Literature Review and Terms of Reference for Case Study for Linking the Setting of Water Quality License Conditions with Resource Quality Objectives and/or Site-Specific Conditions in the Vaal Barrage Area and Associated Rivers within the Lower Sections of the Upper Vaal River Catchment

Report to the

Water Research Commission

By

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EXECUTIVE SUMMARY

In a recent study of the Vaal Catchment, the WRC, DWS and major industries agreed that there are identified challenges in the approaches used to setting applicable water use license conditions, including discharge quality specifications, which do not take all stakeholder and ecological requirements into consideration. There were concerns from stakeholders regarding how the license conditions are set and used to achieve the set Resource Quality Objectives (RQOs) and how to improve the resource class to a desired class. It was clear that both regulators and users have no clear understanding of the link between Source Directed Controls (SDCs) and Resource Directed Measures (RDMs), and how they inform each other. This obscurity in clearly linking discharge standards with RQOs and/or site specific conditions have caused contestation between regulators and resource users, as the latter feel limits are not realistic or defensible, either operationally or ecologically. This notwithstanding, both parties i.e. regulators and users, agreed to a process of clarifying and deepening understanding of the link between resource class, RQOs and effluent discharge standards since both parties have the same goals; to responsibly and sustainably manage water resources. Therefore, the aim of this study was to engage with all relevant stakeholders to develop an agreed Terms of Reference (TOR) for a substantive case study research project that will investigate the link between SDCs and RDMs using the lower section of the Vaal Catchment. As part of the current study, a scoping workshop was held on 17th May 2017, at Sarabi Country Lodge in Kempton Park, Johannesburg. The main objective of the workshop was to consult with and seek stakeholders' inputs into the TOR for the case study. Thirty-two (32) participants attended from almost all major organisations in the catchment, including SASOL, Sibanye, Rand Water, Eskom, IUCMA, DWS, WRC, Omnia Fertiliser, Anglo American and NatRef. The stakeholders' inputs and discussion from the workshop were synthesised into a draft TOR. This was then recirculated to all stakeholders for their comments. At the same time, major industries in the catchment were separately contacted to ensure that their particular concerns are captured. Thus, this final TOR report is the culmination of the above process.

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Special thanks to all stakeholders who attended and contributed actively at the workshop and also provided feedback on the draft TOR. To Mr Martin Ginster for travelling all the way to Grahamstown so he could properly brief the research team on the project's origins and Eskom's expectations, and Simone Liefferink of Sibanye, we say we appreciate your commitment towards the success of this project.

We express our profound gratitude to the Institute of Water Research at Rhodes University for providing basic facilities and logistical support for the study, especially Profe Tally Palmer for your invaluable technical support and Juanita Mclean for administrative assistance.

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LIST OF ABBREVIATIONS

AIP:	Affected and interested party
CME:	Compliance, Monitoring and Evaluation
DSS:	Decision Support System
DWS:	Department of Water and Sanitation
FRAI:	Fish response assessment index
IUA:	Integrated Units of Analysis
IUCMA:	Inkomati-Usuthu Catchment Management Agency
IWRM:	Integrated Water Resources Management
MC:	Management Class
MIRAI:	Macroinvertebrate response assessment index
NL:	Numerical limit
NWA:	National Water Act
NWRS:	National Water Resource Strategy
RDM:	Resource-Directed Measure
RQO:	Resource Quality Objective
RU:	Resource Unit
SASS5:	South African Scoring System version 5
SDC:	Source-Directed Controls
SES:	Socio-ecological systems
TDS:	Total dissolved solids
WMA:	Water Management Area
WRC:	Water Research Commission
WRCS:	Water Resource Classification System
WUL:	Water use license

1 INTRODUCTION

1.1 Background

In a recent study of the Vaal Catchment, the Water Research Commission (WRC), Department of Water and Sanitation (DWS) and major industries agreed that there are identified challenges in the approach used to setting applicable water use license conditions, including discharge quality specifications which do not take all stakeholder and ecological requirements into consideration. There were concerns from stakeholders regarding how the license conditions (including discharge standards) are used set and used to achieve the set RQOs and how to improve the resource class to a desired class. It is clear that misunderstandings exist between regulators (DWS, CMAs) and users e.g. industries, farmers and businesses. Much of this relates to the links between Source-Directed Controls (SDCs) and Resource-Directed Measures (RDMs), and how they inform each other. This is the main thrust of contestation in the Upper Vaal Catchment. Although contestation and lack of conceptual clarity exist, both users and regulators have agreed to a process of clarifying and deepening understanding of the link between resource class, Resource Quality Objectives (RQOs) and effluent discharge standards since both parties have the same goals: to responsibly and sustainably manage water resources. In the context of such contestation and to clarify the links between SDC and RQOs and/or site specific conditions, the WRC call for a proposal for a research to develop a TOR for the lower section of the Upper Vaal River catchments for linking SDC and RQOs and/or site specific conditions.

1.2 Aim and objectives

Therefore, the main aim of the current study was to engage through a consultative process with key stakeholders with an interest in the lower section of the Upper Vaal catchment (Vaal Barrage area) to develop an agreed Terms of Reference (ToR) for a comprehensive joint catchment case study to improve water resource management through better application of applicable regulatory tools and guidelines. To achieve this aim, the following specific objectives were set out:

- To consult with all relevant stakeholders as identified in the preliminary meetings held between Sasol, WRC and DWS to ensure the study ToR addresses the relevant needs of all stakeholders; including DWS (all relevant units), proto-CMA, Catchment Management Forums, Local Municipalities, small industries, Sasol, Eskom and Rand Water.

- To frame the scope of the case study that will investigate how RQOs are set and in turn how effluent discharge limits are informed by the RQOs and applicable water quality guidelines which are introduced into water use licenses as conditions. The scope should also consider parameters for which no RQOs have been published, but which have been included in water use licence conditions, and should inform future discharge specifications for water quality parameters identified to be of relevance to the catchment.
- To ensure buy-in from the sub-units and stakeholders in terms of the localisation of the case study in the proposed study area.
- To agree and set the objectives, timeframes, budgets and deliverables of the catchment case study

2 BRIEF DESCRIPTION OF THE STUDY AREA

2.1 Biophysical context

The Vaal River forms the boundary between Free State and Gauteng, Mpumalanga and North-West. In the study region, it flows through a part of the country that has long supported a large population and substantial mining and industrial activity in Gauteng and northern Free State. This has led the river in the study region being entitled "the hardest working river in South Africa", as a consequence of increasing regulation and pollution issues (Tempelhoff 2009).

The Vaal Barrage was completed in 1923 following a project to secure a supply of potable water for Johannesburg and the Witwatersrand region following the growth of gold mining and financial activity in the area (Tempelhoff 2009). Within a few years of its construction it became to a large extent redundant as the upstream Vaal Dam was completed to act as an irrigation water source for farming, to further secure water for development in the Witwatersrand-Vaal Triangle region, and, in the short term, to offer employment during a worldwide depression (Tempelhoff 2009).

After Vaal Dam construction, the Vaal Barrage became a secondary water storage facility, and water from this region supported growing coal and gold mining, power generation and steel production (Turton et al. 2006, Tempelhoff 2009). Later water from the area was used to support petrochemical production and other industrialization. Growing industrial activity in the region led to an increased population and a consequent increased wastewater load. Treated and raw wastewater from the region entered the Vaal Barrage area via several tributaries. Total dissolved solids in the river increased from 180 $mg \cdot \ell^{-1}$ in 1960 to 650 $mg \cdot \ell^{-1}$ in 1985 (Clarke 2002).

Construction of formalized housing with water and water-borne sanitation as part of the post-1994 Reconstruction and Development Programme led to a considerable increase in the wastewater load from the area (Tempelhoff 2009). These services were (and still are) managed at local government level, and some areas experienced challenges in provision of these services. In 2005, a report noted that faecal pollution in the river was largely a function of discharge of untreated and partially treated sewage into the Vaal and its tributaries (Kolbe 2005).

The area has highly regulated and modified flow regimes. In the study area, flow along the Vaal River is modified by the Vaal Dam and Vaal Barrage in particular (Tempelhoff 2009, DWAF 2009a). A number of interbasin transfer schemes including the Lesotho Highlands Water Project and the Heyshope, Zaaihoek and Tugela Transfer Schemes introduce water to the catchment, and water is also transferred out of the system to support Eskom and Sasol operations (Turton et al. 2006, DWAF 2009a). The river and its impoundments in the study region are also the largest water source for the densely populated Johannesburg and Vaal Triangle regions. Flow modification is known to have a serious impact on aquatic ecosystems (Bunn and Arthington 2000).

A consequence of such development, initially without regulation, is a legacy of water quality issues. Faecal coliform counts in the area remain high (Tempelhoff 2009, 2017 data from Rand Water and DWS). Phosphate levels, which lead to eutrophication, are consistently high (RW 2017 data). Salinity levels also remain high, and these are often accompanied by high levels of sulphate, indicating an origin in acid mine drainage from gold or coal mines (RW 2017 data). In general, the good water quality upstream of the Vaal Dam decreases sharply in the study area and is not able to meet management targets (DWAF 2009b). Some consequences of these water quality issues include fish kills, diarrheal and other diseases, and blooms of invasive aquatic taxa and microalgae (Tempelhoff 2009, DWAF 2009a).

A map of the study area is presented below in Figure 1. Priority catchments that will be included in the final project are UJ (Taaibosspruit), UK (Kromelmboogspruit), UI (Klip River (Gauteng)) and UM (Vaal River from Vaal Dam to C23L), and these are highlighted in Figure 1. The Vaal Barrage lies in C22F in the map.

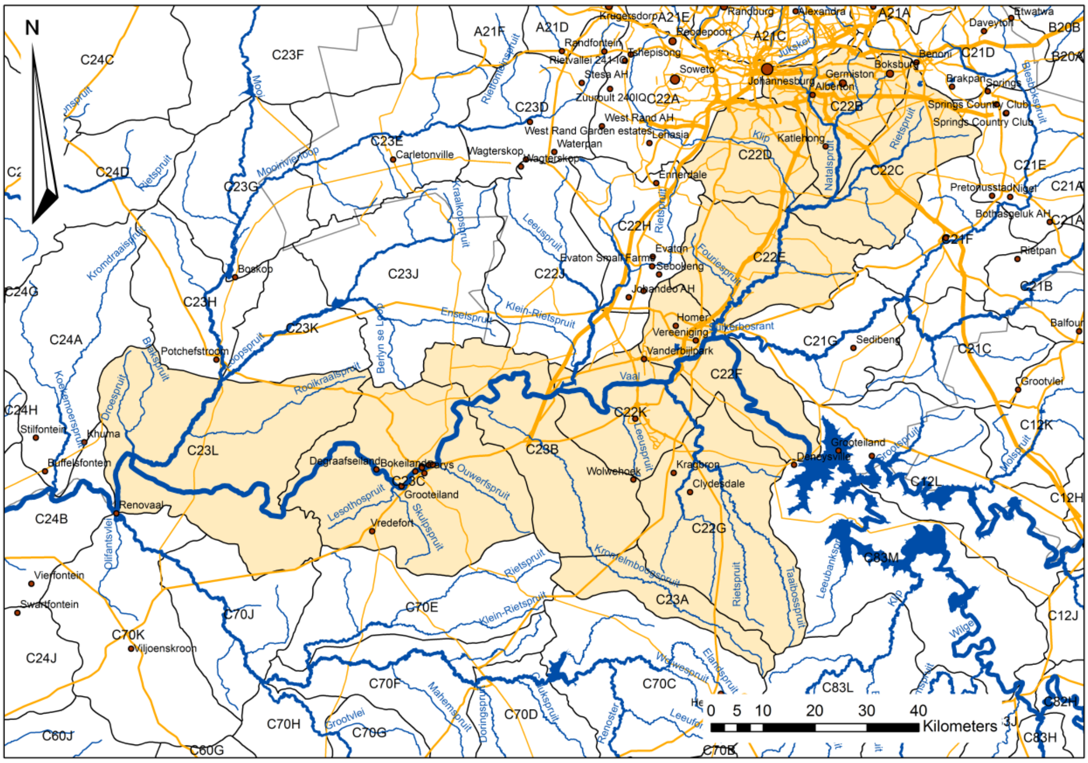

Figure 1 Map of the study area showing water resources and quaternary catchments, towns and major roads. The identified priority catchments are highlighted.

2.2 Social-economic context

The region recently supported a population of 10 million people, with, as noted above, substantial industrialization (van Wyk 2001, Tempelhoff 2009). Runoff water from the urban centres and 13600 wet industries, along with mining water seepages, enters the river in this region (van Wyk 2001, McCarthy et al. 2007, Tempelhoff 2009).

Management of the water resource in this area is complicated by the fact that the region is supported by several interbasin transfers necessitated by the development of a city in a semi-arid country away from a major water resource (Turton et al. 2006). As a result of these water transfers, management and planning has to be undertaken in the context of the Integrated Vaal River System which also includes portions of the Komati, Usutu, Thukela and Senqu River (DWAF 2009b).

The largest irrigation scheme in the country (the Vaalharts Irrigation Scheme) is a significant consumer of irrigation water and lies downstream of the study area. Irrigation farming in this scheme requires both sufficient water for crops, but also water of an adequate standard (e.g. see DWAF 1996).

The Upper Vaal region has significant irrigation water use, largely upstream of the study area (DWAF 2009b). Water use in this sector was found to be increasing. A significant proportion of this is illegal and unregulated. Total irrigation water demand in the Upper Vaal is 304 million $m^3{\cdot}yr^{-1}$.

Industrial bulk water users in the region are dominated by Eskom, Sasol and ArcelorMittal (DWAF 2009b).

Eskom operates 12 coal-fired power stations in the Integrated Vaal River system, and there are plans to develop three more (DWAF 2009b). Not all of these are active all the time, and activity depends on energy demand. Most of these power stations are outside the study area, as 8 are in the Usutu and Komati sub-systems, but they are all active within the greater Integrated Vaal River System that the study area lies within. Predicted water use in 2015 by power stations in or near the study area was 142 million $m^3{\cdot}yr^{-1}$.

Sasol has two plants within the Integrated Vaal River System (DWAF 2009b). Secunda draws water from Grootdraai Dam, far upstream of the study area, and the Sasolburg complex, which releases effluent below the Vaal Barrage, draws water from the Vaal Dam, just upstream of the study area. Sasol's 2015 predicted water use these sources was 140 million $m^3{\cdot}yr^{-1}$, though only 23% of this was for the Sasolburg complex.

ArcelorMittal draw water from the Vaal Dam, and their predicted requirement for 2015 was 17 million $m^3{\cdot}yr^{-1}$.

Rand Water is responsible for the water supply to Johannesburg, the world's largest city not located on a sea, lake or major river (Turton et al. 2006). Water drawn from the system all goes to supply Johannesburg, and other municipalities are supplied by other water authorities (DWAF 2009b). However, return flows from Johannesburg are divided by the watershed that roughly halves the city, and the Vaal River catchment only receives return flows from the south of the city. Twenty seven sewage drainage areas from Johannesburg and municipalities north of the Vaal drain to the Vaal River catchment. Total water requirement predictions for Rand Water under a base level population prediction for 2015 were 1521 million $m^3{\cdot}yr^{-1}$. Of the municipalities supplied, most water was supplied to Johannesburg and Ekurhuleni. Predicted return flows from southern regions to the Vaal for 2015 under base population growth was 398 million $m^3{\cdot}yr^{-1}$.

Beyond Johannesburg, Sedibeng Water draws from the Vaal River and the Allemankraal Dam (DWAF 2009b). Water use in the region is predicted to grow from 56 million $m^3{\cdot}yr^{-1}$ in 2006 to 64 million $m^3{\cdot}yr^{-1}$ in 2030.

2.3 Pollution and water quality challenges

Water quality has long been an issue in the region. For example, the pollution of the Klip River led to livestock deaths in the 1890s following contamination with mine water (Turton at al. 2006). Problems with the Klip River system continue to be reported in recent times (McCarthy et al. 2007).

Salinity has historically been the water quality issue in the Vaal River that received most focus as a management issue (DWAF 2009a). Dilution releases from Vaal Dam were released to keep salinity below a TDS of 600 $mg{\cdot}\ell^{-1}$. Management of nutrients has not received as much attention, and the steps involved in nutrient cycling are less understood, despite algal blooms being noted in the area (Turton et al. 2006, DWAF 2009a).

Flow in the Vaal River is substantially modified by upstream water transfers from the range of catchments outlined above (DWAF 2009a). The quality of input water is currently good, and acts beneficially on water quality status of the Vaal River system. If input water quality changes negatively, this would have considerable implications for the water quality of the Vaal River. Mining and power generation in upstream catchments have been identified as potential threats to water quality in the system.

As noted above, there are a number of water quality challenges in the study area. Salinity, nutrients and eutrophication, and faecal contamination have been highlighted, but other challenges beyond these exist (DWAF 2009a and DWS and RW 2016-2017 data). Known water quality problems are outlined below.

Sources impacting on water quality in the Vaal Barrage catchment include effluent wastewater treatment work operated by Johannesburg Water, ERWAT and Metsi-a-Lekoa, return flows from gold mines, and several industries, most notably Sasol, SAPPI, and ArcelorMittal (DWAF 2009a). Wastewater treatment works effluent input is likely to increase as service provision improves. Poor performance of wastewater treatment works as well as sewerage systems has been identified as having a particularly negative effect on water quality. Atmospheric deposition of sulphur salts may also contribute to salinity levels.

Salinity is an issue in the catchment, and, despite a reasonable understanding of the processes involved, remains a challenge. Salinity increases significantly downstream of the Vaal Dam and before the Vaal Barrage, and remains at this level thereafter (DWAF 2009a). Management of remains challenging for the following reasons:

- Mine water discharge is a significant contributor to salinity and sulphate levels (McCarthy 2011). The quantity of mine water is not well understood because future mine water management plans are not known, neither is funding availability for this purpose. Water in the various mining basins is likewise not clear, and future dewatering and decants cannot be predicted.
- Water quality in upstream impoundments is crucial to maintenance of salinity levels in the study area. Several upstream sources are threatened by mining.
- Dilution water from the Vaal Dam is needed for salinity control downstream. This imposes an additional water demand on the system that may not be maintained in times of water shortage.

Eutrophication in the study area is another primary challenge to water quality (DWAF 2009a). Eutrophication leads to blooms of water hyacinth and potentially toxic microalgae, and is primarily driven by phosphate levels in the catchment. Eutrophication in the catchment has been found to have an economic impact on agriculture and the water treatment process (Sibande 2013). Eutrophication is also a challenge to manage as:

- Several sources of nutrients in the catchment exist and are not well understood. They include irrigation return flows, urban runoff, industrial discharges and wastewater treatment works discharge.
- Many wastewater treatment works and sewerage are poorly managed. As a result, many wastewater treatment works underachieve in nutrient removal.

- Return flows from wastewater treatment works are anticipated to increase in future as service provision improves.
- The links between nutrient levels and land uses, discharge standards and operational management strategies are not well understood.
- Low flows in the study area contribute to the likelihood that algal blooms will form.
- Collapse of the Klip River wetlands has removed their potential contribution to nutrient removal and may, as the wetlands degrade further contribute to nutrient loading downstream (McCarthy et al. 2007).

Microbial contamination in the river is the third of the well-known water quality management challenges in the study area (DWAF 2009a). Problems in this regard relate to poor operation and maintenance of wastewater works and sewerage systems. Poor maintenance of these systems has resulted in degradation in some areas that has significant cost implications for remedy. Microbial contamination in stream has resulted in a significant public health threat. Monitoring data suggest this syndrome is restricted to the area immediately below the release point. Nevertheless, very high microbial levels are found throughout the catchment (DWS and RW 2017 data).

The above are the well-known water challenges. A number of other water quality challenges in the study have been identified. Some of these are listed below.

- Heavy non-essential metals have been found to bioaccumulate in fish in the study area (Crafford and Avenant-Oldwage 2010). Heavy metals, present in water and sediment, were also found to cause oxidative stress in fish (Wepener et al. 2011).
- Bacterial community structure was found to be altered by changes in water quality in the study area (Jordaan and Bezuidenhout 2013).
- Norovirus contamination of rivers in the study area was found which could act as a cause of norovirus infection of water users (Mans et al. 2013).
- Carcinogenic polycyclic aromatic hydrocarbons were found in rivers in the study area (Moja et al. 2013). Wepener et al. (2011) found decreased fish health linked to organic pollutants in the river.

- Changes in diatom community structure indicate poor water quality in the study region (Taylor et al. 2007). Changes in community structure were particularly correlated with changes in phosphate levels and salinity.

3 MANAGING WATER QUALITY IN A COMPLEX SOCIO-ECOLOGICAL CONTEXT: THE CASE OF THE VAAL BARRAGE

3.1 Linking RQOs and SDC

The South African National Water Act (1998) requires that all water resources are protected in order to secure their future and sustainable use. To ensure effective implementation of the NWA, the National Water Resource Strategy (NWRS) was developed, which is also effective through two Integrated Water Resources Management (IWRM) tools, i.e., Resource-Directed Measures (RDMs) and Source-Directed Controls (SDCs). The RDMs involve co-operatively defining the appropriate level of protection for a water resource, and on that basis, setting clear numerical and/or descriptive goals for the resource quality i.e. Resource Quality Objectives (RQOs). RQOs are required for quality and flow (volume, velocity, and distribution through time) of the water resource. On the other hand, SDCs aim to control impacts on the water resource through the use of regulatory measures such as registration, permits, directives, prosecution, and economic incentives such as levies and fees, in order to ensure that the RQOs are met. Typical SDCs include discharge and abstraction permits. Although the RQOs can inform discharge standards and vice versa, the link between these two is still not clear to many water users and even regulators. Also, for water use licenses (WULs) that have no published RQOs, it is not clear what informs the specific conditions included in such WULs, and what is considered an acceptable discharge quality for variables of concern, considering the needs of economic development while ensuring sustainable utilisation of the resource.

3.2 A review of the RQO process in relation to water quality

In response to the NWA, the Water Resource Classification System (WRCS) was established to guide the procedures meant to aid the process of maintaining a balance between protection and use of water resources to meet the socio-economic and ecological goals at catchment-specific levels. This system is based on the social-ecological system (SES) approach and its processes apply transdisciplinary and resilience concepts. The Classification Process is a consultative one and results in setting of Management Class (MC) (i.e., desired characteristics), Reserve and Resource Quality Objectives (RQOs) for each of the significant water resources in a given catchment. The purpose of RQOs is to establish clear goals relating to the quality of relevant water resources. RQOs are numerical and narrative descriptors of conditions that need to be met in order to achieve the required management scenario as provided during the resource classification. The RQOs in the Upper Vaal Water Management Area (WMA8) have been determined and gazetted by the Minister of Department of Water and Sanitation (DWS) in July 2015. The procedure for determining the RQOs involved the seven-step framework established by the WRCS (DWAF, 2007, 2011) as shown below:

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

At the end of the RQOs determination processes, RQOs were defined for each prioritised resource unit (RU) or hydrological node for every IUA in terms of water quantity, quality, habitat and biota. The RQOs for water quality for the Upper Vaal (Vaal Barrage) as reported in DWS (2014) and gazetted in DWS (2015) are presented in the table below:

Table 1: RQOs for river water quality in priority RUs in the Upper Vaal Barrage (UJ = Taaibosspruit, UI = Klip River (Gauteng), UM = Vaal River from Vaal Dam to C23L) (Based on DWS 2014 & DWS 2015)

IUA	Class	River	RU	Node	REC	Component	Sub Component	RQO	Indicator/ measure	Numerical Limits	95th %tile
UI	III	Suikerbosrant	RU62	EWR11	D	Quality	Nutrients	The nutrient concentrations must be improved to an acceptable mesotrophic state.	Phosphate(PO_4)	≤ 0.125 mg/L P	0.5
				UI.3 UI.4					Nitrate (NO_3) & Nitrite (NO_2)	≤ 4.00 mg/L N	1.7
									Phosphate(PO_4)	≤ 0.125 mg/L P	0.5
									Nitrate (NO_3) & Nitrite(NO_2)	≤ 4.00 mg/L N	1.7
UM	III	Vaal	RU75	EWR5	C	Quality	Nutrients	The nutrients should be improved to an acceptable state	Phosphate(PO_4)	≤ 0.025 mg/L P	0.2
									Nitrate (NO_3) & Nitrite (NO_2)	≤ 1.00 mg/L N	0.25
									Total Ammonia	≤ 73 µg/L N	1.5
UI	III	Suikerbosrant	RU62	EWR11	D	Quality	Salts	Salts need to be improved to levels that do not threaten the ecosystem and to provide for users.	Electrical conductivity	≤ 111 mS/m	135
			RU65	UI.3							90.6

IUA	Class	River	RU	Node	REC	Component	Sub Component	RQO	Indicator/ measure	Numerical Limits	95th %tile
		Vaal	RU66	UI.4							98.1
UJ	III	Vaal	RU67	UJ.1	D	Quality	Salts	Salts need to be improved to levels that do not threaten the ecosystem and to provide for users.	Electrical conductivity	≤ 111 mS/m	79.1
UM	III	Vaal	RU75	EWR5	C	Quality	Salts	Salts need to be improved to levels that do not threaten the ecosystem especially fish and to provide for users.	Electrical conductivity	≤ 85 mS/m	84
									Sulphates	≤ 200 mg/L	173
UI	III	Vaal	RU66	UI.4	D	Quality	System variables	Dissolved organic carbon concentrations should not cause the ecosystem to become unsustainable.	DOC	30 day median ±20% of median background mg/L C	No data

IUA	Class	River	RU	Node	REC	Component	Sub Component	RQO	Indicator/ measure	Numerical Limits	95th %tile
UI	III	Suikerbosrant and Vaal	RU62 RU65 RU66	EWR11 UI.3 UI.4	D	Quality	Toxins	The river water should not be toxic to aquatic organisms or be a threat to human health.	F	≤ 3.0 mg/L	0.465
									Al	≤ 150 µg/L	No data
									As	≤ 130 µg/L	No data
									Cd hard	≤ 5.0 µg/L	No data
									Cr(VI)	≤ 200 µg/L	No data
									Cu hard	≤ 8.0 µg/L	No data
									Hg	≤ 1.70 µg/L	No data
									Mn	≤ 1300 µg/L	No data
									Pb hard	≤ 13.00 µg/L	No data
									Se	≤ 30 µg/L	No data
									Zn	≤ 36 µg/L	No data
									Chlorine	≤ 5.0 µg/L free Cl	No data
									Endosulfan	≤ 0.200 µg/L	No data
									Atrazine	≤ 100 µg/L	No data

IUA	Class	River	RU	Node	REC	Component	Sub Component	RQO	Indicator/ measure	Numerical Limits	95th %tile
UJ	III	Vaal	RU67	UJ.1	D	Quality	Toxins	The river water should not be toxic to aquatic organisms or be a threat to human health.	F	≤ 3.0 mg/L	4.95
									Al	≤ 150 µg/L	No data
									As	≤ 130 µg/L	No data
									Cd hard	≤ 5.0 µg/L	No data
									Cr(VI)	≤ 200 µg/L	No data
									Cu hard	≤ 8.0 µg/L	No data
									Hg	≤ 1.70 µg/L	No data
									Mn	≤ 1300 µg/L	No data
									Pb hard	≤ 13.00 µg/L	No data
									Se	≤ 30 µg/L	No data
									Zn	≤ 36 µg/L	No data
									Chlorine	≤ 5.0 µg/L free Cl	No data
									Endosulfan	≤ 0.200 µg/L	No data
UI	III	Suikerbosrant	RU62	EWR11	D	Quality	Pathogens	Pathogens should be maintained at levels safe	E.coli	≤ 130 counts/100 ml	No data

IUA	Class	River	RU	Node	REC	Component	Sub Component	RQO	Indicator/ measure	Numerical Limits	95th %tile
								for human use (excluding for direct consumption).		≤ 130 counts/100 ml	No data
		Vaal	RU65	UI.3							
			RU66	UI.4						≤ 130 counts/100 ml	No data
UM	III	Vaal	RU75	EWRS5	C	Quality	Pathogens	Pathogens should be maintained at levels safe for human use (excluding for direct consumption).	E.coli	≤ 130 counts/100 ml	No data

NOTE: The RQOs for UK = Kromelmboogspruit was not found both DWS 2014 & DWS 2015 documents UK is part of the study area the area.

4 CONTESTATION OF THE RDMS AND SDCS IN THE UPPER CATCHMENT OF THE VAAL (VAAL BARRAGE)

From the seven steps that Resource Quality Objectives (RQOs) determination is involved, steps 5 is the most likely step of contestation. This is because it is in this step that draft RQO and Numerical Limits (NLs) are established. RQOs and NLs are generally quantitative and qualitative descriptors of the different components of the resource such as the water quantity, quality, habitat and biota. In order to achieve the desired MC, the resource directed measures (RQOs and NLs) then become the regulator's target, which are translated to a user-target in the form of source directed controls (SDCs) tools such as water use licences, permits, general authorisations, water quality guidelines and standards. Therefore, it is necessary that processes and procedures that are used to derive the RDMs and SDCs need to be scientifically defensible and socio-economically acceptable so that their implementation is less resisted by any stakeholder or affected and interested party (AIP), especially those who think such implementation will impact negatively on their operations.

This present TOR is the result of such contestation in the upper Catchment of the Vaal (Vaal Barrage). In a recent study of the Vaal Catchment, the WRC, DWS and major industries agreed that there are identified challenges in the approach adopted to setting applicable water use license conditions, including discharge quality specifications which do not take all stakeholder and ecological requirements into consideration. There have been concerns from stakeholders regarding how the license conditions (including discharge standards) are used to achieve the set RQOs and how to improve the resource class to a desired class. Questions were raised about whether the reduction in discharge will lead to achieving the RQOs or desired class, and whether a consideration was given to the upstream and downstream quality on the overall resource quality (i.e., improving or deteriorating). Specific questions included whether:

- There are flaws in the system (e.g., the setting of RQOs, SDCs and CME), and if so, how can these be addressed?
- Setting of targets to achieve the set RQOs or desired class take into consideration the socio-economic sustainability of businesses (e.g., closure of businesses, which may affect job loss and economic growth)?

- Available technologies were factored into setting of the targets to achieve the set RQOs or desired class?

Both users and regulators agreed that they need to understand the link between resource class, RQOs and effluent discharge standards since both parties have the same goals; to responsibly and sustainably manage water resources. All parties further agreed that there is a need to better understand how the process of creating scientifically defendable and realistically achievable standards is undertaken.

4.1 Contestations in managing water quality in the context of complex social-ecological systems

There is a growing call that the management of water resources, including water quality should take a social-ecological system approach (Odume and De Wet 2016). The imperative for this call is that for the effective management of water resources, social, economic, legal, environmental and institutional considerations should be sufficiently taken into account. Therefore, since catchment are inherently complex social-ecological systems (Folke 2007) in managing water quality, sufficient attention must be paid to social (trust building, effective institutions, transparency, appropriate incentives) and ecological processes such as the functionality and characteristics of the aquatic ecosystems. In the context of linking RQOs with SDC for effective water quality management, without a clear understanding of how the two regulatory tools are related and linked, there is bound to be contestation between stakeholders e.g. regulators and resource users. During the course of this study, a small team of experts were assembled to draw up a systemic diagram (Ison 2010), reflecting/indicating possible sources of contestations, with a view to drawing up a final ToR for a case study that would address them. The outcome of the expert adaptive water quality management cycle for the Upper Vaal catchments are presented in Figures 1-4 and discussed.

Figure 1 (red cycle) shows an ideal environmental management cycle in which the present state of aquatic ecosystem is assessed against the desired goals, which are usually expressed and measured as resource quality objectives (RQOs). If discrepancy between the goals and present state exist, appropriate required, permissible or voluntary action is taken and the present state is re-assessed against the ROQs until no discrepancy exists. This ideal environmental management cycle assumes that all parties support and agree with the process of managing the system, including institutional capacity as well as scientific and regulatory procedures. Usually, the ideal environmental management cycle as indicated in the figure would lead to voluntary water user compliance as all stakeholders would have a common understanding and therefore trust within the system.

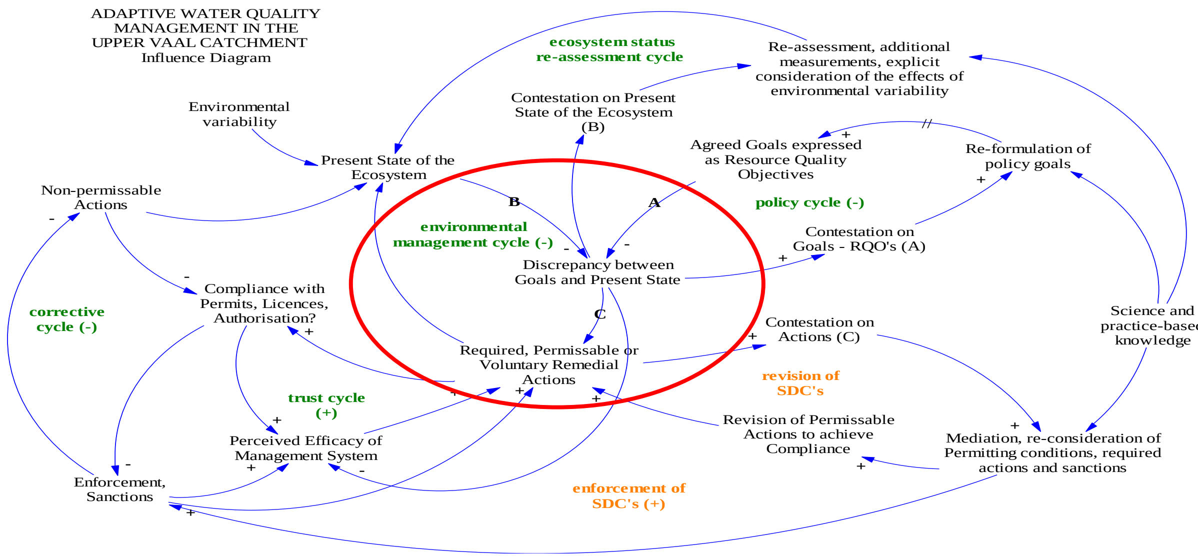

Figure 1: Adaptive water quality management showing the environmental management cycle (within the red cycle).

Trust cycle (Figure 2) ensures effective management of the aquatic ecosystems with increased perception by stakeholders of the efficacy of the management systems. As indicated in the figure, stakeholders would be would be willing to take required, permissible action with a view to complying with their license, permit or authorisation conditions. This willingness arises out of trust in the entire environmental management science, including scientific defensibility of methods and institutional efficiency and effectiveness of enforcement and sanctions, which would lead to reducing non-permissible actions likely to have detrimental impact on the aquatic resource base. As indicated in the trust cycle, trust between all stakeholders within catchments can lead to potentially beneficial social-ecological and economic outcomes.

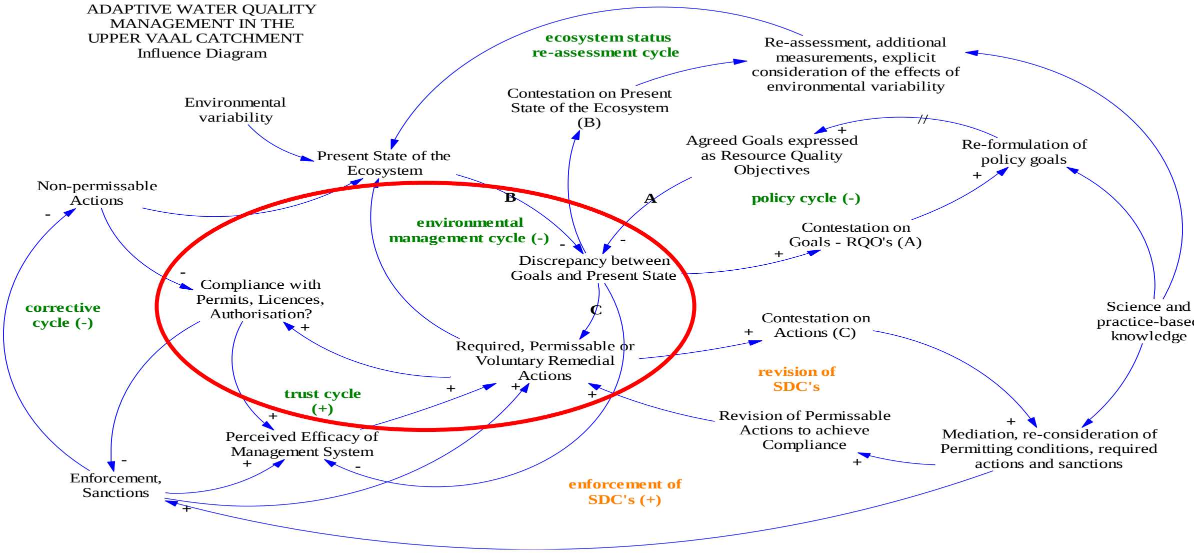

Figure 2: Adaptive water quality management showing the trust cycle and its implication compliance and enforcement.

In managing water quality with an explicit recognition of social-ecological system as inherently complex, several points/sources of contestation potentially exist within the environmental management cycle (Figure 3). As indicated in Figure 3, one of such areas of contestation is on required actions to be taken. As illustrated in the figure, discrepancy exists between the present state of the aquatic ecosystem and the desired goals, expressed as RQOs. Required, permissible or voluntary remedial actions are therefore necessary to reconcile the present ecological state with the desired goals. However, as shown, these required actions are contested for whatever reasons. In the case of this study (the upper Vaal), it was identified that the contested actions were the license conditions. As shown in the this contestation loop, several plausible action can be taken to address stakeholders concerns and these include mediation, re-consideration of permitting conditions, which can either lead to revision of the license condition or further enforcements of its requirement.

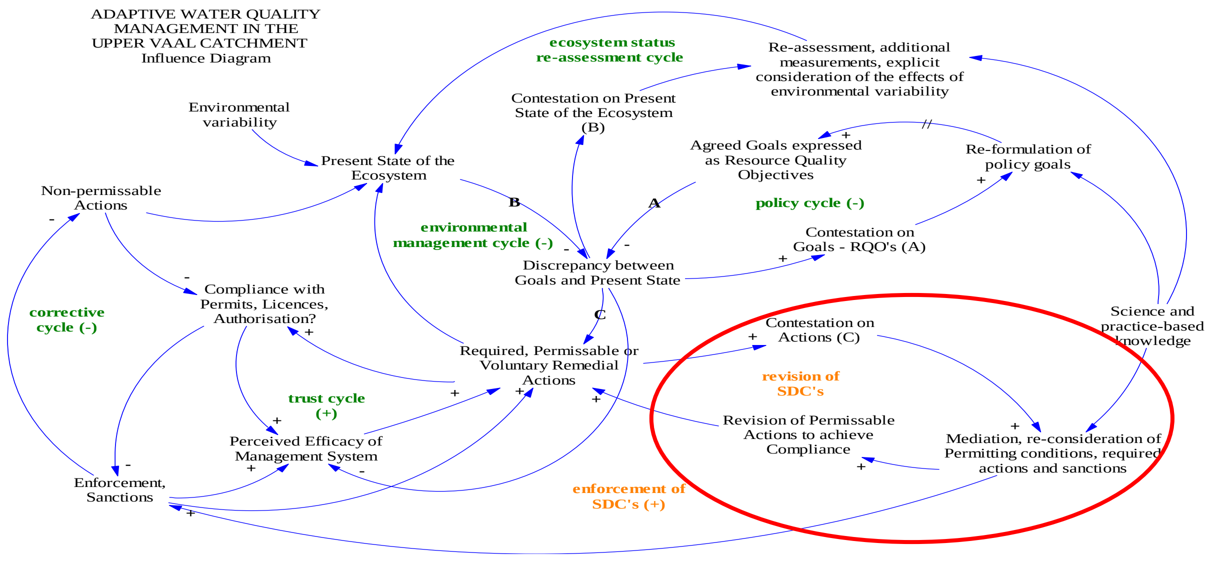

Figure 3: Adaptive water quality management showing the contestation loop of the required action to be taken.

Another potential source/point of contestation in terms of water quality within social-ecological system context is the instream goals/objectives (Figure 4). As indicated in the figure, aggrieved stakeholders for whatever reason can contest the instream goals i.e. the RQOs. However, it must be noted that the RQOs embedded in the law and policy, and once gazetted become legally binding. Because the RQOs are embedded in the law and have legal binding effect, outcome of their contestation would usually take longer compared to other potential sources of contestations. However, if successfully contested, goals can be reformulated and resource state monitored against the reformulated states. In the present study, stakeholders agreed that the RQOs are not being contested. Although not relevant in the context of this study, the present state of the ecosystems can also be contested.

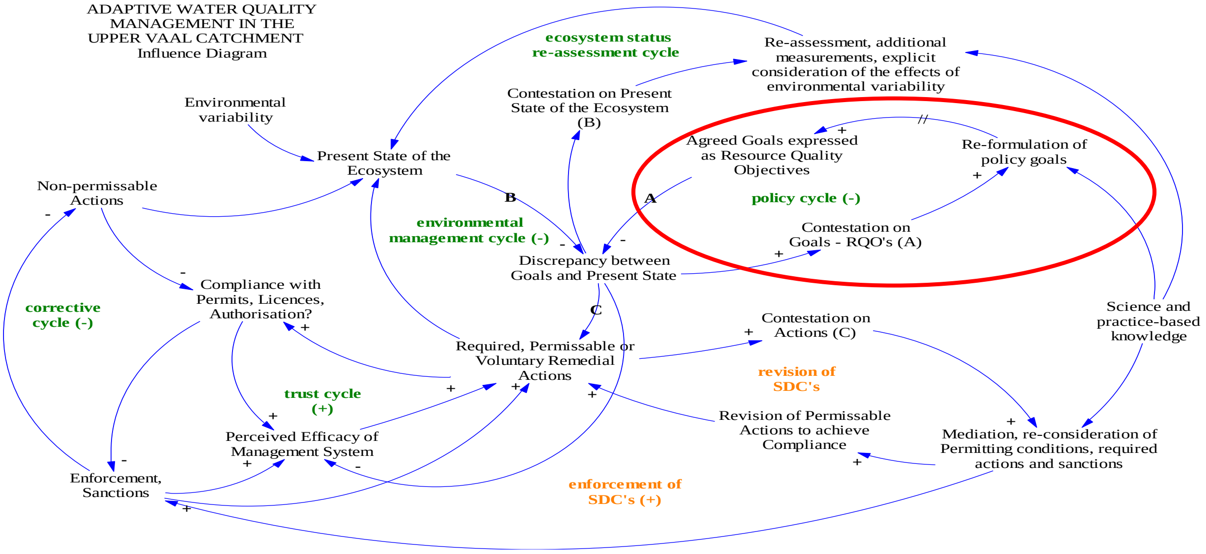

Figure 4: Adaptive water quality management showing the resource quality objective contestation loop.

From the analysis of expert system diagrams and causal loops above, it is clear that meaningful process for managing water quality effectively has to address stakeholders concern with a view to reaching agreed goals and reducing potential sources/point of contestation. To this end, the project team organised a catchment stakeholder.

5 STAKEHOLDER CONSULTATION AND WORKING TOWARDS AGREED TERMS OF REFERENCE FOR A FUTURE CASE STUDY

As part of the consultative process, the project team invited catchment stakeholders to a workshop on 17 May 2017 in Johannesburg. Excluding the project team, the workshop was attended by 16 delegates with representation from the Water Research Commission, Department of Water and Sanitation, Sasol, Rand Water, Sibanye, Inkomati-Usuthu Catchment Management Agency (IUCMA), Eskom and Omnia fertiliser.

The aim of the workshop was to consult with the stakeholders and seek their input into the development of the terms of reference for a case study for linking the RQOs and SDC. The project team therefore sought the input of the stakeholders in terms of: i) framing of the scope of the future case study ii) water quality variables inclusion in the ToR for the case study, iii) ecological, social and economic considerations to be included in the future case study including matters related to scientific defensibility of methods, transparency of processes, iv) and appropriate and scientifically defensible tools/methods and decision support system for better linking of RQOs and license conditions, v) spatial and temporal scale of the case study project as well as timelines, budget and deliverables.

As the causal loop diagram revealed (Figure 3), the stakeholders at the workshop agreed that the main source of contestation within the upper Vaal River catchment was on the required actions to be taken to meet set instreams goals. The contestation arises out of lack of conceptual clarity of the link between RQOs and SDC, scientific defensibility of methods and license requirements. Through a structure facilitated process, stakeholders in the catchment raised several issues and these include i) the importance of considering upstream water quality condition for downstream users requiring water use licenses (WUL), ii) explicit rationale for any water quality included in WUL, iii) procedural requirement for WUL and quality assurance issues, iv) a framework for assessing confidence in evidence with regard to water quality and WUL condition, v) alternative management strategy other than WUL such as ISO and offsets vi) criteria for determining water quality limits for multiple users, considering environmental, social and economic imperatives and vii) the need for capacity building for the regulators and water users in the catchment with regard to the link between RQOs and SDC.

Through a facilitated process, the workshop participants cooperatively engaged to scope the future case study and critical elements agreed upon including:

i. That an assessment of current practices, approaches, methods and tools with regard to setting water license conditions was necessary. Such an assessment of tools would normally include option analysis of the existing practices, approaches, methods/tools.
ii. That as an outcome of the assessment and option analysis – existing practices/tools/methods are either modified or new ones developed to meet the future project objective.
iii. That a case study could give clear guidance on how to set scientifically defensible WUL conditions in cases where RQOs exist or not. That is, a clear link between RQOs and SDC (WUL conditions).
iv. That the lower section of the Upper Vaal as framed in the current study was too large for the case study, and therefore the focus of the study should be on the Vaal Barrage area and the associated rivers: Taaibosspruit, Suikerbosrant River, Rietspruit, Klip River, Leeuspruit and Blesbokspruit.
v. That in setting WUL conditions, there is a need for site-specific consideration over and above the RQOs, which are met to guide the management of the resource base.
vi. That the case study includes elements of stakeholder communication and capacity building to increase acceptance of its outcome.
vii. That the case study should also consider the usefulness of alternative water quality management strategies in the specific catchments such as water offsets.
viii. That 2 years (24 months) was sufficient time to undertake the case study.

Taking all the outcome of the workshop into account, the project team developed the draft terms of reference for the future case study. The draft ToR was then circulated for stakeholders' comments. The project team also engaged stakeholders with specific inputs. Therefore, the final ToR presented here is the outcome of the stakeholder consultative process.

6 TERMS OF REFERENCE

A case study for linking the setting of water quality license conditions with resource quality objectives and/or site-specific conditions in the Vaal Barrage area and associated rivers within the lower sections of the upper Vaal River catchment.

OBJECTIVES:

General: The main objective of this project is to undertake a case study in the Vaal Barrage area and associated rivers catchments UJ (Taaibosspruit), UI (Klip River, Gauteng), Suikerbsrant River, Rietspruit, Leeuspruit and Blesbokspruit, within the lower section of the upper Vaal River catchment to link Source-Directed Controls (SDCs) like the setting of water quality license conditions to Resource Quality Objectives (RQOs) and/or sites-specific conditions, in a way that water quality discharge specifications are clarified for better management of water resources.

Specific objectives

- Undertake a comprehensive and thorough assessments of existing practices, data, approaches, methods, and tools including relevant catchment literature, with regard to Source-Directed Controls (SDCs) and resource quality objectives (RQOs) in the proposed study areas. The assessment should include analysis of all current tools, practices/methods/approaches of setting water quality conditions and their scientific defensibility/or otherwise within the proposed study area. The assessment should be undertaken with both key water users in the catchment and regulators.
- Develop an appropriate robust and scientifically defensible but flexible method/tool/decision support system (DSS) (e.g. a mass balance model) for transparently setting water quality license conditions (point and diffuse) taking

account of receiving resource quality objectives/ site specific conditions. The tool developed/refined should address issues of multiple users and competition as well as submission of data by water users to the regulator. Alternatively, guidance should be given on how to apply an existing tool/model for setting and monitoring water quality license conditions, considering receiving site-specific condition and RQOs. In developing new tools/methods/DSS/ or refining existing ones, issues relating to scientific assumptions, confidence and quality assurance/control, should be addressed. The tool/method/DSS developed/refined, should be embedded within a broader framework that provides guidance for both regulators and water users for setting and implementing water quality license conditions linked to RQOs and/or site-specific conditions for both point and diffuse discharges and monitoring compliance. As a minimum, the framework should guide both regulators and users on (i) process of engagement in the context of a water quality license application and/or amendment (WUL) (ii) scientific/ecological and social-economic considerations for inclusion of water quality variables and ecological indices (e.g. FRAI (Fish response assessment index), MIRAI (macroinvertebrate response assessment index), SASS5 (South African Scoring System version 5)) in license conditions (iii) selection of appropriate monitoring and sampling points as well as frequency of monitoring and sampling (iv) quality assurance measures (v) what needs to be done in cases where the RQOs are yet to be set (vi) the process for amending issued WUL. The framework should also address alternative strategies for improving instream water quality other than WUL e.g. through offsets, ISO requirements. The process of developing the framework should be a multi-stakeholder process involving both the regulators and water users on the catchment.

- Demonstrate and test the implementation and applicability of the developed method/tool/DSS under multiple water quality, site/specific/RQOs scenarios (i.e. scenario analysis) with catchment stakeholders including the relevant units within the Department of Water and Sanitation, catchment management forums and water users e.g. Sasol, ESKOM, Rand Water, Local governments. As part of the scenario analysis, demonstrate how such a tool could be implemented such that a water user is able to determine the likely impacts on water quality objectives and/or site specific conditions.

- Communicate widely with catchment stakeholders and build capacity of the relevant units/sections within the Department of water and sanitation, and water users through training on the use and application of the developed framework and method/tool/DSS. The purpose of this objective is to ensure that the entire process is consultative and widely communicated to ensure that the outcome of the project is widely accepted by all stakeholders.

Rationale

The National Water Act (Act No 36 of 1998) is founded on the core objectives that South Africa's water resources are to be protected, used, developed, conserved, managed and controlled, in such a way that use and protection are balanced. It therefore provides a legal basis for protecting the nation's water resources, while at the same time providing for administrative licensing process for lawful use of water. To give effect to the core objective of balancing use and protection, the Resource Directed Measures (RDM) and Source Directed Controls (SDC) are used as complementary approaches. The RDM involved cooperatively defining the appropriate/desired level of protection for a resource and involved a classification system, classification and setting of resource quality objectives (RQOs) as well as the Reserve (Human and Ecological). The process is consultative whereby the same level of consideration is given to inputs and views from all stakeholders/after interested parties. The SDCs aim to control the use of water and associated impacts (e.g. discharges) through regulatory measures such as water use licenses (WUL) and permits. Once the instream RQOs are set, WUL license conditions are derived so as to meet the instream objectives. That is, the RQOs should inform the water quality license conditions. However, the difficulty arises in situation where water quality license conditions are to be derived in catchments where RQOs have not been set. In this context, it is important to note that in setting WUL conditions, RQOs do not necessary preclude the need for site-specific water quality assessment that should inform license conditions. There is also the question on how RQOs in larger catchments impact on smaller sub-quaternary reaches. For example, can large catchments be allowed to have worse water quality due to the large amount of dilution that should occur before the point where an RQO is set? Although RQOs can inform water quality discharge standards and vice versa, the link between the two is still not clear to many users and regulators, particularly how ROQs inform water quality variables and discharge standards in WUL considering the imperative for social-economic development and environmental sustainability. This lack of clarity has caused contestation between users and regulators with regard to scientific defensibility of methods (SDCs and RQOs) as well as meeting license conditions. Because catchments are complex social-ecological systems, the process of setting water quality license conditions must be as inclusive, transparent and consultative as possible to avoid/and or minimise contestations.

Using the proposed study area (Vaal Barrage area and associated river catchments: UJ (Taaibosspruit), UI (Klip River, Gauteng), Suikerbsrant River, Rietspruit, Leeuspruit and Blesbokspruit) as case study within the lower section of the Upper Vaal River catchment, the overall aim of this project is to link and clarify the setting of water quality license conditions to Resource Quality Objectives (RQOs)/ site-specific conditions in a way that water quality discharge specifications are clarified for better management of water resources.

Deliverables

1) An assessment and option analysis report detailing current practices, tools/methods/approaches/data used for setting water quality conditions linked to RQOs and /or site-specific conditions. Attention should be paid to the credibility and scientific defensibility of the current tools/methods. The report should also include stakeholders consulted and those to be engaged throughout the study.
2) A preliminary report on framework and methods/tool/DSS development/refinement of existing ones. Since the process of the framework and method development is expected to be in consultation with catchment stakeholders, this report should also detailed the input of stakeholders.
3) Final report on framework addressing all the requirements specified in Objective 2.
4) Method/tool/DSS report, including demonstration of implementation, application, scenario analysis as well as appropriate software.
5) Communication and catchment stakeholders capacity building report

6) Draft project final report
7) Final project report, including any software developed

Impact Area: Environment, Economy and Society

Time frame: 2 years

Suggested Budget: R 1.5M

Suggested total Funds for year 1: R 800 000

REFERENCES

Bunn SE and Arthington AH. 2000. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environmental Management 30(4): 492–507.

Clarke J. 2002. Coming back to earth: South Africa’s changing environment. Houghton, Jacana.

Crafford D and Avenant-Oldewage A. 2010. Bioaccumulation of non-essential trace metals in tissues and organs of *Clarias gariepinus* (sharptooth catfish) from the Vaal River system – strontium, aluminium, lead and nickel. Water SA 36(5): 621-640.

Department of Water Affairs and Forestry (DWAF). 1996. South African Water Quality Guidelines (second edition). Volume 4: Agricultural Use: Irrigation. Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (DWAF). 2007. Development of the Water Resource Classification System (WRCS). By Chief Directorate: Resource Directed Measures

Department of Water Affairs and Forestry (DWAF). 2009a. Integrated water quality management plan for the Vaal River system: Task 8: Water Quality Management Strategy for the Vaal River System. Report No. P RSA C000/00/2305/7. Directorate National Water Resource Planning, Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (DWAF). 2009b. Vaal River system: Large bulk water supply reconciliation strategy: second stage reconciliation strategy. Department of Water Affairs and Forestry, Pretoria.

Department of Water and Sanitation (DWS). (2014). Determination of Resource Quality Objectives in the Upper Vaal Water Management Area (WMA8): Resource quality objectives and numerical limits report. Report No: RDM/WMA08/00/CON/RQO/0214. Directorate: Resource Directed Measures Compliance. Study No: WP10535. Prepared by the Institute of Natural Resources (INR) NPC. INR Technical Report No: INR 493/14.(vi). Pietermaritzburg, South Africa.

Department of Water and Sanitation (DWS). (2015). Proposed classes and resource quality objectives of water resources for catchments of the Upper Vaal. Government Gazette No 39001, 17 July 2015. Pretoria, South Africa.

Folke C (2007) Social-ecological systems and adaptive governance of the commons. *Ecological Research* 22: 14 – 15.

Ison, R (2010). System practice: How to act in a climate-change world. London Springer.

Jordaan K and Bezuidenhout CC. 2013. The impact of physico-chemical water quality parameters on bacterial diversity in the Vaal River, South Africa. Water SA 39(3): 385-395.

Kolbe F. 2005. Discharges to the Vaal River: report on mitigating measures. TS21: Emfuleni restructuring grant. Department of Water Affairs and Forestry, Pretoria.

Mans J, Netshikweta R, Magwalivha M, Van Zyl WB and Taylor MB. 2013. Diverse norovirus genotypes identified in sewage-polluted river water in South Africa. Epidemiology Infect. 141: 303–313.

McCarthy TS, Arnold V, Venter J and Ellery WN. 2007. The collapse of Johannesburg's Klip River wetland. South African Journal of Science 103: 391-397.

McCarthy TS. 2011. The impact of acid mine drainage in South Africa. South African Journal of Science 107(5/6) Art. #712.

Moja SJ, Mtunzi F and Madlanga X. 2013. Determination of polycyclic aromatic hydrocarbons (PAHs) in river water samples from the Vaal Triangle area in South Africa. Journal of Environmental Science and Health, Part A, 48(8): 847-854.

Odume ON and de Wet C (2016) The role of environmental ethics in social-ecological systems and water resource management. WRC Report No. 2342/1/16.

Sibande RX. 2013. Costs of eutrophication at the Vaal River system: An integrated economic model. MCom thesis, University of Pretoria.

Taylor JC, Janse van Vuuren MS and Pieterse AJH. 2007. The application and testing of diatom-based indices in the Vaal and Wilge Rivers, South Africa. Water SA 33(1): 51-59.

Tempelhoff JWN. 2009. Civil society and sanitation hydropolitics: A case study of South Africa's Vaal River Barrage. Physics and Chemistry of the Earth 34: 164–175.

Turton A, Schultz C, Buckle H, Kgomongoe M, Malungani T and Drackner M. 2006. Gold, scorched earth and water: the hydropolitics of Johannesburg. International Journal of Water Resources Development 22(2): 313-335.

van Wyk F. 2001. An integrated manual for the management, control and protection of the Vaal River reservoir. MSc Thesis, Rand Afrikaans University, Johannesburg.

Wepener V, van Dyk C, Bervoets L, O'Brien G, Covaci A and Cloete Y.2011. An assessment of the influence of multiple stressors on the Vaal River, South Africa. Physics and Chemistry of the Earth 36: 949–962.