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P RSA C000/00/2305/7

Development of an Integrated Water Quality Management Plan for the Vaal River System

Task 8

Water Quality Management Strategy

September 2009

Development of an Integrated Water Quality Management Plan for the Vaal River System

TASK 8:

WATER QUALITY MANAGEMENT STRATEGY FOR THE VAAL RIVER SYSTEM

FINAL REPORT

Directorate National Water Resource Planning
Department of Water Affairs and Forestry

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EXECUTIVE SUMMARY

Introduction

The Department of Water Affairs and Forestry (the Department) commissioned three studies to reconcile water availability and water requirements and to manage the water quality in the Vaal River System. The three studies were:-

- The development of Large Bulk Water Supply Reconciliation Strategies.
- Water Conservation and Water Demand Management Potential Assessment.
- The Development of an Integrated Water Quality Management Plan (IWQMP) for the Vaal River System (This study).

The first two studies address the reconciliation of water availability and water requirements while the IWQMP developed short, medium and long term strategies to manage the water quality in the Vaal River System. The water quality management strategies are presented in this report.

The IWQMP study only addresses the main stem of the Vaal River. Strategies are not developed for the tributaries of the Vaal River. The IWQMP is to set the framework in which the Catchment Management Strategies for the tributary catchments must be developed. The establishment of a set of integrated Resource Water Quality Objectives (RWQO) for the main stem of the Vaal River and the major tributaries is a key element of the framework.

Description of Vaal River System

The water flow in the Vaal River System is well regulated by the Grootdraai, Vaal and Bloemhof Dams as well as a number of weirs. The larger of these weirs are the Vaal Barrage, Vaal Harts weir and the Douglas Barrage. The land use in the Vaal River Catchment upstream of Grootdraai Dam is characterised by agriculture, coal mining and power generation at the Tutuka, Camden and Majuba Power Stations. The Grootdraai Dam supplies water to Sasol Secunda and the Tutuka Power Station. The supply from Grootdraai Dam is supported by transfers of water from the Zaaihoek and Heyshope Dams.

The incremental catchment from Grootdraai Dam to Vaal Dam is characterised by agriculture and small urban centres such as Bethlehem and Harrismith. The major development in this area is located in the Waterval Catchment where Sasol Secunda as well as coal and gold mines are located. The water quality in this river is impacted by seepage from waste facilities as well as industrial and wastewater treatment plant discharges. Large volumes of water are transferred from the Lesotho Highlands Water Project (LHWP) and the Thukela Catchment. The water transferred from the LHWP flows into the Vaal Dam via the Wilge River while the water transferred from the Thukela River is stored in Sterkfontein Dam for release to Vaal Dam via the Wilge River. The water quality of the transferred water is good with low salinity. The transferred water plays a significant role in maintaining the TDS concentration in Vaal Dam.

The land use in the Vaal Barrage Catchment is characterised by large urban areas, industries and mining. The water quality in the Vaal Barrage is impacted on by the substantial return flows from the large wastewater treatment plants (WWTP) located in the catchment as well as the mine dewatering and industrial discharges. A number of the WWTP are not functioning to specification due to poor maintenance and overloading. The Total Dissolved Solids (TDS) concentration in the Vaal Barrage is maintained at a concentration of 600 mg/ℓ by the release of low TDS concentration dilution water from the Vaal Dam so that the water users in the Middle Vaal get reasonable quality water. The dilution releases currently being made are used to meet the water requirements of the downstream users. However as the return flow volumes from the WWTP increase in the future, excess water will accumulate in Bloemhof Dam.

The water quality in the middle reaches of the Vaal River from Vaal Barrage to Bloemhof Dam is impacted by the water received from upstream as well as mine water and WWTP discharges from the Klerksdorp – Orkney – Stilfontein – Hartebeesfontein (KOSH) area. The water users in the Middle Vaal are subject to high TDS concentrations as well as periodic algal blooms. Midvaal and Sedibeng Water have had to upgrade their water treatment plants to be able to deal with the colour, odour and organics associated with the eutrophic raw water abstracted from the Vaal River.

The land use in the lower reaches of the Vaal River from Bloemhof Dam to the confluence of the Vaal and Orange Rivers is dominated by agriculture. Water is released from Bloemhof Dam to supply the Vaal Harts irrigation scheme which draws water from the Vaal Harts weir on the Vaal River. The water quality in the Lower Vaal is impacted on by the saline water from the Harts and Riet Rivers. The high TDS concentrations in these rivers are largely due to irrigation return flows.

Water Quality Status

A water quality situation assessment was undertaken as part of the study. The assessment identified salinity, eutrophication and microbiological water quality as the key water quality issues that have to be addressed in the strategy. The TDS concentration trends are shown in **Figure 4**. The figure highlights the deterioration in the concentrations from the upper reaches of the Vaal River down to Douglas Barrage. The improvement in the TDS concentrations at Vaal Dam is clearly shown followed by an increase in concentrations in the Vaal Barrage due to the WWTP return flows, mine water and industrial water discharges.

The trophic status of the main stem of the Vaal River varies from oligotrophic in the upper reaches of the Vaal River to eutrophic at Vaal Dam. The middle reaches of the Vaal River from the Vaal Barrage to Bloemhof Dam is hypertrophic and the lower reaches in the vicinity of Douglas Barrage categorised as oligotrophic. The hypertrophic conditions in the middle reaches of the Vaal River are of concern. The hypertrophic conditions are due to the phosphorus loads in the return flows from the WWTP, urban runoff, spills from sanitation systems and irrigation return flows. The major WWTP are meeting their licence conditions however there are a number of WWTP which are not functioning to specification due to overloading and poor operation and maintenance.

The available database shows that the microbiological pollution is a localised problem. The problem is localised to the receiving streams of some of the WWTP.

Setting of RWQO

The process followed in setting the RWQO is summarised as follows:-

- The existing RWQO set for the Vaal main stem and the major tributaries in the Water Management Areas (WMA) were collated and reviewed. The review showed that the RWQO were set in isolation on a priority catchment basis. The RWQO need to be integrated for the Vaal River main stem.
- Where RWQO had not been set, workshops were held with the Regional Offices of the Department to set preliminary RWQO.
- A visioning workshop was held with key role players within the Department. On the basis of the workshop, the initial set of RWQO were then revised. The workshop identified TDS, total phosphorus and e-Coli as the key water quality variables of concern for which RWQO must be set by this study.
- A modelling exercise of the TDS concentrations was then undertaken where different strategies were assessed to see if the RWQO can be met and the RWQO required to be set for the tributaries so that the Vaal River main stem RWQO can be met.

The final set of RWQO is shown in **Figure 9**, **Figure 10**, **Figure 11** and **Figure 12**. The RWQO are regarded as an interim and will be reviewed once the results of the ecological Reserve studies become available.

Assessment of salinity management scenarios

The following salinity management scenarios were formulated for assessment in the water resource planning model (WRPM) and for economic evaluation:-

- Scenario 1a is the continuation of the status quo with the release of dilution water from Vaal Dam to maintain the TDS concentration in the Vaal Barrage at 600 mg/ℓ. Rand Water abstracts water from Vaal Dam.
- Scenario 1b is the same as Scenario 1a except that the dilution in the Vaal Barrage was to achieve a TDS concentration of 450 mg/ℓ. Rand Water abstracts water from Vaal Dam.
- Scenario 1c was the continued dilution of the Vaal Barrage to 600 mg/ℓ but the major mining and industrial saline streams were collected and treated for re-use. Rand Water abstracts water from Vaal Dam.
- Scenario 1c1 was the same as Scenario 1c except that only selected mining discharges of highly saline mine water were treated for re-use as potable water. Rand Water abstracts water from Vaal Dam.
- Scenario 3 was the continued dilution of the Vaal Barrage water to 600 mg/ℓ. There is no treatment of the mine and industrial discharges but Rand Water abstracts water from the Vaal

Barrage as well as Vaal Dam. The water from the two sources is blended to a 300 mg/ℓ TDS concentration.

The above scenarios were investigated for the base water demand projection scenario with Scenarios 1a, 1c and 1c1 being analysed further for the high water demand projection. Both water demand projections include a 15% saving due to water conservation and water demand management.

The WRPM was used to determine the dates of the next augmentation schemes and the time series of the TDS concentrations for the users downstream of the Vaal Barrage. The augmentation schemes considered were Polihali (Lesotho), Jana and Mielietuin Dams (Thukela River). The construction of the Polihali Dam will reduce the flow of good quality water to the Orange River. The Vioolsdrift Dam on the lower Orange was included as an augmentation option for the Lower Orange where required. The treatment options were costed and included in the cash flows for the scenarios. The economic model of water quality dis-benefits due to salinity was used together with the modelled TDS concentrations for the different scenarios to determine the water quality dis-benefit for the water users below the Vaal Barrage. The net present values (NPV) of the augmentation schemes and the treatment options as well as the water quality dis-benefits were determined for discount rates of 6%, 8% and 10%. The resulting NPV are given in **Table E1.**

Table E1: Total NPV for Salinity Management Scenarios

Scenario	NPV Interventions and Treatment (million Rand)			NPV Water Quality Dis-benefits (million Rand)			Total NPV Costs (million Rand)		
	6%	8%	10%	6%	8%	10%	6%	8%	10%
1a (Base Demand)	3 585	2 998	2 536	4 087	3 597	3 194	7 627	6 595	5 730
1c (Base Demand)	19 271	14 475	11 468	3 759	3 303	2 941	23 030	17 778	14 409
1c1 (Base Demand)	8 197	6 424	5 239	3 362	2 958	2 630	11 559	9 382	7 869
3 (Base Demand)	6 833	5 303	4 275	10 754	9 332	8 201	17 587	14 635	12 476
1a (High Demand)	11 954	9 240	7 433	4 087	3 597	3 194	16 041	12 837	10 627
1c (High Demand)	23 216	17 666	14 251	3 759	3 303	2 941	26 975	20 969	17 192
1c1 (High Demand)	10 590	7 913	6 248	3 362	2 958	2 630	13 952	10 871	8 878

The results for the base and high water demand scenarios differ. For the base water demand scenario, the total NPV clearly shows that Scenario 1a is the best from a purely economic perspective with Scenario 1c1 the next best. However for the high water demand scenario, Scenario 1c1 has the lowest total NPV. This is due to the implementation of all three augmentation schemes being required over the period 2019 to 2021 so that the high water demand and the dilution water requirements can be met.

The overall conclusions based on the economic analysis work are as follows:

- The traditional approach of implementing Vaal River Augmentation Schemes to supply water and address water quality issues is still appropriate and economically attractive.
- The treatment and re-use of selected high concentration discharge streams is an attractive scenario. The economic analysis showed that Scenario 1c1 is economically the most attractive for the high water demand scenario while the total NPV for the base water demand scenario is not significantly more expensive than Scenario 1a.
- The treatment and reclamation of selected high salinity mine waters and industrial effluents are becoming increasingly more attractive. The treatment and reclamation of all the mine and industrial effluent discharges, irrespective of size, and salinity load is not economically defensible.
- The simulations highlighted the development of the excess water volume in Bloemhof Dam due to the increased return flows and the dilution water.
- Many other water resource management policy and management considerations over and above the economic aspects, drive the implementation of the saline mine/industrial effluent reclamation schemes. Some of these include:
    - best use of local water resources.
    - application of the "polluter pays" principle.
    - reduced reliance on transferred water.
    - use of good quality water to dilute pollution.

Salinity Management Strategy

The strategy for the management of salinity is summarised as follows:-

- The current salinity status in the Vaal Dam and Grootdraai Dam Catchments should be maintained. This will involve careful and diligent management of the upstream mining activities in particular post closure.
- The short term strategy for the middle reaches from Vaal Barrage to Bloemhof Dam is to implement **Scenario 1a**, *i.e.* the release of dilution water from Vaal Dam to dilute the outflow from the Vaal Barrage to 600 mg/ℓ. The implementation of this scenario does not meet the initial set of RWQOs set for the Vaal River main stem, but does result in an improvement in the water quality in the middle reaches of the Vaal River. The water users will incur economic dis-benefits due to the salinity levels and a waste discharge charge should be used to compensate for these dis-benefits.
- The medium to long term management strategy is to implement **Scenario 1c1**. Saline mine water streams will be selected for treatment and reclamation. This will have a direct benefit in reducing salinity in the Vaal Barrage and middle Vaal River.

- The release of Vaal Dam dilution water is feasible until 2014, after which excess water will start accumulate in Bloemhof Dam. By 2014, a plan to use the excess water needs to have been developed. The plan could be to support the lower Orange from Bloemhof Dam, transfer to the Crocodile West catchment or treat and re-use in the Vaal River System. The use of the excess water, which includes the saline mine water streams should be the subject of a feasibility study.
- The short term RWQOs for the Vaal River main stem and for the tributaries should be established and compliance monitoring reported against the RWQOs. The proposed RWQOs for TDS are given in **Section 5.2.2**. The tributary catchments must be managed to meet the RWQOs established at the downstream point of the catchment.
- The current water quality monitoring programme must be expanded, according to the monitoring programme developed and detailed in the **Task 7 Report** produced as part of the study.
- The impact of the salinity management strategy selected for the Vaal River on the Orange River must be investigated. Before a final decision is made, consideration must be given to the water quality impact on the Lower Orange River of the preferred management option and the RWQOs established. The impact of the releases to support the Lower Orange River reaches on water quality need to be investigated as well as the impact of the next augmentation scheme.

Nutrient Management Strategy

The strategy for the nutrient management is summarised as follows:-

- The Waterval Catchment Management Strategy developed by the Department which includes the improved management of the WWTP to meet the phosphorus RWQO set for the Waterval River should be implemented. This will reduce the nutrient loads reporting to Vaal Dam and should improve the trophic status of Vaal Dam.
- Flow manipulation along the Middle Vaal during the months of September through October will be used to manage the risk of algal blooms in the middle reaches of the Vaal River from Vaal Barrage to Bloemhof Dam in the short term. The Vaal Dam release will be piloted, the impacts monitored and the release protocols documented. This will involve the release of water from the Vaal Barrage (augmented from Vaal Dam) to reduce residence times and improve mixing. The initial release proposed is:-
  - Base flow 15 m^3/s for 28 days - giving a total release volume of 36.3 million m^3
  - 100 m^3/s for 48 hours - giving a total release volume of 17.3 million m^3

  Total of 53.6 million m^3 will be released during the annual flow manipulation programme.

  The flow manipulation recommended will be considered with the Reserve scenarios to ensure the alignment to the ecological water requirements.

- Phosphorus has been selected as the limiting nutrient for the management of eutrophication. A set of RWQOs for phosphorus was developed for the main stem of the Vaal River. The proposed RWQOs are based on an analysis of the available nutrient and algal database.
- The operations and maintenance (O&M) of many of the WWTP are poor and poor quality effluents are discharged. In many cases, the WWTP are not able to handle the hydraulic or the organic loads. As a result, the installed treatment technology is not always working to specification. An audit of the WWTP, especially draining to the Vaal Barrage, is required to determine the works that are not working to specification and develop a programme to retrofit and upgrade these works. It is essential to address the issue of insufficient O&M resources in this process.
- The medium to long term strategy will be the further management of phosphorus by reducing the load discharged from point sources. A better understanding of the nutrient balance in the Vaal Barrage and the Vaal River main stem from the Vaal Barrage to Bloemhof Dam is required, before revised discharge standards can be set. A nutrient balance study is therefore proposed which will result in a better understanding of the sources and fate of nutrients (phosphorus and nitrogen) and will provide the rationale for revising the current 1 mg/ℓ phosphorus discharge standard.
- A perspective is needed on the extent and costs of the measures needed (such as banning phosphorus containing detergents) to reduce the phosphorus loads received at the wastewater treatment works.
- The results of the current Water Research Commission project aimed at developing a perspective on the economics of eutrophication on the water users. This should include recreational impacts as well as water treatment costs.

Microbiological Quality Management Strategy

The strategy for improving the microbiological water quality is related to getting the WWTP operating to their specifications and meeting their licence conditions specifically in terms of discharge quality. The strategy is similar to the nutrient management strategy in that the wastewater treatment works must be audited and the “hot spot” areas identified. Plans must be developed in consultation with the local municipalities to retrofit the works in these target areas.

Institutional

A strategy steering committee is to be established to oversee the further development and implementation of the reconciliation and the water quality management strategies. The details and proposed functions of the strategy steering committee are discussed under implementation. In association with the strategy steering committee the timeframes associated with implementation actions will be specified by the Department.

DOCUMENT INDEX

Reports as part of this project:

Bold type indicates this report.

Report Index	Report number	Report title
1		Inception Report
2	P RSA C000/00/2305/1	Water Quality Status Assessment
3	P RSA C000/00/2305/2	Salinity Balance
4	P RSA C000/00/2305/3	Integration of Resource Water Quality Objectives
5	P RSA C000/00/2305/4	Water Quality Economic Impact Modelling
6	P RSA C000/00/2305/5	Evaluation of Water Quality Management Scenarios
7	P RSA C000/00/2305/6	Monitoring Programme
8	**P RSA C000/00/2305/7**	**Water Quality Management Strategy**

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LIST OF ACCRONYMS AND ABBREVIATIONS

CMA	Catchment Management Agency
CMS	Catchment Management Strategy
DWAF	Department of Water Affairs and Forestry
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMP	Environmental Management Program
ICM	Integrated Catchment Management
ISP	Internal Strategic Perspective
IWQM	Integrated Water Quality Management
IWQMP	Integrated Water Quality Management Plan
IWRM	Integrated Water Resource Management
LBWSRS	Large Bulk Water Supply Reconciliation Strategies
KOSH	Klerksdorp – Orkney – Stilfontein - Hartebeesfontein
NPV	Net Present Value
NWA	National Water Act
NWRS	National Water Resource Strategy
O&M	Operation and Maintenance
RO	Regional Office
RQOs	Resource Quality Objectives
RWQOs	Resource Water Quality Objectives
SAWQGs	South African Water Quality Guidelines
TDS	Total Dissolved Solids
TP	Total Phosphorus
TWQR	Target Water Quality Range
WCWDM	Water conservation and water demand management
WDCS	Waste Discharge Charge System
WMA	Water Management Area
WQM	Water Quality Management
WRPM	Water Resource Planning Model
WWTP	Wastewater Treatment Plant

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1 INTRODUCTION

1.1 Water Resource Management Studies in the Integrated Vaal River System

In terms of the National Water Act (NWA), Act No. 36 of 1998 and in line with the Department of Water Affairs and Forestry's (the Department) obligation to ensure that the country's water resources are fit for use on an equitable and sustainable basis, the Department adopted the approach of the development and implementation of catchment management strategies (CMSs) to fulfil this mandate. Each Catchment Management Agency (CMA) will be responsible for the progressive development of a CMS for its respective Water Management Area (WMA) that is developed in consultation with stakeholders within the area. The Department's eventual aim is to hand over certain water resource management functions to these CMAs. Until such time as the CMAs are established and are fully operational, the Regional Offices of the Department will continue managing the water resources in their areas of jurisdiction with the support of the national office.

The Department initiated the development of management strategies for the various WMAs within South Africa in an attempt to provide the framework and constraints within which the water resources will be managed into the foreseeable future. These various strategies and plans arose out of the Internal Strategic Perspective (ISP) development process, which identified the relevant water resource management issues and concerns in each of the WMAs. The Vaal River System WMAs, which include the Upper, Middle and Lower Vaal and the Modder-Riet Catchment of the Upper Orange WMA, are four such catchments for which management strategies are currently in the process of being finalised. Three major studies that are nearing completion in the Vaal River System, specifically aim to introduce overarching management measures to reconcile water requirements and availability and to ensure the continued fitness-for-use of the water resources. These studies are the Development of Large Bulk Water Supply Reconciliation Strategies (LBWSRS), Water Conservation and Water Demand Management Potential Assessment and the Development of an Integrated Water Quality Management Plan (IWQMP). The immediate objectives of the individual studies are:

- *Development of Large Bulk Water Supply Reconciliation Strategies*: to develop strategies for meeting the growing water requirements of the industrial and urban sectors served by the Integrated Vaal River System (LBWSRS).
- *Water Conservation and Water Demand Management Potential Assessment*: to determine the potential for, and benefits of Water Conservation and Water Demand Management (WCWDM) in the various water use sectors with the focus on the Upper and Middle Vaal WMAs.
- *Integrated Water Quality Management Plan*: to develop water quality management measures to ensure continued fitness-for-use in the Vaal River System.

The management scenarios identified through these three studies have been fed into the reconciliation and water quality management strategy developed for the Vaal River System (

Figure 1). The strategy aims to support current and future water users within the interdependent water resource systems of the Vaal WMAs and associated Modder-Riet Catchment.

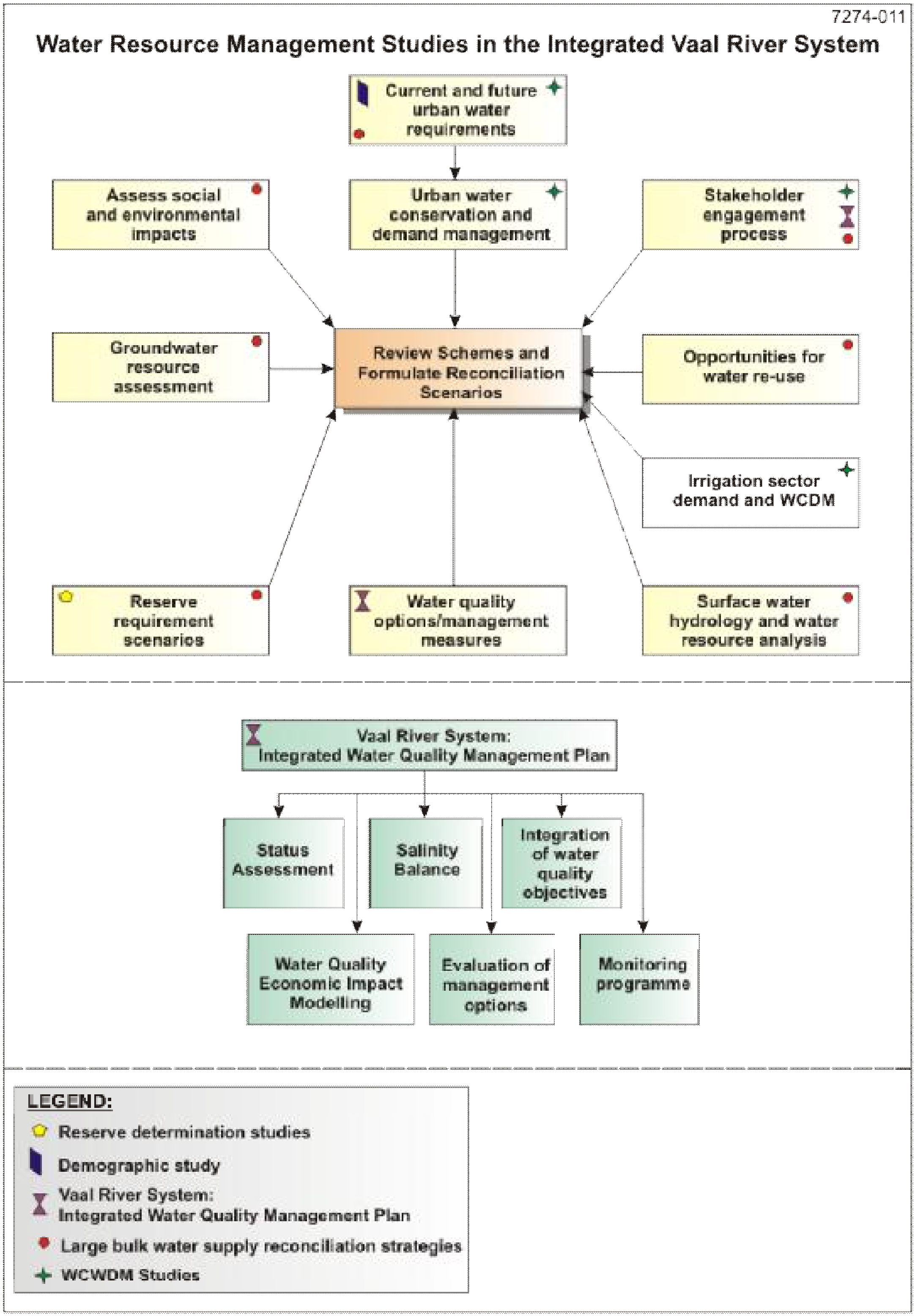

Figure 1: Water Resource Management Studies for the Integrated Vaal River System supporting the identification of reconciliation options (*adapted* DWAF, 2005a)

1.2 Development of an Integrated Water Quality Management Strategy for the Vaal River System

Having water of an acceptable quality is as important as having enough water. Integrated water resource management in the Vaal River System can only be achieved if water quality and quantity are managed in a co-ordinated manner to meet the requirements of water users (including the aquatic ecosystem) and their needs in terms of use of the resource. The more the water resource is used and gets re-used, and as quantities get scarce and feedback loops within this highly developed and utilised water resource system get even tighter, it is water quality that begins to play a dominant role.

The Department realised that just as planning and management are taking place to supplement and control water quantities, these actions also need to take place with respect to water quality. In response to the need to meet the objectives of integrated water resource management (IWRM), the Department initiated this process to address the management of water quality in the Vaal River System. The purpose of this initiative was to develop a management strategy for the Vaal River System, which will serve as a coherent approach for water management institutions and stakeholders to manage the water resources in the inter-dependant Vaal WMAs. In essence, the integrated management strategy developed will serve as a holistic and comprehensive business plan for water quality management in and among the WMAs of the Vaal River System. The plan will also feed into the National Water Resource Strategy (NWRS) as part of the national guiding framework.

The integrated water quality management (IWQM) strategy for the Vaal River System is aimed at:-

- Supporting the continued fitness-for-use of the water resources for all users across the WMAs.
- Guiding the Department, water users and stakeholders in working together to control key water quality issues and problems and thereby ensuring sustainable water resource systems within their catchments (in line with the principles of the NWA).
- Setting management objectives for water quality for the Vaal River System that requires a shared responsibility and action between the Department, water users and stakeholders.
- Providing an accountable and consistent framework that over the short, medium and long term will allow tracking of the efforts to manage water quality.

The WQM strategy for the Vaal River System is based on technically, economically and socially feasible management options and which supports the continued fitness-for-use of the water resources for all users across the WMAs. A range of management scenarios were assessed to arrive at the selected management strategy to maintain or improve the water quality of the Vaal River System. These have been investigated in parallel to the water quantity reconciliation strategies developed in the LBWSR study.

The IWQMP study comprised seven tasks which are depicted in **Figure 2.** The project reports produced per study task are listed in **Table 1**.

The approach followed for the development of the IWQM strategy involved:-

- Assessment of the Vaal River System to obtain a perspective on water quality (variables of concern), pollution sources and key water users. This included the identification of existing Resource Water Quality Objectives (RWQOs) and their establishment, where they are not available. It also included an understanding of the salinity balance of the system to determine where the major salt contributions are originating from.
- Establishing how the Vaal system complies with the RWQOs, which was determined through analysis of available data and undertaking modelling of possible future scenarios.
- Determining an integrated set of RWQOs that were achievable, aligned to the system behaviour, preventing further deterioration of water quality with the potential to progressively improve the system water quality.
- Identifying and developing management measures to reduce the non-compliance cases, address water quality stresses and priorities and allow utilisation of available allocatable water quality to the benefit of the water users in the system. The selected management measures were evaluated on the basis of their technical, environmental, social and economic feasibility. The selected water quality management scenario was then formulated into this proposed strategy for implementation.

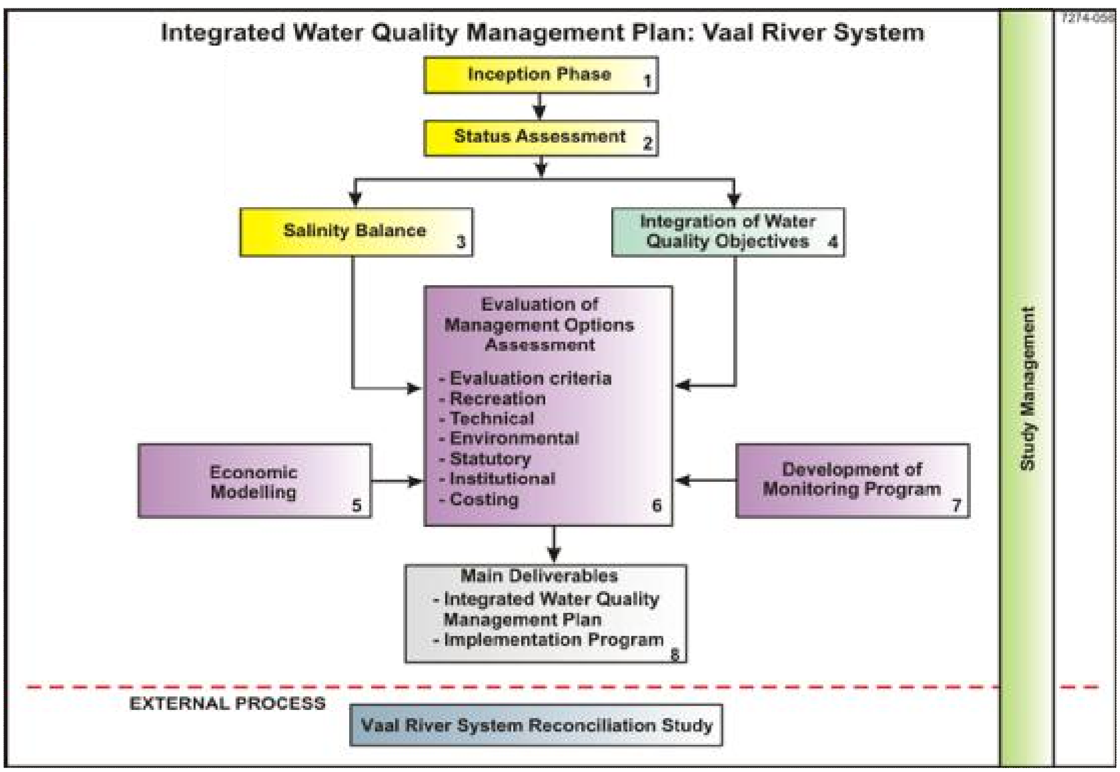

Figure 2: The study tasks comprising the development of the IWQMP for the Vaal River System (DWAF, 2005b)

Table 1: Study reports for the IWQMP tasks

Task	Reports: Vaal River System Integrated WQMP Study
1	Inception report
2	Status assessment report
3	Salinity balance report
4	Integration of Resource Water Quality Objectives report
5	Water Quality Economic Impact Modelling report
6	Evaluation of Water Quality Management Scenarios report
7	Monitoring Programme report
8	Integrated water quality management strategy report (this report)

This report forms the conclusion of the IWQMP study and details the water quality management strategy that is proposed for implementation in the Vaal River System in the immediate, medium (2015) and long term (2025 and beyond).

1.3 The Vaal River System Catchment Area

The study area for the IWQMP study included the entire C drainage region within South Africa. This includes the Upper and Middle Vaal WMAs in their entirety, part of the Lower Vaal WMA (C31, C32, C33, C91 and C92 tertiary catchments), and part of the Upper Orange WMA (C51 and C52 tertiary catchments, *i.e.* Modder-Riet Catchment). Refer to **Figure 3**.

The extent of the study focussed on: -

- The main stem of the Vaal River as it flows from its origin in the Drakensberg to Douglas Barrage (includes Level 1 strategic monitoring points) as indicated on **Figure 4**.
- The major tributaries to the Vaal River. The tributaries were considered just upstream of their confluences with the Vaal River (includes Level 2 strategic monitoring points) (as indicated on **Figure 5**). The strategy does not include the drainage areas of the tributary catchments.

Although the study considers the major tributaries of the Vaal River, the strategy does not address specific water issues in each of the tributary sub-catchments. Rather, the strategy for the Vaal River will feed into the respective catchment management strategies and water quality management plans as they are developed or revised per tributary catchment.

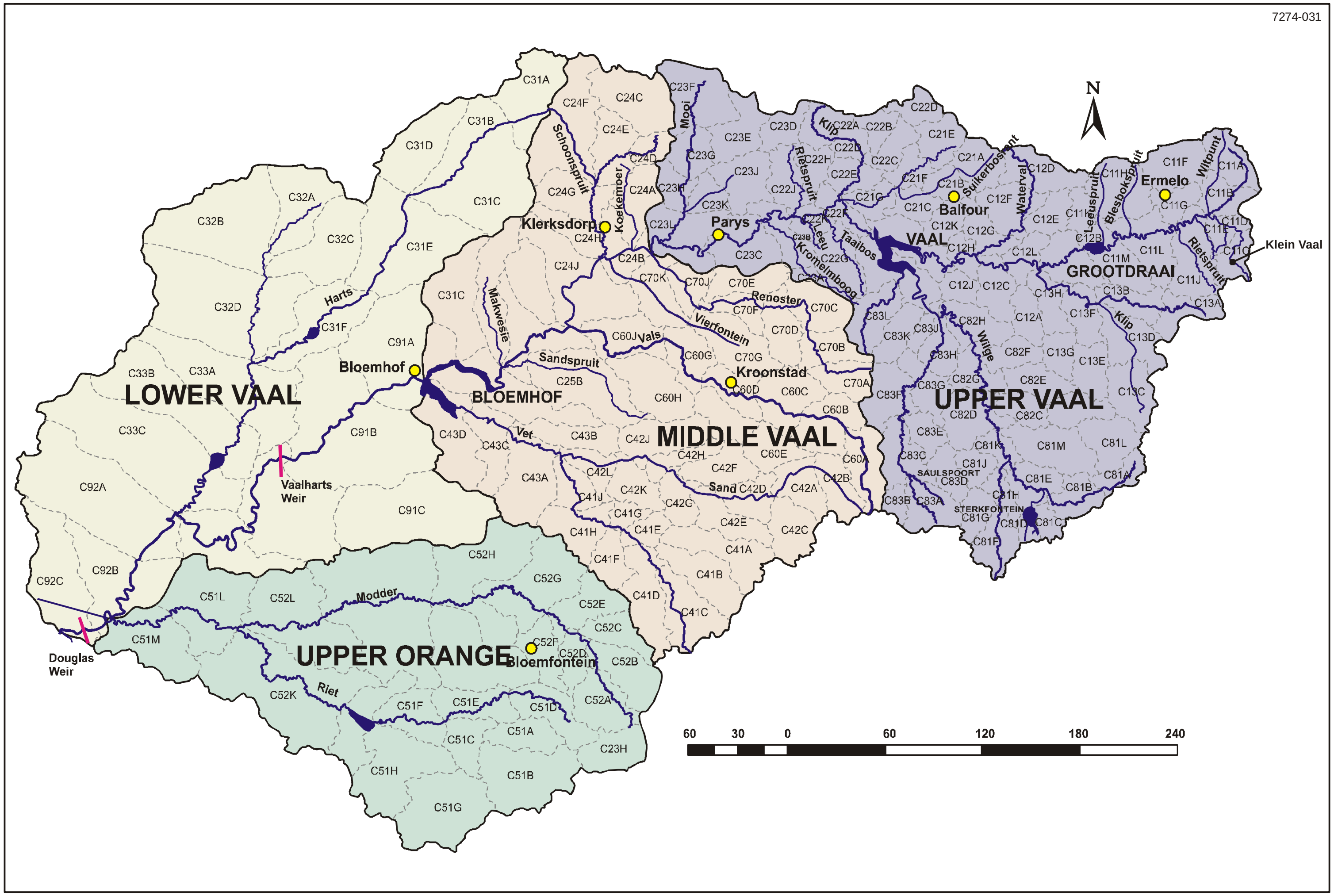

Figure 3: Vaal River System catchment area

2 BACKGROUND

2.1 Introduction

The Vaal River catchment ranges from semi-arid in the east to arid in the west across the catchment. The Upper Vaal WMA is highly altered by catchment and land developments. The developments include extensive urban areas, industrial development, agriculture, power generation and mining. The mining includes both coal and gold mining. The Middle Vaal WMA has a few urban development centres with agriculture and mining being the main economic activities. The Lower Vaal WMA is less developed with agriculture being the predominant land use. The Modder-Riet catchment in the Upper Orange WMA is dominated by agricultural activities with the metropolitan area of Bloemfontein and a few smaller urban centres. These land and other developments impose substantial water demands that remove much of the available water from the resource. Concentration of pollutants in the Vaal River system is caused by cascading re-use along the river course and evaporative concentration in impoundments and river reaches.

The water flow in the main stem of the Vaal River is well regulated by the Grootdraai, Vaal and Bloemhof Dams. There are also a number of weirs located along the main stem of the Vaal River. The larger of these are the Vaal Barrage, Vaal Harts Weir and Douglas Barrage. The regulation of the Vaal River has resulted in a reduction in base flows and flow variations in the river. The low flows and the lack of variation in flow was identified in the water quality status assessment as contributing factors to the eutrophic conditions experienced in the middle reaches of the Vaal River.

The water resources of the Vaal River have been augmented by substantial transfers into the Vaal River catchment since the early 1970s. Water is transferred from the Heyshope (located on the Assegaai River in Usutu to Mhlatuze WMA) and Zaaihoek Dams (located on the Slang River in the Thukela WMA) into the Grootdraai Dam. The Vaal Dam receives water transferred from the Thukela catchment and the Lesotho Highland Water Project. The water transferred into the Vaal River catchment impacts on the water quality of the conveying rivers and the receiving dams. The water quality of the Wilge River and the Vaal Dam is significantly influenced by the large volumes of water transferred from Lesotho. The water quality of the sources of transfer water are currently good. Any change in the water quality of these sources will impact on the water quality of the Vaal River System. Indications are that the water quality of the Heyshope Dam is deteriorating due to developments around the dam. The future augmentation schemes are likely to be located in the Thukela Catchment and Lesotho Highlands where the water quality is currently good. There are also transfers of water out of the Vaal River catchment to the Upper Olifants and Crocodile West catchments.

The Grootdraai Dam supplies water for domestic use, Sasol Secunda and Eskom for power generation. The Grootdraai Dam is operated as an entity on its own and does not support Vaal Dam as an upstream source of water. A pipeline is being constructed to convey water from Vaal Dam to augment the water supply from Grootdraai Dam to Sasol and Eskom as well as the Eskom demands in the upper catchment of the Olifants River WMA. There are a number of defunct and operating coal mines in the Grootdraai Dam catchment as well as the Camden, Tutuka and Majuba power stations. The volume of water that will be discharged from the mines in the Grootdraai Dam post closure was estimated to be 120 ML/d (43.8 million m^3/a). The post closure mine water management plans for this impacted water must now be implemented and the rate at which the mines fill and decant must be monitored.

The most significant pollution sources in the incremental catchment between Vaal Dam and Grootdraai Dam are located in the Waterval River catchment. These include gold and coal mines as well as the Sasol Secunda oil-from-coal petrochemical plant. There are significant waste facilites in the form of ash dumps and tailings storage facilities associated with the mines and Sasol Secunda industrial complex. There are also point source discharges in the form of permitted cooling water blow down from Sasol Secunda plant and the major wastewater treatment works discharges from Embalenhle and Secunda.

The Vaal Dam is a pivitol point in the water supply to the Vaal River System. Rand Water, Sasol Sasolburg, Eskom and Accelor Mittal Steel as well as downstream users such as irrigators, Midvaal Water and Sedibeng Water are supplied or supported with water released from Vaal Dam. Rand Water currently draws water directly from Vaal Dam. Rand Water supplies water to urban areas that fall across the watershed between the Vaal River and Crocodile River catchments. As a result, some of the return flows through the wastewater treatment works report to the Crocodile West catchment and thus the water quality in Vaal Dam also indirectly impacts on the water quality in the Crocodile West catchment.

The Vaal Barrage catchment receives extensive volumes of water from point source treated effluent discharges. The point source discharges include the major wastewater treatment works operated by Johannesburg Water, ERWAT and Metsi-a-Lekoa as well as the discharges from gold mines. The major salt loads from the gold mines being discharged from Petrex (formerly Grootvlei) and ERPM. There are also industrial effluent discharges, the largest being from SAPPI Enstra, Sasol Sasolburg and Accelor Mittal Steel Vanderbijlpark. The discharge volumes from the wastewater treatment plants will grow with time as the water requirements grow and the level of water services is improved with the expansion of waterborne sewerage systems in urban areas.

Smaller, but still very significant, pollution loads emanate from the Midvaal and Free State Goldfields mining areas between Vaal Barrage and Bloemhof Dam. Irrigation return flows at Vaalharts and in the Sand-Vet Government Water Scheme and along the lower Vaal River to Douglas cause further increases in salinity. The water quality in the Spitskop Dam is dominated by the saline and nutrient rich return flows from the Vaalharts Irrigation Scheme. The Modder River and Riet River irrigation schemes consume large amounts of fresh water and raise salinity levels in the depleted river flow to high levels, further adding to the pollution of the lower Vaal River at Douglas Barrage.

Since 1983, the impact of atmospheric deposition of sulphur salts has been identified as a potentially significant long-term phenomenon contributing to the salinity problem. The management of atmospheric deposition has not specifically been addressed in this study. A Water Research Commission project is currently being undertaken to determine the impact of atmospheric depostion on the Vaal River and the upper Olifants River Catchments. The results of this study may lead to the introduction of more stringent air emission standards.

A significant water quality issue identified during the water quality status assessment, was the poor performance of some of the wastewater treatment works as well as the lack of proper management and maintenance of the urban sewerage systems. Monitoring of the microbiological water quality indicated local areas of high *E.coli* counts around the wastewater treatment works discharges, posing a threat to public health. This is largely due to overloaded and poorly operated and maintained works.

Rapid economic development within the Vaal River System has led to deterioration in the water quality of the water resources, which now require management interventions to ensure that water of acceptable quality is available to all users in the system, especially as land use and development activities continue to grow and intensify. If the system is going to sustain the envisaged growth and development, a sound and robust water quality management strategy and diligent follow up actions are necessary. This will ensure that the water resources of the Vaal River System are managed to meet the needs of all water users, while at the same time affording an adequate level of protection of in-stream water resource quality.

2.2 Past actions and initiatives on water quality management

Management of the system has included the development of *ad hoc* catchment management strategies addressing water quality issues in priority catchments. No integrated strategy for water quality management has previously been developed for the Vaal River System. The focus of management has been to a large extent on pollution control (point source management) and in recent years on the development of RWQOs.

Compliance monitoring of the main stem of the Vaal River and the major tributaries has been set up with the establishment of the Level 1 and Level 2 monitoring points as specified by the DWAF's Regional Offices (Gauteng, Frees State and Northern Cape). The 20 Level 1 points are located on the main stem of the Vaal River (see **Figure 4**) and the 26 Level 2 points are located on the major tributaries of the Vaal River (see **Figure 5**). Operational water quality management has also been implemented with the implementation of dilution releases from Vaal Dam to maintain a 600 mg/ℓ TDS concentration in the outflow from Vaal Barrage. These releases maintain an acceptable water quality in the Vaal Barrage and in the middle reaches of the Vaal River down to Bloemhof Dam. The dilution releases made from Vaal Dam are currently used to supply the downstream users.

As part of the Department's approach to the management of water quality, water quality forums were set up as institutional structures to support various activities and studies. There are 13 catchment management forums present in the Upper Vaal WMA, two in the Middle Vaal WMA and one forum for the Modder-Riet catchment. The Lower Vaal WMA has no established catchment management forums. These forums comprise interested and concerned stakeholders, as well as major water users, regulators and polluters, contributing their time and resources to ensure that water resource management issues are addressed. Problems with representivity, participation and sustainability threaten the continued existence of the forums. These forums play a key role in addressing WQM issues and will play a central role in the CMA establishment processes, in the implementation of CMSs and water quality management strategies. These bodies could be used to achieve various water quality management goals of this strategy, however, the users and stakeholders need to take ownership and drive the forums continued functioning.

Another approach to the Vaal River water quality management introduced by the Department, has been the setting of RWQOs for a number of reaches. The RWQOs have been derived through a consultative process at the forums. Typically RWQOs have been set defining ideal, acceptable, tolerable and unacceptable concentrations for selected water quality variables and for identified catchments/river reaches. The objectives have been set based on user requirements, current water uses, existing water quality at the time, detection limits of water quality variables and practical achievability. These RWQOs have often been set in isolation without consideration of impacts on downstream RWQOs and does not include the Reserve as this was not available at the time establishment. The RWQOs have been adopted by the users and have been applied in the management of the water quality of various sub-catchments, especially in the Upper Vaal WMA.

The RWQO approach to date has not considered the Vaal River as an integrated system. The development of the CMSs or water quality management plans for the priority catchments generally involved the setting of the RWQOs and the management of pollution loads to achieve the RWQOs. In developing these local CMSs, the impact on the entire Vaal River was not always considered. The RWQO set for the tributary catchment should be aligned with the main stem Vaal River requirements. Hence, one of the objectives for this study was to set RWQOs for the Vaal River main stem and the main tributaries so that local CMSs can be developed and implemented to meet the requirements of the major tributaries and that of the Vaal River. An additional consideration to the revised proposed RWQOs will be the requirements of the Reserve Determination Study.

Water quality actions in the past has focussed on salinity management and associated modelling. Limited attention has been given to the management of nutrients. Eutrophication is a concern with the Vaal Barrage and Bloemhof Dam categorised as hypertrophic (waters with the high growth of nuisance plants (e.g. water hyacinths) and severe algal blooms, often including cyanobacterial species such as *Microcystis* species that can be toxic to man, livestock and wildlife). The nutrient balance is not as well understood as the salinity balance. The management of nutrients has been by means of controlling point source discharges from industrial and domestic wastewater treatment works. The management has been focussed on phosphorus reduction and management. The 1 mg/ℓ phosphorus (as P) standard was introduced for wastewater treatment works effluent discharge quality to manage the eutrophic status of the Vaal River water resources. The 1 mg/ℓ standard has been implemented at the majority of the major works in the Vaal River System. The plants operated by ERWAT and Johannesburg Water generally meet the 1 mg/ℓ standard, at the 95 percentile level. The plants operated by Metsi-a-Lokoa do not meet the 1 mg/ℓ standard, however, their water use licence does not require the standard to be met at this stage. With the continued increase in the return flows from the wastewater treatment works, more stringent discharge standards will be required for the proper protection of the downstream water resources.

2.3 Water Quality trends identified

From the Vaal River water quality status assessment undertaken, a spectrum of problems has been identified with regard to water quality. Some issues are evident along the entire length of the Vaal River, while others are of a localised nature. Although a number of water quality variables were identified as variables of concern, the main issues are related to salinity, eutrophication and public health. The integrated water quality management strategy has been developed to manage Total Dissolved Solids, phosphorus (eutrophication) and *E.coli* (public health). The management of TDS to meet the RWQOs is a good starting point to manage the major cations and anions in the system. If the TDS concentration meets the RWQO, then there is a good chance that the other ions will meet their respective RWQOs.

The TDS concentration data collected over the last 10 years at the Level 1 monitoring points was analysed as part of the water quality status assessment. The analysis results are presented as box plots showing the 5, 25, 75 and 95 TDS concentration percentiles at the Level 1 monitoring points. The plot (refer to **Figure 4**) shows the increase in the TDS concentrations along the length of the Vaal River. The impact of the effluent discharges and the diffuse sources in the Vaal Barrage catchment is clearly indicated by the substantial increase in the TDS concentration between Vaal Dam (VS7) and Vaal Barrage (VS8). While the upper part of the catchment has water of fairly good quality, the areas of concern include the Vaal Barrage, Middle Vaal River, and Lower Vaal River downstream of the Harts River confluence, where TDS concentrations are generally high. Of further concern, is the impact of the high TDS concentrations on downstream water users below the Vaal Barrage.

Eutrophication is the other key water quality problem in the Vaal River System. This problem has resulted in excessive algal blooms and proliferation of water hyacinths. The extent of the problem is highlighted by the trophic status of the major impoundments and weirs in the Vaal River System. The average Total Phosphorus (TP) concentration measured in the various reaches and impoundments on the Vaal River main stem and the trophic status is shown in **Figure 5**. **Figure 5** also highlights the hypertrophic status of the middle reaches of the Vaal River from the Vaal Barrage to Bloemhof Dam.

Eutrophication impacts have resulted in severe economic impacts on water users. The water supply entities in the Middle Vaal area had to upgrade their water treatment works to deal with odour and colour associated with the trophic waters. The effect of the extensive algal blooms and associated biomass upon water treatment processes and quality of potable water may further increase in severity. The algae also impacts on the irrigators by clogging the irrigation equipment. Algae and water hyacinth pressure also impacts on the recreational use and the ecology of the river systems.

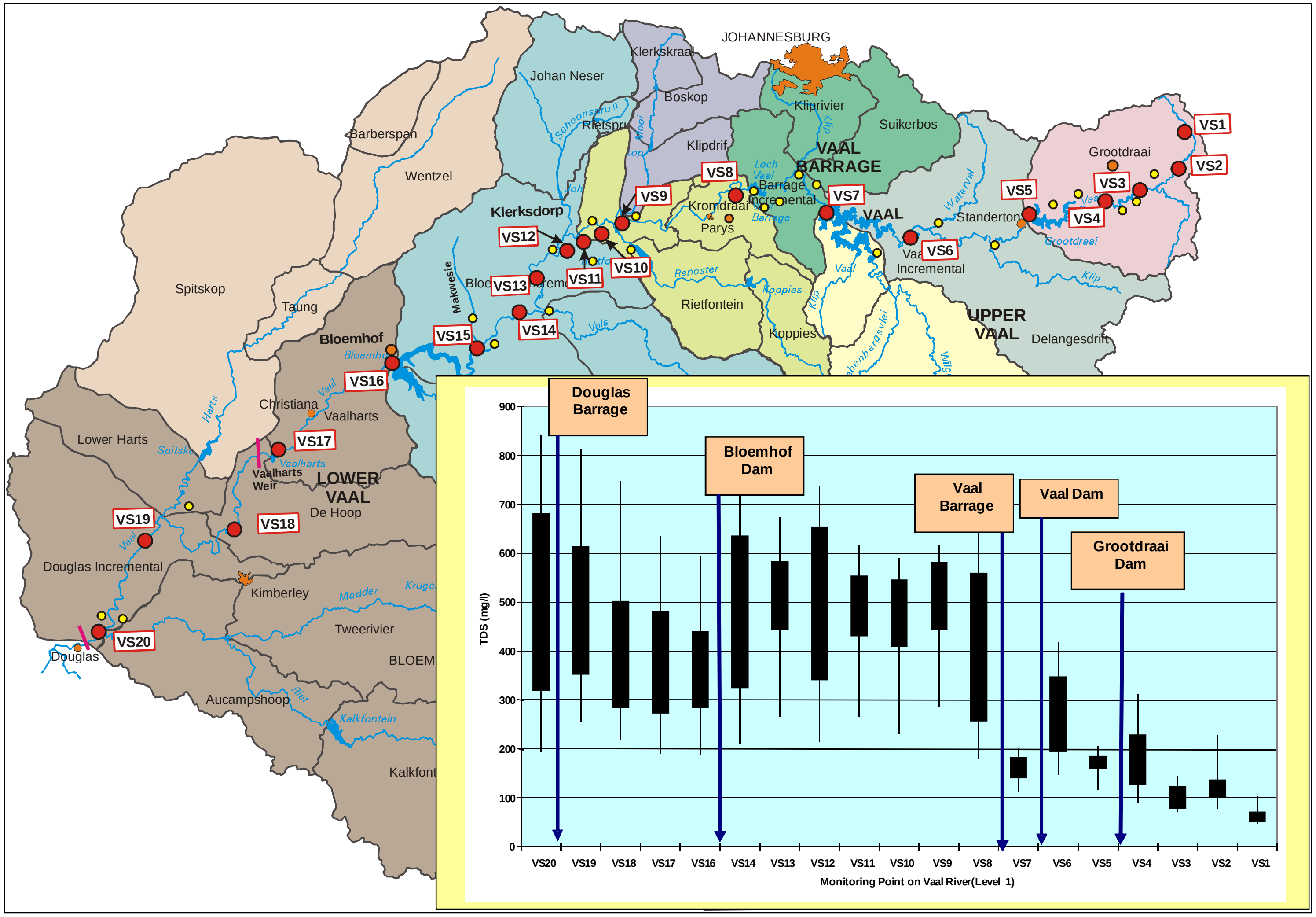

Figure 4: TDS trends along the Vaal River

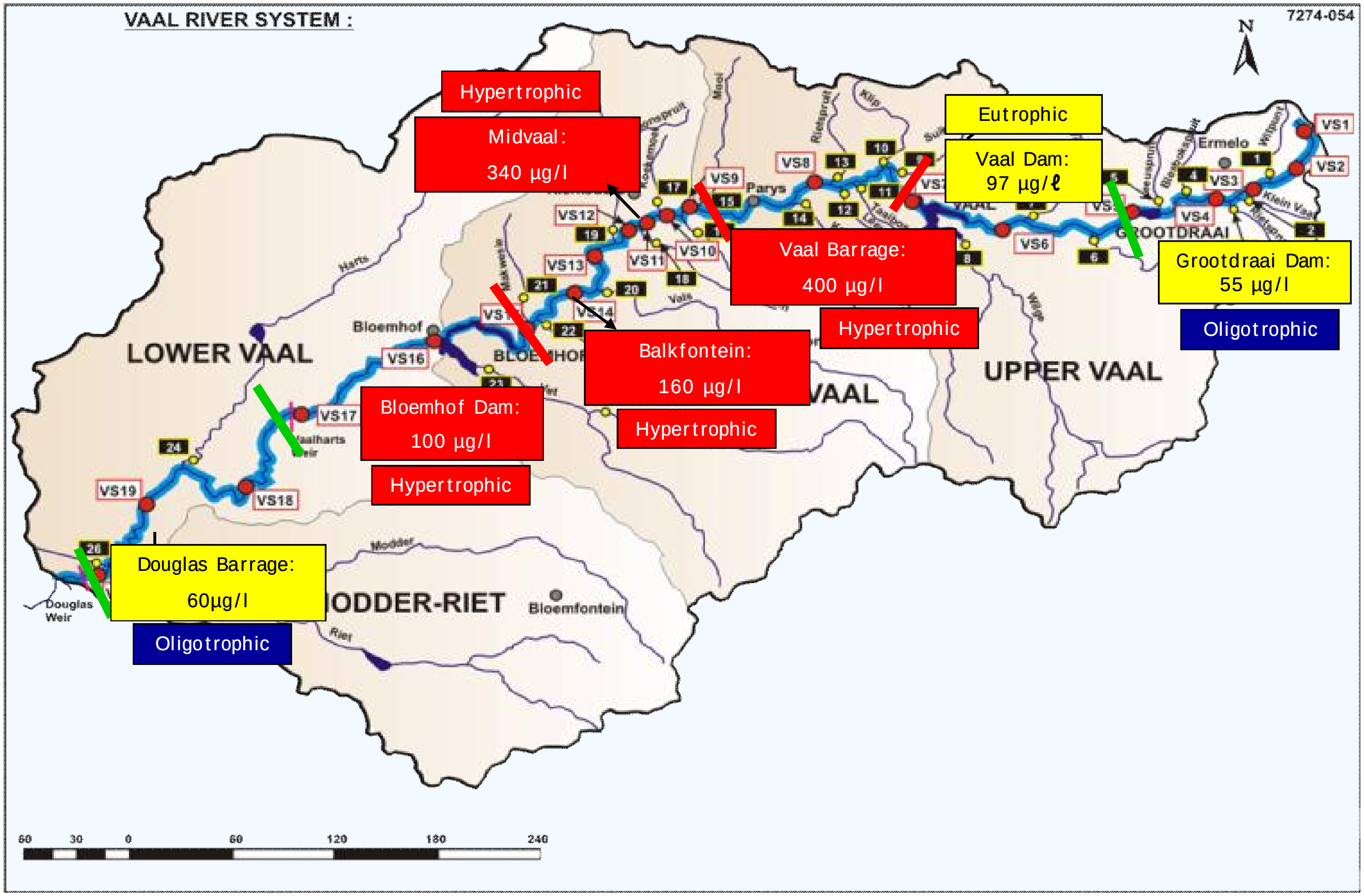

Figure 5 : Summary of the trophic status of Vaal River impoundments (averages for the last three years)

The occurrence of microbiological pollutants as localised problems is also an emerging concern. The available microbiological water quality database shows that the problem is generally localised.

The water quality situation assessment identified tributary catchments which are contributing in general to the deteriorating water quality of the Vaal River. These include the Waterval, Suikerbosrand, Rietspruit, Klip River (Gauteng), Mooi River, Koekemoerspruit, Schoonspruit, Vierfontein, Sand-Vet and the Harts River Catchments.

2.4 Strategies for the use of excess water

The water requirements of Rand Water are expected to grow in the future which implies that the return flow volumes from the wastewater treatment works will also grow. The point source discharges to the Vaal River are currently 492 million m^3/year from the domestic wastewater treatment works and 91 million m^3/year from the mines. A major portion of the point source discharges is into the Vaal Barrage and Mooi River catchments. This discharge water together with the water released from Vaal Dam is currently used to meet the irrigation and domestic water requirements of the downstream Middle and Lower Vaal River reaches.

Application of the Water Resource Planning Model (WRPM) in investigating future reconciliation and water quality management scenarios showed that excess water would start accumulating in Bloemhof Dam from 2015. This scenario is based on a continuation of the current practice of releasing sufficient water from Vaal Dam to meet the downstream water quality objectives. This excess water is available to meet the water requirements of the water users along the Lower Orange River or the water could be used directly at the source of discharges by further treating the effluent for direct re-use. The Vaal River System is also directly linked to the Crocodile River West System through the Rand Water potable water distribution network. The discharges from Tshwane and northern suburbs of Johannesburg contribute large volumes of water to the Crocodile River West catchment. The planning scenarios developed for the Crocodile River West and Marico River catchments show that there are projected short falls where a future Coal to Liquid (CTL) plant and coal fired power station at Lephalale are included in the water requirement projections. The possibility of using some of this excess water in the Vaal River System to support the Crocodile River West catchment is also a possibility.

3 WATER QUALITY ISSUES

The key water quality issues identified as part of this project were briefly described in the previous chapter of this report. The issues were grouped into salinity impacts, eutrophication impacts, microbiological impacts, RWQOs, planning, compliance, water quality monitoring and institutional aspects and are discussed in this chapter.

3.1 Salinity Impacts

The following salinity related issues were identified:-

- The management of the mine water discharges remains a challenge in the Vaal River System for the following reasons:-
  - The future water management plans of many of the mines to closure and beyond closure are not well defined.
  - The available closure funding to manage the excess mine water during the post closure era needs to be audited.
  - The water related behaviour and linkages of the Central, Eastern, Western, Far Western Rand Basins associated with the gold mines are not well understood. The management of the re-watering and potential decant of these mining basins remains an issue for the mining companies and the Department.
  - There are a number of mine water treatment and re-use initiatives taking place in the West Rand and Far West Rand and Klerksdorp-Orkney-Stilfontein-Hartebeesfontein (KOSH) area. Different treatment processes are being investigated and the potential re-use of treated mine water are being investigated. Strategic direction on the institutional, regulatory and funding mechanisms needs to be developed.
- The water quality of the Grootdraai Dam is currently acceptable. However, there are a number of operational and defunct coal mines in the catchment which need to be managed pro-actively. Estimates of the of water volumes decanting from the mines post closure is 48 million m^3/a. The post closure plans need to be finalized and implementation of the plans need to be managed.
- The salinity in the Vaal Barrage and the middle reaches of the Vaal River is currently being managed by dilution releases from Vaal Dam to maintain a TDS concentration of 600 mg/ℓ in the water leaving the Vaal Barrage. The dilution releases of water from Vaal Dam are in effect another water demand on the system and thus play a role in the date of the next Vaal River System transfer scheme. The Vaal Dam releases also influenced the extent to which excess water builds up in Bloemhof Dam. The volume of the Vaal Dam dilution releases depends on the salinity loads and volumes discharged. Thus the management strategy for the saline mine and industrial discharges play an important role in the date of the next Vaal River System augmentation scheme.
- The water quality in the Grootdraai Dam and Vaal Dam are dependent on the water quality of the water transferred into the Vaal River System. Large quantities of water are transferred from the

Lesotho Highlands Project. The water quality in the Wilge River and Vaal Dam is strongly dependent on the water quality of the transfer water. The water quality of the transfer water is currently good, however, any deterioration in quality will impact on the water quality in the Vaal River System. The recent water quality history shows that the water quality in Heyshope Dam is deteriorating, impacting on the water quality of Grootdraai Dam.

- The Ecological Reserve will be available by the early 2010. The findings in terms of Ecological Water Requirements and associated water quality could affect the strategy in terms of the RWQOs required and the volume of dilution water needed to meet the required quality and flows.

3.2 Eutrophication Impacts

The following eutrophication related issues were identified:-

- Eutrophication was confirmed in this study as one of the major water quality issues in the Vaal River System. The sources of the nutrients include irrigation return flows, urban runoff, industrial discharges and wastewater treatment works discharges. The volume of return flows from the wastewater treatment works are anticipated to increase in the future, which will further exacerbate the eutrophication impacts as the nutrient assimilative capacity of the river has been exceeded. The implementation of revised discharge standards for phosphorus will have to be investigated and implemented to stop the further deterioration and improve the eutrophication status of the Vaal River System.
- Many of the wastewater treatment works are not performing to specification in terms of nutrient removal and microbiological discharge quality. This is largely due to poor operation, maintenance and management of the wastewater treatment works and sewerage systems.
- The nutrient balance of the Vaal River System is not well understood and planning level nutrient balance models are not available to investigate the impact of changes in land use practises, discharge standards and operational management strategies to the trophic status of the Vaal River System.
- The flow regulation of the middle reaches of the Vaal River has generally resulted in lower flow rates in the river systems. This has increased the potential for algal blooms due to higher residence times, greater light penetration due to lower turbidity and higher water temperatures due to shallower water depths.

3.3 Microbiological Impacts

Many of the wastewater treatment works are not performing to their specifications and are not complying with their licensed discharge standards. The operations, maintenance and management of the sewerage systems have also deteriorated in many of the local municipalities. This has resulted in microbiological pollution of the receiving streams with resulting public health issues. The available monitoring data show that this problem is generally confined to the receiving water body in the immediate downstream vicinity of the discharge point.

3.4 Resource Water Quality Objectives

The existing RWQOs set for the Vaal River main stem and the major tributaries have gaps in the middle and lower reaches and are not integrated. In many cases, the RWQOs previously set are too stringent and not practically achievable and realistic. An integrated set of achievable RWQOs for the Vaal River main stem and the major tributaries is required. One of the objectives of this study is to set these RWQOs. The RWQOs will be used to check the performance of the water quality management strategy, determine waste discharge charges and determine licence discharge standards and conditions.

3.5 Planning aspects

The following planning issues were identified during the study:-

- The continued growth in the volumes of return flows from the wastewater treatment works will result in excess water accumulating in Bloemhof Dam from 2015. The excess water can be released from Bloemhof Dam to support the water requirements in the lower Orange River. This will deter the need for the development of new bulk water supply infrastructure in the lower Orange River. The release of the excess water from Bloemhof Dam will impact on the water quality of the lower Orange River.
- The return flows from the wastewater treatment works and the mine water discharges could be used to meet future water requirements. Several conceptual schemes for direct and indirect re-use of return flows and mine water discharges can be further developed.

3.6 Compliance aspects

The following compliance issues were identified during the study:-

- The salinity issues in the Vaal River System are largely contributed by irrigation return flows, industrial effluent and mine water discharges. The compliance of the point source discharges with licence conditions and the future water quality requirements for the discharges are to be resolved.
- The continued evaluation of the available compliance monitoring data to check compliance with RWQOs along the Vaal River main stem and major tributaries across the four WMA must now be instituted.

3.7 Water Quality Monitoring

The following water quality monitoring issues were identified:-

- The frequency of monitoring was reduced from weekly monitoring at many of the key points to monthly and even lower frequencies since 2000.
- The water quality variables measured at the key monitoring points must be reviewed.

- The acquisition, handling and management of water quality data are poor. The monitoring assessment and reporting are disaggregated, inconsistent and display data and knowledge gaps. The management and reporting of data need to be integrated and structured into a formal reporting framework to support effective management and decision making.
- Reliable and current information/data on the quantity and quality of major licensed dischargers is not readily available within the Department and in some cases from the dischargers.

3.8 Institutional aspects

The following regulatory issues were identified during the study:-

- A structure of stakeholder forums was been established in the Upper Vaal WMA and parts of the Middle Vaal WMA. The forum structure should be expanded to cover the rest of the Vaal River catchment. The structure should include an overarching structure which allows for communication across the WMAs due to their interdependency.
- Poor communication and information sharing between water users, water organisations, the Department, water boards, local government and stakeholders.

All of the above clearly indicate the need for action and a decisive strategy on a way forward for the management of the water quality in the Vaal River System.

4 ASSESSMENT OF SALINITY MANAGEMENT SCENARIOS

The assessment of salinity management scenarios formed the basis of the approach followed to arrive at the water quality management strategy. The actions and tasks followed in the assessment of the salinity management scenarios are described in the sections below. The analysis of the salinity management scenarios was done in conjunction with the reconciliation study. The water quality scenarios impact on the reconciliation situation in the catchment so the two strategies could not be analysed in isolation. A summary of the reconciliation strategy is also given in the sections below.

4.1 Summary of reconciliation strategy

The reconciliation strategy for the Vaal River System was developed in two stages. During the first stage, an initial strategy was developed which was modified after consultation with the key stakeholders to produce the second stage strategy (DWAF, 2006c). The objectives of the reconciliation strategy are:-

- Develop water requirement and return flow scenarios.
- Determine the potential for Water Conservation and Demand Management by concentrating on the main urban areas.
- Estimate the irrigation water requirements and compile possible future scenarios.
- Identify and assess potential large scale water re-use options.
- Provide an initial indication of how the implementation of the Ecological Water Requirements could influence the projected water balance situation.
- Analysis of water quality management options relating to blending, dilution and water re-use.

A combined public participation process was followed for the reconciliation and the IWQMP studies. The process followed is shown in Figure 6. The IWQMP and the reconciliation study each had their own project steering and management committees. However the two studies reported back to the public through the same stakeholder meetings.

Water requirement projections were prepared for the study area. The water requirement projections included the irrigation, industrial, power generation, water boards and the smaller towns. The following were included in the water requirement projections for the different sectors:-

- In developing the irrigation requirement projections, it was found that a substantial volume of water is being used for irrigation unlawfully. The projection of the irrigation requirement allows for the eradication of the unlawful use. No growth in the irrigation water requirements has been allowed for.
- The water requirements for power generation and the major industries were developed in consultation with the water users.

- Different scenarios were developed for the water requirement projections for Rand Water. The scenarios were a combination of high, base and low population growth scenarios coupled with a WCWDM intervention. The three water conservation and water demand interventions were:-
  - **Scenario C**: 5 Year water loss programme where water wastages are reduced through measures such as leak detection and repair. The loss management measures are maintained after the five year period. This scenario also include measures to improve the efficiency of water use and the assumption was made that a 1% saving can be gained per annum from the year 2015 onwards for the entire planning period (1% of selected large urban users that were assessed in detail).
  - **Scenario D**: Reduction in wastage over 5 years. No efficiency improvement measures were included in this scenario.
  - **Scenario E**: Reduction in wastage over 10 years, allowing for a slower implementation period of the proposed measures.
- The water requirements projections supplied by Midvaal and Sedibeng Water were used in the projection scenarios.

The water requirement projection scenarios that were used in this study for Rand Water were the high and base population growths with a 15% saving in water use due to WCWDM over 5 years (Scenario D). The irrigation projection used assumed that the majority of the unlawful irrigation will be eradicated.

The future water supply interventions that were considered were:-

- The Polihali Dam in Lesotho which forms part of Phase II of the Lesotho Highlands Water Project. This scheme can be implemented by 2019 at the earliest. Since the start of the study, the Minister of the Department announced in December 2008 that the negotiations with Lesotho would start for Phase II of the Lesotho Highlands Water Project.
- The Mielietuin and Jana Dams in the Thukela River Catchment. The Thukela schemes can also be implemented by 2019.
- If the Polihali Dam is constructed then the volume of water that would be flowing to the Orange River from Lesotho will be reduced. This will lead to water shortages in the Orange River and the Vioolsdrift Dam will be required to augment the supply to the water users in the Orange River.

The key aspects of the reconciliation strategy are given below:-

- The eradication of the unlawful water use is an essential strategy that has to be implemented in order to rectify the current deficit (negative water balance) in the Vaal River System. The legal actions and procedures that will be implemented should be designed to achieve legal precedence to protect the entitlements of lawful water users and assist in compliance monitoring and water use regulation in future.
- The continuation of current and the initiation of further WCWDM measures are essential to maintain a positive water balance in the Vaal River System over the next ten years. The potential savings that can be achieved through the reduction of water wastage will ensure the

risk of drought curtailments are reduced until such time as Phase II of the LHWP can deliver water.

- The results from the simulation analysis showed that the re-use of mine water effluent in combination with other interventions could have a significant benefit by postponing the need for further augmentation after the implementation of Phase II of the Lesotho Highlands Water Project. Given the various options and associated implication (costs of treatment as well as environmental considerations) of implementing options of re-using effluent, it is recommended that a feasibility study be commissioned to evaluate all options to compare the advantages and disadvantages with the aim of finding an optimum solution.
- The Minister of the Department of Water Affairs and Forestry and Cabinet made the decision in December 2008 that the Department should proceed with negotiations with the Government of Lesotho for the implementation of the Phase 2 of the Lesotho Highlands Water Project. These negotiations should take into consideration the findings from the Reconciliation Strategy.
- It is proposed that a Strategy Steering Committee (SSC) be established to oversee the implementation of the Reconciliation Strategy. Broadly, the function of the committee will be to continuously monitor the water balance situation of the Vaal River System and advise the responsible institutions on whether or not the objectives of the strategies are being achieved.

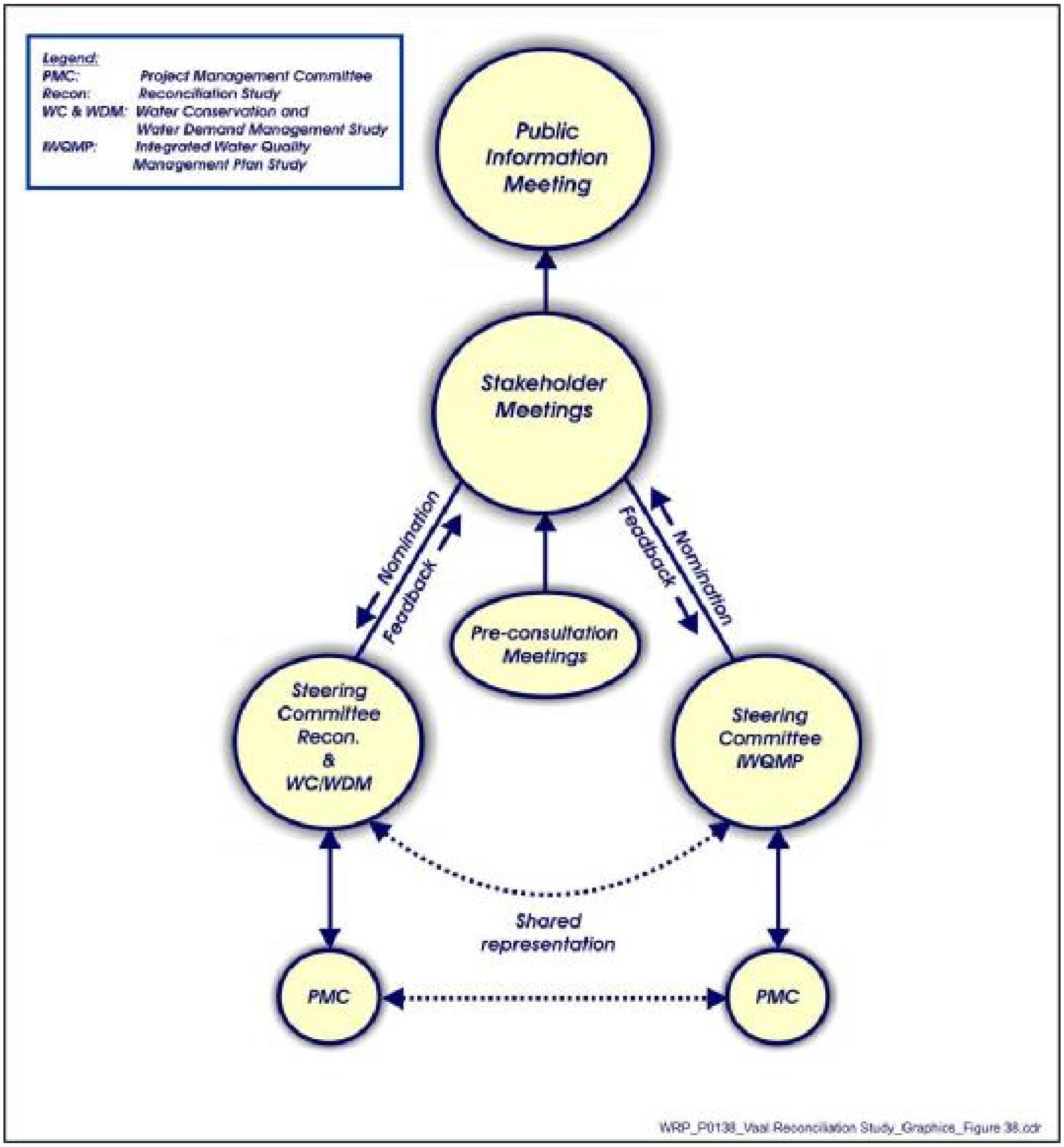

Figure 6: Schematic representation of the Stakeholder Engagement Process

4.2 Process followed in developing salinity management strategy

The following steps were followed in assessing the salinity management scenarios:-

- An initial set of RWQOs were compiled by considering the existing RWQOs, the water user requirements as given in the South African Water Quality Guidelines, the preliminary Reserve Determination results and the existing water quality status. The details of the process followed in setting the new integrated RWQOs are given in the Integrated RWQOs Report produced in **Task 4** (DWAF, 2007a).
- Salinity management scenarios were developed and tested using the WRPM to determine if the initial set of RWQOs could be achieved.

- Based on the WRPM modelling results and the economics of the scenario assessment, management strategies were developed for the short, medium and long term for the Vaal River System.
- A final set of RWQOs to be achieved on the Vaal River main stem and major tributaries in the short term, were then set. The selected RWQOs for the major tributaries were based on the modelling results and the current water quality status (this also included the considerations of user requirements and the preliminary Reserve results).

4.3 Description of management scenarios and analysis approach

The details of the analysis procedures and the assessment of the management scenarios are given in the report produced as part of **Task 6 -** Evaluation of Water Quality Management Scenarios (DWAF, 2007b). The water quality management scenarios considered in the analysis included:-

- The release of low salinity water from Vaal Dam to maintain the TDS concentration in the Vaal Barrage at a level which ensures an acceptable water quality in the middle reaches of the Vaal River. This management scenario is currently being applied with a 600 mg/ℓ TDS concentration target for the Vaal Barrage. Lower target TDS concentrations in the Barrage can also be considered. This will require the release of more water from Vaal Dam and will bring the date of the next Vaal River System augmentation scheme forward.
- The treatment of the major discharges of concentrated high salinity water from the mines and industries. This involved the conceptual level design and costing of desalination plants to treat the water to a potable standard for re-use in the Rand Water supply network. In developing the conceptual designs, accepted reverse osmosis membrane based treatment was used as the reference technology for the desalination plants.

The basic assumption for the analysis was that all the strategies assessed had to meet the reliability of supply and curtailment criteria for the Vaal River System augmentation scheme options. This implied that the scheme implementation dates and the sizes of the augmentation schemes must be able to supply the demand scenario at the required reliability of supply for all the strategies considered. The augmentation scheme included in this analysis was the Polihali Dam in Lesotho for the base case demand scenario with the addition of the Thukela River Jana and Mielietuin Dams as additional sources for the high demand scenario. The preferred Vaal River System augmentation scheme has not as yet been determined. At this stage the Polihali dam is taken as the first choice with the Thukela schemes as the second choice. The transfer of more water from Lesotho to Vaal Dam will result in shortages in the Orange River which implies the construction of augmentation infrastructure to support the Orange River water requirements. In the economic analysis undertaken, the future augmentation scheme *viz.* Vioolsdrift Dam on the Orange River was included. The excess water that accumulates in Bloemhof Dam due to the increased return flow volumes was used to supply the water requirements in the lower Orange River.

The achievement of an economically optimal solution involved determining the cost of a particular strategy and the dis-benefits in terms of the economic impact of salinity on water users. The approach adopted to evaluate the alternative scenarios is summarised in **Figure 7**.

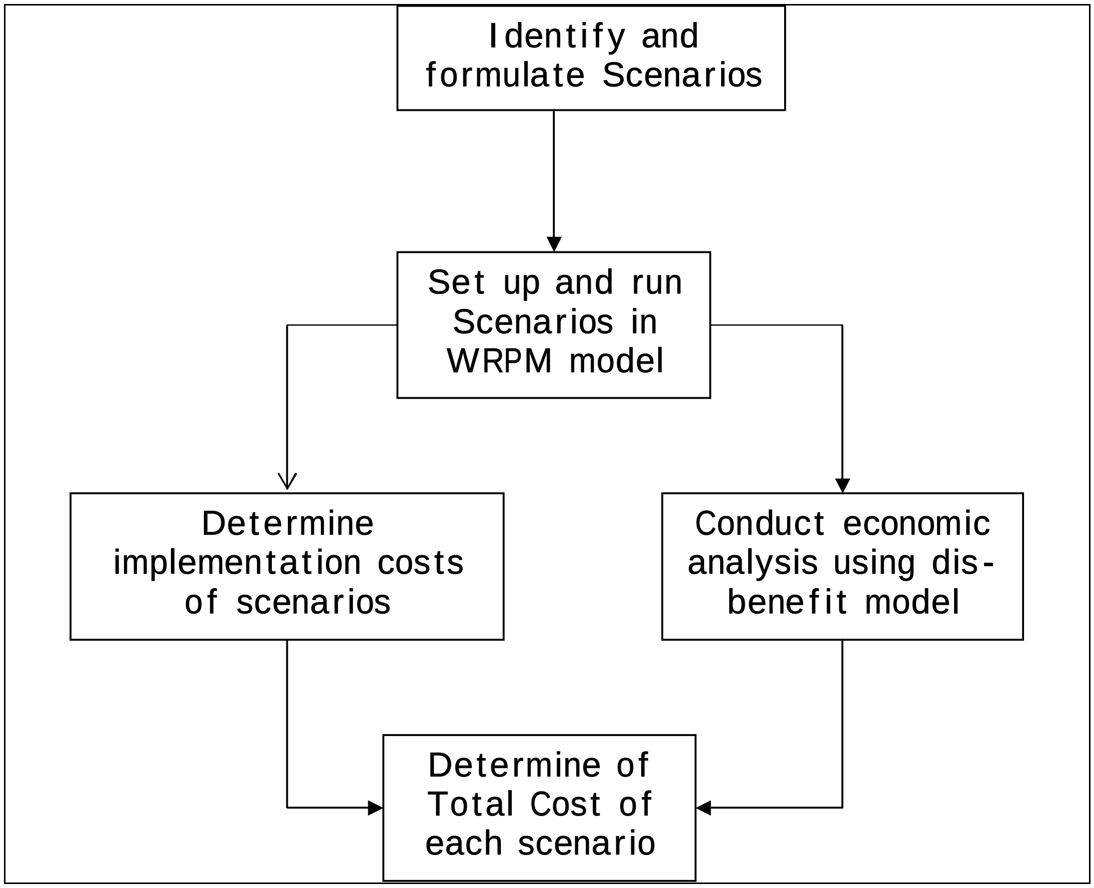

Figure 7: Graphic showing the salinity management scenario evaluation process

The approach involved the following steps:-

- Formulation of alternative scenarios for analysis. The analysis period was assumed to be from 2007 to 2040.
- Setting up the WRPM to represent the scenario. An initial run was undertaken using the WRPM to determine when the next Vaal River augmentation scheme is required, so that the reliability criteria for water supply are met. Based on the results of the initial run, the WRPM was reconfigured in terms of the augmentation scheme timing. The WRPM was run using 100 stochastic sequences. The modelled 95 percentile TDS concentrations in the different reaches of the main stem of the Vaal River and in the main tributaries were determined from the simulation model results. The WRPM was run using the 600 mg/ℓ TDS concentration target for the Vaal Barrage.
- The time series of capital expenditure (Capex) and operational expenditure (Opex) for the augmentation scheme and water quality management measures were determined. The net present values (NPV) of the cash streams over the analyses period were determined for discount rates of 6%, 8% and 10% per annum.

- The economic model of the impact of salinity on the downstream water users was applied to determine the time series of dis-benefit costs to industrial, domestic and agricultural users. The NPV of the water quality dis-benefit costs were determined, similar to the proceeding step.
- The total NPV for a scenario was then determined.
- The process was repeated for each scenario and the total NPV costs could then be compared for different scenarios to determine the most economically attractive option.

During this process, the statistical distribution of TDS concentrations were assessed along the Vaal River and compared to the RWQOs. This assessment might require further refinement to a scenario and the planning model may have to be re-run.

The salinity management scenarios analysed are listed below in **Table 2**. Initially the base water demand scenario was assessed with the higher water demand scenario added later for Scenario 1a and, Scenario 1c and Scenario 1c1 to be in line with the reconciliation strategy. Both water demand scenarios include a 15% reduction due to water conservation and demand management. More detail on the water demand projections is given in DWAF (2008a) and DWAF (2009). The analysis of the high water demand scenarios was not carried out in full in terms of water quality and in the economic analysis of the water quality dis-benefit costs were assumed to be the same as the base water demand scenario options. This is considered to be a reasonable assumption as the water quality in the middle reaches of the Vaal River is unlikely to change significantly between the base and high water demand scenarios for a particular option as the Vaal Barrage dilution concentration is kept the same for the water demand scenarios.

Table 2 : Description of salinity management scenarios analysed

Planning Scenario No.	Intervention/Augmentation Option Included	Water Quality Scenario	Purpose
1a (Base Demand)	LHFP (Polihali Dam) Orange (Vioolsdrift Dam)	No saline effluent / water treatment. Rand Water supplied from Vaal Dam. Dilution to 600 mg/ℓ TDS concentration in Vaal Barrage.	Assessment of: Current management practices. Augmentation from Polihali Dam option. Supply of excess water in Bloemhof Dam to lower Orange River.
1b (Base Demand)	LHFP (Polihali Dam) Orange (Vioolsdrift Dam)	No saline effluent / water treatment. Rand Water supplied from Vaal Dam. Dilution to 450 mg/ℓ TDS concentration in Vaal Barrage.	Augmentation from Polihali Dam option. Improved water quality along middle and lower Vaal River. Supply of excess water in Bloemhof Dam to lower Orange River.
1c (Base Demand)	LHFP (Polihali Dam). Orange (Vioolsdrift Dam) Re-use of mine water and industrial effluent discharges	Treatment of major mine water and industrial effluent discharges. Rand Water supplied from Vaal Dam. Dilution to 450 mg/ℓ in Vaal Barrage.	Evaluate impact of direct re-use of water and the removal of sources of salinity.
1c1 (Base Demand)	LHFP (Polihali Dam) Orange (Vioolsdrift Dam) Re-use of only selected mine discharges	Treatment of only selected mine water discharges. Rand Water supplied from Vaal Dam. Dilution to 450 mg/ℓ in Vaal Barrage.	Evaluate direct re-use of selected mine water discharges and the removal of sources of salinity.
3 (Base Demand)	LHFP (Polihali Dam) Orange (Vioolsdrift Dam)	No saline effluent/water treatment Rand Water supplied from Vaal Barrage. Blend RW supply to 300 mg/ℓ with water from Vaal Dam. Dilution to 600 mg/ℓ in Vaal Barrage.	Assessment of alternative source of supply for Rand Water (Alternative to Scenario 1a).
1a (High Demand)	LHFP (Polihali Dam) Thukela Jana and Mieletuin Dams Orange (Vioolsdrift Dam)	No saline effluent / water treatment. Rand Water supplied from Vaal Dam. Dilution to 600 mg/ℓ TDS concentration in Vaal Barrage.	Assessment of: Current management practices. Augmentation from Polihali Dam and Thukela Dams options. Supply of excess water in Bloemhof Dam to lower Orange River.
1c (High Demand)	LHFP (Polihali Dam) Thukela Jana Dam Orange (Vioolsdrift Dam) Re-use of mine water and industrial effluent discharges	Treatment of major mine water and industrial effluent discharges. Rand Water supplied from Vaal Dam. Dilution to 600 mg/ℓ in Vaal Barrage.	Evaluate impact of direct re-use of water and the removal of sources of salinity.
1c1	LHFP (Polihali Dam)	Treatment of only selected	Evaluate direct re-use of

Planning Scenario No.	Intervention/Augmentation Option Included	Water Quality Scenario	Purpose
(High Demand)	Thukela Jana Dam Orange (Vioolsdrift Dam)	mine water discharges. Rand Water supplied from Vaal Dam. Dilution to 600 mg/ℓ in Vaal Barrage.	selected mine water discharges and the removal of sources of salinity.

Some key information for the different scenarios analysed is summarised in **Table 3**. The required augmentation date for the next scheme for Scenario 1b is 2010. The soonest that the next augmentation scheme can practically be implemented is 2019. Scenario 1b was therefore not pursued further in the analysis. For the other scenarios, the date for the implementation of Polihali Dam was taken as the realistic implementation date of 2019 even though the dam should be delivering water earlier to achieve the required reliability of supply. The WRPM simulation results for the simulated changes in water quality (95 percentile TDS concentrations), are listed in **Table 5**.

Table 3: Summary of elements and implementation dates included in the Scenarios

Scenario	Augmentation scheme implementation	Vioolsdrift Dam	Additional water from Bloemhof Dam to Orange	Saline Water Treatment Options
1a (Base Demand)	2019 (Polihali Dam)	Not needed in planning horizon	140 million m^3/year by 2014 growing to 300 million m^3/year by 2040	None
1b (Base Demand)	2010 (Polihali Dam)	Not needed in planning horizon	-	None
1c (Base Demand)	2024 (Polihali Dam)	1 490 million m^3 Storage needed in 2015	None	Treatment of major mining / industrial discharges by 2014
1c1 (Base Demand)	2020 (Polihali Dam)	Not needed in planning horizon	140 million m^3/year by 2014 growing to 300 million m^3/year by 2040	Treatment of selected ERPM and Petrex discharges by 2014
3 (Base Demand)	2023 (Polihali Dam)	1 770 million m^3 Storage needed in 2015	None	Upgrade Rand Water works to take Vaal Barrage water by 2014
1a (High demand)	2019 Polihali 2020 Jana 2021 Mielietuin	Not needed in planning horizon	Not calculated	None
1c (High demand)	2019 (Polihali Dam)	1 490 million m^3 Storage needed in 2015	Not calculated	Treatment of major mining / industrial discharges by 2014

Scenario	Augmentation scheme implementation	Vioolsdrift Dam	Additional water from Bloemhof Dam to Orange	Saline Water Treatment Options
	2038 (Jana Dam)			
1c1 (High demand)	2019 (Polihali Dam) 2034 (Jana Dam)	Not needed in planning horizon	Not calculated	Treatment of selected ERPM and Petrex discharges by 2014

4.4 Total costs of management scenarios

To allow for an economic comparison of the scenarios, the total NPV associated with each scenario was calculated as the sum of the NPV for the water supply intervention and treatment infrastructure and the NPV of the water quality associated dis-benefits. The total NPV for each scenario are given in **Table 4**.

Table 4: Total NPV for Salinity Management Scenarios

Scenario	NPV Interventions and Treatment (million Rand)			NPV Water Quality Dis-benefits (million Rand)			Total NPV Costs (million Rand)		
	6%	8%	10%	6%	8%	10%	6%	8%	10%
1a (Base Demand)	3 585	2 998	2 536	4 087	3 597	3 194	7 627	6 595	5 730
1c (Base Demand)	19 271	14 475	11 468	3 759	3 303	2 941	23 030	17 778	14 409
1c1 (Base Demand)	8 197	6 424	5 239	3 362	2 958	2 630	11 559	9 382	7 869
3 (Base Demand)	6 833	5 303	4 275	10 754	9 332	8 201	17 587	14 635	12 476
1a (High Demand)	11 954	9 240	7 433	4 087	3 597	3 194	16 041	12 837	10 627
1c (High Demand)	23 216	17 666	14 251	3 759	3 303	2 941	26 975	20 969	17 192
1c1 (High Demand)	10 590	7 913	6 248	3 362	2 958	2 630	13 952	10 871	8 878

The results for the base and high water demand scenarios differ. For the base water demand scenario, the total NPV clearly shows that Scenario 1a is the best from a purely economic perspective with Scenario 1c1 the next best. However for the high water demand scenario, Scenario 1c1 has the lowest total NPV. This is due to the implementation of all three augmentation schemes being required over the period 2019 to 2021 so that the high water demand and the dilution water requirements can be met.

The treatment of all mine and industrial effluent discharges to potable standard is expensive and does not result in a sufficient reduction in water quality dis-benefits and delay in the augmentation date for the next scheme to offset the treatment costs.

The overall conclusions based on the economic analysis work are as follows:

- The traditional approach of implementing Vaal River Augmentation Schemes to supply water and address water quality issues is still appropriate and economically attractive.
- The treatment and re-use of selected high concentration discharge streams is an attractive scenario. The economic analysis showed that Scenario 1c1 is economically the most attractive for the high water demand scenario while the total NPV for the base water demand scenario is not significantly more expensive than Scenario 1a.
- The treatment and reclamation of selected high salinity mine waters and industrial effluents are becoming increasingly more attractive. The treatment and reclamation of all the mine and industrial effluent discharges, irrespective of size, and salinity load is not economically defensible.
- Many other water resource management policy and management considerations over and above the economic aspects, drive the implementation of the saline mine/industrial effluent reclamation schemes. Some of these include:
    - best use of local water resources.
    - application of the “polluter pays” principle.
    - reduced reliance on transferred water.
    - use of good quality water to dilute pollution.

4.5 Compliance with initial RWQOs

Although Scenario 1a and Scenario 1c1 appears to be the best from a purely economic view point, the anticipated in-stream TDS concentrations need to be compared to the RWQOs set for the Vaal main stem. The 95 percentile TDS concentrations were taken from the WRPM simulation results. The values are listed in **Table 5** together with the current status and the initial set of RWQOs based on water user requirements. The results of the model runs were not included in the deliberations on setting new RWQOs.

The WRPM simulation results show that the RWQO set for the catchments upstream of Grootdraai Dam and Vaal Dam are met, except for the reach from Waterval to Vaal Dam where the modelled TDS concentration of 264 mg/ℓ exceeds the RWQO of 200 mg/ℓ. The RWQO is governed by the preliminary determination of the Ecological Reserve water quality requirements of 200 mg/ℓ. The main water users in this reach are irrigation and domestic and the RWQO was relaxed to 250 mg/ℓ which meets the Target Water Quality Range (TWQR) for domestic and irrigation. This revised RWQO will be taken into the Ecological Reserve process for possible re-assessment.

The WRPM model simulation results show that Scenario 1c and 1c1 were the scenarios which come closest to meeting the initial set of RWQOs set for the reaches from Vaal Barrage to Douglas Barrage. *i.e.* the water users in the middle reaches of the Vaal River were incurring economic dis-benefits due to salinity. Scenario 1a is also economically attractive and is also easily implementable in the short term.

Scenarios 1c and 1c1 are attractive from the perspective of improving salinity levels in the middle Vaal down to Bloemhof Dam. Even the treatment and reclamation of only selected large saline mine water discharges produces a significant benefit in terms of salinity reductions in the Vaal Barrage and the middle Vaal.

The salinity levels in the lowest Vaal River reach are relatively insensitive to the different management scenarios, but largely dictated by the salinity loads from the Harts River.

However, before any specific scenario can be proposed, the public health and Ecological Reserve should be considered by comparing the in-stream TDS concentration to the water user requirements. The TWQR for domestic use in terms of TDS concentration is <450 mg/ℓ and the acceptable range is from 450 mg/ℓ to 1 000 mg/ℓ. The 95 percentile TDS concentrations along the middle and lower reaches of the Vaal River fall in the acceptable range for domestic use. The risk to public health can be considered to be low, if Scenario 1a or Scenario 1c1 is implemented and the Vaal River main stem is managed to meet the 95 percentile concentrations given in **Table 5**. The ecological water requirements would have to be considered once the Reserve determination for the Vaal River is completed.

4.6 Accumulation of excess water in Vaal River System

The WRPM runs shows that there is an accumulation of water in the Vaal River System due to the increasing return flow volumes. The modelled growth in the total excess water before the possible transfer to the Crocodile West catchment is shown in **Figure 8** for the high water demand scenario with 15% water conservation and water demand management savings and the Scenario 1a dilution rule. The plot shows that the excess water starts accumulating in 2014 and reaches a significant volume of about 450 million m^3/a by 2040. The use of this excess water volume to meet future water requirements in the Vaal River, Orange River and Crocodile West River needs to be determined. The management strategy for the use of the excess water will involve investigations into treatment, funding and institutional arrangements as well as water quality modelling if the excess water is to be used to support the water requirements of the lower Orange River. A preliminary cost assessment of transferring water from the Johannesburg Water wastewater treatment plants in the Klip River to the Crocodile West catchment to meet the shortfall in the catchment was undertaken. The Unit Reference Values (URV) for transfers of 30, 70 and 140 million m^3/a are given in **Table 6**.

Table 5: Summary of simulated 95 percentile TDS concentrations (mg/ℓ) in Vaal River for different Management Scenarios

River Reach	1a	1b	1c	1c1	3	Current Status Quo	Initial Set of RWQO
Douglas Barrage to Harts	883	828	772	858	958	961	600
Bloemhof Dam to Harts (Vaal Harts weir)	752	584	628	642	717	601	600
Bloemhof Dam	724	581	601	614	691	612	600
Sedibeng off take	763	558	621	623	1 154	742	450
Midvaal off take	612	507	482	484	640	670	450
Vaal Barrage	657	593	487	488	638	647	450
Vaal Dam	116	116	116	116	116	189	125
Waterval to Vaal Dam	264	264	264	264	264	413	250
Grootdraai Dam	174	174	174	174	174	200	180

Table 6: Summary of URV for transfers of wastewater treatment plant effluent to the Crocodile West catchment

Transfer volume (million m^3/a)	30	70	140
URV (R/m^3)	2.61	1.88	1.37

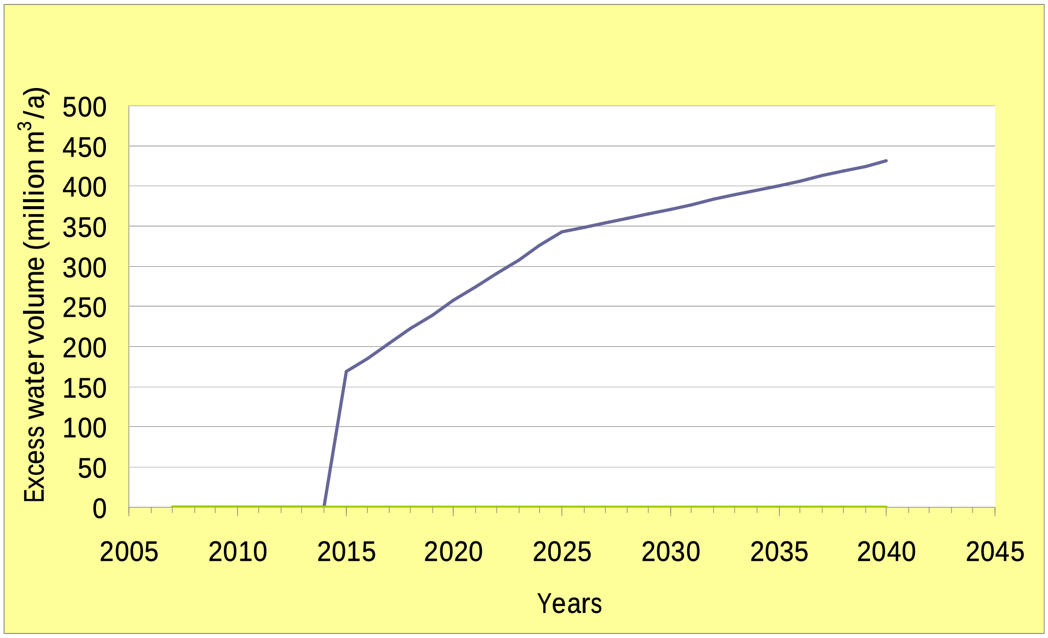

Figure 8 : Plot of growth in total excess water in the Vaal River System

4.7 Conclusions and recommendations from scenario analysis

The following conclusions and recommendations can be drawn from scenario analysis:-

- The dilution Scenario 1a is the lowest total cost option for the base water demand scenario and Scenario 1c1 for the high water demand scenario.
- Scenario 1a, however does not meet the initial set of RWQOs and the water users in the Middle Vaal incur significant dis-benefits due to salinity. The implementation of Scenario 1a requires the construction of the next Vaal River System augmentation scheme as soon as possible. The date of 2019 is the first practical date that the Polihali Dam can be implemented.
- For the base water demand scenario, Scenario 1c1 is the next best scenario from a total cost perspective. The total cost of this Scenario is not significantly more expensive than Scenario 1a, but achieves a significant improvement in the in-stream TDS concentrations. The simulated 95 percentile TDS concentrations are more in line with the initial set of RWQOs for TDS. The implementation of Scenario 1c1 will also delay the need for the next Vaal River System augmentation scheme until 2020.
- The desalination costs to treat all the major mine water and industrial effluent discharge streams remain prohibitively expensive, when compared to the economic benefits of treating and re-using these streams. The desalination costs are based on proven reverse osmosis membrane

technology. A number of mines are investigating alternative treatment technologies and waste management methods. The results of these investigations could impact on the treatment costs and hence the treatment scenarios 1c and 1c1 would become more attractive in future.

- The implementation date of the next Vaal River System augmentation scheme is significantly influenced by the treatment and reclamation of the saline mine water discharges. The implementation date for the next scheme can be shifted by up to 6 years depending on which mine water treatment and reclamation scheme is implemented.
- The accuracy of and confidence in of the simulation results presented in this study depends on the accuracy and quality of the inputs to the WRPM. Critical inputs were the current and future mine water and industrial effluent discharge volumes and qualities. During this study, the information provided by some of the mines was not always supported by a reliable database of measured data. There is still uncertainty on the management of mine water after closure of the mines.
- Although the Vaal River System modelling shows that acceptable salinity profiles on the main stem of the Vaal River are achievable, local water quality impacts on the receiving streams may still not be acceptable.
- The consideration of Vaal River System economics and water quality modelling did not include the Orange River. The deterioration in the water quality of the lower reaches of the Orange River below the Vaal confluence due to releases of excess water from Bloemhof Dam and the impacts of these releases on the lower Orange River water users were not considered in the analysis. Thus these considerations would have to be included before a final decision on the preferred management option is made.
- The WRPM simulations show that excess water volume starts accumulating in Bloemhof Dam from about 2014. The dilution releases and return flows are used to meet the increasing water requirements of the middle and lower Vaal River water users, up until 2014.

5 WATER QUALITY MANAGEMENT STRATEGY

5.1 Introduction

The proposed WQM strategy for the Vaal River System has the following key objectives:-

- Maintaining or improving the water quality of the water resources for all users and beneficial uses (within the economic drivers and considerations that are practical and cost-effective).
- Managing the water resources to the integrated RWQO management targets that have been developed, at a desired level of protection and sustainability.
- Managing and progressively improving the salinity and eutrophication levels in the Vaal River and major tributaries as the key water quality issues identified.
- Improving source management controls and measures as a means to limit and control point sources that significantly impact on the system water resources.
- Improving management of the water resources of the system by more effective monitoring, assessment and reporting.

The summarised strategies for the management of salinity, eutrophication (nutrients) and microbiological water quality are presented in the sections below. The strategies are divided into feasibility and planning work, infrastructure projects and operational actions. An implementation program was developed with a time frame for the actions listed.

5.2 Salinity Management Strategy

5.2.1 Description of salinity strategy

The strategy for the management of salinity is summarised as follows:-

- The current salinity status in the Vaal Dam and Grootdraai Dam Catchments should be maintained. This will involve careful and diligent management of the upstream mining activities in particular post closure.
- The short term strategy for the middle reaches from Vaal Barrage to Bloemhof Dam is to implement **Scenario 1a**, *i.e.* the release of dilution water from Vaal Dam to dilute the outflow from the Vaal Barrage to 600 mg/ℓ. The implementation of this scenario does not meet the initial set of RWQOs set for the Vaal River main stem, but does result in an improvement in the water quality in the middle reaches of the Vaal River. The water users will incur economic dis-benefits due to the salinity levels and a waste discharge charge should be used to compensate for these dis-benefits.
- The medium to long term management strategy is to implement **Scenario 1c1**. Saline mine water streams will be selected for treatment and reclamation. This will have a direct benefit in reducing salinity in the Vaal Barrage and middle Vaal River.

- The release of Vaal Dam dilution water is feasible until 2014, after which excess water will accumulate in Bloemhof Dam. By 2014, a plan to use the excess water needs to have been developed. The plan could be to support the lower Orange from Bloemhof Dam, transfer to the Crocodile West catchment or treat and re-use in the Vaal River System. The use of the excess water, which includes the saline mine water streams should be the subject of a feasibility study.
- The short term RWQOs for the Vaal River main stem and for the tributaries should be established and compliance monitoring reported against the RWQOs. The proposed RWQOs for TDS are given in **Section 5.2.2**. The tributary catchments must be managed to meet the RWQOs established at the downstream point of the catchment.
- The current water quality monitoring programme must be expanded, according to the monitoring programme developed and detailed in the **Task 7 Report** (DWAF, 2008b) produced as part of the study.
- The planning and engineering design of the next Vaal River System augmentation scheme should be completed. The water quality of the water proposed for transfer should be considered in the final selection of the augmentation scheme.
- The impact of the salinity management strategy selected for the Vaal River on the Orange River must be investigated. Before a final decision is made, consideration must be given to the water quality impact on the Lower Orange River of the preferred management option and the RWQOs established. The impact of the releases to support the Lower Orange River reaches on water quality need to be investigated as well as the impact of the next augmentation scheme.

5.2.2 RWQOs for salinity

The basis to the WQM strategy for the Vaal River System is an integrated set of RWQOs that are achievable, aligned to the system behaviour and prevent further deterioration of water quality. Through a consultative and iterative process based on modelling of system behaviour, user requirements and the preliminary results of the water quality Reserve study, the proposed set of TDS RWQOs is given in **Table 7** for the river reaches of the main Vaal River stem and the major tributaries. The values are also shown as plotted on maps of the study area in **Figure 9** and **Figure 10**. The RWQO TDS concentrations correspond to 95 percentile values, which means that the proposed RWQOs must be complied with 95 percent of the time. The RWQO for the major tributaries was set based on the current water quality status, the modelled 95 percentile TDS concentration and the existing RWQO and Reserve (if available) set for the tributaries. These were discussed with the Regional Offices of the Department to select the final values.

Table 7 : Proposed TDS RWQOs for the Vaal River System for the short term

No	River Reach	Status Quo (95th %tile)	Initial set of RWQO	Proposed RWQO for short term	TDS RWQO: Tributaries
1	Vaal River u/s Klein Vaal to origin of Vaal River	159 mg/ℓ (average)	150 mg/ℓ	100 mg/ℓ	Klein Vaal: 100 mg/ℓ Witpuntspruit: 100 mg/ℓ
2	Vaal River u/s and d/s of Rietspruit	144 mg/ℓ	150 mg/ℓ	150 mg/ℓ	Rietspruit: 100 mg/ℓ
3	Vaal River d/s Rietspruit u/s Blesbokspruit	313 mg/ℓ	150 mg/ℓ	150 mg/ℓ	no tributary
4	Vaal River d/s Blesbokspruit to Grootdraai Dam	256 mg/ℓ	180 mg/ℓ	180 mg/ℓ	Leeuspruit: 400 mg/ℓ Blesbokspruit: 400 mg/ℓ
5	D/S Grootdraai Dam to u/s Waterval confluence	200 mg/ℓ	200 mg/ℓ	200 mg/ℓ	Klip River: 200 mg/ℓ
6	Vaal River Downstream Waterval Confluence to inflow Vaal Dam	413 mg/ℓ	200 mg/ℓ	250 mg/ℓ	Waterval River 450mg/ℓ
7	Vaal Dam to Lethabo weir	198 mg/ℓ	180 mg/ℓ	125 mg/ℓ	Wilge River: 110 mg/ℓ
8	Vaal River d/s Lethabo weir to Vaal Barrage	647 mg/ℓ	450 mg/ℓ	600 mg/ℓ	Klip: 600mg/ℓ Suikerbos: 650mg/ℓ; Leeuspruit: 455mg/ℓ; Taaibosspruit: 390mg/ℓ; Rietspruit: 550mg/ℓ; Kromelmboog: 195mg/ℓ
9	Vaal River d/s Vaal Barrage u/s Mooi confluence	647 mg/ℓ	450 mg/ℓ	600 mg/ℓ	no tributary
10	Vaal River d/s Mooi confluence to Vals River confluence	673 mg/ℓ	450 mg/ℓ	600 mg/ℓ	Schoonspruit: 800 mg/ℓ Koekemoer: 800mg/ℓ Renoster: 200 mg/ℓ Mooi: 450 mg/ℓ
11	Vaal River d/s Vals confluence to Sandspruit confluence	807 mg/ℓ	450 mg/ℓ	750 mg/ℓ	Vals River: 700 mg/ℓ
12	Makwassiespruit to Bloemhof Dam	807 mg/ℓ	600 mg/ℓ	750 mg/ℓ	Vet River: 660 mg/ℓ
13	Vaal River d/s Bloemhof Dam and u/s Harts confluence	601 mg/ℓ	600 mg/ℓ	750 mg/ℓ	no tributary
14	Vaal River downstream Harts River confluence to Douglas Barrage	961 mg/ℓ	600 mg/ℓ	800 mg/ℓ	Harts River: 1500 mg/ℓ Riet River: 800 mg/ℓ

5.2.3 Implementation Actions

Planning and feasibility work

Pilot waste discharge charge system: The waste discharge charge system (WDCS) is an important component of the water quality management strategy. The charge is proposed to compensate the middle Vaal water users and will be used to implement mitigate measures to treat the selected saline streams. Progress has been made in formulating the waste discharge charge system. The system was planned to be piloted on the Vaal River System by the Department. The pilot WDCS study still needs to take place to confirm the practical and fair implementation of the system in the Vaal River. This study needs to take place urgently.

Feasibility study on use of excess water in the system: A feasibility study is required to determine the management strategy for the excess water in the system resulting from the increased return flows. This study will determine how the excess water is best utilised. This study will investigate transfers to the Crocodile River West catchment, treatment and reclamation of mine and industrial effluents and support to the lower Orange River. The study will incorporate mine planning, the latest treatment technologies, design, costing, institutional and funding mechanisms for the schemes.

Augmentation Scheme: The necessary studies should be undertaken to select the next Vaal River System augmentation scheme. Once the scheme has been selected, the engineering work should be completed so that the scheme is ready for implementation, once confirmation on the augmentation date is available.

Infrastructure projects

Implementation of projects resulting from excess water feasibility study: The projects resulting from the excess water feasibility study will need to be implemented. The projects could include the construction of desalination plants and bulk water supply infrastructure for treatment and reclamation of mine and industrial effluents and transferring excess water for use to the Crocodile River West catchment.

Operational aspects

Continued dilution releases from Vaal Dam: The short term strategy as per Scenario 1a, should be implemented ***i.e.*** the releases of dilution water should continue to be made from Vaal Dam to maintain the outflow from the Vaal Barrage at less than 600 mg/ℓ.

Acceptance and implementation of RWQOs: The set of RWQOs that are proposed in this study for the main stem of the Vaal River and the major tributaries need to be accepted by the Forums and stakeholders, and then implemented. Compliance reporting must be done against the agreed RWQO and progress of the implementation of the short term strategy measured against the RWQO. The tributary catchments must be managed to meet the RWQOs established at the downstream point of the catchment. The proposed RWQOs for reach 14 (Vaal River downstream Harts River confluence to Douglas Barrage) must also aligned to meet the requirements of the Orange River water quality.

Upgrade of monitoring system: The improved water resource monitoring programme requires the installation of continuous monitoring equipment at key stations in the system as well as expanding the current grab sampling programme. This programme needs to be implemented as soon as possible. The monitoring programme has been developed to include compliance monitoring so that the effectiveness of the short term strategy can be evaluated.

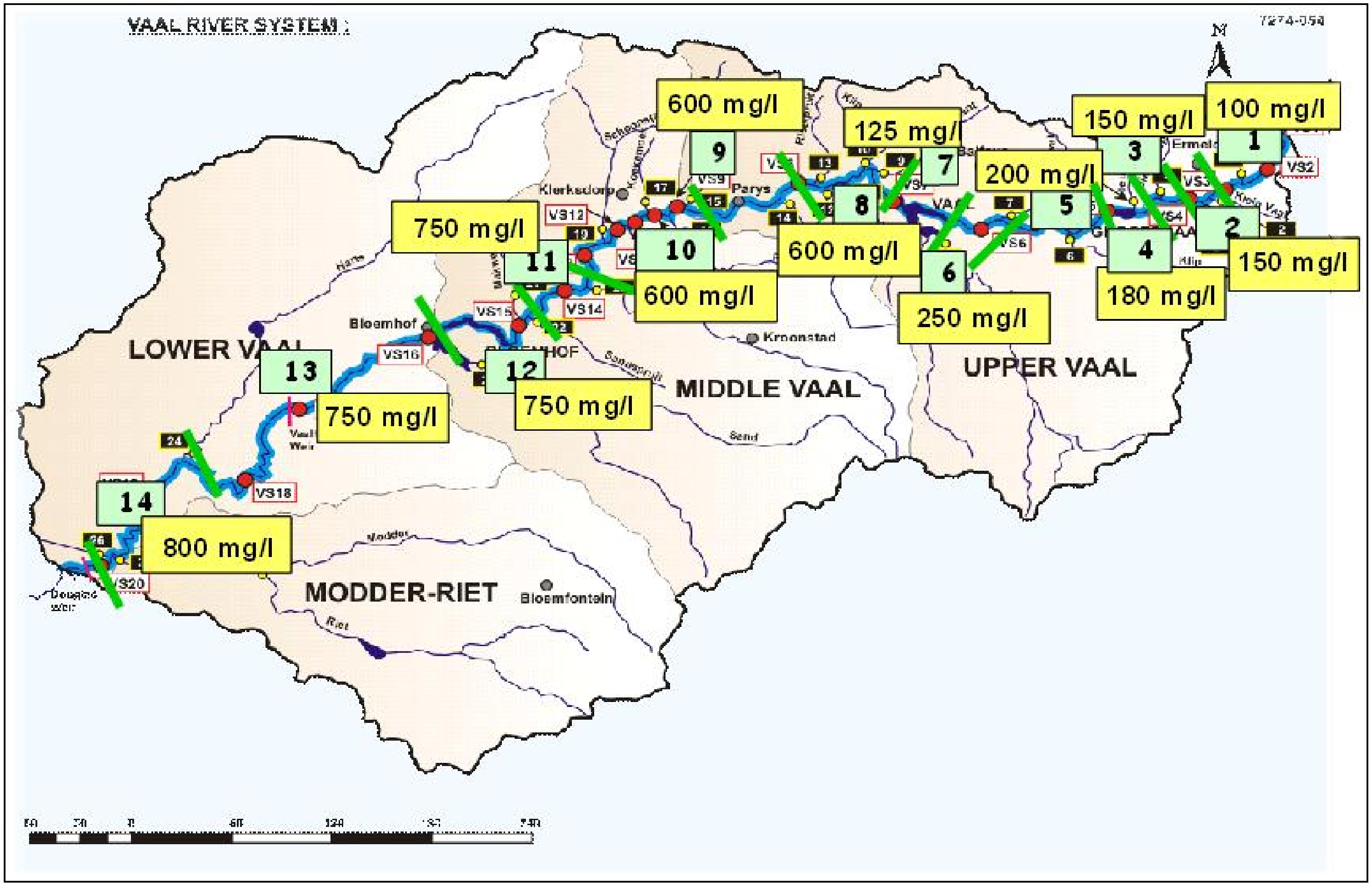

Figure 9: RWQOs for TDS for the Vaal River main stem (95 percentile concentration values)

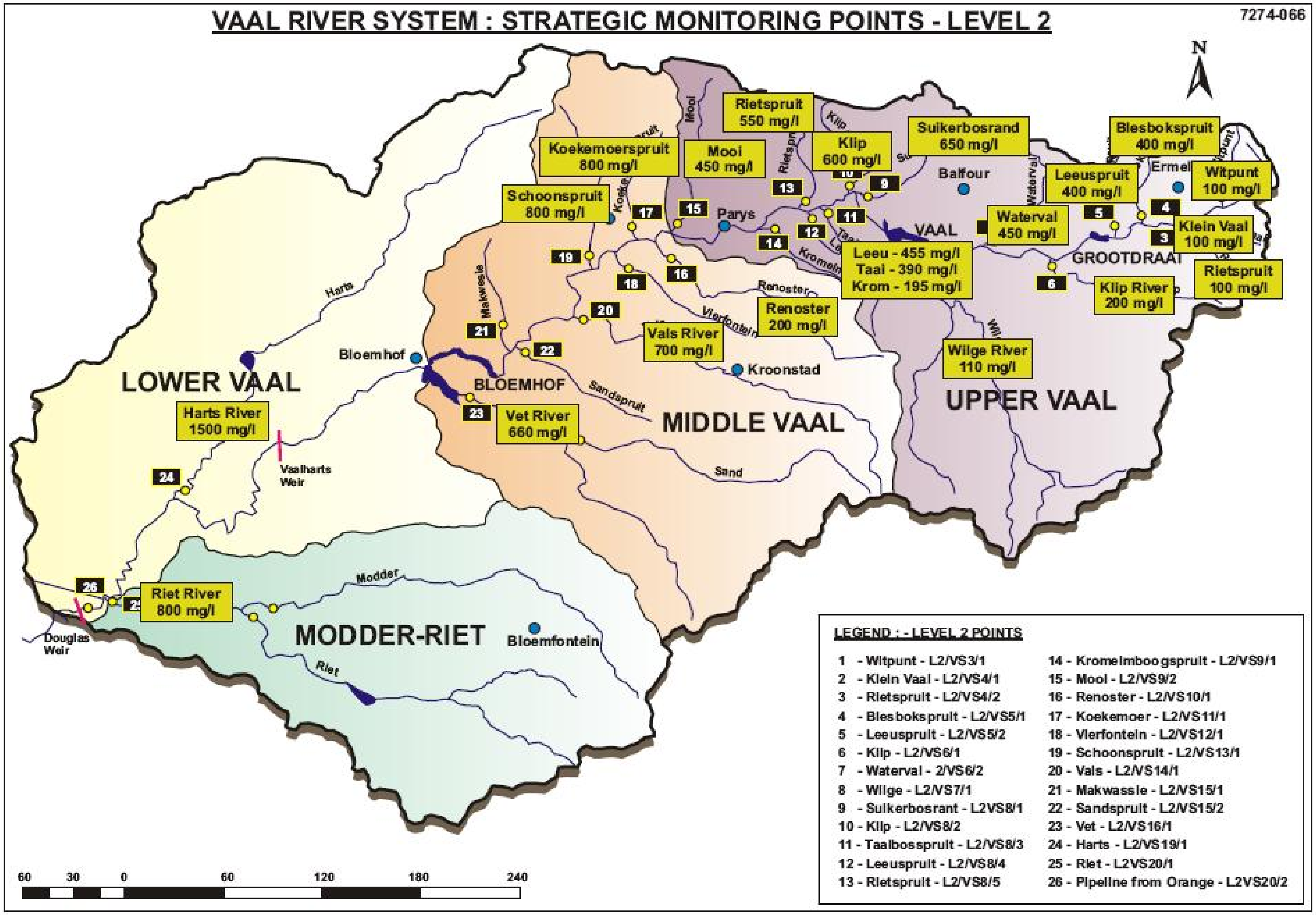

Figure 10: RWQOs for TDS for the tributaries of the Vaal River (95 percentile concentration values)

Licensing: The Department must continue with licensing, the development of Integrated Waste and Water Management Plans and participation in EIA/EMP processes. This will ensure that the various strategies of the Department are implemented and the Department has influence and leverage in water management of mines and industries. The proposed set of RWQOs can be used in setting up the licence conditions for discharges.

Implementation of waste discharge charge system: The findings of the pilot project on the Vaal River System must be implemented on a permanent basis.

Ecological Water Requirements: The Reserve proposed for the Vaal River, once its determination is completed, must be implemented and the WQM strategies must be adapted to accommodate the ecological water requirements and water quality ecological specifications.

5.3 Nutrient Management Strategy

5.3.1 Description of nutrient management strategy

The strategy for the nutrient management is summarised as follows:-

- The Waterval Catchment Management Strategy developed by the Department which includes the improved management of the wastewater treatment works to meet the phosphorus RWQO set for the Waterval River should be implemented. This will reduce the nutrient loads reporting to Vaal Dam and should protect the trophic status of Vaal Dam.
- Flow manipulation along the Middle Vaal during the months of September through October will be used to manage the risk of algal blooms in the middle reaches of the Vaal River from Vaal Barrage to Bloemhof Dam in the short term. The Vaal Dam release will be piloted, the impacts monitored and the release protocols documented. This will involve the release of water from the Vaal Barrage (augmented from Vaal Dam) to reduce residence times and improve mixing. The initial release proposed is:-
    - Base flow 15 m^3/s for 28 days - giving a total release volume of 36.3 million m^3
    - 100 m^3/s for 48 hours - giving a total release volume of 17.3 million m^3

  Total of 53.6 million m^3 will be released during the annual flow manipulation programme.

  The flow manipulation recommended will be considered with the Reserve scenarios to ensure the alignment to the ecological water requirements.
- Phosphorus has been selected as the limiting nutrient for the management of eutrophication. A set of RWQOs for phosphorus was developed for the main stem of the Vaal River. The proposed RWQOs are based on an analysis of the available nutrient and algal database.
- The operations and maintenance (O&M) of many of the wastewater treatment works are poor and poor quality effluents are discharged. In many cases, the treatment plants are not able to

handle the hydraulic or the organic loads. As a result, the installed treatment technology is not always working to specification. An audit of the wastewater treatment works, especially draining to the Vaal Barrage, is required to determine the works that are not working to specification and develop a programme to retrofit and upgrade these works. It is essential to address the issue of insufficient O&M resources in this process.

- The medium to long term strategy will be the further management of phosphorus by reducing the load discharged from point sources. A better understanding of the nutrient balance in the Vaal Barrage and the Vaal River main stem from the Vaal Barrage to Bloemhof Dam is required, before revised discharge standards can be set. A nutrient balance study is therefore proposed which will result in a better understanding of the sources and fate of nutrients (phosphorus and nitrogen) and will provide the rationale for revising the current 1 mg/ℓ phosphorus discharge standard.
- A perspective is needed on the extent and costs of the measures needed (such as banning phosphorus containing detergents) to reduce the phosphorus loads received at the wastewater treatment works.
- The results of the current Water Research Commission project aimed at developing a perspective on the economics of eutrophication on the water users. This should include recreational impacts as well as water treatment costs.

5.3.2 RWQO for phosphorus

The RWQOs set for total phosphorus are listed in **Table 8** and shown in **Figure 11**. The RWQOs are expressed as average concentrations, *i.e.* the average measured total phosphorus concentration must be equal or less than the RWQO if the trophic status of the Vaal River is to improve.

Table 8 : RWQOs for Total Phosphorus as P

No	Reach	Current status (Mean ug/ℓ TP)	RWQO SET
1-7	Vaal River, Headwaters to Vaal Dam	75	50 ug/ℓ
8-9	Vaal River d/s Lethabo weir to u/s Mooi confluence	400	150 ug/ℓ
10-11	Vaal River d/s Mooi confluence to Sandspruit confluence	250	100 ug/ℓ
12-14	Vaal River, Bloemhof Dam to Douglas Douglas Barrage	70	30 ug/ℓ

5.3.3 Management Actions

Planning and Feasibility Studies

Flow manipulation: The flow manipulation must be piloted to determine its effectiveness in controlling algal blooms. The pilot will be used to develop the management protocols for the releases to be applied in the short term to manage the trophic conditions in the middle reaches of the Vaal River.

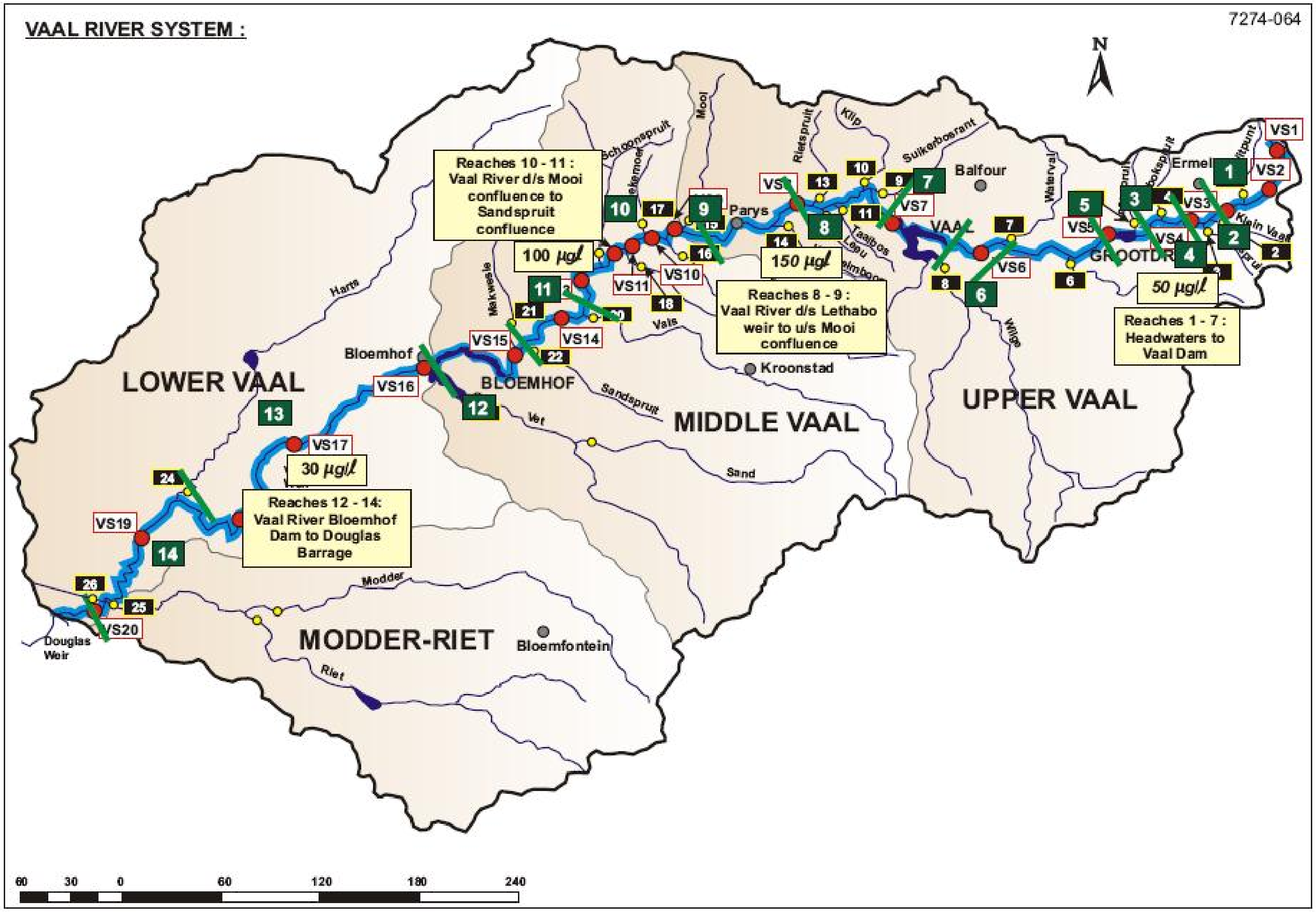

Figure 11: RWQOs for Total phosphorus for the Vaal River

Perspective on costs of phosphorus polishing: The further removal of phosphorus from the wastewater and industrial treatment works discharges will probably use chemical phosphorus removal as an additional polishing step in the treatment train. The implications on wastewater treatment costs must be quantified and placed in perspective of total treatment cost. Therefore, a study to investigate the feasibility of installing further phosphorus removal treatment steps at selected works in the Vaal River System is proposed.

Audit wastewater treatment works: The wastewater treatment works identified by the Department's Regional Offices that are not reliably meeting licence conditions and are not functioning to specification should be listed. The works should be audited, repairs and retrofitting required determined and a program agreed with the local municipalities to implement the work. Specific attention must be paid to providing adequate and appropriate operations and maintenance resources to these works.

Development of phosphorus reduction programme: The necessary monitoring to better understand the nutrient balance must be implemented as part of the Vaal River monitoring program. The data collected should be used to better understand the nutrient balance and should be used to set up a planning level model for phosphorus. The idea being to apply the model to develop a nutrient management strategy and to determine the appropriate phosphorus discharge standard. The economics of eutrophication will also be considered in setting of the discharge standard. The results will be used to develop a phosphorus reduction programme which will result in achieving the RWQO for phosphorus. The use of phosphorus free soaps and detergents will also be considered as part of the programme.

Infrastructure projects

Upgrade and retrofit wastewater treatment works: The wastewater treatment plant upgrades and retrofitting planned during the planning and feasibility study must be implemented as a matter of priority.

Implementation of phosphorus reduction program: The projects to achieve the required reduction in phosphorus must be implemented after the completion of the phosphorus reduction project. The major projects will be the polishing treatment at wastewater treatment works to remove phosphorus.

Operational actions

Flow manipulation: The protocols for the flow manipulation releases will be implemented as part of the ongoing operating rules for the Vaal River System.

Acceptance and implementation of RWQO: The phosphorus RWQOs that are proposed in this study for the main stem of the Vaal River and the major tributaries need to be accepted by the Forums and stakeholders, and then implemented. Compliance reporting must be done against the agreed RWQO and progress of the implementation of the short term strategy measured against the

RWQO. The tributary catchments must be managed to meet the RWQO established at the downstream point of the catchment.

Licensing: The Department must continue to use licensing as the tool to achieve the RWQOs set for the Vaal River main stem. The licence conditions will also be drawn from the phosphorus reduction programme.

5.4 Microbiological quality management strategy

5.4.1 Description of microbiological strategy

The strategy for improving the microbiological water quality is related to getting the wastewater treatment works operating to their specifications and meeting their licence conditions specifically in terms of discharge quality. The strategy is similar to the nutrient management strategy in that the wastewater treatment works must be audited and the “hot spot” areas identified. Plans must be developed in consultation with the local municipalities to retrofit the works in these target areas.

5.4.2 RWQO for microbiology

E. coli has been used as the indicator of microbiological pollution. The full contact recreation guideline of 300 counts/100 ml is proposed as the proposed RWQO for the entire length of the Vaal main stem as shown in **Figure 12** . The proposed RWQO is a 95 percentile value, in that the measured *E. coli* counts must be less than the RWQO for 95 percent of the time.

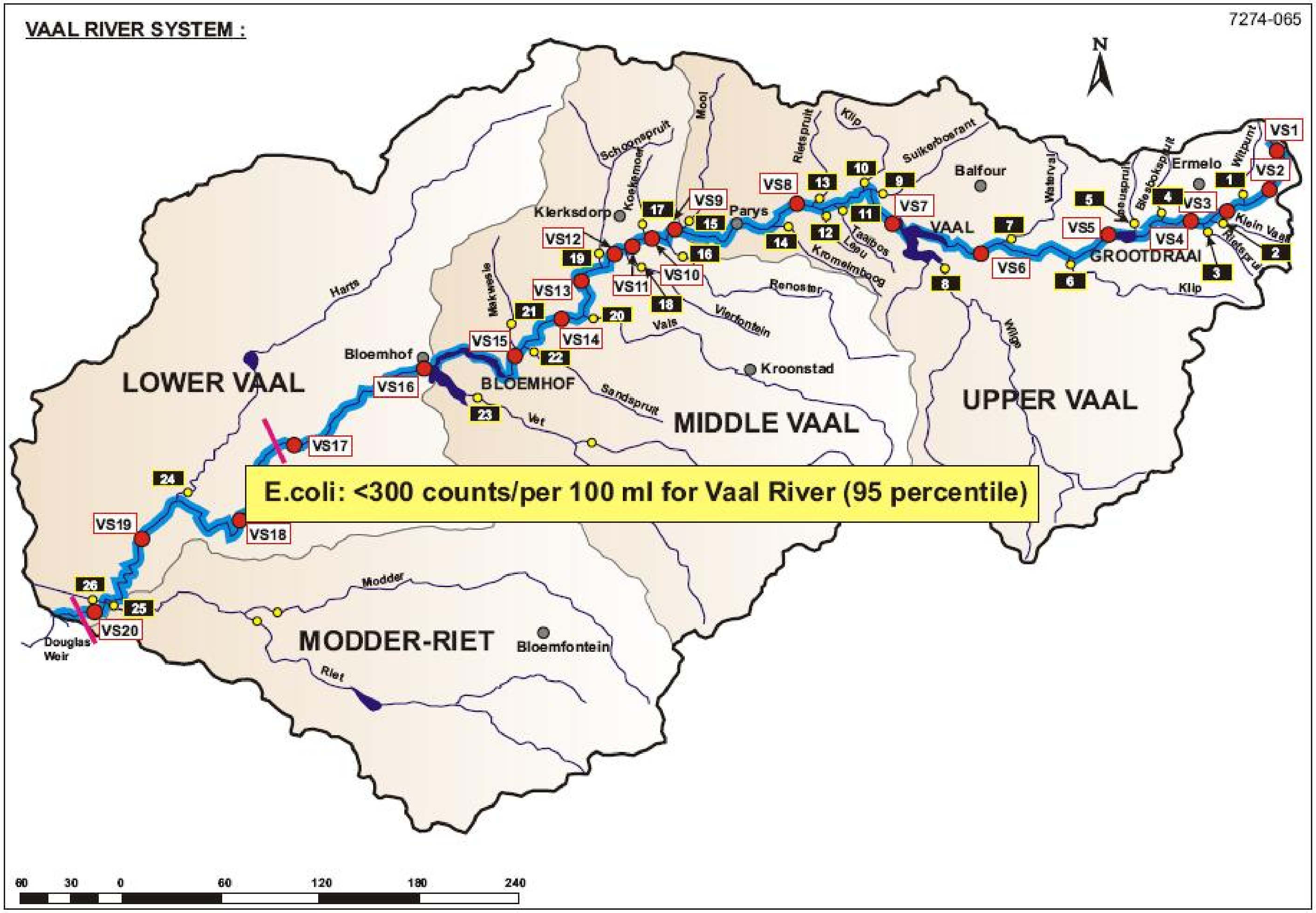

Figure 12: RWQO for *E.coli* for the Vaal River

5.4.3 Management Actions

The proposed management actions are similar to the nutrient strategy. The auditing, development and retrofitting of the wastewater treatment works should be undertaken as part of the same process recommended for the plants assessment and retrofitting aimed at phosphorus removal.

5.5 Institutional Actions

The implementation of this WQM strategy will have to be aligned to the institutional development process of the Department and the requirements of the National Water Act. As Catchment Management Agencies for the Vaal River, WMAs are in progressive stages of establishment. The individual CMSs development is in different phases and the continued evolution of the institutional arrangements must be monitored to ensure that the actions of this strategy are included in catchment management planning; resource management priorities and regional economic development strategies.

In implementing this strategy, the Department will specifically have to consider the role of the catchment committees/organisations and the extent to which they can take responsibility and accountability for specific actions. These organisations could play key roles in communication, co-ordination and providing capacity where necessary.

The role of local government is critical to the success of this strategy. This relates primarily to the management of the discharges of wastewater treatment works. A specific agreement or institutional arrangement has to be entered into between the Department and local government regarding this issue. The problem of non-compliant wastewater treatment works cannot be accepted as a “business as usual” anymore.

A strategy steering committee is to be established to oversee the further development and implementation of the reconciliation and the water quality management strategies. The details and proposed functions of the strategy steering committee are discussed under implementation. In association with the strategy steering committee the timeframes associated with implementation actions will be specified by the Department (***i.e.*** the decision on the management actions, the final RWQOs adopted, the implementation of the RWQOs, etc.).

6 PRINCIPLES UNDERPINNING THE WATER QUALITY MANAGEMENT STRATEGY

The objective of managing the quantity, quality and reliability of South Africa's water resources is to achieve optimum long term, environmentally sustainable, social and economic benefits for society from their use' (DWAF, 1997).

The following principles are seen as the basis to achieve the above objective in the Vaal River System.

6.1 Accountability

'The National Government is the custodian of the nation's water resources, as an indivisible national asset. Guided by its duty to promote the public trust, National Government acting through the Minister of Water Affairs and Forestry and the Department has ultimate responsibility for, and authority over, water resource management, the equitable allocation and usage of water and the transfer of water between catchments and international water matters' (DWAF, 1997).

In line with the above principle underpinning the NWA, the Department is accountable for implementation of this strategy, – that is to ensure sustainable and equitable water resources use of the Vaal River System.

6.2 Commitment

Commitment to this strategy is required from the Department Directorates, Regions, other government departments, water users and key stakeholder organisations for implementation to be successful and achievable. This has been developed through a lengthy process of informed consultation and discussion. The strategy forms a comprehensive, strategic, and integrated approach to the major challenging water quality issues facing the Vaal River System. The various role players and key stakeholders need to endorse this strategy and commit to the need for action, if any improvements in water quality are to be realised.

6.3 Responsibility

'Responsibility for the development and management of available water resources shall where possible and appropriate be delegated to a catchment or regional level in such a manner to enable interested parties to participate' (DWAF, 1997)

This strategy commits the Department as the mandated authority and identified role players to accept shared responsibility to ensure that the objectives and actions of this strategy are implemented and achieved. Management of the system needs to become a responsibility of all role players and in making this commitment each party shares the responsibility for making a contribution to meeting the defined objectives and implementation actions.

6.4 Shared resources

While the Department represents the water users and society as a whole in the Vaal River System, it cannot address all the water quality problems facing the catchment by itself with its current resources (impacts of past activities and uses and current threats). Rather, this strategy requires the Department to establish a decision making body (committee) in which appropriate trade-offs are carefully considered remediation measures are agreed upon, resources are shared, implementation actions are in place and cost sharing arrangements are agreed upon.

The social impacts of the various management actions need to be considered and the responsibilities should be shared across regions and catchments. This strategy recognises that those communities or water users that are most affected by poor water quality should not have to bear all the costs for intervention and action.

6.5 Historical issues and future actions

The strategy recognises that the water quality issues facing the Vaal River System are a combination of impacts of past actions (legacy of history) and future potential impacts (future activities). Thus, implementation of the strategy needs to achieve a balance in addressing water quality impacts of past actions while at the same time accommodating future impacts that provide environmental, economic and social benefits.

6.6 Decision-making

This strategy supports effective and balanced decision making. Implementation actions will require making careful trade-offs and balanced decisions for management of the water quality of the Vaal System. The process should strive to arrive at the best choices and decision in a fair and just manner based on a firm foundation of commonly understood and accepted principles. The decision-making process should facilitate consensus seeking as far as possible and ensure defensibility of decisions.

7 IMPLEMENTATION OF THE STRATEGY

This document reflects the Department's strategy to the management of water quality issues facing the Vaal River System. Certain strategic elements will be given a statutory basis through certain regulatory measures (e.g. implementation of waste discharge charges, compensation, and licensing). The Department will be responsible for implementation of this strategy. However, the Department will have to consider negotiated arrangements and agreements with partner organisations, water users and key role players in system for the desired objectives to be realised.

The Department will have to assist the strategy steering committee, catchment committees and identified task teams to implement the required management actions.

7.1 Capacity required

Implementation of this strategy will require adequate capacity which the Department on its own cannot resource. The responsibility will have to be shared by the Department, water users, key role players, other government departments (national and local) and stakeholders. The Department will have to facilitate this and encourage collaboration and co-ordination. There would have to be encouragement of the sharing of resources, data, information and shared responsibility for implementation actions. This will specifically support the compliance to the RWQOs, source control and monitoring and information management component of the strategy.

However, within the Department itself, the different Directorates and Regional Offices will have to work in a more integrated fashion, aligning their efforts in the management of the Vaal River System. Consideration should be given to the formation of an internal "Vaal River System Task Team" that considers quantity, quality, protection, catchment management, waste discharge, institutional, information management and operational components holistically from a system perspective and not from mandated individual Directorate/Regional perspectives. This will assist in addressing many of the gaps identified in monitoring of the behaviour and status of the system and current management activities. Information sharing and collaboration will be promoted and efforts in addressing issues can be consolidated. In addition, due to the cascading impacts and associated inter-dependency of these WMAs, it is vital that the water resources of this river system are managed in an integrated manner to achieve a balance between meeting specific water user and use requirements in each WMA as well as in fulfilling the transfer obligations between these WMAs, and the donating and receiving WMAs that form part of the larger integrated system. This Task Team will assist in achieving this objective.

A further indirect resource implication to the Department related to the implementation of the Vaal River System strategy is availability of skilled and trained personnel to support all the components of the strategy. Sustainable WQM requires that available knowledge be translated and implemented and as a result, the Department's water resource managers should have the necessary skills to undertake the implementation of these activities. Priority must be given to human resources development through continuous education, in-service training, career development and short and long-term training.

7.2 Strategy Steering Committee

The components of this WQM strategy and the related reconciliation and water conservation/demand management strategy for the Vaal River System cover a wide spectrum of interventions which require involvement of various institutions that are managing water resources and water supply. Monitoring the implementation of the strategies and steering the WQM and reconciliation process, requires a committee consisting of representatives of the organisations that will be responsible for the implementation of the various interventions.

In line with the required interventions identified from the different studies, the proposed Strategy Steering Committee will have the following objectives:

- To ensure that the scenario assumptions are monitored against actual data and that the strategy be updated accordingly.
- To monitor and co-ordinate the implementation of the interventions and related actions proposed in the strategy. (The interventions include quantity and quality related measures).
- To recommend planning activities that will ensure reconciliation of requirements and available supply in the Vaal River System supply area.
- To identify water quality related planning activities that are necessary to improve and sustain the water quality in the Vaal River System.

7.2.1 Functions of the Strategy Steering Committee (SSC)

The proposed functions of the Strategy Steering Committee with regard to WQM are listed below:

- Manage the monitoring, assessing and reporting on water quality at key locations in the system.
- Promote compliance to RWQOs within the catchment context through encouraging users to comply (management by shame).
- Integrate information from mines to check on status of mine water management plans – (Government Task Team).
- Co-ordination of catchment –wide water quality management activities.
- Oversee and monitor the implementation of TDS load reduction programme and ensure that the necessary adaptations are done where necessary.
- Encourage water users to supply waste discharge information to the Department.
- Ensure that the auditing of wastewater dischargers to determine compliance to discharge standards and RWQOs is undertaken.
- Ensure the Waste Discharge Charge System development and implementation is undertaken.
- Oversee and monitor that the upgrading and implementation of wastewater treatment works plans are undertaken.

- Check on performance of the strategy implementation (monitor and evaluate effectiveness/success of actions).
- Establish communication structures for information sharing and dissemination.

7.3 Communication and information sharing

Successful implementation of the strategy requires planned and co-ordinated communication and information sharing at all levels, internal and external to the Department. The main communication tasks include information exchange, community/stakeholder involvement and support of specific information networks (e.g. monitoring). These will have to be applied to ensure that the water quality management activities are conducted as required. The Department will have to invest in supporting these communication activities in order that the necessary feedback is obtained and that the benefits of information sharing are achieved. In addition, the communication with communities, stakeholders and users will enhance the progressive and ongoing optimisation and refinement of this strategy.

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