs	The point was accepted but it should move closer to the confluence of the Molopo River to include the impacts from irrigation at Blouputs. This is the last site before the Namibian Border. Continuous monitoring was recommended by the PPECB (Perishable Products Export Control Board) and water quality monitoring in terms of their requirements are conducted. Data to be obtained from them. D8H004Q01 can be used to set the RWQOs, but should be revised with the new data.
OS14 – Pella	This point was accepted due to the water supplied for domestic, stock watering and mining purposes by the Pella Drift Water Board. Water is supplied to Pella, Pofadder, Agenys and mines (Black Mountain mine which mines coal and sink). Data from D8H008Q01 to be used for the determination of RWQOs.
OS15 – Vioolsdrift	The point was accepted, data from D8H003Q01 to be used to determine RWQOs. Abstractions at Henkries for water supply to Springbok and Kleinzee. All impacts from Pella to Vioolsdrift, including Goodhouse are taken into consideration. International obligations (Namibia) and recreational use in the downstream Ai/Ai-Richtersveld Transfrontier Park should be included in the RWQOs. The point is also located downstream of the proposed dam.
OS16 – Sendelingsdrift	The point was accepted as it is downstream of the Ai/Ai-Richtersveld Transfrontier Park and upstream of the Fish River (Namibia) confluence. A new monitoring point is needed and officials from the Park can be requested to be the observers.

New site: Rosh Pinah	There was a proposal for another RWQO site between OS16 and OS17, downstream of the Fish River confluence. This will cater for the impacts from the Fish River (irrigation) and Rosh Pinah (mining). The data from the existing monitoring site D8H007Q01 should be used for the RWQOs. Continuous monitoring should be considered if problems are experienced with observers. Finally, Brand Kaross (D8H007) was selected as a possible RWQO site.
OS17 – Alexander Bay	This point was accepted because it is located just upstream of the estuary (RAMSAR site). Use D8H012Q01 to determine RWQOs. Water use includes international use (NAMDEB mining) and domestic water supply to Alexander Bay and Port Nolloth. Borehole abstraction in the river is also used for domestic purposes.

Finally, 13 RWQO sites on the lower Orange River, *i.e.* from OS7 at De Hoek (Irene) to OS19 at Alexander Bay, and 1 site on the Vaal River (VS21) at Douglas (new site) were selected and are shown in **Figure 3** and indicated in **Table 6**.

Note the numbering of the sites have changed from the initial proposed sites to the final sites, depending on the sites that was finally accepted for monitoring.

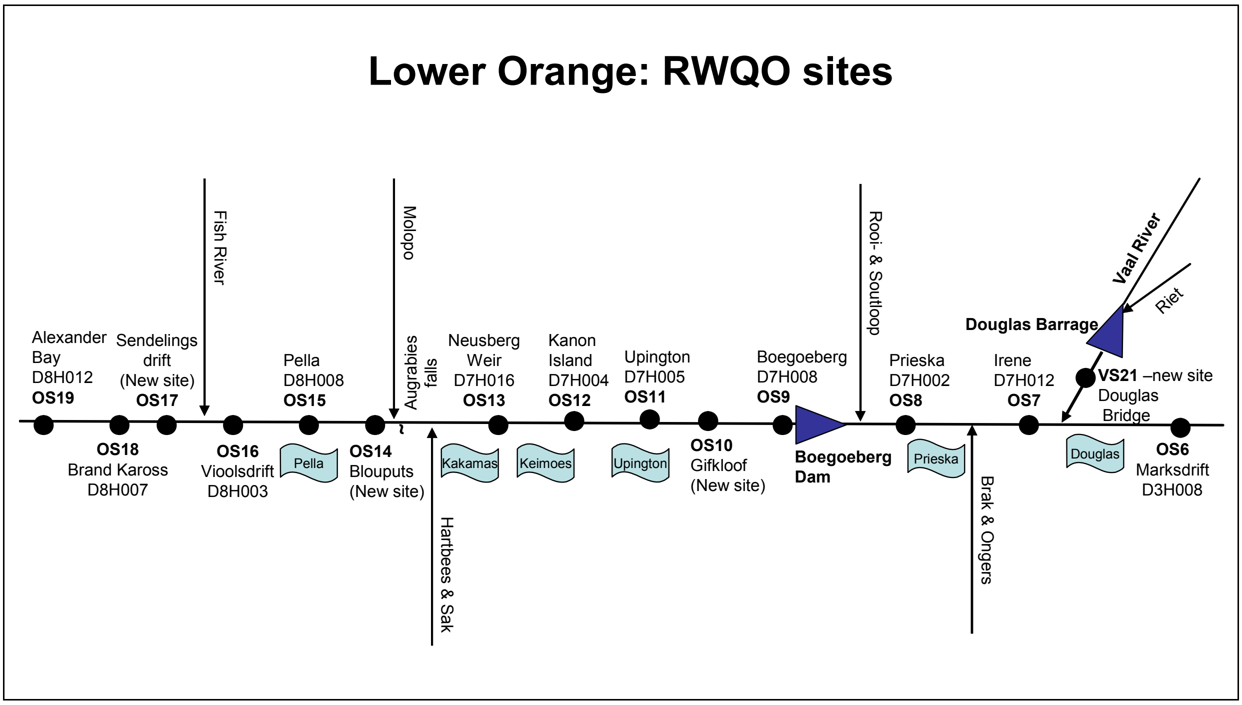

Figure 3: Line diagram of the Lower Orange WMA – RWQO monitoring sites (Level 1).

Table 6: Summary of the RWQO sites selected on Orange River and tributaries in Lower Orange Water Management Area – WMA 14 (See also Figures 3 & 4). Also included are the PES, Present Ecological State; REC, Recommended Ecological Category; EISC, Ecological Importance and Sensitivity Category.

Site Code	Hydro ID	Location	GPS co-ordinates	Qua-ternary	PES	REC	EISC
OS7	New site	Orange River (OR) at **De Hoek.** (Old site, Irene, D7H012)	S29.21069; E23.51447	D71A	C	B	Moderate
OS08	D7H002 (101874)	Orange River (OR) at **Prieska**	S29.65700; E22.74415	D72A	C	B	Moderate
OS09	D7H008 (101878)	Orange River (OR) at **Boegoe-berg** weir	S29.02625; E22.18608	D73B	C	B	High
OS10	New site	Orange River (OR) at Gifkloof	S28.43884; E21.404153	D73E	C	B	Moderate
OS11	D7H005 (101877)	Orange River (OR) at **Upington Water Works**	S28.45259; E21.25994	D73E	C	B	Moderate
OS12	D7H004 (101876)	Orange River (OR) at **Kanon Island**	S28.63543; E21.09020	D73F	C	B	Moderate
OS13	D7H016 (101885)	Orange River (OR) at **Neusberg** weir (north canal)	S28.77481; E20.74558	D73F	C	B	Moderate
OS14	New site	Orange River (OR) at **Blouputs**	S28.51409; E20.18518	D81B	C	B	High
OS15	D8H008 (101893)	Orange River (OR) at **Pella** Mission	S28.96443; E19.15276	D81F	B	B	High
OS16	D8H003 (101888)	Orange River (OR) at **Vioolsdrift**	S28.76208; E17.72631	D82F	B	B	High
OS17	New site	Orange River (OR) at **Sendelingsdrift**	S28.12288; E16.89032	D82K	C	B	High
OS18	D8H007	Orange River (OR) at Korridor/Brand Kaross	S28.48570; E16.69444	D82K	C	B	High
OS19	D8H012 (101894)	Orange River (OR) at **Alexander Bay**	S28.56689; E16.50728	D82L	C	B	Low/ marginal
VS21	New site	**Vaal River** at Douglas bridge	S29.04885; E23.76822	C92B	D	C	High

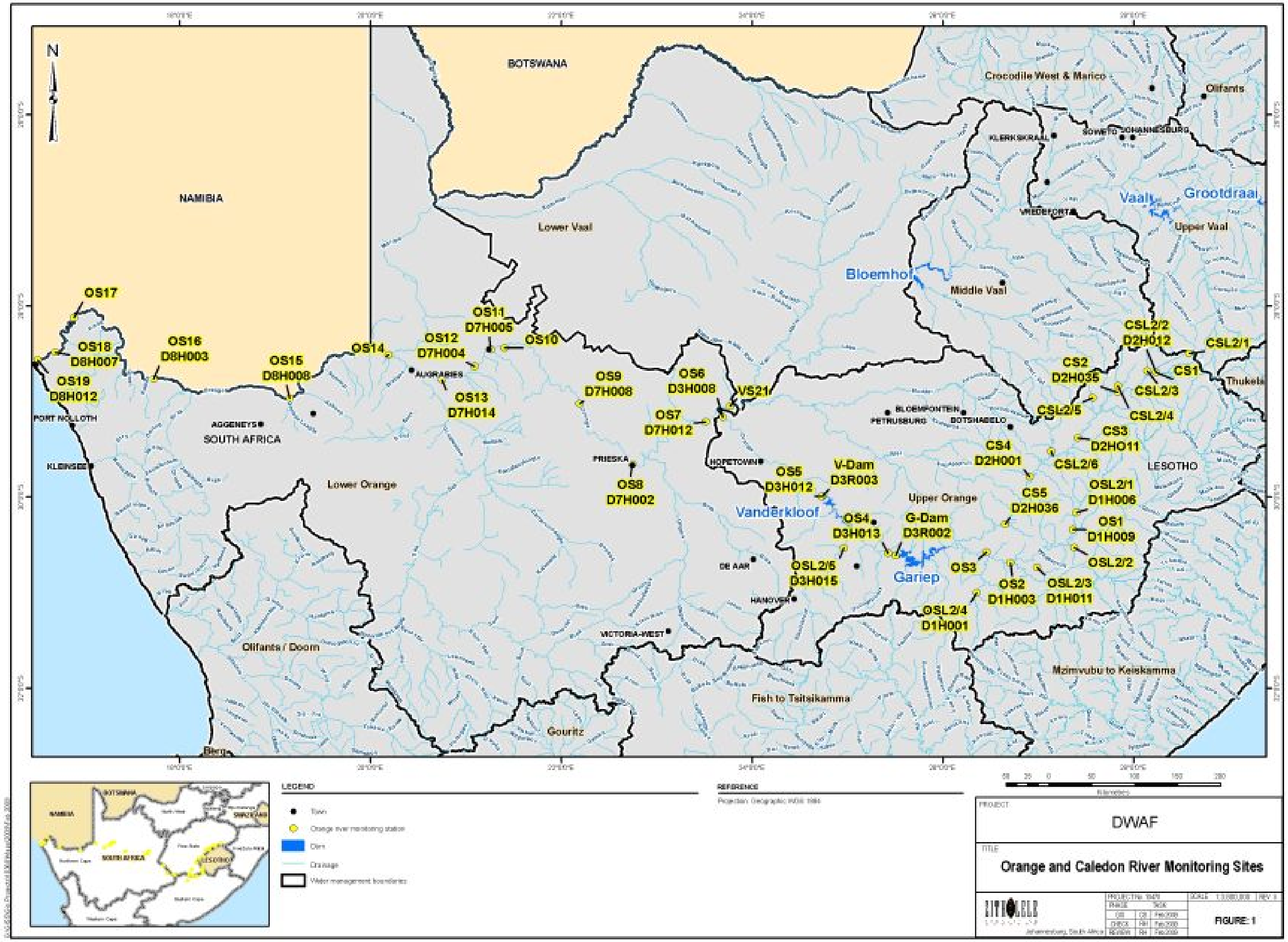

Figure 4: RWQO sites in the Upper and Lower Orange Water Management Areas (WMA 13 & 14).

4 METHODS

The methodology used for the determination of the RWQOs is that set out in DWAF (2006a, 2006b, 2008a) and Hughes (2005). Finally, the RWQOs Model (WQP 1.7.2.1) (DWAF, 2006b) was used to determine the RWQOs and the corresponding allocatable water quality for the resource management unit.

4.1 Background

The water quality assessment is undertaken and RWQOs are established to ensure the suitability (fitness for use) of the water for intended uses. An abundant supply of clean, usable water is a basic requirement for many of the fundamental uses of water on which humans depend. These include, but are not limited to:

- water used for human consumption and public water supply;
- water used in agriculture and aquaculture;
- water used in industry;
- water used for recreation; and for electrical power generation.

In the Orange River the major water user is agriculture (principally irrigation) with on average about 88 %, followed by domestic use 11.4 % (urban 7.6 % and rural 3.8 %), while industry, mining and hydroelectric use the remainder 0.6 % (**Figure 5**).

A well-developed agricultural industry is essential to provide food for the population, raw materials for industry, and to earn needed foreign exchange by exporting surplus production. The pressure on the water supply from dry-land crop production, as well as stock and game farming, is insignificant compared with the demand for irrigation water. The irrigation industry is the biggest single water user in the Orange River.

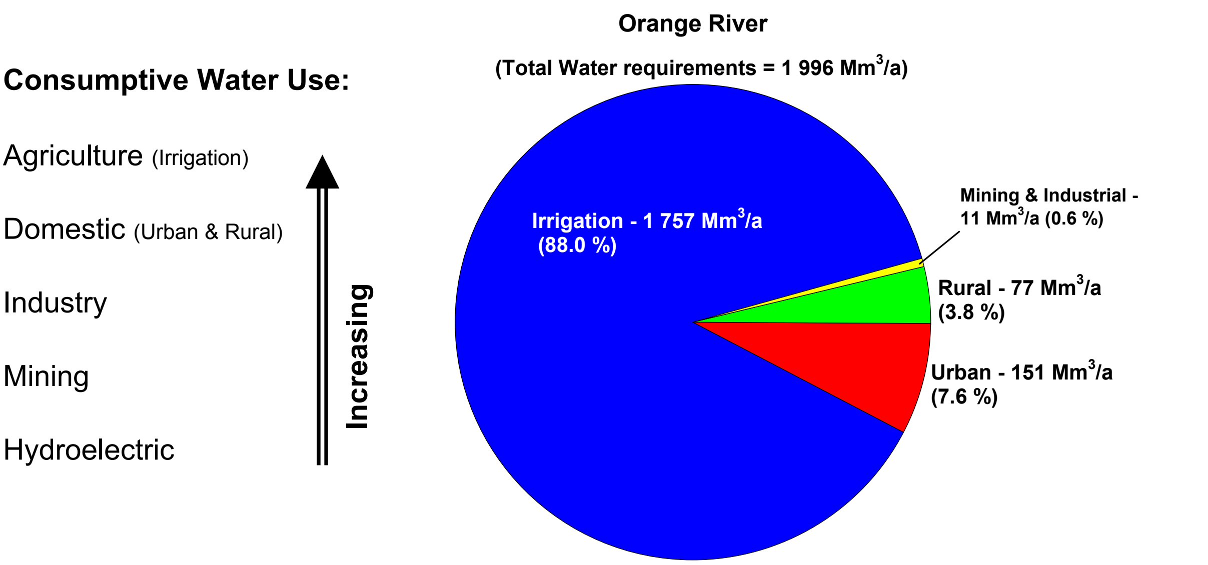

Figure 5: Pie chart of the average water requirements (for the year 2000) from the Upper and Lower Orange River (Modified from DEAT, 2006)

Figure 6: Satellite image (Google Earth) of irrigation fields along the Orange River close to Aliwal North – Upper Orange.

Figure 7: Satellite image (Google Earth) of irrigation fields (pivots) along the Orange River close to Prieska – Lower Orange.

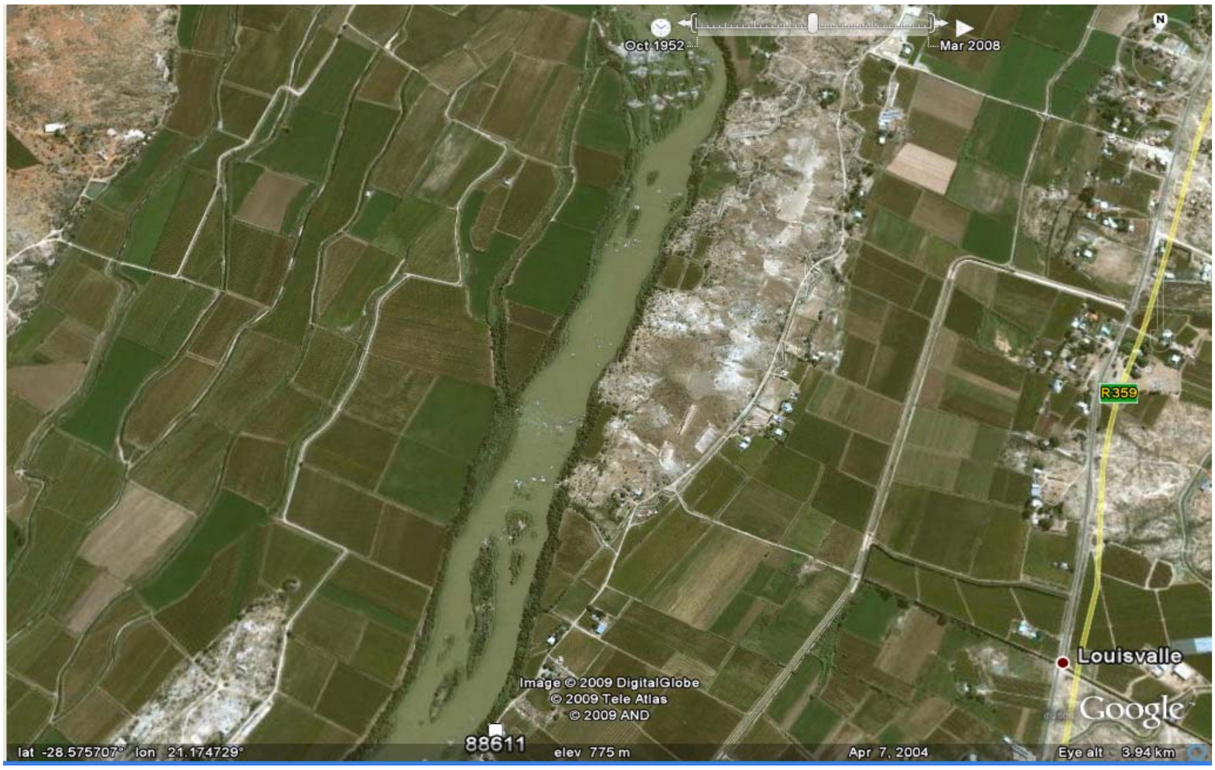

Figure 8: Satellite image (Google Earth) of irrigation fields along the Orange River at Louisvale, close to Upington – Lower Orange.

4.2 Determination of RWQOs

Multiple use of river water may occur within any region of the river basin. Each user sector has different water quality requirements and user conflicts may occur. The desired water user's category (Ideal, Acceptable, Tolerable) can be described in terms of quantitative and descriptive information goals, and the information provided in the form of water user category specifications, *i.e.* domestic, recreational, industrial, irrigation, livestock watering, aquaculture and aquatic ecosystems. Ideally, water quality should meet the most stringent use requirement which, in most cases, is the provision of good quality domestic water. There is always a responsibility for upstream uses to ensure adequate water quality for the needs of downstream users.

No RWQOs are currently available for the Orange River (Upper and Lower), thus the needs of the water users and other stakeholders with respect to the in-stream water quality of the water resources in their catchments', and their needs with respect to the disposal of water that contains waste to the resource have not been accounted for.

The determination of RWQOs will shape the goals for water quality management in the various catchments, and are among the key determinants of the future Catchment Management Strategy development processes. As a wide range of substances can impact on the quality of water, the RWQO determination has generally focussed on the priority water quality concerns in the respective catchments.

These water user category RWQOs that were determined in this process are primarily based on the DWAF South African Water Quality Guidelines (DWAF, 1996) – see **Tables 7 to 10** (through application of the RWQOs Model 4.1 of DWAF), and were guided by the catchment visions of the WMAs that describe the level of protection required by the water users and stakeholders in the area.

4.2.1 Catchment Visions for the Upper and Lower Orange River

The catchment vision reports for the Upper and Lower Orange River has identified many of the current and future water user requirements and the desired state of the catchment through agreement with key stakeholders (DWAF, 2009a; 2009b). Major water user requirements include irrigation (mainly maize, wheat and lucern in upper Orange and mainly grapes in lower Orange), stock farming (mainly cattle sheep and goat farming) and supplying domestic water to towns and rural communities.

In these reports great emphasis is placed on water quality, *i.e.* “to ensure that water supplies are of an acceptable quality to all water users.” In the Lower Orange area, producers of table grapes, dried fruit and wine grapes need to give proof of compliance with the SANS:241 requirements to the Perishable Products Export Control Board (PPECB).

An important component of the Visions stated for the Upper and Lower Orange Water Management areas, is the maintenance of good quality water. The stakeholders strongly agree to maintain overall present status and strongly disagree to allow deterioration of selected water resources in the short-term (DWAF, 2008b, 2009). However, anthropogenic impacts on chemistry may not always lead to a deterioration of the aquatic system, e.g. a tenfold increase in K^+ or Cl^- from 2 to 20 mg/ℓ has no biotic impact and does not limit water use (Meybeck, 2005), which allow for an allocatable value.

4.2.2 Determination process

The RWQOs are determined through the integration of the ecological and water user requirements, with the most stringent water quality or most sensitive water user, defining the RWQOs within the desired category or management class. The water use must be beneficial, in the public interest and promote the values in Section 3(2) of the NWA 36:1998 (DWAF, 2006).

The procedure for the medium confidence determination of RWQOs was followed for most RWQO sites, except for those that only snapshot data was available for causing the level of confidence to be limited to low. The medium confidence method is a determination that is undertaken when there are sufficient water quality data available for the resource unit to assess the present water quality status (DWAF, 2006). Most of the historical data sets at the monitoring sites on the Orange Rivers do have enough data for a medium confidence method. A minimum of 25 samples collected over a 3 year period (2005 – 2007) were used to calculate the relevant percentile concentrations to determine the present status (Hughes, 2005).

Water quality information is available for the most of the monitoring sites along the Orange River but limited on the Caledon River and tributaries. The parameters usually being measured (about 20) are Dissolved major salts (DMS) or Total Dissolved Solids (TDS), Electrical conductivity (EC), sulphates (SO_4), fluorides (F), Chlorides (Cl), total alkalinity (TAL), Total Hardness, sodium (Na), Potassium (K), magnesium (Mg), calcium (Ca), ammonia (NH_3-N), ammonium (NH_4-N), nitrate and nitrite (NO_3 + NO_2-N), phosphate (PO_4-P), Total suspended solids (TSS) and turbidity.

The DIN concentration (NO_3-N + NO_2-N + NH_4-N) used in this report is the same as the TIN (Total inorganic Nitrogen) used in the RWQO Model's Report. The ionic components of the salts were used as well as the inorganic salts, calculated with the TEACHA model, for selected sites on the Orange River.

Tables 17, 32, 43, 51 and **61** presents a summary of the present water quality state in the whole study area, mainly for the last 3 years (2005 to 2007) and snapshot data. The present state values represent the 95th percentile for salts and metals, 50th percentile for nutrients (N & P) concentrations, and the mean for chlorophyll-*a*. The 5th percentile of pH data represents the lower limit and the 95th percentile the upper limit.

The reference conditions for this study were calculated from the percentile concentrations during the first few years of monitoring at the specific site, usually 1976 – 1978. The time period and number of samples are indicated in the Tables that give background on the site. The reference condition describes the condition of the river reach prior to anthropogenic change. Historical information and data, and/or data from reference sites (minimally impacted sites) are used to describe the reference conditions for water quality. Due to data limitations the reference condition may not represent an actual natural river state, but rather the best estimate of a minimally impaired baseline state.

The present/current state concentrations were then used as the input values in the RWQO Model 4.1 to calculate the RWQOs for a specific site. The water users selected includes either the Ecological Reserve Category or Ecological WQ guidelines and then usually Basic human needs, Domestic use, Agriculture – Stock watering, Agriculture – Irrigation, (occasionally Agriculture-aquaculture), Industrial category 3 & 4, Recreational – full contact and intermediate contact.

The specific water users in the catchment were identified for the applicable reach in the Orange River. The present/current state condition is the measured, current water quality for an RWQO site and in many cases provides the point of departure for the development of any management objective.

The fitness for use or level of protection are usually categorised as follows:

- Ideal (Target Water Quality Range, TWQR)
- Acceptable
- Tolerable
- Unacceptable

At present the DWAF Water Quality Guidelines (DWAF, 1996) only reflect the Target Water Quality Range (TWQR), which may be considered as Ideal water quality. The Water Quality Guidelines have been used as a basis for establishing generic water quality limits for each of the water user categories (**Tables 7, 8, 9, and 10**). The proposed level of protection for the Upper and lower Orange WMAs based on the most stringent water user aligned to the catchment vision are shown in **Tables 11, 12**, and **13**.

Table 7: Generic water quality limits for Domestic Use (Modified from DWAF, 1996; 2006, 2008).

Variable	Units	Domestic use				BHN
		Ideal	A#	T#	U#	Ideal
Algae (Chl-a)	µg/ℓ	≤ 1	10	15	>15	–
Aluminum (Al)	mg/ℓ	≤ 0.15	0.5	>0.5	>0.5	–
Ammonia (NH_3-N)	mg/ℓ	1.0	2.0	10.0	>10.0	–
Arsenic (As)	µg/ℓ	≤ 10	50	200	>200	–
Cadmium (Cd)*	µg/ℓ	≤ 3	10	20	>20	–
Calcium (Ca)	mg/ℓ	≤ 32	150	300	>300	80
Chloride (Cl)	mg/ℓ	≤ 100	200	600	>600	200
Chromium (VI)	mg/ℓ	≤ 0.05	1.0	5.0	>5.0	–
Copper (Cu)*	mg/ℓ	≤ 1.0	1.3	2.0	>2.0	–
EC	mS/m	≤ 70	150	370	>370	–
Faecal coliforms	cfu/100 mℓ	0	1	10	>10	–
Fluoride (F)	mg/ℓ	≤ 0.7	1.0	1.5	>1.5	–
Hardness – Total	mg $CaCO_3$/ℓ	≤ 200	300	600	>600	–
Iron (Fe)	mg/ℓ	≤ 0.5	1.0	5.0	>5.0	–
Lead (Pb)*	µg/ℓ	≤ 10	50	100	>100	–
Magnesium (Mg)	mg/ℓ	≤ 70	100	200	>200	100
Manganese (Mn)	mg/ℓ	≤ 0.1	0.4	4.0	>4.0	–
Mercury (Hg)	µg/ℓ	≤ 1.0	5.0	20.0	>20	–
Nitrate + Nitrite (NO_3- & NO_2-N)	mg/ℓ	≤ 6.0	10.0	20.0	>20	–
pH (lower)	Units	5.0	4.5	4.0	< 4.0	5
pH (upper)	Units	9.5	10.0	10.5	> 10.5	9.5
Potassium (K)	mg/ℓ	25	50	100	>100	150
Selenium (Se)	µg/ℓ	≤ 20	50	100	>100	–
Sodium (Na)	mg/ℓ	≤ 100	200	400	>400	200
Sulphate (SO_4)	mg/ℓ	≤ 200	400	600	>600	400
TDS	mg/ℓ	≤ 450	1 000	2 400	>2 400	1 000
Total coliforms	cfu/100 mℓ	0	10	100	>100	–
Vanadium (V)	mg/ℓ	≤ 0.1	0.5	1.0	>1.0	–
Zinc (Zn)	mg/ℓ	≤ 3	5	10	>10	–

A# Acceptable; T# Tolerable; U# Unacceptable; BHN, Basic Human Needs; EC, Electrical conductivity; * moderately hard water; – no value.

Table 8: Generic water quality limits for Aquatic ecosystem and Agricultural Use – Aquaculture (Modified from DWAF 1996, 2006 & 2008).

Variable	Units	Aquatic ecosystem			Aquaculture		
		Ideal	A#	T#	Ideal	A#	T#
Algae (Chl-a)	µg/ℓ	≤ 10	20	30	–	–	–
Alkalinity	mg $CaCO_3$/ℓ	–	–	–	≤ 20	97.5	175
Aluminum (Al)	µg/ℓ	≤ 20	85	150	≤ 30	70	100
Ammonia (NH_3-N)	µg/ℓ	≤ 15	58	100	≤ 30	300	1 000
Arsenic (As)	µg/ℓ	≤ 20	75	130	≤ 50	–	–
Cadmium (Cd)*	µg/ℓ	≤ 0.2	1.3	2.8	≤ 0.8*	–	–
Chloride (Cl)	mg/ℓ	–	–	–	≤ 2.0	6.0	10
Chromium (III)	µg/ℓ	≤ 24	160	340	–	–	–
Chromium (VI)	µg/ℓ	≤ 14	110	200	< 20	20	20
Copper (Cu)*	µg/ℓ	≤ 1.5	3.8	4.6	≤ 5	300	600
Cyanide (CN)	µg/ℓ	≤ 4.0	45	110	≤ 20	110	200
DIN	mg/ℓ	≤ 0.25	0.7	1.0	–	–	–
DO (lower)	mg/ℓ	–	–	–	6	5	4
DO (upper)	mg/ℓ	–	–	–	8	16	20
DO	% saturation	80 – 120	60	40	–	–	–
EC	mS/m	≤ 30	55	85	≤ 40	90	270
Fluoride (F)	mg/ℓ	≤ 1.5	3.0	3.52	–	–	–
Hardness – Total	mg $CaCO_3$/ℓ	–	–	–	≤ 50	175	300
Iron (Fe)	mg/ℓ	–	–	–	≤ 0.01	0.88	1.75
Lead (Pb)*	µg/ℓ	≤ 1.0	4.0	7.0	≤ 10	1 080	2 150
Manganese (Mn)	mg/ℓ	≤ 0.18	0.37	1.3	≤ 0.1	0.3	0.5
Mercury (Hg)	µg/ℓ	≤ 0.08	0.90	1.7	≤ 1.0	140	280
Nitrate (NO_3-N)	mg/ℓ	–	–	–	≤ 300	650	1 000
Nitrite (NO_2-N)	mg/ℓ	–	–	–	≤ 0.05	70.0	140
Salts - inorganic:							
Salt: $MgSO_4$	mg/ℓ	≤ 16	27	37	–	–	–
Salt: Na_2SO_4	mg/ℓ	≤ 20	36	51	–	–	–
Salt: $MgCl_2$	mg/ℓ	≤ 15	33	51	–	–	–
Salt: $CaCl_2$	mg/ℓ	≤ 21	63	105	–	–	–
Salt: NaCl	mg/ℓ	≤ 45	217	389	–	–	–
Selenium (Se)	mg/ℓ	≤ 0.002	0.005	0.030	≤ 0.3	19	35
pH (lower)	Units	≤ 6.5	5.75	5.0	6.5	5.25	4.0
pH (upper)	Units	8.0	9.0	10.0	9.0	9.0	9.0
Phosphate (PO_4-	µg/ℓ	≤ 10	30	130	≤ 80	340	600
TDS	mg/ℓ	≤ 195	360	550	≤ 450	1 000	2 400
Zinc (Zn)	mg/ℓ	≤ 0.002	0.0036	0.036	≤ 1	5	>5

* Moderately hard water; A#, Acceptable; T#, Tolerable; EC, Electrical conductivity; DIN, Dissolved inorganic nitrogen; DO, Dissolved oxygen; TDS, Total dissolved solids; – no value.

Table 9: Generic water quality limits for Agricultural Use – Irrigation and Livestock Watering (Modified from DWAF 1996 and Model).

Variable	Units	Irrigation			Livestock watering		
		Ideal	A#	T#	Ideal	A#	T#
Aluminum (Al)	mg/ℓ	≤ 5.0	12.5	20.0	≤ 5.0	7.5	10.0
Arsenic (As)	mg/ℓ	≤ 0.1	1.05	2.0	≤ 1.0	1.25	1.5
Boron (B)	mg/ℓ	≤ 0.5	0.75	1.0	≤ 5.0	27.5	50
Cadmium (Cd)	µg/ℓ	≤ 10	30	50	≤ 10	15	20
Calcium (Ca)	mg/ℓ	–	–	–	≤ 1 000	1 500	2 000
Chloride (Cl)	mg/ℓ	≤ 100	137.5	175	≤ 1 000	1 750	2 000
Chromium (VI)	mg/l	≤ 0.1	0.55	1.0	≤ 1.0	1.5	2.0
Cobalt (Co)	mg/ℓ	≤ 0.05	2.53	5.0	≤ 1.0	1.5	3.0
Copper (Cu)	mg/ℓ	≤ 0.2	2.6	5.0	≤ 0.5	0.75	1.0
EC	mS/m	≤ 40	270	540	≤ 150	300	450
Faecal coliforms	cfu/100 mℓ	≤ 200	600	1 000	≤ 200	600	1 000
Fluoride (F)	mg/ℓ	≤ 2.0	8.5	15	≤ 2.0	4.0	6.0
Iron (Fe)	mg/ℓ	≤ 5.0	12.5	20	≤ 10	30	50
Lead (Pb)	mg/ℓ	≤ 0.2	1.1	2.0	≤ 0.1	0.15	0.2
Magnesium (Mg)	mg/ℓ	–	–	–	≤ 500	750	1 000
Manganese (Mn)	mg/ℓ	≤ 0.02	5.0	10	≤ 10	30	50
Mercury (Hg)	mg/ℓ	–	–	–	≤ 1.0	3.5	6.0
Molybdenum (Mo)	µg/ℓ	≤ 10	30	50	≤ 10	15	20
Nickel (Ni)	mg/ℓ	≤ 0.2	1.1	2.0	≤ 1.0	3.0	5.0
Nitrate (NO_3-N)	mg/ℓ	≤ 5.0	17.5	30	≤ 100	150	200
pH	Units	6.5 – 8.4	–	–	–	–	–
SAR – crop*	mmol/ℓ	≤ 2.0	8.0	15	–	–	–
SAR – soil**	mmol/ℓ	≤ 1.5	3.0	6.0	–	–	–
Selenium (Se)	µg/ℓ	≤ 20	40	50	≤ 50	63	75
Sodium (Na)	mg/ℓ	≤ 70	92.5	115	≤ 2 000	2 250	2 500
Sulphate (SO_4)	mg/ℓ	–	–	–	≤ 1 000	1 250	1 500
TDS	mg/ℓ	≤ 260	1 755	3 510	≤ 1 000	2 000	3 000
TSS	mg/ℓ	50	75	100	–	–	–
Vanadium (V)	mg/ℓ	≤ 0.1	0.55	1.0	≤ 1.0	1.5	2.0
Zinc (Zn)	mg/ℓ	≤ 1.0	3.0	5.0	≤ 20	30	40

A# Acceptable; T# Tolerable; EC, Electrical conductivity; SAR, Sodium Adsorption Ratio; TDS, Total dissolved salts; TSS, Total suspended solids; * Effect on crop yield and quality; ** Effect on soil physical conditions; – no value

Table 10: Generic water quality limits for Industrial Use (category 3) and Recreational Use – full contact (Modified from DWAF 1996 and 2006).

Variable	Units	Industrial Use: Category 3			Recreational: Full Contact		
		Ideal	A#	T#	Ideal	A#	T#
Algae (Chl-*a*)	µg/ℓ	–	–	–	≤ 15	22.5	30
Alkalinity	mg $CaCO_3$/ℓ	≤ 300	450	600	–	–	–
Chloride (Cl)	mg/ℓ	≤ 100	150	200	–	–	–
Clarity (Secchi disk)	m	–	–	–	≥ 3	2	1
COD	mg/ℓ	≤ 30	50	100	–	–	–
Coliphages	cfu/100 mℓ	–	–	–	≤ 20	60	100
EC	mS/m	≤ 70	120	250	–	–	–
Escherichia coli	cfu/100 mℓ	–	–	–	≤ 130	200	400
Faecal coliforms	cfu/100 mℓ	–	–	–	≤ 130	600	2 000
Faecal streptococci	cfu/100 mℓ	–	–	–	≤ 30	65	100
Hardness – Total	mg $CaCO_3$/ℓ	≤ 250	375	500	–	–	–
Iron (Fe)	mg/ℓ	≤ 0.3	6.5	10	–	–	–
Manganese (Mn)	mg/ℓ	≤ 0.2	6.0	10	–	–	–
pH (lower)	Unit	≤ 6.5	5.75	5	6.5	5.75	5.0
pH (upper)	Unit	8.0	9.0	10.0	8.5	8.75	9.0
Silicon (Si)	mg/ℓ	≤ 20	85	150	≤ 50	63	75
Sulphate	mg/ℓ	≤ 200	250	300	–	–	–
TDS	mg/ℓ	≤ 450	800	1 600	≤ 1 000	2 000	3 000
TSS	mg/ℓ	≤ 5	20	50	–	–	–

A# Acceptable; T# Tolerable; EC, Electrical conductivity; COD, Chemical oxygen demand; TSS Total suspended solids; – no value

Table 11: Water users and level of protection at different sites in Orange River – main stem, level 1

RWQO Sample site	Domestic Use			Irrigation			Livestock Watering			Aquaculture			Aquatic ecosystem			Industrial Use (Category 3)			Recreational Full Contact		
	Ideal	A#	T#	Ideal	A	T	Ideal	A	T	Ideal	A	T	Ideal	A	T	Ideal	A	T	Ideal	A	T
Orange River: Main stem - Level 1																					
Oranjedraai (OS1)	√			√			√			√			√			√			√		-
Aliwal North (OS2)	√			√			√			√			√			√			√		
Gariep Dam (OSD1)	√			√			√			√			√			√			√		
Roodepoort (OS4)	√			√			√				√		√			√			√		
Vanderkloof (OSD2)	√			√			√				√		√			√			√		
Dooren Kuilen (OS5)	√			√			√				√		√			√			√		
Marksdrift (OS6)	√			√			√				–		√			√			√		
Boegoeberg (OS9)		√			√		√				–			√		√			√		
Upington (OS11)		√			√		√				–			√		√			√		
Neusberg (OS13)		√			√		√				–			√		√			√		
Pella (OS15)		√			√		√				–			√			√		√		
Vioolsdrift (OS16)		√			√		√				–			√			√		√		
Alexander Bay (OS19)		√			√		√				–			√			√		√		

A# Acceptable; T# Tolerable; – Not applicable

Table 12: Water users and level of protection at different sites in Orange – tributaries, level 2

RWQO Sample site	Domestic Use			Irrigation			Livestock Watering			Aquaculture			Aquatic ecosystem			Industrial Use (Category 3)			Recreational Full Contact		
	Ideal	A#	T#	Ideal	A	T	Ideal	A	T	Ideal	A	T	Ideal	A	T	Ideal	A	T	Ideal	A	T
Orange River: Tributaries - Level 2																					
Kornetspruit (OSL2/1)	√			√			√			√			√				√		√		-
Sterkspruit (OSL2/2)		√			√		√			–				√			√			√	
Kraai River (OSL2/3)	√			√			√			√			√			√			√		
Stormberg (OSL2/4)			√			√		√		–					√		√				√
Seekoei River (OSL2/5)		√		√				√		–					√		√			√	
Vaal Rivern (VS21)		√			√			√		–				√			√			√	

A# Acceptable; T# Tolerable; – Not applicable

Table 13: Water users and level of protection at different sites in the Caledon River – main stem and tributaries – level 1 & 2

RWQO Sample site	Domestic Use			Irrigation			Livestock Watering			Aquaculture			Aquatic ecosystem			Industrial Use (Category 3)			Recreational Full Contact		
	Ideal	A#	T#	Ideal	A	T	Ideal	A	T	Ideal	A	T	Ideal	A	T	Ideal	A	T	Ideal	A	T
Caledon River: Main stem - Level 1																					
Caledon River at confluence (CS1)	√			√			√				√		√			√			√		-
Ficksburg (CS2)	√			√			√							√		√			√		
Maseru (CS3)		√		√			√							√		√			√		
Tienfontein (CS4)	√			√			√							√		√			√		
Kommissiedrift (CS5)		√			√		√							√			√			√	
Caledon River: Tributaries – Level 2																					
Little Caledon at Golden Gate (CSL2/1)	√			√			√			√			√			√			√		
Little Caledon - Poplars (D33K)	√			√			√				√		√			√			√		
Grootspruit (CSL2/3)		√			√		√							√						√	
Meulspruit (CSL2/4)		√			√		√							√						√	
Moperispruit (CSL2/5)		√			√		√							√						√	
Leeu River (CSL2/6)		√			√		√								√					√	

A# Acceptable; T# Tolerable; – Not applicable

The output RWQOs by the Model were frequently adjusted based on the need for more stringent water quality requirements and expert knowledge to recommend the final RWQO. The reasons for the adjustment are briefly described in the associated Tables and explained in more detail in the text that follows the tables.

The present ecological state (PES) is the measured, current water quality for each water resource management unit and in many cases provides the point of departure for the development of any management objectives. The PES categories for this study was taken from the RWQO Model tables and indicated in the tables on the background information.

Table 14: Ecological Categorisation system for the assessment of the ecological integrity status of surface water resources (Source: DWAF 1997).

	Category	Ecological Integrity Status
Ecologically Sustainable	A	**Unmodified, natural**; the resource base reserve has not been decreased - the resource capability has not been exploited.
	B	**Largely natural** with few modifications; the resource base reserve has been decreased to a small extent. A small change of natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.
	C	**Moderately modified**; the resource base reserve has been decreased to a moderate extent. A change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.
	D	**Largely modified**; the resource base reserve has been decreased to a large extent. Large changes in natural habitat, biota and basic ecosystem functions have occurred.
Ecologically Unsustainable	E	**Seriously modified**; the resource base reserve has been seriously decreased and regularly exceeds the resource base. The loss of natural habitat, biota and basic ecosystem functions is extensive.
	F	**Critically modified**; the resource base reserve has been critically decreased and permanently exceeds the resource base. Modifications have reached a critical level and the resource has been modified completely with an almost total loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

The ecological importance of a river is an expression of its importance to the maintenance of biological diversity and ecological functioning on local and wider scales. Ecological sensitivity (or fragility) refers to the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred (resilience). Both abiotic and biotic components of the system are taken into consideration in the assessment of ecological importance and sensitivity (DWAF, 2006).

The ecological importance and sensitivity (EIS) of catchments and impoundments is a system of grading which uses four main categories (**Table 15**). The ecological status of the RWQO site and its quaternary drainage region is presented in **Table 2, 4** and **6**.

Table 15: Ecological importance and sensitivity categories (Kleynhans 1999).

Ecological importance and sensitivity categories
Very high Quaternary catchments that are considered unique on a national or even international level based on unique biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) are usually very sensitive to flow modifications and have no or only a small capacity for use.
High Quaternary catchments that are considered to be unique on a national scale due to biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) may be sensitive to flow modifications but may have a substantial capacity for use.
Moderate Quaternary catchments that are considered to be unique on a provincial or local scale due to biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) are usually not very sensitive to flow modifications and often have a substantial capacity for use.
Low/marginal Quaternary catchments that are not unique at any scale. These rivers (in terms of biota and habitat) are generally not very sensitive to flow modifications and usually have a substantial capacity for use.

5 RESULTS AND DISCUSSION

The present state concentrations were calculated for the last 3 years (2005 – 2007), for 12 sites with sufficient data on the Orange River (Upper and Lower Orange WMAs), and are summarised in **Tables 17** and **61**.

The management classes defined for the water resources in each of the visioning areas are the 'best' proposed class using the RWQO Model 4.1 of what may occur in the future. These classes are preliminary and where defined for the purpose of linking the catchment visions and the emerging classification system.

5.1 Upper Orange Water Management Area (WMA 13)

The upper reaches of the Orange River, *i.e.* from the Lesotho border (Oranjedraai) to Gariep Dam, including the major tributaries, has been defined as visioning area 1 (DWAF, 2009a). The area lies within the Eastern Cape, Northern Cape and Free State province and borders with Lesotho. Conservation areas include Tussen-2-Riviere, Gariep Conservation Area, and Gariep Transfrontier Venture. Water quality concerns include increased turbidity in the Orange River and Hershell area; Increased nutrients (Sterkspruit at Hershell), Stormbergspruit at Burgersdorp and algal blooms in Gariep Dam (DWAF, 2009). RWQO sites in visioning area 1 include:

- OS1 Oranjedraai
- OS2 Aliwal North
- OS3 Saamwerk
- OSD1 Gariep Dam
- OSL2/1 Kornetspruit
- OSL2/2 Sterkspruit
- OSL2/3 Kraai River
- OSL2/4 Stormbergspruit

Visioning area 2 of the Upper Orange WMA stretches from Gariep Dam to Marksdrift Weir, including the Seekoei River. The tertiary catchments are D31, D32, D33 and D34. The Visioning area lies mainly within the Free State and Northern Cape provinces. Conservation areas include Yellow fish hatchery downstream of Gariep Dam, Rolfontein and Doringkloof Nature Reserves, Huntersmoon (Seekoei River), Orania Bewaararea.

Water quality concerns include possible increase in nutrients. Algal blooms, including blue-green algae at Luckhoff, Oppermans, Jacobsdal, Koffiefontein, Vanderkloof and Hopetown (DWAF, 2009a).

RWQO sites in visioning area 2 include:

- OS4 Roodepoort
- OSD2 Vanderkloof Dam
- OS5 Dooren Kuilen
- OS6 Marksdrift
- OSL2/5 Seekoei River

The PES in the Upper Orange River ranged between B and E, with the majority of the sites in the D category (**Table 2**). However, from a water quality perspective (this study), the Upper Orange is considered to be largely natural and thus in a B category.

5.1.1 Spatial extent

The RWQOs were calculated for all the other sites in the Upper Orange River (main stem) with almost the same outcome because the water quality differs only slightly from Oranjedraai to Marksdrift. The salts concentrations at Marksdrift just started to show an increase (**Figure 9**). The homogenous nature of the river in terms of dissolved major salts is also shown in the snapshot results (**Figures 10 & 11**).

The major difference in the water quality between Oranjedraai and Marksdrift is the sediment load and thus turbidity.

However, two river reaches were identified in the UOWMA to correspond with the visioning areas, although the water quality characteristics were almost the same. It is recommended that the RWQOs proposed for Oranjedraai be applied to the Upper Orange River, *i.e*. visioning area 1 and the RWQOs determined for Gariep Dam be applied to visioning area 2.

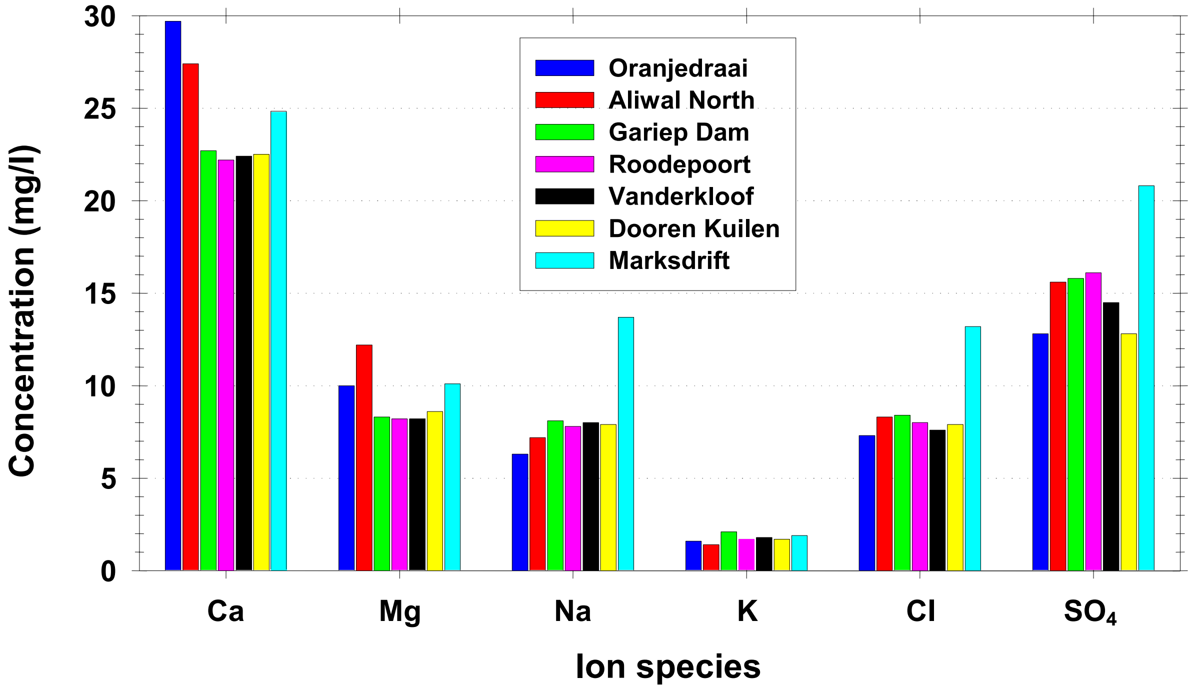

Figure 9: Grouped Bar chart of the Present State (95th percentiles) of major ions concentrations (mg/ℓ) at seven selected sites in the Upper Orange River.

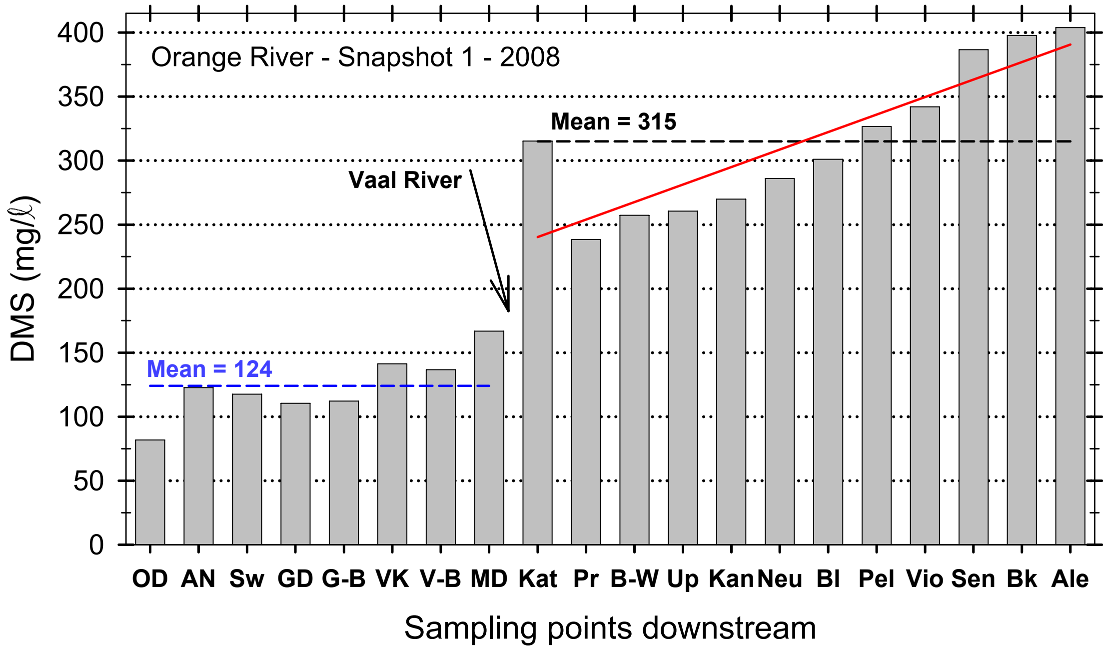

Figure 10: Spatial (downstream) changes in dissolved major salts concentrations (DMS, mg/ℓ) in the Orange River during snapshot survey 1 (2008).

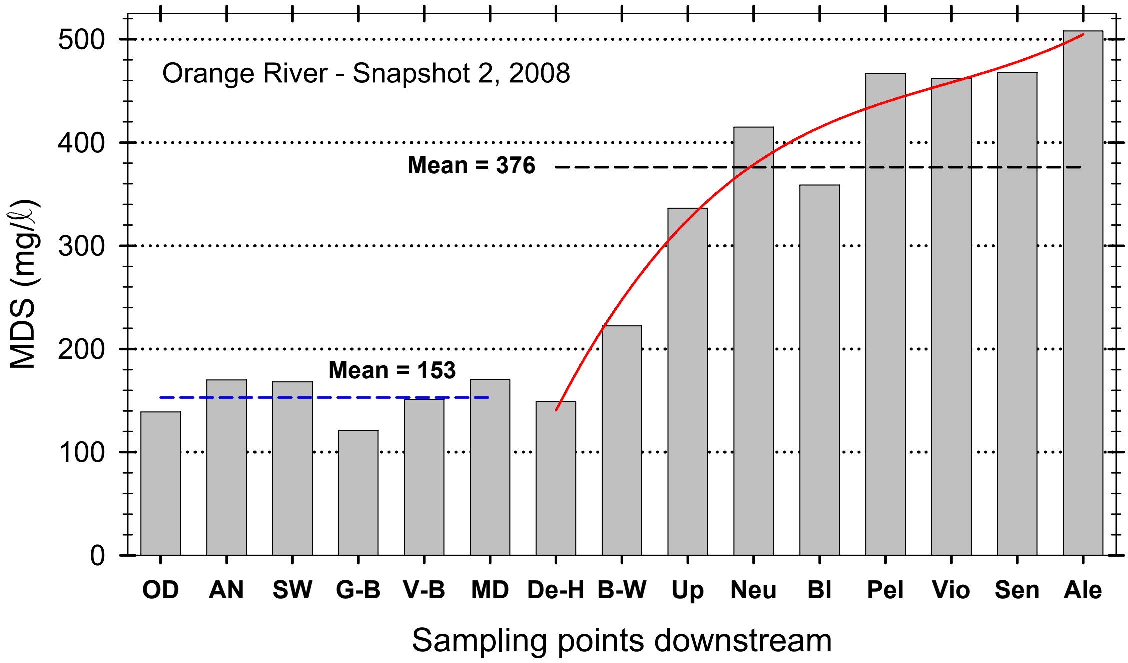

Figure 11: Spatial (downstream) changes in dissolved major salts concentrations (DMS, mg/ℓ) in the Orange River during snapshot survey 2 (2008).

5.1.2 Preliminary RWQOs for Oranjedraai (OS1)

The water quality at Oranjedraai is good and show only small changes the past 30 years; comparing the Reference values (1976 – 1978) with the Present state values (2005 – 2007, **Table 20**).

The PES for the Orange River at Oranjedraai is a B category (largely natural) and the Ecological Importance and Sensitivity Category (EISC) is considered to be high (**Table 16**). The protection of the water quality in the upper reaches of the river is important also for downstream users, therefore strict RWQOs are required. In the RWQO Model, the management class was selected as Natural for Oranjedraai. Aquaculture (acceptable level) was also added as a water user because of the fish breeding station at Gariep Dam, which to increase the sensitivity of the RWQOs.

Table 16: Background information on Oranjedraai in Orange River – WMA 13

River:	Orange	**Study Unit:**	Oranjedraai	**Quat.**	D12A	**WQM site:**	D1H009
PES:	B	**REC:**	B	**EISC:**	High	**Reference state:**	1976–1979 (n ≈ 122)
Management Class:		Natural				**Present State:**	2005–2007 (n ≈ 45)
RWQO Model Vers:		4.1					

Table 17: Present state (95th%tile and 50th%tile) values (2005 -2007) at different sites in the Upper Orange WMA – main stem, level 1

PES	Sample site (Quat)	Ca	Cl	Chl-a**	DMS	EC	Flow*	F	Hard-T	K	Mg	Na	NH_3	NO_3–N*	DIN*	pH#	PO_4-P*	SAR	Si	SO_4	TAL	TSS#	Turb#
B	Oranjedraai (D12A)	29.7	7.3	-	194	25	52	0.2	107	1.6	10	6.3	.008	0.21	0.28	7.3 8.2	.039	0.30	10.8	12.8	111	-	0.5 1095
C	Aliwal North (D14A)	27.4	8.3	-	216	28.7	113	0.25	119	1.4	12.2	7.2	.007	0.37	0.39	7.3 8.3	.034	0.37	11.1	15.6	121	-	0.5 517
E	Gariep Dam (D35K)	22.7	8.4	4.9	168	23.9	-	0.21	90	2.1	8.3	8.1	0.01	0.28	0.37	7.3 8.3	.029	0.38	9.0	15.8	89.6	80.7	1.1 53
D	Roodepoort (D34A)	22.2	8.0	-	167	22.7	107	0.23	89	1.7	8.2	7.8	.009	0.28	0.35	7.7 8.2	.032	0.37	9.1	16.1	88	-	1.8 78
E	Vanderkloof (D31E)	22.4	7.6	2.4	162	22.6	-	0.22	87	1.8	8.2	8.0	.007	0.22	0.28	7.5 8.2	.024	0.38	8.4	14.5	89	2.5 109	0.5 46.4
D	Dooren Kuilen (D33A)	22.5	7.9	-	163	22.1	95	0.22	88	1.7	8.6	7.9	.005	0.27	0.33	7.5 8.1	.021	0.38	8.5	12.8	92	-	0.6 27.7
D	Marksdrift (D33K)	24.8	*13.2*	*-*	*196*	*29.7*	*79*	*0.25*	*102*	*1.9*	*10.1*	*13.7*	*0.01*	*0.31*	*0.34*	*7.5* *8.3*	.022	0.63	8.5	20.8	100	-	0.5 45.4

Present state (95th%tile) of metal concentrations (mg/ℓ) at different sites in Upper Orange WMA (2005 -2007) – level 1

		Al	B	Ba	Cd	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Sr	V	Zn
B	Vanderkloof	*.076*	*0.03*	*0.04*	*.005*	*.003*	*.015*	*0.13*	*.012*	*.016*	*.010*	*.054*	*0.14*	*.017*	*.034*
D	Marksdrift (D33K)	*0.10*	*0.14*	*0.05*	*.005*	*.007*	*.011*	*0.14*	*.007*	*.016*	*.033*	-	*0.47*	*.011*	*.029*

PES, Present Ecological State; * 50th percentile; ** Mean; # 5th and 95th percentile

A typical output Report from the RWQO-Model is shown in **Table 19** and a summary of the results are shown in **Table 20**. The RWQOs according to the Model, the recommended RWQO values ('RWQOs Rec.'), and the motivations for the differences in RWQOs are as follows (**Table 18**):

Table 18: RWQOs values according to the Model and the Recommended RWQOs and the rationale/motivation for any changes at Oranjedraai (OS1) in the Orange River.

Variable	Unit	RWQO Model	RWQO Rec.	Rationale/Motivation
Tot Hardness	mg/ℓ	175	175	The total hardness of 175 mg/ℓ is Acceptable for Aquaculture and ideal for all the other water users, thus accepted as such.
Electrical Conductivity (EC)	mS/m	70	40	EC of 70 is considered to be too high. If the EC is allowed to increase by almost 3 times, then it would be impossible to reach suitable EC values downstream. EC is directly linked to the salt concentrations that are specifically a problem in the lower Orange River. An EC of 40 is recommended because it is in the Ideal range for irrigation and acceptable for the aquatic ecosystem. It also allows for a reasonable 'allocatable value'.
pH (lower) 5th percentile	Unit	6.5	6.9	A RWQO value of 6.9 is recommended, which is based on the criteria for aquatic ecosystems, *i.e.* the pH should not be allowed to vary from the range of the background pH values by >0.5 of a pH unit, or by 5 %, and should be assessed by whichever estimate is the more conservative (DWAF, 1996). Present state, pH 7.3.
pH (upper) 95th percentile		8.0	8.4	The upper limit for pH of 8.0 (RWQO – Model) is ideal for Industrial use, but the pH values in the Orange River are naturally high (present state, 8.2) and a value of 8.4 is recommended which is still ideal for irrigation and as a more natural and practical value.
Alkalinity	mg $CaCO_3$/ℓ	97.5	175	Alkalinity of 97.5 mg/ℓ is acceptable for aquaculture, but the present state (111 mg/ℓ) and reference value (113 mg/ℓ) are higher than the proposed value, which means that the allocatable value would be negative. A RWQO value of 175 mg/ℓ is recommended, which is tolerable for aquaculture and still ideal for the other users.

Ammonia (NH_3)	µg/ℓ	30	15	The RWQO for ammonia (NH_3) of 30 µg/ℓ is Ideal for aquaculture but the Ideal for Aquatic Ecosystems is 15 µg/ℓ and the recommended RWQO value.
Calcium (Ca)	mg/ℓ	80	60	Ca of 80 mg/ℓ is ideal for basic human need, but a stricter concentration of 60 mg/ℓ is recommended because it is already a doubling of the present concentration (29.7 mg/ℓ) and to limit excess salts in general – note the allocatable TDS is only 66 mg/ℓ.
Chloride (Cl)	mg/ℓ	100	40	The RWQO of 100 mg/ℓ for Cl is considered to be too high because it is 13 times higher than the present state and would cause problems downstream. A concentration of 40 mg/ℓ is recommended that is also ideal for all water users.
Fluoride (F)	mg/ℓ	0.70	0.70	The fluoride concentrations in the Orange River are generally low and a concentration of 0.70 mg/ℓ is ideal for domestic use, thus accepted as the RWQO value.
Magnesium (Mg)	mg/ℓ	100	30	To keep the general salts concentration low, it is recommended that a RWQO value for magnesium (Mg) in the upper Orange of 30 mg/ℓ, which is within the ideal range for domestic water use. The model's value of 100 mg/ℓ is unreasonably high and 10 times higher than the present state.
Potassium (K)	mg/ℓ	50	10	K is a conservative element and very low in the Orange River. The RWQO of 50 mg/ℓ is excessively high and a concentration of 10 mg/ℓ is recommended; it is in the ideal range for domestic use and this concentration limits excess salts downstream.
Sodium adsorption ratio (SAR)	mmol/ℓ	2.0	1.5	The SAR is very low at Oranjedraai; present state of 0.3 mmol/ℓ. The RWQO according to the model is 2.0 (ideal for crop yield and quality), but a value of 1.5 is recommended that is ideal on soil physical conditions. The SAR is an index of the potential of a given irrigation water to induce sodic soil conditions. Soil sodicity is usually measured by the percentage of a soil's cation exchange capacity that is occupied by sodium ions (DWAF, 1996).

Sodium (Na)	mg/ℓ	70	30	The RWQO for sodium (Na) of 70 mg/ℓ is in the target water quality range for irrigation (crop yield and quality), but a concentration of 30 mg/ℓ is recommended to limit the general salts and prevent excessive downstream concentrations.
Sulphate (SO_4)	mg/ℓ	200	60	The SO_4 concentrations at Oranjedraai is still very low (Present state, 12.8 mg/ℓ) and a RWQO concentration of 60 mg/ℓ is recommended and not the 200 mg/ℓ proposed by the model, which is an order higher than the present state. The lower concentration (60 mg/ℓ) is already 4 times higher than the present state, but acceptable for Industrial use (category 2) and would limit the general salt levels and prevent excessive downstream SO_4 concentrations, which is specifically a problem downstream in the lower Orange River.
Total Dissolved Salts (TDS)	mg/ℓ	260	260	The RWQO for TDS of 260 mg/ℓ is still ideal for irrigation and recommended as such.
Magnesium sulphate ($MgSO_4$)	mg/ℓ	16	27	The $MgSO_4$ concentration was relatively high (16 mg/ℓ), that equal the limit for Ideal aquatic ecosystems, thus the RWQO is set at 27 mg/ℓ which is acceptable for the ecosystem. The other salts were accepted as Ideal.
Phosphate (PO_4-P)	µg/ℓ	80	45	The phosphate concentrations in the upper Orange are naturally higher (reference 14 µg/ℓ) as would be expected from a natural (oligotrophic) system (<10 µg/ℓ). However, the 80 µg/ℓ, recommended by the Model (Ideal for aquaculture) is too high and can cause eutrophication problems in the river. Because the present state concentration is already 39 µg/ℓ, a RWQO value of 45 µg/ℓ (within the tolerable range of aquatic ecosystems) is recommended.
Nitrate and nitrite nitrogen (NO_3-N)	mg/ℓ	6	0.40	The RWQO value for nitrate of 6 mg/ℓ is based on the ideal for domestic use but does not take the ecological implication into account. The recommended RWQO for nitrate is 0.40 mg/ℓ based on the RWQO for DIN of 0.50 mg/ℓ – refer to discussion in paragraph below. The nitrate concentration forms usually between 70 and 90 % of DIN.

Dissolved Inorganic Nitrogen (DIN)	mg/ℓ	0.25	0.40	The DIN concentration at Oranjedraai was relatively high (present state, 0.28 mg/ℓ), so the RWQO value of 0.25 mg/ℓ proposed by the Model is too low because it is already below the present concentration and thus no allocatable value. Thus, a RWQO of 0.40 mg/ℓ is recommended as a more realistic concentration and within the range for Oligo-mesotrophic waters (DWAF, 2008a).
Silicon (Si)	mg/ℓ	20	20	Silicon is grouped together with the nutrients, because of its importance nutrient for diatoms. The RWQO of 20 mg/ℓ is accepted. Present state, 10.8 mg/ℓ.
Chl-a	µg/ℓ	15	10	No response data is available in DWAF historical data set. Data presented here is based on 2 snapshot surveys. The RWQO for Chlorophyll-*a* (Chl-*a*) is recommended as 10 µg/ℓ which corresponds to natural (Oligotrophic) systems. This is considered to be realistic because the mean of Chl-*a* concentrations in Gariep Dam is only 4.9 µg/ℓ. The RWQO value of 15 proposed by the Model is too high and is based on recreational contact and not on the environment.
E. coli	Cfu/100 mℓ	–	130	The *E. coli* concentrations at Oranjedraai ranged between 4 and 1 580 cfu/100 mℓ. The high concentration was encountered during snapshot 1, following a rainstorm the previous day that cause very turbid water and an increased bacteriological count (worse case scenario). However, the general *E. coli* concentrations in the Orange River were low and a RWQO of 130 is proposed that is acceptable for full contact recreational use (swimming).
SPI		–	13 – 17	The Specific Pollution sensitivity Index (SPI) of diatoms ranged between 6.9 (poor quality) and 14.9 (good quality), however, it is expected that the majority of SPI scores at Oranjedraai would be in the 13 – 17 range (Good quality) and thus recommended as RWQO values.

Table 19: Example RWQO Report from the Model for Orange River at Oranjedraai.

Introduction | Input | Rec Ecological Cat | References | Monthly-Flow | End-of-Pipe | Report

Project: Orange River
Study Unit: Oranjedraai
Recommended ecological category:
D12A
Management Class: Natural
Spatial Extent: Water quality reach
Temporal Extent: Annual
Flow Assurance: 80 %
Target Flow: 52 m^3/sec = 1,639.872Mm^3/annum
Prepared on 2009/04/02
using version 4.1

Water Use	Existing?	Future?	Quality
IO: International obligations	☐	☐	Ideal
Str: Strategic use	☐	☐	Ideal
ERC: Ecological Reserve Category	☐	☐	B
EWQG: Ecological WQ Guidelines	☑	☑	Natural
BHN: Basic Human Needs	☑	☐	Ideal
Dom: Domestic use	☑	☐	Ideal
ASw: Agriculture - Stock watering	☑	☐	Ideal
AIr: Agriculture - Irrigation	☑	☐	Ideal
AAq: Agriculture - Aquaculture	☑	☐	Acceptable
In1: Industrial - Category 1	☐	☐	Ideal
In2: Industrial - Category 2	☐	☐	Ideal
In3: Industrial - Category 3	☑	☐	Ideal
In4: Industrial - Category 4	☑	☐	Ideal
RFull: Recreation - Full contact	☑	☐	Ideal
RInter: Recreation - Intermediate contact	☑	☐	Ideal
RNon: Recreation - Non-contact	☑	☐	Ideal

	Water Quality Variable			Present State		Reference		RWQO	Cutoffs				Allocatable Water Quality		Allocatable Loads	
Category	Variable	Units	Bound	Value	%ile	Value	%ile		I	A	T	User	Value	Confidence	Tonnes/annum	Percentile
Physical	Hardness ($CaCO_3$)	mg/l	Upper	107	95.0			175.000	50.000	175.000	300.000	AAq	68.000	95.0	111,511.296	
Physical	Turbidity	NTU	Upper	1095	95.0			0.100	0.100	1.000	20.000	Dom	-1,094.900	95.0		
Chemical	Alkalinity ($CaCO_3$)	mg/l	Upper	111	95.0			97.500	20.000	97.500	175.000	AAq	-13.500	95.0	-22,138.272	
Chemical	Ammonia (NH_3-N)	mg/l	Upper	0.008	95.0			0.015	0.030	0.300	1.000	AAq	0.007	95.0	11.479	
Chemical	Calcium (Ca)	mg/l	Upper	29.7	95.0			10.000	10.000	150.000	300.000	Dom	-19.700	95.0	-32,305.478	
Chemical	Chloride (Cl)	mg/l	Upper	7.3	95.0			100.000	100.000	137.500	175.000	Dom AIr In3	92.700	95.0	152,016.134	
Chemical	Conductivity (EC)	mS/m	Upper	25	95.0			70.000	70.000	120.000	250.000	Dom In3	45.000	95.0		
Chemical	Fluoride (F)	mg/l	Upper	0.2	95.0			0.700	0.700	1.000	1.500	Dom	0.500	95.0	819.936	
Chemical	Magnesium (Mg)	mg/l	Upper	10	95.0			70.000	70.000	100.000	200.000	Dom	60.000	95.0	98,392.320	
Chemical	NO_2 and NO_3	mg/l	Upper	0.21	95.0			6.000	6.000	10.000	20.000	Dom	5.790	95.0	9,494.859	
Chemical	TIN	mg/l	Upper	0.28	95.0			0.250					-0.030	95.0	-49.196	
Chemical	pH	units	Upper	8.2	95.0			8.000	8.000	8.400	8.400	In3	-0.200	95.0		
			Lower	7.3	5.0			6.500	6.500	6.500	6.500	AIr AAq In3 RFull	0.800	95.0		
Chemical	Potassium (K)	mg/l	Upper	1.6	95.0			25.000	25.000	50.000	100.000	Dom	23.400	95.0	38,373.005	
Chemical	PO_4	mg/l	Upper	0.039	95.0			0.010	0.080	0.340	0.600	AAq	-0.029	95.0	-47.556	
Chemical	SAR	mmol/l	Upper	0.30	95.0			2.000	2.000	8.000	15.000	AIr	1.700	95.0	2,787.782	
Chemical	Sodium (Na)	mg/l	Upper	6.3	95.0			70.000	70.000	92.500	115.000	AIr	63.700	95.0	104,459.846	
Chemical	SO_4	mg/l	Upper	12.8	95.0			200.000	200.000	250.000	300.000	Dom In3	187.200	95.0	306,984.038	
Chemical	TDS	mg/l	Upper	194	95.0			260.000	260.000	800.000	1,600.000	AIr	66.000	95.0	108,231.552	
Chemical	Si	mg/l	Upper	10.8	95.0			20.000	20.000	85.000	150.000	In3	9.200	95.0	15,086.822	
Biological	Algae (Chl-a)	µg/l	Upper	2	95.0			15.000	15.000	22.500	30.000	RFull RInter	13.000	95.0	21.318336	

Table 20: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) and allocatable values for Oranjedraai (OS1) – Upper Orange WMA - Orange River – level 1.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hard-Tot	mg/ℓ	**107**	111	175	AAq-A	**175**	–	68
	EC	mS/m	**25**	24.6	70	Dom-I In3	**40**	AIr-I; d/s	15
	pH 5th	Unit	**7.3**	–	6.5	AIr In3	**6.9**	5 % dev	0.4
	pH 95th	Unit	**8.2**	–	8.0	In3	**8.4**	AIr Nat.	0.2
Chemical variables	Alkalinity	mg/ℓ	**111**	113	97.5	AAq	**175**	AAq-T	64
	Ammonia	µg/ℓ	**8**	–	30	AAq	**15**	Eco-I	7
	Calcium	mg/ℓ	**29.7**	28.3	80	BHN	**60**	2x d/s	26.3
	Chloride	mg/ℓ	**7.3**	4.0	100	Dom AIr	**40**	5x, d/s	32.7
	Fluoride	mg/ℓ	**0.20**	0.22	0.70	Dom-I	**0.70**	–	0.5
	Magnesium	mg/ℓ	**10.1**	10.3	100	BHN	**30**	Dom-I, d/s	19.9
	Potassium	mg/ℓ	**1.6**	1.8	50	Dom–A	**10**	5x, d/s	23.4
	SAR	mmol/ℓ	**0.30**	0.28	2.0	AIr	**1.5**	AIr-soil	1.2
	Sodium	mg/ℓ	**6.3**	6.4	70	AIr	**30**	5x, d/s	23.7
	Sulphate	mg/ℓ	**12.8**	7.8	200	Dom In3	**60**	5x d/s	47.2
	TDS	mg/ℓ	**194**	195	260	AIr-I	**260**	–	66
Chemical Inorganic salts	$MgSO_4$	mg/ℓ	**16.02**	–	16	Eco-I	**23**	Eco-A	6.98
	Na_2SO_4	mg/ℓ	**0.13**	–	20	Eco-I	**20**	–	19.87
	$MgCl_2$	mg/ℓ	**2.47**	–	15	Eco-I	**15**	–	12.53
	$CaCl_2$	mg/ℓ	**5.85**	–	21	Eco-I	**21**	–	15.15
	NaCl	mg/ℓ	**8.01**	–	45	Eco-I	**45**	–	36.99
Nutrients	PO_4-P	µg/ℓ	**39**	14	80	AAq	**45**	Eco-Rec	6
	NO_3&NO_2-N	mg/ℓ	**0.21**	0.28	6.0	Dom	**0.30**	Eco-Rec	0.09
	DIN	mg/ℓ	**0.28**	0.36	0.25	Eco	**0.40**	Eco-Rec	0.12
	Si	mg/ℓ	**10.8**	10.4	20	In3	**20**	Eco-Rec	9.2
Response variable	Chl-a*	µg/ℓ	**2**	–	15	RFull	**5**	Eco-I	3
	Diatoms*	SPI	**6.9-14.9**	–	–	–	**13– 17**	Good qual	-
	*E. coli**	/100mℓ	**792**	–	–	–	**130**	RFull	-662

***** Snapshot values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s**: downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.1.3 Preliminary RWQOs for Aliwal North (OS2)

The water quality at Aliwal North was almost the same as at Oranjedraai that result in almost the same RWQOs (**Table 21**). The diatom score at Aliwal North was surprisingly low (SPI = 10.9), indicating moderate water quality. Diatom samples were collected from riparian vegetation because no lose rocks could be found in the sandy river bed.

Table 21: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Aliwal North – Upper Orange WMA - Orange River – level 1.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hard-Tot	mg/ℓ	**119**	–	175	AAq-A	**175**	–	56
	EC	mS/m	**28.7**	29.1	70	Dom In3	**40**	AIr-I; d/s	11.3
	pH 5th	Unit	**7.3**	–	6.5	AIr In3	**6.9**	5 % dev	0.4
	pH 95th	Unit	**8.3**	–	8.0	In3	**8.4**	AIr Nat.	0.1
Chemical variables	Alkalinity	mg/ℓ	**121**	121	97.5	AAq	**175**	AAq-T	54
	Ammonia	µg/ℓ	**7**	–	15	AAq	**15**	–	8
	Calcium	mg/ℓ	**27.4**	27.4	10	Dom	**80**	BHN	52.6
	Chloride	mg/ℓ	**8.3**	5.56	100	Dom AIr	**40**	5x, d/s	31.7
	Fluoride	mg/ℓ	**0.25**	0.25	0.70	Dom-I	**0.70**	–	0.45
	Magnesium	mg/ℓ	**12.2**	12.4	70	Dom	**30**	–	17.8
	Potassium	mg/ℓ	**1.4**	2.7	25	Dom–I	**25**	Dom-I, d/s	23.6
	SAR	Mmol/ℓ	**0.37**	0.53	2.0	AIr	**1.5**	AIr-soil	1.13
	Sodium	mg/ℓ	**7.2**	11.9	70	AIr	**40**	5x, d/s	32.8
	Sulphate	mg/ℓ	**15.6**	12.3	200	Dom In3	**80**	5x d/s	64.4
	TDS	mg/ℓ	**216**	256	260	AIr	**260**	–	44
Chemical Inorganic salts	$MgSO_4$	mg/ℓ	**18.76**	–	16	Eco-I	**23**	Eco-A	4.24
	Na_2SO_4	mg/ℓ	**1.24**	–	20	Eco-I	**20**	–	18.76
	$MgCl_2$	mg/ℓ	**2.07**	–	15	Eco-I	**15**	–	12.93
	$CaCl_2$	mg/ℓ	**5.23**	–	21	Eco-I	**21**	–	15.77
	NaCl	mg/ℓ	**7.22**	–	45	Eco-I	**45**	–	37.8
Nutrients	PO_4-P	µg/ℓ	**34**	32	10	AAq	**45**	Eco-Rec	11
	NO_3&NO_2-N	mg/ℓ	**0.37**	0.54	6.0	Dom	**0.40**	Eco-Rec	0.03
	DIN	mg/ℓ	**0.38**	0.095	0.25	Eco	**0.50**	Eco-Rec	0.12
	Si	mg/ℓ	**11.1**	11.3	20	In3	**20**	Eco	8.9
Response variable	Chl-a*	µg/ℓ	**8**	–	15	RFull	**10**	Eco-Nat	2
	Diatoms*	SPI	**10.9**	–	–	–	**13– 17**	Good qual	-
	*E. coli**	/100mℓ	**123**	–	–	–	**130**	RFull	7

* Snapshot mean values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Cal-A**: Calibrated Acceptable (modified benchmark); **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.1.4 Preliminary RWQOs for Saamwerk (OS3)

Saamwerk is a new site (upstream of Gariep Dam) and the present state is based only on the results of 2 snapshot surveys (2008), therefore, low confidence RWQO values. The *E. coli* counts ranged between 46 (low flow) and 1 986 cfu/100 mℓ (high flow – very turbid conditions).

Table 22: Present state (snapshot mean), and preliminary Resource Water Quality Objectives (RWQOs) for Saamwerk – Upper Orange WMA - Orange River – level 1

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hard-Tot	mg/ℓ	**80**	–	175	AAq-A	**175**	–	95
	EC	mS/m	**18**	–	70	Dom-I In3	**40**	AIr-I; d/s	22
	pH 5th	Unit		–	–	–	–	–	–
	pH 95th	Unit	**8.4**	–	8.0	In3	**8.4**	AIr	0.0
Chemical variables	Alkalinity	mg/ℓ	**87**	–	97.5	AAq-A	**97.5**	–	10.5
	Ammonia	µg/ℓ	**7**	–	15	AAq	**15**	–	8
	Calcium	mg/ℓ	**21**	–	10	Dom	**60**	3x d/s	39
	Chloride	mg/ℓ	**5.2**	–	100	Dom AIr	**30**	5x, d/s	24.8
	Fluoride	mg/ℓ	**0.08**	–	0.70	Dom-I	**0.70**	–	0.62
	Magnesium	mg/ℓ	**6.9**	–	70	Dom	**40**	5x d/s	33.1
	Potassium	mg/ℓ	**0.8**	–	25	Dom–I	**4**	5x d/s	4.8
	SAR	mmol/ℓ	**0.33**	–	2.0	AIr	**1.5**	AIr-soil	1.17
	Sodium	mg/ℓ	**6.7**	–	70	AIr	**40**	5x, d/s	33.3
	Sulphate	mg/ℓ	**8.1**	–	200	Dom In3	**40**	5x d/s	31.9
	TDS	mg/ℓ	**143**	–	260	AIr	**260**	–	117
Nutrients	PO_4-P	µg/ℓ	**28**	–	10	AAq	**30**	Eco-A	2
	NO_3&NO_2-N	mg/ℓ	**0.22**	–	6.0	Dom	**0.30**	Eco-Rec	0.08
	DIN	mg/ℓ	**0.29**	–	0.25	Eco-I	**0.40**	Eco-Rec	0.11
	Si	mg/ℓ	**7.7**	–	20	In3	**20**	Eco	12.3
Response variable	Chl-a*	µg/ℓ	**6**	–	15	RFull	**10**	Eco-Nat	4
	Diatoms*	SPI	**13.4**	–	–	–	**13– 17**	Good qual	
	*E. coli**	/100mℓ	**1 006**	–	–	–	**130**	RFull	-876

***** Snapshot mean values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.1.5 Preliminary RWQOs for Gariep Dam (OSD1)

The Gariep Dam is the largest dam in the country and marks the end of visioning area 1. The water quality in Gariep Dam was very similar to the upstream points, therefore, almost the same RWQOs as the upstream sites. However, the low diatom score (SPI, 7.8) indicates poor quality.

Table 23: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Gariep Dam – Upper Orange WMA - Orange River – level 1.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hard-Tot	mg/ℓ	**90**	–	175	AAq-A	**175**	–	85
	EC	mS/m	**23.9**	19.7	70	Dom-I In3	**40**	AIr-I; d/s	16.1
	pH 5th	Unit	**7.3**	–	6.5	AIr In3	**6.9**	5 % dev	0.4
	pH 95th	Unit	**8.3**	–	8.0	In3	**8.4**	AIr Nat.	0.1
Chemical variables	Alkalinity	mg/ℓ	**89.6**	84.5	97.5	AAq	**175**	AAq-T	85.4
	Ammonia	µg/ℓ	**10**	–	15	AAq	**15**	–	5
	Calcium	mg/ℓ	**22.7**	19.2	10	Dom	**60**	2x d/s	37.3
	Chloride	mg/ℓ	**8.4**	5.50	100	Dom AIr	**40**	5x, d/s	31.6
	Fluoride	mg/ℓ	**0.21**	0.27	0.70	Dom-I	**0.70**	–	0.49
	Magnesium	mg/ℓ	**8.3**	7.9	70	Dom	**30**	–	21.7
	Potassium	mg/ℓ	**2.1**	2.7	25	Dom–I	**25**	Dom-I, d/s	22.9
	SAR	mmol/ℓ	**0.38**	0.41	2.0	AIr	**1.5**	AIr-soil	1.12
	Sodium	mg/ℓ	**8.1**	8.1	70	AIr	**40**	5x, d/s	41.9
	Sulphate	mg/ℓ	**15.8**	10.1	200	Dom In3	**60**	4x d/s	44.2
	TDS	mg/ℓ	**168**	–	260	AIr	**260**	–	92
Nutrients	PO_4-P	µg/ℓ	**29**	25	10	AAq	**40**	Eco-Rec	11
	NO_3&NO_2-N	mg/ℓ	**0.28**	0.81	6.0	Dom	**0.40**	Eco-Rec	0.12
	DIN	mg/ℓ	**0.37**	–	0.25	Eco-I	**0.50**	Eco-Rec	0.13
	Si	mg/ℓ	**9.0**	–	20	In3	**20**	Eco	11
Response variable	Chl-a*	µg/ℓ	**4.9**	–	15	RFull	**10**	Eco-I	5.1
	Diatoms*	SPI	**7.8**	–	–	–	**13– 17**	Good qual	-5.2
	*E. coli**	/100mℓ	**12**	–	–	–	**130**	RFull	118

* Snapshot mean values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.1.6 Preliminary RWQOs for Roodepoort (OS4)

Visioning area 2 starts here, *i.e.* from below Gariep Dam to Marksdrift. The present water quality below Gariep Dam was very similar to the quality inside the dam, thus almost the same RWQOs as the upstream sites.

The snapshot samples were taken at Waschbank (approximately 1 km downstream of the dam wall at the old iron bridge) and on both occasions the diatom results indicate 'no count possible' that indicate poor habitat conditions below Gariep Dam wall probably linked to the unnatural water releases from the dam (see also Report No. 3).

Table 24: Background information on Roodepoort in Orange River – WMA 13

River:	Orange	**Study Unit:**	Roodepoort	**Quat.:**	D34A	**WQM site:**	D3H013
PES:	D	**REC:**	B	**EISC:**	Moderate	**Reference state:**	1976 – 1980 (n≈ 76)
Management Class:		Natural				**Present State:**	2005 – 2007 (n ≈97)
RWQO Model Vers:		4.1					

Table 25: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Roodepoort (OS4) – Upper Orange WMA – Orange River – level 1.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hard-Tot	mg/ℓ	**89**	–	175	AAq-A	**175**	–	86
	EC	mS/m	**22.7**	29.7	70	Dom-I In3	**40**	AIr-I; d/s	17.3
	pH 5th	Unit	**7.7**	–	6.5	AIr In3	**7.3**	5 % dev	0.4
	pH 95th	Unit	**8.2**	–	8.0	In3	**8.4**	AIr Nat.	0.2
Chemical variables	Alkalinity	mg/ℓ	**89.6**	132	97.5	AAq	**175**	AAq-T	85.4
	Ammonia	µg/ℓ	**9**	–	15	AAq	**15**	–	6
	Calcium	mg/ℓ	**22.2**	27.9	10	Dom-I	**60**	2x d/s	37.8
	Chloride	mg/ℓ	**8.0**	7.0	100	Dom Air	**40**	5x, d/s	32
	Fluoride	mg/ℓ	**0.23**	0.32	0.70	Dom-I	**0.70**	–	0.47
	Magnesium	mg/ℓ	**8.2**	11.8	70	Dom	**30**	–	21.8
	Potassium	mg/ℓ	**1.7**	3.7	25	Dom–I	**10**	5x, d/s	8.3
	SAR	mmol/ℓ	**0.37**	0.60	2.0	Air	**1.5**	AIr-soil	1.13
	Sodium	mg/ℓ	**7.8**	13.8	70	Air	**40**	5x, d/s	32.2
	Sulphate	mg/ℓ	**16.1**	8.6	200	Dom In3	**80**	5x d/s	63.9
	TDS	mg/ℓ	**167**	230.7	260	Air	**260**	–	93
Nutrients	PO_4-P	µg/ℓ	**32**	13	10	AAq	**40**	Eco-Rec	8
	NO_3&NO_2-N	mg/ℓ	**0.28**	0.21	6.0	Dom	**0.40**	Eco-Rec	0.12
	DIN	mg/ℓ	**0.35**	0.25	0.25	Eco-I	**0.50**	Eco-Rec	0.15
	Si	mg/ℓ	**9.1**	9.6	20	In3	**20**	Eco-Rec	10.9
Response variable	Chl-a*	µg/ℓ	**5**	–	15	RFull	**10**	Eco-I	5
	Diatoms*	SPI	**–**	–	–	–	**9 – 13**	Mod qual	-
	*E. coli**	/100mℓ	**6**	–	–	–	**130**	RFull	124

***** Snapshot mean values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.1.7 Preliminary RWQOs for Vanderkloof Dam (OSD2)

The water quality in Vanderkloof Dam was characterised by very low TN and TP concentrations and low chl-a concentrations. Vanderkloof Dam is the first site with metal concentrations. See Marksdrift for the RWQOs of metals (**Table 30**).

Table 26: Background information on Vanderkloof Dam in Orange River – WMA 13

River:	Orange	**Study Unit:**	Vanderkloof Dam	**Quat.:**	D31E	**WQM site:**	D3R003
PES:	E-F	**REC:**	E or F not an acceptable class	**EISC:**	Low/ marginal	**Reference state:**	1976–1979 (n≈122)
Management Class:						**Present State:**	2005–2007 (n ≈ 45)
RWQO Model Vers:		4.1					

Table 27: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Vanderkloof Dam (OSD1) – Upper Orange WMA - Orange River – level 1.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hard-Tot	mg/ℓ	**87**	–	175	AAq-A	**175**	–	88
	EC	mS/m	**22.6**	18.4	70	Dom-I In3	**40**	AIr-I; d/s	17.4
	pH 5th	Unit	**7.5**	–	6.5	AIr In3	**7.1**	5 % dev	0.4
	pH 95th	Unit	**8.2**	–	8.0	In3	**8.4**	AIr Nat.	0.2
Chemical variables	Alkalinity	mg/ℓ	**89**	74.3	97.5	AAq-A	**175**	AAq-T	86
	Ammonia	µg/ℓ	**7**	–	300	AAq-A	**15**	Eco-I	8
	Calcium	mg/ℓ	**22.4**	18.6	10	Dom-I	**60**	2x d/s	37.6
	Chloride	mg/ℓ	**7.6**	7.0	100	Dom AIr	**40**	5x, d/s	32.4
	Fluoride	mg/ℓ	**0.22**	0.23	0.70	Dom-I	**0.70**	–	0.48
	Magnesium	mg/ℓ	**8.2**	7.6	70	Dom-I	**40**	5x d/s	31.8
	Potassium	mg/ℓ	**1.8**	1.96	25	Dom–I	**10**	Dom-I, d/s	23.2
	SAR	mmol/ℓ	**0.38**	0.39	2.0	AIr-I	**1.5**	AIr-soil	1.12
	Sodium	mg/ℓ	**8.0**	7.5	70	AIr-I	**40**	5x, d/s	42
	Sulphate	mg/ℓ	**14.5**	9.6	200	Dom-I In3	**80**	5x d/s	65.5
	TDS	mg/ℓ	**162**	136	260	AIr-I	**260**	–	98
Chemical micro & metals	Al	µg/ℓ	**76**	–	70	AAq	**100**	AAq-T	24
	B	µg/ℓ	**30**	33	500	Air	**150**	5x d/s	120
	Cd	µg/ℓ	**5**	–	0.000	Dom-I	**10**	Dom-A	5
	Cr (III)	µg/ℓ	**3**	–	–		**24**	Eco-I	21
	Cu	µg/ℓ	**15**	–	200	AAq	**15**	Rec-Pr	0
	Fe	µg/ℓ	**130**	–	300	AAq	**300**	–	170
	Mn	µg/ℓ	**12**	–	20	AIr-I	**20**	–	8
	Mo	µg/ℓ	**16**	–	10	AIr-I, ASw	**20**	AIr-T	4
	Ni	µg/ℓ	**10**	–	200	AIr-I	**50**	5x d/s	190
	Pb	µg/ℓ	**54**	–	100	AAq	**100**	–	46
	V	µg/ℓ	**17**	–	100	AIr	**100**	–	83
	Zn	µg/ℓ	**34**	–	1 000	AIr	**36**	Eco-T	2
Nutrients	PO_4-P	µg/ℓ	**24**	36	10	AAq	**43**	Cal-A	19
	NO_3&NO_2-N	mg/ℓ	**0.22**	0.76	6.0	Dom	**0.40**	Eco-Rec	0.18
	DIN	mg/ℓ	**0.28**	0.83	0.25	Eco	**0.50**	Eco-Rec	0.22
	Si	mg/ℓ	**8.4**	8.9	20	In3	**20**	Eco	11.6
Response variable	Chl-a	µg/ℓ	**2.4**	–	15	RFull	**5**	Eco-Rec	2.6
	Diatoms*	SPI	**13.2**	–	–	–	**13– 17**	Good qual	–
	*E. coli**	/100mℓ	**66**	–	–	–	**130**	RFull	64

***** Snapshot mean values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.1.8 Preliminary RWQOs for Dooren Kuilen (OS5)

Dooren Kuilen is just below Vanderkloof Dam with very similar water quality concentrations than inside the dam, resulting in similar RWQOs.

Table 28: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Dooren Kuilen – Upper Orange WMA - Orange River – level 1

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hard-Tot	mg/ℓ	**88**	–	175	AAq-A	**175**	–	87
	EC	mS/m	**22.1**	18.6	70	Dom In3	**40**	AIr-I; d/s	17.9
	pH 5th	Unit	**7.5**	–	6.5	AIr In3	**7.1**	5 % dev	0.4
	pH 95th	Unit	**8.1**	–	8.0	In3	**8.4**	AIr Nat.	0.3
Chemical variables	Alkalinity	mg/ℓ	**92**	83.4	97.5	AAq-A	**175**	AAq-T	83
	Ammonia	µg/ℓ	**5**	–	300	AAq-A	**15**	Eco-I	10
	Calcium	mg/ℓ	**22.5**	20.3	10	Dom-I	**60**	2x d/s	37.5
	Chloride	mg/ℓ	**7.9**	10.3	100	Dom Air	**40**	5x, d/s	32.1
	Fluoride	mg/ℓ	**0.22**	0.39	0.70	Dom-I	**0.70**	–	0.48
	Magnesium	mg/ℓ	**8.6**	6.8	70	Dom-I	**40**	5x d/s	21.4
	Potassium	mg/ℓ	**1.7**	2.8	25	Dom–I	**10**	Dom-I, d/s	23.3
	SAR	mmol/ℓ	**0.38**	0.42	2.0	AIr-I	**1.5**	AIr-soil	1.12
	Sodium	mg/ℓ	**7.9**	7.9	70	AIr-I	**40**	5x, d/s	42.1
	Sulphate	mg/ℓ	**12.8**	20.0	200	Dom In3	**65**	5x d/s	52.2
	TDS	mg/ℓ	**163**	153	260	AIr-I	**260**	–	97
Nutrients	PO_4-P	µg/ℓ	**21**	60	10	AAq	**40**	Eco-Rec	19
	NO_3&NO_2-N	mg/ℓ	**0.27**	0.61	6.0	Dom	**0.40**	Eco-Rec	0.13
	DIN	mg/ℓ	**0.33**	0.71	0.25	Eco	**0.50**	Eco-Rec	0.17
	Si	mg/ℓ	**8.5**	9.8	20	In3	**20**	Eco	11.5
Response variable	Chl-a*	µg/ℓ	**6**	–	15	RFull	**10**	Eco-I	4
	Diatoms*	SPI	**13.1**	–	–	–	**13– 17**	Good qual	–
	*E. coli**	/100mℓ	**5**	–	–	–	**130**	RFull	125

***** Snapshot mean values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.1.9 Preliminary RWQOs for Marksdrift (OS6)

Marksdrift is an important monitoring site and the last one in the Upper Orange WMA. This site was included to represent runoff from the Orange River catchment upstream of the Vaal River confluence. This site was also proposed to be included in SA-Gems/Water monitoring network (Van Niekerk, 2005).

The general water chemistry at Marksdrift does not differ extensively from the upstream points, thus most of the RWQO values are the same as for upstream. However, the dissolved salts increase significantly downstream from Marksdrift (**Figures 8 & 9**) and to make provision for the increases, some of the RWQOs at Marksdrift are set higher than for the upstream points, for example, the RWQO for EC is set at 55 mS/m and thus the RWQO for TDS at 360 mg/ℓ (**Table 31**).

The RWQO for $MgSO_4$ was set at 28 mg/ℓ (maximum for category C systems; DWAF, 2008a), but is still below the present sate concentration of 28.2 mg/ℓ. The present state for Chl-a concentration (18 µg/ℓ) is above the RWQO, but it is based on only 2 measurements during the snapshot survey and would probably be much lower if the mean over an annum is considered.

The PES for Marksdrift is indicated as a D category (poor, based on flow modification), but the REC is a B category (good, **Table 29**), however, in terms of water quality the site is probably a B category and the diatom SPI scores (during both snapshot surveys) also show good water quality (**Table 30**).

Table 29: Background information of Marksdrift on Orange River (Level 1) – Upper Orange WMA 13

River:	Orange	**Study Unit:**	Marksdrift	**Quat.:**	D33K	**WQM site:**	D3H008
PES:	D	**REC:**	B	**EISC:**	High	**Reference state:**	1971–1978 (n ≈ 51)
Management Class:		Moderately impacted				**Present State:**	2005–2007 (n≈140)
RWQO Model Vers:		4.1					

5.1.9.1 Preliminary RWQO for the metals – Marksdrift (Table 30)

Marksdrift and Vanderkloof Dam are the first two monitoring sites with metal concentrations. The metal concentrations were relatively high, but are considered to be largely natural (see Report No. 3). Therefore, different rating values are proposed for the Orange River (see **Table 83**).

Table 30: RWQOs values according to the Model and the Recommended RWQOs and the rationale/motivation for any changes at Oranjedraai (OS1) in the Orange River.

Variable	Unit	RWQO Model	RWQO Recom.	Rationale/Motivation
Aluminium (Al)	µg/ℓ	85	150	The present state concentration for Aluminium at Marksdrift is 100 µg/ℓ, which is higher than the RWQO set by the model of 85 µg/ℓ. An alternative RWQO of 150 µg/ℓ is proposed, which is tolerable for the Aquatic Ecosystem and still Ideal for Domestic use.
Boron (B)	µg/ℓ	750	500	The RWQO for B is, according to the Model, 750 µg/ℓ (Irrigation, acceptable), but a concentration of 500 µg/ℓ (Ideal for Irrigation) is recommended as the RWQO.
Cadmium (Cd)	µg/ℓ	1.0	10	The recommended RWQO for Cd is 10 µg/ℓ, which is acceptable for domestic use and irrigation. The Model's value of 1 µg/ℓ is unrealistically low – the present state concentration is 5 µg/ℓ.
Chromium (Cr)	µg/ℓ	182	24	The Cr concentration was low (present state, 7 µg/ℓ) and the RWQO is set at 24 µg/ℓ (Ecosystem, Ideal) and not the 182 µg/ℓ (Ecosystem Acceptable) proposed by the Model.
Copper (Cu)	µg/ℓ	1.0	10	The present state Cu concentration of 11 µg/ℓ at Marksdrift is above the tolerable range set for aquatic ecosystem (4.6 µg/ℓ). However, a Cu concentration of 10 µg/ℓ is recommended as a realistic RWQO that takes the natural higher concentrations of the Orange River system into account.
Iron (Fe)	µg/ℓ	1 000	70	The Fe concentrations in the upper Orange River is generally low (present state at Marksdrift, 14 µg/ℓ), thus the RWQO for Fe is limited to 70 µg/ℓ (in ideal range for Domestic use) and not the 1 000 µg/ℓ proposed by the Model.

Manganese (Mn)	µg/ℓ	400	20	The RWQO for manganese (Mn) is set at 20 µg/ℓ (Ideal for irrigation, and proposed Tolerable for aquatic ecosystem) and not at the 400 µg/ℓ (acceptable for Irrigation) proposed by the Model.
Molybdenum (Mo)	µg/ℓ	15	20	The Mo concentration at Marksdrift was relatively high (16 µg/ℓ), thus a RWQO of 20 µg/ℓ (acceptable for irrigation and tolerable for stock watering) is recommended because the 15 µg/ℓ proposed by the Model is lower than the present state.
Nickel (Ni)	µg/ℓ	1 100	150	The ideal concentration for Ni in irrigation water is ≤200 µg/ℓ, but 150 is recommended as the RWQO, because it is 5 times higher than the present state. The 1 100 µg/ℓ proposed by the Model is too high for an unpolluted site.
Lead (Pb)	µg/ℓ	54	50	Lead (Pb) – unfortunately no Pb concentrations are available at Marksdrift. However, a RWQO of 50 µg/ℓ (ideal for domestic use) is proposed. The 95th percentile concentration at Vanderkloof Dam is 54 µg/ℓ.
Vanadium (V)	µg/ℓ	550	60	The Vanadium (V) is presently low (11 µg/ℓ) and can 'safely' increase (5x) to 60 µg/ℓ and still be ideal for domestic use and irrigation, thus the recommended RWQO. The 550 µg/ℓ proposed by the Model is not ideal for domestic use.
Zinc (Zn)	µg/ℓ	1 000	36	The Zn RWQO is recommended to be 36 µg/ℓ (tolerable for Aquatic Ecosystems) and not the 1 000 µg/ℓ proposed by the Model (Ideal for Irrigation). The recommended RWQO value is comparable to the most common natural concentration for Zn in World Rivers is 30 µg/ℓ (Martin & Meybeck, 1979).

Table 31: Present state, Reference values, preliminary Resource Water Quality Objectives (RWQOs) and Allocatable values for Marksdrift (OS6) – Upper Orange WMA - Orange River – level 1.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hardness	mg/ℓ	**102**	–	250	Dom	**175**	AAq	73
	EC	mS/m	**29.7**	28.2	70	Dom In3	**55**	Eco-A d/s	25.3
	pH 5th	Units	**7.5**	6.9	6.5	AIr In3	**7.1**	5 % dev	0.4
	pH 95th	Units	**8.3**	8.1	8.0	In3	**8.4**	AIr-I	0.1
Chemical variables	Alkalinity	mg/ℓ	**100**	117	300	In3	**175**	AAq d/s	75
	Ammonia	µg/ℓ	**10**	–	58	Eco-G	**15**	Eco-N	5
	Calcium	mg/ℓ	**24.8**	29.7	80	Dom	**80**	BHN	55.2
	Chloride	mg/ℓ	**13.2**	9.7	100	Dom AIr	**50**	D/s	86.8
	Fluoride	mg/ℓ	**0.25**	0.31	1.0	Dom	**0.75**	Eco-Nat	0.50
	Magnesium	mg/ℓ	**10.1**	10.5	100	Dom	**30**	Dom-I	19.9
	Potassium	mg/ℓ	**1.9**	1.8	50	Dom	**25**	Dom-I	23.1
	SAR	mmol/ℓ	**0.63**	0.53	2.0	AIr	**1.5**	AIr-soil	0.87
	Sodium	mg/ℓ	**13.7**	10.8	70	AIr	**70**	–	36.3
	Sulphate	mg/ℓ	**20.8**	11.0	200	Dom In3	**60**	Rec; d/s	39.2
	TDS	mg/ℓ	**196**	199	260	AIr	**360**	Eco-A	164
Chemical Inorganic salts	$MgSO_4$	mg/ℓ	**28.2**	–	27	Eco-A	**27**	–	-1.2
	Na_2SO_4	mg/ℓ	**0.34**	–	36	Eco-A	**36**	–	35.66
	$MgCl_2$	mg/ℓ	**3.10**	–	33	Eco-A	**33**	–	29.9
	$CaCl_2$	mg/ℓ	**8.80**	–	63	Eco-A	**63**	–	54.2
	NaCl	mg/ℓ	**13.1**	–	217	Eco-A	**217**	–	203.7
Chemical micro & metals	Al	µg/ℓ	**100**	–	85	ASw AIr	**150**	Eco-T	50
	B	µg/ℓ	**140**	–	750	AIr-A	**500**	AIr-I	360
	Cd	µg/ℓ	**5**	–	1	Dom	**10**	Dom AIr	5
	Cr (III)	µg/ℓ	**7**	–	182	Eco-G	**24**	Eco-N	17
	Cu	µg/ℓ	**11**	–	1.0	AIr	**10**	Rec-Pr	-1
	Fe	µg/ℓ	**14**	–	1 000	In3	**70**	Dom-I	56
	Mn	µg/ℓ	**7**	–	400	AIr-A	**20**	AIr-I	13
	Mo	µg/ℓ	**16**	–	15	ASw AIr	**20**	ASw-T	4
	Ni	µg/ℓ	**33**	–	1 100	AIr-A	**150**	5x, Air-I	117
	Pb	µg/ℓ	**54***2	–			**50**	Dom-A	-4
	V	µg/ℓ	**11**	–	550	AIr-A	**60**	AIr-I	49
	Zn	µg/ℓ	**29**	–	1 000	AIr	**36**	Eco-T	7
Nutrients	PO_4-P	µg/ℓ	**22**	14	30	Eco	**30**	Eco-I	8
	NO_3&NO_2-N	mg/ℓ	**0.31**	0.06	6.0	Dom	**0.50**	Eco-Pro	0.19
	DIN	mg/ℓ	**0.34**	0.19	1.0	Eco-G	**0.70**	Eco-A	0.36
	Si	mg/ℓ	**8.5**	9.9	20	AIr	**20**	–	11.5
Response variable	Chl-a*	µg/ℓ	**18**	–	10	Eco	**10**	–	-8
	Diatoms*	SPI	**14.4**	–	–	–	**13– 17**	Good qual	
	*E. coli**	/100mℓ	**50**	–	–	–	**130**	RFull	80

* Snapshot values; *2 Vanderkloof Dam value; **AAq**: Agriculture–Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture–Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Cat:** Category; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **F:** fair; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation–Full contact; **T:** Tolerable.

5.1.10 Orange River tributaries – Level 2

The Present ecological status of the Orange River tributaries were in a fair condition with two sites in the B and 2 in the C category (**Table 2**). The PES for Sterkspruit is unknown because quaternary D12C is indicated as the Orange River (PES B).

Kornetspruit, Sterkspruit and Kraai River show similar characteristics in terms of dissolved salt ions **(Figure 12)**. The ions concentrations in Sterkspruit seems to be a little lower than in the other two systems, but the Sterkspruit concentrations are based only on the 2 measurements determined during the snapshot surveys. The main difference between these systems is the suspended material carried by the stream, which is high in Kornetspruit and low in Kraai River. However, the nutrient concentrations (N & P) in Sterkspruit are significantly higher than in Kornetspruit and Kraai River (**Table 32**).

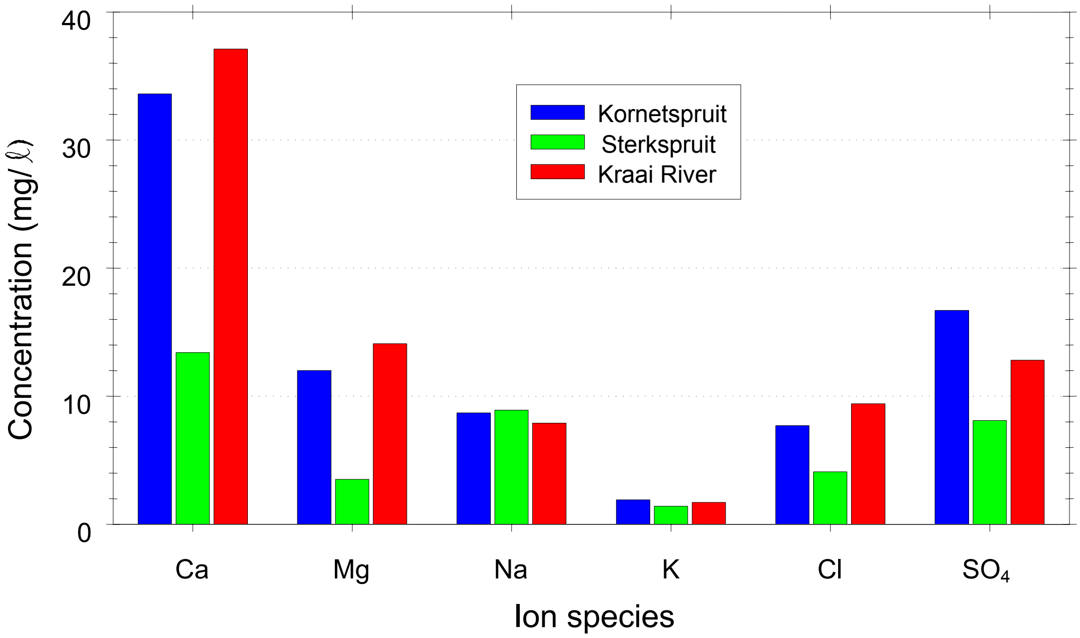

Figure 12: Grouped Bar chart of the Present State (95th percentiles) of major ions concentrations (mg/ℓ) in selected tributaries of the Orange River in Upper Orange Management area.

Table 32: Present state (2005 -2007) and snapshot values (2008) at different sites in Orange River tributaries – level 2 (WMA 13)

PES	Sample site (Quat)	Ca	Cl	Chl-a*	DMS	EC	Flow*	F	Hard T	K	Mg	Na	NH_3	NO_3 –N*	DIN*	pH*2	PO_4-P*	SAR	Si	SO_4	TAL	TSS	Turb*2
C	Kornetspruit (D15H)	33.6	7.7	3#	237	30.6	12.3	0.24	42.1	1.9	12.0	8.7	.007	0.06	.156	7.4 8.4	.031	0.72	11.4	16.7	131	3933	1.0 487
	Sterkspruit# (D12C)	13.4	4.1	6#	103	11	-	0.12	50	1.4	3.5	8.9	.013	0.41	.538	7.8 8.7	.133	0.78	5.9	8.1	57	792	7 2432
C	Kraai River (D13M)	37.1	9.4	3#	252	35.2	8.1	0.18	49.3	1.7	14.1	7.9	.009	0.04	.111	7.5 8.3	.028	0.37	11.8	12.8	140	12.4	0.5 40.6
D	Stormberg (D14F)	70.5	78.5	15#	845	104	0.17	0.47	157	9.5	45	101	0.12	0.87	1.25	7.8 8.5	.430	1.4	7.5	65.4	377	34.1-	17 52#
D	Seekoei River (D32K)	53.3	90	4#	834	102	0.30	0.77	195	7.4	56	109	.009	0.04	.088	8.0 8.5	.038	2.7	6.5	81	371	5.6	0.5 5.1

PES, Present Ecological State; * 50th percentile; *2, 5th and 95th percentile; # snapshot values

Table 32: continues

PES	Sample site (Quat)	*E. coli*	SPI	DO (%)	DOC	Al	As	Cd	Cu	Fe	Mn	Pb	V	Zn
C	Kornetspruit	2750	13.3	94	2.0	.145	.006	.001	.007	.076	.006	.010	.006	.008
	Sterkspruit	4908	13.6	101	4.1	.384	.006	.001	.008	.206	.081	.010	.006	.007
C	Kraai River	55	11.0	89	1.3	.208	.006	.001	.005	.121	.006	.010	.006	.006
D	Stormberg	1072	7.6	82	6.0	.072	.006	.001	.010	.064	.028	.010	.006	.008
D	Seekoei River	19	12.6	95	6.5	.018	.006	.001	.003	.025	.005	.010	.006	.005

5.1.10.1 Preliminary RWQOs for Kornetspruit – OSL2/1

The catchment of Kornetspruit lies mainly in Lesotho, but the water quality was largely natural. A good chemical data set is available for Kornetspruit.

Table 33: Background information of Kornetspruit (Level 2) – Upper Orange WMA 13

River:	Kornet-spruit	**Study Unit:**	Maghaleen	**Quat.**	D15H	**WQM site:**	D1H006
PES:	C	**REC:**	B	**EISC:**	High	**Reference state:**	1975–1978 (n=82)
Management Class:		Mod				**Present State:**	2005–2007 (n=44)
RWQO Model Vers:		4.1					

Table 34: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Kornetspruit (OSL2/1) – Upper Orange WMA – level 2.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hard-Tot	Mg/ℓ	**42.1**	–	50	AAq-I	**50**	–	7.9
	EC	mS/m	**30.6**	27.2	70	Dom In3	**40**	AAq; d/s	9.4
	pH 5th	Unit	**7.4**	–	6.5	AIr In3 R	**7.0**	5 % dev	0.4
	pH 95th	Unit	**8.4**	–	8.0	In3	**8.4**	AIr Nat.	0
Chemical variables	Alkalinity	Mg/ℓ	**131**	108.7	97.5	AAq	**175**	AAq-T	44
	Ammonia	µg/ℓ	**7**	–	30	AAq	**15**	Eco-I	8
	Calcium	Mg/ℓ	**33.6**	28.0	80	BHN	**80**	–	46.4
	Chloride	Mg/ℓ	**7.7**	3.3	100	Dom Air	**40**	5x; d/s	32.3
	Fluoride	mg/ℓ	**0.24**	0.39	0.7	Dom	**0.7**	–	0.46
	Magnesium	mg/ℓ	**12.0**	10.3	100	Dom-A	**70**	Dom-I, d/s	58
	Potassium	mg/ℓ	**1.9**	2.7	25	Dom	**25**	–	23.1
	SAR	mmol/ℓ	**0.72**	0.42	2.0	AIr	**1.5**	AIr-soil	0.78
	Sodium	mg/ℓ	**8.7**	8.3	70	AIr	**45**	5x, d/s	36.3
	Sulphate	mg/ℓ	**16.7**	13.2	200	Dom In3	**80**	5x d/s	63.3
	TDS	mg/ℓ	**237**	194	260	Air	**260**	Eco-A	23
Nutrients	PO_4-P	µg/ℓ	**31**	29	10	Eco	**40**	Eco-Rec	9
	NO_3&NO_2-N	mg/ℓ	**0.06**	0.36	6	Dom	**0.20**	Eco-Rec	0.16
	DIN	mg/ℓ	**0.16**	0.41	0.25	Eco-I	**0.25**	–	0.09
	Si	mg/ℓ	**11.4**	12.4	20	In3	**20**	Eco	8.6
Response variable	Chl-a*	µg/ℓ	**3**	–	–	–	**10**	Eco-I	7
	Diatoms*	SPI	**13.3**	–	–	–	**13 – 17**	Good qual	–
	*E. coli**	/100mℓ	**2 750**	–	–	–	**130**	RFull	-2620

* Snapshot values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Cat:** Category; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.1.10.2 Preliminary RWQOs for Sterkspruit – OSL2/2

The Sterkspruit site falls in the D12C quaternary area with a PES of C, the REC of a B and the EISC high. The dissolved salts concentration was relatively low, but the high pH, nutrients and *E. coli* concentrations indicate sewage pollution.

Table 35: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Sterkspruit – Upper Orange WMA – level 2

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hard-Tot	mg/ℓ	**50**	–	50	AAq-I	**100**	2x d/s	50
	EC	mS/m	**11**	–	70	Dom In3	**30**	Eco-I, d/s	19
	pH 5th	Unit	**7.8**	–	6.5	AIr	**7.4**	5 % dev	0.4
	pH 95th	Unit	**8.7**	–	8.0	In3	**8.5**	AIr-A	-0.2
Chemical variables	Alkalinity	mg/ℓ	**57**	–	97.5	AAq	**175**	AAq-T	118
	Ammonia	µg/ℓ	**13**	–	30	AAq	**15**	Eco-I	2
	Calcium	mg/ℓ	**13.4**	–	80	BHN	**80**	–	66.6
	Chloride	mg/ℓ	**4.1**	–	100	Dom Air	**20**	5x Rec d/s	15.9
	Fluoride	mg/ℓ	**0.12**	–	0.7	Dom	**0.7**	–	0.58
	Magnesium	mg/ℓ	**3.5**	–	100	Dom-A	**20**	5x, d/s	16.5
	Potassium	mg/ℓ	**1.4**	–	25	Dom	**10**	5x, d/s	8.6
	SAR	mmol/ℓ	**0.78**	–	2.0	AIr	**1.5**	AIr-soil	0.72
	Sodium	mg/ℓ	**8.9**	–	70	AIr	**50**	5x, d/s	41.1
	Sulphate	mg/ℓ	**8.1**	–	200	Dom In3	**40**	5x, d/s	31.9
	TDS	mg/ℓ	**103**	–	260	AIr	**200**	Eco-I	97
Nutrients	PO_4-P	µg/ℓ	**133**	–	10	Eco	**130**	Eco-T	-3
	NO_3&NO_2-N	mg/ℓ	**0.41**	–	6	Dom	**0.55**	Eco-Rec	0.14
	DIN	mg/ℓ	**0.54**	–	0.25	Eco-I	**0.70**	Eco-A	0.16
	Si	mg/ℓ	**5.9**	–	20	In3	**20**	–	14.1
Response variable	Chl-a*	µg/ℓ	**6**	–	–	–	**10**	Eco-I	4
	Diatoms*	SPI	**13.6**	–	–	–	**13 – 17**	Good qual	–
	*E. coli**	/100mℓ	**4 908**	–	–	–	**400**	RFull-T	-4508

* Snapshot values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Cat:** Category; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.1.10.3 Preliminary RWQOs for Kraai River – OSL2/3

The Kraai River drains the Drakensberg D13 catchment towards the Orange River. There are very little potential for human impact although some farming activities does occur in the catchment. Twenty five years of historical flow and water quality data are available. This site was also proposed for inclusion in SA-Gems/Water monitoring network (Van Niekerk, 2005).

Due to the good ecological present state of the Kraai River catchment (tertiary catchment D13); it was proposed that it should form a separate visioning area. However, for the purposes of the first round of visioning, it was included in visioning area 1, but it will be highlighted as a unique area within the larger visioning area (DWAF, 2009). Because of the good quality of water with little impacts, this site was recommended as a global baseline monitoring site (Van Niekerk, 2005). The GEMS/Water definition for baseline stations is as follows (WHO, 1992): "Baseline stations are typically located in undisturbed upstream river stretches where no direct diffuse or point sources of pollution are likely to be found. They will be used to establish the natural water quality conditions, to provide a basis for comparison with stations having significant direct human impact, to determine through trend analyses the influence of long range transport of contaminants and of climatic conditions."

Interesting to note that the RWQOs (**Table 37**) are very similar to the values calculated for the Upper Orange at Oranjedraai (**Table 20**). The reason for the relatively low diatom score (average 11, moderate quality) in the Kraai River is unclear.

The RWQOs according to the Model and the recommended RWQO values ('RWQOs Rec'), are shown in **Table 37.** Motivations for the differences in RWQOs are given in **Table 38**:

Table 36: Background information of Kraai River (Roodewal) – Upper Orange WMA 13

River:	Kraai River	**Study Unit:**	Roodewal	**Quat.**	D13M	**WQM site:**	D1H011
PES:	C	**REC:**	B	**EISC:**	High	**Reference state:**	1971–1975 (n=37)
Management Class:		Natural				**Present State:**	2005–2007 (n=22)
RWQO Model Vers:		4.1					

Table 37: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Kraai River at Roodewal (OSL2/3) – Upper Orange WMA – level 2.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hard-Tot	mg/ℓ	**155**	–	175	AAq-A	**175**	Future use	20
	EC	mS/m	**35.2**	31.4	70	Dom In3	**40**	AAq-I; d/s	4.8
	pH 5th	Unit	**7.5**	7.3	6.5	AIr In3	**7.1**	5 % dev	0.4
	pH 95th	Unit	**8.3**	8.6	8.0	In3	**8.4**	AIr Nat.	0.1
Chemical variables	Alkalinity	mg/ℓ	**140**	141	97.5	AAq	**175**	AAq-T	35
	Ammonia	µg/ℓ	**9**	–	30	AAq	**15**	Eco-I	6
	Calcium	mg/ℓ	**37.1**	36	80	BHN	**60**	2x; d/s	22.9
	Chloride	mg/ℓ	**9.4**	8.2	100	Dom AIr	**20**	2x Rec d/s	10.6
	Fluoride	mg/ℓ	**0.18**	0.22	0.7	Dom	**0.4**	2x Rec	0.22
	Magnesium	mg/ℓ	**14.1**	14.9	100	BHN	**30**	Dom-I, d/s	15.9
	Potassium	mg/ℓ	**1.7**	2.1	25	Dom	**5**	2x, d/s	3.3
	SAR	mmol/ℓ	**0.32**	0.58	2.0	AIr	**1.0**	AIr-soil	0.68
	Sodium	mg/ℓ	**7.9**	12.1	70	AIr	**20**	2x, d/s	12.1
	Sulphate	mg/ℓ	**12.8**	14.1	200	Dom In3	**25**	2x; d/s	12.2
	TDS	mg/ℓ	**252**	220	260	AIr	**260**	Eco-A	8
Nutrients	PO_4-P	µg/ℓ	**28**	20	10	Eco-I	**30**	Eco-A	2
	NO_3&NO_2-N	mg/ℓ	**0.04**	0.23	6	Dom	**0.15**	Eco-Rec	0.11
	DIN	mg/ℓ	**0.11**	–	0.25	Eco-I	**0.20**	Eco-I	0.09
	Si	mg/ℓ	**11.8**	–	20	In3	**20**	Eco-Rec	8.2
Response variable	Chl-a*	µg/ℓ	**3**	–	15	RFull	**10**	Eco-I	7
	Diatoms*	SPI	**8.9-13.1**	–	–	–	**13 – 17**	Good qual	–
	*E. coli**	/100mℓ	**55**	–	–	–	**130**	RFull	75

***** Snapshot values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Cal-A**: Calibrated Acceptable (modified benchmark); **Cat:** Category; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem; requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

Table 38: RWQOs values according to the Model and the Recommended RWQOs and the rationale/motivation for any changes at Kraai River (OSL2/3) – Orange River tributary.

Variable	Unit	RWQO Model	RWQO Recom.	Rationale/Motivation
Tot Hardness	mg/ℓ	175	175	The total hardness of 175 mg/ℓ is acceptable for Aquaculture and ideal for all the other water users, thus accepted as such.
Electrical Conductivity (EC)	mS/m	70	40	EC of 70 is considered to be too high. An EC of 40 is recommended because it is in the Ideal range for irrigation and acceptable for the aquatic ecosystem. It will limits salinisation of the system.
pH (lower)	Unit	6.5	7.1	A RWQO value of 7.1 is recommended, *i.e.* the pH should not be allowed to vary from the range of the background pH values by >0.5 of a pH unit, or by 5 %, and should be assessed by whichever estimate is the more conservative (DWAF, 1996). Present state 7.5.
pH (upper)		8.0	8.4	The upper limit for pH of 8.0 (RWQO – Model) is ideal for Industrial use, but the pH values in the Kraai River are naturally high (present state, 8.3) and a value of 8.4 is recommended which is still ideal for irrigation and as a more natural and practical value.
Alkalinity	mg $CaCO_3$/ℓ	97.5	175	An Alkalinity of 97.5 mg/ℓ is acceptable for aquaculture, but the present state (140 mg/ℓ) and reference value (141 mg/ℓ) are higher than the proposed value, which means that the allocatable value would be negative. A RWQO value of 175 mg/ℓ is recommended, which is tolerable for aquaculture and still ideal for the other users.
Ammonia (NH_3)	µg/ℓ	30	15	The RWQO for ammonia (NH_3) of 30 µg/ℓ is Ideal for aquaculture but the Ideal for Aquatic Ecosystems is 15 µg/ℓ and thus recommended as the RWQO value.
Calcium (Ca)	mg/ℓ	80	60	Ca of 80 mg/ℓ is ideal for basic human need, but a stricter concentration of 60 mg/ℓ is recommended because it is almost a doubling of the present concentration (37.1 mg/ℓ) and to limit excess salts in general – note the allocatable TDS is only 8 mg/ℓ.

Chloride (Cl)	mg/ℓ	100	20	A RWQO of 100 mg/ℓ for chloride (Cl) is considered to be too high because it is 10 times higher than the present state and would cause problems downstream. A concentration of 20 mg/ℓ (2x present state) is recommended, that is also ideal for all water users.
Fluoride (F)	mg/ℓ	0.70	0.40	The fluoride concentration in the Kraai River is low and a concentration of 0.70 mg/ℓ is almost 4x higher than the present state. A concentration of 0.4 mg/ℓ is closer to the natural concentrations.
Magnesium (Mg)	mg/ℓ	100	30	To keep the general salts concentration low, it is recommended that the RWQO value for magnesium (Mg) in the Kraai River is limited to 30 mg/ℓ, which is within the ideal range for domestic water use. The model's value of 100 mg/ℓ is unacceptably high and 7 times higher than the present state.
Potassium (K)	mg/ℓ	25	5	K is a conservative element and very low in the Kraai River (present state = 1.7 mg/ℓ). The RWQO of 25 mg/ℓ (Model value) is excessively high and a concentration of 5 mg/ℓ is recommended – ideal for domestic use and this concentration limits excess salts downstream.
Sodium adsorption ratio (SAR)	mmol/ℓ	2.0	1.0	The SAR is very low in thr Kraai; present state of 0.32 mmol/ℓ. The RWQO according to the model is 2.0 (ideal for crop yield and quality), but a value of 1.0 is recommended that is ideal on soil physical conditions.
Sodium (Na)	mg/ℓ	70	20	The RWQO for Na of 70 mg/ℓ is in the target water quality range for irrigation (crop yield and quality), but a concentration of 20 mg/ℓ is recommended to limit the general salts and prevent excessive downstream concentrations.
Sulphate (SO_4)	mg/ℓ	200	25	The SO_4 concentrations in Kraai is still very low (Present state, 12.8 mg/ℓ) and a RWQO concentration of 25 mg/ℓ is recommended and not the 200 mg/ℓ proposed by the model, which is an order higher than the present state. The lower concentration (25 mg/ℓ) is about 2 times higher than the present state and would limit the general salt levels and prevent excessive downstream SO_4 concentrations, which is specifically a problem downstream in the lower Orange River.

TDS	mg/ℓ	260	260	The RWQO for TDS of 260 mg/ℓ is ideal for irrigation, close to the present state and recommended as such.
Phosphate (PO_4-P)	µg/ℓ	10	30	The mean PO_4 concentration in the Kraai River was relatively high (present state = 28 µg/ℓ). The 10 µg/ℓ, recommended by the Model (Ideal for aquaculture) is too low and below the present state concentration. It is recommended that the phosphate concentration be limited to 30 µg/ℓ (acceptable limit for aquatic ecosystems) to prevent eutrophication in the river.
Nitrate and nitrite nitrogen (NO_3-N)	mg/ℓ	6.0	0.15	The RWQO value for nitrate of 6.0 mg/ℓ (suggest by the Model) is based on the ideal for Domestic use. The recommended RWQO for nitrate is 0.15 mg/ℓ based on the RWQO for DIN of 0.20 mg/ℓ – refer to discussion in paragraph below.
Dissolved Inorganic Nitrogen (DIN)	mg/ℓ	0.25	0.20	The DIN concentration in the Kraai River was relatively low (present state, 0.11 mg/ℓ). The RWQO value of 0.25 mg/ℓ proposed by the Model is more than double the present sate, thus to keep the nutrients low, a RWQO of 0.20 mg/ℓ is recommended and within the range for Oligo-mesotrophic waters (DWAF, 2008a).
Silicon (Si)	mg/ℓ	20	20	Silicon concentration in the Kraai is relatively high (11.8 mg/ℓ), thus the RWQO of 20 mg/ℓ is accepted.
Chlorophyll-a	µg/ℓ	15	10	No response data is available in DWAF historical data set. Data presented in **Table 37** is based on 2 snapshot surveys. The RWQO for Chlorophyll-*a* (Chl-*a*) is recommended as 10 µg/ℓ which corresponds to natural (Oligotrophic) systems. The RWQO value of 15 proposed by the Model is too high and is based on recreational contact and not on the environment.
E. coli	Cfu/100 mℓ	–	130	The mean *E. coli* concentration in the Kraai River was low at 55 cfu/100 mℓ. A RWQO of 130 is proposed that is ideal for full contact recreational use (swimming).
SPI			13 – 17	The Specific Pollution sensitivity Index (SPI) of diatoms ranged between 8.9 (poor quality) and 13.1 (good quality), however, it is expected that the majority of SPI scores at Roodewal would be in the 13 – 17 range (Good quality) and thus recommended as RWQO values.

5.1.10.4 Preliminary RWQOs for Strombergspruit – OSL2/4

The Stormbergspruit and Seekoei River are ionic rich systems, but Stormbergspruit is contaminated by sewage and Seekoei River contains naturally high background salt values, therefore, different RWQOs.

The Stormbergspruit is in a poor condition (PES, D), with especially high salts and high nutrients. Because the system is already under stress, several present state values are higher than the RWQOs, thus negative allocatable values (Pink coloured in **Table 41**). Thus, rehabilitation should be implemented in this spruit. The REC is a B, but this is very idealistic; a C is recommended as more realistic (**Table 40**).

Table 39: Background information on Stormbergspruit – tributary of the Orange River (Level 2) – Upper Orange WMA 13

River:	Stormberg-spruit	**Study Unit:**	At Burgersdorp	**Quat.**	D14HG	**WQM site:**	D1H001
PES:	D	**REC:**	C	**EISC:**	Moderate	**Reference state:**	1975 – 1979 (≈ 51)
Management Class:		Heavily impacted				**Present State:**	2005 – 2007 (n≈20)
RWQO Model Vers:		4.1					

Table 40: Background information on Seekoei River – tributary of the Orange River (Level 2) – Upper Orange WMA 13

River:	Seekoei	**Study Unit:**	At De Eerste Poort	**Quat.**	D32K	**WQM site:**	D3H015
PES:	D	**REC:**	C	**EISC:**	Moderate	**Reference state:**	1981 – 1983 (≈ 62)
Management Class:		Moderately impacted				**Present State:**	2003 – 2007 (n≈10)
RWQO Model Vers:		4.1					

Table 41: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Stormbergspruit – Orange River Tributary; Upper Orange WMA 13.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hardness	mg/ℓ	**157**	–	300	Dom-A	**300**	–	143
	EC	mS/m	**104**	87	120	Dom In3	**85**	Eco-T	-19
	pH 5th		**7.8**	–	6.5	AIr In3	**7.4**	5% dev	0.4
	pH 95th		**7.5**	–	8.4	In3	**8.4**	AIr-I	0.9
	TSS	mg/ℓ	**34**	–	20	In3	**20**	–	-14
Chemical variables	Alkalinity	mg/ℓ	**377**	276	450	In3	**450**	–	73
	Ammonia	µg/ℓ	**12**	–	58	Eco-A	**58**	–	46
	Calcium	mg/ℓ	**70.5**	48.9	150	Dom	**150**	–	79.5
	Chloride	mg/ℓ	**78.5**	59.2	138	Dom AIr	**138**	–	76.5
	Fluoride	mg/ℓ	**0.47**	0.66	1.0	Dom	**1.0**	–	0.53
	Magnesium	mg/ℓ	**45**	46.5	100	Dom-A	**100**	–	55
	Potassium	mg/ℓ	**9.5**	5.6	50	Dom-A	**50**	–	40.5
	SAR	mmol/ℓ	**2.4**	1.99	8.0	AIr-A	**3.0**	AIr-soil-A	0.6
	Sodium	mg/ℓ	**102**	77.2	92.5	AIr-A	**92.5**	–	-9.5
	Sulphate	mg/ℓ	**65.4**	93.2	250	In3-A	**100**	Rec; d/s	34.6
	TDS	mg/ℓ	**845**	696	800	AIr	**550**	Eco-T	-295
Chemical micro & metals	Al	µg/ℓ	**72***	–	85	ASw AIr	**85**	–	13
	As	µg/ℓ	**6***	–	50	Dom	**50**	–	44
	Cd	µg/ℓ	**1.0***	–	1.0	Dom	**10**	Dom AIr	9
	Cu	µg/ℓ	**10***	–	1.0	AIr	**10**	Rec-Pr	0
	Fe	µg/ℓ	**64***	–	1000	In3	**300**	In3-I	236
	Mn	µg/ℓ	**28***	–	400	AIr	**50**	Dom-I	22
	Pb	µg/ℓ	**10***	–	2?	ASw	**50**	Dom-A	40
	V	µg/ℓ	**6***	–	550	AIr-A	**100**	AIr-I	94
	Zn	µg/ℓ	**8***	–	3000	AIr	**35**	Eco-Rec	27
Nutrients	PO_4-P	µg/ℓ	**432**	18	30	Eco	**130**	Eco-T	-302
	NO_3&NO_2-N	mg/ℓ	**0.87**	0.22	10.0	Dom	**0.75**	Eco-Rec	-0.12
	DIN	mg/ℓ	**1.25**	0.38	1.0	Eco	**1.0**	Eco-T	-0.25
	Si	mg/ℓ	**7.5**	7.4	85	AIr	**20**	Eco-Rec	12.5
Response variable	Chl-a*	µg/ℓ	**15**	–	22.5	RFull	**20**	Eco-A	5
	Diatoms*	SPI	**7.6**	–	–	–	**9 – 13**	Mod-qual	-1.4
	*E. coli**	/100mℓ	**1 072**	–	–	–	**400**	RFull-A	-672

* Snapshot values; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.1.10.5 Preliminary RWQOs for Seekoei River – OSL2/5

The water quality in the upper reaches of the Seekoei River is different to the lower reaches due to geology and should be considered during the determination of the RWQOs (DWAF, 2009a). Therefore, the very high salt concentrations are considered to be largely natural.

Table 42: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Seekoei River (OSL2/5) – Orange River Tributary; Upper Orange WMA 13.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hardness	mg/ℓ	**195**	–	375	In3	**300**	Dom-A	105
	EC	mS/m	**102**	140	120	Dom In3	**150**	Dom-A	48
	pH 5th		**8.0**	–	6.5	AIr In3	**7.6**	5% dev	0.4
	pH 95th		**8.5**	–	8.4	In3	**8.5**	AIr Nat	0.0
Chemical variables	Alkalinity	mg/ℓ	**371**	333	450	In3-A	**450**	–	79
	Ammonia	µg/ℓ	**9**	–	58	Eco-G	**15**	–	6
	Calcium	mg/ℓ	**53.3**	41.9	1 500	BHN	**80**	Dom-A	26.7
	Chloride	mg/ℓ	**90**	164	138	AIr In3	**138**	–	48
	Fluoride	mg/ℓ	**0.77**	1.1	4.0	Asw	**1.0**	Dom	0.33
	Magnesium	mg/ℓ	**56**	70	750	BHN	**70**	Dom-A	14
	Potassium	mg/ℓ	**7.4**	5.0	150	BHN	**50**	Dom-I	42.6
	SAR	mmol/ℓ	**2.7**	4.1	8.0	AIr	**6.0**	AIr-soil C	3.3
	Sodium	mg/ℓ	**109**	162	92.5	AIr	**115**	AIr-A	6
	Sulphate	mg/ℓ	**81**	126	250	Dom In3	**150**	Rec; d/s	69
	TDS	mg/ℓ	**834**	943	800	AIr	**1 000**	Dom-T	166
Chemical micro & metals	Al	µg/ℓ	**18**	–	85	ASw AIr	**85**	–	67
	As	µg/ℓ	**6**	–	50	Dom	**50**	–	44
	Cd	µg/ℓ	**1.0**	–	1.0	Dom	**10**	Dom AIr	9
	Cu	µg/ℓ	**3**	–	1.0	AIr	**10**	Rec-Pr	7
	Fe	µg/ℓ	**25**	–	1000	In3	**300**	In3-I	275
	Mn	µg/ℓ	**5**	–	400	AIr	**50**	Dom-I	95
	Pb	µg/ℓ	**10**	–	2?	ASw	**50**	Dom-A	40
	V	µg/ℓ	**6**	–	550	AIr-A	**100**	AIr-I	94
	Zn	µg/ℓ	**5**	–	3000	AIr	**35**	Eco-Rec	30
Nutrients	PO_4-P	µg/ℓ	**38**	28	30	Eco	**50**	Eco Rec	22
	NO_3&NO_2-N	mg/ℓ	**0.04**	0.02	10.0	Dom	**0.20**	Eco-Rec	0.16
	DIN	mg/ℓ	**0.088**	0.085	1.0	Eco	**0.25**	Eco-I	0.162
	Si	mg/ℓ	**6.5**	7.0	85	AIr	**20**	Eco-Rec	13.5
Response variable	Chl-a*	µg/ℓ	**4**	–	22.5	RFull	**10**	Eco-I	6
	Diatoms*	SPI	**12.6**	–	–	–	**9 – 13**	Mod-qual	
	*E. coli**	/100mℓ	**19**	–	-		**130**	RFull-I	111

* Snapshot values; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Mod-qual:** Moderate quality; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.1.11 Caledon River – Main stem (Level 1)

The Caledon River and its tributaries form Visioning Area 3 of the UOWMA. Conservation areas include Golden Gate National Park and the conservation of wetlands (mostly Lesotho). Water quality concerns include increased turbidity in the Caledon River; Sesbania infestation (seeds toxic to animals); localised nutrient loading; manganese in Grootspruit and Welbedacht Dam – might be due to geology (DWAF, 2009a). The PES categories of the Caledon River and tributaries were either a C or a D and the REC one higher (**Table 2**).

Five monitoring sites were identified on the Caledon River, *i.e.* Caledon at the confluence with Little Caledon River (CS1), at Ficksburg (CS2), at Maseru (CS3), Tienfontein pump station (CS4), and Kommissiedrift (CS5). The present state values are given in **Table 43**.

The water quality at the different sites in the Caledon River was comparable (**Figure 13**), however, the TDS concentration at Kommissiedrift (the most downstream site) was significantly higher than the upstream sites (Present state, 437 mg/ℓ) (**Table 43**).

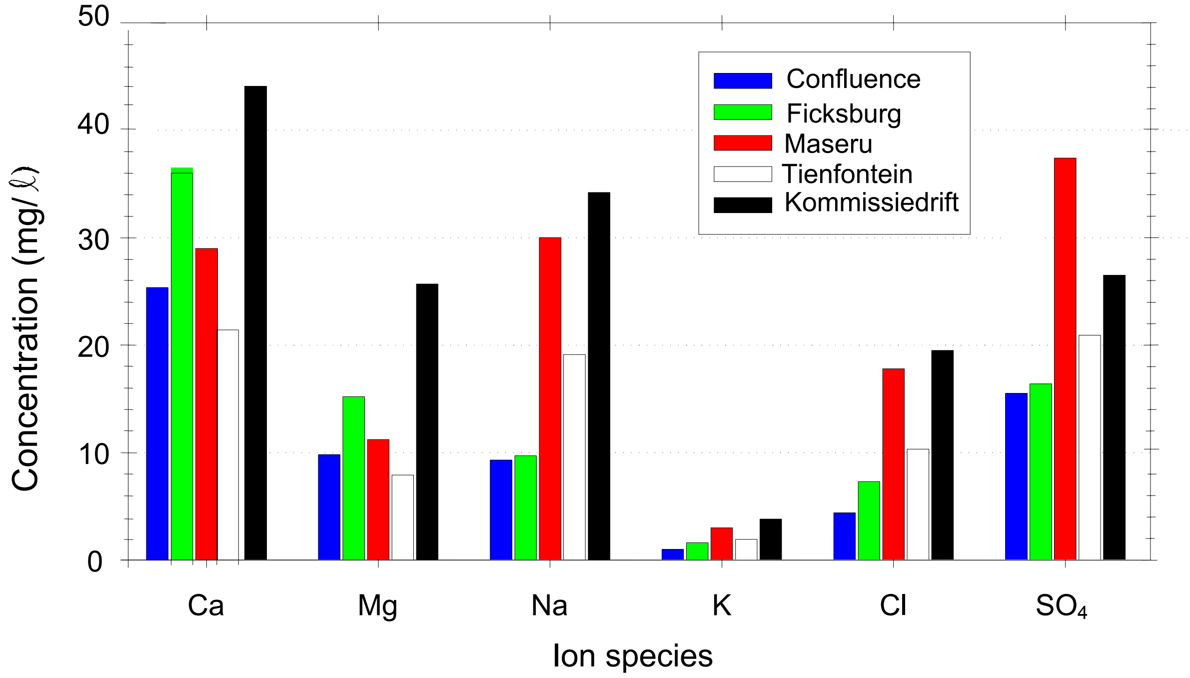

Figure 13: Grouped Bar chart of the Present State (95th percentiles) of major ion concentrations (mg/ℓ) in the Caledon River main stem (level 1).

To accommodate the higher salts in lower Caledon, it is proposed to divide the river in two river reaches (or management areas), *i.e.* River reach 1, from the confluence with the Little Caledon to Maseru and River reach 2, from Maseru to Kommissiedrift.

The RWQO values for Ficksburg are considered to be representative of the upper Caledon (River reach 1) and RWQO values determined for Kommissiedrift be applied from Maseru and downstream (River reach 2).

The higher salts in the lower end of the Caledon River is probably because of irrigation return flows and the accumulation of salts from upstream points, especially return flows from big towns like Ficksburg and Maseru. The high salt concentrations were also present at Wilgedraai, a DWAF site at Hobhouse (D2H037), just downstream of the confluence with the Leeu River (**Figure 14**). The 95 percentile for the period 2005 – 2007 (present state) at Wilgedraai was 460 mg/ℓ.

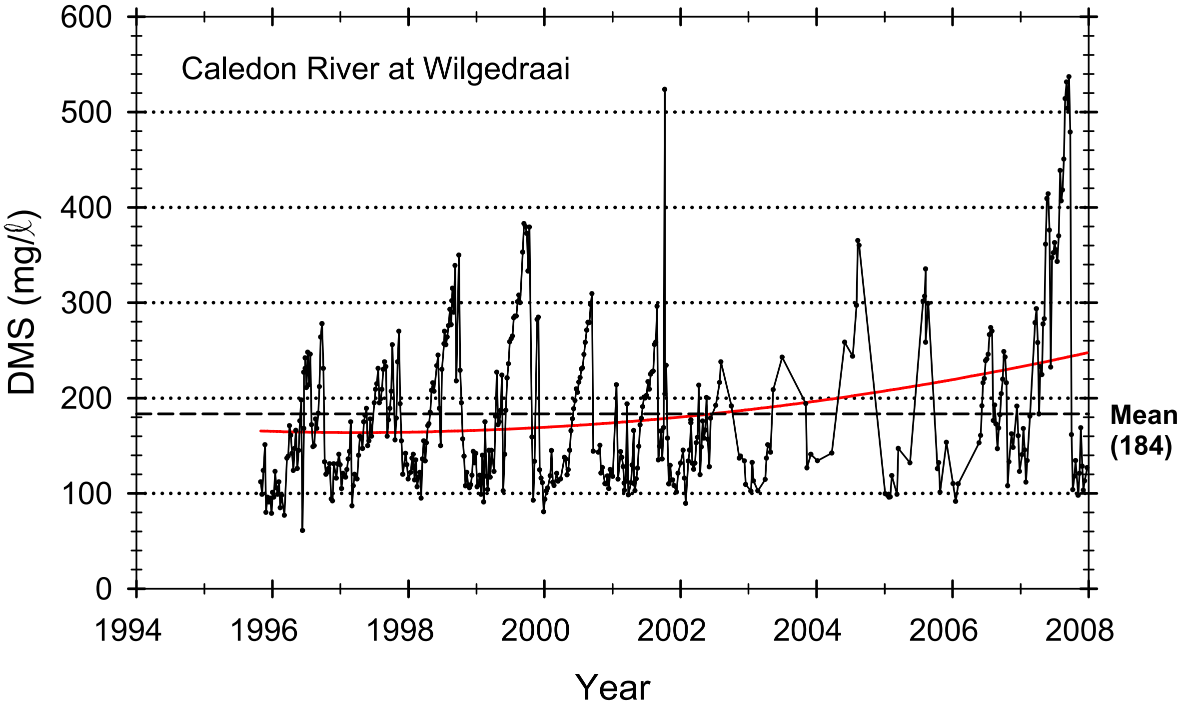

Figure 14: Temporal variation of dissolved major salts (DMS) concentrations (mg/ℓ) in the Caledon River at Wilgedraai/Hobhouse.

Table 43: Present state (2005 – 2007) and snapshot values (2008) at different sites in the Caledon River – level 1 – WMA 13

PES	Sample site (Quat)	Ca	Cl	Chl-a*	DMS	EC	Flow*	F	Hard	K	Mg	Na	NH_3	NO_3 –N*	DIN*	pH	PO_4-P*	SAR	Si	SO_4	TAL	TSS	Turb
D	Caledon-Confl*	25.4	4.4	2	175	18	-	0.05		0.97	9.8	9.3	0.01	0.29	0.40	8.3	.028	0.95	7.8	15.5	102	27.6	13
C	Ficksburg (D22D)	36.5	7.3	-	275	37.4	9.7	0.18	58	1.6	15.2	9.7	.009	0.14	.184	7.5 8.4	.029	0.38	9.4	16.4	159	-	0.5 153
D	Maseru* (D23A)	29	17.8	10	258	27.5	-	0.08	118	3.0	11.2	30	.030	0.36	0.71	8.1	.080	1.0	5.7	37.4	125	42	31
	Tienfontein* (D23J)	21.9	10.3	1.0	181	17	-	0.17	87	1.9	7.9	19.1	.030	0.62	0.80	7.9	.080	0.89	5.73	20.9	92.6	2414	1560
D	Kommissie (D24J)	44.1	19.5	-	437	56.2	-	0.31	90	3.8	25.7	34.2	.011	0.20	0.23	7.5 8.3	.036	1.0	8.2	26.5	231	-	0.5 1540

PES, Present Ecological State; * Snapshot values

PES	Sample site (Quat)	*E. coli*	DO (%)	DOC	Al	Cd	Cu	Fe	Mn	Pb	Zn
C	Caledon-Confl	1244	93	0.68	.146	.001	.005	.124	.010	.010	.016
C	Ficksburg	1643	96.5	1.3	.096	.001	.004	.135	.008	.010	.007
D	Maseru	2420	77	2.5	.076	.001	.022	.088	.007	.010	.008
	Tienfontein	6488	90	2.2	.015	.001	.004	.019	.001	.010	.006
D	Kommissie	284	88	2.4	.293	.001	.007	.154	.010	.010	.007

5.1.11.1 Preliminary RWQOs for Caledon River at Confluence – CS1

The Caledon River at the confluence with the Little Caledon is a new site, thus no historical data, only snapshot data. The water quality in the Caledon River at CS1 was generally good. The site falls in the D22H quaternary area with a PES of C and a REC of a B and the EISC is high.

Table 44: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Caledon River at Confluence – Upper Orange WMA 13 – level 2.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hard-Tot	mg/ℓ	**104**	–	175	AAq-A	**175**	–	71
	EC	mS/m	**18**	–	70	Dom In3	**30**	Eco-I; d/s	12
	pH 5th	Unit	**-**	–	6.5	AIr In3	**7.1**	5 % dev	
	pH 95th	Unit	**8.3**	–	8.0	In3	**8.4**	AIr Nat.	0.1
Chemical variables	Alkalinity	mg/ℓ	**102**	–	97.5	AAq-A	**175**	–	73
	Ammonia	µg/ℓ	**10**	–	58	AAq-A-	**15**	AAq-I	5
	Calcium	mg/ℓ	**25.4**	–	10	Dom	**80**	BHN	54.6
	Chloride	mg/ℓ	**4.4**	–	100	Dom AIr	**25**	5x, d/s	20.6
	Fluoride	mg/ℓ	**0.05**	–	0.7	Dom	**0.7**	–	0.65
	Magnesium	mg/ℓ	**9.8**	–	70	Dom	**30**	Dom-I, d/s	20.2
	Potassium	mg/ℓ	**0.97**	–	25	Dom	**25**	Dom-I, d/s	24.0
	SAR	mmol/ℓ	**0.95**	–	2.0	AIr	**1.5**	AIr-soil	0.55
	Sodium	mg/ℓ	**9.3**	–	70	AIr	**50**	5x, d/s	40.7
	Sulphate	mg/ℓ	**15.5**	–	200	Dom In3	**80**	5x; d/s	64.5
	TDS	mg/ℓ	**175**	–	260	AIr	**195**	Eco-I	20
Nutrients	PO_4-P	µg/ℓ	**28**	–	30	AAq	**50**	Eco-Rec	22
	NO_3&NO_2-N	mg/ℓ	**0.29**	–	6	Dom	**0.40**	Eco-Rec	0.11
	DIN	mg/ℓ	**0.40**	–	1.0	Eco-B	**0.50**	Eco-Rec	0.10
	Si	mg/ℓ	**7.8**	–	20	In3	**20**	Eco	12.2
Response variable	Chl-a*	µg/ℓ	**2**	–	15	Eco	**10**	Eco-I	8
	Diatoms*	SPI	**13.9**	–	–	–	**13 – 17**	Good-qual	-
	*E. coli**	/100mℓ	**1 244**	–	–	–	**400**	RFull-A	-844

* Snapshot values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.1.11.2 Preliminary RWQOs for Ficksburg – CS2

The snapshot surveys have shown that the nutrients concentrations and bacteriological contamination are high downstream of Ficksburg.

Table 45: Background information on the Caledon River at Ficksburg – Level 1 – Upper Orange WMA 13.

River:	Caledon River	**Study Unit:**	Ficksburg	**Quaternary:**	D13M	**WQM site:**	D2H035
PES:	C	**REC:**	B	**EISC:**	High	**Reference state:**	1994–1995 (n = 51)
Management Class:		Natural				**Present State:**	2003–2007 (n = 23)
RWQO Model Vers:		4.1					

Table 46: Present state, Reference values and Resource Water Quality Objectives (RWQOs) for Caledon River at Ficksburg – Upper Orange WMA 13 – level 2

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hard-Tot	mg/ℓ	**154**	–	200	Dom	**200**	–	46
	EC	mS/m	**37.4**	33.4	70	Dom In3	**55**	Max, B; d/s	17.6
	pH 5th	Unit	**7.5**	7.0	6.5	AIr In3 R	**7.1**	5 % dev	0.4
	pH 95th	Unit	**8.4**	8.4	8.0	In3	**8.4**	AIr Nat.	0
Chemical variables	Alkalinity	mg/ℓ	**159**	160	300	In3	**300**	–	141
	Ammonia	µg/ℓ	**9**	-	– ?	-	**15**	Eco-I	6
	Calcium	mg/ℓ	**36.5**	38.2	10	Dom	**80**	BHN	43.5
	Chloride	mg/ℓ	**7.3**	6.8	100	Dom AIr	**40**	5x, d/s	32.7
	Fluoride	mg/ℓ	**0.18**	0.41	0.7	Dom	**0.7**	–	0.52
	Magnesium	mg/ℓ	**15.2**	16.1	70	Dom	**70**	–	54.8
	Potassium	mg/ℓ	**1.6**	3.8	25	Dom-I	**10**	5x, d/s	23.4
	SAR	Mmol/ℓ	**0.38**	0.46	2.0	AIr	**1.5**	AIr-soil	1.12
	Sodium	mg/ℓ	**9.7**	10.8	70	AIr	**50**	5x, d/s	40.3
	Sulphate	mg/ℓ	**16.4**	15.9	200	Dom In3	**80**	5x; d/s	63.6
	TDS	mg/ℓ	**275**	280	260	AIr	**360**	Eco-A	85
Nutrients	PO_4-P	µg/ℓ	**29**	28	10	Eco	**40**	Eco-Rec	11
	NO_3&NO_2-N	mg/ℓ	**0.14**	0.13	6	Dom	**0.20**	Eco-Rec	0.06
	DIN	mg/ℓ	**0.18**	0.15	1.0	Eco-T	**0.30**	Eco-Rec	0.12
	Si	mg/ℓ	**11.8**	7.5	20	In3	**20**	Eco	8.2
Response variable	Chl-a*	µg/ℓ	**6**	–	15	Eco	**15**	Eco-Rec	9
	Diatoms*	SPI	**6.1**	–	–	–	**9 – 13**	Mod-qual	-2.9
	*E. coli**	/100mℓ	**1 643**	–	–	–	**400**	RFull-A	-1243

* Snapshot values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.1.11.3 Preliminary RWQOs for Maseru – CS3

The old monitoring site at Maseru (D2H011) was unfortunately discontinued during 1994. Therefore, a new site was identified downstream of Maseru to monitor impacts from the city. The high phosphate concentrations and high bacteriological counts indicate sewage pollution (**Table 47**). The site falls in the D23A quaternary, the PES is a C with the REC as a B and the EISC is high.

Table 47: Present state (Snapshot), Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Caledon River at Maseru (CS3) – Upper Orange WMA 13.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hard-Tot	mg/ℓ	**118**	–	200	Dom-I	**200**	–	82
	EC	mS/m	**27.5**	–	70	Dom In3	**55**	Eco-A; d/s	27.5
	pH 5th	Unit	**-**	–	6.5	AIr In3	**7.1**	5 % dev	
	pH 95th	Unit	**8.1**	–	8.0	In3	**8.4**	AIr Nat.	0.3
Chemical variables	Alkalinity	mg/ℓ	**125**	–	450	In3-A	**300**	In3–I	175
	Ammonia	µg/ℓ	**30**	–	58	?	**58**	Eco-A	28
	Calcium	mg/ℓ	**29**	–	10	Dom	**80**	BHN	51
	Chloride	mg/ℓ	**17.8**	–	100	Dom AIr	**100**	-	82.2
	Fluoride	mg/ℓ	**0.08**	–	0.7	Dom	**0.7**	–	0.62
	Magnesium	mg/ℓ	**11.2**	–	70	Dom	**30**	Dom-I, d/s	18.8
	Potassium	mg/ℓ	**3.0**	–	25	Dom	**25**	Dom-I, d/s	22
	SAR	mmol/ℓ	**1.0**	–	2.0	AIr	**1.5**	AIr-soil	0.5
	Sodium	mg/ℓ	**30**	–	70	AIr	**70**	-	40
	Sulphate	mg/ℓ	**37.4**	–	200	Dom In3	**200**	-	163
	TDS	mg/ℓ	**258**	–	450	AIr-A	**360**	Eco-A	102
Nutrients	PO_4-P	µg/ℓ	**80**	–	30	?	**100**	Eco-T	20
	NO_3&NO_2-N	mg/ℓ	**0.36**	–	6	Dom	**0.75**	Eco-Rec	0.39
	DIN	mg/ℓ	**0.71**	–	1.0	Eco-B	**1.0**	Eco-T	0.29
	Si	mg/ℓ	**5.7**	–	20	In3	**20**	Eco	14.3
Response variable	Chl-a*	µg/ℓ	**10**	–	15	Eco	**15**	Eco-A	5
	Diatoms*	SPI	**6.9**	–	–	–	**9 – 13**	Mod-qual	-2.1
	*E. coli**	/100mℓ	**2 420**	–	–	–	**400**	RFull-A	-2020

* Snapshot values; **?:** no user indicated; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.1.11.4 Preliminary RWQOs for Tienfontein – CS4

Tienfontein is also a new site, thus limited data. The site is just upstream of Welbedacht Dam and falls in the D23J quaternary. The PES is indicated as a C with the REC a B and the EISC is high.

Table 48: Present state (Snapshot), Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Caledon River at Tienfontein – Upper Orange WMA 13 – level 2

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hard-Tot	mg/ℓ	**87**	–	200	Dom-I	**200**	–	113
	EC	mS/m	**17**	–	70	Dom In3	**30**	Eco-I; d/s	13
	pH 5th	Unit	**-**	–	6.5	AIr In3	**7.1**	5 % dev	
	pH 95th	Unit	**7.9**	–	8.0	In3	**8.4**	AIr Nat.	0.5
Chemical variables	Alkalinity	mg/ℓ	**92.6**	–	300	In3-I	**300**	–	207.4
	Ammonia	µg/ℓ	**30**	–	15	?	**58**	Eco-A	28
	Calcium	mg/ℓ	**21.9**	–	10	Dom	**80**	BHN	58.1
	Chloride	mg/ℓ	**10.3**	–	100	Dom AIr	**100**	-	89.7
	Fluoride	mg/ℓ	**0.17**	–	0.7	Dom	**0.7**	–	0.53
	Magnesium	mg/ℓ	**7.9**	–	70	Dom	**30**	Dom-I, d/s	22.1
	Potassium	mg/ℓ	**1.9**	–	25	Dom	**25**	Dom-I, d/s	23.1
	SAR	mmol/ℓ	**0.89**	–	2.0	AIr	**1.5**	AIr-soil	0.61
	Sodium	mg/ℓ	**19.1**	–	70	AIr	**70**	-	50.9
	Sulphate	mg/ℓ	**20.9**	–	200	Dom In3	**100**	5x, d/s	79.1
	TDS	mg/ℓ	**181**	–	260	AIr-A	**195**	Eco-A	14
Nutrients	PO_4-P	µg/ℓ	**80**	–	10	?	**100**	Eco-Rec	20
	NO_3&NO_2-N	mg/ℓ	**0.62**	–	6	Dom	**0.80**	Eco-Rec	0.18
	DIN	mg/ℓ	**0.80**	–	1.0	Eco-B	**1.0**	Eco-T	0.20
	Si	mg/ℓ	**5.73**	–	20	In3	**20**	Eco	14.27
Response variable	Chl-a*	µg/ℓ	**1.0**	–	15	RFull	**10**	Eco-I	9
	Diatoms*	SPI	–	–	–	–	**9 – 13**	Mod-qual	
	*E. coli**	/100mℓ	**6 488**	–	–	–	**400**	RFull-T	-6088

* Snapshot values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.1.11.5 Preliminary RWQOs for Kommissiedrift – CS5

The water at Kommissiedrift was characterised by high dissolved salts and extremes in turbidity, which range from 0.5 to 10 000 NTU with a mean of 400 NTU that makes the Caledon River probably the most turbid river in South Africa (cf. **Figure 15**) – see also Report No. 3).

Figure 15: Water samples from the Caledon River: on the left is untreated water from the river (raw water) with a turbidity of 1 560 NTU. Second from the left is raw water centrifuged and then filter trough a GF/C glass fibre filter. Third from the left is raw water centrifuged and filter 4 times through GF/C filters. Note the high turbidity still present in the water, indicating coloured organic material and very fine suspended material. On the right is distilled water for comparison.

Table 49: Background information on Caledon River at Kommissiedrift – Level 1 – Upper Orange WMA 13.

River:	Caledon River	**Study Unit:**	Kommissie-drift	**Quaternary:**	D24J	**WQM site:**	D2H036
PES:	C	**REC:**	B	**EISC:**	High	**Reference state:**	1993–1995 (n = 43)
Management Class:		Natural				**Present State:**	2003–2007 (n = 34)
RWQO Model Vers:		4.1					

Table 50: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Caledon River at Kommissiedrift (CS5) – Upper Orange WMA 13.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hard-Tot	mg/ℓ	**90**	–	200	Dom	**200**	–	110
	EC	mS/m	**56.2**	51.2	70	Dom In3	**70**	Eco-T	13.8
	pH 5th	Unit	**7.5**	7.4	6.5	AIr In3	**7.1**	5 % dev	0.4
	pH 95th	Unit	**8.3**	8.6	8.0	In3	**8.4**	AIr Nat.	0.1
Chemical variables	Alkalinity	mg/ℓ	**231**	230	300	In3	**300**	–	69
	Ammonia	µg/ℓ	**11**	31	58	Eco-A	**15**	Eco-N	4
	Calcium	mg/ℓ	**44.1**	40.3	10	Dom	**80**	BHN	35.9
	Chloride	mg/ℓ	**19.5**	11.7	100	Dom Air	**40**	5x, d/s	20.5
	Fluoride	mg/ℓ	**0.31**	0.45	0.7	Dom	**0.7**	–	0.39
	Magnesium	mg/ℓ	**25.7**	28.2	70	Dom	**70**	Dom-I, d/s	44.3
	Potassium	mg/ℓ	**3.8**	4.1	25	Dom	**25**	Dom-I, d/s	21.2
	SAR	mmol/ℓ	**1.0**	0.76	2.0	Air	**1.5**	AIr-soil	0.5
	Sodium	mg/ℓ	**34.2**	28.2	70	Air	**70**		35.8
	Sulphate	mg/ℓ	**26.5**	20.9	200	Dom In3	**80**	3x d/s	53.5
	TDS	mg/ℓ	**437**	406	260	Air	**450**	Eco-T	13
Chemical Inorganic salts	$MgSO_4$	mg/ℓ	**32.6**	–	16	Eco-I	**37**	Eco-T	4.4
	Na_2SO_4	mg/ℓ	**2.4**	–	20	Eco-I	**20**	–	17.6
	$MgCl_2$	mg/ℓ	**2.9**	–	15	Eco-I	**15**	–	12.1
	$CaCl_2$	mg/ℓ	**5.5**	–	21	Eco-I	**21**	–	15.5
	NaCl	mg/ℓ	**27.7**	–	45	Eco-I	**45**	–	17.3
Nutrients	PO_4-P	µg/ℓ	**36**	31	30	Eco	**50**	Eco-Rec	14
	NO_3&NO_2-N	mg/ℓ	**0.20**	0.73	6.0	Dom	**0.25**	Eco-Rec	0.05
	DIN	mg/ℓ	**0.23**	0.75	1.0	Eco-A	**0.35**	Eco-Rec	0.12
	Si	mg/ℓ	**8.2**	6.4	20	In3	**20**	Eco	11.8
Response variable	Chl-a*	µg/ℓ	**7.5**	–	15	Eco	**15**	-	7.5
	Diatoms*	SPI	**12.8**	–	–	–	**9 – 13**	Mod-qual	
	*E. coli**	/100mℓ	**284**	–	–	–	**400**	RFull-T	116

***** Snapshot values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.1.12 Caledon River – tributaries (Level 2)

Five tributaries (six sites) of the Caledon River were identified as potential RWQO sites, *i.e.* Little Caledon River at Golden Gate, and at The Poplars (confluence with Caledon River), Grootspruit, Meulspruit, Moperispruit, and Leeu River. A good chemical data set exists for the Little Caledon River at the confluence, therefore, a set of RWQOs of medium confidence. The present state values (mainly based on the snapshot surveys) are given in **Table 51**.

The water quality in the other tributaries, *i.e.* Little Caledon River at the confluence, Grootspruit, Meulspruit, and Leeu River, were in the same order with comparable ionic concentrations, however, Moperispruit was notably different with fairly high sodium, chloride, and potassium concentrations (**Figure 16**) as well as high nutrients. Grootspruit differ also primarily because of relatively high nutrient concentrations and is grouped together with Moperispruit.

However, separate RWQOs were calculated for the different site – see **Tables 52, 55, 56, 57, 59 and 60**.

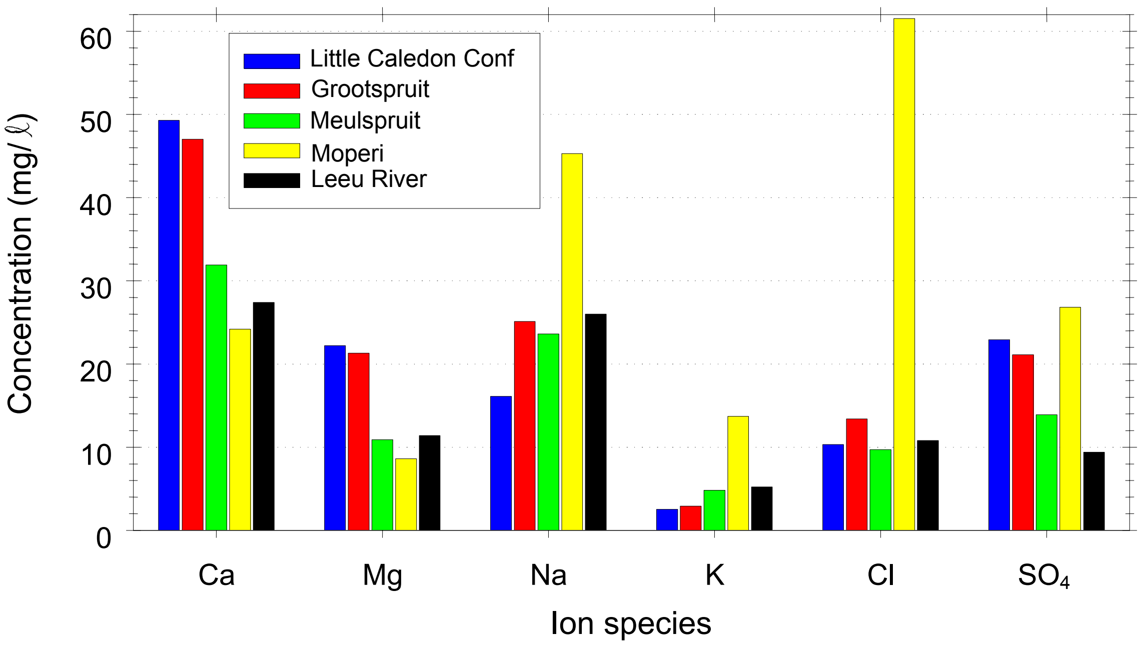

Figure 16: Grouped Bar chart of the Present State (95th percentiles) of major ions concentrations (mg/ℓ) in the tributaries of the Caledon River (level 2).

5.1.12.1 Preliminary RWQOs for Little Caledon River at Golden Gate – CSL2/1

The Little Caledon River downstream of Golden Gate is in a natural (unmodified) state. The water was characterised by very low suspended solids (6 mg/ℓ), low algal biomass (Chl-*a*, 1 µg/ℓ), thus very clear water, and high dissolved oxygen (11 mg/ℓ; 88 %) – see **Figure 17**.

The RWQOs for this site are thus strict to preserve its pristine condition (**Table 52**). However, the confidences level of these RWQOs are low because it's based on only one sampling during the snapshot survey. In the users selected, aquaculture was included as a possible future use.

Figure 17: Secchi Disk (1 m, at bottom) indicates clear water in Little Caledon River close to Golden Gate.

This site falls in the D21E Quaternary drainage region. The PES category for the upper Little Caledon River is a C with a REC as a B. The EISC is high.

Errors occur in the Models Report because the RWQO for Cd and Pb were indicated as 0.000 mg/ℓ (**Table 52**).

Table 51: Present state (2005 – 2007)* and snapshot values (2008) in Caledon tributaries – Level 2 – Upper Orange WMA 13

PES	Sample site (Quat)	Ca	Cl	Chl-a*	DMS	EC	Flow*	F	Hard-T	K	Mg	Na	NH_3	NO_3 –N*	DIN*	pH	PO_4-P*	SAR	Si	SO_4	TAL	TSS	Turb
C	Little Cal–G (D21E)	26.8	2.6	1.0	186	29	-	0.03	107	0.82	9.8	12.3	15	0.14	0.32	8.2	.025	0.52	10.6	11.4	112	6	1
D	Little Cal-Pop (D21G)*	49.3	10.3		381	47.5	0.48	0.20	77.3	2.5	22.2	16.1	0.01	0.04	.113	7.5 8.5	.041	0.48	11.3	22.9	216	-	0.5 31.6
D	Grootspruit (D21H)	47	13.4	10	361	37	-	0.17	204	2.9	21.3	25.1	0.01	0.11	0.20	8.3	.063	0.76	6.3	21.1	224	17.3	10
	Meulspruit (D22D)	31.9	9.7	18	261	30	-	0.23	124	4.8	10.9	23.6	10	0.02	0.21	7.6	0.03	0.92	5.3	13.9	161	45	25
	Moperispruit (D22G)	24.2	61.5	30	300	38	-	0.36	96	13.7	8.6	45.3	13	0.20	0.33	7.5	.075	2.0	3.5	26.8	116	14	11
D	Leeu River (D23E)	27.4	10.8	7.5	241	25	-	0.23	116	5.2	11.4	26	11	0.29	0.39	7.6	0.04	1.1	5.2	9.4	146	37	35

PES, Present Ecological State

PES	Sample site (Quat)	*E. coli*	SPI	DO (%)	DOC	Al	As	Cd	Cu	Fe	Mn	Pb	V	Zn
C	Little Cal–G	179	14	88	1.25	.014	.006	.001	.003	.196	.023	.010	<	.005
C	Little Cal-Pop	119	11.1	94	1.92	.144	.006	.001	.005	.135	.064	.010	.006	.008
D	Grootspruit	573	14.6	110	3.9	.190	.006	.001	.005	.176	.079	.014	.006	.013
	Meulspruit	29	10.5	74	5.95	.050	.006	.001	.004	.119	.039	.010	.006	.007
	Moperispruit	96	8.3	83	8.72	.030	.006	.001	.004	.106	.027	.010	.006	.006
D	Leeu River	1700	14.1	73	5.2	.197	.006	.001	.005	.150	.012	.011	.006	.009

Table 52: Present state (2008 snapshot values), and preliminary Resource Water Quality Objectives (RWQOs) for the Little Caledon River at Golden Gate (CSL2/1) – Caledon Tributary – Level 2 – Upper Orange WMA 13.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hardness	mg/ℓ	**107**	–	200	Dom-A	**175**	AAq-A	68
	EC	mS/m	**29**	–	70	Dom In3	**30**	AIr-I	1
	pH 5th			–	–	–	**7.0**	System	
	pH –upper		**8.2**	–	8.0	In3	**8.4**	AIr Nat	0.2
	TSS	mg/ℓ	**6**	–	5	In3	**10**	In3-A	4
Chemical variables	Alkalinity	mg/ℓ	**112**	–	300	In3	**175**	AAq	63
	Ammonia	µg/ℓ	**15**	–	15	Eco-I	**15**	–	0
	Calcium	mg/ℓ	**26.8**	–	10	Dom	**50**	BHN	23.2
	Chloride	mg/ℓ	**2.6**	–	100	Dom AIr	**5**	2x; d/s	2.4
	Fluoride	mg/ℓ	**0.03**	–	0.7	Dom	**0.1**	2x	0.07
	Magnesium	mg/ℓ	**9.8**	–	70	Dom-A	**20**	Dom-I	10.2
	Potassium	mg/ℓ	**0.82**	–	25	Dom-I	**5**	Rec	9.18
	SAR	mmol/ℓ	**0.52**	–	2.0	AIr	**1.0**	AIr-soil	0.48
	Sodium	mg/ℓ	**12.3**	–	70	AIr	**25**	–	12.7
	Sulphate	mg/ℓ	**11.4**	–	200	Dom In3	**25**	2x; d/s	13.6
	TDS	mg/ℓ	**186**	–	260	AIr	**195**	Eco-I	9
Chemical micro & metals	Al	µg/ℓ	**14**	–	20	ASw AIr	**20**	–	6
	As	µg/ℓ	**6**	–	10	Dom	**10**	–	4
	Cd	µg/ℓ	**1.0**	–	0.000?	Dom	**5**	Dom AIr	4
	Cu	µg/ℓ	**3.0**	–	1.0	AIr	**3.8**	Eco-A	0.8
	Fe	µg/ℓ	**196**	–	300	In3	**300**	In3-I	104
	Mn	µg/ℓ	**23**	–	20	AIr	**50**	Dom-I	27
	Pb	µg/ℓ	**<10**	–	0.000?	ASw	**4**	Eco-A	–
	V	µg/ℓ	**<6**	–	100	AIr-I	**10**	Rec	
	Zn	µg/ℓ	**5**	–	1000	AIr	**10**	Eco-T	30
Nutrients	PO_4-P	µg/ℓ	**25**	–	10	Eco-I	**30**	Eco-A	5
	NO_3&NO_2-N	mg/ℓ	**0.14**	–	6.0	Dom	**0.30**	Eco-Rec	0.16
	DIN	mg/ℓ	**0.32**	–	0.25	Eco	**0.40**	Eco-Rec	0.08
	Si	mg/ℓ	**10.6**	–	20	In3	**20**	Eco	9.4
Response variable	Chl-a	µg/ℓ	**1.0**	–	15	RFull	**5.0**	Eco-I	4.0
	Diatoms	SPI	**14**	–	–	–	**13– 17**	Good qual	
	E. coli	/100mℓ	**179**	–	-	–	**130**	R-Full-I	-49

* Snapshot values; **AAq:** Agriculture – aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

Table 53: RWQOs values according to the Model and the Recommended RWQOs with the rationale/motivation for any changes at Little Caledon River at Golden Gate (CSL2/1) – Caledon River tributary.

Variable	Unit	RWQO Model	RWQO Recom.	Rationale/Motivation
Tot Hardness	mg/ℓ	200	175	The total hardness of 175 mg/ℓ is acceptable for Aquaculture and ideal for all the other water users, thus recommended as such.
Electrical Conductivity (EC)	mS/m	70	30	EC of 70 is considered to be too high. An EC of 40 is recommended because it is in the Ideal range for irrigation and acceptable for the aquatic ecosystem. It limits salinisation of the system.
pH (upper)		8.0	8.4	The upper limit for pH of 8.0 (RWQO – Model) is ideal for Industrial use, but the pH value in the Little Caledon River are naturally high (present state, 8.2) and a value of 8.4 is recommended which is still ideal for irrigation and as a more natural and practical value.
Alkalinity	mg $CaCO_3$/ℓ	300	175	An alkalinity of 300 mg/ℓ is too high; a RWQO value of 175 mg/ℓ is recommended, which is tolerable for aquaculture and still ideal for the other users.
Ammonia (NH_3)	µg/ℓ	15	15	The RWQO for ammonia (NH_3) of 15 µg/ℓ is Ideal for the aquatic ecosystem and the recommended RWQO value.
Calcium (Ca)	mg/ℓ	10	50	Ca of 10 mg/ℓ is ideal for domestic use, but less than the present state (26.8 mg/ℓ). The recommended RWQO value of 50 mg/ℓ is closer to the natural concentration and ideal for basic human health.
Chloride (Cl)	mg/ℓ	100	5	The RWQO of 100 mg/ℓ for chloride (Cl) is too high because it is almost 40 times higher than the present state (2.6 mg/ℓ) and could cause problems downstream. A concentration of 5 mg/ℓ (2x present state) is recommended that is also ideal for all water users.
Fluoride (F)	mg/ℓ	0.70	0.10	The fluoride concentration in the Little Caledon at Golden Gate was very low and a concentration of 0.70 mg/ℓ is 23x higher than the present state (0.03 mg/ℓ). The recommended RWQO of 0.1 mg/ℓ is closer to the natural concentrations.

Magnesium (Mg)	mg/ℓ	70	20	To keep the general salts concentration low, it is recommended that a RWQO value for magnesium (Mg) in the Little Caledon River at Golden Gate set at 20 mg/ℓ, which is within the ideal range for domestic water use. The model's value of 70 mg/ℓ is unacceptably high and 7 times higher than the present state.
Potassium (K)	mg/ℓ	25	5	K is a conservative element and very low in the Little Caledon River (at Golden Gate) (present state, 0.82 mg/ℓ). The RWQO of 25 mg/ℓ is excessively high and a concentration of 5 mg/ℓ is recommended – ideal for domestic use and this concentration limits excess salts downstream.
Sodium adsorption ratio (SAR)	Mmol/ℓ	2.0	1.0	The SAR is low in the Little Caledon (Golden Gate); present state of 0.52 mmol/ℓ. The RWQO according to the model is 2.0 (ideal for crop yield and quality), but a value of 1.0 is recommended that is in the ideal range for soil physical conditions.
Sodium (Na)	mg/ℓ	70	25	The RWQO for sodium of 70 mg/ℓ is in the target water quality range for irrigation (crop yield and quality), but a concentration of 25 mg/ℓ is recommended to limit the general salts and prevent excessive downstream concentrations.
Sulphate (SO_4)	mg/ℓ	200	25	The SO_4 concentrations at Golden Gate is still very low (present state, 11.4 mg/ℓ) and a RWQO concentration of 25 mg/ℓ is recommended and not the 200 mg/ℓ proposed by the model, which is an order higher than the present state. The lower concentration (25 mg/ℓ) is about 2 times higher than the present state and would limit the general salt levels and prevent excessive downstream SO_4 concentrations.
Total Dissolved Salts (TDS)	mg/ℓ	260	195	The recommended RWQO for TDS of 195 mg/ℓ is ideal for aquatic ecosystems and irrigation, and close to the present state (186 mg/ℓ) to conserve the natural condition of the river.
Phosphate (PO_4-P)	µg/ℓ	10	30	The phosphate concentration in the Little Caledon River (at Golden Gate) is in the range of mestrophic systems. However, the 10 µg/ℓ, recommended by the Model is too low and below the present state concentration (25 µg/ℓ). It is recommended that the phosphate concentration be limited to 30 µg/ℓ (acceptable limit for aquatic ecosystems) to prevent eutrophication in the river.

Nitrate and nitrite nitrogen (NO_3-N)	mg/ℓ	6.0	0.30	The RWQO value for nitrate of 6.0 mg/ℓ is based on the ideal for Domestic use. The recommended RWQO for nitrate is 0.30 mg/ℓ based on the RWQO for DIN of 0.40 mg/ℓ – refer to discussion in paragraph below.
Dissolved Inorganic Nitrogen (DIN)	mg/ℓ	0.25	0.50	The DIN concentration in the Little Caledon River (Golden Gate) was relatively high (present state, 0.32 mg/ℓ). The RWQO value of 0.25 mg/ℓ proposed by the Model is higher than the present sate, therefore, to keep the nutrients closer to the natural concentration, a RWQO of 0.40 mg/ℓ is recommended and within the range of oligo-mesotrophic waters.
Silicon (Si)	mg/ℓ	20	20	Silicon concentration in the Little Caledon River was relatively high (10.6 mg/ℓ), thus the RWQO of 20 mg/ℓ is accepted.
Chl-a	µg/ℓ	15	5	The RWQO for Chlorophyll-*a* is recommended as 5 µg/ℓ which is in the ideal range of aquatic ecosytems. The RWQO value of 15 proposed by the Model is too high and is based on recreational contact and not on the environment.
E. coli	cfu/100 mℓ	–	130	The *E. coli* concentration in the Little Caledon River was relatively high at 179 cfu/100 mℓ. A RWQO of 130 is proposed that is ideal for full contact recreational use (swimming).
SPI			13 – 17	The Specific Pollution sensitivity Index (SPI) for diatoms was high 14 (good quality) and in the recommended RWQO range of 13 to 17.

5.1.12.2 Preliminary RWQOs for the Little Caledon River at the Poplars (confluence with Caledon River) – CSL2/2

The Little Caledon River at the Poplars shows signs of deterioration with increased nutrients, algal growth and high salt concentrations (cf. **Figure 18**).

Figure 18: Clear water with excessive algal growth (filamentous algae) in Little Caledon River at the confluence with Caledon River.

Table 54: Background information on the Little Caledon River at the Poplars (confluence) (level 2) – Caledon tributary – Upper Orange WMA 13

River:	Little Caledon	**Study Unit:**	The Poplars	**Quat.:**	D21G	**WQM site:**	D2H012
PES:	D	**REC:**	C	**EISC:**	High	**Reference state:**	1975– 1978 (n ≈ 106)
RWQO Model Vers:		4.1				**Present State:**	2005 – 2007 (n ≈ 24)

Table 55: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for the Little Caledon River at the confluence (CSL2/2) – Caledon Tributary – Upper Orange WMA 13.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO New	Reason	Alloc Value
Physical variables	Hardness	mg/ℓ	**77.3**	–	200	Dom-I	**200**	–	123
	EC	mS/m	**47.5**	46.3	70	Dom In3	**60**	–	22.5
	pH 5th		**7.5**	–	6.5	AIr In3	**7.1**	5 % dev	0.4
	pH 95th		**8.5**	–	8.4	In3	**8.5**	AIr Nat	0.0
Chemical variables	Alkalinity	mg/ℓ	**216**	224	300	In3	**300**	In3–I	84
	Ammonia	µg/ℓ	**10**	–	15	Eco-G	**15**	–	5
	Calcium	mg/ℓ	**49.3**	50.0	10	Dom	**80**	BHN	30.7
	Chloride	mg/ℓ	**10.3**	7.3	100	Dom AIr	**50**	5x d/s	89.7
	Fluoride	mg/ℓ	**0.20**	0.28	0.7	Dom	**0.7**	–	0.50
	Magnesium	mg/ℓ	**22.2**	22.4	70	Dom-A	**30**	Dom-I	7.8
	Potassium	mg/ℓ	**2.5**	3.1	25	Dom-I	**25**	–	22.5
	SAR	mmol/ℓ	**0.48**	0.6	2.0	AIr	**1.5**	AIr-soil	1.02
	Sodium	mg/ℓ	**16.1**	19.6	70	AIr	**70**	–	53.9
	Sulphate	mg/ℓ	**22.9**	18.9	200	Dom In3	**80**	4x Rec d/s	57.1
	TDS	mg/ℓ	**381**	388	260	AIr	**400**	Dom; Eco-T	19
Chemical micro & metals*	Al	µg/ℓ	**144**	–	20	ASw AIr	**150**	Eco-T	6
	As	µg/ℓ	**<6**	–	5	Dom	**5**	–	-
	Cd	µg/ℓ	**1.0**	–	5	Dom	**5**	Dom AIr	4
	Cu	µg/ℓ	**5**	–	1.0	AIr	**10**	Rec-Prac	5
	Fe	µg/ℓ	**135**	–	300	In3	**300**	–	165
	Mn	µg/ℓ	**64**	–	20	AIr	**50**	Dom-I	-14
	Pb	µg/ℓ	**10**	–	100	ASw	**50**	Dom-A	40
	V	µg/ℓ	**6**	–	100	AIr-I	**100**	–	94
	Zn	µg/ℓ	**8**	–	1000	AIr	**36**	Eco-Rec	27
Nutrients	PO_4-P	µg/ℓ	**41**	18	10	Eco	**50**	Eco-Rec	9
	NO_3&NO_2-N	mg/ℓ	**0.20**	0.02	10.0	Dom	**0.40**	Eco-Rec	0.20
	DIN	mg/ℓ	**0.33**	0.075	1.0	Eco	**0.50**	Eco-Rec	0.17
	Si	mg/ℓ	**11.3**	13.5	20	In3	**20**	Eco-Rec	8.7
Response variable	Chl-a*	µg/ℓ	**10**	–	15	RFull	**15**	Eco-A	5
	Diatoms*	SPI	**11.1**	–	–		**9 – 13**	Mod quality	-
	*E. coli**	/100mℓ	**119**	–	–		**130**	R-Full-I	11

* Snapshot values; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Cal-A**: Calibrated acceptable (modified benchmark); **Cat:** Category; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.1.12.3 Preliminary RWQOs for Grootspruit – CSL2/3

This is also a new RWQO site, which is just outside of Ficksburg on R48 road bridge. The site falls in the D21H quaternary.

Table 56: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Grootspruit – Caledon Tributary – Upper Orange WMA 13.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO New	Reason	Alloc Value
Physical variables	Hardness	mg/ℓ	**204**	–	200	Dom-I	**300**	Dom-A	96
	EC	mS/m	**37**	–	70	Dom In3	**60**	Eco-T	23
	pH 5th		–	–	–	–	–	–	–
	pH 95th		**8.3**	–	8.4	In3	**8.4**	-	0.1
	TSS	mg/ℓ	**17.3**	–	20	In3	**50**	AIr-I	32.7
Chemical variables	Alkalinity	mg/ℓ	**224**	–	300	In3-I	**300**	–	76
	Ammonia	µg/ℓ	**10**	–	58	Eco-A	**58**	-	48
	Calcium	mg/ℓ	**47**	–	10	Dom-I	**80**	BHN	33
	Chloride	mg/ℓ	**13.4**	–	100	Dom AIr	**50**	5x d/s	36.6
	Fluoride	mg/ℓ	**0.17**	–	0.70	Dom	**0.70**	–	0.53
	Magnesium	mg/ℓ	**21.3**	–	70	Dom-I	**70**	-	48.7
	Potassium	mg/ℓ	**2.9**	–	25	Dom-I	**25**		22.1
	SAR	mmol/ℓ	**0.92**	–	2.0	Air	**1.5**	AIr-soil I	0.58
	Sodium	mg/ℓ	**25.1**	–	70	AIr-I	**70**	–	44.9
	Sulphate	mg/ℓ	**21.1**	–	200	Dom In3	**80**	4x d/s	58.9
	TDS	mg/ℓ	**361**	–	260	AIr-I	**400**	Dom-I	39
Chemical micro & metals	Al	µg/ℓ	**190**	–	85	ASw AIr	**150**	Eco-T	-40
	As	µg/ℓ	**6**	–	10	Dom-I	**10**	–	4
	Cd	µg/ℓ	**1.0**	–	0.000?	Dom	**3.0**	Dom AIr	2
	Cu	µg/ℓ	**5**	–	1.0	Air	**10**	Rec-Prac	5
	Fe	µg/ℓ	**176**	–	300	In3-I	**300**	–	124
	Mn	µg/ℓ	**79**	–	20	AIr-I	**100**	Dom-I	21
	Pb	µg/ℓ	**14**	–	2	ASw	**50**	Dom-A	36
	V	µg/ℓ	**6**	–	100	AIr-I	**30**	5x d/s	24
	Zn	µg/ℓ	**13**	–	1000	Air	**36**	Eco-Rec	23
Nutrients	PO_4-P	µg/ℓ	**63**	–	30	Eco	**80**	Eco-Rec	17
	NO_3&NO_2-N	mg/ℓ	**0.11**	–	6.0	Dom	**0.40**	Eco-Rec	0.29
	DIN	mg/ℓ	**0.20**	–	1.0	Eco	**0.50**	Eco-Rec	0.30
	Si	mg/ℓ	**6.3**	–	20	In3-I	**20**	-	13.7
Response variable	Chl-a*	µg/ℓ	**10**	–	22.5	RFull	**20**	Eco-A	10
	Diatoms*	SPI	**14.6**	–			**9 – 13**	Mod qual	
	*E. coli**	/100mℓ	**573**	–	-		**400**	R-Full-T	-173

***** Snapshot values; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.1.12.4 Preliminary RWQOs for Meulspruit – CSL2/5

The Meulspruit site is upstream of the Meulspruit Dam and falls in the D22D quaternary. The water quality was generally good.

Table 57: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Meulspruit – Caledon Tributary – Upper Orange WMA 13.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO Rec	Reason	Alloc Value
Physical variables	Hardness	mg/ℓ	**124**	–	200	Dom-I	**200**	–	76
	EC	mS/m	**30**	–	70	Dom In3	**50**	Eco-A	25
	pH 5th		–	–	–	–	–	–	
	pH 95th		**7.6**	–	8.4	In3	**8.4**	–	0.8
	TSS	mg/ℓ	**45**	–	20	In3	**50**	AIr-I	5
Chemical variables	Alkalinity	mg/ℓ	**161**	–	450	In3	**300**	In3–I	139
	Ammonia	µg/ℓ	**19.5**	–	58	Eco-A	**40**	Rec	20.5
	Calcium	mg/ℓ	**31.9**	–	10	Dom-I	**80**	BHN	48.1
	Chloride	mg/ℓ	**9.7**	–	100	Dom AIr	**50**	5x d/s	40.3
	Fluoride	mg/ℓ	**0.23**	–	0.70	Dom	**0.70**	–	0.47
	Magnesium	mg/ℓ	**10.9**	–	70	Dom-I	**30**	Rec d/s	19.1
	Potassium	mg/ℓ	**4.8**	–	25	Dom-I	**25**		20.2
	SAR	mmol/ℓ	**0.92**	–	2.0	AIr	**1.5**	AIr-soil I	0.58
	Sodium	mg/ℓ	**23.6**	–	70	AIr-I	**70**	–	46.4
	Sulphate	mg/ℓ	**13.9**	–	200	Dom In3	**60**	4x d/s	46.1
	TDS	mg/ℓ	**261**	–	260	AIr-I	**325**	Eco-A	64
Chemical micro & metals	Al	µg/ℓ	**50**	–	85	ASw AIr	**85**	–	35
	As	µg/ℓ	**6**	–	10	Dom-I	**10**	–	4
	Cd	µg/ℓ	**1.0**	–	0.000?	Dom	**3.0**	Dom AIr	2
	Cu	µg/ℓ	**4**	–	1.0	AIr	**10**	Rec-Prac	6
	Fe	µg/ℓ	**119**	–	500	In3	**300**	In3-I	181
	Mn	µg/ℓ	**39**	–	20	AIr-I	**50**	Dom-I	11
	Pb	µg/ℓ	**10**	–	2	ASw	**50**	Dom-A	40
	V	µg/ℓ	**6**	–	100	AIr-I	**30**	5x d/s	24
	Zn	µg/ℓ	**7**	–	1 000	AIr	**36**	Eco-Rec	29
Nutrients	PO_4-P	µg/ℓ	**30**	–	30	Eco-A	**45**	Eco-Rec	15
	NO_3&NO_2-N	mg/ℓ	**0.020**	–	6.0	Dom	**0.20**	Eco-Rec	0.38
	DIN	mg/ℓ	**0.21**	–	1.0	Eco-T	**0.30**	Eco-Rec	0.09
	Si	mg/ℓ	**5.3**	–	85	In3	**20**	In3-I	14.7
Response variable	Chl-a*	µg/ℓ	**18**	–	22.5	RFull	**20**	Eco-A	2
	Diatoms*	SPI	**10.5**	–	–	–	**9 – 13**	Mod qual	
	*E. coli**	/100mℓ	**29**	–	–	–	**130**	R-Full-I	101

* Snapshot values; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

Water quality Reserve data are available for Meulspruit and compared with RWQOs determined during this study (**Table 58**).

Table 58: Water Quality Reserve values (DWAF), Present state, and preliminary Resource Water Quality Objectives (RWQOs) of this study for Meulspruit (Quaternary catchment D22B) – Upper Orange WMA 13.

Parameter	Water Quality Reserve	Present State	RWQO
General Chemistry			
Sodium (Na, mg/ℓ)	<10	23.6	70
Magnesium (Mg, mg/ℓ)	<14	10.9	30
Calcium (Ca, mg/ℓ)	<34	31.9	80
Chloride (Cl, mg/ℓ)	<11	9.7	50
Sulphate (SO_4, mg/ℓ)	<21	13.9	60
Nutrients and Nutrient ratios			
Soluble Phosphate (mg/ℓ)	<0.065	0.030	0.045
Total Inorganic Nitrogen (TIN)	<2.12	0.21	0.30
Physical Water Quality			
Ammonia (mg-N/ℓ as NH_3)	<0.034	0.020	0.040
pH (10^{th} – 90^{th} percentile)	6.5 – 8.5	7.5 – 8.5*	7.1 – 8.5
Dissolved Oxygen (mg/ℓ)	>6.5	11.1*2	–

* 5^{th} – 95^{th} percentile; *2 Snapshot data

The snapshot survey indicates fairly good water quality in Meulspruit (above dam). However, on the one hand, some of the water quality Reserve values are very stringent e.g. sodium concentration of <10 mg/ℓ is well below the present state of 23.6 mg/ℓ. On the other hand the TIN concentration of 2.12 mg/ℓ is too high and could lead to eutrophic conditions in the spruit. Nevertheless, more data are necessary to determine the full concentration range of different variables and to determine high confidence RWQOs.

5.1.12.5 Preliminary RWQOs for Moperispruit – CSL2/4

Moperispruit is a new site thus with limited data – 2 snapshot surveys. The site falls in the D22G quaternary with a PES as a D and the REC set at C and the EISC is high.

Table 59: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Moperispruit – Caledon Tributary – Upper Orange WMA 13

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO New	Reason	Alloc Value
Physical variables	Hardness	mg/ℓ	**96**	–	300	Dom-A	**200**	Dom-A	104
	EC	mS/m	**38**	–	120	Dom In3	**55**	Cat B	17
	pH 5th			–					
	pH 95th		**7.5**	–	8.4	In3	**8.4**	AIr Nat	0.9
	TSS	mg/ℓ	**14**	–	20	In3	**20**	–	6
Chemical variables	Alkalinity	mg/ℓ	**116**	–	450	In3	**300**	In3–I	184
	Ammonia	µg/ℓ	**13**	–	58	Eco-G	**58**	–	45
	Calcium	mg/ℓ	**24.2**	–	150	Dom	**80**	BHN	55.8
	Chloride	mg/ℓ	**61.5**	–	138	Dom AIr	**100**	Dom-I	38.5
	Fluoride	mg/ℓ	**0.36**	–	1.0	Dom	**1.0**	–	0.64
	Magnesium	mg/ℓ	**8.6**	–	100	Dom-A	**30**	Dom-I	21.4
	Potassium	mg/ℓ	**13.7**	–	50	Dom-I	**25**	Dom-I	11.3
	SAR	mmol/ℓ	**2.0**	–	8.0	AIr	**3.0**	AIr-soil B	4.0
	Sodium	mg/ℓ	**45.3**	–	92.5	AIr	**92.5**	–	47.3
	Sulphate	mg/ℓ	**26.8**	–	250	Dom In3	**100**	4x d/s	73.2
	TDS	mg/ℓ	**300**	–	800	AIr	**360**	Eco-A	60
Chemical micro & metals	Al	µg/ℓ	**30**	–	85	ASw AIr	**85**	Eco-A	55
	As	µg/ℓ	**6**	–	50	Dom	**50**	–	44
	Cd	µg/ℓ	**1.0**	–	1.0?	Dom	**5**	Dom AIr	4
	Cu	µg/ℓ	**4**	–	1.0	AIr	**10**	Rec-Prac	6
	Fe	µg/ℓ	**106**	–	1 000	In3	**300**	In3-I	194
	Mn	µg/ℓ	**27**	–	400	AIr	**50**	Dom-I	73
	Pb	µg/ℓ	**10**	–	2?	ASw	**50**	Dom-A	40
	V	µg/ℓ	**6**	–	550	AIr-A	**100**	AIr-I	94
	Zn	µg/ℓ	**6**	–	3000	AIr	**35**	Eco-Rec	29
Nutrients	PO_4-P	µg/ℓ	**75**	–	30	Eco-A	**100**	Eco-T	25
	NO_3&NO_2-N	mg/ℓ	**0.20**	–	10.0	Dom	**0.35**	Eco-Rec	0.15
	DIN	mg/ℓ	**0.33**	–	1.0	Eco	**0.50**	Eco-A	0.17
	Si	mg/ℓ	**3.5**	–	85	AIr	**20**	Eco-Rec	16.5
Response variable	Chl-a*	µg/ℓ	**30**	–	22.5	RFull	**20**	Eco-A	-10
	Diatoms*	SPI	**8.3**	–			**9 – 13**	Mod qual	-0.7
	*E. coli**	/100mℓ	**96**	–	-		**400**	R-Full-T	304

* Snapshot values; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.1.12.6 Preliminary RWQOs for the Leeu River – CSL2/6

The Leeu River is highly regulated because of several dams build in the river with significant irrigation in the rivers catchment. High aluminium and *E. coli* concentrations are a matter of concern. Sampling site falls in the Quaternary D23E.

Table 60: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Leeu River – Caledon Tributary – level 2 – Upper Orange WMA 13.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO New	Reason	Alloc Value
Physical variables	Hardness	mg/ℓ	**116**	–	200	Dom-I	**200**	-	84
	EC	mS/m	**25**	–	70	Dom In3	**45**	Eco-A	20
	pH 5th			–					
	pH 95th		**7.6**	–	8.4	In3	**8.4**	-	0.8
	TSS	mg/ℓ	**37**	–	20	In3	**50**	AIr-I	13
Chemical variables	Alkalinity	mg/ℓ	**146**	–	450	In3-A	**300**	In3–I	154
	Ammonia	µg/ℓ	**11**	–	58	Eco-A	**15**	Eco-I	4
	Calcium	mg/ℓ	**27.4**	–	10	Dom-I	**80**	BHN	52.6
	Chloride	mg/ℓ	**10.8**	–	100	Dom AIr	**50**	5x d/s	39.2
	Fluoride	mg/ℓ	**0.23**	–	0.70	Dom	**0.70**	–	0.47
	Magnesium	mg/ℓ	**11.4**	–	70	Dom-I	**30**	Rec d/s	18.6
	Potassium	mg/ℓ	**5.2**	–	25	Dom-I	**25**		19.8
	SAR	mmol/ℓ	**1.1**	–	2.0	AIr-I	**1.5**	AIr-soil I	0.58
	Sodium	mg/ℓ	**26**	–	70	AIr-I	**70**	–	44
	Sulphate	mg/ℓ	**9.4**	–	200	Dom In3	**50**	5x d/s	40.6
	TDS	mg/ℓ	**241**	–	260	AIr-I	**300**	Eco-A	59
Chemical micro & metals	Al	µg/ℓ	**197**	–	5000	ASw AIr	**150**	Eco-T	-47
	As	µg/ℓ	**6**	–	10	Dom-I	**10**	–	4
	Cd	µg/ℓ	**1.0**	–	0.000?	Dom	**3.0**	Dom AIr	2
	Cu	µg/ℓ	**5**	–	200	Air	**10**	Rec-Prac	5
	Fe	µg/ℓ	**150**	–	500	In3	**300**	In3-I	150
	Mn	µg/ℓ	**12**	–	20	AIr-I	**20**	-	8
	Pb	µg/ℓ	**11**	–	100	ASw	**50**	Dom-A	39
	V	µg/ℓ	**6**	–	100	AIr-I	**30**	5x d/s	24
	Zn	µg/ℓ	**9**	–	1000	Air	**36**	Eco-Rec	27
Nutrients	PO_4-P	µg/ℓ	**40**	–	30	Eco-A	**50**	Eco-Rec	10
	NO_3&NO_2-N	mg/ℓ	**0.29**	–	6.0	Dom	**0.40**	Eco-Rec	0.11
	DIN	mg/ℓ	**0.39**	–	-?		**0.50**	Eco-Rec	0.11
	Si	mg/ℓ	**5.2**	–	85	In3	**20**	In3-I	14.8
Response variable	Chl-a*	µg/ℓ	**7.5**	–	22.5	RFull	**20**	Eco-A	12.5
	Diatoms*	SPI	**14.1**	–	-		**9 – 13**	Mod qual	
	*E. coli**	/100mℓ	**1 700**	–	-		**400**	R-Full-T	-1300

* Snapshot values; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.2 Lower Orange Management Area (WMA 14)

The Lower Orange WMA was divided into four sub-catchments or visioning areas, *i.e.*:

1) Just upstream of the confluence of the Orange River with the Vaal River (Marksdrift) to Boegoeberg Dam (including just upstream of both the Orange and Vaal Rivers;
2) Boegoeberg Dam to Kanoneiland;
3) Kanoneiland to Pella, and
4) Pella to Alexander Bay (DWAF, 2008a).

RWQO sites include:

- OS08 Prieska
- OS09 Boegoeberg Dam
- OS11 Upington
- OS13 Neusberg Weir
- OS15 Pella
- OS16 Vioolsdrift
- OS19 Alexander Bay

From a management perspective and considering the gradual downstream change in water quality, it makes sense to determine RWQOs for the same 4 areas. For the RWQOs, Neusberg was selected instead of Kanoneiland because data collection at Kanoneiland (D7H004) was terminated in 1988. Initially, 13 monitoring sites were identified for sampling in the Lower Orange, but only 9 were finally accepted for continuous monitoring (Refer to Monitoring Programme Report of study). Good data is available at six sites, *i.e*. Marksdrift, Boegoeberg Dam, Upington, Neusberg Weir, Pella, and Vioolsdrift.

The PES in the Lower Orange River sites was primarily in the C category (**Table 4**). The two sites that are considered largely natural (B category) are Pella and Vioolsdrift with a high EISC. However, from a water quality perspective, these 2 sites are also considered to be in a C category because of the high salt concentrations in the river (EC between 55.1 and 85 mS/m), which is in the range of a C category river.

A clear downstream increase in salt ionic species is evident from **Figure 19**. Marksdrift is included in the graph for comparison and Marksdrift is sometimes included as part of the Lower Orange Management area.

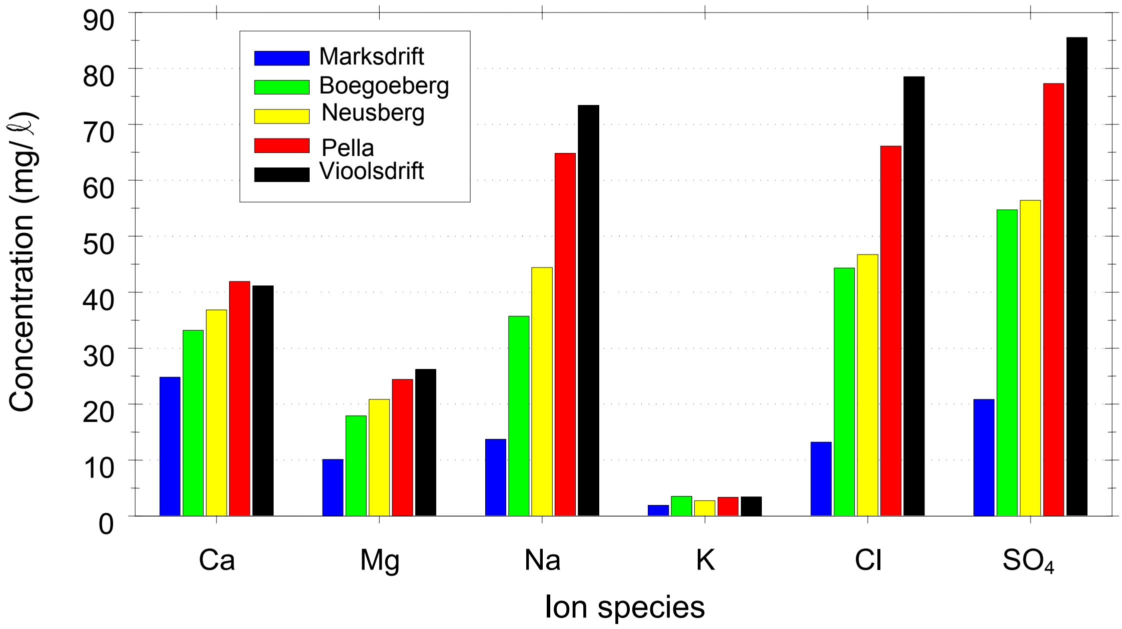

Figure 19: Grouped Bar Chart of the Present State (95th percentiles) of major ion concentrations (mg/ℓ) in the lower Orange River main stem (level 1).

Table 61: Present state (95th%tile and 50th%tile) values (2005 -2007) at different sites in Lower Orange WMA – main stem, level 1

PES	Sample site (Quat)	Ca	Cl	Chl-a**	DMS	EC	Flow*	F	Hard-T	K	Mg	Na	NH_3	NO_3–N*	DIN*	pH#	PO_4-P*	SAR	Si	SO_4	TAL	TSS#	Turb#
C	Boegoeberg (D73B)	33.2	44.3	-	346	51.2	58	0.26	161	3.5	17.9	35.7	0.01	0.20	0.25	7.7 8.4	.020	1.24	8.0	54.7	118	-	0.5 31.6
C	Upington (D73E)	38.8	58.6	7.6	425	63	67	0.39	187	3.9	21.5	52.2	.013	0.14	0.21	7.6 8.4	.022	1.67	8.2	73.6	145	2.8 87.2	-
C	Neusberg (D73E)	36.8	-	6.5	384	55.9		0.34	174	2.7	20.8	44.4	.015	0.04	0.12	8.0 8.4	.018	1.48	9.12	56.4	157	-	-
B	Pella (D81F)	41.9	66.1	13.8	474	68.5	22.3	0.42	200	3.3	24.4	64.8	.013	0.04	0.12	7.8 8.4	.022	1.97	10.3	77.3	167	2.8 138	-
B	Vioolsdrift (D82F)	41.1	78.5	8.4	509	74.5	31.9	.048	205	3.4	26.2	73.4	.008	0.04	.096	7.4 8.4	.025	2.2	9.4	85.5	170	-	-

Present state (95th %tile) of metal and micro-element concentrations (mg/ℓ) at different site in whole Orange River (2005 -2007) – level 1

PES	Sample site	*Al*	*B*	*Ba*	*Cd*	*Cr*	*Cu*	*Fe*	*Mn*	*Mo*	*Ni*	*Pb*	*Sr*	*V*	*Zn*
C	Upington	.114	.092	.047	.005	.003	.006	.043	.001	.016	.031	.054	.242	.027	.022
C	Neusberg	.171	-	-	-	.007	.006	.056	.013	.016	.038	.054	.230	.034	.018
B	Pella	*.035*	*.206*	*.058*	*.077*	*.003*	*.006*	*.044*	*.006*	*.016*	*.004*	*.358*	*0.26*	*.013*	*.005*
	Vioolsdrift	.168	.109	.048	.012	.009	.006	.030	.004	.045	.044	.054	.28	.037	.010

PES, Present Ecological State; * 50th percentile; ** Mean; # 5th and 95th percentile

It is interesting to note that while the salts, alkalinity and hardness are increasing, the nutrients, especially nitrogen, show a decreasing trend downstream (**Figure 20**).

RWQOs were calculated for all 4 monitoring sites to compensate for the increasing salts and decreasing nitrogen (see **Tables 32, 35, 37, and 39**).

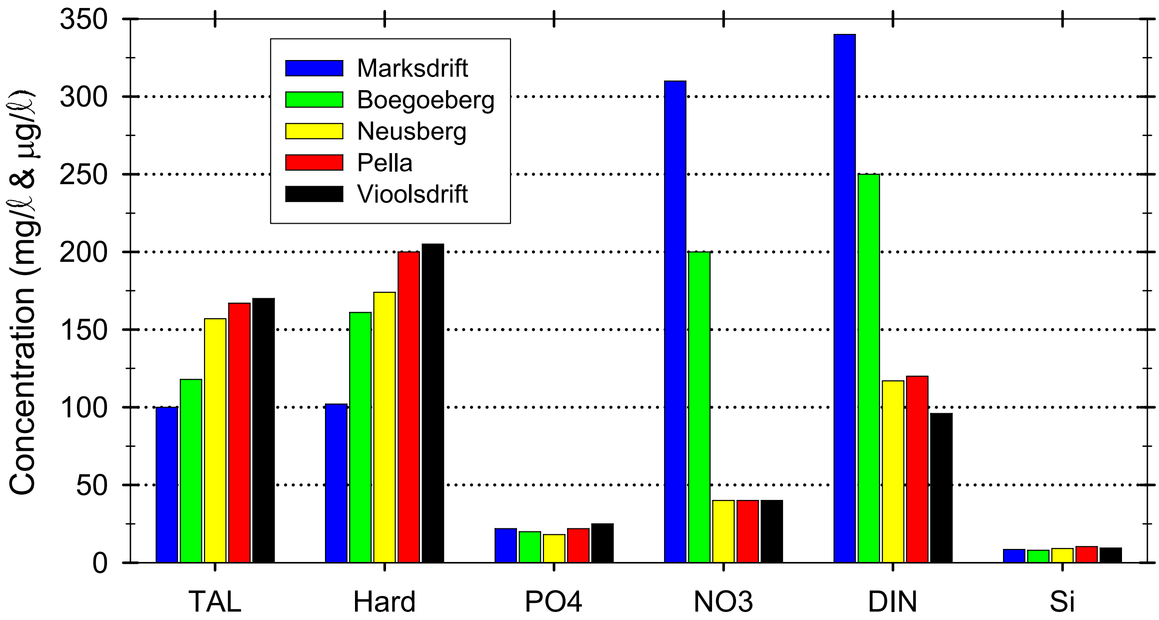

Figure 20: Grouped Bar chart of the Present State (95th percentiles) of total alkalinity (TAL), total Hardness (Hard), and nutrients (phosphate (PO_4-P), nitrate (NO_3-N), dissolved inorganic nitrogen (DIN), and silica (Si). The TAL, Hard, and Si concentrations are in (mg/ℓ); PO_4, NO_3 and DIN concentrations are in (µg/ℓ).

5.2.1 Preliminary RWQOs for Prieska (OS08)

The data collection was unfortunately ended during 2001, therefore the present state is only based on one measurement during the snapshot survey (2008).

Table 62: Background information on Prieska in Orange River (Level 1) – Lower Orange WMA 14.

River:	Orange River	**Study Unit:**	Prieska	**Quat.**	D72A	**WQM site:**	D7H002
PES:	C	**REC:**	B	**EISC:**	Moderate	**Reference state:**	1966–1978 (n ≈ 38)
Management Class:		Natural				**Present State:**	2008 (n = 1)
RWQO Model Vers:		4.1					

Table 63: Present state (snapshot 2008), Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Prieska (OS08) – Lower Orange WMA - Orange River – level 1.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO New	Reason	Alloc Value
Physical variables	Hardness	mg/ℓ	**118**	–	200	Dom In3	**200**	–	82
	EC	mS/m	**33**	38	70	Dom In3	**55**	Eco-A	22
	pH 5th		**-**	-	6.5	AIr In3	**7.2**	5 % dev	0.4
	pH 95th		**8.3**	-	8.0	In3	**8.4**	AIr	0.1
	TSS	mg/ℓ	**29.3**	221	5	In3	**50**	AIr-I	20.7
Chemical variables	Alkalinity	mg/ℓ	**103**	146	300	In3-I	**300**	-	197
	Ammonia	µg/ℓ	**15**	–	15	Eco-I	**58**	Eco-A	43
	Calcium	mg/ℓ	**26.7**	43.5	10	Dom-I	**80**	BHN	53.3
	Chloride	mg/ℓ	**24.7**	26.1	100	Dom Air	**100**	–	75.3
	Fluoride	mg/ℓ	**0.19**	0.46	0.7	Dom-I	**0.7**	–	0.51
	Magnesium	mg/ℓ	**12.4**	18.7	70	Dom-I	**70**	Dom-I	57.6
	Potassium	mg/ℓ	**2.23**	3.8	25	Dom-I	**25**	Dom-I	22.7
	SAR	mmol/ℓ	**1.1**	0.91	2	AIr-I	**2.0**	-	0.9
	Sodium	mg/ℓ	**27.0**	29.7	70	AIr-I	**70**	–	43
	Sulphate	mg/ℓ	**36.2**	59.7	200	Dom In3	**100**	Rec d/s	63.8
	TDS	mg/ℓ	**238.4**	336	260	Air	**360**	Eco-A	121.6
Chemical micro & metals	Al	µg/ℓ	**95**	–	20	Air	**150**	Eco-T	55
	Cd	µg/ℓ	**<1**	–	0.000	Dom-I	**3**	Dom-I AIr	2
	Cu	µg/ℓ	**4**	–	0.000	Air	**10**	Prop-Pr	6
	Fe	µg/ℓ	**92**	–	300	In3	**100**	Dom-I	8
	Mn	µg/ℓ	**9**	–	20	Air	**20**	Dom-I	11
	Pb	µg/ℓ	**<10**	–	0.000	ASw	**50**	Dom-A	40
	V	µg/ℓ	**8**	–	100	AIr-I	**100**	-	92
	Zn	µg/ℓ	**7**	–	1000	AIr-I	**36**	Eco-Rec	29
Nutrients	PO_4-P	µg/ℓ	**25**	11	10	Eco	**30**	Eco-A	5
	NO_3&NO_2-N	mg/ℓ	**0.30**	0.11	6.0	Dom	**0.40**	Eco-Rec	0.10
	DIN	mg/ℓ	**0.46**	0.17	0.25	Eco-N	**0.50**	Eco-A; Rec	0.04
	Si	mg/ℓ	**5.6**	8.9	20	In3	**20**	–	14.4
Response variable	Chl-a	µg/ℓ	**18**	–	15	RFull	**20**	Eco-T	2
	Diatoms*	SPI	**12.2**	–	–	–	**9 – 13**	Mod qual	-
	E. coli	/100mℓ	**52**	–	–	–	**130**	RFull	78

***** Snapshot values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.2.2 Preliminary RWQOs for Boegoeberg Dam (OS09)

The PES of Boegoeberg Dam is indicated as a C, but it is recommended that is should be managed to achieve a B class (**Table 64**). The high $MgSO_4$ concentration is a problem because it is outside the range reported for aquatic ecosystems, but it could be a problem in the TECHA Model as suggested in report (DWAF, 2008b).

The flow modification in the river caused various problems, *inter alia*, the invasion of blackfly problem. **Figure 21** shows the high concentration of blackfly larvae on the rocks that deteriorate the habitat on rocks. However, the diatom score (SPI) was fairly high (13.9) and indicate good water quality.

Figure 21: Blackfly larvae on rocks downstream of Boegoeberg Dam (2008).

Table 64: Background information on Boegoeberg Dam in Orange River (Level 1) – Lower Orange WMA 14.

River:	Orange River	**Study Unit:**	Boegoeberg Dam	**Quat.**	D73B	**WQM site:**	D7H008
PES:	C	**REC:**	B	**EISC:**	High	**Reference state:**	1966–1978 (n ≈ 38)
Management Class:		Natural				**Present State:**	2005– ‘07 (n ≈ 117)
RWQO Model Vers:		4.1					

Table 65: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Orange River at Boegoeberg Dam (OS09) – Lower Orange WMA 14.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO New	Reason	Alloc Value
Physical variables	Hard-Tot	mg/ℓ	**161**	–	200	Dom-A	**200**	–	39
	EC	mS/m	**51.2**	38	70	Dom In3	**60**	Eco-T; d/s	8.8
	pH 5th	Unit	**7.7**	7.1	6.5	AIr In3	**7.1**	5 % dev	0.6
	pH 95th	Unit	**8.4**	7.9	8.0	In3	**8.4**	AIr Nat.	0.0
Chemical variables	Alkalinity	mg/ℓ	**118**	150	300	In3	**300**	–	182
	Ammonia	µg/ℓ	**10**	–	15	Eco	**15**	–	5
	Calcium	mg/ℓ	**33.2**	38.9	32	Dom	**80**	BHN	46.8
	Chloride	mg/ℓ	**44.3**	20.6	100	Dom Air	**100**	–	55.7
	Fluoride	mg/ℓ	**0.26**	0.48	0.7	Dom	**0.7**	–	0.44
	Magnesium	mg/ℓ	**17.9**	15.4	70	Dom	**30**	Dom-I, d/s	12.1
	Potassium	mg/ℓ	**3.5**	3.75	25	Dom-I	**15**	4x, d/s	11.5
	SAR	mmol/ℓ	**1.24**	0.88	2.0	Air	**1.5**	AIr-soil	0.26
	Sodium	mg/ℓ	**35.7**	24	70	Air	**70**	–	34.3
	Sulphate	mg/ℓ	**54.7**	49.5	200	Dom In3	**80**	Rec; d/s	25.3
	TDS	mg/ℓ	**346**	303	260	Air	**400**	Eco-T	54
Chemical Inorganic salts	$MgSO_4$	mg/ℓ	**68.2**	–	16	Eco-I	**37**	Eco-T	-31.2
	Na_2SO_4	mg/ℓ	**0.16**	–	20	Eco-I	**20**	–	19.84
	$MgCl_2$	mg/ℓ	**5.19**	–	15	Eco-I	**15**	–	9.81
	$CaCl_2$	mg/ℓ	**16.21**	–	21	Eco-I	**21**	–	4.79
	NaCl	mg/ℓ	**67.0**	–	45	Eco-I	**191**	Eco-A	124
Nutrients	PO_4-P	µg/ℓ	**20**	14	30	Eco-A	**30**	–	10
	NO_3&NO_2-N	mg/ℓ	**0.20**	0.02	6	Dom	**0.40**	Eco-Rec	0.20
	DIN	mg/ℓ	**0.25**	0.14	0.25	Eco	**0.50**	Eco-Rec	0.25
	Si	mg/ℓ	**8.0**	9.0	20	In3	**20**	Eco	12
Response variable	Chl-a	µg/ℓ	**4.1**	–	–		**10**	Eco-I	5.9
	Diatoms*	SPI	**13.9**	–	–	–	**13 – 17**	Good quality	
	*E. coli**	/100mℓ	**8**	–	–	–	**130**	RFull-I	126

* Snapshot; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

A preliminary determination of the Reserve for Water Quality for the drainage region D73B (Boegoeberg Dam) was determined in 2001 (DWAF, 2001). **Table 66** show the comparison between the Reserve values and the present state and the RWQOs values from the present study.

Table 66: Water Quality Reserve values (DWAF, 2001), Present state, and Resource Water Quality Objectives (RWQOs) from the present study for the Orange River at Boegoeberg Dam – Lower Orange WMA 14

Parameter	Water Quality Reserve	Present State	RWQO
General Chemistry			
TDS (mg/ℓ)	<421	346	400
Sodium (Na, mg/ℓ)	<172	35.1	70
Magnesium (Mg, mg/ℓ)	<21	17.9	30
Potassium (K, mg/ℓ)	<49	3.5	15
Chloride (Cl, mg/ℓ)	<62	44.3	100
Calcium (Ca, mg/ℓ)	<40	33.2	80
Sulphate (SO_4, mg/ℓ)	<70	54.7	80
Nutrients and Nutrient ratios			
Soluble Phosphate (mg/ℓ)	<0.070	0.020	0.030
TIN: Soluble Phosphate	<13:1	12.5	-
Physical Water Quality			
Ammonia (mg-N/ℓ as NH_3)	<0.034	0.010	0.015
pH (10^{th} – 90^{th} percentile)	6.5 – 8.5	7.7 – 8. 4*	7.1 – 8.4
Dissolved Oxygen (%)	93	94^{*2}	-

* 5^{th} – 95^{th} percentile; ^{*2} Snapshot data

The RWQOs proposed in this study is generally stricter than the water quality Reserve values especially the TDS and phosphates concentrations, to prevent eutrophication in the system and to protect the downstream users from exesive salt concentrations.

5.2.3 Preliminary RWQOs for Upington (OS11)

Upington is a major town in the Visioning area 2 of the Lower Orange WMA. The vision is "To contribute towards securing suitable water supplies of qualities for all LOWMA catchments between Boegoeberg and Kanon Island, that will sustain: a thriving table grape export marked and wine production; local agricultural activities via an extensive irrigation canal system; a thriving stock farming industry (**Figure 22**); domestic and light industrial water use in all towns, specifically including Upington; and supplying water to rural communities via both the Kalahari West and Karos-Geelkoppan water supply schemes." (DWAF, 2009b).

Figure 22: Stock farming (sheep) and irrigation from the Orange River close to Upington.

Table 67: Background information on Upington in Orange River (Level 1) – Lower Orange WMA 14.

River:	Orange River	**Study Unit:**	Upington	**Quat.:**	D73E	**WQM site:**	D7H005
PES:	C	**REC:**	B	**EISC:**	High	**Reference state:**	1985–1988 (n ≈ 42)
Management Class:		Natural				**Present State:**	2005– '07 (n ≈ 78)
RWQO Model Vers:		4.1					

Table 68: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Upington (OS11) – Lower Orange WMA - Orange River – level 1.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO New	Reason	Alloc Value
Physical variables	Hardness	mg/ℓ	**187**	–	250	Dom In3	**250**	–	63
	EC	mS/m	**63**	35.2	70	Dom In3	**70**	–	7
	pH 5th		**7.6**	-	6.5	AIr In3	**7.2**	5 % dev	0.4
	pH 95th		**8.4**	-	8.0	In3	**8.4**	Air Nat	0.0
	TSS	mg/ℓ	**87.2**	2121	20	In3	**100**	Air-T	12.8
Chemical variables	Alkalinity	mg/ℓ	**145**	113.6	450	In3-A	**300**	In3-I	155
	Ammonia	µg/ℓ	**13**	–	58	Eco-A	**58**	–	45
	Calcium	mg/ℓ	**38.8**	32.2	10	Dom-I	**80**	BHN	41.2
	Chloride	mg/ℓ	**58.6**	23.7	100	Dom AIr	**100**	–	41.4
	Fluoride	mg/ℓ	**0.39**	0.29	0.7	Dom-I	**0.7**	–	0.31
	Magnesium	mg/ℓ	**21.5**	10.7	70	Dom-I	**70**	Dom-I	48.5
	Potassium	mg/ℓ	**3.9**	3.8	25	Dom-I	**25**	Dom-I	21.1
	SAR	mmol/ℓ	**1.67**	1.2	8	Air	**3.0**	Air – soil-A	1.33
	Sodium	mg/ℓ	**52.2**	27.5	92.5	AIr-A	**92.5**	–	40.3
	Sulphate	mg/ℓ	**73.6**	31.1	200	Dom In3	**200**	–	126.4
	TDS	mg/ℓ	**425**	245	450	Air	**450**	–	25
Chemical Inorganic salts	$MgSO_4$	mg/ℓ	**89.9**	-	27	Eco-A	**37**	Eco-T	-52.9
	Na_2SO_4	mg/ℓ	**13.7**	-	36	Eco-A	**36**	–	22.3
	$MgCl_2$	mg/ℓ	**6.7**	-	33	Eco-A	**33**	–	26.3
	$CaCl_2$	mg/ℓ	**29.8**	-	63	Eco-A	**63**	–	33.2
	NaCl	mg/ℓ	**80.5**	-	217	Eco-A	**217**	–	136.5
Chemical micro & metals	Al	µg/ℓ	**114**	–	20	ASw	**150**	Eco-T	36
	B	µg/ℓ	**92**	–	750	AIr-A	**500**	Air-I	408
	Cd	µg/ℓ	**5**	–	5	Dom-I	**20**	Dom-T AIr	15
	Cr (III)	µg/ℓ	**3**	–	24	Eco	**24**	Ecol-I	21
	Cu	µg/ℓ	**6**	–	1.6	Eco	**10**	Prop-Pr	4
	Fe	µg/ℓ	**43**	–	300	In3	**100**	Dom-I	57
	Mn	µg/ℓ	**1**	–	200	Air	**50**	Dom-I	49
	Mo	µg/ℓ	**16**	–	10	ASw AIr	**20**	ASw Air-A	4
	Ni	µg/ℓ	**31**	–	200	Air-I	**200**	–	169
	Pb	µg/ℓ	**54**	–	100	ASw	**100**	Dom-T ASw	46
	V	µg/ℓ	**27**	–	550	AIr-A	**100**	Dom-I AIr-I	73
	Zn	µg/ℓ	**22**	–	1000	AIr-I	**36**	Eco-Rec	13
Nutrients	PO_4-P	µg/ℓ	**22**	18	10	Eco	**25**	Eco	3
	NO_3&NO_2-N	mg/ℓ	**0.14**	0.74	6.0	Dom	**0.20**	Eco-Rec	0.06
	DIN	mg/ℓ	**0.21**	0.75	0.25	Eco-N	**0.25**	N-lim,	0.04
	Si	mg/ℓ	**8.2**	8.9	20	Air	**20**	–	11.8
Response variable	Chl-a	µg/ℓ	**7.6**	–	15	RFull	**15**	Eco-A	7.4
	Diatoms*	SPI	**14.4**	–	–	–	**13– 17**	Good qual	-
	E. coli	/100mℓ	**62**	–	–	–	**130**	RFull	68

***** Snapshot values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.2.4 Preliminary RWQOs for Neusberg Weir (OS13)

Neusberg weir is about 40 km downstream from Kanon Island which is considered to be the beginning of visioning area 3. Monitoring site D7H014 (Orange River at Kakamas South/Neusberg left side) was initially proposed as the appropriate site for Neusberg (see **Appendix A**). However, sampling was discontinued in 2002 at this site, as a result, data from monitoring site D7H016 (Northern Bank Canal (right) at Kakamas) was use because it is a more complete data set (still active), including chlorophyll-*a* data, and representative of the water chemistry inside the weir (**Figure 23**).

Figure 23: Northern bank canal at Neusberg weir close to Kakamas.

The PES for Neusberg Weir is a C, but it is recommended that this category should be improved to a B (**Table 69**). However, the aluminium and lead concentrations are perhaps too high for a healthy aquatic environment and a concern that should be addressed (**Table 70**).

Table 69: Background information on Neusberg weir in Orange River (Level 1) – Lower Orange WMA 14.

River:	Orange	**Study Unit:**	Neusberg Weir	**Quat.:**	D73E	**WQM site:**	D7H016
PES:	C	**REC:**	B	**EISC:**	Moderate	**Reference state:**	1995 – 1997 (n ≈ 94)
Management Class:		Moderately impacted				**Present State:**	2005–2007 (n ≈ 41)
RWQO Model Vers:		4.1					

Table 70: Present state, Reference values, preliminary Resource Water Quality Objectives (RWQOs), and Allocatable values for the Orange River at Neusberg Weir (OS13) – Lower Orange WMA 14.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO New	Reason	Alloc Value
Physical variables	Hardness	mg/ℓ	**173.9**	–	200	Dom	**200**	–	26.1
	EC	mS/m	**55.9**	46.6	70	Dom In3	**70**	–	14.1
	pH 5th		**8.06**	7.9	6.5	Alr In3	**7.6**	5 % dev	0.46
	pH 95th		**8.4**	8.5	8.0	In3	**8.4**	Air Nat	0
Chemical variables	Alkalinity	mg/ℓ	**157.2**	154	300	In3	**300**	–	142.8
	Ammonia	µg/ℓ	**15**	7	?		**30**	–	15
	Calcium	mg/ℓ	**36.8**	34.1	10	Dom	**80**	BHN	43.2
	Chloride	mg/ℓ	**46.7**	33.4	100	Dom Alr	**100**	–	53.3
	Fluoride	mg/ℓ	**0.34**	0.31	0.7	Dom	**0.7**	–	0.36
	Magnesium	mg/ℓ	**20.8**	16.8	70	Dom	**50**	Dom-A	29.2
	Potassium	mg/ℓ	**2.73**	4.8	25	Dom	**25**	Dom-I	22.3
	SAR	mmol/ℓ	**1.48**	1.32	2.0	Alr	**2.0**	Air	0.52
	Sodium	mg/ℓ	**44.8**	34.5	70	Alr	**70**	–	25.2
	Sulphate	mg/ℓ	**56.4**	57.2	200	Dom In3	**100**	Rec d/s	43.6
	TDS	mg/ℓ	**384**	344	260	Air	**450**	Cat-C, Pr	93.6
Chemical micro & metals	Al	µg/ℓ	**171**	–	5000	ASw	**150**	Eco-T	-21
	Cd	µg/ℓ		–	10	Dom	**10**	Dom Air	
	Cr (III)	µg/ℓ	**7**	–	?		**24**	Ecol-N	17
	Cu	µg/ℓ	**6**	–	200	Alr	**10**	Prop-Pr	4
	Fe	µg/ℓ	**56**	–	300	In3	**100**	Dom	44
	Mn	µg/ℓ	**13**	–	20	Alr	**50**	Alr-I	37
	Mo	µg/ℓ	–	–	15	ASw Alr	**20**	Alr-A	-
	Ni	µg/ℓ	**38**	–	200	Alr	**200**	–	162
	Pb	µg/ℓ	**54**	–	100	ASw	**50**	Dom-A	-4
	V	µg/ℓ	**34**	–	100	Alr	**100**	–	63
	Zn	µg/ℓ	**18**	–	1000	Alr	**35**	Eco-Rec	17
Nutrients	PO_4-P	µg/ℓ	**18**	22	25	Eco	**25**	Eco	7
	NO_3&NO_2-N	mg/ℓ	**0.04**	0.097	6.0	Dom	**0.20**	Eco-Rec	0.16
	DIN	mg/ℓ	**0.117**	0.130	?		**0.25**	Eco-I N-lim	0.133
	Si	mg/ℓ	**9.12**	8.19	20	In3 Alr	**20**	–	11.8
Response variable	Chl-a	µg/ℓ	**6.5**	–	15	RFull	**10**	Eco-I	3.5
	Diatoms*	SPI	**13.3**	–	–	–	**13– 17**	Good qual	
	*E. coli**	/100mℓ	**128**	–	–	–	**130**	RFull	2

* Snapshot values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **Alr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Cat:** Category; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.2.5 Preliminary RWQOs for Pella Mission (OS15)

Pella marks the end of Visioning area 3 and the beginning of Visioning area 4. Part of the Visioning statement is "… to secure sufficient water of qualities that are fit for use. These water uses include: A thriving conservation and eco-tourism industry; A favourable diamond mining industry; A viable date export marked (**Figure 24**); and various water supply schemes for the purpose of supplying the needs of commercial and subsistence farmers, domestic users and base-metal mining." (DWAF, 2009b).

Figure 24: Date palm tree plantation on Karsten Farms at Klein Pella (next to the Orange River) under irrigation.

The PES for Pella is high and considered to be largely natural, class B (**Table 71**). However, the lead and cadmium concentrations at Pella are very high and pose a potential human health risk to the users of this water and could have a negative impact on the aquatic ecosystem. The source of these metals should be investigated.

Table 71: Background information on Pella in Orange River (Level 1) – Lower Orange WMA 14.

River:	Orange	**Study Unit:**	Pella	**Quat.:**	D81G	**WQM site:**	D8H008
PES:	B	**REC:**	B	**EISC:**	High	**Reference state:**	1971–1976 (n = 30)
Management Class:		Natural				**Present State:**	2005–2007 (n = 45)
RWQO Model Vers:		4.1					

Table 72: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Pella (OS15) – Lower Orange WMA - Orange River – level 1.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO New	Reason	Alloc Value
Physical variables	Hardness	mg/ℓ	**200**	–	250	Dom In3	**250**	–	50
	EC	mS/m	**68.5**	60.5	70	Dom In3	**85**	Eco-T	16.5
	pH 5[th]		**7.8**	7.0	6.5	AIr In3	**7.4**	5 % dev	0.4
	pH 95[th]		**8.4**	8.7	8.0	In3	**8.4**	AIr Nat	0.0
Chemical variables	Alkalinity	mg/ℓ	**167**	172	300	In3-I	**300**	–	133
	Ammonia	µg/ℓ	**13**	–	15	Eco	**30**	–	17
	Calcium	mg/ℓ	**41.9**	34.8	80	Dom	**80**	BHN	38.1
	Chloride	mg/ℓ	**66.1**	41.8	100	Dom AIr	**100**	–	33.9
	Fluoride	mg/ℓ	**0.42**	0.43	1.0	Dom	**1.0**	–	0.58
	Magnesium	mg/ℓ	**24.4**	19.5	100	Dom-A	**70**	Dom-I	45.6
	Potassium	mg/ℓ	**3.3**	7.3	50	Dom-A	**25**	Dom-I Nat	21.7
	SAR	mmol/ℓ	**1.97**	1.6	8	AIr	**3.0**	AIr – soil B	1.03
	Sodium	mg/ℓ	**64.8**	47.2	92.5	AIr-A	**92.5**	–	27.7
	Sulphate	mg/ℓ	**77.3**	52.8	200	Dom In3	**150**	Rec; d/s	72.7
	TDS	mg/ℓ	**474**	402	450	AIr	**550**	Cat-C, Pr	76
Chemical micro & metals	Al	µg/ℓ	**35**	–	20	ASw	**62.5**	Cat-B	27.5
	B	µg/ℓ	**206**	–	750	AIr-A	**500**	AIr-I	294
	Cd	µg/ℓ	**77**	–	5	Dom-I	**20**	Dom-T AIr	-57
	Cr (III)	µg/ℓ	**3**	–	24	Eco	**24**	Ecol-N	21
	Cu	µg/ℓ	**6**	–	1.6	Eco	**10**	Prop-Pr	4
	Fe	µg/ℓ	**44**	–	300	In3	**100**	Dom-I	56
	Mn	µg/ℓ	**6**	–	200	AIr	**50**	Dom-I	44
	Mo	µg/ℓ	**16**	–	10	ASw AIr	**20**	ASw AIr-A	4
	Ni	µg/ℓ	**4**	–	200	AIr	**200**	–	196
	Pb	µg/ℓ	**358**	–	100	ASw	**100**	Dom-T ASw	-258
	V	µg/ℓ	**13**	–	550	AIr-A	**100**	Dom-I AIr-I	87
	Zn	µg/ℓ	**5**	–	1000	AIr-I	**35**	Eco-Rec	30
Nutrients	PO_4-P	µg/ℓ	**22**	19	10	Eco	**30**	Eco-A	8
	NO_3&NO_2-N	mg/ℓ	**0.04**	0.02	6.0	Dom	**0.15**	Eco-Rec	0.11
	DIN	mg/ℓ	**0.12**	0.04	0.25	Eco-I	**0.25**	N-lim,	0.13
	Si	mg/ℓ	**10.3**	8.3	20	AIr	**20**	–	9.7
Response variable	Chl-a*	µg/ℓ	**10.3**	–	–	–	**15**	Eco-A	4.7
	Diatoms*	SPI	**11.3**	–	–	–	**9 – 13**	Mod qual	
	*E. coli**	/100mℓ	**12**	–	–	–	**130**	RFull	118

* Snapshot values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.2.6 Preliminary RWQOs for Vioolsdrift (OS16)

The hydrometric gauging station at Vioolsdrift receives runoff from 87 % of the Orange River Catchment. This site is the most appropriate site for inclusion in the Global River Flux monitoring network, as this site has already been identified as the most appropriate site for monitoring loads of water quality constituents from the Orange River catchment. It is therefore also the ideal site for trend monitoring of runoff from the interior of South Africa (Van Niekerk, 2005). Agricultural activities (irrigation) are important along the whole Orange River (cf. **Figure 25**).

Figure 25: Agricultural activity (irrigated tomato production under plastic covers) next to the Orange River close to Vioolsdrift.

Vioolsdrift's ecological state is also rated high – B class (**Table 73**). However, the high salt concentration (present state, 509 mg/ℓ), is associated with a C Class water quality. The inorganic salt, magnesium sulphate, aluminium, lead, and molybdenum concentrations are already above the RWQOs and indicate that the system is stressed in terms of these variables (**Table 74**).

Table 73: Background information on Vioolsdrift in Orange River (Level 1) – Lower Orange WMA 14.

River:	Orange	**Study Unit:**	Vioolsdrift	**Quat.:**	D82F	**WQM site:**	D8H003
PES:	B	**REC:**	B	**EISC:**	High	**Reference state:**	1976–1978 (n ≈ 66)
RWQO Model Vers:		4.1				**Present State:**	2005–2007 (n = 111)

Table 74: Present state, Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Vioolsdrift – Lower Orange WMA - Orange River.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO New	Reason	Alloc Value
Physical variables	Hardness	mg/ℓ	**205**	–	250	AAq In3	**250**	–	45
	EC	mS/m	**74.5**	41.5	70	Dom In3	**85**	Cat C	10.5
	pH 5th		**7.4**	–	6.5	AIr In3	**7.0**	5 % dev	0.4
	pH 95th		**8.4**	–	8.0	In3	**8.4**	Air Nat	0
Chemical variables	Alkalinity	mg/ℓ	**170**	135	300	In3	**300**	–	130
	Ammonia	µg/ℓ	**8**	–	30	AAq	**30**	–	22
	Calcium	mg/ℓ	**41.1**	35.7	150	Dom	**80**	BHN	38.9
	Chloride	mg/ℓ	**78.5**	24.1	100	Dom Air	**100**	–	21.5
	Fluoride	mg/ℓ	**0.48**	0.38	1.0	Dom	**1.0**	–	0.52
	Magnesium	mg/ℓ	**26.2**	14.6	100	Dom	**70**	Dom-I	43.8
	Potassium	mg/ℓ	**3.4**	3.4	50	Dom	**25**	Dom-I	21.6
	SAR	mmol/ℓ	**2.2**	1.1	8	Air	**3.0**	AIr Soil	0.8
	Sodium	mg/ℓ	**73.4**	28.6	92.5	Air	**92.5**	–	19.1
	Sulphate	mg/ℓ	**85.5**	43.9	200	Dom In3	**150**	Rec	64.5
	TDS	mg/ℓ	**509**	281	450	Air	**550**	Eco-T	41
Chemical Inorganic salts	$MgSO_4$	mg/ℓ	**105.7**	–	27	Eco-A	**37**	Eco-T	-68.7
	Na_2SO_4	mg/ℓ	**2.7**		36	Eco-A	**36**	–	33.3
	$MgCl_2$	mg/ℓ	**3.6**		33	Eco-A	**33**	–	29.4
	$CaCl_2$	mg/ℓ	**13.5**		63	Eco-A	**63**	–	49.5
	NaCl	mg/ℓ	**116.3**		217	Eco-A	**217**	–	100.7
Chemical micro & metals	Al	µg/ℓ	**168**	–	70	AAq	**150**	Eco-T	-18
	B	µg/ℓ	**109**	–	750	AIr	**500**	AIr-I	391
	Cd	µg/ℓ	**12**	–	10	Dom	**20**	Dom AIr	8
	Cr (III)	µg/ℓ	**9**	–	182	EcoI	**24**	Eco-I	15
	Cu	µg/ℓ	**6**	–	1.6	Eco	**10**	Rec-Pr	4
	Fe	µg/ℓ	**30**	–	300	AAq	**300**	–	270
	Mn	µg/ℓ	**4**	–	200	AIr	**50**	Dom-I	46
	Mo	µg/ℓ	**45**	–	15	ASw AIr	**30**	AIr-A	-15
	Ni	µg/ℓ	**44**	–	200	AIr	**200**	–	156
	Pb	µg/ℓ	**54**	–	4	Eco	**50**	Dom-A	-5
	V	µg/ℓ	**37**	–	100	AIr	**100**	–	63
	Zn	µg/ℓ	**10**	–	1000	AIr	**35**	Eco-Rec	25
Nutrients	PO_4-P	µg/ℓ	**25**	22	30	AAq	**30**	Eco-A	5
	NO_3&NO_2-N	mg/ℓ	**0.04**	0.04	6.0	Dom	**0.15**	Eco-Rec	0.11
	DIN	mg/ℓ	**0.096**	0.13	1.0	Eco-G	**0.25**	Eco-A; N-lim	0.154
	Si	mg/ℓ	**9.4**	8.7	20	AIr	**20**	–	10.6
Response variable	Chl-a	µg/ℓ	**10.6**	–			**15**	Eco-A	4.4
	Diatoms*	SPI	**13**	–	–	–	**13 -17**	Good qual	
	*E. coli**	/100mℓ	**7**	–	–	–	**130**	RFull	123

* Snapshot values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.2.7 Preliminary RWQOs for Sendelingsdrift (OS18)

Sendelingsdrift is a proposed new site in the D82F quaternary. The PES is a B, the REC a B and the EISC is high.

Table 75: Present state (Snapshot, 2008), Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Sendelingsdrift – Lower Orange WMA - Orange River – level 1.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO New	Reason	Alloc Value
Physical variables	Hardness	mg/ℓ	**176**	–	250	Dom	**250**	–	74
	EC	mS/m	**45**	–	70	Dom In3	**85**	Eco-T	40
	pH 5th			–	6.5	Alr In3	**7.5**	Rec	-
	pH		**8.7**	–	8.0	In3	**8.5**	Rec	-0.2
Chemical variables	Alkalinity	mg/ℓ	**156**	–	300	In3	**300**	–	144
	Ammonia	µg/ℓ	**8**	–	15		**15**	Eco-I	7
	Calcium	mg/ℓ	**35.4**	–	80	Dom	**80**	–	44.6
	Chloride	mg/ℓ	**71**	–	100	Dom Alr	**100**	–	29
	Fluoride	mg/ℓ	**0.40**	–	1.0	Dom	**0.7**	Dom-I	0.3
	Magnesium	mg/ℓ	**21.1**	–	100	Dom	**70**	Dom-I	48.9
	Potassium	mg/ℓ	**2.95**	–	50	Dom	**25**	Dom-I	22.05
	SAR	mmol/ℓ	**2.16**	–	8	Alr	**3.0**	Alr Soil	0.84
	Sodium	mg/ℓ	**66.0**	–	92.5	Alr	**92.5**	–	26.5
	Sulphate	mg/ℓ	**78**	–	200	Dom In3	**200**	–	122
	TDS	mg/ℓ	**433**	–	450	Alr	**550**	Eco-T	117
Chemical micro & metals	Al	µg/ℓ	**27**	–	20	ASw	**85**	Eco-A	58
	Cd	µg/ℓ	**<1**	–	0	Dom	**10**	Dom-A	9
	Cu	µg/ℓ	**13**	–	0	Alr	**10**	Rec-Pr	-3
	Fe	µg/ℓ	**18**	–	300	In3	**300**	–	282
	Mn	µg/ℓ	**6**	–	200	Alr	**50**	Dom-I	44
	Pb	µg/ℓ	**<10**	–	0	ASw	**50**	Dom-A	40
	V	µg/ℓ	**<6**	–	550	Alr	**100**	Dom-I	94
	Zn	µg/ℓ	**<6**	–	3 000	Alr	**36**	Eco-T	30
Nutrients	PO_4-P	µg/ℓ	**37**	–	10		**50**	Eco-T	13
	NO_3&NO_2-N	mg/ℓ	**0.24**	–	6.0	Dom	**0.40**	Eco-Pro	0.16
	DIN	mg/ℓ	**0.29**	–	0.25	-	**0.50**	N-lim, Eco-A	0.21
	Si	mg/ℓ	**2.1**	–	20	In3	**20**	–	17.9
Response variable	Chl-a	µg/ℓ	**34**	–	15	RFull	**30**	Eco-T	-4
	Diatoms*	SPI	**11.3**	–	–	–	**9 - 13**	Mod qual	
	*E. coli**	/100mℓ	**25**	–	–	–	**130**	RFull	105

* Snapshot values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **Alr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.2.8 Preliminary RWQOs for Alexander Bay (OS19)

The RWQO site at Alexander Bay (D8H12) is approximately 10 km upstream of the river mouth (**Figure 26**). Unfortunately, monitoring was ended at this site in 2003. The present state values are based on the 2 snapshot surveys during 2008.

Figure 26: Satellite image (Google Earth) of the Orange River mouth – a Ramsar site. Note the diamond mining activity along the southern side (South African side) of the river posing a threat to the sensitive Ramsar site area.

Table 76: Background information on the site (OS19) at Alexander Bay in Orange River (Level 1) – Lower Orange WMA 14.

River:	Orange	**Study Unit:**	Alexander Bay	**Quat.**	D82F	**WQM site:**	D8H012
PES:	C	**REC:**	B	**EISC:**	Low/ marginal	**Reference state:**	1995 – 1996 (n ≈ 123)
Management Class:		Natural				**Present State:**	Snapshot 2008 (n = 2)
RWQO Model Vers:		4.1					

Table 77: Present state (Snapshot, 2008), Reference values and preliminary Resource Water Quality Objectives (RWQOs) for Alexander Bay (OS19) – Lower Orange WMA - Orange River – level 1.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO New	Reason	Alloc Value
Physical variables	Hardness	mg/ℓ	**186**	–	250	Dom	**250**	–	64
	EC	mS/m	**49**	83.8	70	Dom In3	**85**	Eco-T	36
	pH 5th			8.0	6.5	Alr In3	**7.5**	Rec	0.5
	pH 95th		**8.5**	8.6	8.0	In3	**8.5**	Rec	0
Chemical variables	Alkalinity	mg/ℓ	**155**	188	300	In3	**300**	–	145
	Ammonia	µg/ℓ	**7**	–	15		**15**	Eco-I	8
	Calcium	mg/ℓ	**38.7**	45.2	80	Dom	**80**	–	41.3
	Chloride	mg/ℓ	**79.4**	81.3	100	Dom Alr	**100**	–	20.6
	Fluoride	mg/ℓ	**0.38**	0.53	1.0	Dom	**0.7**	Dom-I	0.32
	Magnesium	mg/ℓ	**21.7**	25.8	100	Dom	**70**	Dom-I	48.3
	Potassium	mg/ℓ	**3.1**	5.25	50	Dom	**25**	Dom-I	21.9
	SAR	mmol/ℓ	**2.24**	2.66	8	Alr	**3.0**	Alr Soil	0.76
	Sodium	mg/ℓ	**70.8**	82.4	92.5	Alr	**92.5**	–	21.7
	Sulphate	mg/ℓ	**83.5**	76.1	200	Dom In3	**150**	Rec	66.5
	TDS	mg/ℓ	**456**	532	450	Alr	**550**	Eco-T	94
Chemical Inorganic salts	$MgSO_4$	mg/ℓ	**84.8**	–	27	Eco-A	**37**	Eco-T	-47.8
	Na_2SO_4	mg/ℓ	**37.8**		36	Eco-A	**51**	Eco-T	13.2
	$MgCl_2$	mg/ℓ	**3.1**		33	Eco-A	**33**	–	29.9
	$CaCl_2$	mg/ℓ	**23.8**		63	Eco-A	**63**	–	39.2
	NaCl	mg/ℓ	**61.3**		217	Eco-A	**217**	–	155.7
Chemical micro & metals	Al	µg/ℓ	**30**	–	20	ASw	**85**	Eco-A	55
	Cd	µg/ℓ	**<1**	–	0	Dom	**10**	Dom-A	9
	Cu	µg/ℓ	**13**	–	0	Alr	**10**	Rec	-3
	Fe	µg/ℓ	**24**	–	300	In3	**300**	–	276
	Mn	µg/ℓ	**5**	–	200	Alr	**50**	Dom-I	45
	Pb	µg/ℓ	**<10**	–	0	ASw	**50**	Dom-A	~40
	V	µg/ℓ	**<6**	–	550	Alr	**100**	Dom-I	~96
	Zn	µg/ℓ	**3**	–	3 000	Alr	**36**	Eco-T	33
Nutrients	PO_4-P	µg/ℓ	**25**	26	10		**30**	Eco-A	5
	NO_3 &NO_2-N	mg/ℓ	**0.18**	0.11	6.0	Dom	**0.25**	Eco-Pro	0.07
	DIN	mg/ℓ	**0.25**	0.13	0.25	-	**0.30**	N-lim, Eco-A	0.05
	Si	mg/ℓ	**2.7**	7.6	20	In3	**20**	–	17.3
Response variable	Chl-a	µg/ℓ	**25**	–	15	RFull	**30**	Eco-T	5
	Diatoms*	SPI	**13.7**	–	–	–	**13 -17**	Good qual	-
	*E. coli**	/100mℓ	**85**	–	–	–	**130**	RFull	45

* Snapshot values; **A**: Acceptable; **Alloc**: Allocatable; **Alr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

5.2.9 Preliminary RWQOs for Vaal River (VS21)

The major tributary in the Lower Orange is the Vaal River. This is a new proposed RWQO site in the town of Douglas (at the road bridge). The Vaal River was charcterised by high salts concentrations and high algal growth, especially filamentous algae.

Table 78: Present state (Snapshot, 2008), Reference values and preliminary Resource Water Quality Objectives (RWQOs) for the Vaal River – Lower Orange WMA - Orange River – level 2.

Variable group	Variable	Units	Present State	Ref. value	RWQO Model	User	RWQO New	Reason	Alloc Value
Physical variables	Hardness	Mg/ℓ	**295**	–	300	Dom	**300**	–	5
	EC	mS/m	**90**	–	30	Dom In3	**100**	Dom-A	10
	pH 5th			–	–	–	–	–	–
	pH		**7.8**	–	8.0	In3	**8.5**	Rec	0.7
Chemical variables	Alkalinity	Mg/ℓ	**144**	–	450	In3	**300**	–	156
	Ammonia	µg/ℓ	**12**	–	15		**15**	Eco-I	3
	Calcium	Mg/ℓ	**46.7**	–	80	Dom	**80**	–	33.3
	Chloride	Mg/ℓ	**185.5**	–	137.5	Dom AIr	**200**	BHN	14.5
	Fluoride	Mg/ℓ	**0.33**	–	1.0	Dom	**0.7**	Dom-I	0.37
	Magnesium	Mg/ℓ	**43.4**	–	100	Dom	**70**	Dom-I	26.6
	Potassium	Mg/ℓ	**5.7**	–	50	Dom	**25**	Dom-I	19.3
	SAR	mmol/ℓ	**2.88**	–	8	AIr	**6.0**	AIr Soil-T	3.12
	Sodium	Mg/ℓ	**114.6**	–	92.5	AIr	**115**	AIr–T	0.4
	Sulphate	Mg/ℓ	**157**	–	250	Dom In3	**200**	Dom-I	43
	TDS	Mg/ℓ	**700**	–	800	AIr	**800**	–	100
Chemical micro & metals	Al	µg/ℓ	**29**	–	20	ASw	**85**	Eco-A	56
	Cd	µg/ℓ	**<1**	–	–	–	–	–	–
	Cu	µg/ℓ	**4.5**	–	0	AIr	**10**	Prop-Pr	5.5
	Fe	µg/ℓ	**28**	–	1 000	In3	**300**	In3-I	272
	Mn	µg/ℓ	**9**	–	200	AIr	**50**	Dom-I	41
	Pb	µg/ℓ	**<10**	–	–	ASw	**50**	Dom-A	40
	V	µg/ℓ	**<6**	–	–	AIr	**100**	Dom-I	94
	Zn	µg/ℓ	**8**	–	3 000	AIr	**36**	Eco-T	28
Nutrients	PO_4-P	µg/ℓ	**42.5**	–	5		**50**	Eco-T	7.5
	NO_3&NO_2-N	Mg/ℓ	**0.32**	–	10	Dom	**0.40**	Eco-Pro	0.08
	DIN	Mg/ℓ	**0.43**	–	0.25	-	**0.50**	Eco-A	0.07
	Si	Mg/ℓ	**3.86**	–	85	In3	**20**	–	16.14
Response variable	Chl-a	µg/ℓ	**28.5**	–	10	RFull	**30**	Eco-T	1.5
	Diatoms*	SPI	**11**	–	–	–	**9 – 13**	Mod qual	
	*E. coli**	/100mℓ	**318**	–	–	–	**400**	RFull-T	82

***** Snapshot values; **AAq**: Agriculture – Aquaculture; **A**: Acceptable; **Alloc**: Allocatable; **AIr**: Agriculture – Irrigation; **ASw**: Agriculture – Stock watering; **BHN**: Basic Human Needs; **Dom:** Domestic; **d/s:** downstream users; **Eco:** Ecosystem requirement; **I:** Ideal; **In3:** Industrial – Category 3; **Nat:** Natural; **N-lim:** Nitrogen limitation; **Rec:** recommended value; **Ref**: Reference value; **RFull:** Recreation – Full contact; **T:** Tolerable.

6 SUMMARY AND RECOMMENDATIONS

6.1 Upper Orange River

The whole Upper Orange River (from Oranjedraai to Marksdrift) is fairly homogenous in terms of water chemistry, but is divided in 2 river reaches to coincide with the visioning areas – Orange 1 and Orange 2. The RWQOs for priority WQ variables calculated for Oranjedraai (**Table 79**) is applicable to river reach 1, *i.e.* from Oranjedraai to Gariep Dam. The RWQOs calculated for Gariep Dam is applicable to the river reach 2, *i.e.* from just below Gariep Dam to Marksdrift. The RWQOs for TDS for the different river reaches are indicated in **Figure 27**.

6.1.1 Orange River tributaries – Level 2

The water chemistry of the five tributaries differs significantly, therefore, different RWQOs were calculated for each site – see **Table 80** for a summary of RWQO for key water quality variables.

The Stormbergspruit and Seekoei River are ionic rich systems, but Stormbergspruit is contaminated by sewage and several variables exceeded the RWQOs and the Seekoei River contains naturally high background salt values, therefore, different RWQOs.

6.1.2 Caledon River

The Caledon River and tributaries has been grouped together as one visioning area, however, the salt concentrations in the lower end of the Caledon River was significantly higher than the upper end which justify the separation of the river into 2 reaches. The Caledon River reach 1 stretch from the confluence with the Little Caledon to Maseru and river reach 2 from Maseru to Kommissiedrift (confluence with Orange River). RWQOs for the Caledon River at Ficksburg are recommended as the representative site for the river reach 1 (**Tables 79**) and RWQOs at Komissiedrift are recommended for river reach 2 (**Tables 79**) for certain key water quality variables.

6.1.3 Caledon River tributaries – level 2

The Little Caledon River at Golden Gate is a natural (pristine) site with a different and more stringent set of RWQOs (**Table 52**). The Little Caledon River (at the confluence with the Caledon River) has been moderately modified, therefore a different set of RWQOs.

The other four tributaries to the Caledon River (Groot, Meul, Moperi and Leeu) show moderate differences therefore different preliminary RWQOs (cf. **Table 81**). However, more data are needed to increase the confidence levels of the RWQOs based on 1 or 2 determinations.

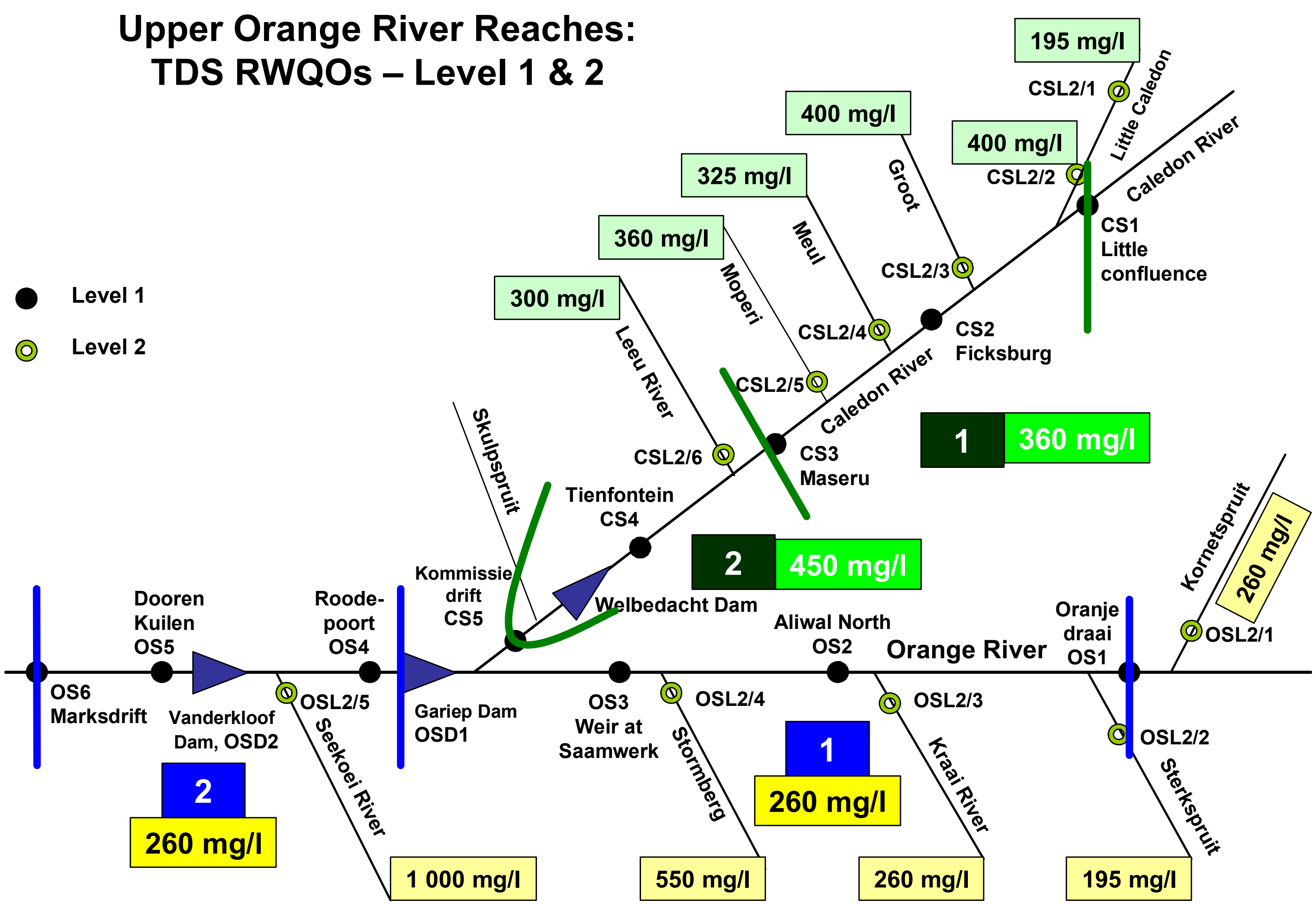

Figure 27: Upper Orange – River Reaches in Orange River and Caledon River with TDS RWQOs for level 1 and 2.

Table 79: RWQOs for priority variables in the Upper Orange WMA. River reaches 1 and 2 in Orange River and Caledon River main stem – level 1.

Variable	Units	Upper Orange River – RWQO Level 1			
River reach		Orange 1	Orange 2	Caledon 1	Caledon 2
EC	mS/m	40	40	55	70
Sulphate	mg/ℓ	60	60	80	80
Chloride	mg/ℓ	40	40	40	40
TDS	mg/ℓ	260	260	360	450
Nitrate	mg/ℓ as N	0.30	0.40	0.20	0.25
DIN	mg/ℓ as N	0.40	0.50	0.30	0.35
Phosphate	µg/ℓ as P	45	40	40	50

Table 80: Summary of RWQOs for priority variables in the Upper Orange WMA. Orange River tributaries – level 2.

Variable	Units	Upper Orange River – RWQO Level 2				
Catchment Unit		Kornet	Sterk	Kraai	Stormberg	Seekoei
EC	mS/m	40	30	40	85	150
Sulphate	mg/ℓ	80	40	25	100	150
Chloride	mg/ℓ	40	20	20	138	138
TDS	mg/ℓ	260	200	260	550	1 000
Nitrate	mg/ℓ as N	0.20	0.55	0.15	0.75	0.20
DIN	mg/ℓ as N	0.25	0.70	0.20	1.0	0.25
Phosphate	µg/ℓ as P	40	130	30	130	50

Table 81: Summary of RWQOs for priority variables in the Upper Orange WMA. Caledon River tributaries – level 2.

Variable	Units	Caledon River – RWQO Level 2					
Management Unit		Little Caledon at GG*	Little Caledon at Confl**	Groot-spruit	Meul-spruit	Moperi-spruit	Leeu River
EC	mS/m	30	60	60	50	55	45
Sulphate	Mg/ℓ	25	80	80	60	100	50
Chloride	Mg/ℓ	5	50	50	50	100	50
TDS	Mg/ℓ	195	400	400	325	360	300
Nitrate	Mg/ℓ as N	0.30	0.40	0.40	0.20	0.35	0.40
DIN	Mg/ℓ as N	0.40	0.50	0.50	0.30	0.50	0.50
Phosphate	µg/ℓ as P	30	50	80	45	100	50

* GG, Golden Gate; ** Confl, confluence with Caledon River

6.2 Lower Orange WMA

The lower Orange WMA is divided in 4 management units similar to the visioning areas, *i.e.*:

(I) Marksdrift (Douglas) to Boegoeberg Dam

(II) Boegoeberg Dam to Neusberg Weir (Kakamas)

(III) Neusberg Weir to Pella

(IV) Pella to Alexander Bay

The downstream changes in RWQOs for the total dissolved salts (TDS, 95th percentiles) are shown in **Figure 28**. In general as one progresses downstream RWQOs become less stringent. However, an exception is the RWQOs for DIN that becomes more stringent downstream (**Table 82**).

6.2.1 Metal default values:

The default concentrations for most of the metals (User: Aquatic Ecosystem, SAWQG, 1996) are impracticably low for the Orange River, especially for Al, Cd, Cu, Pb and Zn, and 'new' rating concentrations for the Orange River and tributaries are proposed (see **Table 83**).

However, The Department of Water Affairs and Forestry has initialised the discussion of concepts around the development of risk-based guidelines against the background of reviewing the South African Water Quality Guidelines (SAWQG) of 1996 (Jooste – personal communication). The relatively high concentrations in the Orange River and tributaries are considered to be natural background values.

Table 82: Summary of RWQOs for priority variables at the four river reaches in the Lower Orange WMA. Orange River main stem – level 1 and Vaal River (Level 2).

Variable	Units	Lower Orange WMA – RWQO Level 1				Level 2
River reach		1 (Marksdrift)	2 (Boegoeberg)	3 (Neusberg)	4 (Pella)	Vaal at confl
EC	mS/m	55	60	70	85	100
Sulphate	mg/ℓ	60	80	100	150	200
Chloride	mg/ℓ	50	100	100	100	200
TDS	mg/ℓ	360	400	450	550	800
Nitrate	mg/ℓ as N	0.50	0.40	0.25	0.15	0.40
DIN	mg/ℓ as N	0.70	0.50	0.30	0.25	0.50
Phosphate	µg/ℓ as P	30	30	30	30	50

Table 83: Proposed rating values (95 percentile) for metals in the Orange River (user: Aquatic Ecosystem).

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
Al	µg/ℓ	≤ 30	100	200	>200
Cd	µg/ℓ	≤ 5	40	80	>80
Cr	µg/ℓ	≤ 25	160	340	>340
Cu	µg/ℓ	≤ 5	10	15	>15
Mo	µg/ℓ	≤ 10	15	20	>20
Pb	µg/ℓ	≤ 10	50	100	>100
Zn	µg/ℓ	≤ 5	25	50	>50

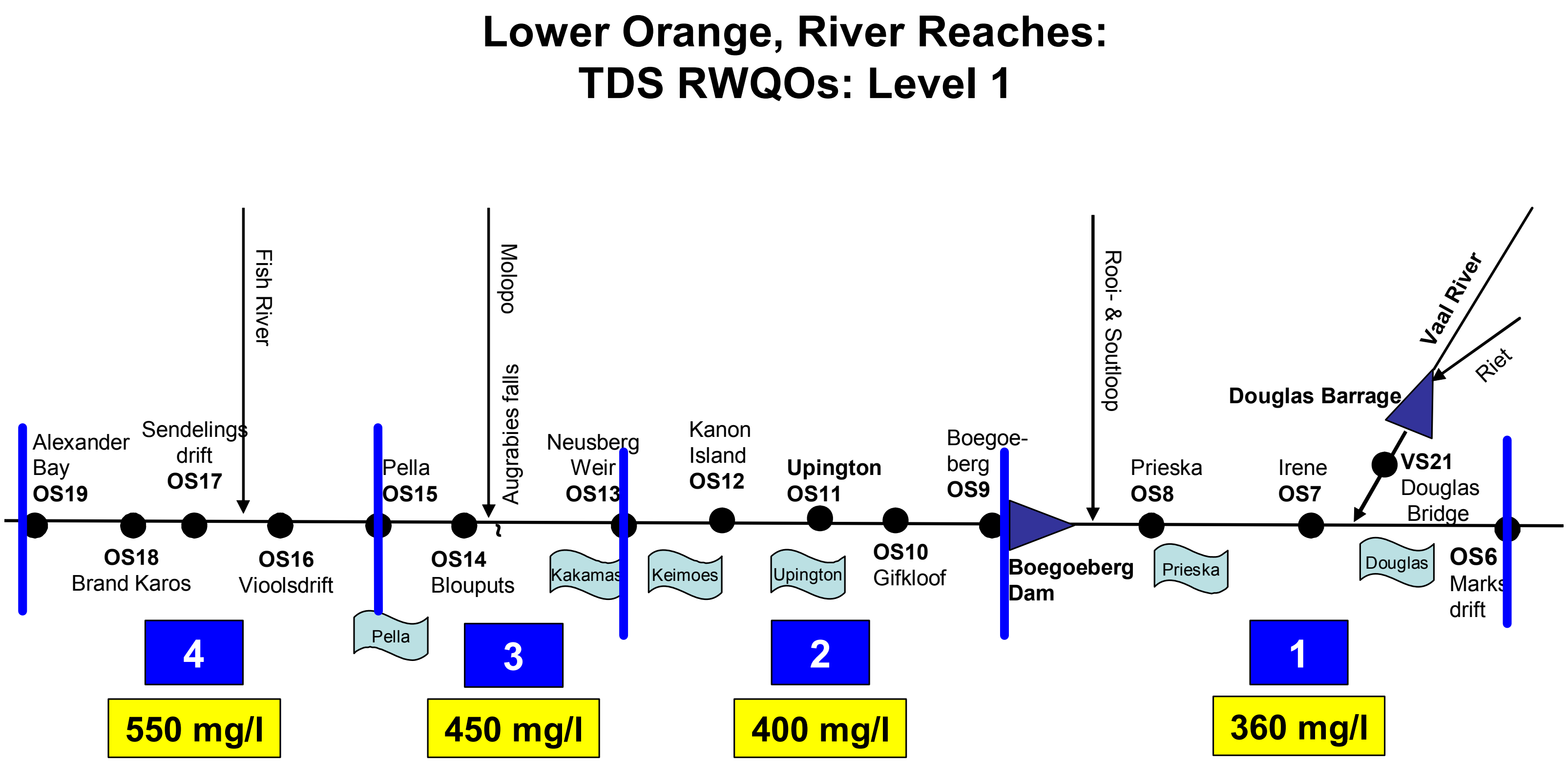

Figure 28: Lower Orange River Reaches with TDS RWQOs.

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6.3 RWQO Model 4.1:

The Model should be upgraded to include:

(i) *E. coli* concentrations, especially for recreational use and

(ii) Diatoms index (SPI).

Correct the following errors in the Model:

(i) Dissolved organic carbon (DOC) and dissolved oxygen (DO) are options to fill in, but the Model Report does not show any RWQO values for these variables.

(ii) Add EC values for irrigation that are not listed in the Reference Tables.

(iii) Add Zn concentrations to Reference Tables for Agriculture-aquaculture.

(iv) The Reference Table, indicate the I (Ideal) concentrations for Cd as 0.000, but it is suppose to be 0.005 mg/ℓ.

(v) In the Report table, the Cutoff values for Cu (user Agriculture-Irrigation) are indicated as I, 0.2; A, 0.75 and T, 1.0, but the RWQO value is given as 0.000.

7 CONCLUSION

The RWQOs provide the numeric or descriptive goals, within which the water resource must be managed. However, these water quality 'limits' can also assist the Department in assessing the extent of the remaining allocatable water quality within a water resource management unit, and how a possible license application may impact upon this allocatable resource.

From the assessment conducted, a set of RWQOs have been recommended for the Orange River. In order to ensure that the water quality of the Orange River is maintained or improved, the adoption of the preliminary RWQOs proposed will aid in achieving the management targets and ensure the needs of users of the river are met.

The final RWQOs that are established will also be dependent on the flow requirements and related operating rules of the Orange River System. Once the modelling (of salts and nutrients) as part of a reconciliation strategy for the Orange River System is undertaken and various water quality management options considered, the RWQOs that can be holistically and realistic achieved can be confirmed. While compliance to RWQOs is definitely a necessity, the level to which this can happen is dependent on the viable options that can be cost-effectively implemented. The economic implications for achievement and the impact on the downstream users will also have to be considered. These cascading effects will be considered in the follow up study envisaged for the Orange River System. The economic impact modelling related to the management options and operating rules would also be a key determinant in the final RWQOs that are adopted.

Setting the RWQOs is one component; the second more important component is its implementation and compliance, which extends beyond the study. Thus the implementation of these preliminary RWQOs by the Regional Offices is critical to ensuring that effective management of the Orange River does occur into the future.

8 WAY FORWARD

Recommendations on a preliminary set of RWQOs for the Orange River have been made as part of this study. The Department as the custodian of the RWQOs has accepted these recommendations and it is now the responsibility of the relevant DWAF Directorates and Regional Offices to ensure implementation. The RWQOs form a basis for water quality management in the catchment areas of the Orange River, and should be included in the water use authorisations of water users.

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APPENDIX A

Lower Orange River – Resource Water Quality Objectives

Minutes of meeting No. 1 with the Northern Cape Regional Office

DWAF Offices, Upington, 20 November 2006

LOWER ORANGE RIVER

RESOURCE WATER QUALITY OBJECTIVES

MINUTES OF MEETING NO.1 WITH REGIONAL OFFICE

VENUE: DWAF OFFICES, UPINGTON

DATE: 20 NOVEMBER 2006

1. Welcome

H Abbott welcomed everyone and introduced the attendees.

2. Purpose of the meeting

J van Wyk introduced the purpose of the meeting as three components:

- RWQOs (this covers discussions on the proposed RWQOs, preliminary RWQOs and also variables of concern),
- Visioning, and
- Monitoring.

3. Attendance

See the attached list.

4. Approval of the agenda

The agenda was accepted without any additions or corrections.

5. Background

J van Wyk provided the background for the proposed meeting and stressed the importance of visioning for the catchment, especially with the impacts from the Vaal and Upper Orange that causes the deterioration of the water quality.

6. RWQOs

6.1 Proposed RWQOs sites

The first comment from H Abbott was that he is pleased by the initiative but concerned about the number of monitoring points due to the lack of officials to undertake the monitoring. R Stassen indicated that most of the proposed RWQOs sites are linked to existing monitoring sites with data available from the Water Management System (WMS).

The proposed sites OS1-OS5 on the map falls within the Upper Orange and will not be discussed during the meeting.

The proposed RWQO sites for the Lower Orange were discussed by the members of the meeting.

6.2 Level 1 RWQO sites

OS6 – Marksdrift. This is an important and suitable point because it is located just before the confluence of the Vaal and Upper Orange Rivers. Use existing D3H008Q01 monitoring station.

OS7 – Irene. B Conradie mentioned that there are currently no observers and that the site is used as a flood section only. She suggested that the site be moved closer to the confluence of the Vaal and Upper Orange Rivers and that farmers (W Bruwer) nearby be requested to take the samples.

OS8 – Prieska. There is a reliable observer for this site. There is currently no data at this site (D7H002Q01). The impact from the Ongers River (irrigation) will also be included at this site.

0S9 – Boegoeberg. The point was accepted, but it was suggested that it should be moved to Boegoeberg Dam (D7H008). This will include the impacts of the irrigation upstream of the dam.

New site: Gifkloof. B Conradie suggested a site between OS9 and OS10 because of the impacts from irrigation (algae).

OS10 – Upington. This point was accepted, but should be moved to the intake at Upington Water Works. This point will include objectives for Upington domestic supply, international obligations (Nakop border post) and Kalahari West pipeline for domestic and stock watering purposes.

New site: Islands. A new site should be added between OS10 and OS11 to monitor the impacts of the irrigation on the Islands. Blue-green algae have been observed.

OS11 – Neusberg. The point was accepted, data from D7H014Q01 monitoring site will be used. The site includes abstractions for domestic, irrigation and industrial use at Kakamas (wine cellars and raisin companies).

OS12 – This point was taken out due to little impact from the Hartbees River (irregular flow).

OS13 – Blouputs. The point was accepted but it should move closer to the confluence of the Molopo River to include the impacts from irrigation at Blouputs. This is the last site before the Namibian Border. Continuous monitoring was recommended by the PPECB (Perishable Products Export Control Board) and water quality monitoring in terms of their requirements are conducted. Data to be obtained from them. D8H004Q01 can be used to set the RWQOs, but should be revised with the new data.

OS14 – Pella. This point was accepted due to the water supplied for domestic, stock watering and mining purposes by the Pella Drift Water Board. Water is supplied to Pella, Pofadder, Agenys and mines (Black Mountain mine which mines coal and sink). Data from D8H008Q01 to be used for the determination of RWQOs.

OS15 – Vioolsdrift. The point was accepted, data from D8H003Q01 to be used to determine RWQOs. Abstractions at Henkries for water supply to Springbok and Kleinzee. All impacts from Pella to Vioolsdrift, including Goodhouse are taken into consideration. International obligations (Namibia) and recreational use in the downstream Ai/Ai-Richtersveld Transfrontier Park should be included in the RWQOs. The point is also located downstream of the proposed dam.

OS16 – Sendelingsdrift. The point was accepted as it is downstream of the Ai/Ai-Richtersveld Transfrontier Park and upstream of the Fish River (Namibia) confluence. A new monitoring point is needed and officials from the Park can be requested to be the observers.

New site: Rosh Pinah. There was a proposal for another RWQO site between OS16 and OS17, downstream of the Fish River confluence. This will cater for the impacts from the Fish River (irrigation) and Rosh Pinah (mining). The data from the existing monitoring site D8H007Q01 should be used for the RWQOs. Continuous monitoring should be considered if problems are experienced with observers.

OS17 – Alexander Bay. This point was accepted because it is located just upstream of the estuary (RAMSAR site). Use D8H012Q01 to determine RWQOs. Water use includes international use (NAMDEB mining) and domestic water supply to Alexander Bay and Port Nolloth. Borehole abstraction in the river is also used for domestic purposes.

6.3 Level 2 RWQO sites

L2OS/10 – Ongers. Point not essential. Smarrt Sindicate WUA can assist as observers. Impacts mainly irrigation. OS8 can be used for impacts.

Rest of proposed level 2 sites is on episodic rivers and is not viable as RWQO sites.

For the level 2 sites on the. The same numbers as for the Vaal River Reconciliation study should be used for the Vaal and Modder/Riet Rivers.

6.4 Reserve determination resource units

The proposed RQO sites are adequate for the initially identified resource units.

6.5 Water uses/impacts per proposed RWQOs site

Included in the notes on the proposed level 1 RWQO sites.

6.6 Preliminary RWQOs from model

This was not discussed in detail due to time constraints and changes to the location, monitoring points and variables of concern for the proposed RWQO sites. A follow-up meeting will be scheduled to discuss the RWQOs.

6.7 Variables of concern

pH is the main variable of concern, with Cla-a and E-coli.Other variables that could be considered are PO_4-P, NO_3+NO_2+N, KJEL-N, P-tot COD and Cd.

7. Vision for Lower Orange WMA

More than one vision should be considered for the Lower Orange WMA. This can be per area (river and inland), homogeneous sector (irrigation, mining, etc) or type of resource (mainstem Orange, episodic tributaries, groundwater).

The vision for the Lower Orange WMA is to:

- Create awareness,
- Introduce an early warning system (water quality), and
- Improve the water quality of the mainstem (eutrophication and bacteriological).

There was a proposal to sub divide the vision into areas of concern. These areas are:

- Douglas to Boegoeberg (Use WUA, W Bruwer)
- Boegoeberg to Augrabies/Kakamas (Irrigation Boards)
- Kakamas to the Mouth, including Springbok and Namaqualand
- Episodic rivers (Hartbees, Ongers, etc)
- Groundwater driven areas around the Molopo and Kalahari areas

H Abbott to ensure officials from the groundwater section at the RO is included.

WQP to assist the RO with the desktop visions before taking it to the LORRF.

8. Monitoring

M Daswa to contact Joleen for data that is available at the Regional Office that needs to be captured onto WMS.

The other entities that need to be contacted for data are Orange-Vaal WUA, Pella Drift Water Board, Namaqua Water Board and Henkries Water Board.

B Conradie provided data for the episodic rivers and the Kenhardt area.

Data on algae is also available from previous studies.

A snap-shop monitoring study (once-off during high and low flow periods) will be undertaken by WQP at all the proposed RWQO sites. This will assist with the refinement of the proposed bjectives.

9. General

No discussions.

10. Way forward

It was agreed by the Regional Office and Head Office (WRPS: WQP) that there is a need to undertake the snap-shot monitoring and that WQP will assist with the desktop visions.

11. Closure

J van Wyk closed the meeting.

APPENDIX B

Upper Orange River

Visioning, Resource Water Quality Objectives and Monitoring.

Minutes of meeting No. 1 with the Free State Regional Office

DWAF Offices, Bloemfontein, 17 January 2008

UPPER ORANGE RIVER

VISIONING, RESOURCE WATER QUALITY OBJECTIVES AND MONITORING

MINUTES OF MEETING NO.1 WITH REGIONAL OFFICE

VENUE: DWAF OFFICES, BLOEMFONTEIN

DATE: 17 JANUARY 2008

1. Welcome

JV welcomed everybody attending the meeting at 09h20.

2. Attendance

Willem Grobler (WG)
Gerda Venter (GV)
Mariette Swart (MS)
Jackie van Bosch – (JB)
Jurgo Van Wyk (JvW)
Retha Stassen (RS)
Johan van Van der Merwe (JV)
Samantha Boshoff (SB)

The attendance register is attached as Annexure A.

3. Additions to agenda

The following points were added to the agenda:
8.1 Samantha to share on her work on the Lower Orange River
8.2. Share on work in Lesotho
8.3 Waste Discharge Charge System
8.4 Monitoring standards and methods

4. Purpose of the meeting (JvW)

An exploratory, informal meeting with the following goal:

- Two main WMAs, hence, need integration across areas as well as with the Vaal River System
- Identification of any past initiatives e.g. catchment assessment studies, objectives and what data is available
- Explain the linkages/interaction between WQP and the other directorates within the Integrated Water Resources Planning chief directorate, Regional Offices and Resource Quality Services
- Discuss the importance of water quality monitoring and the use by WQP for scenario planning , foresight and reconciliation
- Provide background to the snap-shot monitoring project for the Orange River System

5. Resource Water Quality Objectives (RWQOs) (JvW)

A number of considerations were discussed, namely:

- DWAF is legally obliged to set Resource Quality Objectives
- WQP is considering the planning level, mainly the main stem and major tributaries, while Regional Offices need to consider objectives at a more detail level, i.e. at the sub-catchment level
- Level 1 objectives are set for the main stem and major tributaries, e.g. Caledon River and Level 2 for smaller tributaries

- There is a need to formulate rules to differentiate between Level 1 and 2 for rivers. (JB) suggested that catchment area can be a consideration. WG suggested impacts as a criterion, the more impacted tributaries should be Level 1, e.g. discharges of sewage treatment works to a tributary
- The parameters for each RWQO site should be considered separately
- RWQO sites should be coupled with existing monitoring sites where possible. However, RWQO sites can guide strategic monitoring where specific gaps are identified in national monitoring.
- Both the users upstream and the water uses downstream of the RWQO site should be considered when determining the objectives
- JvW explained the difference between RWQO, Reserve and RQOs

5.1 Proposed RWQO sites (RS)

The proposed Level 1 and 2 RWQO sites were discussed using a schematic diagramme of the Upper Orange River System. The following RWQO sites were proposed:

- ***OS1*** Orange River just before confluence with Kornetspruit
  Good quality water from Lesotho
- ***OSL2/1*** Kornetspruit
  Decision was made to include a level 2 RWQO site on the Kornetspruit as it brings good quality water from Lesotho
- ***OSL2/2*** Sterkspruit
  Decision taken to include as a level 2 RWQO site due to farming, communities and sewage impacts in the catchment
- ***OS20*** Orange River between Sterkspruit and Kraai confluences
  Impacts of Sterkspruit and good quality water from Kornetspruit
- ***OSL2/3*** Kraai River
  Good quality water with little impacts
  One level 2 site just before confluence with Orange River
  A second level 2 RWQO site in the vicinity of Barkley East might be considered in the future
- ***OS2*** Orange at Aliwal North
  Aliwal North sewage works discharges into river and the location of this RWQO site should be below the STW
- ***OSL2/4*** Stormberge
  Relatively drier than the other upstream tributaries
  Only small tanneries and stock farming in the upstream catchment, thus good quality water
- ***OS3*** Orange River upstream Caledon confluence
  This RWQO site should be close to Gariep Dam
- ***OS4*** Orange River downstream of Gariep Dam
  Agreed to keep this site
- ***OSL2/5*** Seekoei River
  Quite dry but a rather large catchment
  Regular sampling is done
  The Seekoei River confluence with the Orange River is close to Vanderkloof Dam
- ***OS5*** Orange River downstream Vanderkloof Dam
  Agreed to keep this site
- ***OS6*** Orange River at Marksdrift
  Some irrigation between OS5 and OS6
  Agreed to keep this site, but responsibility of Kimberley Office

It was agreed to change the Caledon River main stem to level 1 and the major tributaries of the Caledon River to level 2. The following RWQO sites were identified:

- ***CSL2/1*** Little Calendon River at Golden Gate
  Site to be situated just downstream of Golden Gate
- ***CSL2/2*** Little Caledon at Oorlogspoort
  Move site further upstream due to possible backwater from main Caledon River
- ***CS1*** Caledon River at Little Caledon confluence
  This site will provide information as to impacts upstream of the confluens from both Lesotho and SA
- ***CSL2/3*** Groot River
  RWQO site to be included for the snap shot monitoring
  If impacts are significant, this will stay as a level 2 RWQO site
- ***CS2*** Caledon at Ficksburg
  RWQO site should be situated after the sewage treatment works
  Lesotho's industrial impacts to Calendon River (material dying)
- ***CSL2/4*** Meulspruit
  A number of farm dams for irrigation purposes in the upstream catchment
  Sediment problems in the catchment
  Meulspruit Dam results in river largely being dry
  RWQO site to be situated upstream of the dam, perhaps at the Roosendal road bridge
- ***CSL2/5*** Moperi River
  Some irrigation in the catchment
  Sediment might be a problem
  Snap shot monitoring to determine if a RWQO site is really necessary
- ***CS3*** Caledon River at Maseru
  This RWQO site should be situated after Maseru to monitor the impacts
  A RWQO site should also be considered at Ladybrand
  Snap shot monitoring to determine if a second RWQO site is needed
- ***CSL2/6*** Leeuspruit at Hobhouse
  A number of large dams (Armenia, Newberry, Lovedale) for irrigation are situated in the upstream catchment
  Possible location of RWQO site is at the Hophouse Road bridge
- ***CS4*** Caledon River at Welbedacht Dam
  General water quality dam is good, although sediment a huge problem, hence move RWQO site above dam to Tienfontein pump station (abstraction point to Knellpoort Dam).
- ***CS5*** Caledon upstream of Gariep Dam
  Agreed to keep this RWQO site

Other relevant points discussed:

- Gariep Dam has three small rivers (Slykspruit, Suurbergspruit and Brakspruit) flowing directly into the dam. It was agreed that there's no need to have RWQO sites on them
- Vanderkloof Dam has two small rivers (Hondeblafrivier and Bergrivier) flowing directly into the dam. It was agreed that there's no need to have RWQO sites on them
- Sedimentation is a concern for the catchment, especially the Caledon River catchment (land use), ground formation and slope contributes to this problem (JB)

- The inclusion of additional RWQO sites can be considered to clearly establish what impacts are coming from Lesotho (JvW)
- Currently, no RWQO site is considered for the Sandspruit at Wepener as it's mostly dry. However, the point of discharge from Wepener STW should be established before a final decision is made.
- No RWQO site is currently considered for the Skulpspruit, tributary of the Caledon River that flows past Smithfield.
- Smaller tributaries should be included on the schematic diagramme even if no RWQO sites are situated on them

A table summarizing the RWQO site description, river name and number is attached as Annexure B. Annexure C presents the updated schematic diagramme indicating the RWQO sites.

5.2 Existing monitoring sites (MS)

- National monitoring point's data will be on WMS
- Regional Office monitoring points – data may exist but mostly not on WMS as it is with the Regional Office. RQS can assist with the updating if requested through the Director of RQS. A Diefenbach is currently acting director
- Regional Office (Danie Wagenaar, Cell 082 8048 051) has a template that can be used to enter data to be send to RQS for capturing. WQP to contact him to see what his concerns are (JB)
- Most of the regional points are for compliance monitoring, e.g. discharge of sewage treatment works (WG)
- MS generated a map showing the surface water points for the Upper Orange River system. This map includes all the monitoring sites for national and regional monitoring programmes that are registered. These monitoring points should be checked for data availability
- Other possible contacts for monitoring data are Dr Potgieter by (Department of Health, CSIRor CEM for Welbedacht Dam)
- The Regional Office is in the process to appoint an official to manage their WMS and data entry. Korien de Kock is currently responsible (JB)
- The frequency of the monitoring is important as the distances between the monitoring points in the catchment can have an influence, especially in the upper reaches of the catchment (JB)
- A committee is responsible for overseeing the water quality monitoring in Lesotho. JB has a contact name

5.3 Existing objectives

No previous objectives have been set for the Upper Orange River System (WG and GV).

5.4 Water uses/impacts

The main impacts are:

- Mainly irrigation impacts throughout the catchments
- Erosion (sedimentation) and suspended solids. Results are available from work conducted on the Modder and Riet Rivers
- Sewage treatment works discharges to the rivers have localized impacts. Most of these works are oxidation pond systems
- Impacts from industries in Lesotho, mainly from Maseru. The main impact is from the dying industries that discharge the waste water to the rivers

- Sedimentation in the Caledon River and upper reaches of the Orange River

5.5 Variables of concern

The main variables are:

- Nitrates and phosphates, especially the Gariep Dam area due to agricultural activities
- TDS, DSS throughout the catchment
- E coli, especially around Maseru and Ficksburg. Maybe also protozoan at some points

6. Snap-shot monitoring (JvW)

- WQP is in the process to appoint consultants and the study includes both the Upper and Lower Orange and a desktop study on the water quality of Lesotho
- Two sampling trips are planned, one high flow and one low flow sampling survey
- Chemical and algal sampling will be conducted. SASS (macro-invertebrate) would be an additional survey that might be included. This need to be discussed with the consultants when they are appointed.
- WG request his inclusion in the sampling surveys as he would like to do fish surveys (FAII) at selected sites
- The study will only provides an overview, without any high level of detail
- The outcomes of the study will be a proposed sampling programme, confirmation of variables of concern, future work, and what water quality data is available in Lesotho
- The study will be done in close liaison with the Regional Offices
- The first meeting to be in Bloemfontein and then to alternate between Bloemfontein and Kimberley

7. Visioning

The visioning process is important as this is translated into objectives for planning and management purposes.
It forms the basis of the CMS and also links to the National Water Resource Classification System (NWRCS).

No visions are available for the Upper Orange River System. The following should be considered when planning to undertake visioning:

- Possible future dam in the Kraai River catchment
- The number of visions (how many areas?). The management units as identified in the ISP documents can be used as a guide
- No existing forums. The current focus of the Regional Office is on the Vaal River System due to it having larger impacts. Catchment management committees are being used and not catchment forums. The Regional Office plan to initiate the institutional establishment of the CMA in 2009 (GV)
- Key role players are Bloemwater, district municipalities, water user associations, and irrigation boards. The Eastern Cape Regional Office in Cradock could also assist with the transfer Gariep Dam to Eastern Cape. Theo Geldenhuys as the contact person.

- Maps should be drawn up showing the visioning areas

The proposed areas for visioning are:

- Caledon River
- Upstream Gariep Dam, including the Kraai and Stormberge catchments
- Downstream Gariep Dam to Marksdrift

8. General

8.1 Samantha to share on her work on the Lower Orange River

SB is following a similar process in the Lower Orange and will document existing information.

8.2 Share on work in Lesotho

JvW to speak to Prof Roos to get water quality data from Lesotho. JB will provide contact person for Lesotho. Contact should be made with the committee responsible for the water quality monitoring in Lesotho. Peter Pyke might be the responsible official in DWAF.

8.3 Waste Discharge Charge System

Discuss at point 9 – way forward.

8.4 Monitoring standards and methods

- JB questioned the quality standards between laboratories as all should have the same standards (accredited). Standard procedures for collecting samples exist (MS)
- MS is investigating an efficient scheme for internal DWAF as RQS is overloaded
- The responsibility for the analysis of the samples taken during the snap shot monitoring should be discussed with the consultants to be appointed.
- RS to register a monitoring project with RQS if required
- The D: RQS requirements as being used in WMS should be used for numbering and naming of new monitoring points

9. Way Forward

The following should be addressed:

- The current internal DWAF initiative will identify stressed and priority areas
- The snap shot project will provide additional information for the identification of the priority areas
- Scenario analysis will be done as part of a larger study that may include economic modeling
- The implications of the Waste Discharge Charge System requirements will be addressed as part of a larger study
- The purpose of the above is to develop an integrated water quality management plan for the Orange River System

10. Next Meeting

No meeting was scheduled as the meetings for the water quality assessment project (snap shot) will cater for this.

11. Closure Meeting

JvW closed the meeting at 12h00

Annexure B

Summary table of proposed RWQO sites, Rivers and level

Summary of proposed RWQOs for Upper Orange River System

Code	River	Description
Orange River		
OS1	Orange	Upstream confluence with Kornetspruit
OS20	Orange	Downstream Sterkspruit confluence
OS2	Orange	Downstream Kraai confluence
OS3	Orange	Upstream Caledon confluence
OS4	Orange	Downstream Gariep Dam
OS5	Orange	Downstream Vanderkloof Dam
OS6	Orange	Marksdrift
OSL2/1	Kornetspruit	Kornetspruit
OSL2/2	Sterkspruit	Sterkspruit
OSL2/3	Kraai River	Kraai
OSL2/4	Stormberge River	Stormberge
OSL2/5	Seekoei River	Seekoei
Caledon River		
CS1	Caledon	Upstream Little Caledon confluence
CS2	Caledon	Caledon at Ficksburg
CS3	Caledon	Caledon at Maseru
CS4	Caledon	Caledon upstream Welbedaght Dam
CS5	Caledon	Caledon upstream Gariep Dam
CSL2/1	Little Caledon	Little Caledon at Golden Gate
CSL2/2	Little Caledon	Little Caledon at Oorlogspoort
CSL2/3	Grootspruit	Groot River at R26 road bridge
CSL2/4	Meulspruit	Above Meulspruit Dam
CSL2/5	Moperi River	At R26 road bridge
CSL2/6	Leeuspruit	At R26 road bridge at Hobhouse