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

Task 2

Water Quality Status Assessment

September 2009

ZITHOLELE CONSULTING

WRP

DMM

Golder Associates

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

TASK 2:

WATER QUALITY STATUS ASSESSMENT OF THE VAAL RIVER SYSTEM

FINAL REPORT

Directorate National Water Resource Planning
Department of Water Affairs and Forestry

September 2009

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EXECUTIVE SUMMARY

This report is intended to provide an overview of the water quality status of the water resources of the Vaal River catchment (C drainage region). It forms part of the study of the Department of Water Affairs and Forestry to develop an integrated water quality management plan (IWQMP) for the Vaal River System. The study comprises eight tasks of which the status assessment forms task 2. The information derived from the status assessment will support the development of management options for the water quality of the system, the key output of the IWQMP study.

Having water of the right quality is just 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 together 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 exploited and utilised water resource system get even tighter, it is water quality that begins to take on a dominant role. The Department realises that just as planning and management are taking place to supplement and control water quantities, they also need to take place around water quality.

This report concentrates on the water quality of the Vaal River System in terms of chemical and biological quality. It does not deal with the microbiological status of the water resources as this information is not readily available yet. A snapshot of some areas is however given.

This report has been structured into four parts:

- Part One: Context and Background to the Study
- Part Two: Description of the Catchment Area
- Part Three: Water Quality Status
- Part Four: Discussion and Conclusions Drawn

Part One provides background to the study and the context of the task, and provides the framework for this study. Part Two primarily deals with the characterisation of the study area, physical attributes, water resource systems, description of the current land use activities and development. Part Three provides an assessment of the results indicating the current water quality status of the Vaal River System, while Part Four deals in essence with discussion of the findings of the assessment, formulating and prioritising the water quality issues, concerns, problems. It also provides concluding remarks and recommendations regarding possible management options.

The study area for the assessment comprised the C drainage area, which includes the Upper Vaal WMA, Middle Vaal WMA, part of the Lower Vaal WMA (C secondary drainage regions), and part of the Upper Orange WMA *viz.* the Modder Riet Catchment.

To simplify the assessment and to present the information in such a way that it would be useful for water quality management purposes, strategic monitoring points at two levels were identified for the system. Level 1 points were located on the main stem of the Vaal River and level 2 points on the major tributaries, just upstream of their confluences with the Vaal River. Water quality was assessed on the basis of compliance to resource water quality objectives (RWQOs), and based on the fitness for use for different user groups in terms of the South African Water Quality Guidelines (SAWQGs).

The assessment was limited to historical data and a once-off sampling and field survey conducted during May and June 2006. A review of the literature including limnological and ecological studies and water quality data from the Department of Water Affairs and the three major water boards, *viz*. Rand Water, Midvaal Water and Sedibeng Water., served as the primary source of data for the analysis for the Level 1 and Level 2 strategic monitoring points. An average study period of 10 years was used for assessing water quality.

The data used for the analysis has different time scales, different sampling frequencies, variation in the water quality variables monitored and different laboratories and analytical methods used. The lack of an integrated holistic monitoring programme for the Vaal River System has made the identification of water quality trends difficult. Taking these limitations into account, the data obtained has been used to determine the downstream trends in the Vaal River and to correlate these with the contributions received from the tributary catchments and to the discharges being released into the Vaal River and its tributaries.

The results of the assessment (Part three) are presented in a series of graphs.

From this water quality status assessment task, a spectrum of problems has been identified with regard to the current water quality in the Vaal River. Some issues are related to the whole length of the Vaal River while others are of a localised nature. This study has confirmed that increase in salinity (and related macro ions) has had the greatest impact on the usage of the water in the Vaal River. The increase in TDS and concomitant increase in constituents such as chloride and sulphate has major implications on domestic, industrial and agricultural water use. The occurrence of microbiological pollutants as localised problems are also an emerging concern, as well elevated levels of certain metals. Eutrophication is the other key water quality problem in the Vaal River System. This problem has resulted in excessive algal blooms and growth of water hyacinth. Eutrophication impacts have resulted in economic implications for users and large expenditure to control it. The effect of the extensive algal blooms and biomass upon water treatment processes and quality of potable may yet increase in significance.

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 levels are high. Of further concern is the impact of the high TDS concentrations on downstream water users below the Vaal Barrage and those abstracting from the Barrage.

Specific catchments are of concern as well in terms of their contributions 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. These catchments must ensure the development of water quality management strategies to manage the impacts originating from them, thereby alleviating the stress currently being placed on the Vaal River.

It is apparent that the status quo in terms of land based activities and water use practices cannot continue unabated as they have. Water users, major role players and the Department have to all start taking responsibility where required, to ensure the situation does not worsen, and to ensure sustainable use of the water resources. While it is accepted that socio-economic development is needed in South Africa, with the Vaal River System being a key area for this, it cannot occur at the expense of the water resource system. A range of management strategies and control measures are required to deal with the current situation.

In conclusion, the study has identified that while high salinity concentrations is currently a serious problem in the Vaal River System, the current trends indicate that the problem is not expected to increase substantially in the future. Thus the issue hand is how to handle the current situation in terms of management measures and reduction. Eutrophication on the other hand is a looming threat, and the system is considered to be a high risk from eutrophication.

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LIST OF ACCRONYMS AND ABBREVIATIONS

Al	Aluminium
BID	Background Information Document
BG	Blue green algae
CMA	Catchment Management Agency
CMS	Catchment Management Strategy
DIN	Dissolved Inorganic Nitrogen
DOC	Dissolved Organic Carbon
DM	Diatoms
DWAF	Department of Water Affairs and Forestry
EC	Electrical Conductivity
EIS	Ecological Importance and Sensitivity
ERWAT	East Rand Water Care Company
G	Green algae
GDP	Gross Domestic Product
ICM	Integrated Catchment Management
ISP	Internal Strategic Perspective
IWQMP	Integrated Water Quality Management Plan
IWRM	Integrated Water Resource Management
KOSH	Klerksdorp-Orkney-Stilfontein-Hartbeesfontein
LBWSRS	Large Bulk Water Supply Reconciliation Strategies
Mn	Maganese
MIB	2-methylisoborneol
N	Nitrogen
NEMP	National Eutrophication Management Programme
NMMP	National Biological Monitoring Programme
NWA	National Water Act
NWRS	National Water Resource Strategy
P	Phosphate
PES	Present Ecological State
PWV	Pretoria-Witwatersrand-Vereeniging

RDM	Resource Directed Measures
RQOs	Resource Quality Objectives
RO	Regional Office
RWQO	Resource Water Quality Objectives
SAWQGs	South African Water Quality Guidelines
TAL	Total Alkalinity
TDS	Total Dissolved Salts
TWQR	Target Water Quality Range
VRSAU	Vaal River System Analysis Update
WCWDM	Water Conservation Water Demand Management
WDCS	Waste Discharge Charge System
WMA	Water Management Area
WMIs	Water Management Institutions
WMS	Water Management System
WRC	Water Research Commission
WUA	Water User Association
WWTWs	Wastewater Treatment Works

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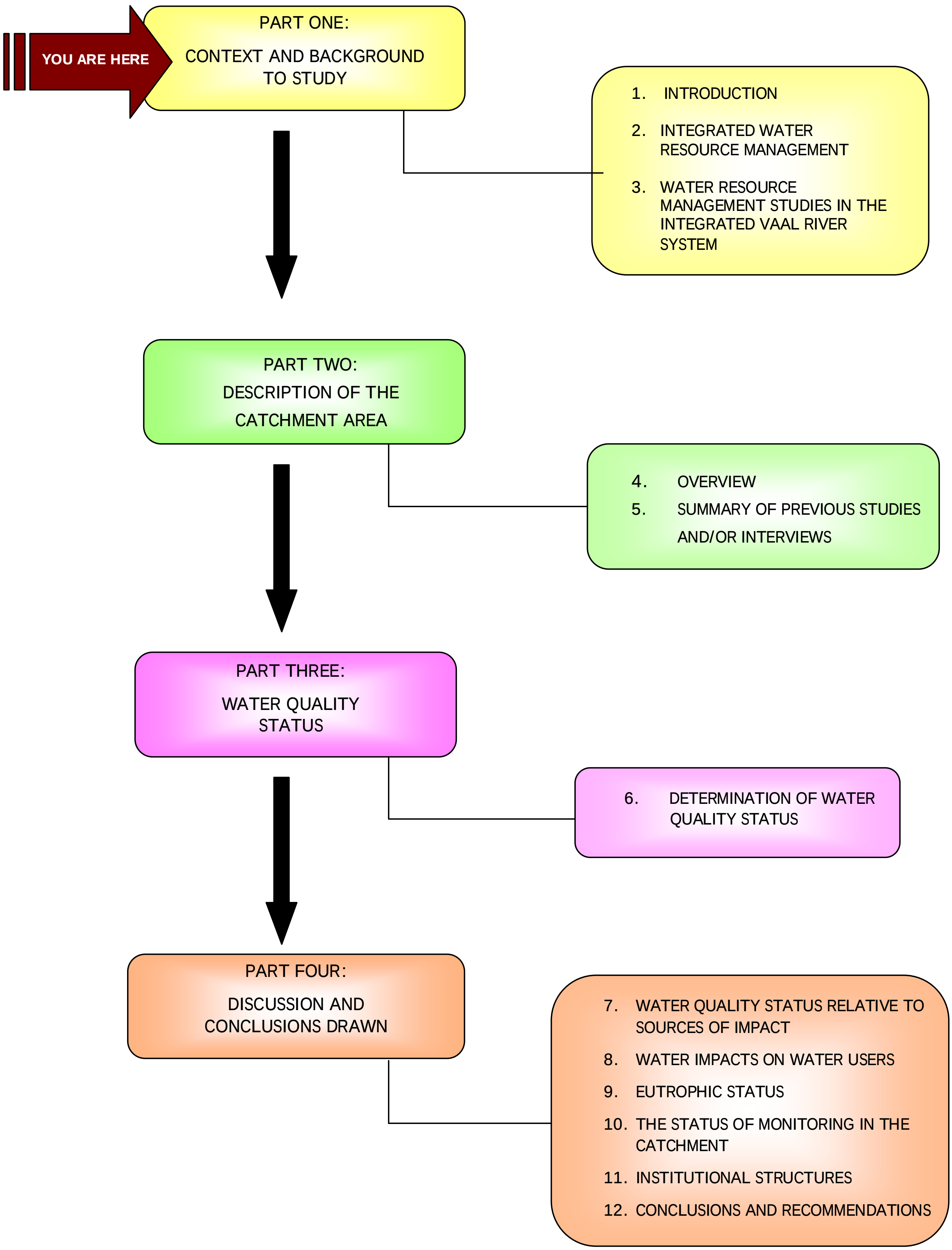
STRUCTURE OF THE REPORT



PART ONE:
CONTEXT AND BACKGROUND OF THE STUDY

1 INTRODUCTION

The water resources of the Vaal River System are an important asset to the country and its people, supporting major economic activities and a population of about 12 million people. The Vaal River System comprises the pimary drainage region C within the water management drainage regions of South Africa and spans four water management areas (WMAs), *viz.* the Upper, Middle, part of Lower Vaal and part of the Upper Orange (Modder Riet catchment) WMAs. Due to the cascading orientation 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 (**Figure 1**). The Vaal River serves as a conduit to transfer water among the three Vaal WMAs and significant transfers out of the Upper Vaal WMA occur through the distribution system of Rand Water to the Crocodile West and Marico WMA. The Vaal River System has extensive water resource infrastructure and is linked to other water resource systems (Thukela, Usutu, Lesotho) through substantial transfers between them (shown in **Figure 1**).

The Upper Vaal is highly altered by catchment development, with the Middle Vaal having a few major development centres with agriculture and mining being the main activities. The Lower Vaal WMA is less developed with agriculture being the predominant land use. The Modder Riet catchment is dominated by agricultural activities, with limited mining, and a few urban centres. The significant development within the system includes both formal and informal urbanisation, industrial growth, agricultural activities and widespread mining activities. This development has led to deterioration in the water quality of the water resources in the system, requiring that management interventions are sought to ensure that water of acceptable quality is available to all users in the system, especially as land use activities continue to grow and intensify. Salinisation and eutrophication of the water resources in the Vaal River System appear to be the two major water quality problems being experienced. If the system is going to sustain the envisaged growth and development, sound strategies and actions are needed to 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 resource quality.

The challenge is to develop a detailed understanding of the current water quality situation of the water resources within the system and the processes that drive the impact and associated pollution sources such that the resulting water quality management plan identifies optimum, sustainable solutions that not only serve to alleviate the water quality issues but also allow for the interdependency of the linked resource systems.

One of the basic principles of management is that "*you can only manage what you can measure*". This principle applies to any human endeavour and to the world that surrounds us, with the domain of water resource management being no different. Thus, in order that the water resources in the Vaal River System are effectively managed into the future and sound strategies for water quality management are developed, relevant information about water related conditions, issues and developments in the WMAs is needed to appropriately address the threats and problems that currently prevail. This "measurement" process of collating, processing and interpreting such information either takes the form of situation analyses, catchment studies or in this case a status assessment. Thus the purpose of the status assessment is to better understand the existing water quality situation within the Vaal River System, which will subsequently support the development of the integrated water quality management plan.

1.1 Structure of the Report

This report has been structured into four parts:

- **Part One**: Context and Background to the Study
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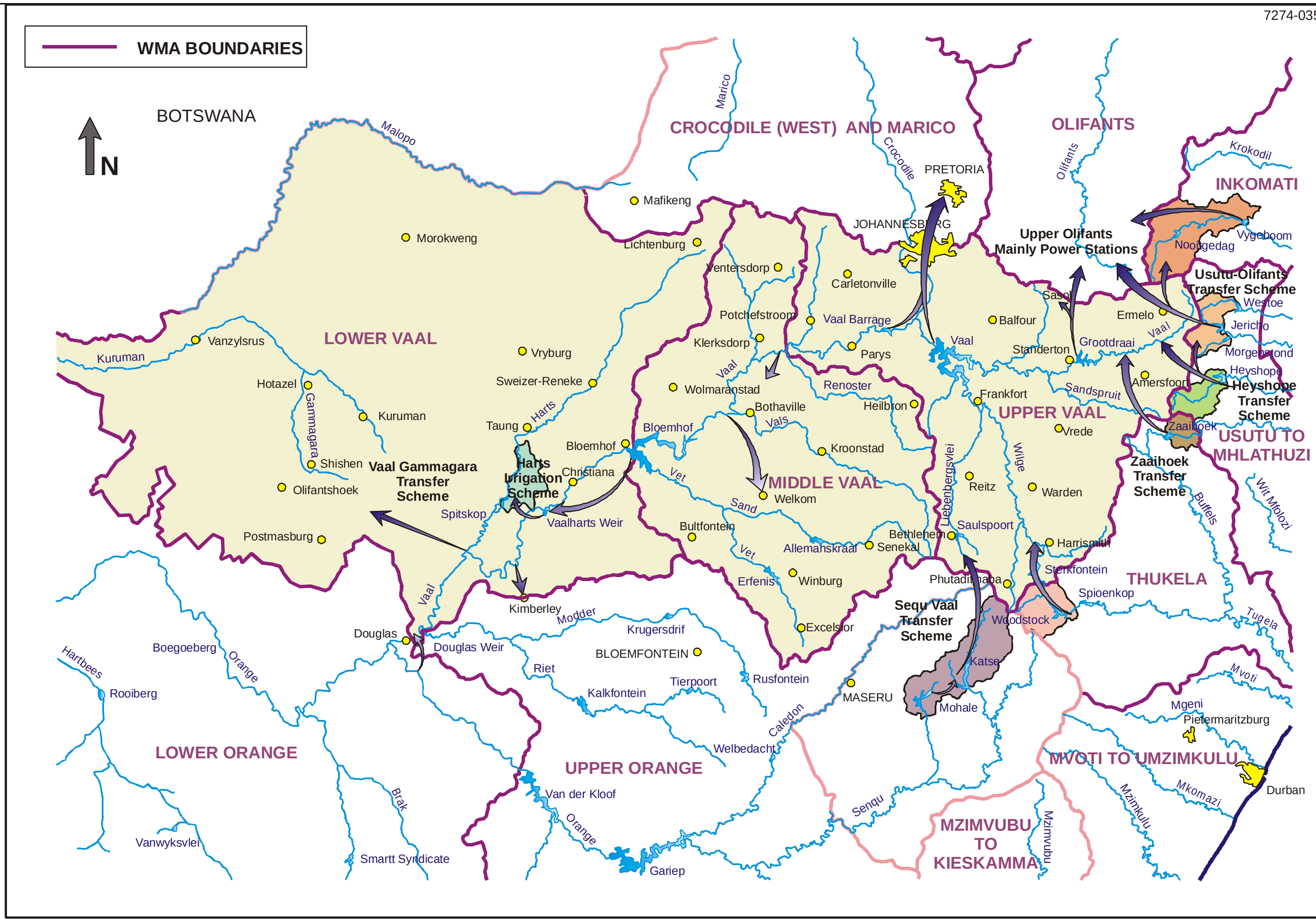

Figure 1: The Vaal River System depicting water resource infrastructure and associated transfers within the integrated system (*adapted* DWAF, 2005a)

2 INTEGRATED WATER RESOURCE MAGEMENT IN SOUTH AFRICA

One of the most important milestones in the revision of the Water Law in South Africa was the publication of the document the 'White Paper on a National Water Policy for South Africa'. This policy document sets out overarching policy principles regarding water resource management which were later taken up into the National Water Act (Act No. 36 of 1998) (NWA).

The National Water Policy is firmly founded on the concept of *integrated water resource management (IWRM) on a catchment basis* and entrusts the Department of Water Affairs and Forestry (the Department) with the custodianship of the water resources of South Africa. Amongst others, the policy together with the NWA binds the Department to play a distinctive and pioneering role in promoting and facilitating the establishment of statutorily directed catchment management in fulfilment of IWRM (DWAF, 1997). This obligation requires that the Department meet the implementation needs of catchment management by driving and facilitating catchment management processes and the establishment of related institutions ***i.e.*** the catchment management agencies (CMAs).

The pursuance of IWRM by the Department has thus become the declared goal of water management at national, regional and catchment level.

2.1 Integrated Water Resource Management in a Catchment Context

Integrated water resource management (IWRM) may be defined simultaneously as a philosophy, a process and strategy which promotes at a local catchment, regional, national and international level the co-ordinated development and management of water resources, in order to ensure optimum economic and social benefits in an equitable manner without compromising the sustainability of aquatic ecosystems (DWAF, 1998). IWRM therefore aims to strike a balance between the use of water resources for livelihoods and the conservation and protection of these resources to sustain their functions for future generations. It is also aimed at promoting the guiding principles of the NWA, which include the sustainable and equitable use of water resources for the "optimum social and economic benefit" for the country. Coupled to this, is the need for a transparent and a participative approach to water resource management. Because the water resource cannot be considered separately from the people who use it, a balanced mix of technological and social approaches must be used to achieve integrated management.

2.1.1 Dimensions of IWRM

Freshwater is a complex ecological system that has a number of dimensions. Surface water, groundwater, quantity and quality are all linked in a continuous cycle – the hydrological cycle – of rainfall, runoff from the land, infiltration into the ground, and evaporation from the surface back to the atmosphere. Each component may influence the other components and each must therefore be managed with regard to its inter-relationships with the others (DWAF, 2004e).

Water as a system also interacts with other systems. Human activities such as land use, waste disposal and air pollution can have major impacts on the quantity and quality of water available for human use, while the abstraction and storage of water and the discharge of waste into water resources can impact on the quality of the water resource. These interactions must also be addressed in the management of water resources.

Taking an even broader view, water must also be managed in the full understanding of its importance for social and economic development (DWAF, 2004e).

From the above it is evident that water resource management at the catchment or regional level occurs within a highly integrated environment, where water quality, quantity and the aquatic ecosystem are all interlinked and interdependent

2.1.2 Framework for Integrated Water Resource Management in South Africa

IWRM in South Africa is seen to be achieved through a three tiered framework comprising (i) a statutory framework provided through the NWA, (ii) the National Water Resource Strategy (NWRS) and (iii) catchment management processes, strategies and plans in WMAs formalised through the Catchment Management Strategy (CMS) (DWAF, 1998).

The facilitation and co-ordination of catchment management in and between WMAs is achieved at a national level by the National Water Resource Strategy (NWRS), which forms a coherent planning framework, and at a catchment or WMA level by Catchment Management Strategies (CMSs). These strategies link together the management elements required by water quality, quantity and the aquatic ecosystem components of the water resources in a catchment into a coherent approach that aims to secure beneficial, equitable and sustainable use of the water resource.

The above framework for IWRM ensures considerable vertical and horizontal integration of water resource management with catchments as a basis. However such water-focussed catchment management falls outside of the ideal accepted concept of integrated catchment management (ICM), which is aimed at a sustainable balance between utilisation and protection of *all* natural resources in a catchment.

A fundamental principle of ICM is that land and water form a continuum and must therefore be managed together in an integrated way (DWAF, 1998). However, apart from forestry and certain aspects of mining and solid waste disposal, the Department has no jurisdiction[1] over land use planning and regulation.

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[1] However, section 12 of the NWA does enable the Department in terms of the classification system for water resources to set out for each class land based activities which must be regulated or prohibited in order to protect the water resource. While this section does allow some control of land based activities it is linked primarily to the classification system and thus does not influence land use planning at the regional or local level per se.

Given this intimate inter-dependence between land-use and the characteristics of run-off, this means that for water resource focussed catchment management to become more integrated and effective, other national and provincial government departments and local authorities, as well as stakeholders in the catchment need to be brought into the process formally and informally. This has the following implications (DWAF, 1998):

- the need for CMAs and related institutions to be representative of both stakeholders and organs of state in a catchment;
- the need for catchment management processes to be based not only on direct intervention or control and enforcement but also on persuasion, influence and advocacy; and
- the need for catchment management related policy and planning co-ordination at provincial and national government levels.

IWRM can thus be seen as a component of the broader integrated planning framework of government that is realised through tiered planning initiatives at the national, provincial and local levels. This relationship is depicted in **Figure 2**.

The need for stakeholder participation for the successful implementation of the IWRM process has been identified and is taken up in the NWA, by the devolution of management of the water resource to regional and catchment levels via the CMAs and other institutional structures. These structures must include stakeholders in both the ongoing development of the CMS and in giving effect to the strategy. Apart from the legal requirement for public consultation, the reason for inclusion of stakeholders is that they are more likely to identify the issues at hand with respect to the water resource and are more equipped to ensure implementation of the necessary actions to realise the requirements.

It is recognised that due to a shortfall of skills and resources in South Africa the implementation of catchment management processes and the establishment of CMAs will be a gradual process, dependent on the development of management, technical and financial resources within a WMA. Thus in the short to medium term the Department's Regional Offices have the responsibility of driving the development CMSs and establishing CMAs (DWAF, 1998).

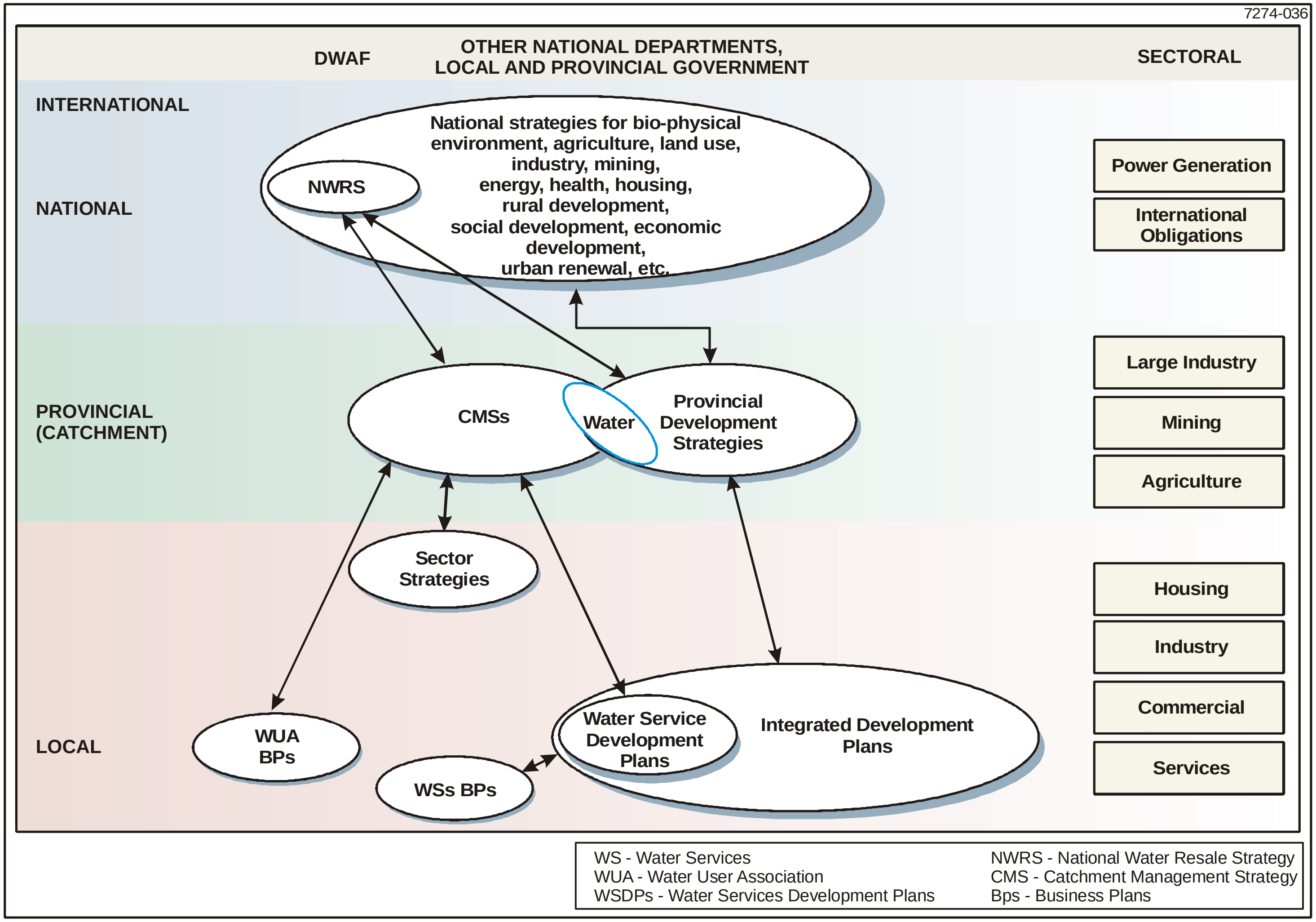

Figure 2: Integrated Planning approach at various levels of government in South Africa (*adapted* DWAF, 2004a)

2.1.3 The National Water Resource Strategy

The NWRS gives effect to IWRM at a national strategic level, by providing the framework within which water resources will be managed between and within the nineteen WMAs of the country, as well as the institutions to be established. As such it presents estimates of present and future water requirements in each WMA, makes provision for the transfer of water from water-rich catchments to water poor catchments and provides overview assessments of the water quality issues in each WMA (DWAF, 2003b). Nationally, certain water uses of strategic importance (for example power generation and international obligations) are allocated priority use by the NWRS. Similarly, certain international water quality and quantity obligations with respect to water resources that cross South Africa’s borders are spelt out in the NWRS.

The NWRS is legally binding and may consist of a number of functional and/or issue based strategies for the protection, use, development, conservation, management and control of water resources (DWAF, 2004e).

Although the NWRS is intended to be an enduring framework for water resource management it may be amended to suit changing circumstances with five yearly reviews. However such amendments may only be made after mandatory consultations with stakeholders (DWAF, 2004e).

An aim of the NWRS is to ensure coherence in the functions of catchment management in the various WMAs through the statutory tools and processes contained in the NWA, and to iteratively inform the catchment management processes and CMSs in the individual WMAs, or to be informed by these. It is important to highlight this iterative management process by which the NWRS provides the context for IWRM on a catchment basis, but in turn is informed by the application of the statutory framework and CMSs and processes.

2.1.4 The Catchment Management Strategy

A catchment management strategy (CMS) is the framework for water resource management in a WMA and provides a coherent approach (and intent) for managing water resources in the WMA. The CMS should be viewed as both a process and framework for management, which binds the Department and the CMA as well as the water users, stakeholders and their representative structures in a social and/or legal “contract”. The CMS can be considered to be a business plan for IWRM in the WMA, which focuses on priority water resource management issues, and specifies activities, resources, responsibilities, timeframes and institutions required to address these priorities in an efficient and sustainable manner. The CMS is therefore simultaneously a technical water resources management strategy, an organisational-institutional development strategy and a stakeholder participation-communications strategy (DWAF, 2003a).

The NWRS provides a framework within which all CMSs will be prepared and implemented in a manner that is consistent throughout the country. In particular, in terms of section 9(b) of the NWA a CMS must not be in conflict with the NWRS. It is anticipated that insights and information gathered during the development of CMSs will inform the regular review of the NWRS, enabling it to remain relevant to local conditions and circumstances (DWAF, 2004e).

2.1.5 Internal Strategic Perspectives (ISPs)

In the interim until CMAs are established and fully operational, and the Department's Regional Offices are able to hand over the water resource management functions to them, the Department has developed Internal Strategic Perspectives (ISPs) for each of the 19 WMAs, to serve as the frameworks for the management of water resources in each WMA. This is aimed at ensuring consistency in terms of protection, use, development, management, conservation and control of the water resources for the respective WMAs. The ISPs will feed into the development of the respective CMSs.

The ISP is the Department's approach to the management of water resources within a WMA. This will in the longer term, be replaced by a CMS which will be developed by a CMA.

2.2 The Catchment Management Process

Catchment management requires an open-ended process with different activities being required at different times. The catchment management process can in general include the following stages however these stages should not be confined to a given time period and are characterised as being ongoing, iterative and adaptive (WRC, 1998).

The stages include:

- *Initiation*: of the process, triggered by one or more water-environment related issues;
- *Assessment (Situation analysis)*: to gain understanding of the social, economic, technical and institutional environments governing the water-related issues;
- *Planning:* for catchment management in the area, which would result in a CMS. (based on the assessment reach consensus on institutional needs, water and land use management strategies, resource directed measures, social and economic concerns and considerations; responsibilities and actions, etc. which would lead to a vision for the catchment);
- *Implementation*: of the actions and procedures of the strategies specified in the CMS;
- *Administration*: of the catchment by the institutional structures in place in terms of managing and supporting the implementation measures instituted and maintaining stakeholder support.
- *Monitoring*: and processing of data and information collected in the catchment; and
- *Auditing*: of catchment management by periodically reassessing, re-planning, revising objectives and strategies, based on performance indicators, which would lead to regular review of the strategy.

Stakeholder participation and public consultation in catchment management are not explicitly identified as stages of the process, as these form the backbone of all stages in the process. This is critical to the sustainability of catchment management as these components ensure the buy-in and ownership by the stakeholders. The stakeholder engagement processes for the CMS development process and the CMA establishment process must be linked to ensure stakeholder support.

3 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's obligation to ensure that the country's water resources are fit for use on an equitable and sustainable basis, it has adopted the approach of the progressive development and implementation of catchment management strategies (CMS) to fulfil this mandate. Each CMA is responsible for the progressive development of a CMS for its respective 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.

In terms of meeting this obligation the Department has 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 that arose out of the 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 being developed. At present three major studies are underway in the Vaal River System, which 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 to:

- Develop strategies for meeting the growing water requirements of the industrial and urban sectors served by the Integrated Vaal River System (Large Bulk Water Supply Reconciliation Study).
- Determine the potential for, and benefits of Water Conservation and Water Demand Management (WC/WDM) in the various water use sectors with the focus on the Upper and Middle Vaal WMAs.
- Develop water quality management measures to ensure continued fitness for use in the Vaal River System for the planning period up to the year 2025 (IWQMP Study).

A fourth ongoing study is also underway which aims to provide continuous technical support to the Department and water users regarding the management and planning of the operations of the Integrated Vaal River System.

The management options identified through these studies aim to eventually feed into reconciliation options that will be determined for the Vaal River System that will support current and future water users and uses within the interdependent water resource systems of the Vaal WMAs and associated Modder Riet catchment (**Figure 3**).

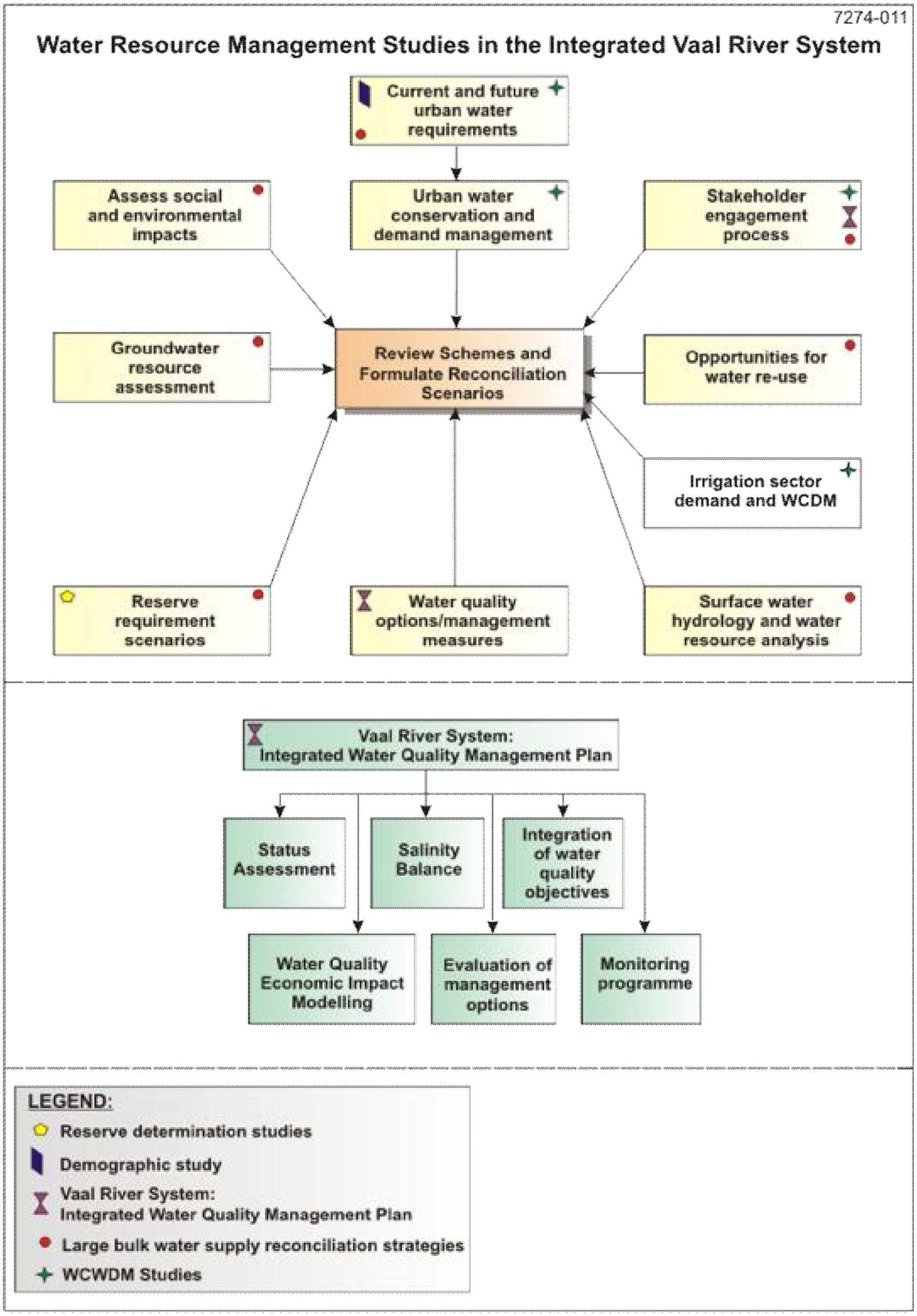

Figure 3: Water Resource Management Studies for the Integrated Vaal River System supporting the identification of reconciliation options (*adapted* DWAF, 2005a).

An important further study recently initiated by the Department is the Comprehensive Reserve Determintation Study for the Integrated Vaal River System. While this study has a significant bearing on the reconcialition study and water quality study it will only be concluded two years after (2009) the end of these studies and thus the reserve scenarios will not be available for inclusion. However an attempt will be made to incorporate some of the preliminary Reserve determination results into the final reconciliation strategy and IWQMP. The requirements of the Reserve determinations will however have to be incorporated into/accommodated for by the management strategies during implementation.

3.1 Stakeholder Engagement

An integral part of the development of the water resource management strategies, and a key requirement of the NWA (Act No. 36 of 1998), is the participation of stakeholders and the devolution of water resource management to catchment level. Thus in support of this principle, an intensive stakeholder engagement process has been developed as part of the water resource management studies on the integrated Vaal River System to get buy-in of water users and to ensure stakeholders eventually take ownership of the implementation of the strategies.

In this regard an integrated stakeholder engagement process was adopted which consolidated the participation processes of the IWQMP Study, the WCWDM Study and the LBWSR Study for the Vaal River System (**Figure 4**). This was done to eliminate stakeholder fatigue, ensure more effective and efficient study management of all three studies from the Department's perspective and ensure an optimal implementation of the study outcomes. The stakeholder engagement process has been designed to run parallel with the technical processes. In terms of the stakeholder engagement process thus far:

- A database of stakeholders has been prepared which is continually updated through the development of the studies.
- A background information document (BID) has been prepared and circulated to stakeholders. Its purpose is to provide sufficient information on the studies and the public participation process, to ensure that stakeholders are adequately informed and capacitated to participate.
- One-on-one stakeholder meetings have been held with the key stakeholders at the onset of the studies to identify their critical water related issues.
- A pre-consultation meeting has been held with the key stakeholders presenting the proposed scope of work and obtaining further input on the priority issues for the studies. The meeting was held on 29 July 2005.
- A stakeholder meeting including a wider stakeholder base was held on 11 November 2005 at which the proposed steering committees envisaged membership was confirmed.
- Two steering committees have been established, one for the LBWRS and WCWDM Studies and one for the IWQMP Study. The two steering committee meetings were held in March 2006 which were well represented and at which members sanctioned the progress and process thus far.

- A first edition newsletter has been prepared and circulated to all stakeholders on the database as an update to the progress on the respective studies and the process.
- A second round of PSC meetings was held in November 2006 at which the first round reconciliation strategy and preliminary WQM management options were presented.

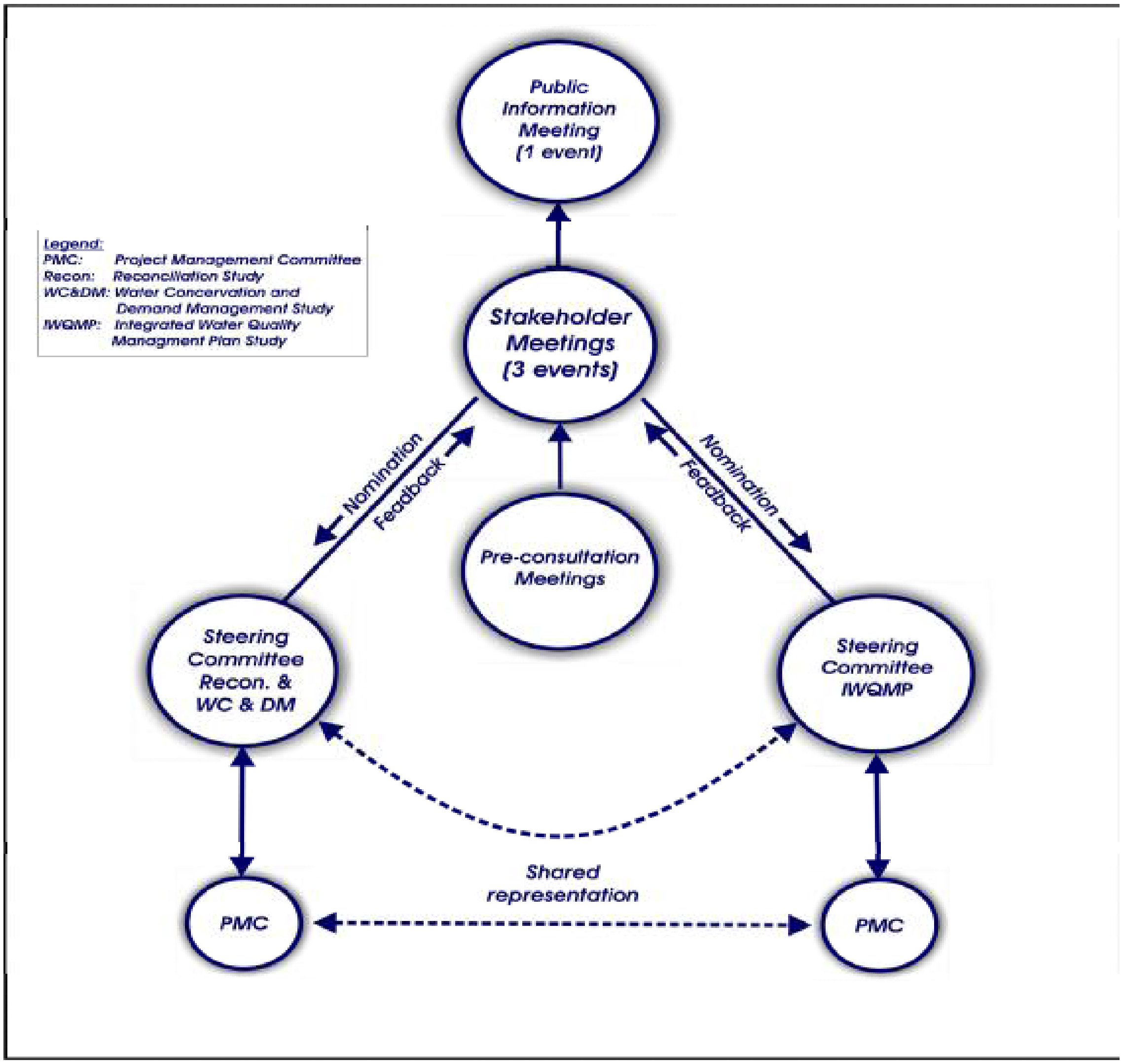

Figure 4: Integrated stakeholder engagement process adopted for the IWQMP Study, the WCWDM Study and the LBWSR Study for the Vaal River System

However following on from the March 2006 project steering committee (PSC) meetings, stakeholders requested that the above process be revised to reduce the number of stakeholder meetings as many members of the PSC would also be the designated representative at the stakeholder meetings. The Department took heed of the request and the following revised process depicted in **Figure 5** was adopted for the remainder of the studies. The process now has additional newsletters and a fact sheet as opposed to the remaining two stakeholder meetings that remained.

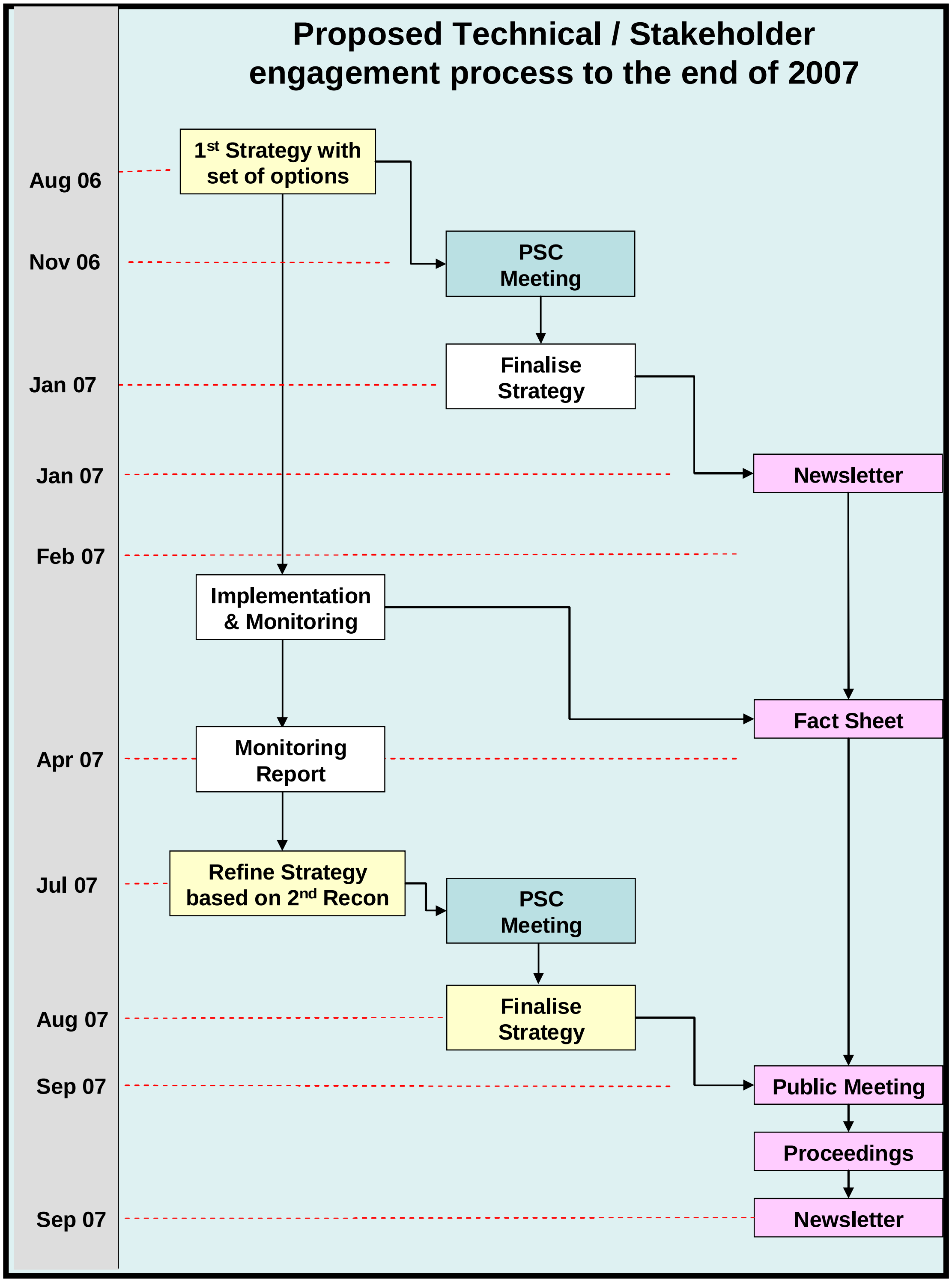

Figure 5: Revised integrated stakeholder engagement process adopted for the IWQMP Study, the WCWDM Study and the LBWSR Study for the Vaal River System

3.2 IWQMP Study description and context of the status assessment task

Having water of the right quality is just 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 together 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 exploited and utilised water resource system get even tighter, it is water quality that begins to take on a dominant role. The Department realises that just as planning and management are taking place to supplement and control water quantities, they also need to take place around water quality. In response to the need to meet the objectives of IWRM, the Department has initiated this process to address the management of the water quality in the Vaal River System. This need was identified through the ISP process that specifically highlighted the necessity for an integrated management plan to manage water quality within the Vaal system. The purpose of this initiative is to eventually develop a management plan 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 interdependent Vaal WMAs. In essence the integrated management plan developed would 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 NWRS as part of the national guiding framework.

The focus of this study is thus to develop an integrated water quality management plan (IWQMP) for the Vaal River System, which aims to identify management options that are technically, economically and socially feasible and which will support the continued fitness for use of the water resources for all users across the WMAs.

The proposed approach for the development of the IWQMP involves (DWAF, 2005b):

- The assessment of the Vaal River System to obtain a perspective of water quality (variables of concern), pollution sources and key water users. This will include the identification of existing Resource Water Quality Objectives (RWQOs) and their establishment where they are not available.
- The definition of integrated and balanced RWQOs that will maintain or improve the systems water quality, using as a point of departure the existing RWQOs.
- Establishing how the system complies with the RWQOs, which will be determined through analysis of available data and undertaking modelling of possible future scenarios.
- Identifying and developing management measures that will improve 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 management measures will be evaluated on the basis of their technical, environmental (range of aspects), social and economic feasibility.

The IWQMP study comprises seven tasks which are depicted in **Figure 6 .**

In order that the Department is able to effectively manage the water resources of the Vaal River System catchment it needs to "measure" the existing situation; thus the actual plan/strategy development for the catchment is preceded by a status assessment which supports the state of knowledge that is needed. This task is therefore focussed on understanding the current water quality status of the Vaal River System, which is aimed at collating and interpreting the information, currently available on the water resources in relation to the current water users and water uses. This report focuses on the water quality status assessment which comprises task 2 of the study.

The output of this task will identify the water quality issues, stresses and trends and the priority areas requiring specific focus and attention. These will feed into the ensuing tasks 3 and 4 and eventually 6 which develops the management options to deal with the issues identified in the status assessment and the salinity modelling.

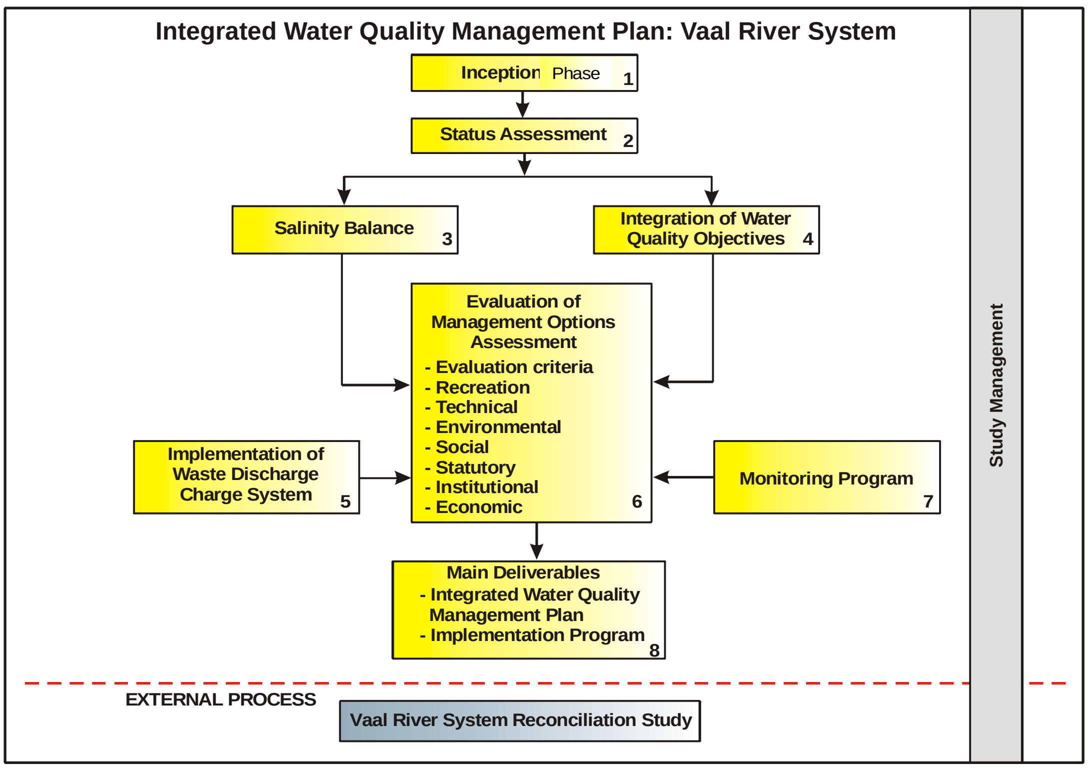

Figure 6: The study tasks comprising the development of the IWQM Plan for the Vaal River System (DWAF, 2005b)

3.3 Spatial extent of study

The spatial extent for the IWQMP Study includes 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) (**Figure 7**).

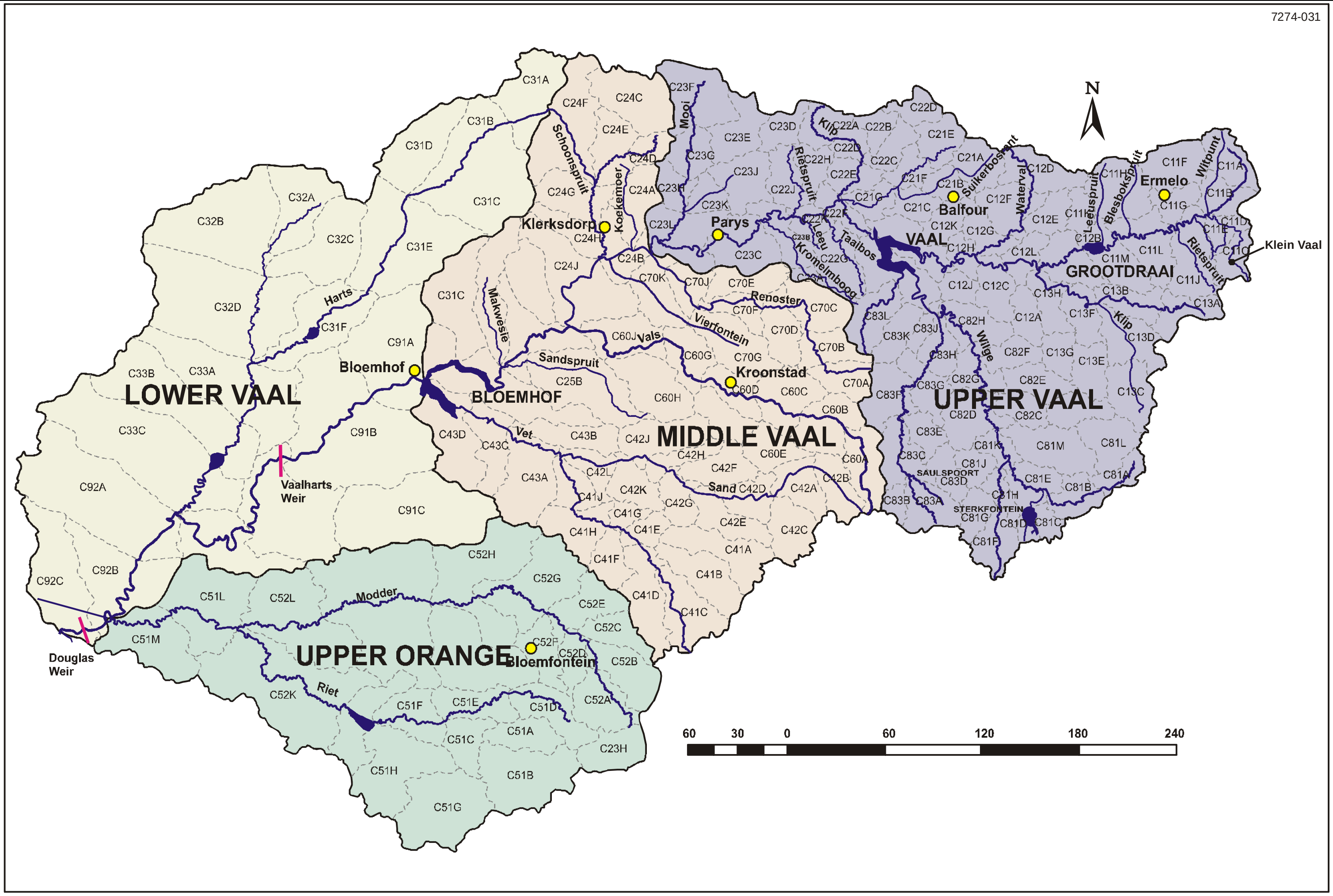

Figure 7: Spatial extent of IWQMP Study

The extent and approach of the study is focused on:

- The main stem of the Vaal River as it flows from its origin in the Drakensberg escarpment to Douglas weir;
- All the major tributaries to the Vaal River. The tributaries were treated as point sources and consideration of the factors determining the water quality of individual tributaries were not considered in detail in this report.
- Water quality issues identified based on available data and information obtained from the Department, water users and review of reports, and
- Once-off sampling exercise undertaken along the length of the Vaal River.

Although the study and the status assessment task, will consider upstream impacts of the major tributaries, it will not look at management strategies for each of the sub-catchments. Rather the management options identified for the Vaal River will feed into the respective catchment management strategies and water quality management plans as they are developed or revised.

3.4 Objectives of the status assessment task

The status assessment task was designed as part of the study to provide a high level analysis of the available information of the current water quality situation of the Vaal River System in terms of water quality, pollution sources and key water users (DWAF, 2005b).

The overall objective of the status assessment task is to:

- Create a clearer picture of the current water quality status and in doing so identify the water quality "hot spots" and issues/aspects that have an impact on the overarching management of the system. Known areas of water quality concern will be verified and others will be identified through this task.

In order to achieve the overall objective, the specific objectives of the status assessment tasks are:

- To assess the available water quality data of the system to determine trends of the key water quality variables, and to compare the current quality to existing resource water quality objectives (RWQOs)
- To determine salinity and eutrophication status of the system
- To identify the key water users in the systems and understand their water uses and associated water quality impacts on the receiving water resource (relates to the identification of sources of pollution)
- To identify a list of key priority water quality management issues based on the assessment.

3.5 Approach adopted

To achieve the objective of the status assessment, the task was split into 6 sub-tasks (DWAF, 2005b):

Task 2a: Review of existing information and interviews with Departmental officials

Task 2b: Assessment of water quality data

Task 2c: Mine water assessments

Task 2d: Assessment of eutrophication

Task 2e: Identification of water quality management issues

Task 2f: Reporting

The water quality assessment carried out was based on the data, which was available to the project team.

3.6 Future tasks

As outlined in **Section 3.2**, **Figure 6** the IWQMP Study comprises seven tasks, with this status assessment task comprising task 2. The status assessment provides outputs that support all the ensuing tasks in some form or the other.

The future tasks as part of the study include (DWAF, 2005b):

Task 3: Salinity Balance

- An annual salinity balance will be developed for the years 1995 to 2004. This is aimed at determining the relative contributions of pollution sources and identifying significant divergence from the assumptions that drove the Vaal River System Analysis Update (VRSAU) study calibrations.

Task 4: Integration of Resource Water Quality Objectives

- The purpose of this task is to check and balance the alignment of the RWQOs among sub-catchments and WMAs in the Vaal River System. This tasks aims to identify the RWQOs in the system that are out of balance, find out the reasons for the setting of the RWQOs initially and the identification of areas where particular attention will have to be given to the development of options in the management option analysis.

Task 5: Implementation of the Waste Discharge Charge System (WDCS)

- The principles of the WDCS will be demonstrated in this study by including the calculation of the charges for the Vaal River System into the economic evaluation of the proposed management options. This will entail defining the appropriate parameters for the two types of charges as defined in the Pricing Strategy (Government Gazette No. 27732, Notice 1045 of 2005) and calculating the charges based on the pollution loads and the supply quality of water users in the system. The WDCS is now entering an implementation phase in which the charge system will be applied in selected priority catchments. The outcomes of this phase of the project assist in defining the charge parameters for the Vaal River System.

Task 6: Evaluation of water quality management options

- This task forms the core activity for the development of the IWQMP and has the objective of assessing the feasibility of possible management options that could be implemented to cover the following three time horizons:

  a) Options, most likely operational in nature, to be implemented over the first five years.

  b) Medium term strategies that would require further investigations and have the objective of covering a ten year planning period. (Pre-feasibility assessment level of detail).

  c) Long term management measures to ensure the water quality in the system is maintained or even improved and considers the planning period up to the year 2025. (Reconnaissance assessment level of detail).

Task 7: Monitoring Programme

- This task entails a gap analysis in terms of the prevailing water quality monitoring network, the development of a revised monitoring programme based on the monitoring needs and requirements, and a resource requirement evaluation in terms of implementation.

The outputs of the above tasks will feed to the Integrated Water Quality Management Plan for the Vaal River System which will form the final deliverable of the study.

STRUCTURE OF THE REPORT

PART ONE:

CONTEXT AND BACKGROUND TO STUDY

1. INTRODUCTION
2. INTEGRATED WATER RESOURCE MANAGEMENT
3. WATER RESOURCE MANAGEMENT STUDIES IN THE INTEGRATED VAAL RIVER YSTEM

YOU ARE HERE

PART TWO:

DESCRIPTION OF THE CATCHMENT AREA

4. OVERVIEW
5. SUMMARY OF PREVIOUS STUDIES AND/OR INTERVIEWS

PART THREE:

WATER QUALITY STATUS

6. DETERMINATION OF WATER QUALITY STATUS

PART FOUR:

DISCUSSION AND CONCLUSIONS DRAWN

7. WATER QUALITY STATUS RELATIVE TO SOURCES OF IMPACT
8. WATER IMPACTS ON WATER USERS
9. EUTROPHIC STATUS
10. THE STATUS OF MONITORING IN THE CATCHMENT
11. INSTITUTIONAL STRUCTURES
12. CONCLUSIONS AND RECOMMENDATIONS

PART TWO:
DESCRIPTION OF THE CATCHMENT AREA

4 OVERVIEW

The Vaal River is the major water resource within the system with a number of significant tributaries along its length. Rising at Sterkfontein Beacon near Breyten, in Mpumalanga province, the Vaal River flows 1 415 km southwest to its confluence with the Orange River near Douglas (**Figure 8**). In the middle Vaal River (especially between Kromdraai and Bloemhof Dam) the topography results in a flat slope with an average of about 0.28 m/km (gradient, 1:3 538). The Vaal River forms the main tributary to the Orange River.

The Vaal River catchment area stretches from Ermelo in the northeast to Vryburg in the northwest to Douglas in the southwest to Harrismith in the east. The catchment area covers approximately 197000 km^2 and is situated in the geographic centre of the country (refer to **Figure 9**)

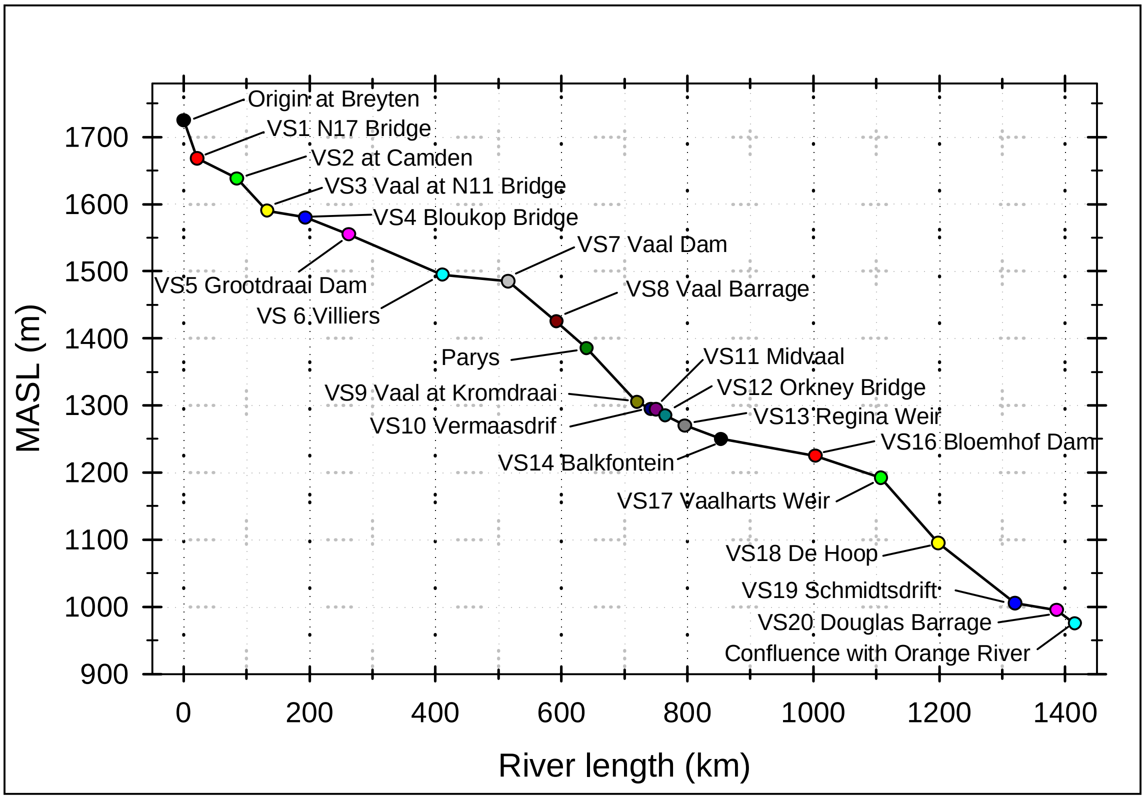

Figure 8: Vaal River altitude profile, i.e. river length (km) vs. meters above sea level (MASL) with strategic monitoring points.

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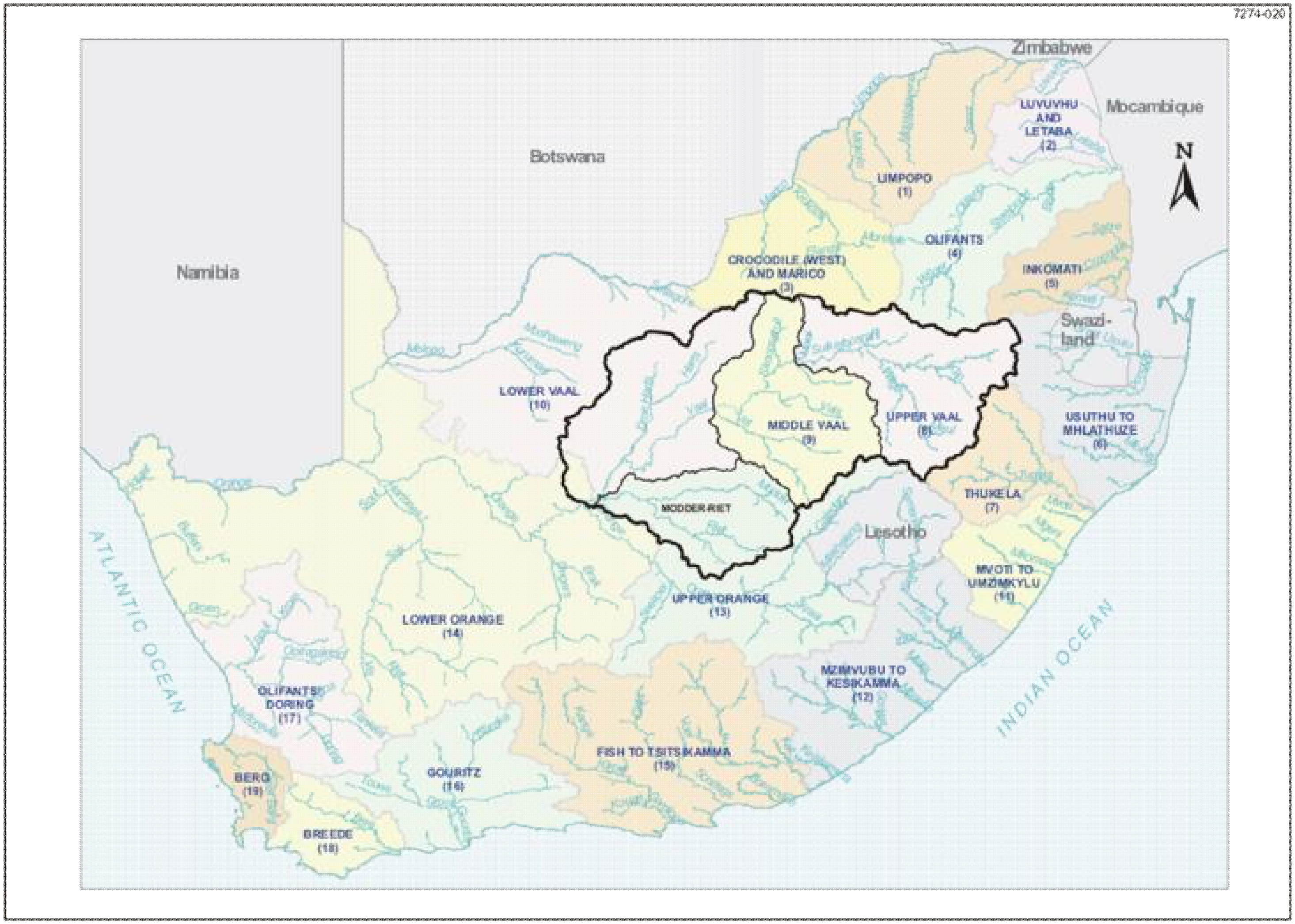

Figure 9: Vaal River System catchment area

OVERVIEW OF CATCHMENT AREA

The Vaal River is probably the most developed and regulated river in Southern Africa – it has some 90 major man made impoundments situated on the main stem and its tributaries (Bruwer, *et al*., 1985). A particular characteristic of the Vaal WMAs is the extensive intercatchment transfer of water within the WMAs as well as interbasin transfers between these and adjoining WMAs. In addition to the direct linkages through these transfers, the impacts of water resource management also indirectly extend to other WMAs within South Africa. The main interdependencies among the Vaal/Orange System (and other interlinked WMAs) relate to flow volume and flow regime in addition to water quality.

4.1 Upper Vaal WMA

4.1.1 Bio-physical Environment

The Upper Vaal WMA being centrally located in the country covers a catchment area of 55 562 km^2, and includes parts of Gauteng, Mpumulanga, Free State and North-West Provinces. It is the uppermost WMA in the Vaal River System and includes the major dams of Grootdraai and Vaal Dam of importance. The Upper Vaal WMA comprises nine sub-catchment areas as listed in **Table 1**. The WMA consists of the C11, C12, C13, C21, C22, C23, C81, C82 and C83 tertiary catchments. The location and general layout of the WMA is depicted in **Figure 10**.

Table 1: Sub-catchments and related quaternary drainage regions within the Upper Vaal WMA (*adapted* DWAF, 2002a)

PRIMARY CATCHMENT	SUB-CATCHMENT AREA	QUARTENARY CATCHMENTS	AVERAGE GROSS AREA (Km^2)
C	Wilge	C81A-M, C82A-H, C83A-M	18167
	Klip (Free State)	C13A-H	5182
	Grootdraai	C11A-L	7995
	Grootdraai to Vaal Dam	C11M,C12A-L	7294
	Suikerbosrand	C21A-G	3541
	Klip (Gauteng)	C22A-E	2282
	Rietspruit	C22J & C22H	1123
	Leeu/Taaibosspruit	C22F,C22G,C22K	1705
	Mooi	C23D-K	4494
	Vaal Barrage to Mooi	C23A-C,C23L	3239

<u>Topography, Vegetation and Climate</u>

The WMA is located on the South African plateau, with a general rolling topography. The Drakensberg mountains forms the eastern and boundary, while the Maluti Mountains are found to the south and the Witwatersrand in the north. The Upper Vaal catchment slopes from its highest elevation on the eastern boundary from about 1800m to 1450m to the west. The topography is flatter in the west than the east.

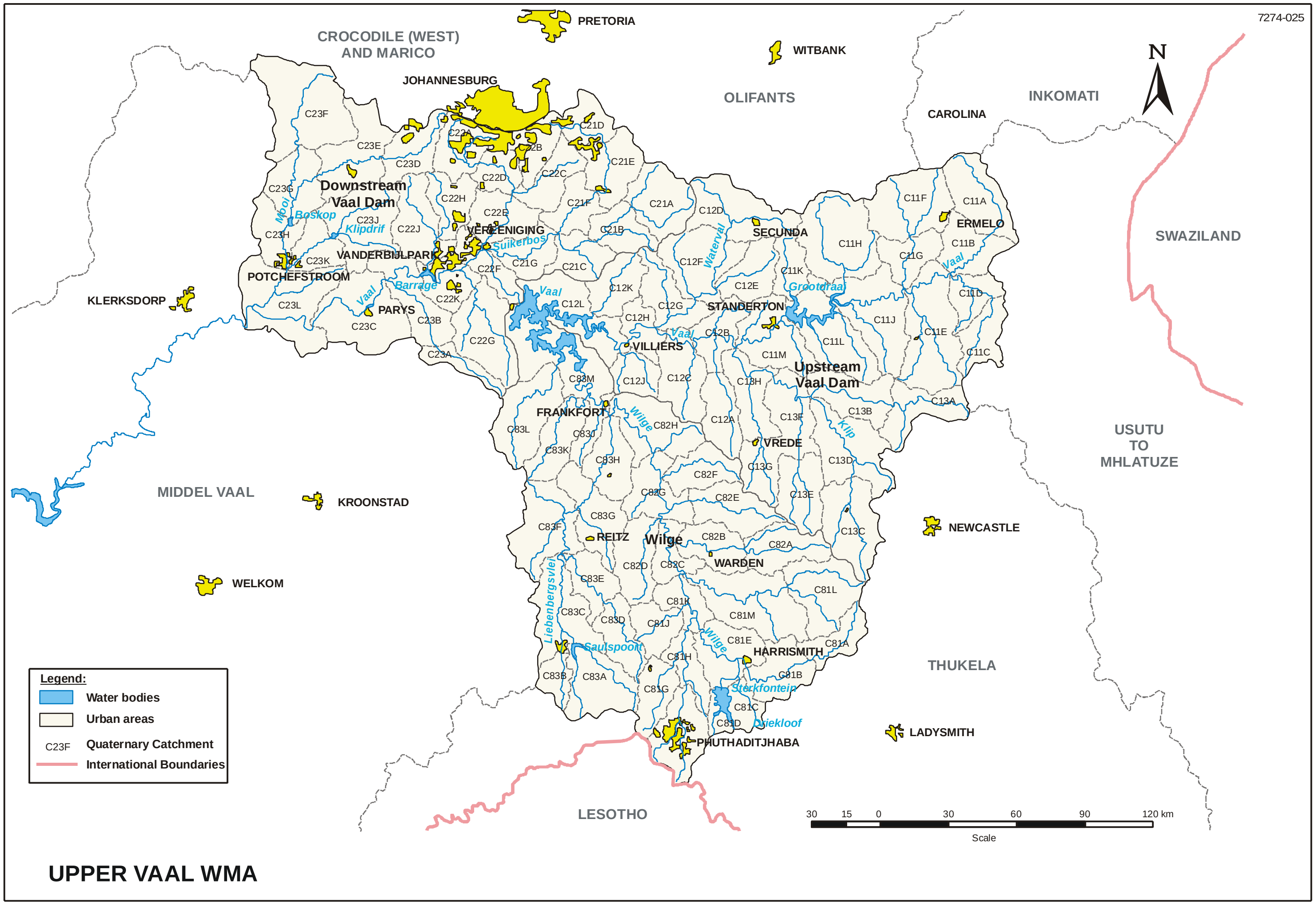

Figure 10: Location and general layout of the Upper Vaal WMA

OVERVIEW OF CATCHMENT AREA:
Upper Vaal WMA

Climate is relatively uniform over the Upper Vaal WMA. The average temperature for the WMA is 15˚C, with the mean annual temperatures ranging between 16˚C in the west to 12˚C in the east. Mean annual rainfall ranges between 600m and 800mm per year over most of the WMA and evaporation ranges between 1300mm and 1700mm per year. The dry western parts of the WMA experiences higher evaporation rates. The relative humidity is higher in summer than in winter as is the rainfall. The WMA is dominated by the "pure grassveld" veld type with some mixed agriculture. The Wilge River catchment does however exhibit a slightly different pattern which includes a "temperate and transitional forest and scrub" along the escarpment (DWAF, 2002). Maize and wheat are the main crops in the area.

4.1.2 Water Resource Systems

The Upper Vaal WMA has the Vaal River as its major river, contributing 46% of the surface flow in the WMA. The Upper Vaal catchment is fed by a number of tributaries of which the most significant are the Wilge River, Liebensbergvlei River, Klip, Waterval River, Suikerbos, Mooi River and Klip (Gauteng) (**Figure 10**). The Wilge and Liebenbergsvlei rivers contribute 36% of surface flow, while the remaining 18% of surface flow originates from the tributaries downstream of Vaal Dam. From a water resources point of view the most important tributaries are the Wilge and Liebenbergsvlei (Lesotho Highlands Water Project). Important wetlands occur along the Klip River and there are several vlei areas throughout the WMA. The Blesbokspruit wetland which occurs in the Suikerbosrand River catchment is the most highly impacted ecologically sensitive area in the Upper Vaal WMA.

The surface water resources occurring in the WMA has been well developed and the system is highly regulated. There are several large dams that have been developed (**Table 2**), allowing very limited potential for further development. The main dams include, Grootdraai Dam, Vaal Dam and Sterkfontein Dam.

Table 2: Major Dams in the Upper Vaal WMA (*adapted,* DWAF, 2003a)

Dam name	Quaternary catchment	River	Purpose	Full Storage Capacity (million m^3)
Boskop	C23G	Mooi	Irrigation	20.7
Douglas	C11F	Brummerspruit	Domestic	1.8
Fika-Patso	C81F		Domestic	28.0
Grootdraai	C11L	Vaal	Domestic	356.0
Klerkskraal	C23F	Mooi	Irrigation	8.3
Klipdrif	C23J	Loop Spruit	Irrigation	13.6
Saulspoort	C83A	Liebenbergsvlei	Domestic	16.9
Sterkfontein	C81D	Nuwejaarspruit	Domestic	2 617.0
Vaal	C22F	Vaal	Domestic	2 609.8
Vaal Barrage	C22K	Vaal	Domestic	55.4
Vrede	C13G	Spruitsonderdrif	Domestic	1.6
Water	C81F		Domestic	4.4

Large quantities of water are transferred into the WMA to augment local water resources. Transfers into the WMA are from the Thukela and Usutu to Mhlatuze WMAs and from the Senqu River in Lesotho. Transfers out of the WMA are to the Crocodile (West) to Marico and Olifants WMAs and through releases along the Vaal River to the Middle and Lower Vaal WMAs.

4.1.3 Demography

The Upper Vaal WMA has a population of about 5.6 million people (1995), which makes it the most populous WMA in the country (DWAF, 2004b). Most of the population (80%) reside in the area downstream of Vaal Dam, and about 97% live in the urban areas.

4.1.4 Developmental attributes

The Upper Vaal WMA is the most developed, industrialised and populous of all the Vaal WMAs. It is an economically important region of South Africa, contributing nearly 20% to its Gross Domestic Product, which is the second largest contribution to the national wealth amongst all nineteen of the WMAs in the country (DWAF, 2003c). The WMA displays a well diversified economy and a strong industrial and financial base. The largest contributing sectors in the WMA were manufacturing (31,6%), Trade (16,6%), Financial services (12,9%) and mining (10,8%) (DWAF, 2003a). Agriculture contributes a small percentage to the Gross Geographic Product (2%) however it is important to other sectors and supports much of the rural population. The WMA has potential for future economic growth.

It is also the pivotal WMA in the country from a water resource management perspective with large quantities of water being transferred into the WMA, out of the WMA and large quantities of water being released along the Vaal River to the Middle and Lower Vaal WMAs. Due to this high development and regulation of water resources in the WMA, only marginal potential for further water resource development remains.

4.1.5 Land Use

Land use in the WMA is characterised by expansive urban, mining and industrial areas in the northern and western parts between the Grootdraai Dam and Mooi River catchments. This urbanised area is situated mainly in the province of Gauteng and extends beyond the WMA boundary. Other development in the WMA relates to dry land agriculture. The WMA includes several large towns located around the mining, industrial and agricultural development areas.

About 1700km^2 land in the Upper Vaal WMA is currently used. Of this urbanisation accounts for 60% of that use, irrigation 17%, alien vegetation 20% and afforestation is negligible. The extent of dryland farming is unkwown (DWAF, 2003c).

The water requirements for the Upper Vaal WMA, were determined through the ISP process and for the year 2000 was found to be 2 424 million m^3/a (DWAF, 2004b).

Agricultural activities

The main agricultural activities in the WMA are dryland agriculture and livestock farming. Dryland cultivation comprising much of the agricultural activity occurring mainly in the central and south-western parts where maize, wheat and other annual crops are grown. There is also significant irrigation along the main river reaches.

Urban Areas

The urban areas occurring within the Upper Vaal WMA are listed in **Table 3** and their locations shown in **Figure 11**. The large metropolitan areas in the WMA include Germiston, Boksburg, Alberton, Benoni, Brakpan, Springs, and Nigel on the East Rand, Vereeniging, Vanderbijlpark, Sasolburg, Westonaria and Carletonville on the West Rand. These areas represent the most heavily populated areas of the WMA and all the areas are supplied by Rand Water via its bulk water network from the Vaal Dam. The large urban users are heavily dependent on water transferred into this WMA. Many of the urban and industrial areas were established around mining activities.

Other significant areas include Bethlehem, Harrismith and Phuthaditjhaba in the Wilge River sub-catchment, Highveld complex, Standerton and Ermelo in the Vaal River sub- catchment upstream of Vaal Dam and Potchefstroom in the Mooi River sub-catchment.

Table 3: Major towns in the Upper Vaal WMA

Quaternary	Urban Area/Town
Grootdraai sub-catchment:	
C11F	Ermelo
C11H	Bethal
Grootdraai to Vaal Dam sub-catchment:	
C11M	Standerton
C12D	Highveld Ridge (includes Secunda, Evander, Kinross, Trichardt)
C12H	Villiers
Klip Sub-catchment :	
C13G	Vrede
Suikerbosrand sub-catchment:	
C21B	Balfour
C21D	Benoni, Brakpan and Springs
C21E	Nigel
C21F	Heidelberg
Klip (Gauteng) sub-catchment:	
C22A	Soweto, Elderado Park, Lenasia (Greater Johannesburg)
C22B	Boksburg
C22D	Germiston
Vaal Dam to Barrage sub-catchment:	
C22F & H	Vereeniging
C22J & K	Vanderbijlpark
C22K	Sasolburg
Vaal downstream Barrage sub-catchment:	
C23C	Parys

Mooi sub-catchment:	
C23D	Westonaria
C23E	Carletonville
C23H	Potchefstroom
Wilge sub-catchment:	
C81E	Harrismith
C81F	Phuthditjhaba
C82B	Warden
C83C	Bethlehem
C83J	Frankfort

The urban areas contribute large volumes of sewage return flow to Vaal River. These return flows also carry significant pollution loads. A number of municipalities discharge wastewater into the catchment, particularly via the tributaries directly into the Vaal River. These wastewater discharges are listed in **Table 4**.

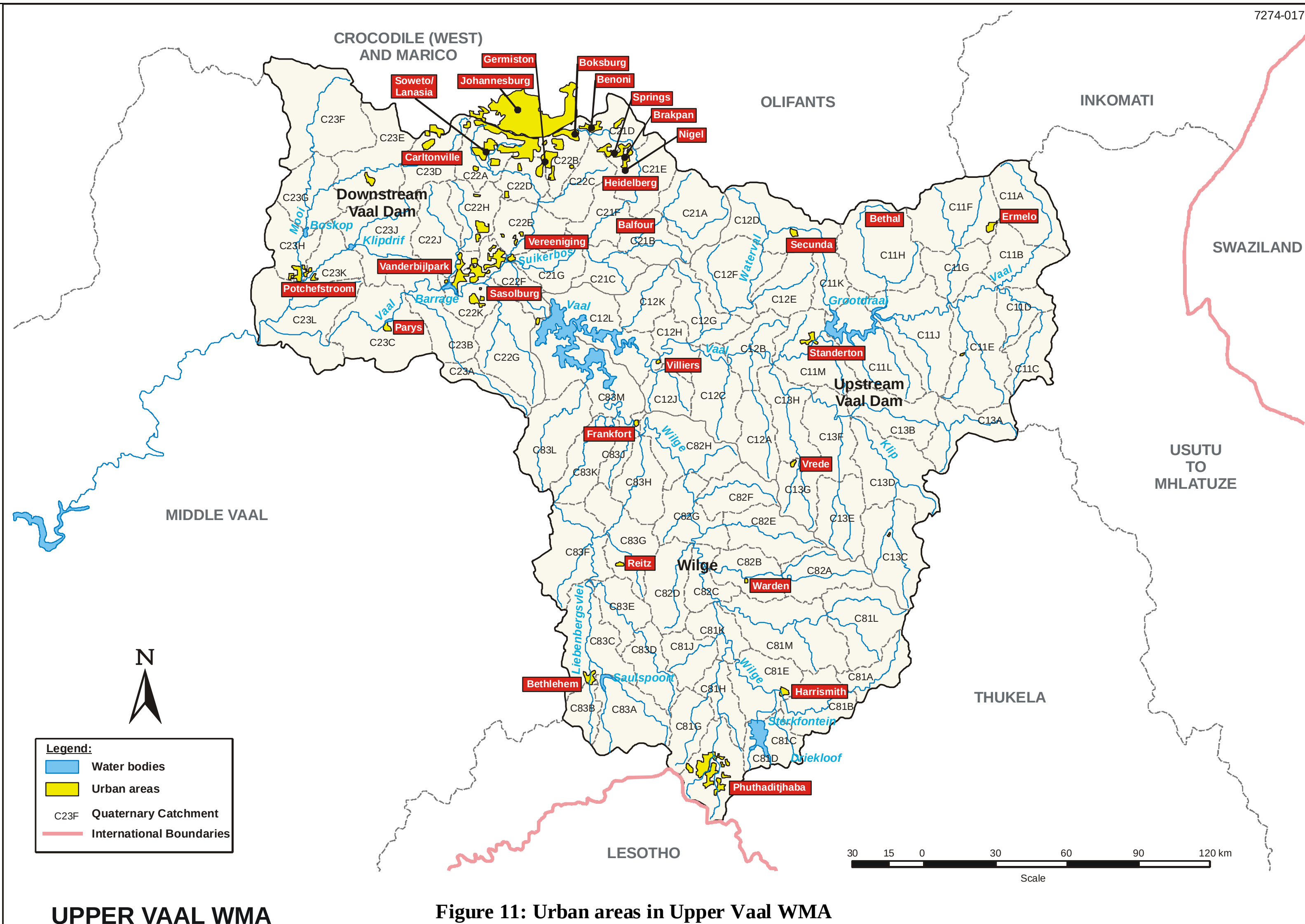

Figure 11: Urban areas in Upper Vaal WMA

Table 4: Municipalities in the Upper Vaal WMA that discharge wastewater directly into the Vaal River System

Wastewater treatment Plant	Municipality		Destination River	Discharge Volumes
	Local Municipality	Metro/District Municipality		Current discharge
Anchor	Ekurhuleni Metro	Ekurhuleni Metro	Blesbokspruit	20.91 Ml/day
Benoni	Ekurhuleni Metro	Ekurhuleni Metro	Blesbokspruit	10.55 Ml/day
Daveyton	Ekurhuleni Metro	Ekurhuleni Metro	Blesbokspruit	12.3 Ml/day
Dekema	Ekurhuleni Metro	Ekurhuleni Metro	Natalspruit	31.20 Ml/day
Carl Grindling	Ekurhuleni Metro	Ekurhuleni Metro	Blesbokspruit	1.73 Ml/day
Herbert Bickley	Ekurhuleni Metro	Ekurhuleni Metro	Blesbokspruit	5.4 Ml/day
Jan Smuts	Ekurhuleni Metro	Ekurhuleni Metro	Blesbokspruit	10.77 Ml/day
J P Marais	Ekurhuleni Metro	Ekurhuleni Metro	Blesbokspruit	10.00 Ml/day
Rondebult	Ekurhuleni Metro	Ekurhuleni Metro	Natalspruit	27.00 Ml/day
Rynfeld	Ekurhuleni Metro	Ekurhuleni Metro	Blesbokspruit	13.20 Ml/day
Tsakane	Ekurhuleni Metro	Ekurhuleni Metro	Blesbokspruit	7 Ml/day
McComb	Ekurhuleni Metro	Ekurhuleni Metro	Blesbokspruit	closed
Welgedacht	Ekurhuleni Metro	Ekurhuleni Metro	Blesbokspruit	4.8 Ml/day
Nigel Marivale	Ekurhuleni Metro	Ekurhuleni Metro	Blesbokspruit	0.3 Ml/day
Vlakplats	Ekurhuleni Metro	Ekurhuleni Metro	Rietspruit	62.00 Ml/day
Waterval	Ekurhuleni Metro	Ekurhuleni Metro	Rietspruit	60.00 Ml/day
Goudkoppies	City of Johannesburg	City of Johannesburg	Klipspruit	127.3 Ml/day
Olifantsvlei	City of Johannesburg	City of Johannesburg	Klip River	132 Ml/day
Bushkoppies	City of Johannesburg	City of Johannesburg	Harringtonspruit	103.7 Ml/day
Enerdale	City of Johannesburg	City of Johannesburg	Groot Riet	30.9 Ml/day
eMbalenhle	Highveld East	Govan Mbeki	Waterval River	4.8 Ml/day
Bethal	Highveld East	Govan Mbeki	Leeuspruit	9.0 Ml/day
Evander	Highveld East	Govan Mbeki	Grootspruit	6.6 Ml/day
Ratanda	Lesedi	Sedibeng	Blesbokspruit	0.5 Ml/day
Secunda	Highveld East	Govan Mbeki	Waterval River	6.4 Ml/day
Standerton	Lekwa	Govan Mbeki	Vaal River	
Ermelo	Msukaligwa	Govan Mbeki	Blesbokspruit	8.0 Ml/day
Meyerton	Emfuleni	Sedibeng	Klip	3.8 Ml/day
Iscor Vereeniging Klip Works	Emfuleni	Sedibeng	Vaal Barrage	
Iscor Vereeniging Vaal works	Emfuleni	Sedibeng	Vaal Barrage	
Leeuwkuil (Vereeniging)	Emfuleni	Sedibeng	Vaal River	7.5 Ml/day
Vanderbijlpark	Emfuleni	Sedibeng	Rietspruit	0.96 Ml/day
Sebokeng biofilter STW	Emfuleni	Sedibeng	Riet River	4.0 Ml/day
Sebokeng Nutrient removal	Emfuleni	Sedibeng	Riet River	20 Ml/day
Heidelberg	Lesedi	Sedibeng	Blesbokspruit	5.72 Ml/day
Potchefstroom	Potchefstroom	Southern District Municipality	Wonderfonteinspruit	22 Ml/day
Flip Human	Mogale City	West Rand	Wonderfonteinspruit	
Carletonville	Merafong City	West Rand	Wonderfonteinspruit	4.8 Ml/day
Fochville	Merafong City	West Rand	Loopspruit	4.6 Ml/day
Khustong	Merafong City	West Rand	Lower Wonderfonteinspruit	2.7 Ml/day
Villiers	Mafube	Northern Free State		
Rafenkgotso	Metsimaholo	Northern Free State		
Sasolburg (Sasol Bioworks)	Metsimaholo	Northern Free State	Vaal River	36 Ml/day
Parys	Ngwathe	Northern Free State	Vaal River	
Bethlehem	Maluti a Phofung	Thabo Mofutsanyane	Jordaan	
Harrismith/Phomolong	Maluti a Phofung	Thabo Mofutsanyane	Wilge River	
Matsoakeng	Maluti a Phofung	Thabo Mofutsanyane		
Qwaqwa	Maluti a Phofung	Thabo Mofutsanyane		
Memel	Phumelela	Thabo Mofutsanyane		
Vrede	Phumelela	Thabo Mofutsanyane		
Volksrust	Seme	Gert Sibande		
Phutaditjhaba			Tributary of Wilge	

Major industries and Power Stations

Extensive industrial and mining development occurs in the Upper Vaal WMA. This land use relates primarily to:

- Power stations (strategic users)
- Major industries
- Mining

Power Stations (Strategic Users)(**Table 5**):

There are three operational coal fired power stations (Eskom owned) in the WMA, namely Tutuka (C11), Majuba (C13) and Lethabo (C23) Power Stations. The power stations play a major role in the economy of the region but also have impacts as they are water intensive, requiring large volumes of water at high assurances of supply. The power stations do not discharge any effluent from their process circuits. Blow down water from the cooling circuits and stormwater from these complexes is collected for re-use. Typically the only discharge is from the wastewater treatment plant treating domestic sewage effluent before discharge.

Major Industries (**Table 5**)

Sasol Sasolburg (includes Sasol Midlands) is located in the Free State province near Sasolburg (C23) and until recently have abstracted water from the Vaal Barrage. This has stopped due to the deterioration of the water quality in the Vaal Barrage, with water now only being abstracted from Lethabo weir (Vaal Dam water). The production of petro-chemicals is the main activity.

Mittal Steel is located in Gauteng Province near Vanderbijlpark (C22) and abstracts raw water from the Vaal Barrage and Vaal Dam (Vereeniging pump station). The production of iron and steel products is the main activity. Sasol Secunda is located in Mpumalanga Province near the Secunda urban area (C12). Water for Sasol Secunda is supplied by pipeline from Grootdraai Dam. The requirement of this bulk user is the largest in the WMA. The production of petro-chemicals products is the main activity. Other important industries such as Sappi (C22) receive water from the urban centres where they are located.

These industries are major contributors to the economy of the country both in terms of contribution to GDP and to employment.

The location of the major industries are indicated in **Figure 12**.

Table 5: Major Industries in the Upper Vaal WMA

Drainage Region	Industry	Location	Source of Water	Bulk requirement ($10^6 m^3/a$)	Effluent discharged ($10^6 m^3/a$)	Destination River
C11K	Tutuka Power Station	Grootdraai Catchment	Grootdraai Dam	27	0.33 (wastewater treatment plant)	Leeuspruit
C13D	Majuba Power Station	Grootdraai Catchment (Vrede)	Slang River GWS (Zaaihoek transfer)	31	0.15 (wastewater treatment plant)	Geelspruit
C22K	Lethabo Power Station	Leeu-Taaibospruit catchment (Sasolburg)	Vaal River – Lethabo Weir	53	No effluent	-
C12F	Sasol II and Sasol III	Waterval Catchment (Secunda)	Grootdraai Dam	98	7.3	Bossiespruit to Waterval
C22K	Sasol I	Leeu-Taaibospruit catchment (Sasolburg)	Vaal River Rand Water	24	13	Vaal River
C22K	Sasol Midlands (Infrachem)	Leeu-Taaibosspruit catchment (Sasolburg)	Vaal River Rand Water	10	2.3	Taaibosspruit
C22J	Mittal Steel	Rietspruit catchment (Vanderbijlpark)	Vaal River/ Vaal Dam Rand Water	28	No effluent (stormwater discharge)	-
C22D	Sappi	Blesbokspruit cactchment (Springs)	Rand Water	11.7	9.9	Blesbokspruit

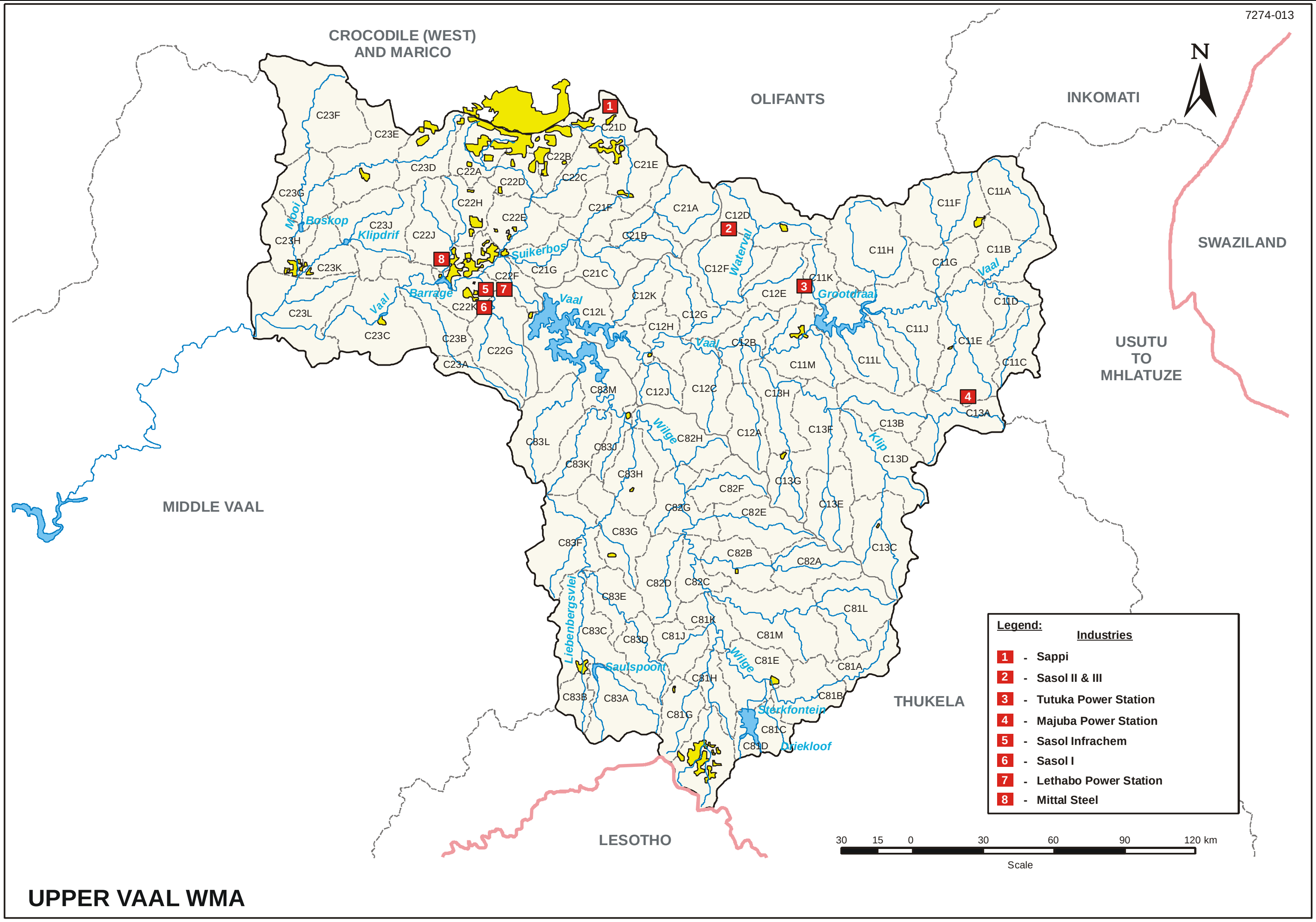

Figure 12: Location of major industries in the Upper Vaal WMA

Mining

Products of the mining industry in the Upper Vaal WMA include precious metals (e.g. gold, uranium.) base metals, semi-precious stones, industrial minerals and coal. The impact of mining on the economy of this area is significant. There are a number of mines currently operating in the WMA which are listed in **Table 6**.

Coal mining occurs in the Bethal to Secunda area (C11 and C12 tertiary catchments). Gold mining occurs in the upper Waterval catchment (Secunda area). The area downstream of the Vaal Dam is also characterised by a large number of mining activities ranging from gold mining to quarrying. These mining activities occur in the Klipspruit, Suikerbosrand, Vaal Dam to Vaal Barrage and Mooi sub-catchments (Grootvlei mine, Durban Roodepoort Deep, ERPM, Western Areas Gold Mine). Large gold mining operations are also located on the West Rand (e.g. Libanon, West Rand Consolidated, Driefontein, Blyvooruitzicht, Deelkraal, Kloof, Anglo Gold and Leeudoorn Gold Mines). Operating collieries are located in the Vereeniging-Vanderbijlpark-Sasolburg area adjacent to the Vaal River.

The location of the mines in the Upper Vaal WMA are indicated in **Figure 13.**

Table 6: Operating Mines in the Upper Vaal WMA (*adapted* DWAF, 2002)

Drainage Region	Mine	Location	Source of Water	Bulk water requirement ($10^6m^3/a$)	Mine pumpage & effluent discharge ($10^6m^3/a$)	Destination River
C13A	Volksrust area – mines (coal)	Near Majuba Power station	From Eskom		0.365	Schulpspruit
C11H/F	Bethal area – mines (coal)	Near Bethal	Municipality		0.024	Blesbokspruit
C11K	Tutuka Colliery	Near Power station	Grootdraai Dam	0.902	0.323	Leeuspruit
C12D	Evander Gold Mine	Secunda area	Vaal Dam (Rand Water)	0.33	1.27	Waterval River
C22B/C	East Daggafontein (Anglo Gold)	Brakpan / Springs	Blesbokspruit – direct Vaal Dam (Rand Water)	2.18 0.11	0	-
C22B/C	ERGO Daggafontein	Springs	Blesbokspruit – direct	0.42	0	-
C21D/E	Grootvlei Gold Mine (Petrex)	Springs	Rand Water		29.93	Blesbokspruit (started 95/96)
C22A	Durban Roodepoort Deep Gold Mine(mining has stopped)	Roodepoort	Vaal Dam (Rand Water)	0.12	5.63	Klip River
C21D	ERPM	Boksburg	Vaal Dam (Rand Water)	0.62	7.3	Elsburgspruit
C23D	Western Areas Gold Mine (PDWAJV)	Westonaria	Vaal Dam (Rand Water)	0.34	7.6	Leeuwspruit
C23D	Harmony Randfontein (Randfontein Estates Gold Mine)	Randfontein	Vaal Dam (Rand Water)	0.49	3.65	Loopspruit (joins Wonderfonteinspruit
C23GE	Elandsrand Gold Mining Co	Carletonville area	Vaal Dam (Rand Water)	`0.36	0.73	Tributary of Mooi River
C23J	West Wits (Western Deep Levels) Anglo Gold	Carletonville	Vaal Dam (Rand Water)	0.66	0	No discharge
C23G/E	Blyvooruitzicht Gold Mine	Carletonville	Vaal Dam (Rand Water)	0.22	3.65	Tributary of Mooi River
C23G/E	Driefontein Gold Mine	Carletonville	Vaal Dam (Rand Water)	0.17	9.49	Wonderfonteinspruit below pipeline
C23G/E	Doornfontein Gold Mine	Vicinity of Carletonville	Municipality		3.65	Wonderfonteinspruit
C22J	Kloof Gold Mine (Libanon and Kloof)	Carletonville / Potchefstroom	Vaal Dam (Rand Water)		12.41	Loopsruit/Wonderfonteinspruit via 1m pipeline
C23G/E	Leeudoorn Gold Mine	Carletonville / Potchefstroom	Vaal	0	0.15	Loopspruit

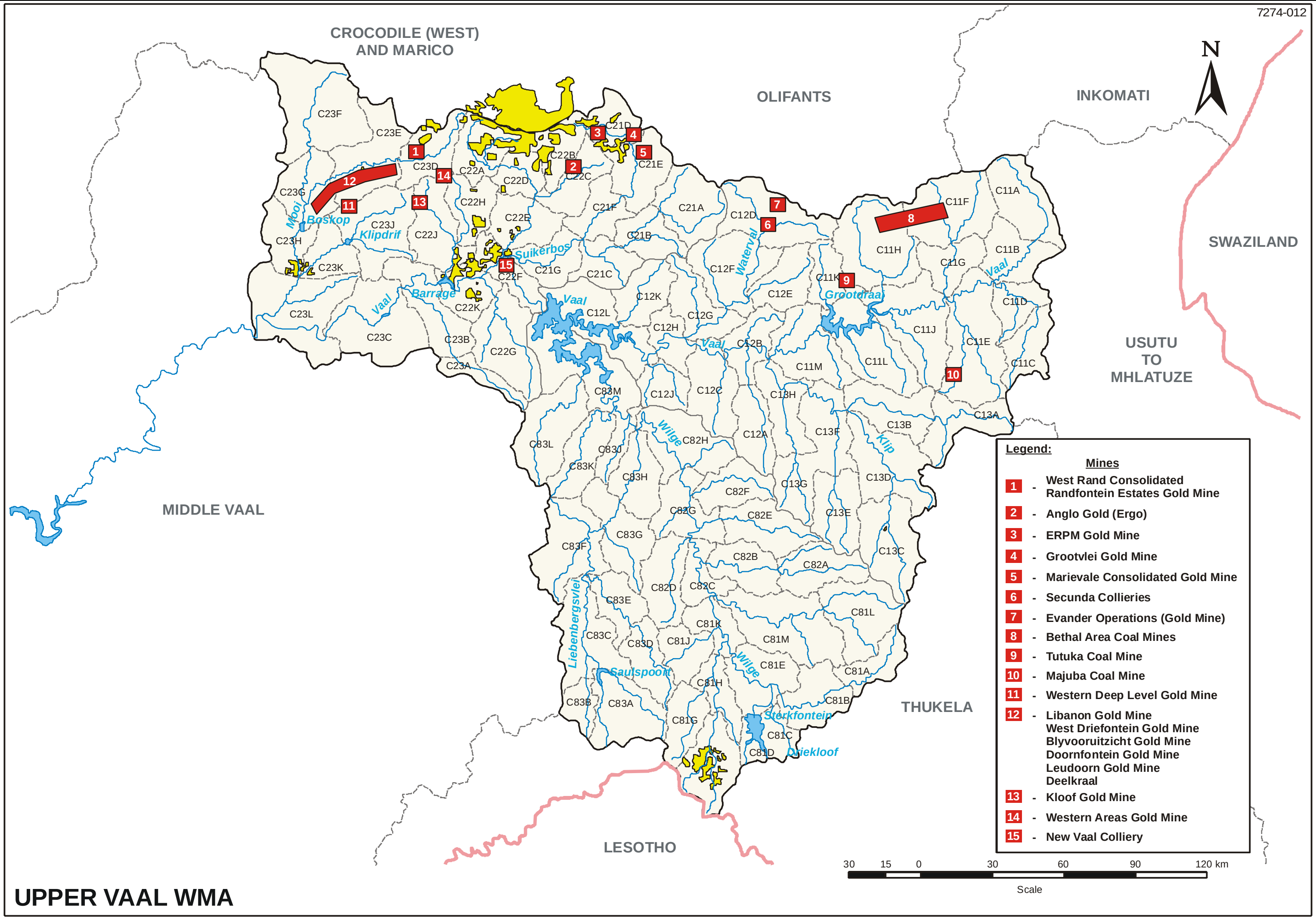

Figure 13: Location of major mines in the Upper Vaal WMA

4.2 Middle Vaal WMA

4.2.1 Bio-physical Environment

The Middle Vaal WMA forms part of the Orange River watercourse. It covers a catchment area of 52 563 km^2, and includes parts of the Free State and North-West Provinces. The Vaal River flows in a westerly direction to the Lower Vaal WMA. It is the middle WMA within the Vaal River System, with water being transferred *via* the Vaal River through this WMA to Bloemhof Dam, from the Upper Vaal WMA to the Lower Vaal WMA. The Middle Vaal WMA comprises eight sub-catchments as listed in **Table 7**. The WMA consists of the C24, C25, C41, C42, C43, C60 and C70 tertiary catchments. The location and general layout of the WMA is depicted in **Figure 14**.

Table 7: Sub-catchments and related quaternary drainage regions within the Middle Vaal WMA (*adapted* DWAF, 2002b)

PRIMARY CATCHMENT	SUB-CATCHMENT AREAS	QUARTENARY CATCHMENTS	AVERAGE GROSS AREA (Km^2)
C	Renoster	C70A-K	6656
	Vals	C60A-J	7871
	Schoonspruit	C24C-G	5644
	Middle Vaal	C24A-B, C24H-J, C25A-C	8281
	Bloemhof	C25D-F	4959
	Allemanskraal	C42A-E	3628
	Erfenis	C41A-E	4724
	Sand	C42F-L	3927
	Vet	C41F-J, C43A-D	6873

Topography, Vegetation and Climate

The WMA is relatively flat with no distinct features. Hilly terrain occurs to the south-east of the WMA. The Middle Vaal WMA ranges in elevation of about 2 200m as a maximum in the hilly upper reaches of the Vals River to a minimum elevation of about 1 250m in the area of Bloemhof Dam. The western parts of the WMA are characterised by pans and other drainage regions. The climate in the Middle Vaal WMA can vary considerably from west to east. The average temperature for the WMA is 16˚C, with the mean annual temperatures ranging between 18˚C in the west to 14˚C in the east. The overall feature of the mean annual precipitation over the WMA is that it decreases fairly uniformly westwards from the eastern escarpment regions to the central plateau area. Mean annual precipitation per year ranges between 500mm in the west and 700mm in the east of the WMA. Mean annual evaporation ranges from 1800mm in the east to a high of 2600mm per year in the dry western parts of the WMA, and is well in excess of rainfall. The relative humidity is higher in summer than in winter as is the rainfall. The WMA is dominated by the "pure grassveld" veld type with sparse bushveld in patches. The northern areas have some regions of "false grassveld", while the area upstream of Bloemhof Dam includes some "tropical bush and savanna". Maize, wheat and fodder crops are the main crops in the WMA.

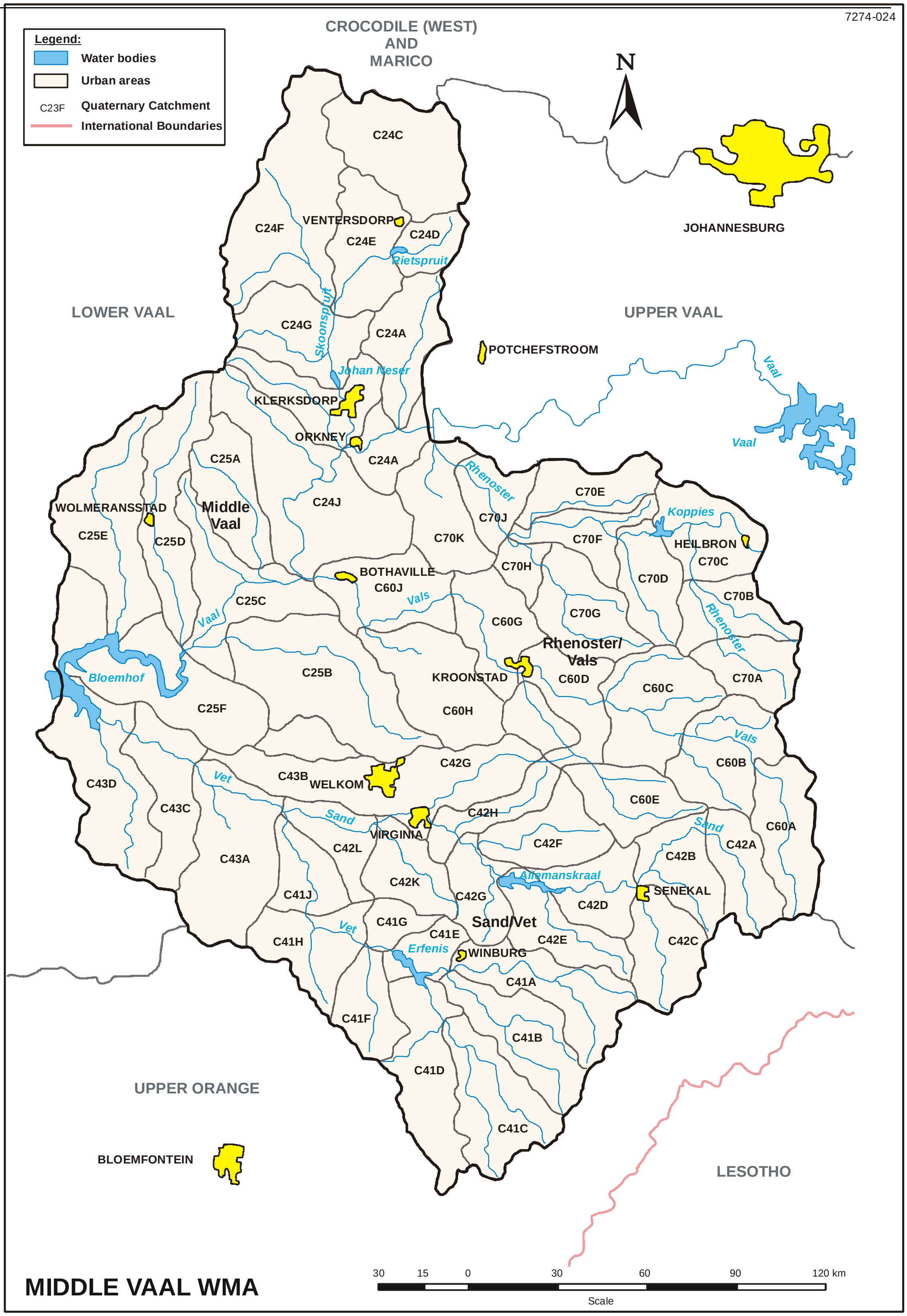

Figure 14: Location and general layout of the Middle Vaal WMA

4.2.2 Water Resource Systems

The surface flow of the Vaal River, most of which originates in the Upper Vaal WMA, represents the bulk of the surface water in the Middle Vaal WMA. The surface water flows that originate within the WMA are highly seasonal and intermittent. The Vaal River is fed by a number of tributaries of which the most significant are the Renoster, Schoonspruit, Vals and Vet Rivers (**Figure 14**). Vlei areas occur along the lower Vet River and in the upper Schoonspruit catchment.

The surface water occurring in the WMA has been developed to its potential and all water is being fully utilised. There are several large dams that have been developed (**Table 8**) in the WMA.

Table 8: Major Dams in the Middle Vaal WMA (*adapted,* DWAF, 2003b)

Dam name	Quaternary catchment	River	Purpose	Full Storage Capacity million m^3
Bloemhof	C91A	Vaal	Irrigation	1 218.0
Allemanskraal	C42E	Sand	Irrigation	179.3
Bloemhoek	C60D	Jordaan Spruit	Domestic	19.6
Erfenis	C41E	Vet	Irrigation	212.3
Johan Neser	C24G	Schoonspruit	Irrigation	5.7
Klipplaatdrift	C25A	Vaal		5.7
Koppies	C70C	Renoster	Irrigation	41.1
Marquard	C41A	Laai Spruit	Domestic	2.3
Rietspruit	C24D	Schoonspruit	Irrigation	7.3
Three Sisters	C42F	Sand		1.2
Uniefees	C70C	Eland Spruit	Domestic	1.4

The Middle Vaal WMA from a water resources perspective is dependant on the Upper Vaal WMA for meeting the bulk water requirements of its mining, industrial and urban sectors in the Klerksdorp-Orkney and Welkom-Virginia areas. Large quantities of water are transferred into the WMA to augment local water resources. The local water resources within the WMA are used by smaller towns (Bothaville and Wolmaranstad) and for irrigation. Some small transfers also occur from Vaal Dam to Heilbron in the Middle Vaal WMA and out of Erfenis Dam to the Upper Orange WMA. Water is also transferred via the Vaal River through this WMA to Bloemhof Dam, from the Upper Vaal WMA to the Lower Vaal WMA. Management of water quality and quantity in the Middle Vaal WMA is therefore integrally linked to both the Upper and Lower Vaal WMAs.

The water entering Middle Vaal WMA from the Upper Vaal WMA brings with it a large contribution of urban, industrial and mining return flows from the highly industrialised and urbanised areas within the Upper Vaal WMA. These carry with it high salinity levels and high nutrient concentrations which are “transferred” into the Middle WMA. As a consequence these high salinity levels need to be managed through dilution with fresh water from Vaal Dam to ensure water of an acceptable quality reaches the Middle Vaal WMA.

4.2.3 Demography

The Middle Vaal WMA has a population of about 1,5 million people (1995), with approximately 1,1 million being urban and 0,4 million being rural population (DWAF, 2004c). Most of the population (75%) reside in the urban areas of Klerksdorp, Orkney, Stilfontein (Schoon-Koekemoer sub-catchment), in Welkom and Virginia (Sand-Vet sub-catchment); and in Kroonstad in the Renoster/Vals sub-catchment.

4.2.4 Developmental attributes

The Middle Vaal WMA is rural in nature with the land use typically characterised by extensive livestock farming, dry land agriculture and some irrigation farming. The economy of the Middle Vaal WMA contributes about 4% of the GDP of South Africa with the most dominant economic activity being the mining sector, contributing more than 45% of the GDP in the WMA, trade (12,3%), and agriculture (8,9%) (DWAF, 2003d). Few of the gold mines in the area have a secure future beyond 2010, although the reserve base could support mining up to the year 2030 (DWAF, 2003b). Due to a decline in gold mining activity, a decline in population is also projected for the WMA, with a concomitant effect on the regional economy. Manufacturing activities in the WMA relate to the mining and agriculture sectors as well as items for local consumption. No dramatic changes to the economy of the WMA are foreseen for the medium term. The agricultural sector in the region is relatively stable and will continue to make an important contribution to the regional economy.

A minimal change in water requirements is therefore projected.

4.2.5 Land Use

The present character of land use in the WMA has been shaped by the discovery of diamonds in the north-western part of the WMA around 1870, and of gold in Klerksdorp, Welkom and Virginia in the late 1800s. Cultivation of land began around the 1930's (DWAF, 2003d). Current land use in the WMA is characterised by extensive dry land cultivation in the central parts of the WMA. The largest urban areas are Welkom, Klerksdorp (North West Goldfields) and Kroonstad (Free State Goldfields). Irrigation is practiced downstream of dams and along the main tributaries and at locations along the Vaal River. The WMA is characterised by a large number of goldmines.

About 530km^2 land in the Middle Vaal WMA is currently used. Of this urbanisation accounts for 47% of that use, irrigation 39% and alien vegetation 13% (DWAF, 2002b).

The water requirements of the Middle Vaal WMA were determined through the ISP Process and for the year 2000 was found to be 872 million m^3/a (DWAF, 2004c).

<u>Agricultural activities</u>

Agriculture is one of the main activities in this WMA. The irrigation of crops such as wheat, maize and fodder crops occurs throughout the WMA. The Sand-Vet Government Water Scheme is the most important irrigation area in the WMA. Irrigated crops include maize, groundnuts, sorghum and sunflowers.

Urban Areas

The urban areas occurring within the Middle Vaal WMA are listed in **Table 9** and their locations shown in **Figure 15.** These areas are mainly concentrated in the North West Goldfields area and Free State Goldfields. The WMA exhibits relatively little urbanisation with the largest urban area being Welkom. Other urban areas include Klerksdorp, Stilfontein, Kroonstad, Winburg, Marquard, Senekal, Lindley, Bothaville, Viljoenskroon, Heilbron, Virginia, Makwassie, Wolmaranstad, Leeudoringstad, Ventersdorp and Orkney. The Midvaal Water Company is the major supplier of bulk water to the areas in the North West Goldfields and while Sedibeng Water is the major supplier of bulk water to the Free State Goldfields.

Table 9: Major towns in the Middle Vaal WMA

Quaternary	Urban Area/Town
Schoonspruit sub-catchment area:	
C24A	Stilfontein
C24B	Orkney
C24H	Klerksdorp
C24E	Ventersdorp
C24F	Coligny
Bloemhof sub-catchment area:	
C25B	Odendaalsrus
C25D	Wolmaransstad
Sand Vet sub-catchment area:	
C42J	Virginia
C43B	Welkom
Allemanskraal sub-catchment area:	
C42B	Senekal
Erfenis sub-catchment area:	
C41A	Winburg
Vals sub-catchment area:	
C60D	Kroonstad
C60J	Bothaville
Renoster sub-catchment area:	
C70C	Heilbron
C70D	Koppies

The urban areas contribute sewage return flows to Vaal River. These return flows also carry significant pollution loads. A number of municipalities discharge wastewater into the catchment, particularly via the tributaries directly into the Vaal River. These wastewater discharges are shown in **Table 10**.

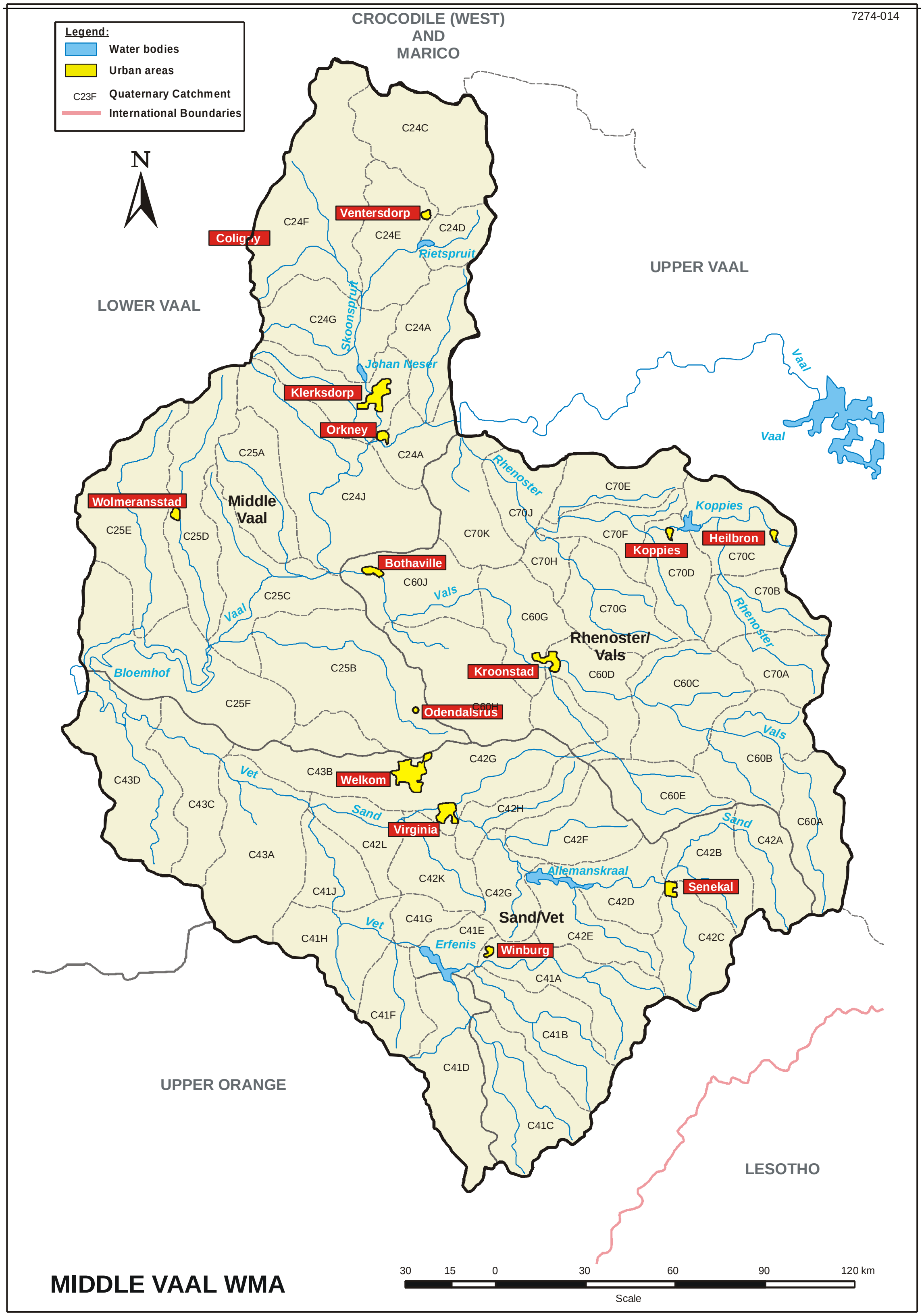

Figure 15: Urban areas in Middle Vaal WMA

Table 10: Municipalities in the Middle Vaal and Upper Orange WMAs that discharge wastewater directly into the Vaal River System

Wastewater treatment works	Municipality		WMA	Water Use Authorisation	Destination River	Discharge Volumes
	Local Municipality	District Municipality				Current discharge
Henneman	Matjhabeng	Lejweleputswa	Middle Vaal	Exemption		
Kerkhof	Matjhabeng	Lejweleputswa	Middle Vaal			
Thabong	Matjhabeng	Lejweleputswa	Middle Vaal	Exemption	Mosterd Canal	
Theronia	Matjhabeng	Lejweleputswa	Middle Vaal	Exemption	Toronto Pan	
Ventersburg	Matjhabeng	Lejweleputswa	Middle Vaal	Exemption	Spruit end in Sand River	
Virginia	Matjhabeng	Lejweleputswa	Middle Vaal	Exemption	Sand River	
Witpan (Welkom)	Matjhabeng	Lejweleputswa	Middle Vaal	Exemption	Sand River	
Koppies	Ngwathe	Northern Free State	Middle Vaal	Exemption	Renoster River	
Orkney & Kana	City Council of Klerksdorp	North West Region	Middle Vaal	Exemption	Schoonspruit	25.4 Ml/day
Stilfontein	City Council of Klerksdorp	North West Region	Middle Vaal	License	Koekemoerspruit	6.32 Ml/day
Klerksdorp	City Council of Klerksdorp	North West Region	Middle Vaal	License	Schoonspruit	17.0 Ml/day
Ventersdorp	City Council of Klerksdorp	North West Region	Middle Vaal		Schoonspruit	8.0 Ml/day
Makeleketle	Masilonyana	Lejweleputswa	Middle Vaal	Oxidation Ponds	Irrigated	none
Verkeerdevlei	Masilonyana	Lejweleputswa	Middle Vaal	Oxidation Ponds	Irrigated	none
Kroonstad	Moqhaka	Northern Free State	Middle Vaal	Exemption		
Bothaville	Nala	Lejweleputswa	Middle Vaal	License	Vals River	
Heilbron	Ngwathe	Northern Free State	Middle Vaal	Exemption	Elandspruit	
Senekal	Setsoto	Thaba Mofutsanyana	Middle Vaal	Exemtion	Sand River	
Midvaal Water		North West Region	Middle Vaal	Section 21 Company	Vaal River	0,3ML/day
Bloemspruit	Manguang	Motheo	Upper Orange	Exemption	Bloemspruit	72 Ml/day
Welvaart	Manguang	Motheo	Upper Orange	Expired	Nameless tributary of Kaalspruit	3.9 Ml/day
Sterkwater	Manguang	Motheo	Upper Orange	Expired	Renosterspruit	10.5 Ml/day
Botshabelo	Manguang	Motheo	Upper Orange	Expired	Klein Modder	14.7 Ml/day
Northern Works	Manguang	Motheo	Upper Orange	Expired	Unnamed stream	0.5 Ml/day
Bainsvlei	Manguang	Motheo	Upper Orange	Expired	Stormwater channel to dam	4.0 Ml/day
Thaba Nchu	Manguang	Motheo	Upper Orange	Expired	Sepane spruit	

Major industries and Power Stations

Major mining development occurs in the Middle Vaal WMA, with industrial users being very limited. There are no operational power stations in this WMA.

Major Industries:

There are no major industries in this WMA. There are some other bulk users which are small users (e.g. farmers, rural institutions) that receive water from Sedibeng Water and from Midvaal Water Company.

Mining

This WMA is characterised by a large number of gold mines (Free State Goldfields area and North West Goldfields area) especially in the KOSH area (Klerksdorp-Orkney-Stilfontein-Hartbeesfontein area). Products of the mining industry in the WMA include precious metals (gold, uranium, etc.), base metals, semi-precious stones and industrial minerals. There are five major gold mines active in the area and several diamond mine activities (varying from small scale one man operations to larger scale operations) which are listed in **Table 11**.

The location of the major mines is shown in **Figure 16**.

Table 11: Operating Mines in the Middle Vaal WMA (*adapted* DWAF, 2002)

Drainage Region	Mine	Location	Source of Water	Bulk requirement ($10^6 m^3/a$)	Mine pumpage & effluent disc. ($10^6 m^3/a$)	Destination River of mine effluent or groundwater decanted
C24A	Buffelsfontein Gold Mine (DRD)	Near Stilfontein	Vaal River (Midvaal)	11.4	2.92	Koekemoerspruit
C24A	Stilfontein Gold Mine	Stilfontein	Vaal River (Midvaal)	0.2	13.5	Koekemoerspruit
C24B	AngloGold Vaal Reefs Gold Mine	Buffelsfontein / Orkney area	Vaal River (direct)		<0.365	Vaal River
C24B	Harmony Vaal Reefs	Buffelsfontein / Orkney area	Vaal River (Midvaal)		0.73	Koekemoerspruit
C24A	Hartebeestfontein Gold Mine	Klerksdorp area	Vaal River (Midvaal); Groundwater (Margaret shaft)	8.2	0	Slimes dams
C24J	Vierfontein Colliery (defunct)	South of Orkney		0	1.10	Vierfonteinspruit
C25B	Avgold Mine (prev. Loraine Gold) Mine (JR Mining)		Vaal River (Sedibeng)	2.2	0	Not known
C42H	Harmony Gold Mines (Erfdeel, Unisel, Saaiplaas)	Virginia	Vaal River (Sedibeng)	15.4	0	Seepage into system possible
C41J	Beatrix Gold Mine (Gencor)	South of Virginia	Vaal River (Sedibeng)	1.5		Theronspruit
C42K	Joel Gold Mine (JCI)	South of Virginia	Vaal River (Sedibeng)	0.9		Theronspruit
C43A	Oryx Gold Mine (Gencor)	South of Virginia	Vaal River (Sedibeng)	0.5		Bosluisspruit
C41G	Star Diamonds	South of Virginia	Vaal River (Sedibeng)	0.1	0	Not known
C42L	St Helena Gold Mines	Welkom	Vaa River (Sedibeng)	2.1	0	Not known
C42J	Anglogold Ashanti	Welkom	Vaal River (Sedibeng)	0.02	0	Not known

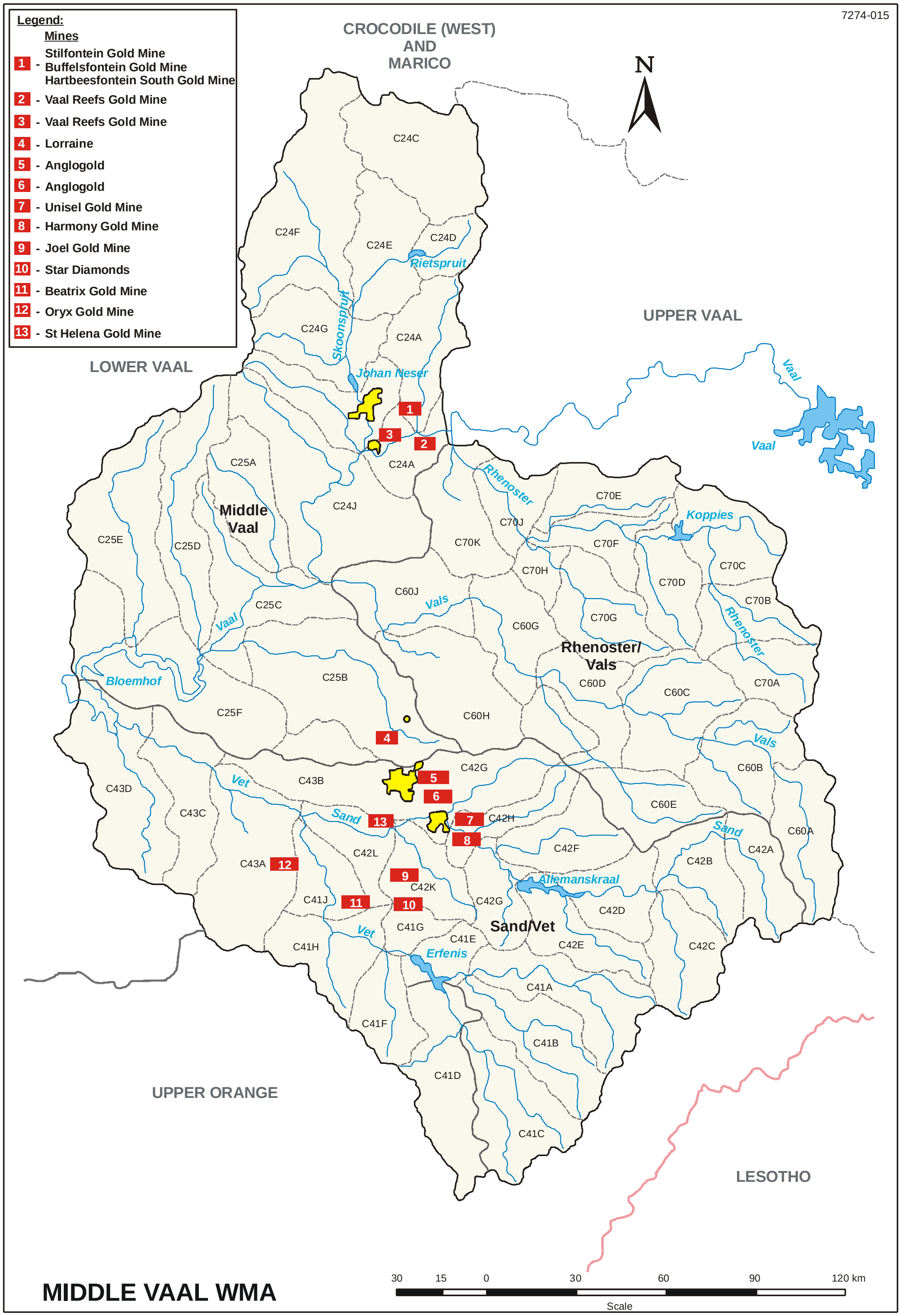

Figure 16: Major mines in the Middle Vaal WMA

4.3 Lower Vaal WMA

4.3.1 Bio-physical Environment

The Lower Vaal WMA is situated in the north-western part of the country and forms part of the Orange River watercourse. It covers a catchment area of 133 354 km^2, and includes parts of the Northern Cape and North-West Provinces, and a small part of the Free State Province. The Vaal River is the only major river in the WMA, as it flows in a westerly direction from Bloemhof Dam to the confluence with the Orange River. The largest part of the WMA falls within the catchment of the Molopo River, a tributary of the Orange River. The Molopo, Nossob and Kuruman rivers drain the remainder of the WMA but due to the very low rainfall in the WMA, these rivers are insignificant. The WMA consists of the D41 (excluding D41A), parts of D42C and D42D, parts of D73A and D73C, C31, C32, C33, C91, and C92 tertiary catchments. For the purpose of this study only the C drainage region is of relevance as it forms part of the Vaal River System, which includes the Harts River catchment and the Vaal River catchment. These two catchments as part of the Vaal River System cover a catchment area of 53 500km^2 within the Lower Vaal WMA. The C drainage region of the Lower WMA comprises four sub-catchments as listed in **Table 12**. The location and general layout of the WMA is depicted in **Figure 17**.

Table 12: Sub-catchments and related quaternary drainage regions within the C Drainage tertiary Catchment within the Lower Vaal WMA (*adapted* DWAF, 2003c)

PRIMARY CATCHMENT	SUB-CATCHMENT	QUARTENARY CATCHMENTS	AVERAGE GROSS AREA (Km^2)
C	Dry Harts	C32A-D	10 205
	Harts	C31A-F	11 023
	Vaalharts	C33A-C	9843
	Vaal downstream Bloemhof	C91A-E, C92A-C	22 427

<u>Topography, Vegetation and Climate</u>

As in the Middle Vaal WMA, this WMA has relatively flat terrain with no distinct topographic features. The WMA has no climatic barriers and thus climate varies gradually according to the larger regional patterns, and is fairly uniform from east to west. The average temperature for the WMA is 16˚C. The rainfall is strongly seasonal occurring mainly in the summer months. The overall feature of the mean annual precipitation over the WMA is that it decreases fairly uniformly westwards from the western parts of the North West Province to the eastern parts of the Northern Cape Province. Mean annual rainfall precipitation ranges between 100mm in the west and 500mm to the east of the WMA. Mean annual evaporation can reach as high as 2800 mm per year which is in excess of rainfall.

As a result of the arid climate, vegetation over the WMA is sparse, consisting mainly of grassland and some thorn trees (notably the majestic camel thorns). The WMA is dominated by tropical bush and savannah with small areas of pure grassveld to the east.

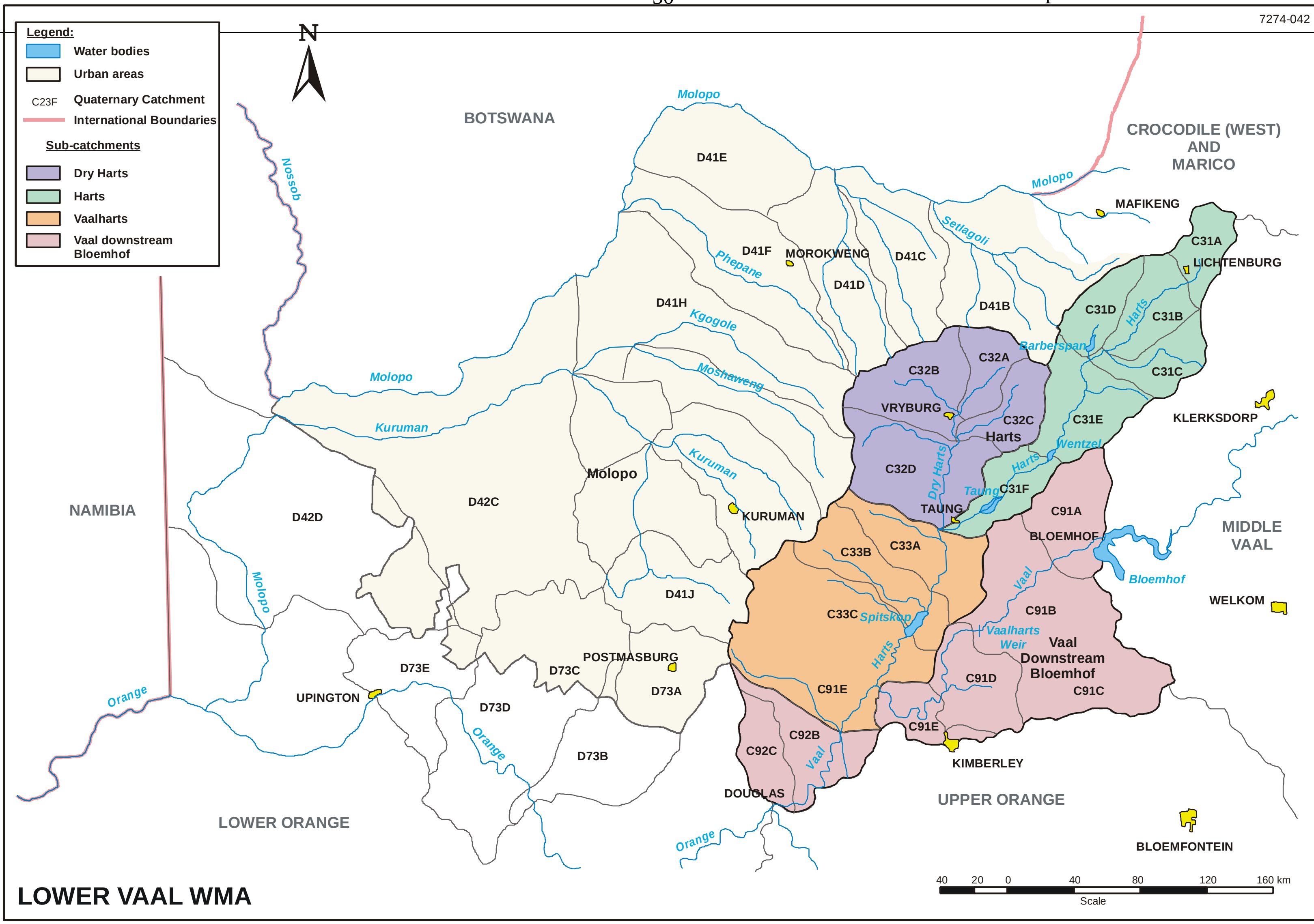

Figure 17: Location and general layout of the Lower Vaal WMA

OVERVIEW OF CATCHMENT AREA: Lower Vaal WMA

4.3.2 Water Resource Systems

Virtually all the surface flow of the Vaal River, the main source of water in the Lower Vaal WMA, originates from the Upper and Middle Vaal WMAs. Very little surface run-off originates within the WMA itself due to the low rainfall, flat topography and sandy soils. The groundwater resource is more substantial, supplying an estimated 128 million m^3/annum. The Vaal River is fed by the only tributary, the Harts River which drains a catchment area of 31 000km^2, with the Dry Harts being the major tributary of the Harts River, joining it just downstream of Taung. The only lake and wetlands of note are at Barberspan in the Upper Harts River catchment which has been given Ramsar status as a wildlife conservation area.

Large quantities of water are transferred from the Vaalharts weir on the Vaal River to supply the Vaalharts irrigation scheme in the Harts River catchment. The Vaalharts Irrigation scheme generates irrigation return flows which enter the Harts River upstream of Spitskop Dam. The return flows contribute salinity and nutrients to the Harts River.

The development of the surface water resources occurring in the WMA has reached its potential, however all water is not being fully utilised. The water in Taung Dam and Spitskop Dam are currently not utilised and further studies are required to determine best how to utilise the water contained in these dams. There are several large dams that have been developed in the WMA. The main dams are listed in **Table 13.**

Table 13: Major Dams in the Lower Vaal WMA (*adapted*, DWAF 2003c)

Dam name	Quaternary catchment	River	Purpose	Full Storage Capacity million m^3
Boegoeberg	D73B	Oranje	Irrigation	20.3
Douglas Weir	C92B	Vaal	Information	16.7
Spitskop	C33B	Harts	Irrigation	56.6
Taung Dam	C31F	Harts	Irrigation	6.6
Vaalharts Weir	C91B	Vaal	Domestic	48.7
Wentzel	C31E	Harts	Irrigation	6.6

The Lower Vaal WMA is dependant on the Upper Vaal and Middle Vaal WMAs for supply of utilisable surface water resources, with over 90% of the water required being sourced through releases from the Upper Vaal WMA and from Bloemhof Dam. More than 50% of the yield from natural water resources in the tributary catchments within the WMA is supplied from groundwater.

Most of the water is used for urban, agricultural and mining purposes within the WMA. Water is also transferred into the WMA from the Upper Orange WMA into Douglas Weir. The water quality of the rivers in the WMA is of acceptable quality, but do exhibit high turbidity at times.

4.3.3 Demography

The Lower Vaal WMA has a population of about 1,3 million (1995), with approximately 0,7 million being urban and 0,6 million being rural population (DWAF, 2004d). The largest concentration of urban population is in Kimberley. There are large rural populations in areas west of Mafikeng, around Kuruman, Pampierstad and Lichtenberg.

4.3.4 Developmental attributes

The economy of the Lower Vaal WMA is relatively small, with the WMA generating about 2% of the Gross Domestic Product of South Africa (DWAF, 2003e). The economy is still dominated by mining, however much of the beneficiation is done in other areas. Kimberley is the largest urban centre in the area. Most of the economic activity is concentrated in Kimberley and at other major mining areas. Manufacturing activities in the WMA include cement and cheese factories and relate to the agriculture sectors as well as items for local consumption. The trade sector is concentrated in wholesale of primary products and related services to the community. No significant changes to the economy of the WMA are foreseen over the medium term. The agricultural and mining sectors in the region are strong and will continue to make an important contribution to the regional economy.

As is in the Middle Vaal WMA, the Lower Vaal WMA also shows minimal potential for strong economic growth, and thus a low population growth is projected. Consequently, limited growth in water requirements is expected.

4.3.5 Land Use

Early development in the Lower Vaal WMA began in the early 1800's with large scale cultivation, and was later influenced by the discovery of diamonds near Kimberly and later in Bloemhof/Christiana. Another major development which influenced the present character of development was the establishment of the Vaalharts irrigation scheme in the mid 1930s. Current land use in the WMA, due to the arid climate is characterised by extensive livestock farming as the main activity and large scale dry land cultivation in the north eastern part of the WMA. Intensive irrigation (about 80% of water use) is practised at Vaalharts, as well as at locations along the Vaal River. The most significant urban area in the WMA is Kimberley to the South, which borders on the Upper Orange WMA as well. Several towns as well as scattered rural settlements are found mainly in the central and eastern part of the WMA. Iron ore, diamonds and manganese are mined in the WMA.

About 1 220 km^2 of the land in the Lower Vaal WMA is currently used. Of this urbanisation accounts for 23% of that use, irrigation 40% and alien vegetation 37% (DWAF, 2002e). The water requirements for the Lower Vaal WMA were determined through the ISP process and for the year 2000 was found to be 595 million m^3/a (DWAF, 2004d).

Agricultural activities

Agricultural land use within the Lower Vaal WMA is dominated by stock farming. The reason for this is that most of the area is too dry to support dry-land crops. Livestock farming includes beef and dairy cattle, goats, non-wooled sheep, pigs and ostriches. In the east of the WMA, especially in the vicinity of Lichtenberg and Delareyville, dry-land crops (maize, sunflower, cotton, groundnuts and vegetables) are grown, but it is debatable whether or not this is commercially viable due to the low and erratic rainfall. There are large areas under irrigated crops in the Vaalharts area, but compared to the total area of the WMA, this area is small. The largest irrigation scheme is the Vaalharts Government Water Scheme, which is supplied via the Vaalharts weir with support from Bloemhof Dam. It is generally recognised that future growth in irrigation will be severely limited by the availability of water. In more water-scarce areas it may even become necessary to curtail some irrigation to meet the growing requirements of domestic and urban water use.

Urban Areas

The urban areas occurring with the Lower Vaal WMA are listed in **Table 14** and shown in **Figure 18**. The WMA exhibits very little urbanisation with the significant urban areas being Kimberley in the South, which lies only partly in the WMA, Lichtenburg in the north-east and Kuruman in the central part of the WMA. Other towns include Schweizer Reineke, Jan Kempdorp, Pampierstad, Christiana, Warrenton, Riverton, Delportshoop, Olifantshoek and Postmasburg. The Kalahari East Water Board and the North West Supply Authority are two water boards responsible for supplying bulk water to the users in the areas in the WMA. The large urban users are heavily dependent on water transferred into this WMA from the Upper Vaal WMA.

Table 14: Major towns in the Lower Vaal WMA

Quaternary	Towns
Dry Harts sub-catchment area:	
C32A	Stella
C32B	Vryburg
Harts sub-catchment area:	
C31A	Lichtenburg
C31E	Delareyville
C31F	Taung
Vaalharts sub-catchment area:	
C33A	Pampierstad
C33B	Jan Kempdorp
Vaal downstream Bloemhof sub-catchment area:	
C91A	Bloemhof
C91B	Christiana & Hertzogville
C91C	Boshof
C91D	Warrenton
C91E	Kimberley
C92C	Douglas

Some municipalities discharge wastewater into the catchment, via the Harts River or directly into the Vaal River. These wastewater discharges are shown in **Table 15**.

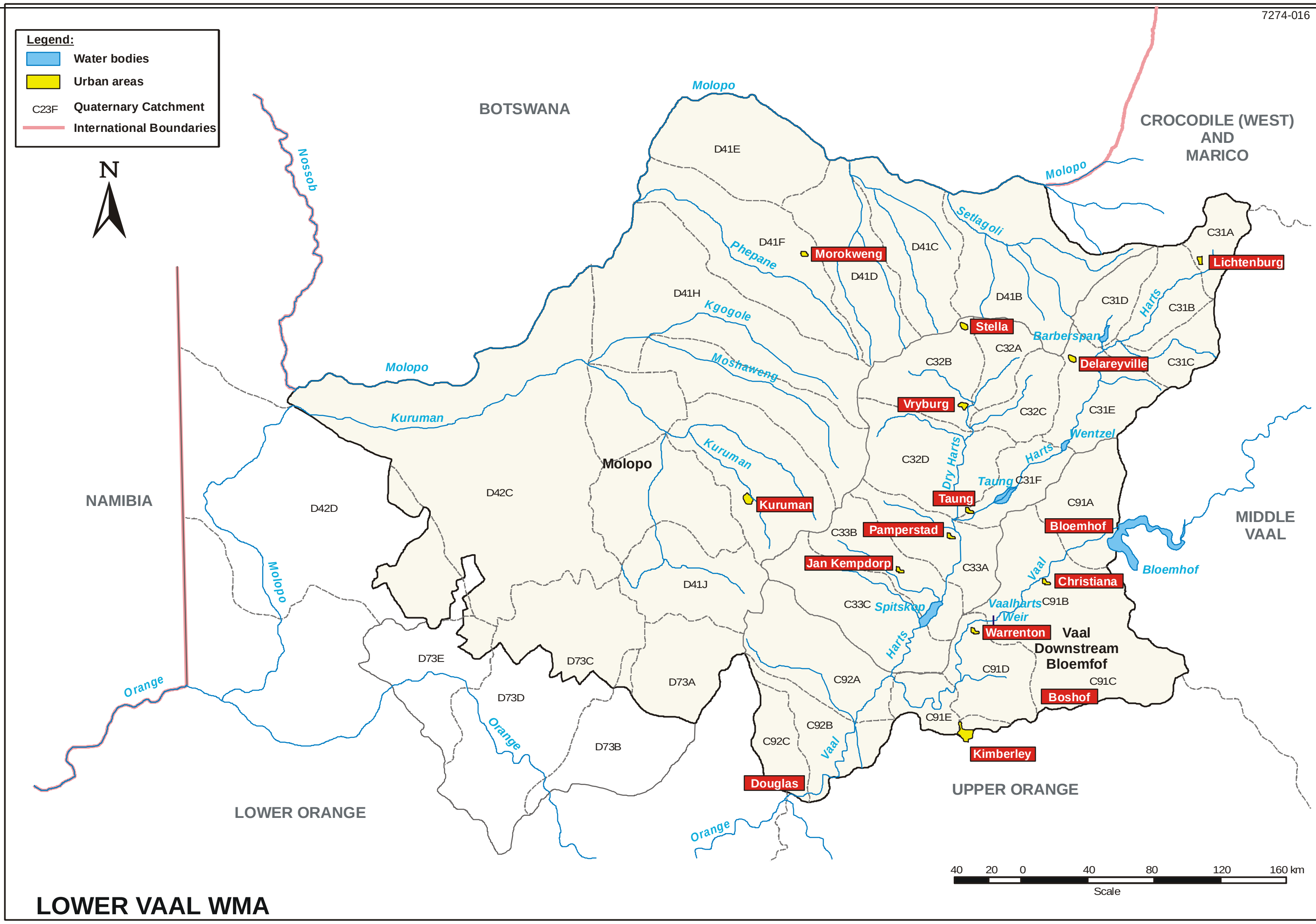

Figure 18: Major towns in Lower Vaal WMA

OVERVIEW OF CATCHMENT AREA: Lower Vaal WMA

Table 15: Municipalities in the Lower Vaal WMA and their respective wastewater management practices

Municipality			Treatment technology	WMA	Current Water Use Authorisation	Discharge - Destination River	Discharge Volumes
Town	Local Municipality	District Municipality					Current discharge
Bloemhof	Lekwa Teemane	Bophirima	Activated sludge	Lower Vaal	None	Vaal River	No flow meter
Christiana	Lekwa Teemane	Bophirima	Oxidation ponds	Lower Vaal	None	Vaal River	
Warrenton	Magareng	Frances Baard	Activated sludge	Lower Vaal		Vaal River	No flow meter
Vryburg	Naledi	Bophirima	Activated sludge	Lower Vaal	None	Small stream - Harts River	$4.5m^3$
Taung	Greater Taung	Bophirima	Oxidation ponds	Lower Vaal	None	No discharge	
Ottosdal	Tswaing	Central	Oxidation ponds	Lower Vaal	None	No discharge	
Delareyville	Tswaing	Central		Lower Vaal			
Pampierstad	Phokwane	Bophirima	Activated sludge	Lower Vaal	None		
Schweizer Reneke	Mamusa	Frances Baard	Ponds systems	Lower Vaal		No discharge	
Jan Kempdorp	Phokwane	Frances Baard	Activated sludge	Lower Vaal		No discharge	
Barkley West	Dikgatlong	Frances Baard	Ponds systems	Lower Vaal		Groenwaterspruit	
Hartswater	Phokwane	Frances Baard					

Major industries, Mines and Power Stations

There are no power stations or major water consuming industries within the Lower Vaal WMA.

Mines and Industries

There are a number of manganese and iron mines in the Lower Vaal WMA which have significant water requirements. These are all situated in the dry north-west section of the WMA (Listed in **Table 16** below and indicated in **Figure 19** in the D primary drainage region, but are supplied with water from the Vaal River System by the Vaal Gamagara Transfer Scheme. The other significant mines are the Finsch Diamond mine and Iscor's iron ore mine near Sishen. Iscor also make use of ground water to meet their water requirements. The De Beer's Finsch Diamond Mine is the only mine situated within the study area of Vaal River System (primary drainage region C). The only major industry of note in the WMA and within the study area is the lime works (PPC factory) situated at Lime Acres just outside Postmasburg.

Table 16: Mines in the Lower Vaal WMA (DWAF, 2002c)

Mine
Iscor (Sishen)
Middelplaas Manganese
De Beers Consolidated Mines (Finsch Mine)
Associated Manganese of SA (Devon)
Associated Manganese of SA (Beeshoek)
Associated Manganese of SA (Gloria 1)
Associated Manganese of SA (Blackrock)
SA Manganese of SA (Wessels)
SA Manganese Amcor (Hotazel)
SA Manganese Amcor (Mamatwana)
SA Manganese Amcor (Lohatiha)

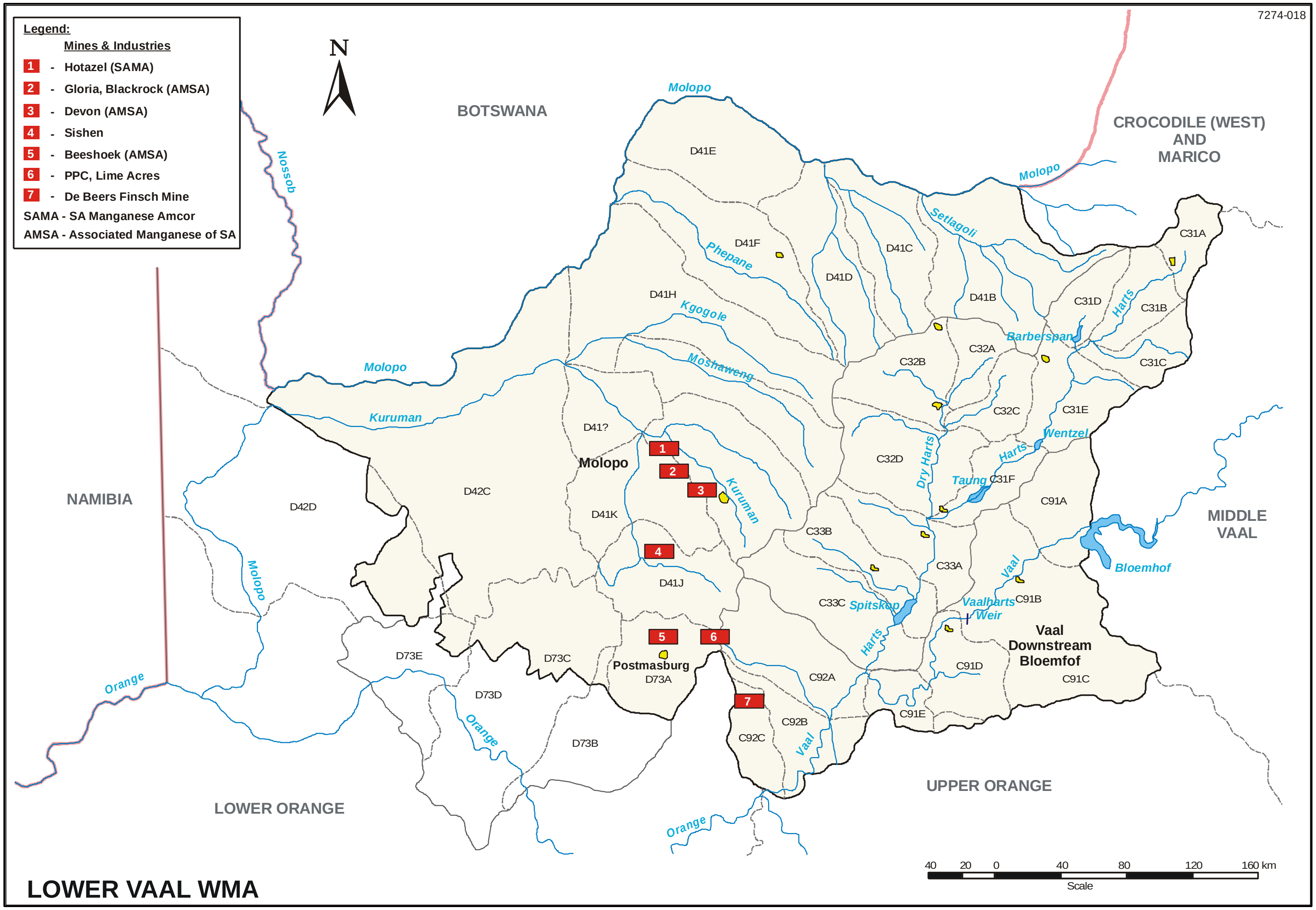

Figure 19: Major mines and industries in the Lower Vaal WMA

OVERVIEW OF CATCHMENT AREA: Lower Vaal WMA

4.4 Modder Riet Catchment

4.4.1 Bio-physical Environment

The Modder Riet catchment is situated in the Free State and Northern Cape Provinces. It is part of the Upper Orange WMA, but forms part of the C drainage region (Vaal River System). It covers a catchment area of 35 000 km^2. The Modder and Riet Rivers are the only major rivers in the catchment, which drain into the Vaal River which subsequently flows into the Orange River. The catchment includes Kalkfontein, Rustfontein, Tierpoort, Groothoek and Krugersdrift Dams. The catchment comprises two sub-catchment areas as listed in **Table 17**. The location and general layout of the catchment is depicted in **Figure 20**.

Table 17: Sub-catchments within the C drainage tertiary catchment of the Upper Orange WMA

PRIMARY CATCHMENT	SUB-CATCHMENT AREA	QUARTENARY CATCHMENTS	AVERAGE GROSS AREA (Km^2)
C	Modder	C52A-L	17 366
	Riet	C51A-M	17 449

4.4.2 Water Resource Systems

The Riet River generally flows in a north-westerly, to the confluence with the Vaal River. The Tierpoort dam which is used for irrigation purposes is situated on the tributary of the Riet River, and the Kalkfontein Dam which supplies water to the Riet River Government Water Scheme, is located just downstream of the confluence of the Kromellenboogspruit and Riet Rivers. The Modder River is the main tributary of the Riet River and joins the Riet River just upstream of Ritchie. The Modder River has its source in the high hills at the watershed near Dewetsdorp (1600m above mean sea level). The Krugersdrift Dam is located on the Modder River. Most of the natural runoff into the Modder River is from above the confluence of the Modder and Klein Modder Rivers. The rest of the Modder River catchment is very flat and very little runoff occurs.

4.4.3 Developmental attributes and Land Use

Current land use in the catchment is related agricultural activities, urbanisation and mining and industrial activities. In the Modder and Riet River catchments agricultural use comprises primarily the irrigation of crops. Agricultural activities are concentrated around the dams in the catchment. Livestock watering also occurs, but to a lesser extent. The major urban centres in the catchment are Bloemfontein, Botshabelo and Thabu Nchu whose collective population is 1.2 million people. The Modder River is a major source of water to these urban areas. Most industries in the Modder and Riet catchments are centred around Bloemfontein and use treated water from the municipal supply system. Only one industry that uses water directly out of the river is known. This is the diamond mining operation at Koffiefontein. The diamond mine at Koffiefontein is an underground mine that mines Kimberlite from a pipe. Aside from the ecological and domestic needs of the rivers, both rivers support recreational use at the dams.

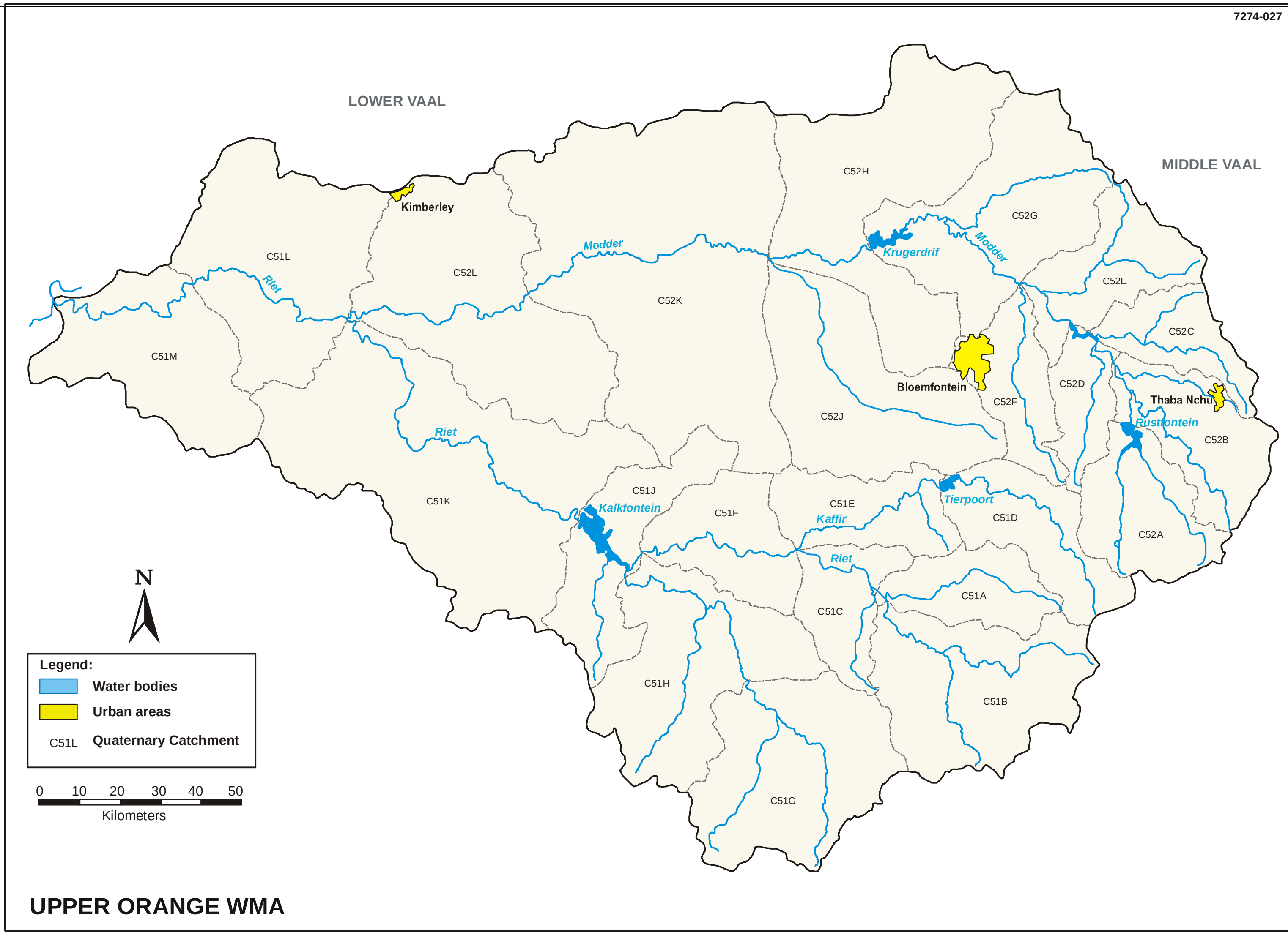

Figure 20: Location and general layout of Modder Riet Catchment

4.5 Recreational Potential of Vaal River System

The Vaal River System has a huge recreational potential. The Vaal River is a major recreational asset to the local communities in the four WMAs. A number of holiday resorts, caravan parks, recreational and picnic areas, angling and boating clubs and the like are located along the river. The recreational areas are often located where the impoundments and weirs are constructed e.g. Grootdraai Dam, Vaal Dam, Vaal Barrage, Bloemhof Dam, Douglas Weir.

4.6 Resource Directed Measures

At present, in terms of the statutory requirements of the NWA, no management class, resource quality objectives (RQOs) or Reserves have been determined for the water resources in the Vaal River System. This process is still an unfolding one, and Reserve determinations are being carried out on a priority need basis, in response to water use licence applications. These Reserve determinations are however preliminary Reserve determinations in terms of the NWA, until such time that the water resources have been classified and methodologies for comprehensive reserve determinations have been determined. In the interim while Reserve determinations are being initiated, the ecological state of the various water resources of South Africa are being managed based on their present ecological state (PES) and ecological importance and sensitivity. This classification of each of tertiary catchments throughout South Africa was done in 2000 by the Department as an input to the national water balance model (DWAF, 2004e). The summarised PES and EIS per tertiary catchment for the Vaal River System is reflected in **Table 18**.

Although RQOs have not yet been determined in terms of the statutory requirements, interim in-stream resource water quality objectives (RWQOs) have been set for many of the sub-catchments within the Vaal River System by the water users in the catchment, in a participatory process in conjunction with the Department. In addition for those sub-catchments that did not have any RWQOs established during this assessment task, these were established by the study team in consultation with the Department's Regional Offices and responsible Head Office Directorates. These objectives serve as management objectives that the Department and water users aim to achieve in terms of management of the water quality of the rivers in the catchment. The current in-stream resource water quality objectives for the various sub-catchments in the Vaal River System are discussed under **Section 6.3**.

4.6.1 Reserve determinations

The Reserve requirements for most of the water resources of the Vaal River System, and the main stem of the Vaal River still need to be determined. The Department is currently underway with a process to undertake a comprehensive Reserve determination for the Integrated Vaal River System. This is however a complex and detailed study which is expected to take two and a half years to complete. In the interim, an Environmental Flow Management Plan for the main stem of the Vaal River was developed as part the Vaal River System Analysis Update Study, and at present the system is being managed based on this plan. In addition the Department has determined low confidence desktop estimates of the ecological water requirements and in some instances the water quality

Reserves in catchments where the need has arisen. However this has been based primarily on responses to water use licence applications.

Within the study area the following preliminary Reserve determinations of surface water resources, as indicated in **Table 19** have been done (shown on **Figure 21**). The determinations have in some cases been conducted at a desktop low confidence level and in others on a higher confidence level. These ecological categories that are proposed will have to be considered when the RWQOs are being confirmed and integrated.

The comprehensive reserve determination studies on the Vaal River System concludes after the IWQMP study is completed, thus RWQOs may have to be re-evaluated at the end of that process.

Table 18: Summarised PES and EIS per tertiary catchment for the Vaal River System

Tertiary	PES	EIS
Upper Vaal WMA		
C11	C	Moderate
C12	C to D	Moderate
C13	B to C	High
C21	D	Moderate to high
C22	D to E/F	Moderate
C23	D	Moderate to high
C81	C	Moderate
C82	C	Moderate
C83	C and E/F	Moderate
Middle Vaal WMA		
C24	C to D	Moderate to high
C25	C	Moderate
C41	C	Moderate
C42	C to D	Moderate
C43	C	Moderate
C60	C	Moderate
C70	B to C	Moderate
Lower Vaal WMA		
C31	C	Moderate
C32	C	Moderate
C33	C to D	Moderate
C91	D	Moderate
C92	C	Moderate
Modder Riet Catchment (Upper Orange) WMA		
C51	D	Low to moderate
C52	D	Low to moderate

Table 19: Preliminary reserve determinations of surface water resources that have been undertaken within the study area

River	Water Management Area	Quaternary catchment	Preliminary Reserve Determined	Determination Level	Present Ecological State	Ecological Importance and Sensitivity	Ecological Category
HIGHER CONFIDENCE RESERVE DETERMINATIONS							
Waterval	Upper Vaal	C12F	Quantity and Quality	Intermediate	D	Low	D (C alternative)
Waterval	Upper Vaal	C12G	Quantity and Quality	Intermediate	D	Low	D (C alternative)
Blesbokspruit	Upper Vaal	C21D	Quantity and Quality	Rapid III	E	Moderate	D
Blesbokspruit wetland	Upper Vaal	C21E	Quantity and Quality	Rapid III	B	High	B
Blesbokspruit	Upper Vaal	C21F	Quantity and Quality	Rapid III	D/E	Moderate	C
Mooi River	Middle Vaal	C23H	Quantity and Quality	Rapid III	C	Moderate	C
Mooi River	Middle Vaal	C23L	Quantity and Quality	Rapid III	C	Moderate	C
Mooi River (Loop)	Middle Vaal	C23K	Quantity and Quality	Rapid III	C	Moderate	C
Sand River	Middle Vaal	C42H	Quantity	Rapid III	C/D	Moderate	B/C
Sand River	Middle Vaal	C42L	Quantity	Rapid III	C	Moderate	B/C
Modder River	Upper Orange	C52F	Quantity and Quality	Intermediate	D	Moderate	D
Modder River	Upper Orange	C52H	Quantity and Quality	Intermediate	D	Low	D
Riet River	Upper Orange	C51K	Quantity and Quality	Intermediate	D	Low	D
Vaal main stem	Lower Vaal	C91E	Quantity and Quality	Rapid III	C	Moderate	C
Vaal main stem	Lower Vaal	C92A	Quantity and Quality	Rapid III	C	Moderate	C
LOW CONFIDENCE RESERVE DETERMINATIONS							
Natalspruit (catchment outlet)	Upper Vaal	C22B	Quantity	Rapid	D	Low	D
Klipspruit (tributary of Klip)	Upper Vaal	C22A	Quantity and Quality	Rapid	D	Low	D
Rietspruit (tributary of Klip)	Upper Vaal	C22C	Quantity and Quality	Rapid	D	Low	D
Klip River	Upper Vaal	C22D	Quantity and Quality	Rapid	D	Low	D
Rietspruit (catchment oulet)	Upper Vaal	C22J	Quantity and Quality	Rapid	D	Low	D
Vaal River (C23B outlet)	Upper Vaal	C23B	Quantity and Quality	Rapid	D	Moderate	D
Mooi River	Upper Vaal	C23E	Quantity and Quality	Rapid	C	Moderate	C
Mooi River	Upper Vaal	C23G	Quantity	Rapid	C	Moderate	C

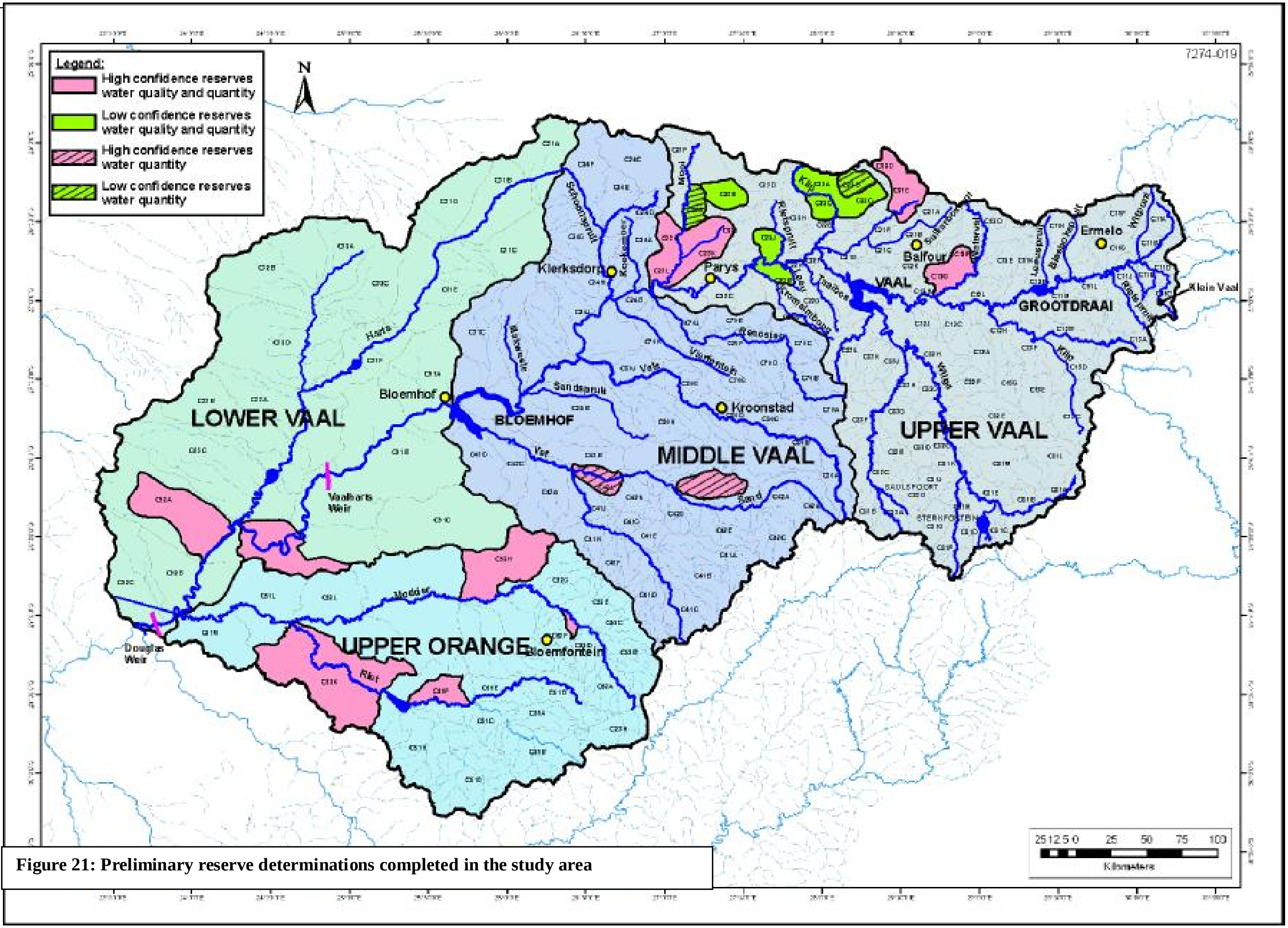

Figure 21: Preliminary reserve determinations completed in the study area

5 SUMMARY OF FINDINGS FROM PREVIOUS STUDIES AND/OR INTERVIEWS

A number of studies that were previously carried out for Vaal River System catchment area are of relevance and have been consulted in this study. The ISPs developed by the Department for the Upper Vaal, Middle Vaal and Lower Vaal WMAs were of particular relevance to this status assessment task and to the IWQMP as a whole. The list of studies consulted and the summary of the findings of some of the studies are included in **Appendix A**.

5.1 Previous Studies

In terms of the previous studies reviewed, the major water quality issues that were identified of key concern that were widespread throughout the system are salinity and eutrophication, which became apparent through this task as well. Much of the findings relate this back to source impacts and poor management practices and diffuse pollution, in addition to general non-compliance to prescribed waste discharge standards. Other water quality issues such as microbiological pollution and organic pollution were also highlighted however these are not as significant and appear to be more localised problems, which need to be addressed through catchment specific water quality management plans and greater enforcement. Another related aspect that was identified, is the impact of atmospheric deposition in the Vaal River catchment, which needs to be given further consideration attention in the near future. This is specifically of relevance in the Grootdraai Dam and Klip River (Free State) sub-catchments. Much of the emphasis of previous studies has been the management of the salinity and the associated on the impacts on downstream users (including the current blending and dilution option of the water in the Vaal Barrage). The focus of recent studies has been on the understanding of catchment status and water users, and on the establishment of resource water quality objectives (RWQOs) within the various sub-catchments. There are various initiatives underway at different stages of development in the sub-catchments of the Vaal River System, however many of these being done in isolation without consideration of the Vaal River main stem.

Salinity and eutrophication are thus the two primary water quality issues identified that affect the entire Vaal River System in its entirety and affects all WMAs due to their interdependency. However by managing these problems, other related water quality issues will also be addressed. In addition the setting of RWQOs and by ensuring their integration throughout the system will also address many of the issues raised in previous studies which highlighted this aspect as a key management area requiring focus.

5.2 Interviews/Discussions with Departmental Staff and Stakeholders

Through discussions with Departmental Officials and stakeholders the following also emerged:

- Total Dissolved Salts is acceptable at the current levels for most stakeholders, except probably for Eskom and Sasol, provided that the current TDS concentrations are maintained using the present dilution management blending options.

- The Water Service Providers such as Rand Water, Sedibeng Water and MidVaal Water raised issues related to odour, colour and dissolved organic carbon in the intake water to their water treatment facilities. These are impacting on the treatment costs and processes needed to achieve potable water quality.
- The human resources and institutional requirements needed to implement the IWQM plan were raised as a key concern.
- The Northern Cape and Free State Regional Offices expressed concern of the poor water quality being received from the Upper Vaal WMA – related to salinity and eutrophication.
- The Northern Cape Regional Office also raised the issue of the huge impact of the irrigation practices in the Harts sub-catchment that is contributing huge salt loads to the Douglas Barrage and impacting on Vaal Gamagara.
- The issue of non-compliance of the wastewater treatment works to discharge standards and lack of commitment to improve the situation was also raised as a key concern by stakeholders and especially Departmental officials.
- The flow passed Douglas Barrage is kept to a minimum to limit the impact of the Vaal River on the Orange River. At present the Orange River has water of generally good quality, however the impact of the Vaal River on the Orange River related eutrophication needs to determined.

5.3 Preliminary Management Options identified through previous studies and discussions

- Continue blending option of Vaal Barrage water
- Grootdraai Dam – implications of deteriorating quality of water in Heyshope Dam – look at option to divert water from Sterkfontein Dam/ directly from Tugela
- Consider conjunctive uses
- Reuse of mine water – KOSH area (Amanzi Project: abstraction/treatment/sale of groundwater)
- Desalinisation
- Transfer of effluents to other catchments
- Groundwater as a resource – use for blending
- Importation of Orange River Water to PWV/Middle Vaal – cost implications?
- Stricter effluent discharge standards – source control/management – “tighter hold”
- Direct reclamation of saline effluents
- Use of evaporative salt sinks – for highly saline effluent
- Klipbank Dam and Rietfontein Dam Option in Middle Vaal WMA
- Utilise Spitzkop Dam (define operating rules)

- Institute measures to manage agricultural return flows
- Utilise Taung Dam (determine yields, system operation rules)
- Optimise Vaalharts Scheme – currently 30-40% losses – results in return flow to Spitzkop Dam

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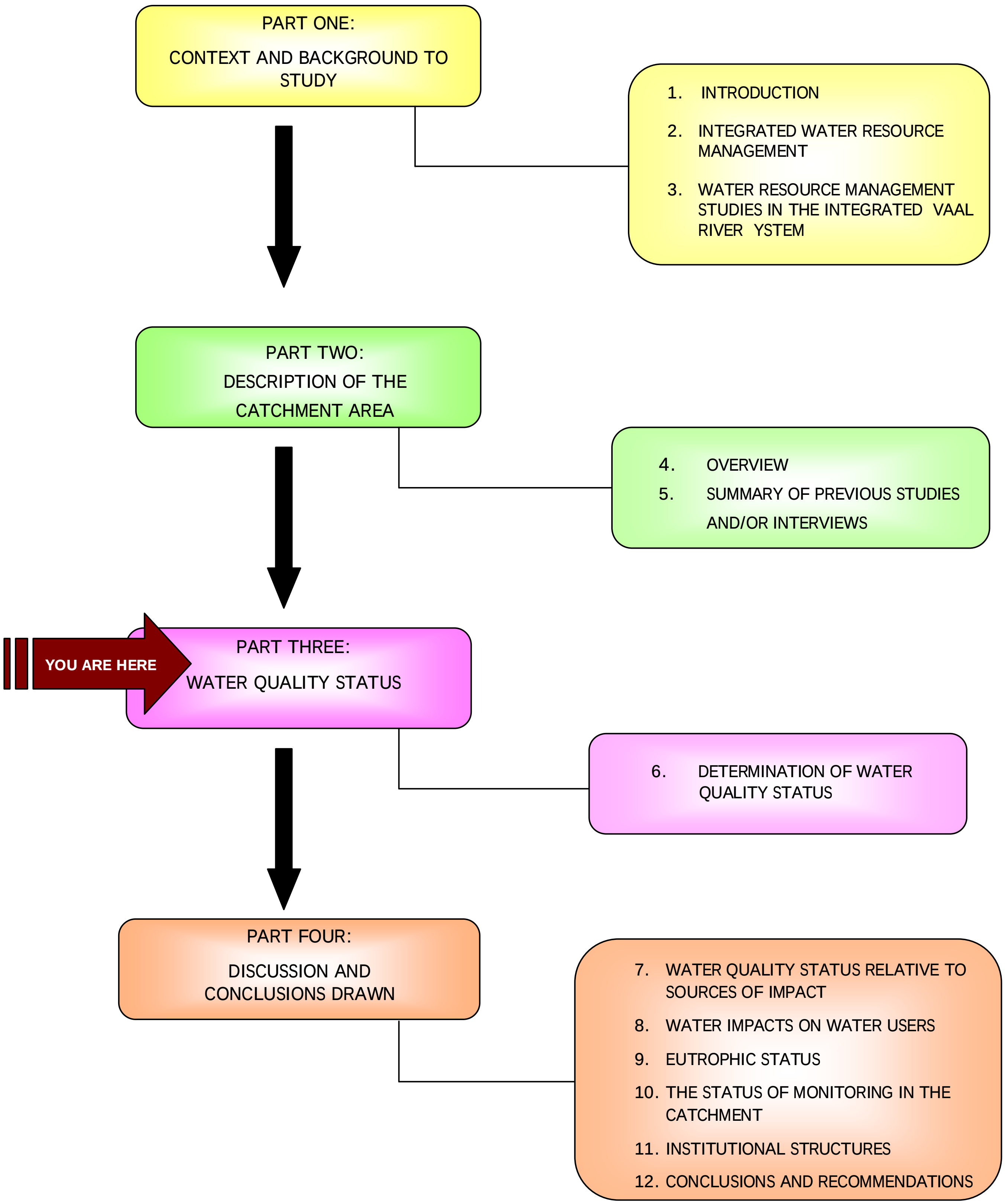


PART THREE:
WATER QUALITY STATUS

6 DETERMINATION OF CURRENT WATER QUALITY STATUS

6.1 Introduction

Significant catchment development, including industrial growth, widespread mining activities and formal and informal urbanisation has impacted on the surface water resources of the Vaal River System. The objective of this chapter is to present the current chemical water quality status of the Vaal River in order to determine the extent of the impacts and to identify the most significant issues of concern.

In order to determine the water quality status the following approach was adopted:

- The spatial extent of the task was confirmed by determining the strategic monitoring points within the catchment study area at which an assessment of the water quality would be done;
- RWQOs for the Vaal River and its tributaries within the catchment area were then collated or established if required;
- Historical monitoring data for these strategic points within the system was then collected, primarily from the Department, and from some water users;
- An analysis of the data (of past 10 years) was then conducted and water quality trends and issues of concern were then identified.

6.2 Identification of Strategic Monitoring Points

In order to ensure that a true reflection of the current water quality status of a catchment is obtained it is important that the sites selected for the analysis are appropriately situated and adequately spatially distributed. Failure to do so could resulted in a skewed picture depicting a serious situation or alternatively, the other extreme, a catchment with little or no impact.

The extent of the study area and due to the high level nature of the analysis to be conducted necessitated the identification of monitoring points within the Vaal River System that would be strategically located and sufficiently widespread to provide an adequate indication of the prevailing water quality status.

Strategic monitoring points were identified at two levels:

- Level 1: Points on the Vaal River from its origin to Douglas Weir; and
- Level 2: Points on the major tributaries of the Vaal River just upstream of their confluences.

These points, both Level 1 and 2 had been established for the Upper Vaal WMA, however they still had to be determined for the Middle and Lower Vaal WMAs.

In order to determine and then confirm these strategic points within the system that would adequately reflect the catchment water quality situation, a workshop was held with the all the major role players of the Departmental Regional Offices (Gauteng, Free State and Northern Cape) and of Head Office on 29 August 2005, at the Department's Regional Office in Bloemfontein.

6.2.1 Level 1 Points

The Level 1 strategic monitoring points refer to the monitoring points that are located on the Vaal River. Twenty Level 1 strategic points were identified and subsequently confirmed by the workshop participants as the key points on which this study would focus. The 20 level 1 strategic monitoring points are listed in **Table 20** and their locations are indicated on **Figure 22**.

The points are:

- numbered from 1 to 20 from the most upstream point to the most downstream point in the Vaal catchment; and
- preceded by the letters 'VS' which implies 'Vaal System' (for example VS 10)

The table also indicates the monitoring point, the WMA in which it is located, the tertiary catchment, its identification number on the Departmental monitoring system, and its co-ordinates.

6.2.2 Level 2 Points

The Level 2 strategic monitoring points identified for this task refer to the monitoring points that are located on the major tributaries of the Vaal River, just upstream of their confluences. Twenty six level 2 strategic points were identified and subsequently confirmed by the workshop participants as the key sub-catchment points on which this study would focus. The 26 level 2 strategic monitoring points are listed in **Table 21** and their locations are indicated on **Figure 23** .

The level 2 points are:

- numbered from 1 to 26 from the most upstream tributary to the most downstream tributary in the Vaal catchment; and
- named indicating that it is a level 2 point (*i.e.* L2),
- at which Level 1 point (VS point – Vaal System) they occur just upstream of (*i.e.* L2/VS6); are
- numbered as they occur before each Level 1 point (*i.e.* L2/VS6/2), as in some instances more than one tributary occurs upstream of a Level 1 point.

Table 20: Level 1 Strategic Monitoring Points identified for the Vaal River System

Strategic Monitoring Points: Level 1						
WMA	**Monitoring Point ID**	**VS number**	**Monitoring Point Name**	**Tertiary Drainage Region**	**Latitude**	**Longitude**
Upper Vaal	177935	VS1	VS1 GDDC01 VAAL RIVER ORIGIN AT N17 BRIDGE	C11	-26.3625	30.108056
	177949	VS2	VS2 GDDC10 VAAL RIVER AT R29/N2 BRIDGE AT CAMDEN	C11	-26.647222	30.151667
	100001098	VS3	VS3 VAAL RIVER ON N11 BRIDGE TO AMERSFORT	C11	-26.778611	29.920833
	177950	VS4	VS4 GDDC11 VAAL RIVER AT R35 BLOUKOP BRIDGE	C11	-26.854722	29.698056
	90612	VS5	VS5 C1R002Q01 GROOTDRAAI DAM vs	C11	-26.918056	29.295
	90597	VS6	VS6 C1H017Q01 VAAL RIVER AT VILLIERS FLOOD SECTION	C12	-27.0225	28.594444
	90678	VS7	VS7 C2H122Q01 VAAL DAM ON VAAL RIVER: DOWN STREAM WEIR	C21	-26.854167	28.121111
	90780	VS8	VS8 C2R008Q01 VAAL BARRAGE ON VAAL RIVER NEAR BARRAGE WALL	C22	-26.765556	27.684722
	90763	VS9	VS9C2H260Q01 VAAL RIVER AT LOW WATER BRIDGE	C23	-26.887222	26.926944
Middle Vaal	*RO WQ point	VS10	VS10 VERMAASDRIFT	C24	-26.933	26.852
	*RO WQ point	VS11	VS11 MIDVAAL WATER COMPANY	C24	-27.935	26.808
	90656	VS12	VS12 C2H007Q01 VAAL RIVER AT PILGRIMS ESTATE/ORKNEY	C24	-26.956667	26.651111
	*RO WQ point	VS13	VS13 REGINA BRIDGE	C24	-27.1028	26.528
	90645	VS14	VS14 C2H061Q01 BALKFONTEIN/SEDIBENG (VAAL RIVER AT KLIPPLAATDRIFT)	C25	-27.3875	26.4625
	*RO WQ point	VS15	VS15 UPSTREAM BLOEMHOF DAM (MAKWASSIE AT GREYLINGSDRIFT BRIDGE)	C25	-27.6	26.094
Lower Vaal	90908	VS16	VS16 C9H021Q01 BLOEMHOF DAM ON VAAL RIVER: DOWN STREAM WEIR	C91	-27.669167	25.618056
	90898	VS17	VS17 C9H008Q01 VAALHARTS BARRAGE ON VAAL RIVER: DOWN STREAM WEIR	C91	-28.114167	24.915278
	90899	VS18	VS18 C9H009Q01 VAAL RIVER AT DE HOOP	C91	-28.515833	24.601111
	101770	VS19	VS19 C9H024Q01 AT SCHMIDTSDRIFT (WEIR) ON VAAL RIVER	C92	-28.711111	24.073333
	101787	VS20	VS20 C9R003Q01 DOUGLAS BARRAGE ON VAAL RIVER: NEAR BARRAGE WALL	C92	-29.043333	23.836944

*RO WQ point (Regional Office Water Quality point): This monitoring point does not form part of the Department's national chemical monitoring network, but is rather a monitoring point that is managed by the Regional Office only. However these points shoud be eventually registered on the Department's national chemical monitoring network (on the Water Management System).

WATER QUALITY STATUS: Level 1 Points

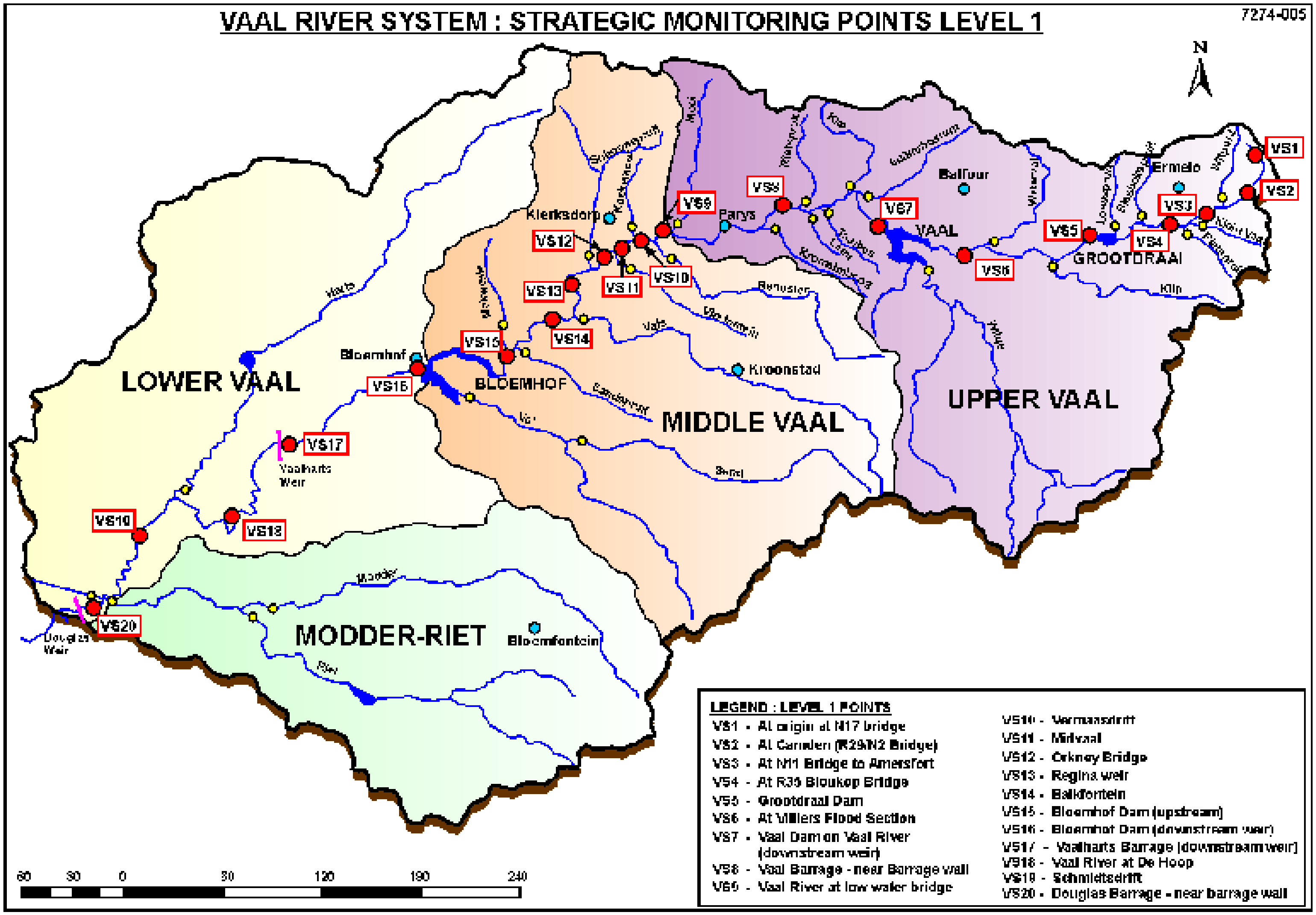


Figure 22: Location of Level 1 strategic monitoring points in Vaal River System

Table 21: Level 2 Strategic Monitoring Points identified for the Vaal River System

Strategic Monitoring Points: Level 2							
WMA	Monitoring Point ID	Tributary number	Tributary name	Monitoring Point Name	Drainage Region	Latitude	Longitude
Upper Vaal	177947	L2/VS3/1	Witpuntspruit	GDC09 WITPUNTSPRUIT AT R29/N2 CAMDEN BRIDGE	C11	-26.592778	30.096944
	100001153	L2/VS4/1	Klein Vaal	KLEIN VAAL	C11	-26.788611	30.1288333
	100001044	L2/VS4/2	Rietspruit	RIETSPRUIT AT N11 TAPFONTEIN BRIDGE	C11	-26.913056	29.872222
	177951	L2/VS5/1	Blesbokspruit	C1H006Q01 BLESBOKSPRUIT AT R39 BRIDGE RIETVLEY	C11	-26.755556	29.543333
	177962	L2/VS5/2	Leeuspruit	C1H005Q01 LEEUSPRUIT AT WELBEDACHT	C11	-26.854167	29.325278
	100000521	L2/VS6/1	Klip	C1H002Q01 KLIP RIVER AT STERKFONTEIN/DELANGESDRIFT	C13	-27.169444	29.233889
	90591	L2/VS6/2	Waterval	C1H030Q01 WATERVAL AT WOLWEFONTEIN U/S VAAL	C12	-28.969444	28.727778
	90859	L2/VS7/1	Wilge	C8H001Q01 WILGE RIVER AT FRANKFORT	C83	-27.273889	28.49
	90615	L2/VS8/1	Suikerbosrant	C2H004Q01 SUIKERBOS AT UITVLUGT	C21	-26.67075	28.03044444
	90624	L2/VS8/2	Klip	C2H015Q01 KLIP RIVER AT WALDRIFT/VEREENIGING	C22	-26.705	28.937222
	90623	L2/VS8/3	Taaibosspruit	C2H014Q01 TAAIBOSSPRUIT AT VERDUN (RW/T1)	C22	-26.823889	27.925833
	100000949	L2/VS8/4	Leeuspruit	LTS13 LEEUSPRUIT AT R59 BRIDGE	C22	-26.409722	28.098611
	90616	L2/VS8/5	Rietspruit	C2H005Q01 RIETSPRUIT AT KAAL PLAATS	C22	-26.729722	27.717778
	100000958	L2/VS9/1	Kromelmboog	LTS30 KROMELMBOOGSPRUIT ON R59 BRIDGE	C23	-26.848889	27.6557222
	90668	L2/VS9/2	Mooi	C2H085Q01 MOOI RIVER AT HOOGEKRAAL/KROMDRAAI	C23	-26.880278	26.965
Middle Vaal	90853	L2/VS10/1	Renoster	C7H006Q01 RENOSTER RIVER AT ARRIESRUST	C70	-27.044444	27.005
		L2/VS11/1	Koekemoer	C2H132 WEIR ON KOEKEMOERSPRUIT BUFFELFONTEIN	C24	-26.545800	26.490200
		L2/VS12/1	Vierfontein	C2H274 NEW WEIR - RECENTLY INSTALLED	C24		
	90656	L2/VS13/1	Schoonspruit	C2H073Q01 SCHOONSPRUIT AT GOEDGENOEG	C24	-26.956667	26.651111
	90846	L2/VS14/1	Vals	C6H002Q01 VALS RIVER AT GROOTDRAAI/BOTHAVILLE	C60	-27.398611	26.614722
		L2/VS15/1	Makwassie	C2H066Q01 MAKWASSIE SPRUIT AT VLIEGEKRAAL	C25	-27.495556	26.074722
		L2/VS15/2	Sandspruit	C2H067Q01 AT LEEGTE ON SANDSPRUIT	C25	-27.560278	26.233333
	90795	L2/VS16/1	Vet	C4H004Q01 AT FAZANTKRAAL NOOITGEDACHT ON VET RIVIER	C43	-27.935000	26.126667
Lower Vaal	90788	L2/VS19/1	Harts	C3H016Q01 HARTS RIVER AT DELPORTSHOOP LLOYDS WEIR	C33	-28.376940	24.303056
	90835	L2/VS20/1	Riet	C5H048Q01 RIET RIVER AT ZOUTPANSDRIFT	C51	-29.033330	23.983330
		L2/VS20/2	Canal from Orange	C9H025 ORANGE-VAAL CANAL AT ST CLAIR/DOUGLAS BARRAGE	C51	-29.045833	23.841389

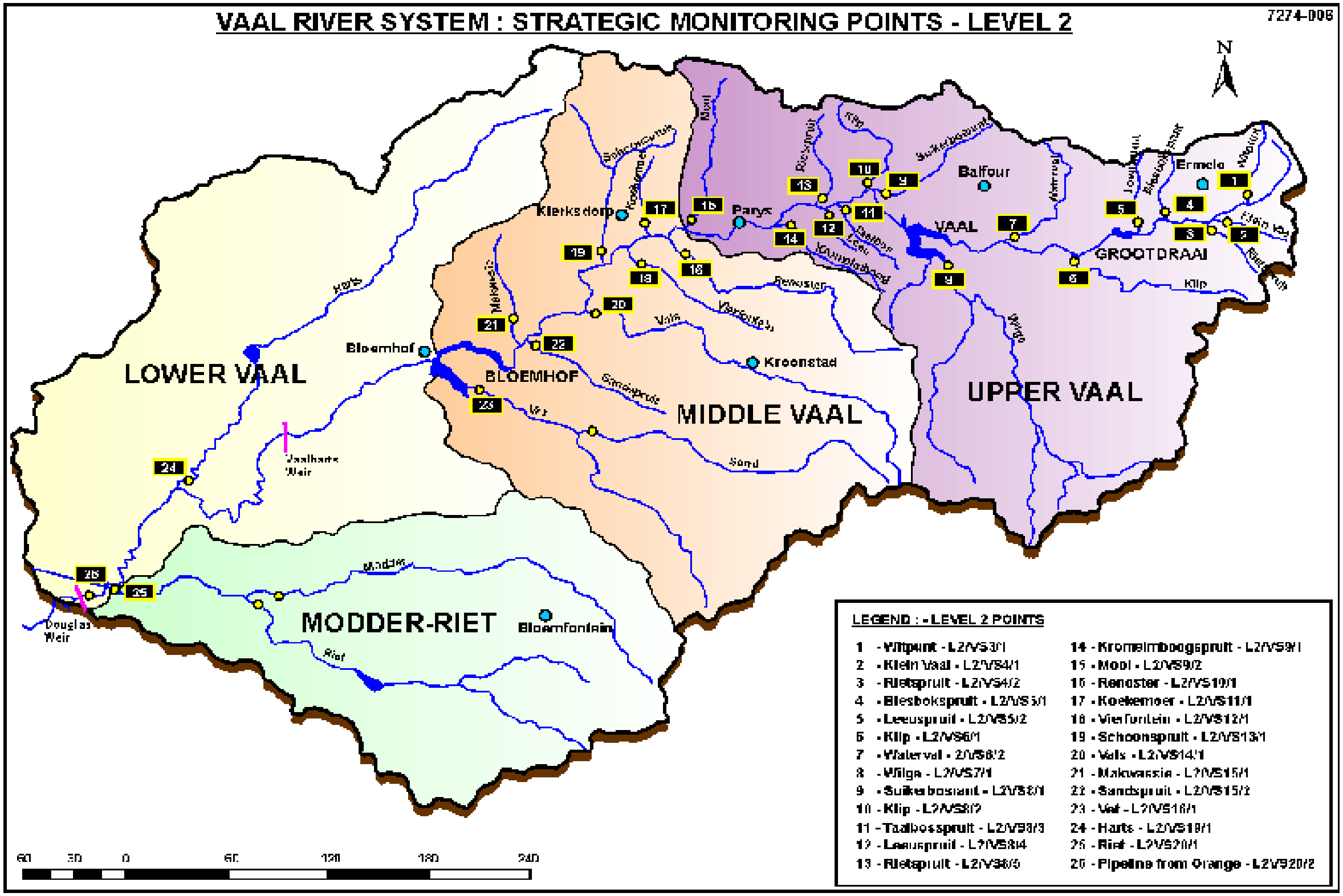


Figure 23: Location of Level 2 strategic monitoring points in Vaal River System

6.3 Resource Water Quality Objectives

Resource Water Quality Objectives (RWQOs) is a mechanism through which this balance between sustainable and optimal water use and protection of the water resource can be achieved. RWQOs are either narrative or quantitative, spatial or temporal, and ultimately allows realisation of the catchment vision by giving effect to the water quality component of the gazetted resource quality objectves (RQOs). The catchment vision is a collective statement from all stakeholders of their future aspirations of the relationship between the stakeholders (in particular their quality of life) and the water resources in the catchment. The RWQOs form part of the strategy to attain that vision.

RWQOs are aimed at ensuring that local priorities are appropriately balanced with broader spatial and temporal perspectives (WMA and national level) and at meeting the objectives of the resource directed measures. They incorporate stakeholder needs, give effect to the Resource Directed Measures (RDM) and dictate the tolerable level of impact collectively produced by upstream users. RWQOs forms part of the mechanism to make the definition of pollution in terms of the National Water Act (Act No. 36 of 1998) operational in the current context of resource directed water quality management (DWAF, 2005c). As such, this allows for different levels of impact for different water resources though aligned with catchment visions. Particular emphasis is given to effective stakeholder participation in the development of RWQOs. The levels at which RWQOs are set demand that they are practical and cost-effective as possible.

6.3.1 Overarching Policy

The policy of DWAF (DWAF, 2005c) regarding RWQOs is that they should:

- Ultimately allow realisation of the catchment vision;
- Give effect to the water quality component of gazetted RQOs;
- Express more detailed stakeholder needs than those accounted for RQOS (where necessary);
- May equal these gazetted RQOS, but may be set at a finer spatial/or temporal resolution;
- Dictate the tolerable level of impact collectively produced by upstream users.

The Department recognises the importance of a strong technical basis for defining RWQOs, and a heavy reliance on a catchment/situation assessment.

6.3.2 Modification of RWQOs

Based on the principles of flexibility and adaptive management RWQOs may be revised, following due process, in the following circumstances:

- The baseline ecological data upon which the RWQOs have been based change because new data has ecome available. RWQOs may thus be revised/modified based on the new information that has come to light.

- Significant changes to vision for the catchment have occurred (through due process), and the present RWQOs are inconsistent with that vision.
- Water treatment technology improves and becomes more cost effective. RWQOs can be made more stringent supporting protection of the water resource.
- Other drivers e.g. political decisions for socio-economic development, or national or presidential imperatives could form the basis for RWQOs to be modified to support these.

The Department has developed a common basis from which to derive RWQOs through the development of the South African Water Quality Guidelines (SAWQG) for different water user groups (DWAF, 1996). These guidelines offer a platform towards developing target RWQOs for water resources.

6.3.3 RWQOs for the Vaal River System

Many of the catchments of the Vaal River Sytem, especially in the Upper Vaal WMA have established these RWQOs in order to manage the water quality impacts while at the same ensuring the needs of the users are met. Currently RWQOs for the Vaal River in the Upper Vaal WMA, Middle and Lower Vaal WMAs are available, and discussed further in paragraphs below.

It must be noted that what is presented in this report is the RWQOs as they currently exist. No refinement, integration or changes have been made to the RWQOs. The integration, verification, alignment and applicability of the RWQOs in the context of the system and related water quality status will be undertaken in the Task 4.

This report (Sections 1.1 and 1.1) compares water quality status to RWQOs as they currently exist.

Upper Vaal WMA

RWQOs for the Vaal River Catchment were available for the Vaal River and its sub-catchments in the Upper Vaal WMA. These RWQOs have been set through a consultative process between the Department's Regional Office and the water users in the various sub-catchments of the Upper Vaal WMA. This process has been facilitated over recent years by the various forums in the WMA and involved numerous workshops with all the relevant stakeholders in the respective catchments. The RWQOs have been set based on user requirements, current water uses, existing water quality at the time, detection limits of water quality variables and achievability. The RWQOs have been adopted by the users and have been applied in the management of the water quality in the Upper Vaal WMA for sometime now.

However the RWQOs that have been set for the Vaal River in the sub-catchment downstream of the Vaal Barrage was done so between the Department's Gauteng South Regional Office and the Free State Regional Office water quality personnel through an in-house process and was not a consultative process as was for the setting of RWQOs for other sub-catchments. The RWQOs that were agreed upon were done so at a workshop between the Regional Offices on 3 June 1998.

In the Upper Vaal WMA the RWQOs for the Vaal River have been set for management units based on the following sub-catchments (as indicated in **Figure 24**):

- Grootdraai Catchment (Vaal Origin)
- Grrotdraai Catchment (Upstream Grootdraai Dam)
- Vaal Dam Catchment
- Vaal Barrage Catchment
- Downstream Vaal Barrage

The RWQOs for the Vaal River in Upper Vaal WMA sub-catchments are shown in **Table 22**, **Table 23, Table 24**, **Table 25** and **Table 26.** The RWQOs for other physical variables, macro-elements, micro-elements and some biological variables, which are not contained in the above tables are listed in **Appendix 2.**

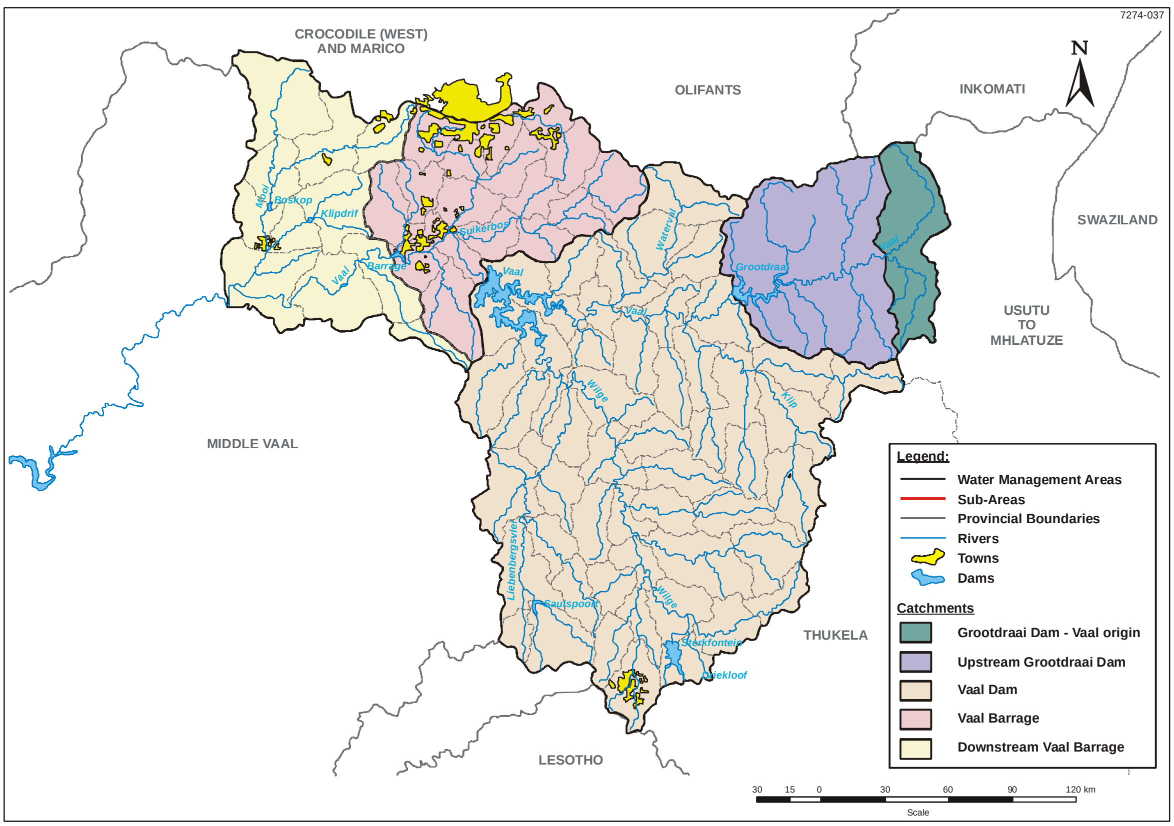


Figure 24: Sub-catchments of the Upper Vaal WMA as they relate to the management units for which RWQOs have been set.

Table 22: RWQOs for the Vaal River in Grootdraai sub-catchment for Vaal origin (points VS 1, VS 2 and VS 3)

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l) as N	<0.05	0.05-0.25	0.25-0.5	>0.5
Ammonia	(mg/l) as N	<0.02	0.02-0.5	0.5-1	>1
Sulphate	(mg/l)	<10	10-20	20-30	>30
Chloride	(mg/l)	<10	10-15	15-20	>20
EC	(mS/m)	<10	10-15	15-25	>25
TDS	(mg/l)	65	65 -97.5	97.5-162.5	>162.5
Phosphate	(mg/l) as P	<0.05	0.05-0.08	0.08-1	>1

Table 23: RWQOs for the Vaal River in Grootdraai sub-catchment for upstream Grootdraai Dam (point VS4)

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l) as N	<0.05	0.05-0.25	0.25-0.5	>0.5
Ammonia	(mg/l) as N	<0.02	0.02-0.5	0.5-1	>1
Sulphate	(mg/l)	<15	15-35	35-50	>50
Chloride	(mg/l)	<10	10-20	20-30	>30
EC	(mS/m)	<15	15-30	30-50	>50
TDS	(mg/l)	<97.5	97.5-195	195-325	>325
Phosphate	(mg/l) as P	<0.05	0.05-0.25	0.25-0.5	>0.5

WATER QUALITY STATUS: RWQOs

Table 24: RWQOs for the Vaal River in Vaal Dam sub-catchment in the Upper Vaal WMA

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l) as N	<0.1	0.1-0.2	0.2-0.3	>0.3
Ammonia	(mg/l) as N	<0.2	0.2-0.5	0.5-1.0	>1
Sulphate	(mg/l)	<20	20-45	45-70	>70
Chloride	(mg/l)	<25	25-50	50-75	>75
EC	(mS/m)	<10	10-30	30-45	>45
TDS	(mg/l)	<65	65-195	195-293	>293
Phosphate	(mg/l) as P	<0.05	0.05-0.25	0.25-0.5	>0.5

Table 25: RWQOs for the Vaal River in Vaal Barrage sub-catchment in the Upper Vaal WMA

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l) as N	<0.5	0.5-3	3-6	>6
Ammonia	(mg/l) as N	------	<0.5	0.5-1.0	>1
Sulphate	(mg/l)	<20	20-100	100-200	>200
Chloride	(mg/l)	<5	5-50	50-75	>75
EC	(mS/m)	<18	18-30	30-70	>70
TDS	(mg/l)	<117	117-195	195-455	>455
Phosphate	(mg/l) as P	------	<0.03	0.03-0.05	>0.05

Table 26: RWQOs for the Vaal River in Downstream Vaal Barrage sub-catchment in the Upper Vaal WMA

Variable	Units	Ideal	Acceptable
Nitrate	(mg/l) as N	<6	6
Ammonia	(mg/l) as N	0.015	0.1
Sulphate	(mg/l)	80	150
Chloride	(mg/l)	50	80
EC	(mS/m)	30	61
TDS	(mg/l)	195	397
Phosphate	(mg/l) as P	<0.26	0.26

***Note:** No tolerable or unacceptable levels of RWQOs were set for the catchment downstream Vaal Barrage. The decision taken was to set a management target based ona combination of most stringent user requirements (ideal and acceptable), current status anda 20% improvement where necessary.*

Middle and Lower Vaal WMAs

RWQOs for the Vaal River in the Middle and Lower WMAs had not been determined at the start of this study. Thus it was necessary for the progress of the study that this process be initiated to ensure that there is benchmark against which water quality could be measured to identify where the issues of water quality concern exist. As part of this status assessment task, RWQOs were thus set for the Middle and Lower Vaal WMAs.

The process to set RWQOs for the Vaal River and its tributaries in the Middle and Lower Vaal WMA involved a one day workshop with each of the responsible Departmental Regional Offices. The respective workshops included the study team, the Department's Regional Office staff and Head Office personnel.

The workshops were held as follows:

- Setting of RWQOs for the Middle Vaal WMA: 01 February 2006, DWAF Free State Regional Office, Bloemfontein; and

- Setting of RWQOs for Lower Vaal WMA: 06 February 2006, DWAF Northern Cape Regional Office, Kimberley.

The RWQOs that were set were based on the expert knowledge of the Department's personnel responsible for water resources management in the WMA, the expertise of Departmental Head Office personnel, consideration of the water users in the catchment, the impacts being experienced and the consideration of the upstream and receiving catchments. The RWQOs Model developed by the Directorate Water Resources Planning Systems of Department was used as the basis to set the objectives. Only one set of RWQOs were set for the Vaal River in each WMA as it was agreed by the respective participants that it was not necessary to define management sub-units as the nature of the water users and uses were fairly uniform in each WMA. In addition the RWQOs that were set were at this stage defined for an acceptable level of concentration only for the identified water quality variables.

This exercise was not meant to be consultative in terms of inclusion of external stakeholders. The aim was to establish a set of RWQOs that would serve as a starting point. The RWQOs that are eventually confirmed through this study will then have to be workshopped with the stakeholders and water users before they are considered as final.

The RWQOs for the Middle Vaal WMA and Lower Vaal WMA are shown in **Table 27** and **Table 28** respectively.

Table 27: RWQOs for the Vaal River in the Middle Vaal WMA

Variable	Units	Acceptable
Nitrate	(mg/l) as N	3
Ammonia	(mg/l) as N	0.1
Sulphate	(mg/l)	250
Chloride	(mg/l)	100
EC	(mS/m)	90
TDS	(mg/l)	630
Phosphate	(mg/l) as P	0.03

Table 28: RWQOs for the Vaal River in the Lower Vaal WMA

Variable	Units	Acceptable
Nitrate	(mg/l) as N	3
Ammonia	(mg/l) as N	0.1
Sulphate	(mg/l)	250
Chloride	(mg/l)	100
EC	(mS/m)	120
TDS	(mg/l)	840
Phosphate	(mg/l) as P	0.04

Resource water quality objectives for the tributaries of the Vaal River

The RWQOs for the major tributaries of the Vaal River (Level 2 points) were available for the sub-catchments of the Upper Vaal WMA. These RWQOs have also been set through a consultative process over recent years between the Department's Regional Office and the water users in the Upper Vaal catchment through the various well established forums. The water users in these sub-catchments have taken ownership of these RWQOs and they are used in the management of the water quality within the respective sub-catchments.

The RWQOs for the Middle and Lower Vaal WMA tributaries were set through the same process as that for the Vaal River. For the tributaries of the Middle Vaal WMA, the 95th percentile current status values were adopted as RWQOs and only acceptable levels of concentration were defined for all the sub-catchments, except for the Schoonspruit/Koekemoerspruit and Sand/Vet River Catchments. In the Lower Vaal the RWQOs for the Vaal River were adopted for the Harts River (acceptable level), and the RWQOs for the Modder Riet sub-catchment are awaited from a current study that is nearing completion.

The RWQOs for the various tributary management units (see **Figure 25)** of the Vaal River are listed in the tables below (**Table 29** to **Table 45**). The complete list of RWQOs for these sub-catchments are contained in **Appendix 2**.

Table 29: RWQOs for the Vaal Origin tributary catchment

Level 2: Sub-unit 1 - Vaal Origin Catchment

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l) as N	<0.05	0.05-0.25	0.25-0.5	>0.5
Ammonia	(mg/l) as N	<0.02	0.02-0.5	0.5-1	>1
Sulphate	(mg/l)	<10	10-20	20-30	>30
Chloride	(mg/l)	<10	10-15	15-20	>20
EC	(mS/m)	<10	10-15	15-25	>25
TDS	(mg/l)	65	65 -97.5	97.5-162.5	>162.5
Phosphate	(mg/l) as P	<0.05	0.05-0.08	0.08-1	>1

Table 30: RWQOs for the Schulpspruit tributary catchment

Level 2: Sub-unit 2 - Schulpspruit Catchment

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l) as N	<0.05	0.05-0.25	0.25-0.5	>0.5
Ammonia	(mg/l) as N	<0.02	0.02-0.5	0.5-1	>1
Sulphate	(mg/l)	<10	10-20	20-30	>30
Chloride	(mg/l)	<10	10-15	15-20	>20
EC	(mS/m)	<10	10-15	15-25	>25
TDS	(mg/l)	65	65 -97.5	97.5-162.5	>162.5
Phosphate	(mg/l) as P	<0.05	0.05-0.08	0.08-1	>1

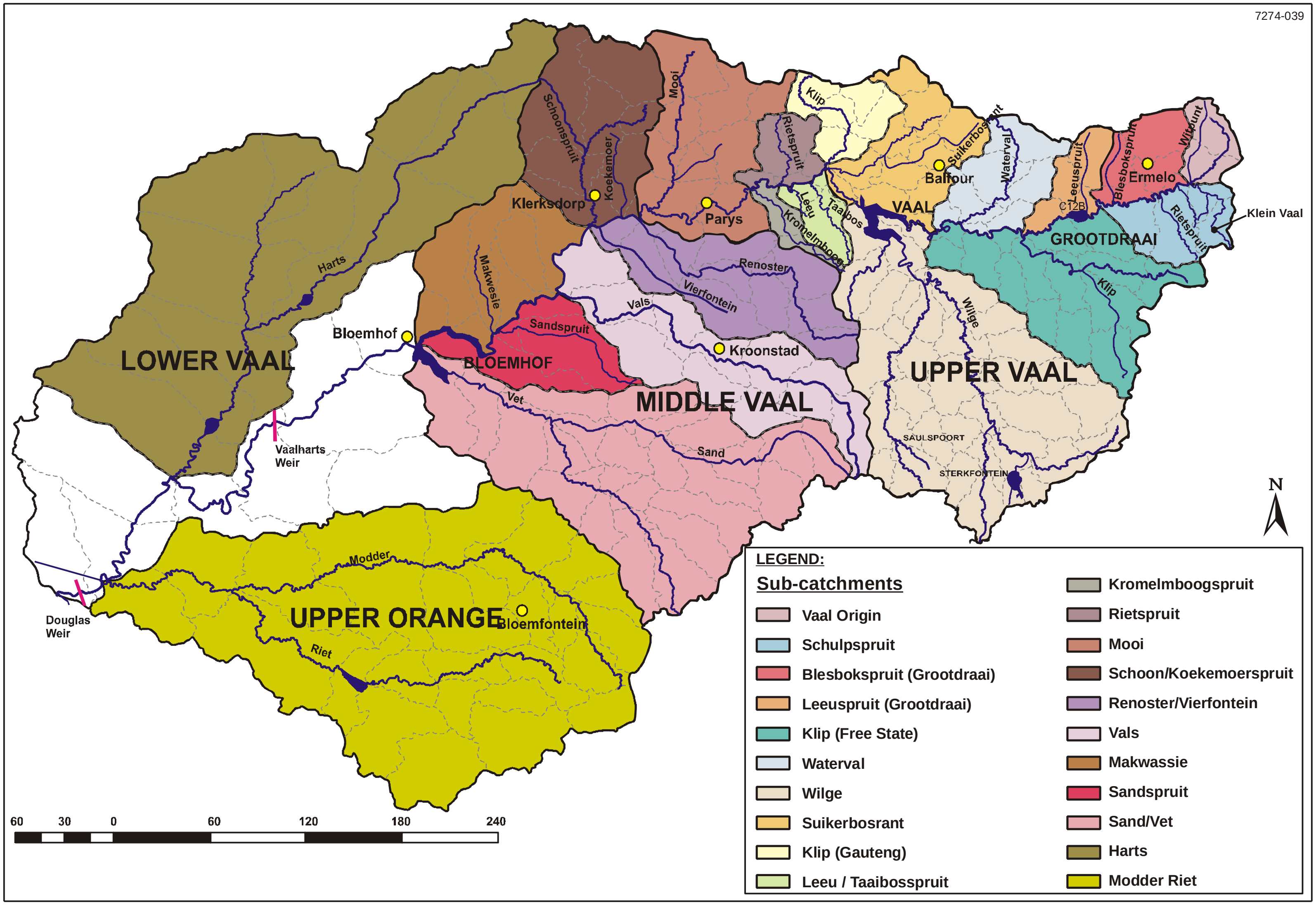


Figure 25: Tributary sub-catchments of the Vaal River System as they relate to the management units for which RWQOs have been set.

Table 31: RWQOs for the Blesbokspruit tributary catchment (Grootdraai Dam catchment)

Level 2: Sub-unit 3 - Blesbokspruit Catchment

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l) as N	<0.05	0.05-0.25	0.25-0.5	>0.5
Ammonia	(mg/l) as N	<0.02	0.02-0.5	0.5-1	>1
Sulphate	(mg/l)	<15	15-35	35-50	>50
Chloride	(mg/l)	<25	25-50	50-70	>70
EC	(mS/m)	<15	15-30	30-50	>50
TDS	(mg/l)	97.5	97.5-195	195-325	>325
Phosphate	(mg/l) as P	<0.05	0.05-0.25	0.25-0.50	>0.50

Table 32: RWQOs for the Leeuspruit tributary catchment (Grootdraai Dam catchment)

Level 2: Sub-unit 4 - Leeuspruit Catchment

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l) as N	<0.05	0.05-0.25	0.25-0.5	>0.5
Ammonia	(mg/l) as N	<0.02	0.02-0.5	0.5-1	>1
Sulphate	(mg/l)	<15	15-35	35-50	>50
Chloride	(mg/l)	<10	10-20	20-30	>30
EC	(mS/m)	<15	15-30	30-50	>50
TDS	(mg/l)	97.5	97.5-195	195-325	>325
Phosphate	(mg/l) as P	<0.05	0.05-0.25	0.25-0.50	>0.50

WATER QUALITY STATUS: RWQOs

Table 33: RWQOs for the Klip River tributary catchment (Free State)

Level 2: Sub-unit 5 - Klip Catchment

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l) as N	<0.1	0.1-0.2	0.2-0.3	>0.3
Ammonia	(mg/l) as N	<0.2	0.2-0.5	0.5-1.0	>1
Sulphate	(mg/l)	<20	20-45	45-70	>70
Chloride	(mg/l)	<25	25-50	50-75	>75
EC	(mS/m)	<10	10-30	30-45	>45
TDS	(mg/l)	<65	65-195	195-293	>293
Phosphate	(mg/l) as P	<0.05	0.05-0.25	0.25-0.5	>0.5

Table 34: RWQOs for the Waterval River tributary catchment

Level 2: Sub-unit 6 - Waterval Catchment

Variable	Units	Ideal	Acceptable	Tolerable
Nitrate	(mg/l) as N	0.5	2.5	10
Ammonia	(mg/l) as N	0.025	0.3	0.8
Sulphate	(mg/l)	60	100	200
Chloride	(mg/l)	75	150	300
EC	(mS/m)	40	90	370
TDS	(mg/l)	260	585	
Phosphate	(mg/l) as P	<0.005	0.025	0.25

Table 35: RWQOs for the Wilge tributary catchment

Level 2: Sub-unit 7 - Wilge Catchment

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l) as N	0.1	0.1-0.2	0.2-0.3	>0.3
Ammonia	(mg/l) as N	<0.05	0.05-0.10	0.1-0.2	>0.2
Sulphate	(mg/l)	<5	5-10	10-15	>15
Chloride	(mg/l)	<5	5-10	10-15	>15
EC	(mS/m)	<10	10-30	30-45	>45
TDS	(mg/l)	65	65-195	195-292.5	>292.5
Phosphate	(mg/l) as P	<0.05	0.050.15	0.15-0.3	>0.3

Table 36: RWQOs for the Blesbokspruit tributary catchment (Vaal Barrage Catchment)

Level 2: Sub-unit 8 - Blesbokspruit Catchment

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l) as N	<0.5	0.5-3.0	3.0-6.0	>6.0
Ammonia	(mg/l) as N	<0.1	0.1-1.5	1.5-5.0	>5.0
Sulphate	(mg/l)	<150	150-300	300-500	>500
Chloride	(mg/l)	80	80-150	150-200	>200
EC	(mS/m)	<45	45-70	70-120	>120
TDS	(mg/l)	292.5	292.5-455	455-780	>780
Phosphate	(mg/l) as P	<0.2	0.2-0.4	0.4-0.6	>0.6

WATER QUALITY STATUS: RWQOs

Table 37: RWQOs for the Klip River tributary catchment (Gauteng)

Level 2: Sub-unit 9 - Klip River Catchment

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l) as N	<2	2-4	4-7	>7.0
Ammonia	(mg/l) as N	<0.5	0.5-1.5	1.5-4.0	>4.0
Sulphate	(mg/l)	<200	200-350	300-500	>500
Chloride	(mg/l)	<50	50-75	75-100	>100
EC	(mS/m)	<80	80-100	100-150	>150
TDS	(mg/l)	<520	520-650	650-975	>975
Phosphate	(mg/l) as P	<0.2	0.2-0.5	0.5-1.0	>1.0

Table 38: RWQOs for the Taaibosspruit tributary catchment

Taaibosspruit

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l) as N	<0.5	0.5-3.0	3.0-6.0	>6.0
Ammonia	(mg/l) as N	<0.25	0.25-0.50	0.50-1.0	>1.0
Sulphate	(mg/l)	<150	150-300	300-500	>500
Chloride	(mg/l)	<50	50-60	60-75	>75
EC	(mS/m)	<42	42-60	60-70	>70
TDS	(mg/l)	<273	273-390	390-455	>455
Phosphate	(mg/l) as P	<0.2	0.2-0.4	0.4-0.6	>0.6

Table 39: RWQOs for the Leeuspruit tributary catchment (Vaal Barragecatchment)

Leeuspruit

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l) as N	<0.5	0.5-3.0	3.0-6.0	>6.0
Ammonia	(mg/l) as N	<0.1	0.1-1.5	1.5-5.0	>5.0
Sulphate	(mg/l)	<150	150-300	300-500	>500
Chloride	(mg/l)	<80	80-150	150-200	>200
EC	(mS/m)	<45	45-70	70-120	>120
TDS	(mg/l)	<293	293-455	455-780	>780
Phosphate	(mg/l) as P	<0.2	0.2-0.4	0.4-0.6	>0.6

Table 40: RWQOs for the Kromelmboogspruit tributary catchment

Kromelmboogspruit

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l) as N	<0.5	0.5-3.0	3.0-6.0	>6.0
Ammonia	(mg/l) as N		<0.5	0.50-1.0	>1.0
Sulphate	(mg/l)	<20	20-100	100-200	>200
Chloride	(mg/l)	<5	5-50	50-75	>75
EC	(mS/m)	<18	18-30	30-70	>70
TDS	(mg/l)	<117	117-195	195-455	>455
Phosphate	(mg/l) as P		<0.03	0.03-0.05	>0.05

Table 41: RWQOs for the Rietspruit tributary catchment

Level 2: Sub-unit 11 - Rietspruit Catchment

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l) as N	<1.0	1.0-3.0	3.0-6.0	>6.0
Ammonia	(mg/l) as N	<0.25	0.25-5.0	5.0-10.0	>10.0
Sulphate	(mg/l)	<100	100-200	200-300	>300
Chloride	(mg/l)	<50	50-100	100-150	>150
EC	(mS/m)	<30	30-70	70-100	>100
TDS	(mg/l)	<195	195-455	455-650	>650
Phosphate	(mg/l) as P	<0.25	0.25-0.50	0.50-1.0	>1.0

Table 42: RWQOs for the Mooi tributary catchment

Level 2: Sub-unit 12 - Mooi River Catchment

Variable	Units	RWQO
Nitrate	(mg/l) as N	0.3
Ammonia	(mg/l) as N	0.03
Sulphate	(mg/l)	75
Chloride	(mg/l)	36
EC	(mS/m)	57
TDS	(mg/l)	370.5
Phosphate	(mg/l) as P	0.4

***Note:** No levels of RWQOs were Mooi River catchment. The decision taken was to set a management target based ona combination of most stringent user requirements (ideal and acceptable), current status anda 20% improvement where necessary.*

WATER QUALITY STATUS: RWQOs

Table 43: RWQOs for the Schoonspruit/Koekemoerspruit tributary catchment

Level 2: Sub-unit 13 - Schoonspruit/Koekemoerspruit Catchment

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l) as N	<0.2	0.2-1.0	1-3	>3.0
Ammonia	(mg/l) as N	<0.25	0.25-1.0	1.0-5.0	>5.0
Sulphate	(mg/l)	<100	100-200	200-400	>400
Chloride	(mg/l)	<50	50-100	100-150	>150
EC	(mS/m)	<31	31-62	62-92	>92
TDS	(mg/l)	<200	200-400	400-600	>600
Phosphate	(mg/l) as P	<0.2	0.2-0.4	0.4-1.0	>1.0

Table 44: RWQOs for the Middle Vaal WMA tributary catchments: Renoster/Vierfontein, Vals, Makwassie, Sandspruit and Sand/Vet Catchments

Renoster/Vierfontein (1/2), Vals (3), Makwassie (4), Sandspruit (5) and Sand/Vet (6) Catchments

Variable	Units	Acceptable Range					
Management Unit		1	2	3	4	5	6
Nitrate	(mg/l) as N	0.2-1.0	0.6	2.0	3.5	0.9	Awaiting RWQOs from study
Ammonia	(mg/l) as N	0.25 -1.0	0.15	0.15	0.14	0.2	
Sulphate	(mg/l)	100-200	40	120	38	60	
Chloride	(mg/l)	50-100	30	100	52	107	
EC	(mS/m)	31-62	45	98	69	94	
TDS	(mg/l)	200-400	293	637	449	611	
Phosphate	(mg/l)	0.2-0.4	0.2	1.0	0.1	0.4	

Table 45: RWQOs for the Lower Vaal WMA tributary catchments: Harts and Modder Riet

Harts (1) and Modder Riet (2) Catchments

Variable	Units	Acceptable Range:	
Management Unit		1	2
Nitrate	(mg/l) as N	3	Awaiting RWQOs from study
Ammonia	(mg/l) as N	0.1	
Sulphate	(mg/l)	250	
Chloride	(mg/l)	100	
EC	(mS/m)	120	
TDS	(mg/l)	840	
Phosphate	(mg/l)	0.04	

6.4 Salinity Water Quality Status of the Vaal River System

The salinity water quality status of the Vaal River System is provided here at an overview level, with the key water quality variables of concern being identified. This overview provides an indication of the fitness for use of the water resources in the system and the key areas where intervention is required within the catchment.

6.4.1 Methodology

Collection of data

The primary source of data for the analysis was the Department, which included historical data from the national monitoring networks (Directorate Resource Quality Services), as well as data from the Regional Offices (Gauteng and Free State). Data was also obtained from Rand Water and Midvaal Water Company.

The water quality data used in the assessment was collected for the Level 1 and Level 2 strategic monitoring points as defined for the Vaal River System see Section **6.2**). The points are listed in **Table 46** and **Table 47** and their location shown in **Figure 26** and **Figure 27**. The applicable flows for these points were also obtained from the Department flow monitoring weirs.

The data used for the analysis has different time scales, different sampling frequencies, variation in the water quality variables monitored and different laboratories and analytical methods used. In addition many of the tributary catchments (Level 2) points have monitoring programmes that do not relate to the monitoring programme of the Vaal River. There were gaps in the available data.

The lack of an integrated holistic monitoring programme for the Vaal River System has made the identification of water quality trends difficult. Taking these limitations into account, the data obtained has been used to determine the downstream trends in the Vaal River and to correlate these with the contributions received from the tributary catchments and to the discharges being released into the Vaal River and its tributaries.

The specific issues and gaps identified regarding the current monitoring for the water resources of the Vaal River System is discussed in **Section 10.2** of this report.

Table 46: Level 1 Water Quality monitoring points on the Vaal River that were used for the assessment

Monitoring Point ID	Level 1 Point (VS number)	Monitoring Point	Monitoring Point Name	Drainage Region	Latitude	Longitude	Period of Record
177935	VS1	GDDC01	Vaal River Origin At N17 Bridge	C11	-26.3625	30.108056	16/11/1999 to 13/10/2005
177949	VS2	GDDC10	Vaal River At R29/N2 Bridge At Camden	C11	-26.647222	30.151667	01/07/1999 to 13/10/2005
100001098	VS3		Vaal River On N11 Bridge To Amersfort	C11	-26.778611	29.920833	16/10/2003 to 13/10/2005
177950	VS4	GDDC11	Vaal River At R35 Bloukop Bridge	C11	-26.854722	29.698056	03/09/1999 to 13/10/2005
90612	VS5	C1R002Q01	Grootdraai Dam	C11	-26.918056	29.295	18/11/1982 to 20/10/2004
90597	VS6	C1H017Q01	Vaal River At Villiers Flood Section	C12	-27.0225	28.594444	16/11/1975 to 28/10/2004
90678	VS7	C2H122Q01	Vaal Dam On Vaal River: Down Stream Weir	C21	-26.854167	28.121111	05/10/1981 to 27/10/2005
90780	VS8	C2R008Q01	Vaal Barrage On Vaal River Near Barrage Wall	C22	-26.765556	27.684722	06/06/1980 to 19/01/2005
90763	VS9	C2H260Q01	Vaal River At Low Water Bridge	C23	-26.887222	26.926944	29/12/1998 to 8/12/2005
RO WQ point	VS10		Vermaasdrift	C24	- 26.933	26.852	06/10/2000 to 28/09/2005
RO WQ point	VS11	Midvaal intake	Midvaal Water Company	C24	- 27.935	26.808	06/10/2000 to 28/09/2005
90656	VS12	C2H007Q01	Vaal River At Pilgrims Estate/Orkney	C24	-26.956667	26.651111	31/03/1980 to 02/11/2004
RO WQ point	VS13		Regina Bridge	C24	- 27.1028	26.528	13/10/2000 to 27/09/2005
90645	VS14	C2H061Q01	Balkfontein/Sedibeng (Vaal River At Klipplaatdrift)	C25	-27.3875	26.4625	14/05/1972 to 02/11/2004
RO WQ point	VS15		Upstream Bloemhof Dam (Makwassie At Greylingsdrift Bridge)	C25	- 27.6	26.094	No data vavailable yet – recently established point
90908	VS16	C9H021Q01	Bloemhof Dam On Vaal River: Down Stream Weir	C91	-27.669167	25.618056	23/11/1972 to 15/09/2004
90898	VS17	C9H008Q01	Vaalharts Barrage On Vaal River: Down Stream Weir	C91	-28.114167	24.915278	23/11/1957 to 16/09/2004
90899	VS18	C9H009Q01	Vaal River At De Hoop	C91	-28.515833	24.601111	09/12/1971 to 02/09/2004
101770	VS19	C9H024Q01	At Schmidtsdrift (Weir) On Vaal River	C92	-28.711111	24.073333	01/06/1995 to 28/10/2004
101787	VS20	C9R003Q01	Douglas Barrage On Vaal River: Near Barrage Wall	C92	-29.043333	23.836944	03/10/1977 to 13/10/2004

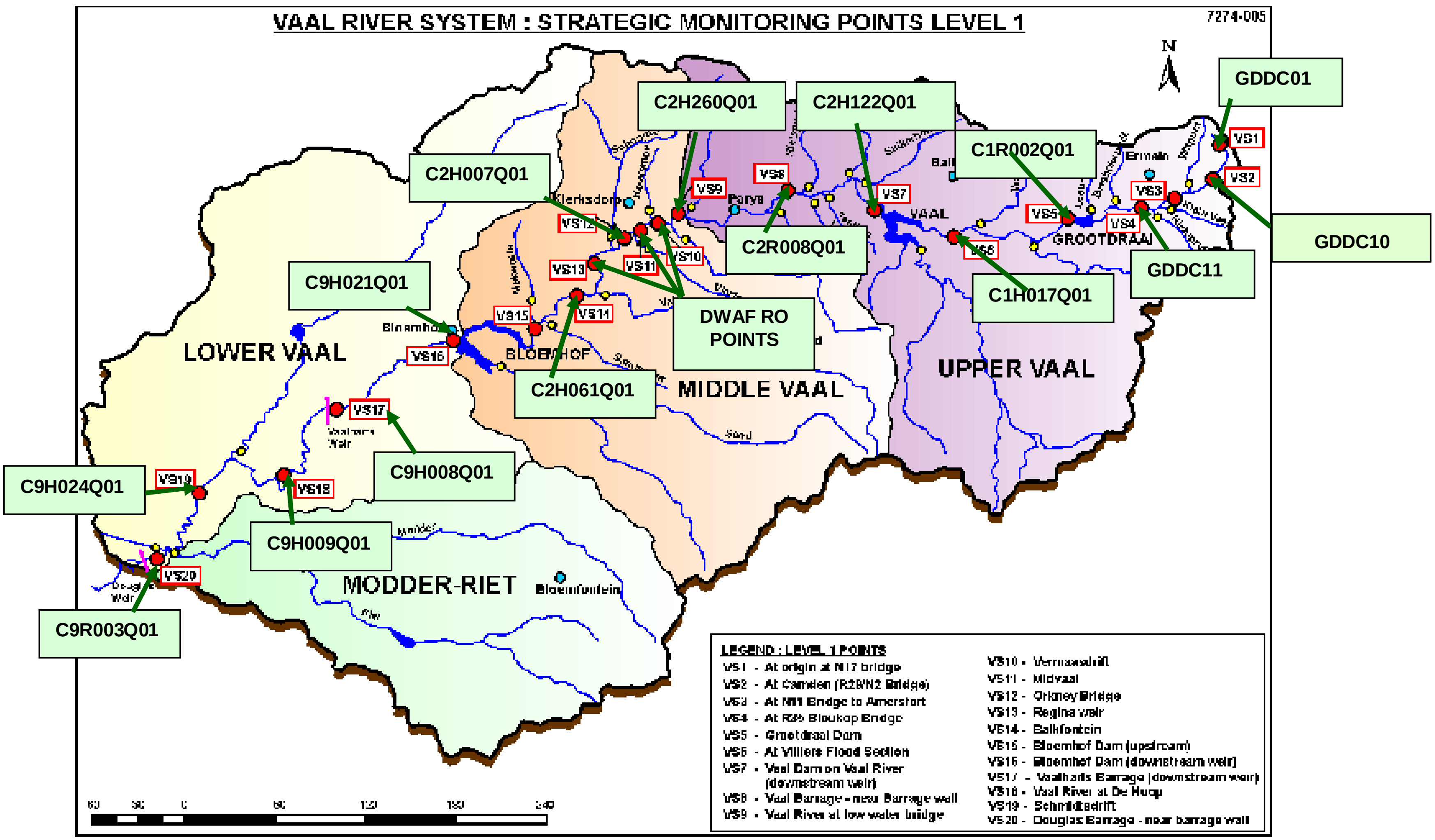


Figure 26: Location of the Level 1 monitoring points used in the study

Table 47: Level 2 Water Quality monitoring points on the Vaal River that were used for the assessment

Monitoring Point ID	Level 2 Point (number)	Monitoring Point	Monitoring Point Name	Drainage Region	Latitude	Longitude	Period of Record
177947	L2/1	**GDC09**	**Witpuntspruit At R29/N2 Camden Bridge**	C11	-26.592778	30.096944	01/07/1999 to 08/12/2005
100001153	L2/2		**Klein Vaal**	C11	-26.788611	30.1288333	12/05/2004 to 08/12/2005
100001044	L2/3		**Rietspruit at N11 Tapfontein Bridge**	C11	-26.913056	29.872222	16/10/2003 to 08/12/2005
177951	L2/4	**C1H006Q01**	**Blesbokspruit at R39 Bridge Rietvley**	C11	-26.755556	29.543333	17/01/1974 to 01/11/2004
177962	L2/5	**C1H005Q01**	**Leeuspruit at Welbedacht**	C11	-26.854167	29.325278	17/01/1974 to 01/11/2004
100000521	L2/6	C1H002Q01	**Klip River at Sterkfontein/Delangesdrift**	C13	-27.169444	29.233889	
90591	L2/7	**C1H030Q01**	**Waterval at Wolwefontein U/S Vaal**	C12	-28.969444	28.727778	02/12/1993 to 13/12/2005
90859	L2/8	**C8H001Q01**	**Wilge River at Frankfort**	C83	-27.273889	28.49	06/12/1971 to 16/11/2004
90615	L2/9	**C2H004Q01**	**Suikerbos at Uitvlugt**	C21	-26.67075	28.03044444	23/03/1984 to 14/03/2006
90624	L2/10	**C2H015Q01**	**Klip River at Waldrift/Vereeniging**	C22	-26.705	28.937222	27/06/1997 to 30/11/2005
90623	L2/11	**C2H014Q01**	**Taaibosspruit at Verdun (Rw/T1)**	C22	-26.823889	27.925833	29/11/1984 to 19/01/2005
100000949	L2/12	**LTS13**	**Leeuspruit at R59 Bridge**	C22	-26.409722	28.098611	11/05/2001 to 11/10/2004
90616	L2/13	**C2H005Q01**	**Rietspruit at Kaal Plaats**	C22	-26.729722	27.717778	08/03/1984 to 12/04/2006
100000958	L2/14	**LTS30**	**Kromelmboogspruit on R59 Bridge**	C23	-26.848889	27.6557222	23/05/2002 to 12/02/2004
90668	L2/15	**C2H085Q01**	**Mooi River at Hoogekraal/Kromdraai**	C23	-26.880278	26.965	03/01/1994 to 14/11/2004
90853	L2/16	**C7H006Q01**	**Renoster River at Arriesrust**	C70	-27.044444	27.005	19/12/1974 to 29/09/2004
	L2/17	**C2H139**	**Weir on Koekemoerspruit Buffelfontein**	C24	-26.545800	26.490200	
	L2/18	**C2H274**	**New Weir - Recently installed**	C24			No data vavailable yet – recently established point
90656	L2/19	**C2H073Q01**	**Schoonspruit at Goedgenoeg**	C24	-26.956667	26.651111	31/03/1980 to 1/11/2005
90846	L2/20	**C6H002Q01**	**Vals River at Grootdraai/Bothaville**	C60	-27.398611	26.614722	01/08/1972 to 02/11/2004
	L2/21	**C2H066Q01**	**Makwassie Spruit at Vliegekraal**	C25	-27.495556	26.074722	02/08/1972 to 10/05/04
	L2/22	**C2H067Q01**	**At Leegte on Sandspruit**	C25	-27.560278	26.233333	To little data
90795	L2/23	**C4H004Q01**	**At Fazantkraal Nooitgedacht on Vet Rivier**	C43	-27.935000	26.126667	03/08/1972 to 20/01/2004
90788	L2/24	**C3H016Q01**	**Harts River at Delportshoop Loyds Weir**	C33	-28.376940	24.303056	05/11/1992 to 22/10/2004
90835	L2/25	**C5H048Q01**	**Riet River at Zoutpansdrift**	C51	-29.033330	23.983330	10/08/1990 to 27/10/2004
	L2/26	**C9H025**	**Orange-Vaal Canal at St Clair/Douglas Barrage**	C51	-29.045833	23.841389	03/01/1996 to 28/01/2004

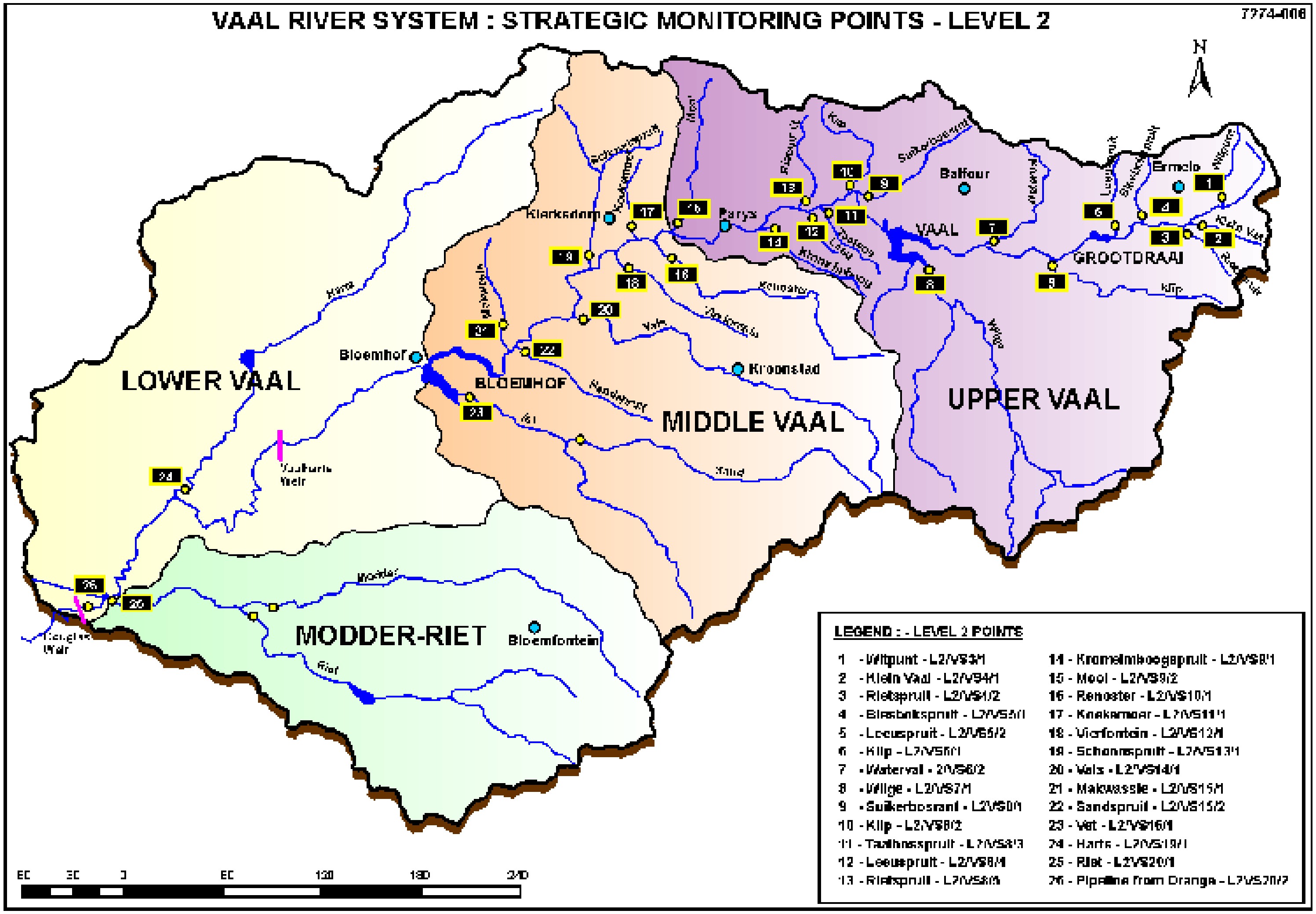


Figure 27: Location of the Level 2 monitoring points used in the study

Water Quality Data Analysis

The water quality status of the Vaal River along its length is presented in this section as graphical comparisons. These plots compare the water quality status along the river with the RWQOs sets applicable to the particular reach of river.

The data sets obtained have been represented in these plots in the form of box and whisker diagrams, which depicts the data distribution as:

- 5^{th}, 25^{th}, 50^{th}, 75^{th} and 95^{th} percentiles.

The distribution plots were calculated from the original Departmental data available for the identified monitoring stations along these rivers. The data sets varied considerably with some points having limited data, with others covering periods in excess of 30 years. Although a sufficiently long record was not available in all cases to produce a statistically meaningful result, the analysis of the short period of data available was useful in reflecting the current water quality situation in that part of the catchment. Most points however included data sets of 6 years or more. For point VS15 no analysis was carried out, as it is a recently created monitoring point in the monitoring network that has no monitoring data available at this stage. For point VS9 only analysis of TDS was done as too little data was available for the macro ions sulphate and chloride.

The comparison plots provide an evaluation of identified water quality variables at the strategic monitoring stations along the length of the Vaal River and the evaluation of the impact of the tributaries on the Vaal River. The plots also provide an evaluation of compliance of the water quality variables with the RWQOs set for the water resources in the Vaal River System

The water quality status assessment has been based on the routine monitoring conducted by the Department in recent years and it must be borne in mind that this is a high level qualitative assessment of historical water quality in the Vaal River System making use of the data available to the study team.

Identification of Key Water Quality Variables

During the inception phase an assessment of the water quality at key points along the Vaal River was undertaken to identify the water quality variables of concern that should be considered in the study. The key points used in the analysis were Grootdraai Dam, Vaal Dam, Vaal Barrage, Bloemhof Dam, Vaalharts weir and Douglas weir. The results of the analysis (**Appendix 3**) were agreed with stakeholders at the stakeholder meetings held as part of the public participation process. This analysis thus focused on total dissolved salts (TDS) and the major ions sulphate and chloride, which emerged as possible variables of concern.

6.4.2 Salinity trends observed

The available water quality data for the Vaal River was analysed and evaluated.. This section of the report highlights the general trends in the water quality and some specific problem areas.

The water quality salinity trend in the Vaal River from point VS1 to VS20 is shown below in **Figure 28**. The ionic composition of the major macro ions are depicted in **Figure 29** and **Figure 30**, and the trends of sulphate and chloride are depicted in **Figure 46** and **Figure 47.** The current status is shown from the most upstream (Vaal origin) point in the catchment to the most downstream point at Douglas Barrage. The trends are compared to the acceptable level RWQO concentration as this is considered to be the current management target in most Upper Vaal WMAs catchments. The management target RWQOs set for the Middle and Lower Vaal WMAs were used in the comparative plots.

TDS along the Vaal River: Level 1

The general trend is an increase in TDS concentrations along the length of the Vaal River. The ratio of the median TDS concentrations at the level 1 points to the median concentration at VS1 listed in **Table 48** highlights this trend. The trend is also shown by examining the average TDS concentrations along the length of the Vaal River. The reach of the Vaal River to Vaal Dam (VS1 to VS7) has an average TDS concentration of 155 mg/ℓ. There is a significant increase in the average TDS concentration to 455mg/ℓ between VS7 and VS14 *i.e.* the outflow from Vaal Dam to the Vals and Vaal River confluence. There is a slight drop in the average TDS concentration to 338mg/ℓ from the Vals and Vaal River confluence to the de Hoop weir. The average TDS concentration increases to 470mg/ℓ at points VS18 and VS20 below De Hoop weir.

Table 48: TDS increase as a ratio along length of Vaal River from origin

Monitoring site	*Ratio of increase in TDS along Vaal River from Background Concentration at origin
VS1 (Background concentration)	1.0
VS2	1.7
VS3	1.7
VS4	2.4
VS5	2.7
VS6	4.1
VS7 (Outflow Vaal Dam)	2.6
VS8 (Vaal Barrage)	7.3
VS9	8.3
VS10	7.8
VS11	7.7
VS12	8.9
VS13	8.0
VS14	8.0
VS16 (Outflow Bloemhof Dam)	5.6
VS17	5.5
VS18	5.4
VS19	8.0
VS20 (In flow Orange River Canal)	7.4

*(*Note: Ratio of increase in TDS was determined using the 50th percentile value at each point and dividing that value by the 50th percentile value at point VS 1 which was taken as 'background concentration'. This provides an indication of the increase).*

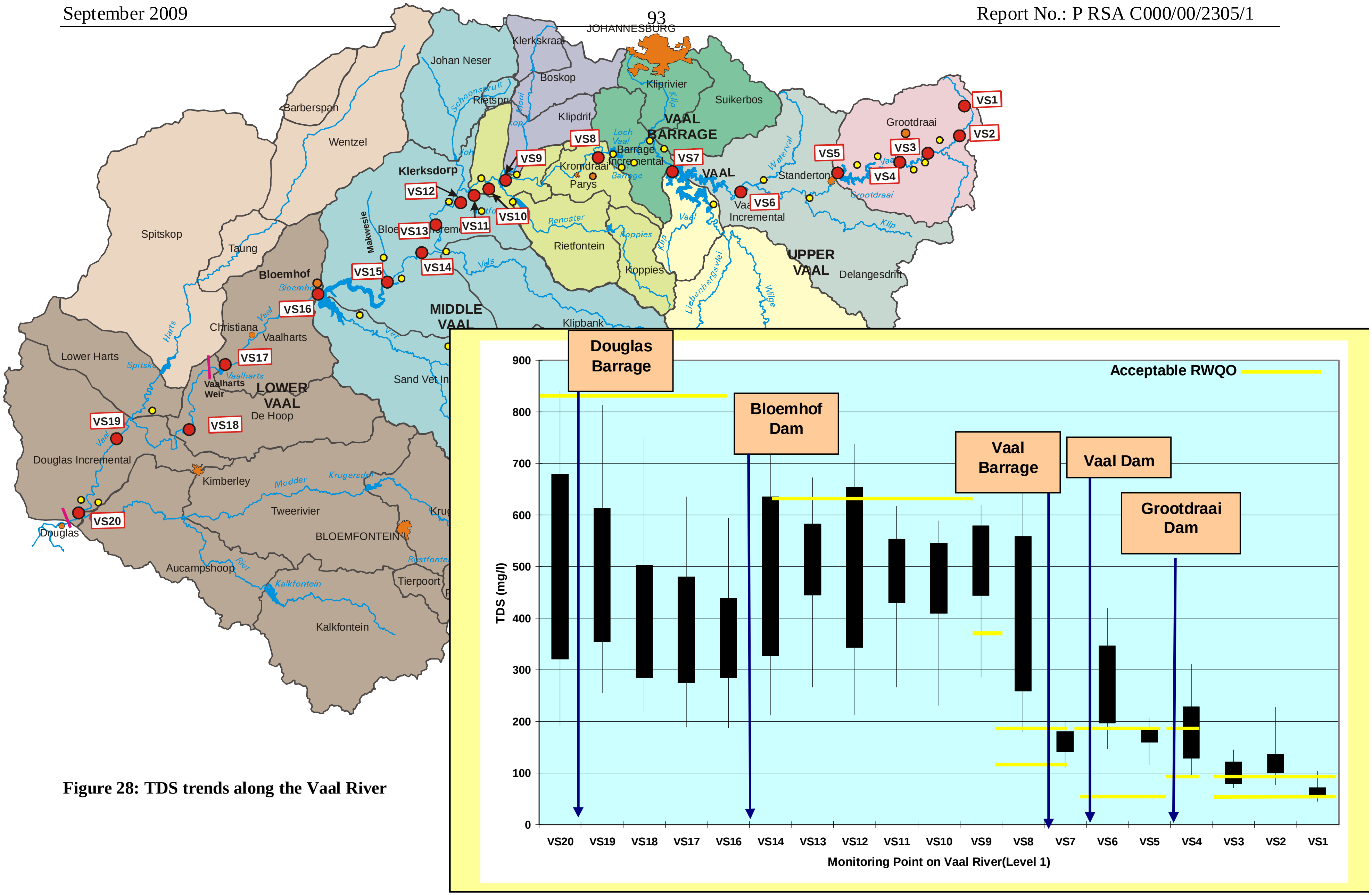


Figure 28: TDS trends along the Vaal River

WATER QUALITY STATUS:
Salinity Status: Level 1 Points

The ionic composition of the Vaal River water also changes along the length of the Vaal River the composition of the water in the upper Vaal at VS6 (inflow to Vaal Dam at Villiers) is shown in **Figure 29**. The dissolved salts composition in the upper Vaal River is dominated by bicarbonate ions. The order of prominence is HCO_3^- > $S0_4^{2-}$ >Ca^{2+} > Na^+ > Ca^{2+-} >Mg^{2+} >K^+. The dominance of the bicarbonate ions is shown in **Figure 29** by the significant positive correlation between the alkalinity and TDS concentrations.

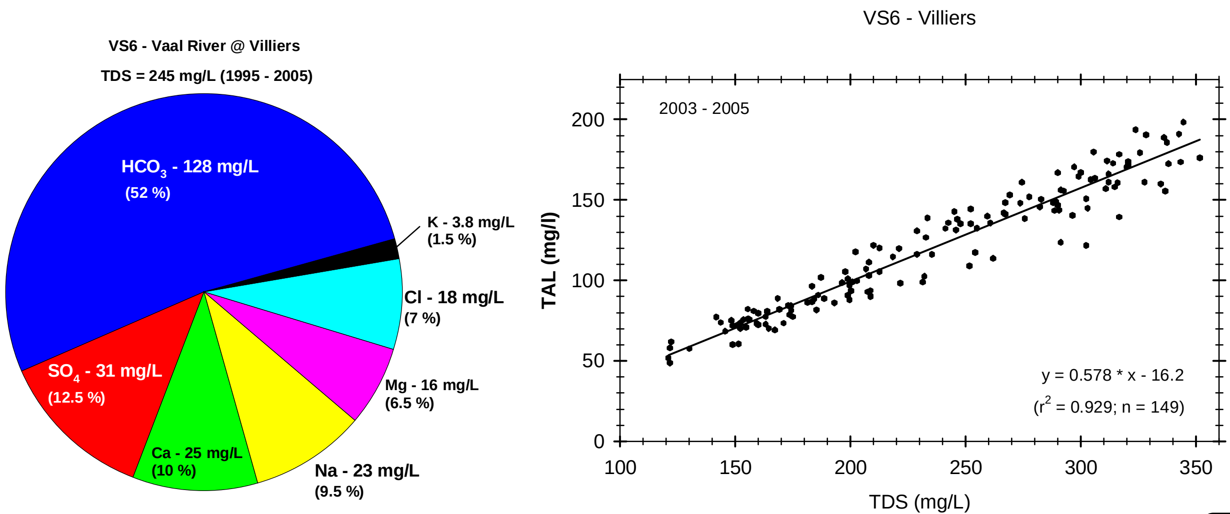


Figure 29: The mean composition of the major ions in the Vaal River at Villiers (1995 – 2005), and the relationship between the dissolved salts and total alkalinity (expressed as $CaCO_3$)

The ionic composition changes from a HCO_3 dominated water to $S0_4^{-2}/HCO_3$ dominated water in the middle reaches of the Vaal River. The ionic composition of the water at Midvaal (VS11) is given in **Figure 30**. The increase in sulphate concentration is an indication of mining related discharges. Midvaal monitoring points being below the Koekemoerspruit and theVaal Barriage both receive mining discharges.

The seasonal trends in the concentrations of the major cations and anions are also shown in **Figure 30** for the period 2003 to 2006 at Midvaal. There is a steady upward trend over the low flow winter periods with a sharp reduction with the onset of the rains and increases with in flow.

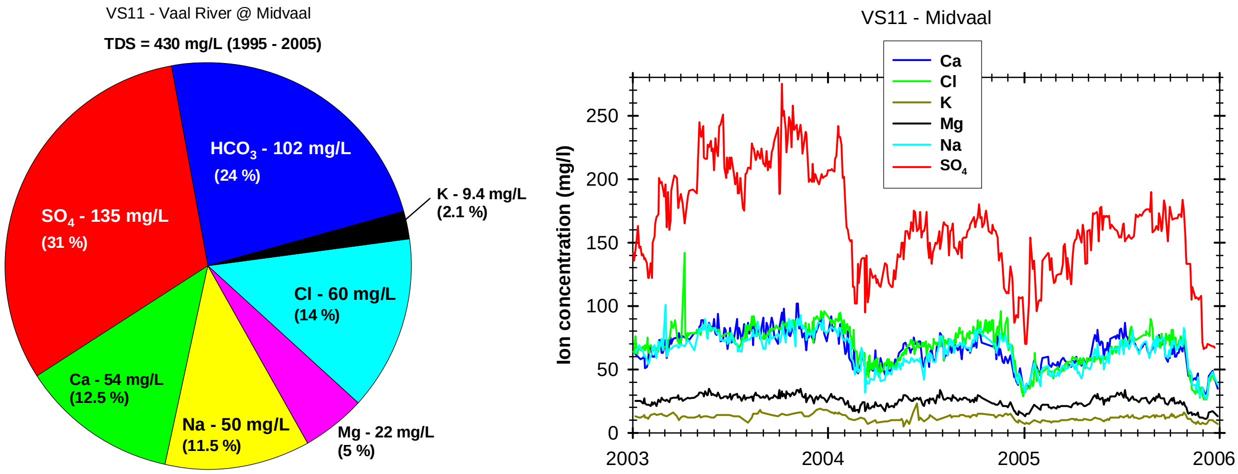


Figure 30: The mean composition of the major ions in the middle Vaal River at Midvaal (1995 – 2005), and the annual variation in ionic concentrations.

<u>TDS: Monitoring Points VS1 to VS6: Vaal Origin to just upstream Vaal Dam</u>

The upper part of the catchment at VSI complies with the RWQO targets with regard to TDS. However, other points in this catchment area show non-compliance to the acceptable RWQO, with more than 50% of the values showing exceedance. These points are VS2, VS4 and VS6. This trend would have been carried through to VS5 and VS7, however the situation is alleviated by the attenuating affects of Grootdraai Dam and Vaal Dam respectively.

While the TDS concentration in the Vaal River at Camden (VS2) was relatively low (mean 150 mg/ℓ) and shows little seasonal variation with no increasing trend during the past seven years, it does increase from point VS1 and exceeds the acceptable RWQO level 75% of the time

The time series analysis for point VS4 is depicted in **Figure 31**. It does reflect some seasonal trend peaking over the winter months and dropping over summer. It is apparent that the TDS levels are bordering on unacceptable levels for 50% of the time. It is not completely understood why point VS4 shows this increase but it could be attributable to diffuse pollution from the coal mines in the area and possibly to atmospheric deposition, which is emerging as a possible water quality threat or it could be due to the some local impacts from the towns or expanding informal settlement areas in the catchment.

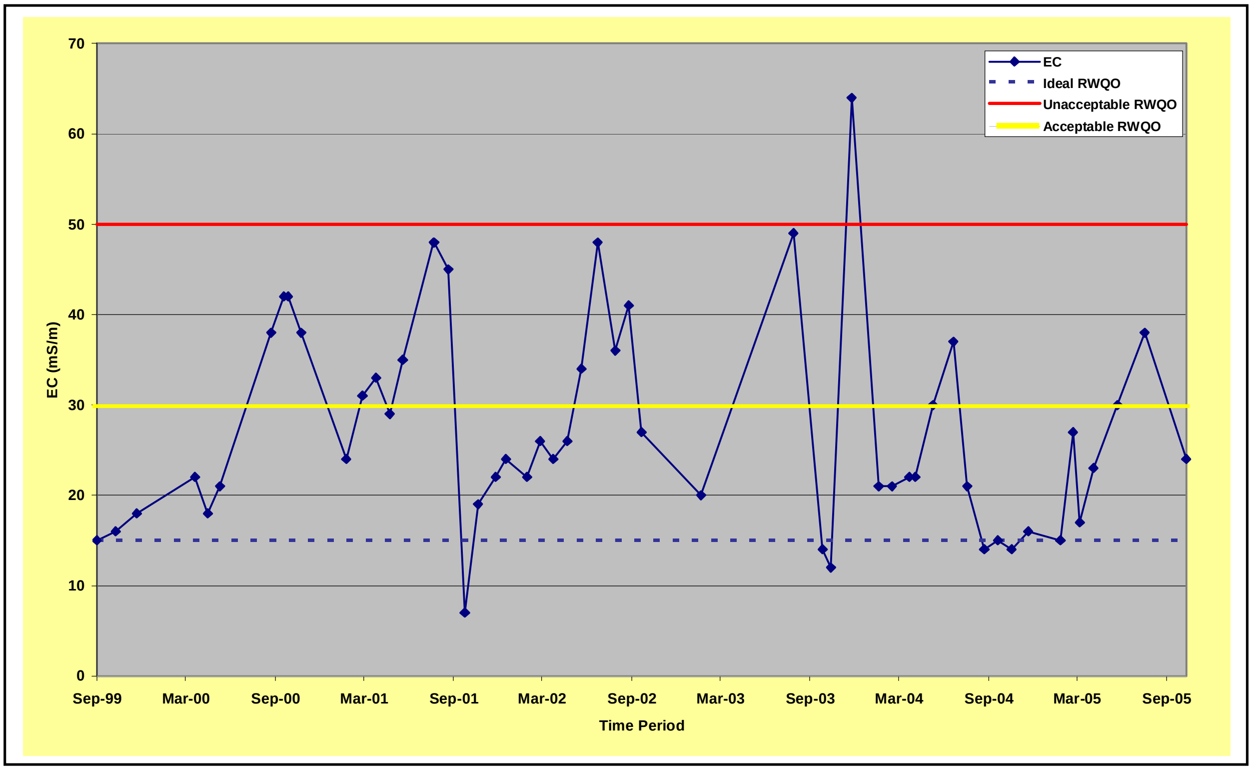


Figure 31: Time series graph of EC on Vaal River at Bloukop Bridge (monitoring point VS4)

If the water quality data of the contributing tributaries Klein Vaal and Rietspruit are analysed (**Figure 32** and **Figure 33**), no definitive conclusions can be drawn regarding their impact. Both tributaries do exhibit exceedance of the RWQO for electrical conductivity (EC), however the record is too short to establish a trend. However these results show that it is not a once off impact but some "seasonal trend" which in the case of the Klein Vaal does coincide to some extent with that of point VS4 (around September). The data sets are too limited to show any definite statistical trend. An investigation into the diffuse pollution sources within this sub-catchment is required to determine the origin of this increase in TDS concentrations at point VS4.

Grootdraai Dam itself exhibits good water quality with a mean TDS concentration of 161 mg/l. Point VS5, outflow of Grootdraai Dam, exhibits relatively low TDS concentrations (average 162 mg/l). The dam levels fluctuate significantly because of water transfers and releases from the dam, but the chemistry is fairly stable.

Point VS6 on the Vaal River shows a definitive increase in TDS concentrations with almost 80% of the values exceeding the acceptable RWQO TDS concentration of 195 mg/l. As VS5 displays a low TDS concentration it is evident that the catchment activities in this area contribute to this increase. If one looks at the trend at the point (**Figure 34** and **Figure 35**) it is apparent that there is a seasonal trend with the TDS concentration increasing from May to October due to low flows.

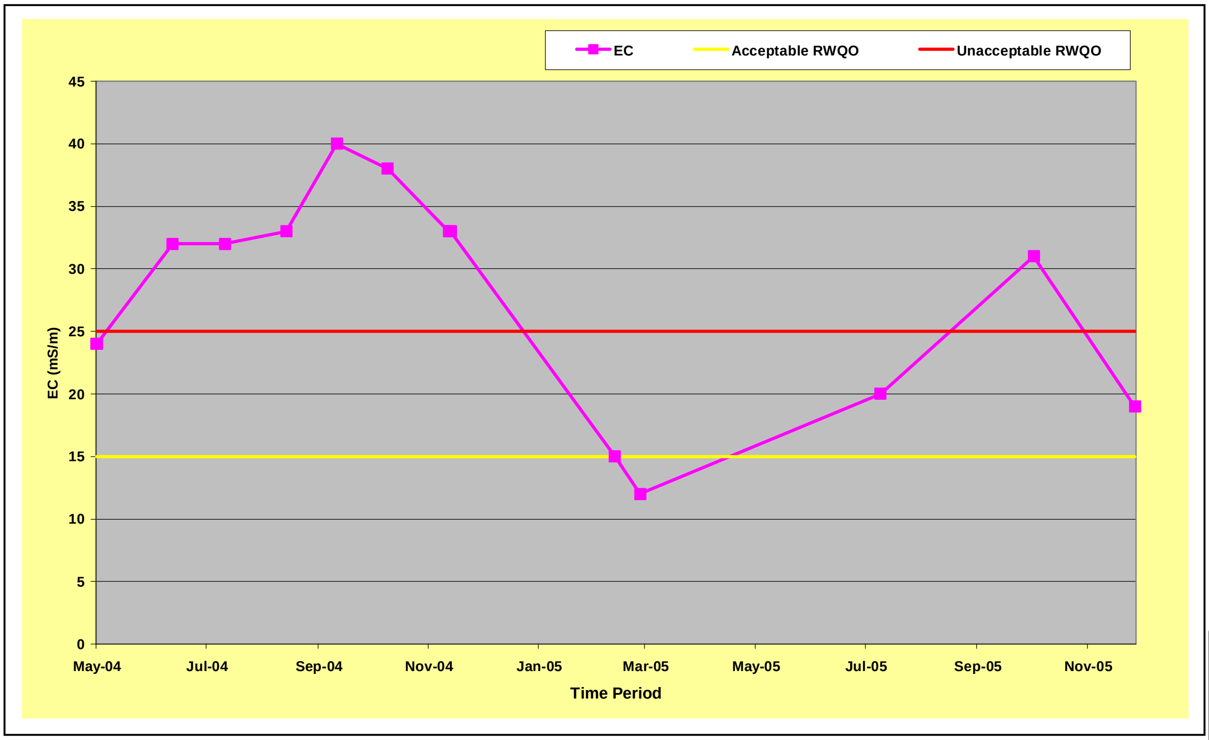


Figure 32: Time series graph of EC at level 2 monitoring point on the Klein Vaal

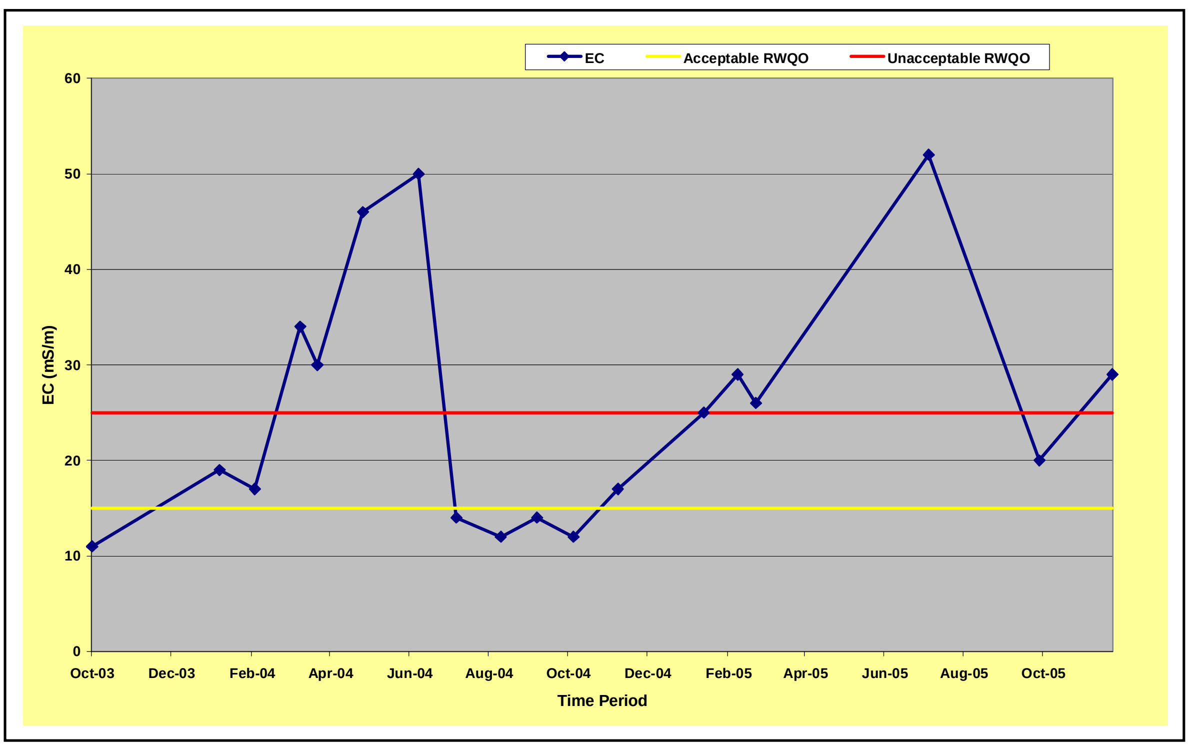


Figure 33: Time series graph of EC at level 2 monitoring point on the Rietspruit

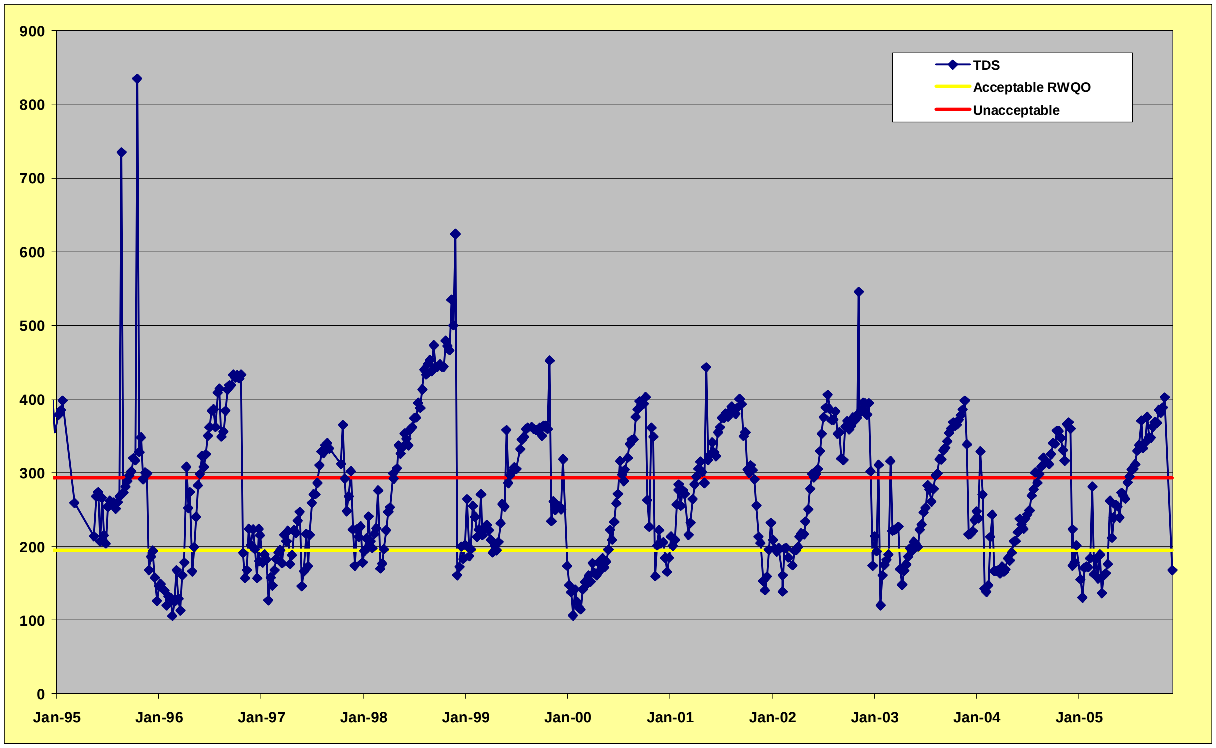


Figure 34: Times Series graph of EC on Vaal River at Villiers (point VS6)

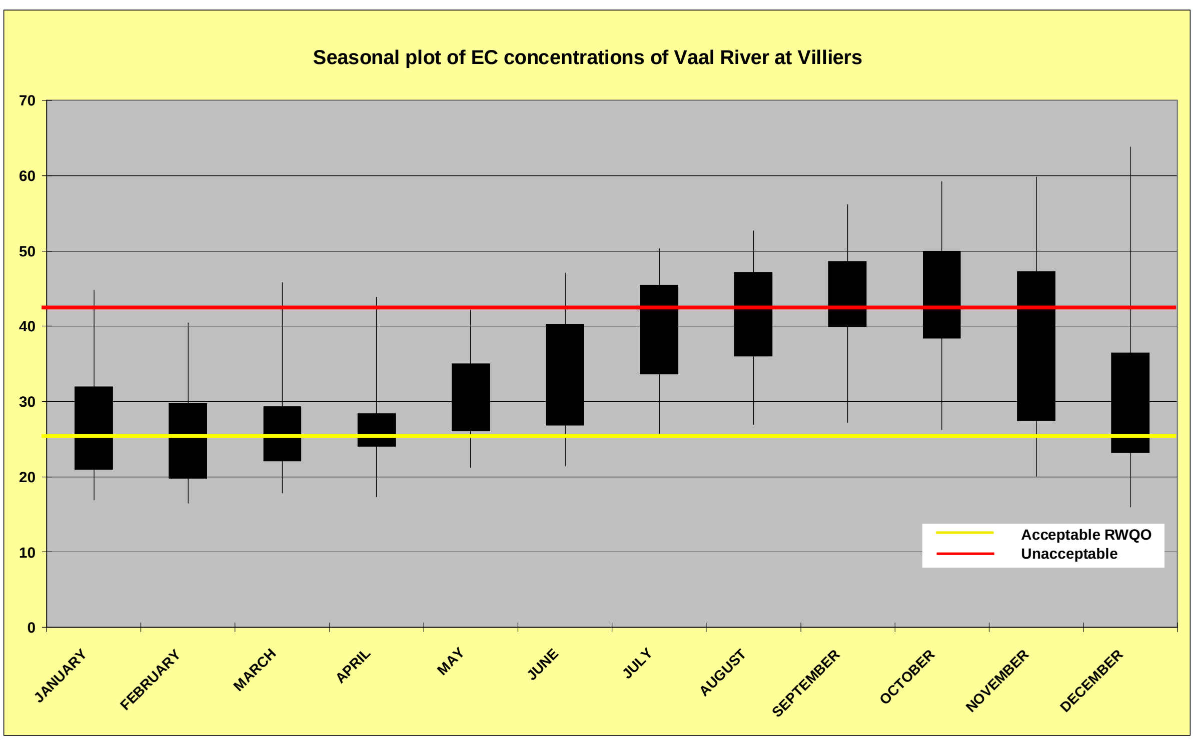


Figure 35: Box and whisker seasonal plot of EC on Vaal River at Villiers (VS6)

This trend is due to the influence of the extensive mining and industrial activities that are present in the Waterval catchment. The Sasol II and III complexes and the Evander mining operations are two of the major users in Waterval catchment and it is highly likely that these impactors amongst others (major towns of Secunda, Kinross, Evander) are contributing to these TDS levels. If one looks at the Waterval River (**Figure 36**) a seasonal trend emerges with regard to TDS concentrations *i.e.* increase concentrations during winter months. The time series plot of TDS indicates general compliance to the acceptable RWQO concentration for the river. However there is a discrepancy between the RWQOs of this tributary and that of the Vaal main stem regarding many variables. The acceptable RWQO of the Vaal River main stem at VS6 for TDS is 195 mg/l while that of the Waterval River 585 mg/l. Thus if the acceptable RWQO concentration of 195 mg/l for TDS is used for the Waterval River, then there is general exceedance of this management target. From **Figure 34** it is evident the flow in the Vaal River is not able to dilute the impact of the Waterval River, as reflected by the water poor water quality at point VS6 (Vaal River at Villiers).

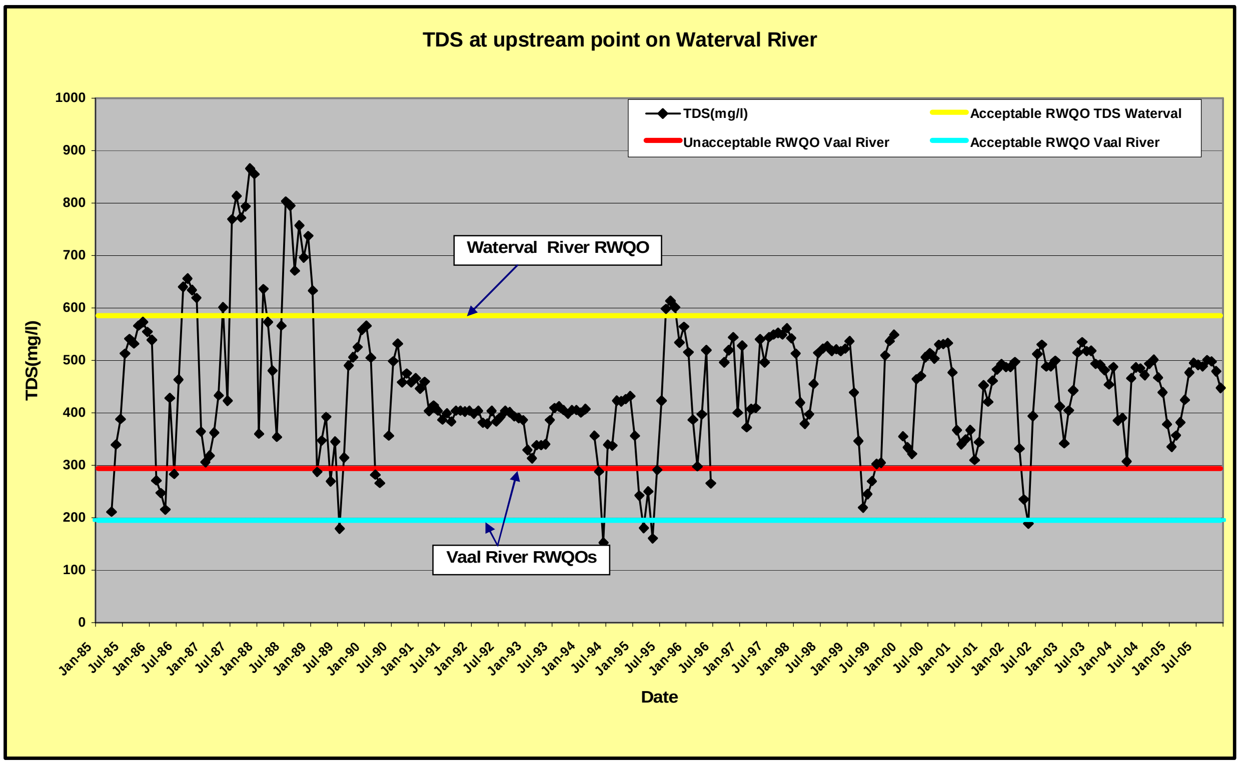


Figure 36: Time series graph of TDS on an upstream monitoring point on the Waterval River

Compliance to current RWQOs

From the tables below it is evident that compliance to the current RWQOs is fairly good from point VS1 to VS5 in the upper part of the Upper Vaal WMA. There are some exceedances of the unacceptable RWQO for a few variables however, this occurs in most instances only 5% of the time and no apparent trend can be identified. This could be due to certain isolated impacts. VS6, Vaal River at Villiers however does depict non-compliance to RWQOs of TDS 25% of the time and compliance to acceptable to tolerable level RWQOs the rest of the time. This indicates that point VS6 is a “problematic area” requiring some intervention as the acceptable level RWQO is also achieved only 25% of time, which is reflected above. The impact is not felt at VS7 as the good water quality from the Wilge River (Katse Dam water) dilutes the TDS concentration in Vaal Dam.

However, the current picture of fairly good compliance to currently applicable RWQOs in the upper part of the WMA maybe masked due to the difference in the level of stringency of RWQOs applied at each point.

- At VS1:

VS1 VAAL RIVER ORIGIN AT N17 BRIDGE (GDDC01)										
Variable	Units	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	Resource Water Quality Objectives			
							Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l)	0.05	0.05	0.05	0.05	0.3	<0.05	0.05-0.25	0.25-0.5	>0.5
Ammonia	(mg/l) as N	0.05	0.05	0.2	0.2	2.1	<0.02	0.02-0.5	0.5-1	>1
Sulphate	(mg/l)	5	5	12	16	24	<10	10-20	20-30	>30
Chloride	(mg/l)	7.8	12	13	14	20	<10	10-15	15-20	>20
EC	(mS/m)	8	9	10	12	16	<10	10-15	15-25	>25
TDS	(mg/l)	52	58.5	65	78	104	65	65 -97.5	97.5-162.5	>162.5
Phosphate	(mg/l) as P	0.05	0.05	0.05	0.05	0.1625	<0.05	0.05-0.08	0.08-1	>1

- At VS2:

VS2 VAAL RIVER AT R29/N2 BRIDGE AT CAMDEN (GDDC10)										
Variable	Units	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	Resource Water Quality Objectives			
							Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l)	0.024	0.05	0.05	0.18	0.4	<0.05	0.05-0.25	0.25-0.5	>0.5
Ammonia	(mg/l) as N	0.02	0.05	0.05	0.2	0.64	<0.02	0.02-0.5	0.5-1	>1
Sulphate	(mg/l)	5	10	16	25.25	45.75	<10	10-20	20-30	>30
Chloride	(mg/l)	6.3	10	13	17	20.7	<10	10-15	15-20	>20
EC	(mS/m)	12	16	17	21	35.15	<10	10-15	15-25	>25
TDS	(mg/l)	78	104	110.5	136.5	228.475	65	65 -97.5	97.5-162.5	>162.5
Phosphate	(mg/l) as P	0.05	0.05	0.075	0.2375	0.6225	<0.05	0.05-0.08	0.08-1	>1

- At VS3:

VS3 VAAL RIVER ON N11 BRIDGE TO AMERSFORT										
Variable	Units	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	Resource Water Quality Objectives			
							Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l)	0.05	0.05	0.05	0.2	0.315	<0.05	0.05-0.25	0.25-0.5	>0.5
Ammonia	(mg/l) as N	0.05	0.05	0.2	0.2	0.995	<0.02	0.02-0.5	0.5-1	>1
Sulphate	(mg/l)	5	12.25	14.5	21.75	37.65	<10	10-20	20-30	>30
Chloride	(mg/l)	5.25	7.75	10	12.25	15.5	<10	10-15	15-20	>20
EC	(mS/m)	10.85	12.25	16.5	18.75	22.3	<10	10-15	15-25	>25
TDS	(mg/l)	70.525	79.625	107.25	121.875	144.95	65	65 -97.5	97.5-162.5	>162.5
Phosphate	(mg/l) as P	0.05	0.05	0.05	0.05	0.6	<0.05	0.05-0.08	0.08-1	>1

- At VS4:

VS4 GDDC11 VAAL RIVER AT R35 BLOUKOP BRIDGE										
Variable	Units	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	Resource Water Quality Objectives			
							Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l)	0.04	0.05	0.10	0.30	0.74	<0.05	0.05-0.25	0.25-0.5	>0.5
Ammonia	(mg/l) as N	0.03	0.05	0.05	0.25	0.62	<0.02	0.02-0.5	0.5-1	>1
Sulphate	(mg/l)	9.2	23.0	31.0	45.5	70.5	<15	15-35	35-50	>50
Chloride	(mg/l)	9.3	11.3	16.0	19.0	28.3	<10	10-20	20-30	>30
EC	(mS/m)	14.0	20.8	25.0	36.3	48.3	<15	15-30	30-50	>50
TDS	(mg/l)	91	134.875	162.5	235.625	313.625	<97.5	97.5-195	195-325	>325
Phosphate	(mg/l) as P	0.05	0.05	0.05	0.19	1.00	<0.05	0.05-0.25	0.25-0.5	>0.5

- At VS5

VS5 C1R002Q01 GROOTDRAAI DAM ON VAAL RIVER: NEAR DAM WALL										
Variable	Units	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	Resource Water Quality Objectives			
							Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l)	0.04	0.12	0.21	0.31	0.56	<0.1	0.1-0.2	0.2-0.3	>0.3
Ammonia	(mg/l) as N	0.04	0.04	0.04	0.06	0.09	<0.2	0.2-0.5	0.5-1.0	>1
Sulphate	(mg/l)	14.5	18.9	22.7	26.8	32.3	<20	20-45	45-70	>70
Chloride	(mg/l)	6.5	8.7	10.1	12.3	16.5	<25	25-50	50-75	>75
EC	(mS/m)	17.5	21.6	23.5	25.6	28.5	<10	10-30	30-45	>45
TDS	(mg/l)	119	154	167	180	200	<65	65-195	195-293	>293
Phosphate	(mg/l) as P	0.01	0.01	0.02	0.03	0.07	<0.05	0.05-0.25	0.25-0.5	>0.5

- At VS6

VS6 C1H017Q01 VAAL RIVER AT VILLIERS FLOOD SECTION										
Variable	Units	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	Resource Water Quality Objectives			
							Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l)	0.04	0.04	0.11	0.26	0.79	<0.1	0.1-0.2	0.2-0.3	>0.3
Ammonia	(mg/l) as N	0.03	0.04	0.04	0.05	0.11	<0.2	0.2-0.5	0.5-1.0	>1
Sulphate	(mg/l)	17.0	23.9	30.3	36.0	46.0	<20	20-45	45-70	>70
Chloride	(mg/l)	7.8	11.3	15.7	22.8	32.0	<25	25-50	50-75	>75
EC	(mS/m)	20.4	26.9	36.3	46.5	52.9	<10	10-30	30-45	>45
TDS	(mg/l)	128	178	227.5	324	413	<65	65-195	195-293	>293
Phosphate	(mg/l) as P	0.02	0.03	0.04	0.07	0.13	<0.05	0.05-0.25	0.25-0.5	>0.5

WATER QUALITY STATUS: Salinity Status: Level 1 Points

TDS: Monitoring Points VS7 and VS8: Downstream Vaal Dam to Vaal Barrage

This increase in TDS concentration is attenuated by Vaal Dam, and this indicated by the improvement in water quality at point VS7, where TDS levels are within the acceptable RWQO range limits. The average TDS concentration of water in Vaal Dam is 154 mg/l. The water quality of Vaal Dam is under not threat as long as Katse Dam water continues to enter the system and current staus s maintained.

However beyond point VS7 downstream the problem of TDS increases almost three fold, where the impact of the Vaal Barrage and the middle Vaal River is seen. From the previous studies, various interviews, stakeholder inputs and the inception phase of this study it has become apparent that this area is probably the most central to the management of the water quality in the Vaal River, as it is the area where the most impact in terms of TDS is seen and from which point impacts significantly on downstream users.

From the Vaal Barrage to upstream Bloemhof Dam TDS levels in the Vaal River level off at around 500mg/l. If the seasonal historical TDS concentrations at point VS8 are analysed the trend depicted in **Figure 37** emerges.

The increase in the TDS concentrations from the point VS7 to VS8 is attributable to the highly impacted tributaries that drain into the Vaal Barrage but also includes some contribution of diffuse pollution. These main tributaries include the Rietspruit, Klip, Suikerbosrant, Leeuspruit and Taaiboosspruit rivers. The Vaal Barrage sub-catchment is one of the most complex catchments in South Africa. It is highly developed with industries, urban areas and mining activities. In excess of 90% of the dry weather flow is made up of return flow emanating from the respective tributaries. This is evident in **Figure 37** which reflects a peak in the TDS concentrations in the Vaal Barrage from May to September when the impact of the dry weather flows of the tributaries are assimilated in the Barrage. The TDS concentration levels off at about 600mg/ℓ due to the dilution rule practiced in the Vaal Barrage.

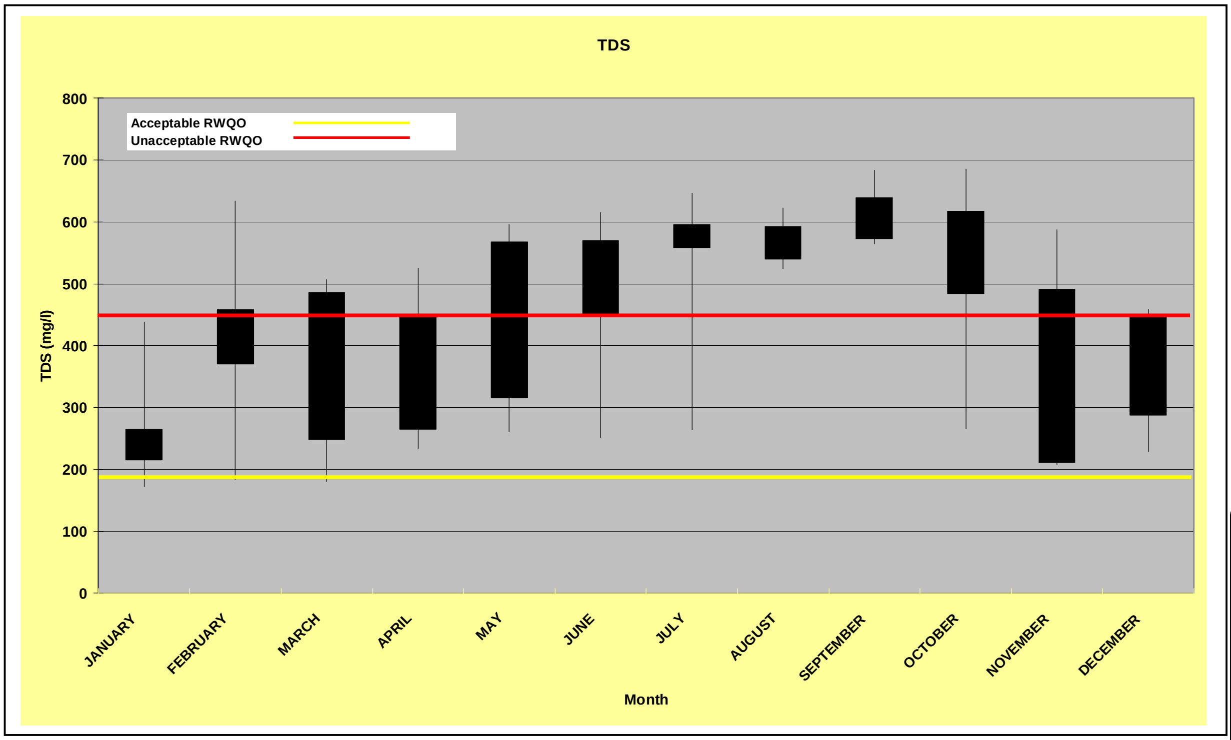


Figure 37: Box and whisker seasonal plot of TDS at point VS8 (Vaal Barrage)

This trend is aligned to the winter season, when the dilution capacities in the tributaries are reduced or in some cases absent. Although there is a decline in the TDS levels during the rainy seasons, the levels still relatively high, well above the acceptable RWQO concentration, bordering towards the unacceptable levels. This situation highlights the issue of how realistic the current RWQOs for the Vaal Barrage are. In relation to this is the non-alignment between the RWQOs of the tributary catchments and that of the Vaal Barrage.

The salinity levels of the contributing tributaries are reflected in **Figure 38** to **Figure 41**. It is evident that these major contributing tributaries are adding salt load to the Vaal Barrage as they exhibit similar seasonal trends similar to that seen at point VS8.

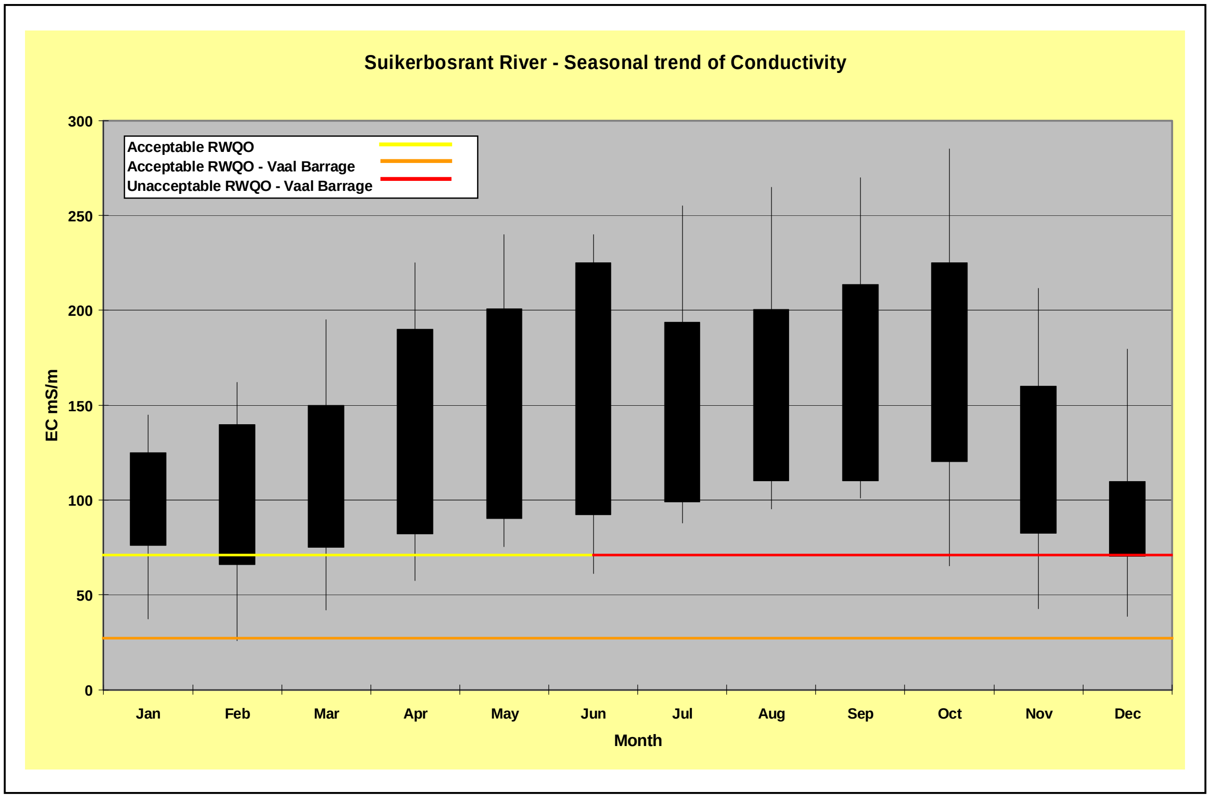


Figure 38: Box and whisker seasonal plot of EC at level 2 monitoring point on the Suikerbosrant River

WATER QUALITY STATUS:
Salinity Status: Level 1 Points

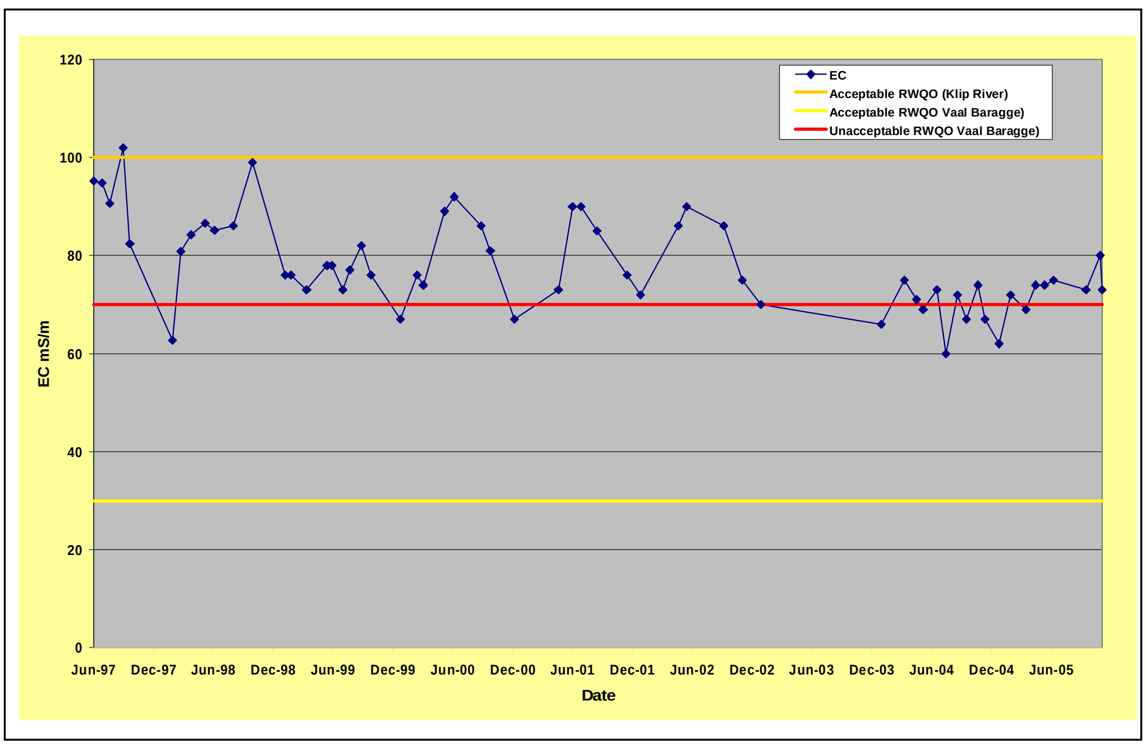


Figure 39: Time series graph of EC at level 2 monitoring point on the Klip River

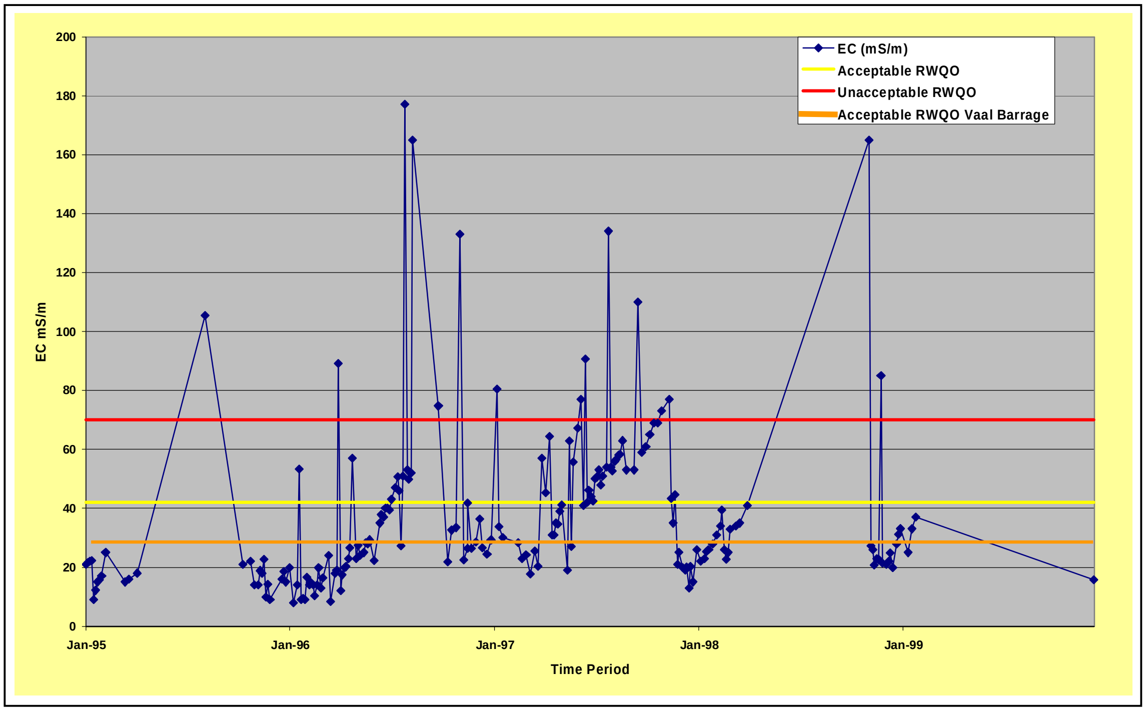


Figure 40: Time series graph of EC at level 2 monitoring point on the Taaibosspruit

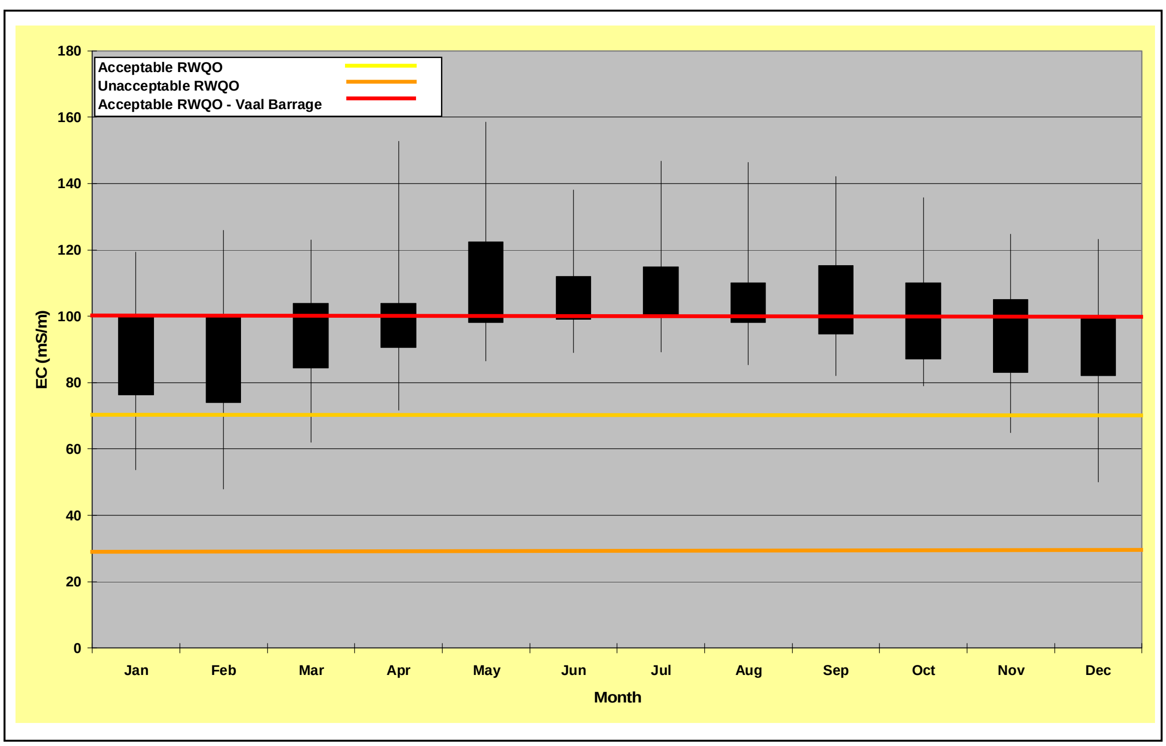


Figure 41: Box and whisker seasonal plot of EC at level 2 monitoring point on the Rietspruit River

Compliance to cuurent RWQOs

Good compliance to the RWQOs is being achieved at VS7 with the ideal to acceptable level RWQO being achieved 75% of the time. VS8 shows non-compliance to the applicable RWQOs 75% of the time for salinity. The current RWQOs for TDS at VS8 need to be investigated. It may require either more stringent levels to improve the situation or more lenient RWQOs to accommodate the reality of the contributing catchments and activities. However there could be a long term strategy adopted which progressively requires stricter RWQOs to be implemented. Although the current RWQOs for the Vaal Barrage are quite strict considering the highly impacted catchments draining into the Barrage, these RWQOs do not seem to be met, either due to non-alignment with the RWQOs of contributing catchments (due to lack of dilution capacity in Vaal River) or the extent of deterioration of water quality.

WATER QUALITY STATUS: Salinity Status: Level 1 Points

- At VS7

VS7 C2H122Q01 VAAL DAM ON VAAL RIVER: DOWN STREAM WEIR										
Variable	Units	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	Resource Water Quality Objectives			
							Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l)	0.04	0.14	0.25	0.41	0.66	<0.5	0.5-3	3-6	>6
Ammonia	(mg/l) as N	0.04	0.04	0.04	0.07	0.10	------	<0.5	0.5-1.0	>1
Sulphate	(mg/l)	7	12	17	22	30	<20	20-100	100-200	>200
Chloride	(mg/l)	5	9	10	11	14	<5	5-50	50-75	>75
EC	(mS/m)	13	18	22	24	27	<18	18-30	30-70	>70
TDS	(mg/l)	94	126	155	175	198	<117	117-195	195-455	>455
Phosphate	(mg/l) as P	0.01	0.02	0.03	0.05	0.10	------	<0.03	0.03-0.05	>0.05

- At VS8:

VS8 C2R008Q01 VAAL BARRAGE ON VAAL RIVER NEAR BARRAGE WALL										
Variable	Units	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	Resource Water Quality Objectives			
							Ideal	Acceptable	Tolerable	Unacceptable
Nitrate	(mg/l)	0.17	0.70	1.28	2.29	3.91	<0.5	0.5-3	3-6	>6
Ammonia	(mg/l)	0.02	0.02	0.04	0.13	0.51	------	<0.5	0.5-1.0	>1
Sulphate	(mg/l)	37.5	68.9	160.0	183.3	222.7	<20	20-100	100-200	>200
Chloride	(mg/l)	14.3	23.3	56.0	68.2	76.8	<5	5-50	50-75	>75
EC	(mS/m)	27.5	40.8	73.5	83.2	91.7	<18	18-30	30-70	>70
TDS	(mg/l)	180.4	259.0	471.0	559.0	647.8	<117	117-195	195-455	>455
Phosphate	(mg/l)	0.06	0.12	0.18	0.25	0.61	------	<0.03	0.03-0.05	>0.05

<u>TDS: Monitoring Points VS9 to VS15: Middle Vaal River</u>

No significant change is observed in the level of the TDS concentrations from the Vaal Barrage to just upstream Bloemhof Dam, point VS8 (471mg/l) to VS14 (515mg/l) . There is a slight increase in TDS at points VS9 and VS12, where the 50th percentile values are 539mg/l and 576mg/l respectively. This is attributable to the impacts of the tributaries that confluence just upstream of these points. At VS9 the Mooi River tributary brings with it large return flows from mine discharges and seepages (Wonderfontein catchment – West Rand Area), sewage effluents and irrigation return flows which accounts for this increase from the Vaal Barrage TDS values. This is reflected in **Figure 42** which depicts the water quality observed in the Mooi River.

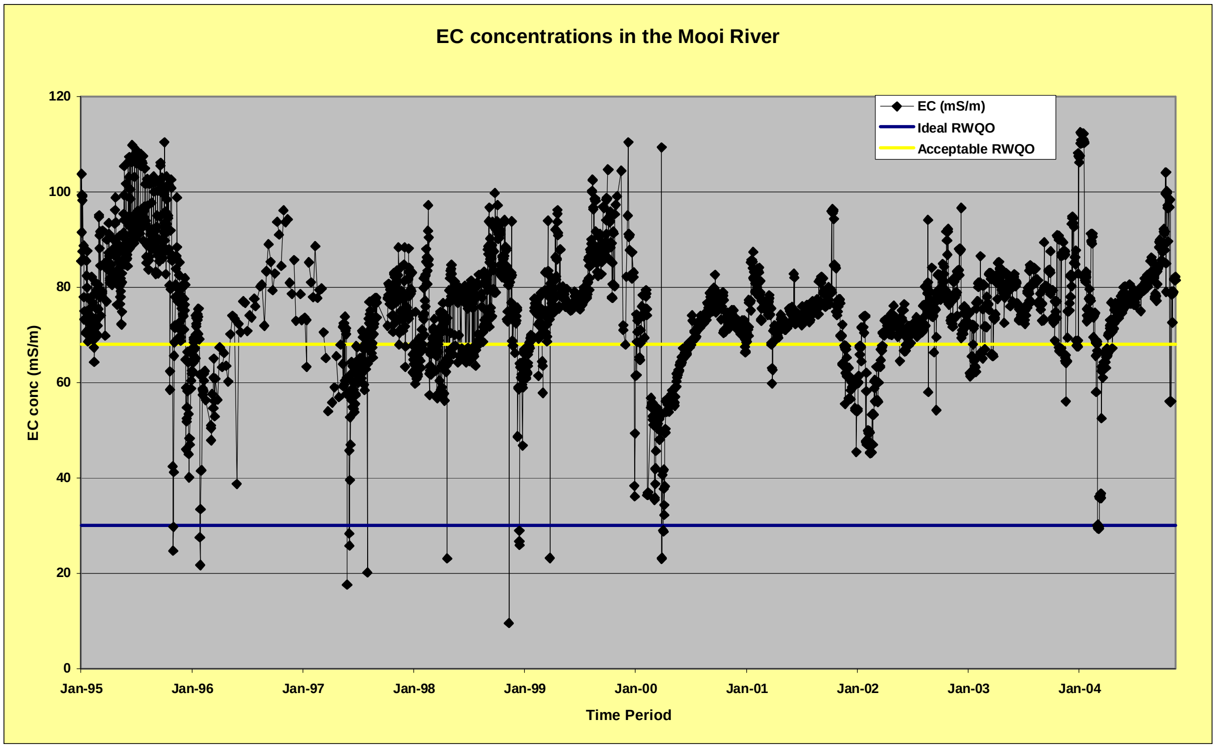


Figure 42: Time series graph of EC at level 2 monitoring point on the Mooi River

From the trend analysis it is evident that Mooi River does have an impact on the Vaal River with TDS concentrations ranging between 420mg/ℓ and 560mg/ℓ. Yet again the situation worsens during dry weather flows.

At point VS12, Orkney Bridge the peak in TDS concentrations can possibly be attributed to the impact of the Koekemoerspruit and Vierfontein tributaries which carry the impact of the mines in the area. Koekemoerspruit carries up to 1000mg/l TDS (DWAF, 2004f). However this high impact is not felt due to the dilution capacity of the Vaal River (The flow of the Koekemoerspruit is small compared to the Vaal River). The overall impact is thus not significant but does explain the slight increase of TDS at monitoring point VS12. No real change is seen in the TDS levels from Orkney Bridge onwards to Bloemhof Dam (points VS13, Regina Weir to VS15, upstream Bloemhof Dam).

Compliance to current RWQOs

The compliance of current water quality status to the applicable RWQOs at point VS9 is depicted in the table below. As it can be seen the situation is bad, with compliance only being achieved 5% of the time.

- At VS9:

VS9 C2H260Q01 VAAL RIVER LOW WATER BRIDGE AT KROMDRAAI								
Variable	Units	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	Resource Water Quality Objectives	
							Ideal	Acceptable
TDS	(mg/l)	285.41	444.44	539.45	580.14	619.6	195	397

For the middle Vaal River, it appears that there is a general non-compliance to the RWQOs for TDS at VS10-VS13 for 5% of the time and for 25% of the time at VS14. While this represents a fairly good situation, the applicability of the RWQO needs to be determined. These objectives, specifically TDS were set based on the current status of the Middle Vaal River (February 2006) and thus were meant to manage the situation at the current levels and not to focus on the improvement to better levels/ or in terms of what is sustainable for the system. This however will have to be considered in the task, which focuses on the integration of the RWQOs.

- At VS10:

VS10 VERMAASDRIFT							
Variable	Units	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	RWQO Acceptable Management Target
Nitrate	(mg/l)	0.4	0.5	0.5	2.3	2.5	3
Sulphate	(mg/l)	49.12	109	149	178	209	250
Chloride	(mg/l)	21.8	51	66	72	86.6	100
EC	(mS/m)	35.6	63	78	84	90.6	90
TDS	(mg/l)	249.2	441	546	588	634.2	630
Phosphate	(mg/l) as P	0.1	0.19	0.34	0.53	0.9	0.03

- At VS11:

VS11 MIDVAAL INTAKE							
Variable	Units	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	RWQO Acceptable Management Target
Nitrate	(mg/l)	0.50	0.50	0.55	2.30	2.50	3
Sulphate	(mg/l)	58	118	156	186	221	250
Chloride	(mg/l)	25	55	69	75	87	100
EC	(mS/m)	41	66	77	85	95	90
TDS	(mg/l)	287	463.75	539	596.75	665	630
Phosphate	(mg/l) as P	0.11	0.20	0.33	0.53	0.90	0.03

- At VS12:

VS12 VAAL RIVER AT PILGRIMS ESTATE/ORKNEY							
Variable	Units	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	RWQO Acceptable Management Target
Nitrate	(mg/l)	0.28	0.5	0.6	2.3	2.5	3
Sulphate	(mg/l)	53	125	179	208	242	250
Chloride	(mg/l)	23	55	72	79	87	100
EC	(mS/m)	39	69	82	92	103	90
TDS	(mg/l)	250.9	448.5	533	598	670.8	630
Phosphate	(mg/l) as P	0.05	0.17	0.29	0.53	0.98	0.03

- At VS13:

VS13 REGINA BRIDGE							
Variable	Units	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	RWQO Acceptable Management Target
Nitrate	(mg/l)	0.50	0.50	0.50	2.03	2.50	3
Sulphate	(mg/l)	58	128	166	201	227	250
Chloride	(mg/l)	23	52	66	79	91	100
EC	(mS/m)	41	69	79	90	104	90
TDS	(mg/l)	266.5	445.25	513.5	583.375	673.075	630
Phosphate	(mg/l) as P	0.09	0.22	0.27	0.53	0.96	0.03

- At VS14:

C2H061Q01 VAAL RIVER AT KLIPPLAATDRIFT							
Variable	Units	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	RWQO Acceptable Management Target
Nitrate	(mg/l)	0.04	0.04	0.1	0.4	0.9	3
Ammonia	(mg/l) as N	0.03	0.04	0.04	0.05	0.11	0.1
Sulphate	(mg/l)	40.3	86.2	163.4	217.4	265.4	250
Chloride	(mg/l)	13.6	27.6	56.2	76.3	96.0	100
EC	(mS/m)	30.1	48.0	74.6	91.8	106.2	90
TDS	(mg/l)	211	362	528	650	807	630
Phosphate	(mg/l) as P	0.03	0.06	0.09	0.15	0.27	0.03

TDS: Monitoring Points VS16 to VS20: Lower Vaal River

The quality of the water in the Vaal River improves at the outflow of Bloemhof Dam (VS16) with the TDS values dropping to the range of 350 mg/l (50th percentile value). It is evident that increasing dam levels are associated with decreasing salts levels (**Figure 43**). Therefore, the dam reached very high TDS during the last three years of drought (maximum of 720 mg/ℓ) (**Figure 43**).

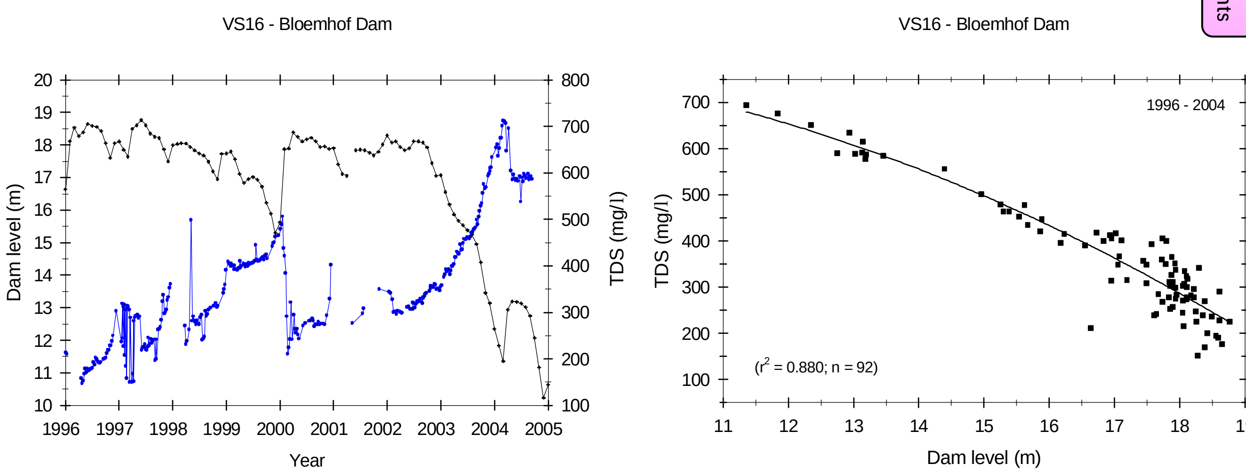


Figure 43: Variation in dam level (m) and TDS concentration in Bloemhof Dam since 1996

The TDS concentration of 350mg/l from the outflow of Bloemhof Dam stays approximately constant in the Vaal River to point VS19 (Schmidtsdrift), where the impact of the Harts River is felt. At this point TDS levels increase, due to the high TDS loads that the Harts River carries from the irrigation return flows of the Vaalharts irrigation scheme. The times series graph of EC in the Harts River is shown in **Figure 45** supports this reasoning. There was a gap in the monitoring data between 1998 and 2001.

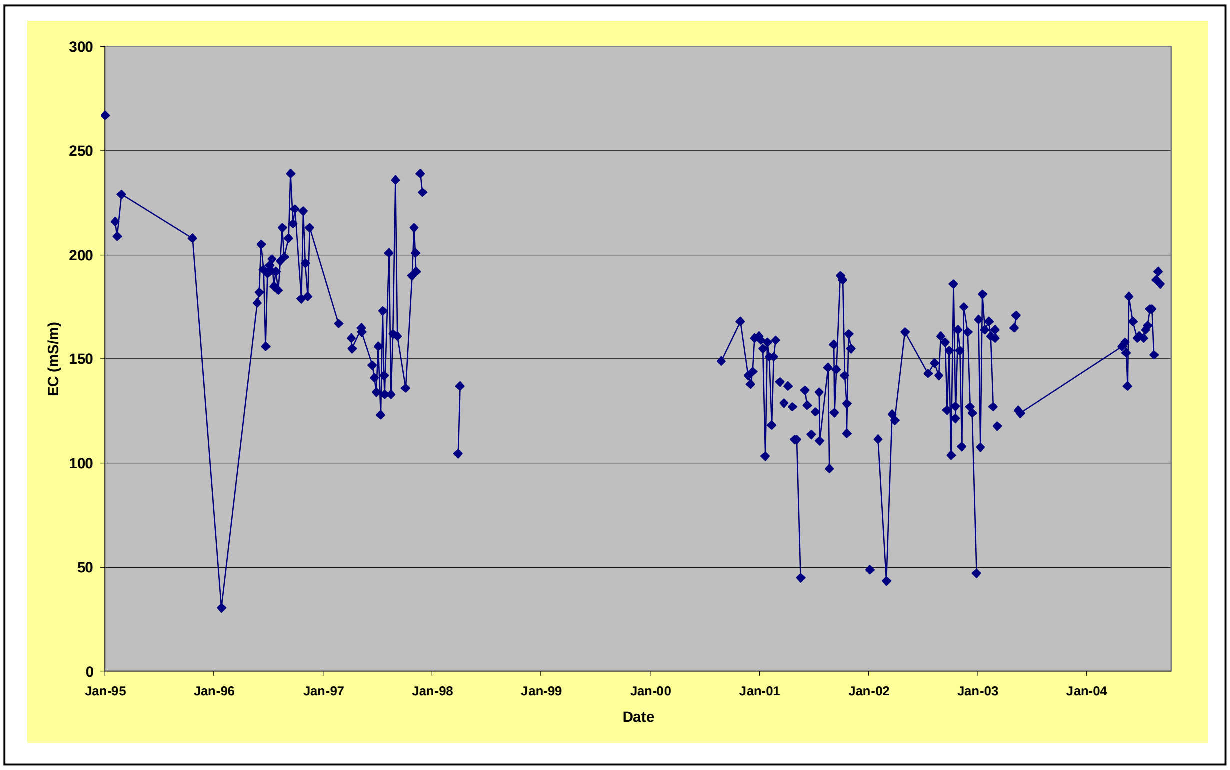


Figure 44: Time series graph of EC at level 2 monitoring point on the Harts River

From the graph above it is evident that the TDS concentrations in Harts River average around 800mg/l. This would thus account for the peak in TDS levels (average 550 mg/l) seen at point VS19 at Scmidtsdrift. In addition to the Vaal Barrage, this area is the other key area requiring some major water quality management intervention.

At point VS20, Douglas Barrage the average TDS concentration was high (average 500 mg/ℓ), and the concentrations have increased significantly over recent years. One would expect the TDS levels to improve more substantially due to the good quality Orange River water that enters the system at this point, however the high salinity loads of the Riet River (**Figure 45**) minimise this diluting effect. The resulting situation is the “salt plug” that exists at Douglas Barrage.

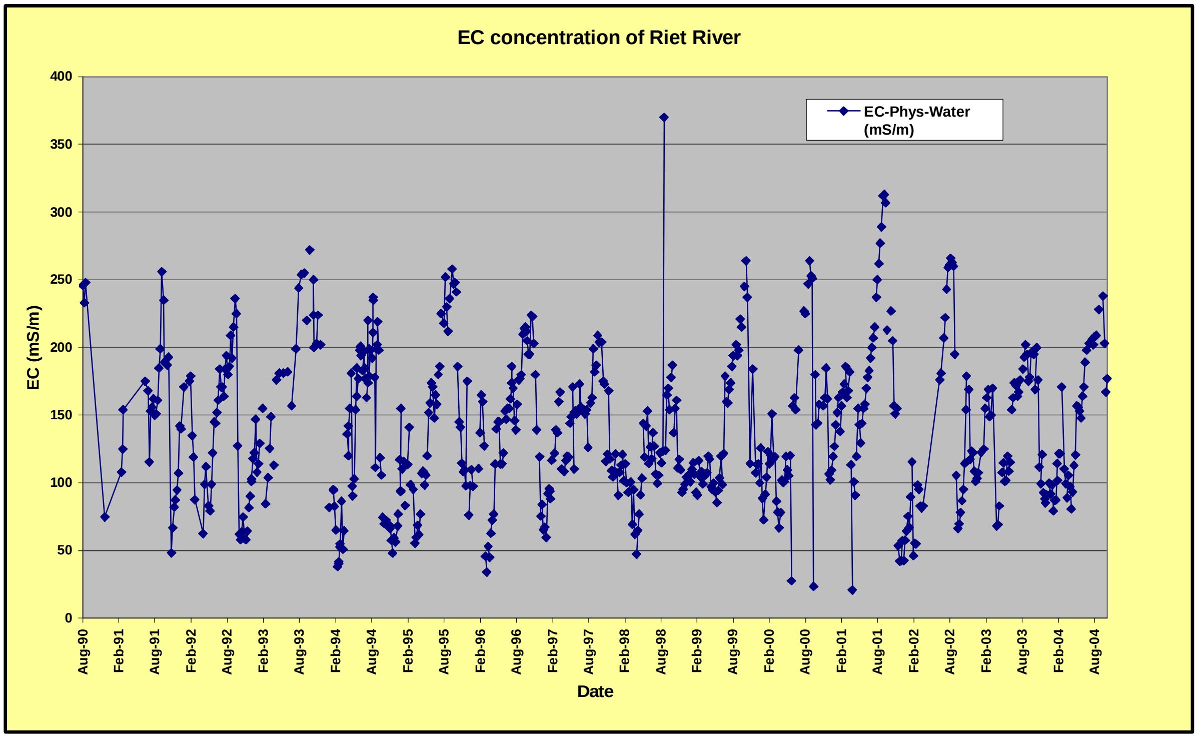


Figure 45: Time series graph of EC at level 2 monitoring point on the Riet River

Compliance to current RWQOs

The situation in the Lower Vaal WMA for compliance to the applicable RWQOs at the strategic monitoring points depicts a fairly good situation (see tables below). Non compliance to RWQOs appears to occur only 5% of the time for certain variables at points VS16 to VS20. However here again, although good compliance is indicated, the applicability of the RWQOs, especially for TDS needs to be determined. These objectives, were set based on the current status of the water quality in the Lower Vaal River (February 2006) and thus were meant to manage the situation at the current levels and not to focus on the improvement to better levels or on the sustainanbility of the system. This however will also have to be considered in the task to integrate the RWQOs.

- At VS16:

C9H021Q01 BLOEMHOF DAM ON VAAL RIVER: DOWN STREAM WEIR							
Variable	Units	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	RWQO Acceptable Management Target
Nitrate	(mg/l)	0.04	0.04	0.09	0.16	0.70	3
Ammonia	(mg/l) as N	0.03	0.04	0.04	0.07	0.25	0.1
Sulphate	(mg/l)	37	60	103	139	204	250
Chloride	(mg/l)	12	24	38	54	83	100
EC	(mS/m)	28	42	54	68	91	120
TDS	(mg/l)	204	270	373	450	599	840
Phosphate	(mg/l) as P	0.01	0.02	0.03	0.04	0.07	0.04

- At VS17:

C9H008Q01 VAALHARTS BARRAGE ON VAAL RIVER: DOWN STREAM WEIR							
Variable	Units	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	RWQO Acceptable Management Target
Nitrate	(mg/l)	0.04	0.04	0.06	0.14	0.59	3
Ammonia	(mg/l) as N	0.02	0.04	0.04	0.05	0.09	0.1
Sulphate	(mg/l)	31	60	95	131	202	250
Chloride	(mg/l)	12	24	33	54	87	100
EC	(mS/m)	27	41	51	67	92	120
TDS	(mg/l)	204	256	328	424	626	840
Phosphate	(mg/l) as P	0.01	0.02	0.02	0.04	0.07	0.04

- At VS18:

C9H009Q01 VAAL RIVER AT DE HOOP							
Variable	Units	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	RWQO Acceptable Management Target
Nitrate	(mg/l)	0.04	0.04	0.04	0.08	0.55	3
Ammonia	(mg/l) as N	0.02	0.04	0.04	0.04	0.08	0.1
Sulphate	(mg/l)	37	65	88	150	250	250
Chloride	(mg/l)	15	23	33	63	118	100
EC	(mS/m)	32	41	51	75	113	120
TDS	(mg/l)	228	291	360	463	701	840
Phosphate	(mg/l) as P	0.01	0.01	0.02	0.03	0.07	0.04

- At VS19:

C9H024Q01 AT SCHMIDTSDRIFT (WEIR) ON VAAL RIVER							
Variable	Units	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	RWQO Acceptable Management Target
Nitrate	(mg/l)	0.04	0.04	0.04	0.09	0.39	3
Ammonia	(mg/l) as N	0.02	0.04	0.04	0.04	0.07	0.1
Sulphate	(mg/l)	51	84	135	169	230	250
Chloride	(mg/l)	19	39	72	99	132	100
EC	(mS/m)	36	53	76	89	120	120
TDS	(mg/l)	255	354	523	614	821	840
Phosphate	(mg/l) as P	0.01	0.01	0.02	0.03	0.08	0.04

- At VS20:

C9R003Q01 DOUGLAS BARRAGE ON VAAL RIVER: NEAR BARRAGE WALL							
Variable	Units	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	RWQO Acceptable Management Target
Nitrate	(mg/l)	0.04	0.05	0.12	0.24	0.57	3
Ammonia	(mg/l) as N	0.03	0.04	0.04	0.06	0.12	0.1
Sulphate	(mg/l)	26	69	118	180	235	250
Chloride	(mg/l)	14	34	82	136	195	100
EC	(mS/m)	28	47	73	103	135	120
TDS	(mg/l)	151	298	516	698	961	840
Phosphate	(mg/l) as P	0.01	0.02	0.02	0.03	0.07	0.04

WATER QUALITY STATUS:
Salinity Status: Level 1 Points

Sulphate and Chloride along the Vaal River: Level 1

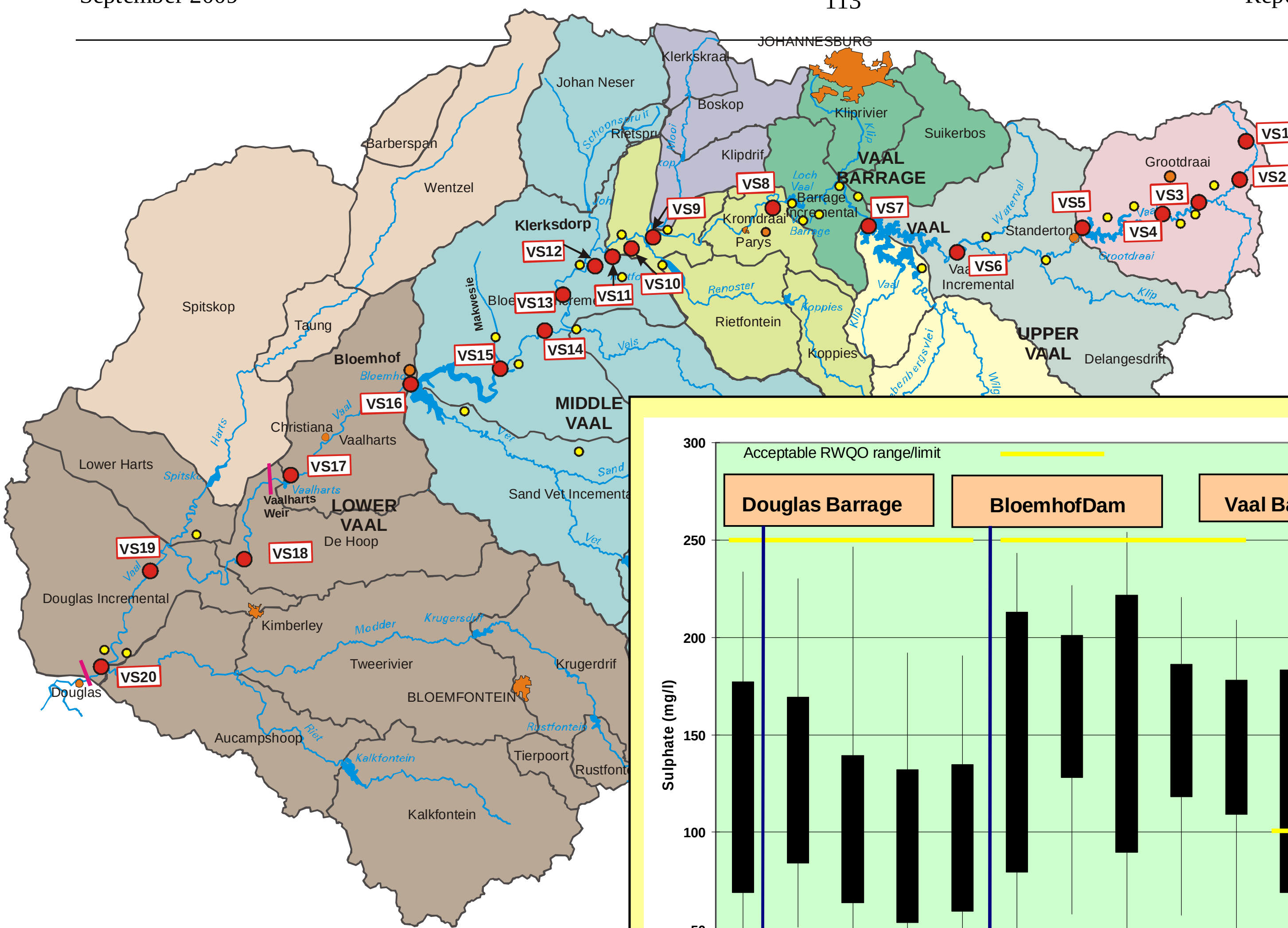
The analysis of sulphate and chloride trends along the Vaal River depicted in **Figure 46** and **Figure 47**. From the analysis it is evident that they mirror the TDS trends all the way along the Vaal River. These macro ions are at acceptable conentrations up to point VS5. However they also show peaks at point VS4 and VS6, similar to the TDS graph. Sulphate and chloride also exhibit a significant increase at point VS8 (Vaal Barrage), after which they stabilise in concentration to Bloemhof Dam. This peak is probably attributable to the mine water discharges and decants that occur between Vaal Barrage and the KOSH area. Although they do not increase much in concentration, their levels are high. While chloride levels drop slightly at the point upstream of Bloemhof Dam, sulphate levels do not change much. The concentrations of sulphate and chloride are improved at the outflow of Bloemhof Dam, but rise again after the confluence of the Harts River which can be expected due to the high salt levels present in the Harts River.

Chloride values increase quite substantially in the Douglas Barrage after the impact of the Harts River. This increase could be the impact of the Harts River that carries large quantities of chloride that eventually accumulates in Douglas Barrage or it could also be a contribution of the Riet River which also carries some salt load from the irrigation return flows in the Modder Riet Catchment (**Figure 45**). It is evident from the seasonal plot of EC of the Riet River that there is a definite seasonal trend in salt loads. The EC concentrations increase and are high during the dry weather flow, and improve again during wet weather flow. The dry weather flow concentrations of EC in the Riet River exceed the acceptable level RWQO (management target) of 120mg/l in the Vaal River.

It is evident that in managing the TDS levels (by management of the impacting activities), the levels of sulphate and chloride will be managed. However, management of TDS will also reveal those areas where sulphate or chloride are isolated issues requiring independent interventions.

Conclusion

From the above analysis of salinity it is evident that two key areas of concern in the study area are the Vaal Barrage/Middle Vaal River reach of the Vaal River, the Harts River area and the reach of the Vaal River after the confluence of the Waterval River. This situation is attributable to the land use activities typical of these areas. Thus the first option considered would be to ensure stricter source control, after which other avenues could be followed.



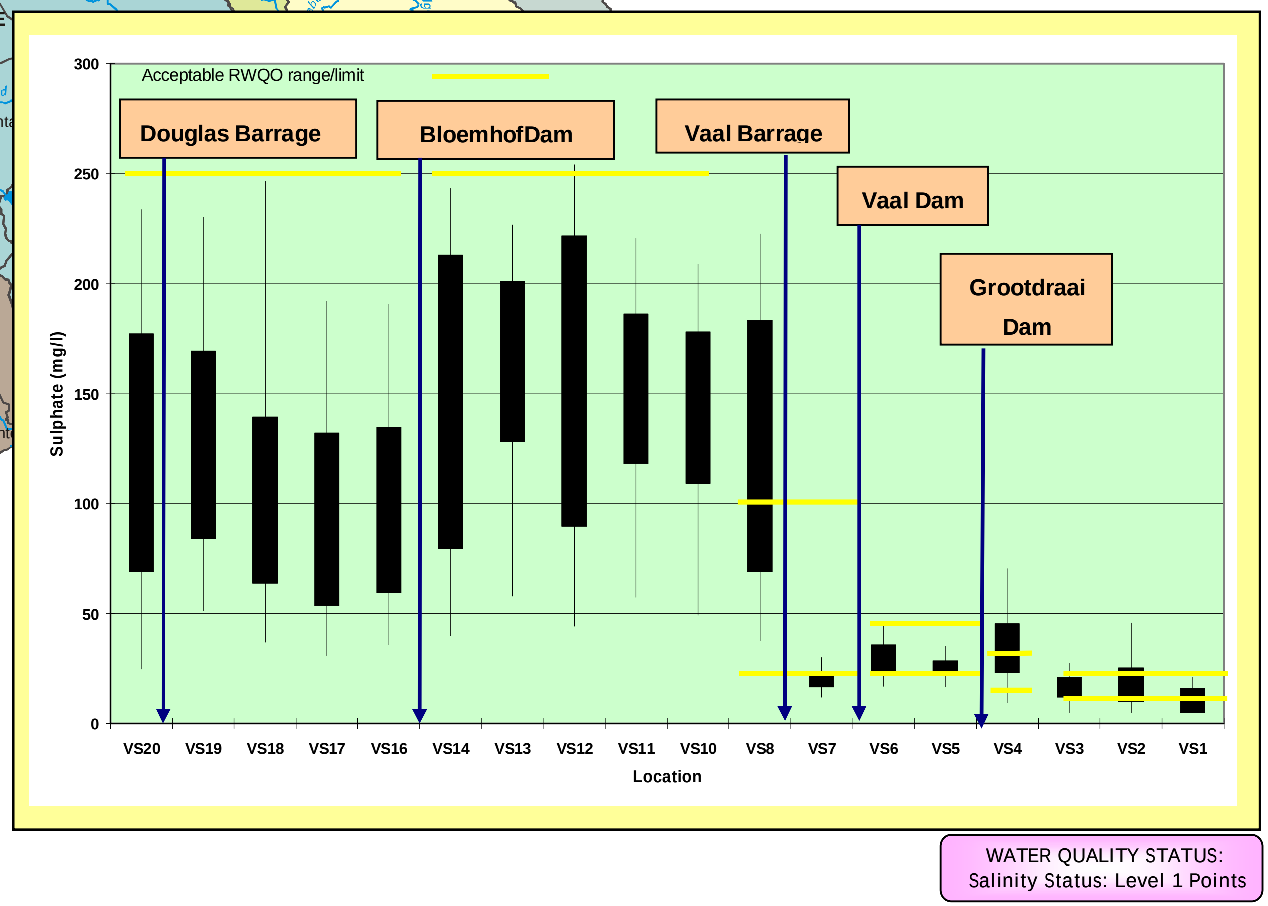


Figure 46: Sulphate trends along the Vaal River

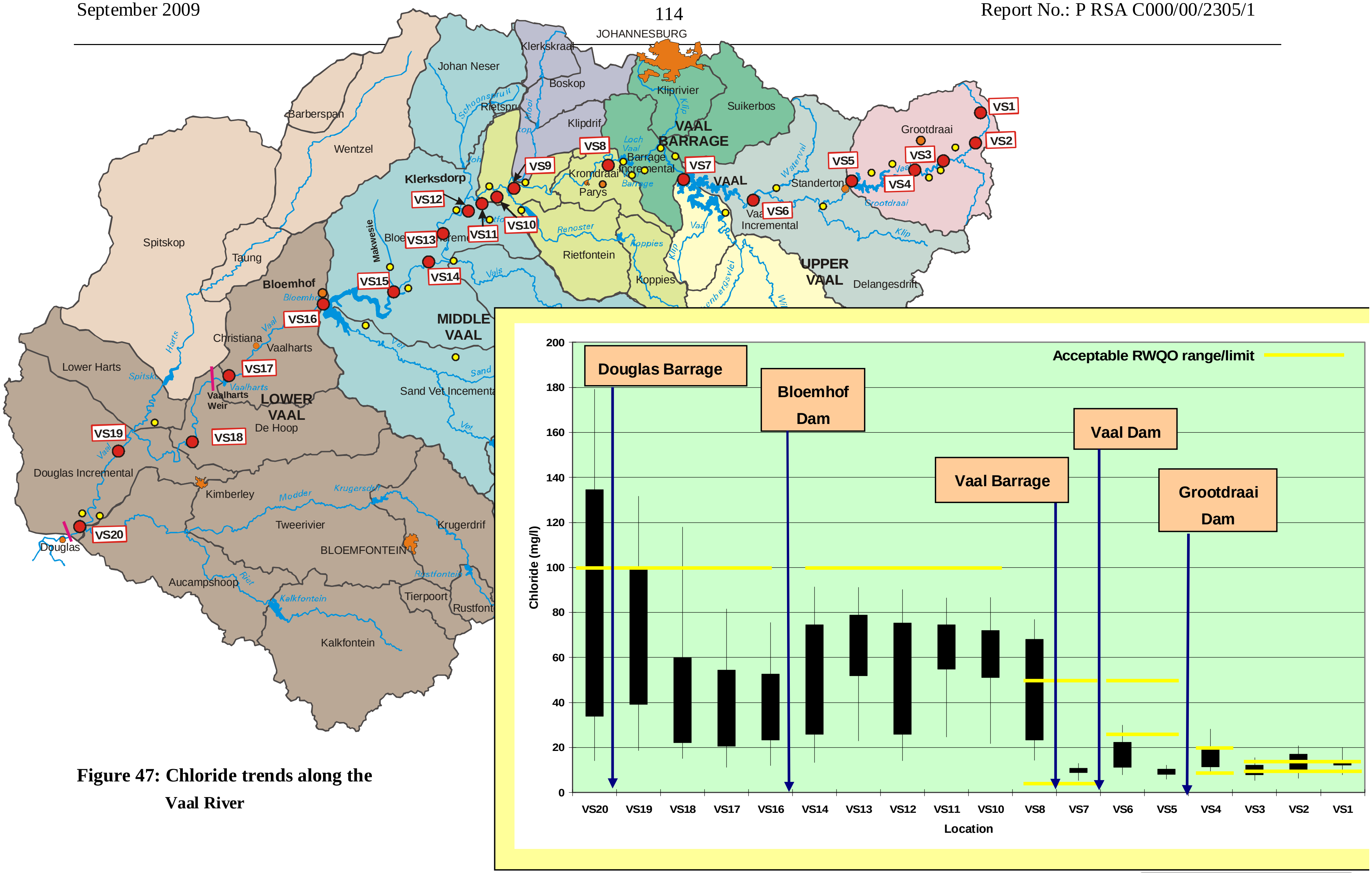


Figure 47: Chloride trends along the Vaal River

WATER QUALITY STATUS:
Salinity Status: Level 1 Points

6.5 General trends in relation to other water quality variables (physical and chemical)

- **Turbidity:**

The high TDS concentrations in the Vaal River evidently influence the turbidity of the water. Because light is a driving force for primary production, changes in light attenuation will have a direct influence on the trophic dynamics of aquatic ecosystems.

A significant inverse correlation shows that higher salts concentrations in the Vaal River were associated with lower turbidity (**Figure 48**), thus deeper light penetration into the water and higher light availability for algal growth. Increased cation concentrations enhance flocculation of clay particles because their zeta potential (a measure of the nett negative charge on a clay particle in suspension) is lowered and should therefore result in a reduction in turbidity due to an increased settling rate of suspended clay particles.

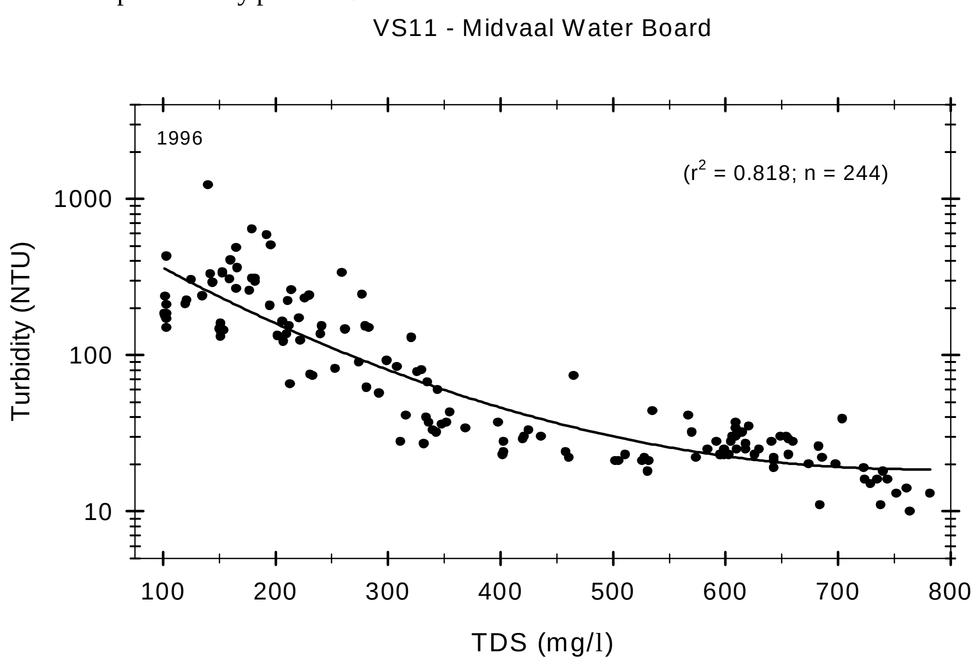


Figure 48: Relationship between dissolved salts (mg/ℓ) and turbidity (NTU) in the Vaal River at Midvaal. Note the log scale on the y-axes.

- **pH Values**

The pH is an important variable in water quality assessment, as it influences many biological and chemical processes within a water body and all processes associated with water supply and treatment. The pH of most natural waters is between 6.0 and 8.5, although lower values can occur in diluted waters rich in organic content, and higher values in eutrophic waters, and salt lakes (DWAF, 1995).

However, the pH of the Vaal River water (main stream) was generally high (alkaline, overall mean 8.05). The pH values were relatively low in the upper part of the river (average 7.4) (**Figure 49**). The higher pH values in the middle and lower part of the Vaal River are primarily ascribed to higher algal concentrations.

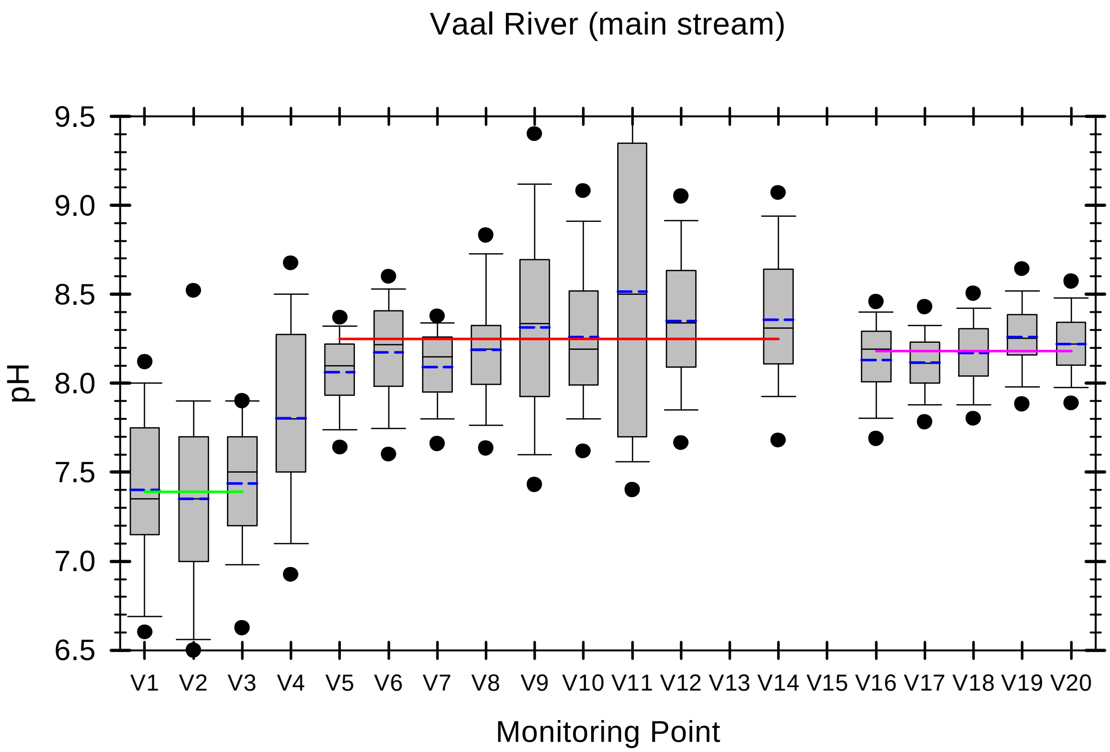


Figure 49: Box plot of downstream variation in pH values in the Vaal River (main stream) during the last 10 years (1996 – 2005).

WATER QUALITY STATUS:
Salinity Status: Level 1 Points

The pH in the Vaal River water was significantly influenced by the chlorophyll concentration in the water (**Figure 50**) because the photosynthesis by the algae during the day increases the pH, as each mole (12 g) of carbon taken up by the algae releases 1.196 moles (20.332 g) of hydroxyl ions (OH^-) into the water. It is generally observed in eutrophic systems that peak pH levels coincide with peak dissolved oxygen concentrations, with peak levels occurring mid afternoon and minimum levels at pre-dawn.

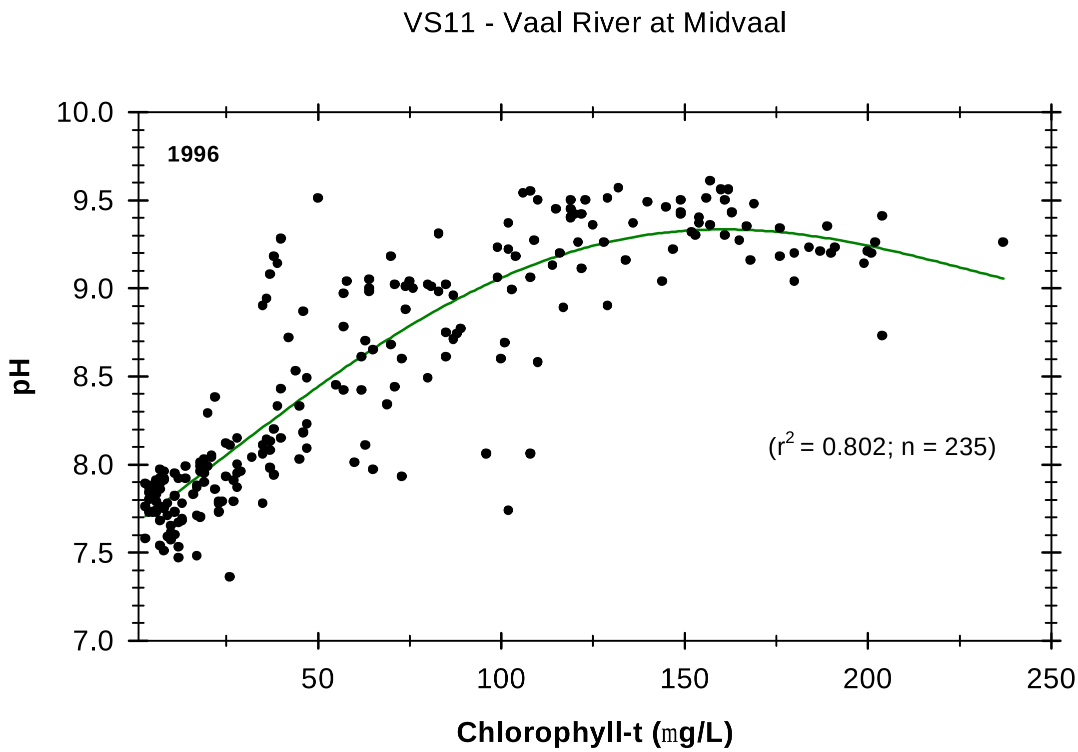
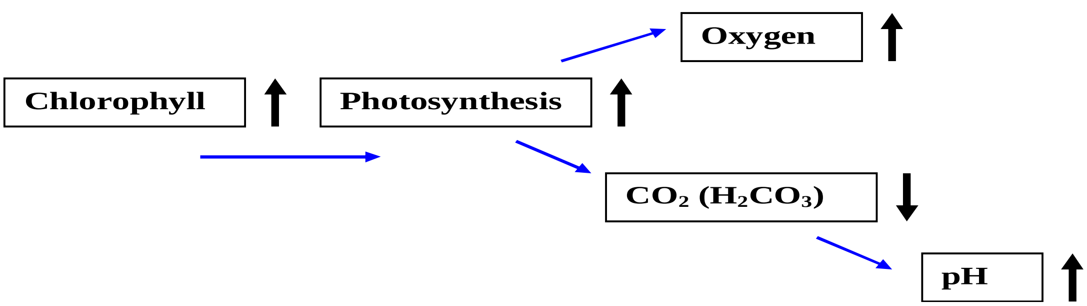
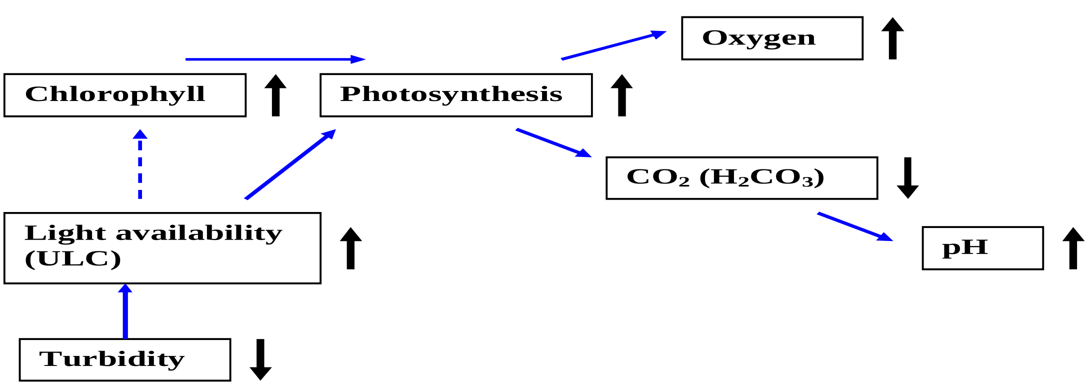


Figure 50: Relationship between cholorphyll and pH in the Vaal River at Midvaal



There is also a significant correlation between turbidity and pH i.e. lower turbidity results in higher underwater light climate that results in higher photosynthesis, lower carbonic acid, thus higher pH.



In the Vaal River (at Midvaal) about 50 % of the variation in turbidity could explain the variation in the total chlorophyll concentration (**Figure 51**).

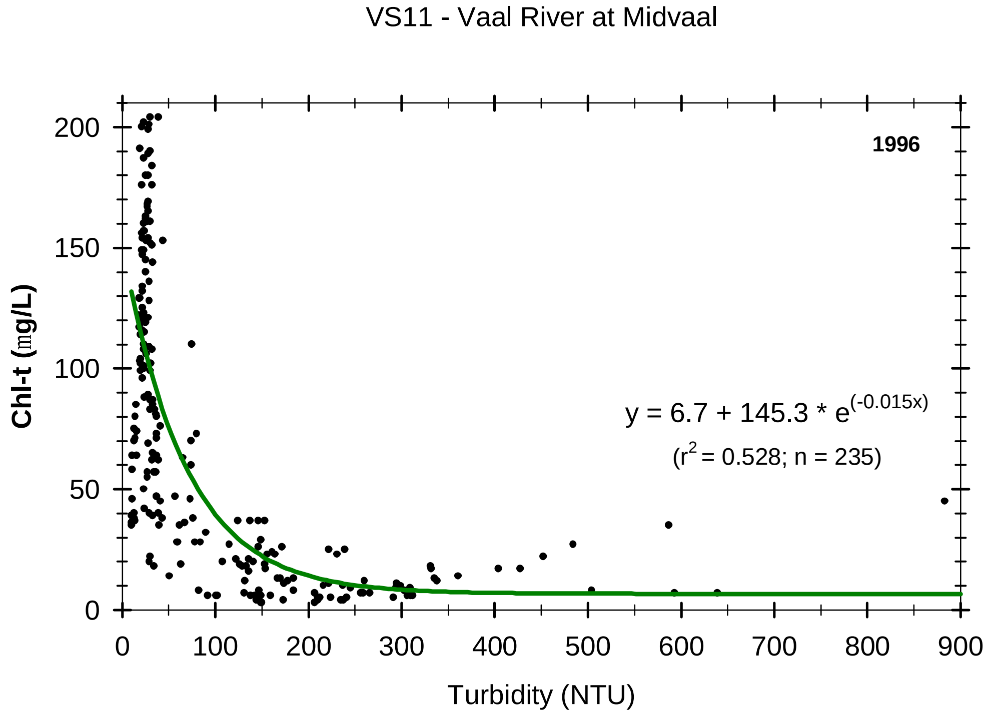


Figure 51: Relationship between turbidity (NTU) and chlorophyll concentration in the Vaal River at Midvaal

- **Alkalinity**

Alkalinity is the acid-neutralising capacity of water and is usually expressed as mg $CaCO_3$/ℓ. Alkalinity is mostly taken as an indication of the concentration of carbonate, bicarbonate and hydroxide, but may include contributions from borate, phosphates, silicates and other basic compounds. The total alkalinity (TAL) concentrations typically found in freshwater system ranged between 50 and 250 mg/ℓ.

However, in the Vaal River, the TAL values have increased significantly (average, 22 %) during the past 10 years (**Figure 52**).

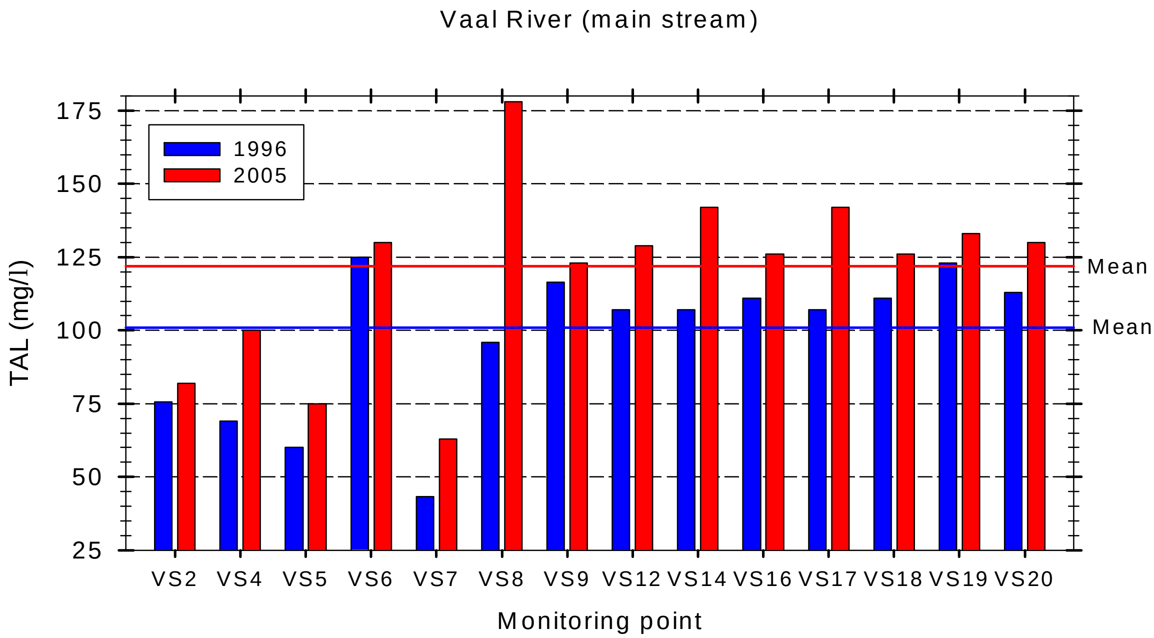


Figure 52: Bar chart of total alkalinity (TAL, mg/L) at different Level 1 sampling points in the Vaal River during 1996 compared with concentration in 2005

- **Nitrogen – Alkalinity Interaction**

Nitrogen inputs to catchment areas have dramatically increased as a result of anthropogenic activities. A portion of this nitrogen (N) enters river systems, degrading river water quality. However, not all nitrogen loaded into rivers is ultimately exported to estuaries or the ocean. Processes such as denitrification, organic matter burial in sediments, sediment sorption, and plant and microbial uptake can remove nitrogen from the river, and thus affect the amount of N that is transported by rivers to coastal ecosystems.

In the Vaal River an interesting relationship was found between the total alkalinity (TAL, express as $CaCO_3$) and nitrate (NO_3). Although no direct correlation was illustrated between TAL and NO_3, it was clear that high TAL concentrations were associated with low NO_3 concentrations. The annual averages of TAL were significantly correlated (inversely) with NO_3 (**Figure 53**). Abril and Frankignoulle (2001) shows that bacterial processes of ammonification, nitrification and denitrification rapidly and strongly affect the alkalinity in rivers.

Refer to **Appendix 5** for a explanation of denitrification and an example as its relates to the Vaal River System.

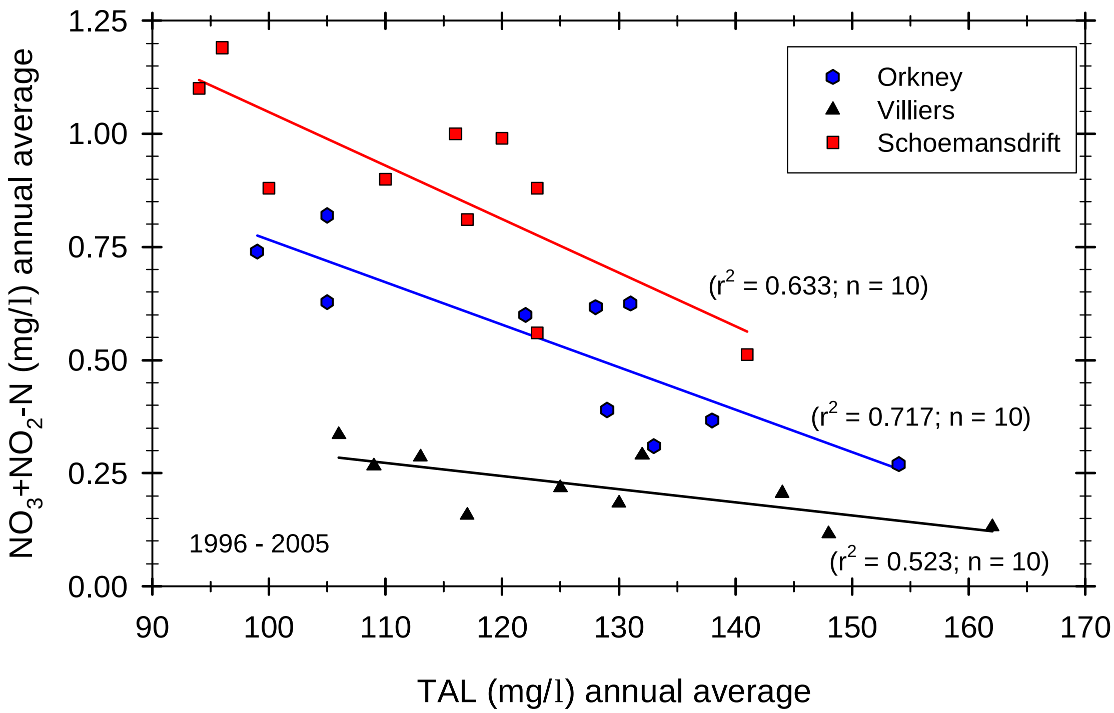


Figure 53: Relationship between total alkalinity (TAL, mg/L) and nitrate & nitrite concentrations (annual averages) at selected sampling points in the Vaal River during the study period (1996 – 2005)

6.6 Eutrophic Status of the Vaal River System: Level 1 Points

The water quality status of the Vaal River System with regard to nutrient levels is provided here at an overview level, with the key water quality variables related to eutrophication being analysed. This overview provides an indication of the issues of concern in the system and areas where intervention is required within the catchment.

6.6.1 Methodology

The eutrophic assessment was limited to historical data and a once-off sampling and field survey conducted during May and June 2006.

A review of the literature including limnological and ecological studies and water quality data from the Department of Water Affairs and the three major water boards, *viz*. Rand Water, Midvaal Water and Sedibeng Water. A once-off monitoring sites visit was undertaken to the Vaal River system for a situation evaluation, field measurements and sample collection during the period 28 May to 3 June 2006. Water samples were collected at 42 sites.

The following analyses were done:

- Water quality parameters, including total dissolved salts, alkalinity, mineral ions (HCO_3^-, Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^-, F^-, Si & SO_4^{2-}), turbidity, suspended solids, nutrients [nitrogen (NO_3^{2-} & NH_4^+) and phosphorus (PO_4^{3-})], total organic carbon (TOC), chemical oxygen demand (COD), and metals (Al, Hg, Li, Fe, Mn, Cu, Cd, Pb, and Zn) were analysed.

- *In situ* values of pH, Secchi depth, temperature & dissolved oxygen and electrical conductivity were recorded with a HANNA HI 9023 microcomputer pH meter, YSI Model 58 dissolved oxygen meter, and HI 9811 EC-TDS meter respectively.

Standard water analysis methods were used for all the above-mentioned water quality and biological assessments. The Institute for Ground Water Studies at the University of the Free State, an accredited laboratory, did most of the chemical and bacteriological analysis.

The water quality data used in the assessment was collected for the Level 1 and Level 2 strategic monitoring points as defined for the Vaal River System (same points as that used for the salinity assessment). The points are listed in **Table 46** and **Table 47** and shown in **Figure 26** and **Figure 27**.

Constraints:

The study was limited to a once-off field trip and data collection, while we know that diurnal and seasonal changes in water quality could be extreme in shallow, nutrient enriched lakes and rivers like the Vaal River. No tests were done for pesticides or POPs (persistent organic pollutants).

Eutrophic trends along Vaal River

VS1 – Vaal river at origin at N17 bridge

The phosphate concentrations in the Vaal River at the origin were relatively low (mean 0.088 mg/ℓ), but very low (0.05 mg/ℓ) during the last two years, however, this concentration is lower than the detection limit of 0.10 mg/ℓ. A concentration of 2.3 mg/ℓ was rejected as an outlier (**Figure 54**).

The nitrogen concentrations (NH_4-N + NO_3-N = DIN) were generally low (mean, 0.512 mg/ℓ) and frequently less than the detection limit of 0.1 mg/ℓ for both NH_4 and NO_3. The peak DIN (Dissolved Inorganic Nitrogen) concentrations were caused by high NH_4 concentrations, which indicate decomposition of organic material. VS1 can be classified as negligibly modified from natural conditions (**Figure 55**).

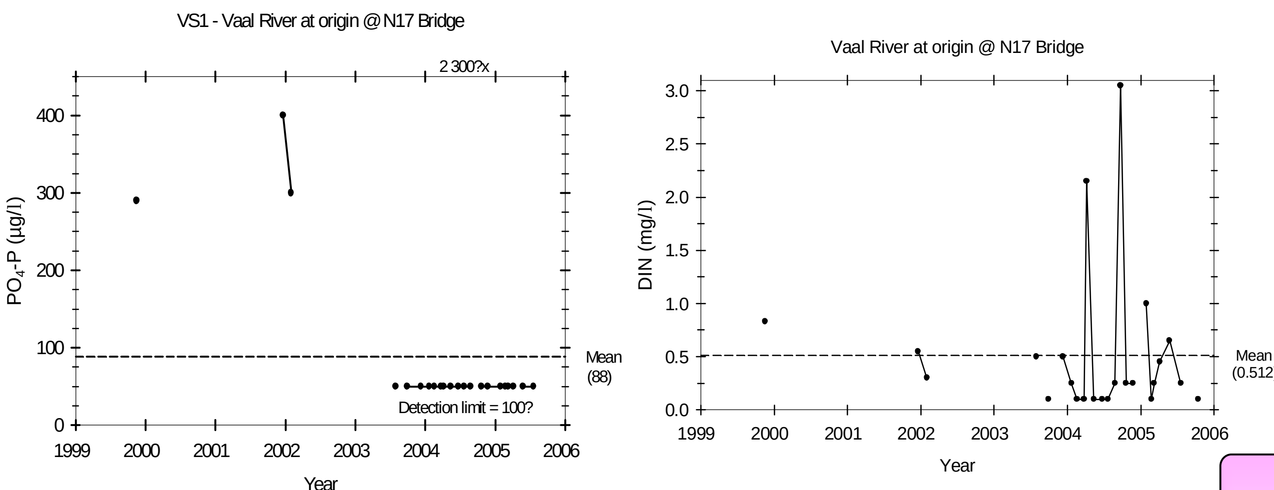


Figure 54: Variation in phosphate (PO_4-P, µg/ℓ) and dissolved inorganic nitrogen (DIN, mg/ℓ) in the Vaal River at origin during the last 7 years (1999 – 2005).

WATER QUALITY STATUS: Eutrophic Status: Level 1

Figure 55: Clear water at pristine site at origin of Vaal River (30/5/2006)

<u>VS2 – Vaal River at Camden @ N2 bridge</u>

WATER QUALITY STATUS:
Eutrophic Status: Level 1

The average PO_4-P concentration of 177 µg/ℓ in the Vaal River at Camden is high and indicates some nutrient pollution source. However, a decreasing trend in the phosphate concentration was observed during the past seven years (**Figure 56**). The average DIN concentration was relatively low (0.293 mg/ℓ) with a slight, but not significant, increase during the same period (**Figure 56**). The low alkalinity at this point (mean 65 mg/ℓ) indicates poorly buffered water, which can explain the relatively large variation in the pH (min; 6.3; max, 8.7; mean 7.35).

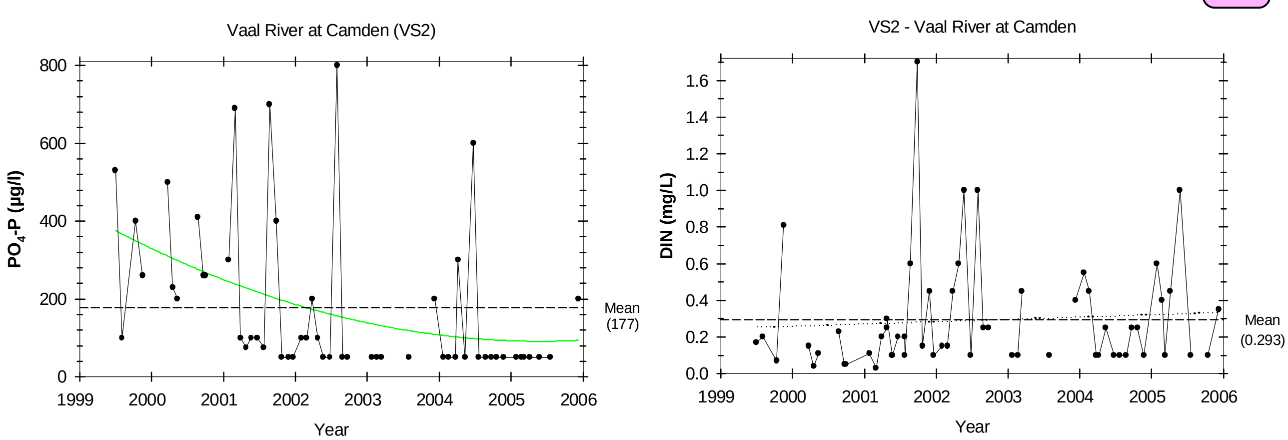


Figure 56: Variation in phosphate (PO_4-P, µg/ℓ) and dissolved inorganic nitrogen (DIN, mg/ℓ) in the Vaal River at Camden during the last 7 years (1999 – 2005)

VS3 – Vaal River at N11 bridge to Amersfort

The DIN concentrations at this point were relatively low (mean, 0.445 mg/ℓ) (**Figure 57**). The phosphate concentrations were also relatively low and indicated as <0.05 mg/ℓ on several occasions. The general water quality at VS3 was good (**Figure 58**).

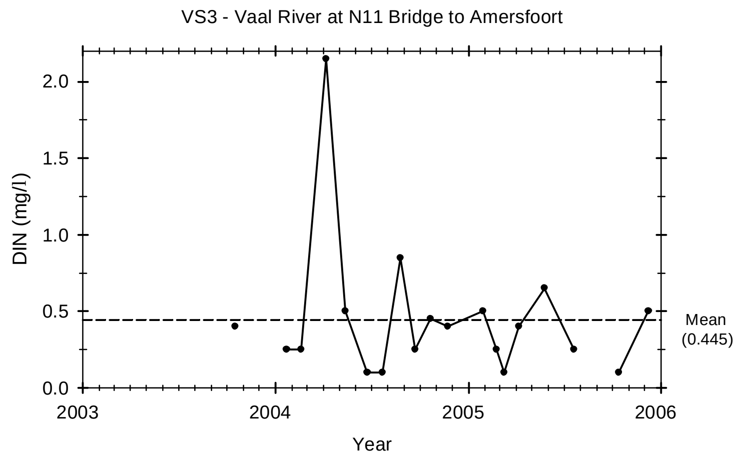


Figure 57: Variation in DIN concentrations (mg/ℓ) in the Vaal River at N11 bridge during the last two years (2004 – 2005).

Figure 58: Photograph of Vaal River at N11 bridge (30/5/2006). Note the clear water and sandy river bed and banks

VS4 – Vaal River at R35 Bloukop bridge

The general water quality at Bloukop bridge was fair and decreasing trends in the nutrient concentrations were observed (**Figure 59**). The dissolved inorganic nitrogen was low (mean, 0.396 mg/ℓ) (**Figure 59**).

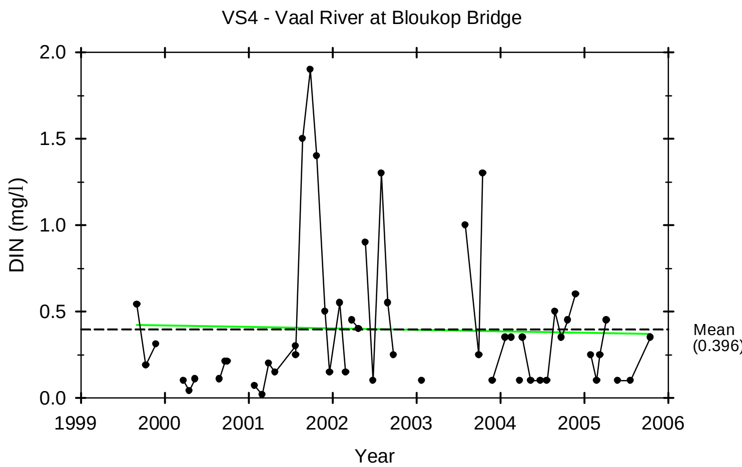


Figure 59: Variation in dissolved inorganic nitrogen (DIN, mg/ℓ) in the Vaal River at Camden during the last 7 years (1999 – 2005)

However, the phosphate concentrations were surprisingly high (mean, 200 µg/ℓ)(**Figure 60**), which could be the reason for the high algal (periphyton) biomass in the stream (see photograph below, **Figure 60**).

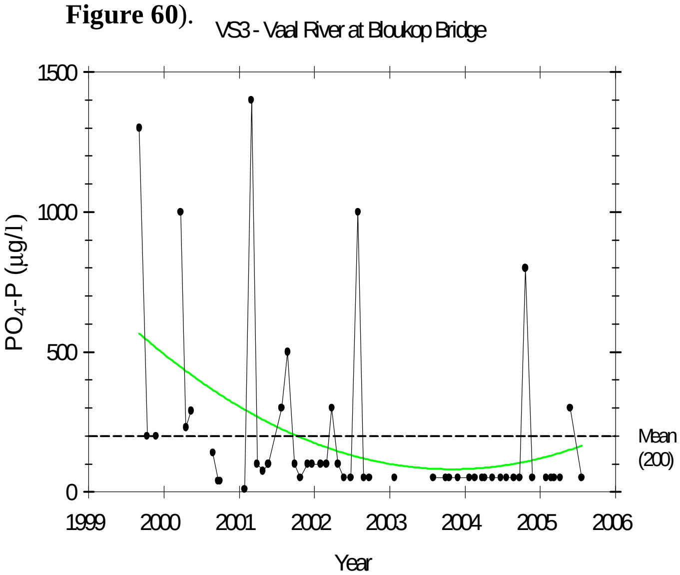


Figure 60: Variation in phosphate (PO_4-P, µg/ℓ) in the Vaal River at Bloukop bridge during the past seven years (1999 – 2005). The photograph shows filamentous green algae growing on the bottom of the river (29/5/2006)

WATER QUALITY STATUS:
Eutrophic Status: Level 1

VS5 – Grootdraai dam

The algal biomass (measured as chlorophyll-***a*** concentration) in Grootdraai Dam was relatively low (mean, 9.7 µg/ℓ, **Figure 61**). Eighty percent (80 %) of the samples were ≤10 µg/ℓ and only 8 % of the samples were >30 µg/ℓ, which indicate a moderate nuisance value of algal bloom productivity (**Figure 63**).

In Grootdraai Dam the P concentrations were relatively low (mean PO_4-P, 39 µg/ℓ and TP, 75 µg/ℓ), with no significant trend during the past 10 years (**Figure 64**). However, TP values >47 µg/ℓ, can indicate a significant potential for algal productivity (DWAF, 2002f).

Nevertheless, significant algal blooms have occurred on several occasions (**Figure 61**). In many circumstances, blooms and accumulations are seasonal. Diatoms (*Cyclotella* spp. or *Melosira* sp.) usually dominates during the winter months, June - September (**Figure 62**). Cyanobacteria, especially *Microcystis* and *Anabaena* species, dominate on several occasions during summer months, January – May (**Figure 61 & Figure 62**). Cyanobacterial blooms tend to recur in the same water bodies (WHO, 2006).

WATER QUALITY STATUS:
Eutrophic Status: Level 1

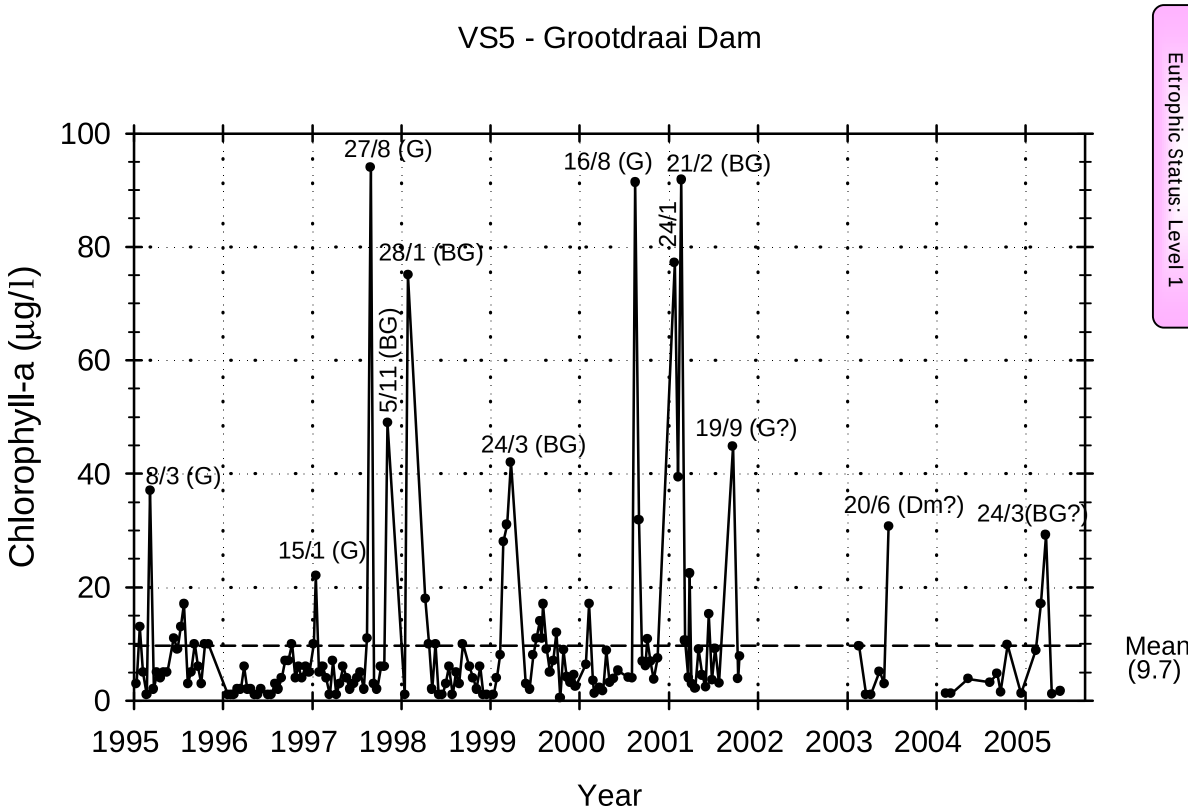
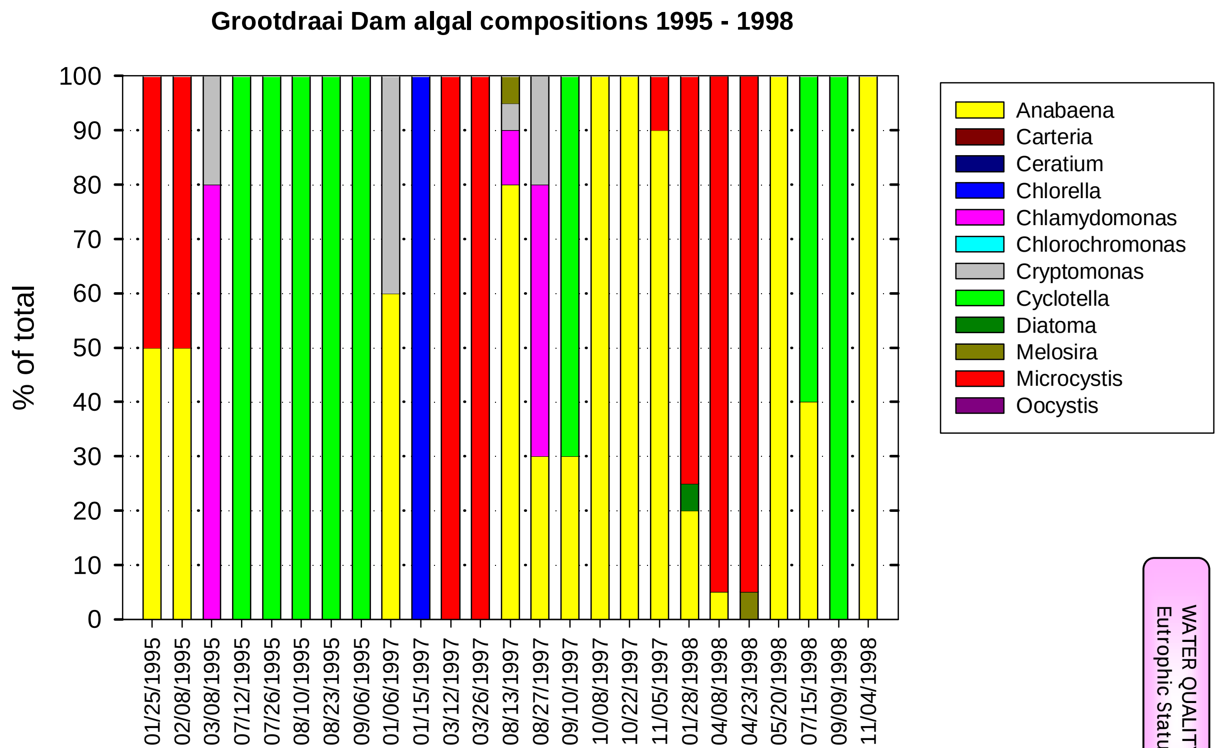


Figure 61: Annual variation in chlorophyll-a concentration in Grootdraai Dam. Peak concentrations were marked by the specific date and dominant algal group.
(G = green algae; BG = blue-green algae; Dm = diatoms).



WATER QUALITY STATUS:
Eutrophic Status: Level 1

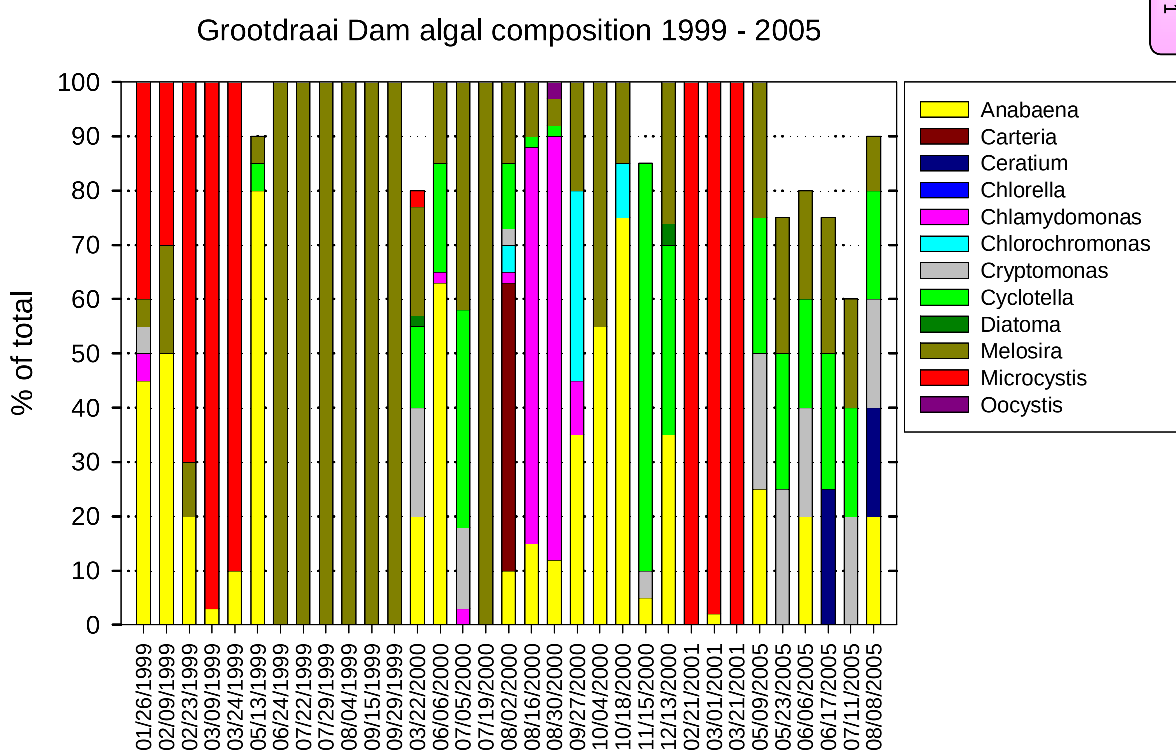


Figure 62: Algal species composition (%) in Grootdraai Dam (1995 – 2005)

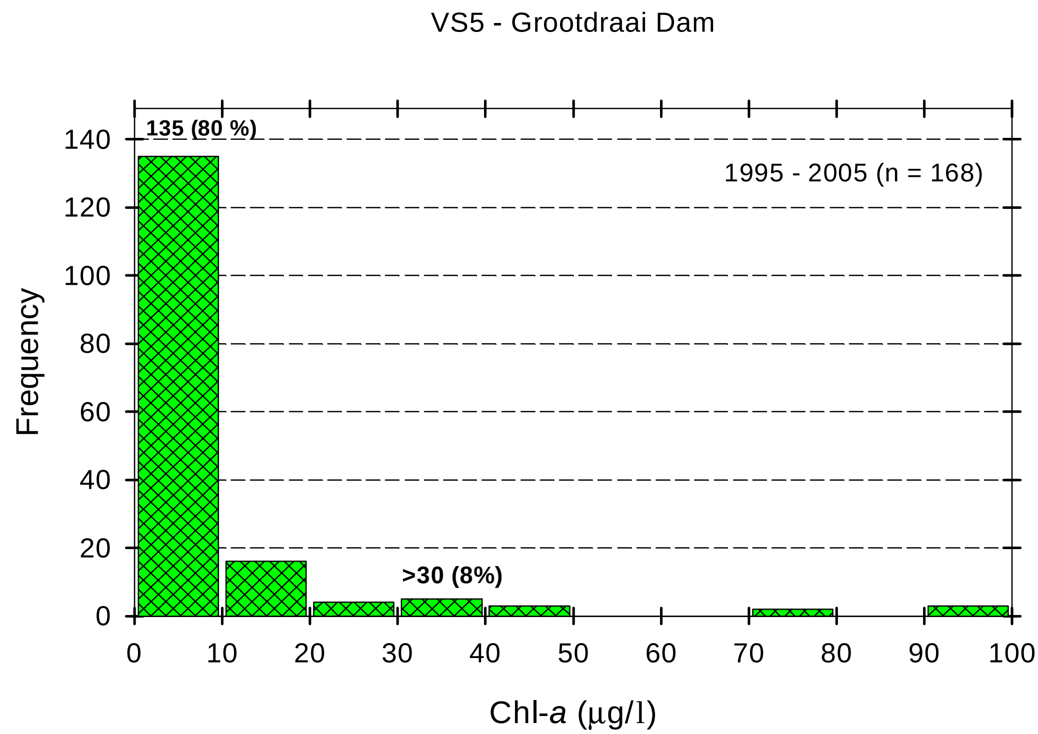


Figure 63: Frequency histogram of chlorophyll-a concentrations in Grootdraai Dam for the period 1995 2005.

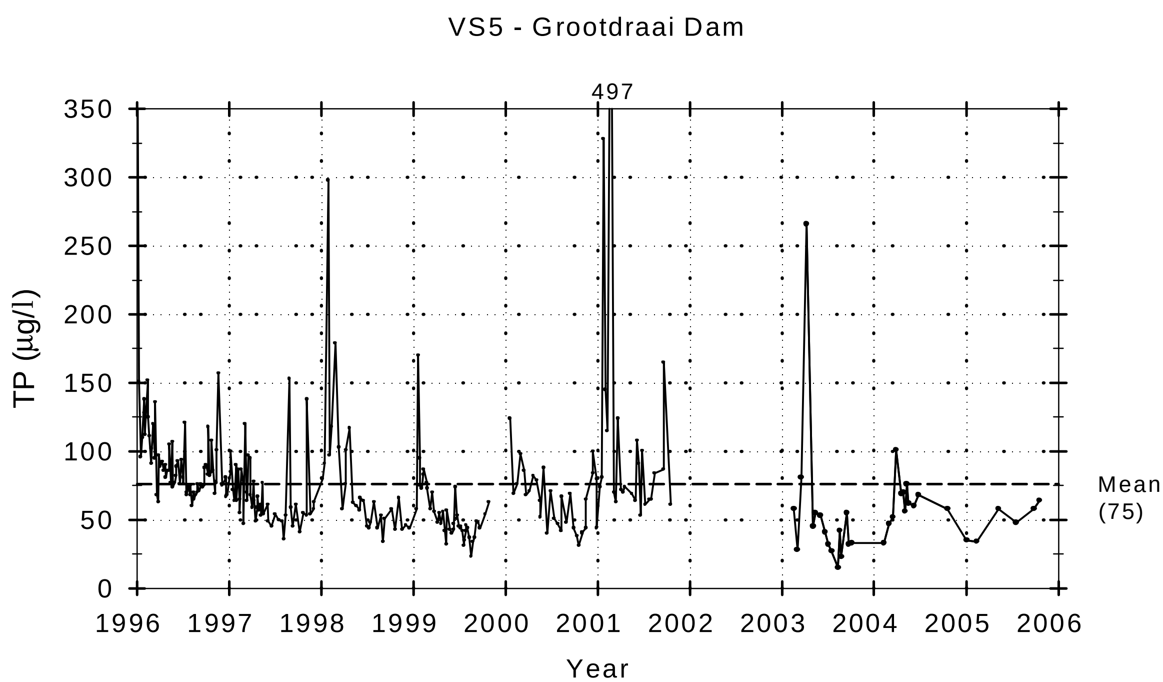


Figure 64: Variation in total phosphorus (TP) concentration (µg/ℓ) in Grootdraai Dam (1996 – 2005).

WATER QUALITY STATUS:
Eutrophic Status: Level 1

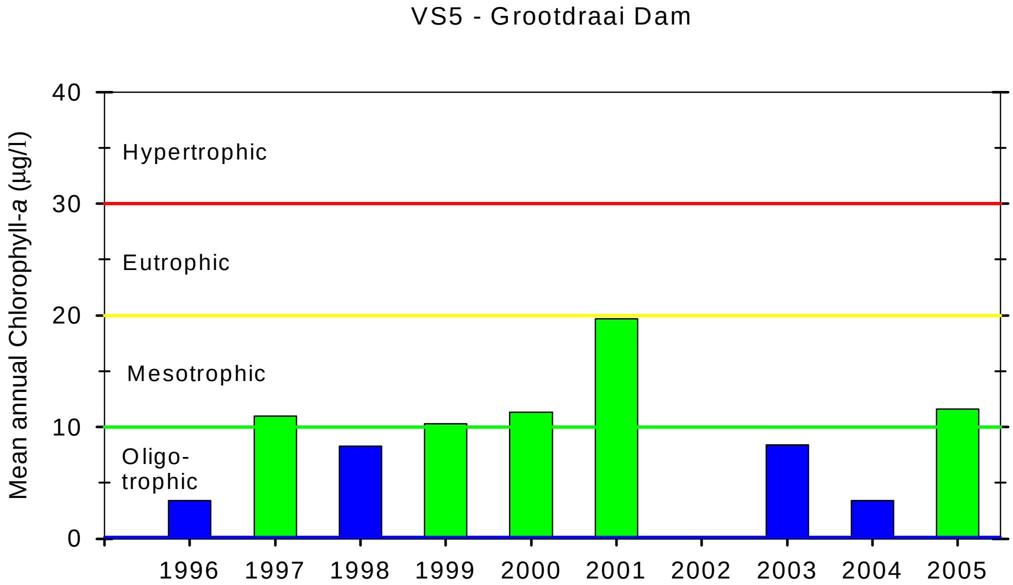


Figure 65: Bar chart of the trophic status of Grootdraai Dam for the period 1996 – 2005

WATER QUALITY STATUS: Eutrophic Status: Level 1

Based on the mean annual chlorophyll-*a* concentrations, Grootdraai Dam can be classified as oligo-mesotrophic (**Figure 65**). However, the high N and P concentrations in Leeuspruit pose a treat to the long-term eutrophication condition of Grootdraai Dam. The spruit, that enter directly into the dam, can serves as an incubation area for algal blooms to develop, which serves as an inoculum to the dam (**Figure 66**). This situation should be monitored closely.

Figure 66: Cyanobacterial bloom (*Microcystis aeruginosa)* in Leeuspruit that enters Grootdraai Dam (29/5/2006)

VS6 – Vaal River at Villiers flood section

A very good data set (weekly analyses) exists at the Villiers monitoring point

The phosphate concentrations at Villiers were relatively low (mean, 50 µg/ℓ), but shows a slight increase during the past 10 years (**Figure 67**). However, the total phosphorus (TP) was relatively high (mean, 142 µg/ℓ), which indicate a serious threat for algal and plant productivity.

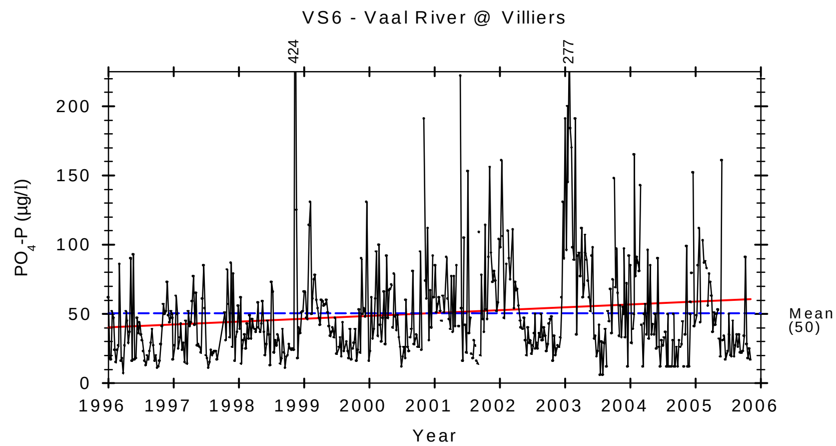


Figure 67: Variation in phosphate (µg/ℓ) concentration in the Vaal River at Villiers during the past 10 years (1996 – 2005)

VS7 – Vaal Dam

Algal data presented for the Vaal Dam is at the confluence of the Vaal and Wilge River in the dam (data supplied by Rand Water). The phytoplankton concentration (expressed as chlorophyll-*a*) in the Vaal Dam shows an increasing trend with an overall average of 20 µg/ℓ (**Figure 68**). The increasing trend in chlorophyll-a concentration could be ascribed to the increasing trend in P concentrations in the dam (**Figure 70**). The average phosphate increases from about 40 to 60 µg/ℓ, *i.e.* a 50 % increase, during the past 10 years. The significant increase in TP during the last three years is a matter of concern (**Figure 70 & Figure 71**), because it results in and decrease in the TN:TP ratio, which could mean that the conditions in the dam become more favourable for cyanobacterial growth.

The peak chlorophyll concentrations also seems to increase (Figure 68), with a recorded maximum of 250 µg/ℓ. Generally it is the peaks of algal development (the blooms) that cause the management problems in most reservoirs.

Even though 57 % of the observed data was the chlorophyll-a concentration ≤10 µg/ℓ, the percentage of time with chlorophyll-*a* concentrations >30 µg/ℓ was 11 %, which indicate a significant nuisance value of algal bloom productivity (**Figure 72**).

Algal composition data from Scientific Services (Rand Water) indicated that cyanobacteria (especially *Microcystis* and *Anabaena*) dominate (55 %) the algal composition in Vaal Dam (**Figure 69**).

WATER QUALITY STATUS: Eutrophic Status: Level 1

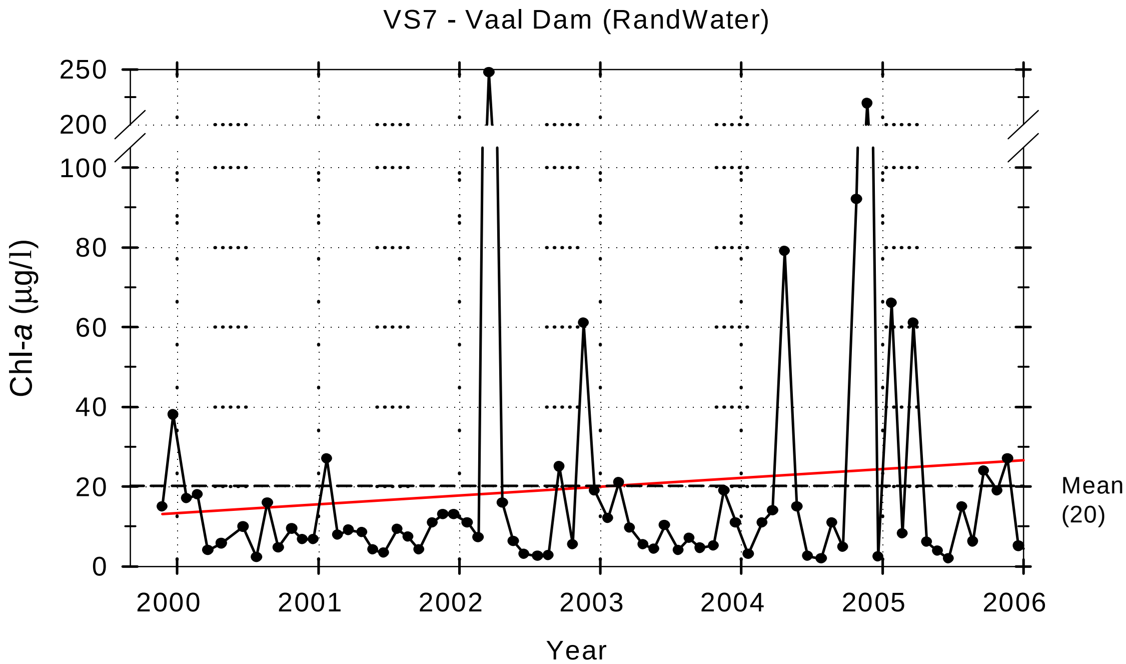


Figure 68: Variation in the chlorophyll-a concentration in the Vaal Dam (2000 – 2005). The algalbloom during 2002 was dominated by *Microcystis aeruginosa* and the bloom during 2004 was dominated by the green algae, *Chlamydomonas sp*

WATER QUALITY STATUS:
Eutrophic Status: Level 1

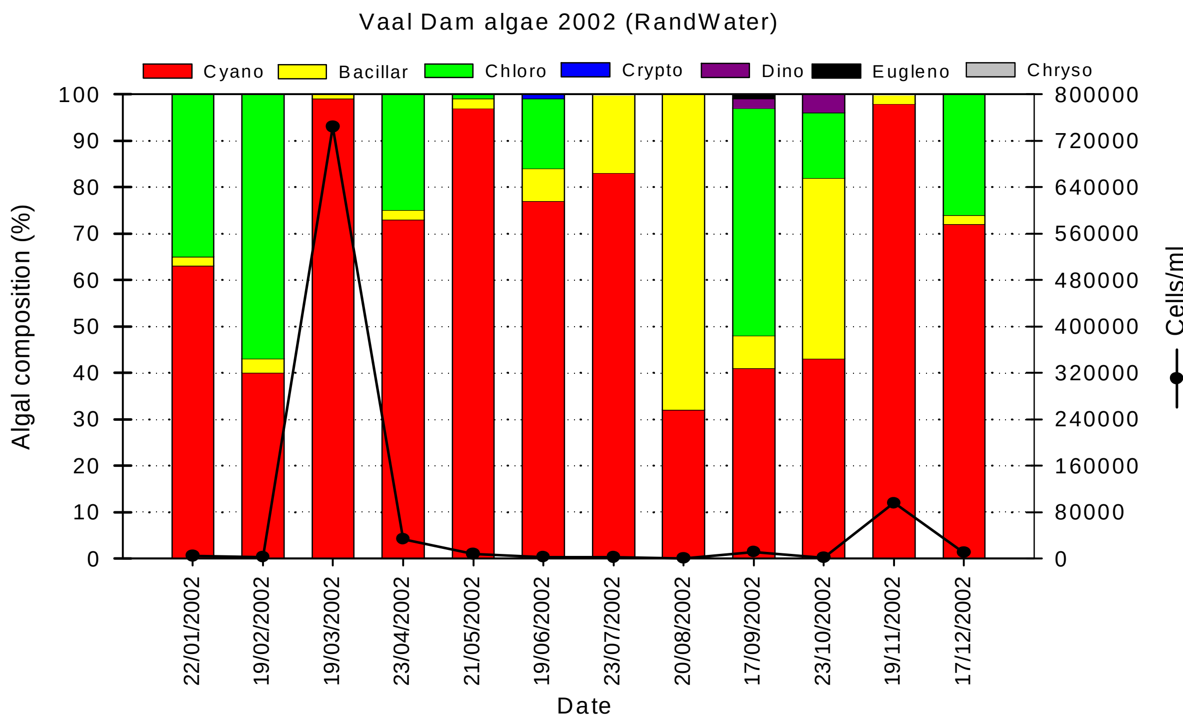


Figure 69: Algal composition (%) in the Vaal Dam (2002). Cyanobacterial bloom during March 2002, was dominated by *Microcystis*

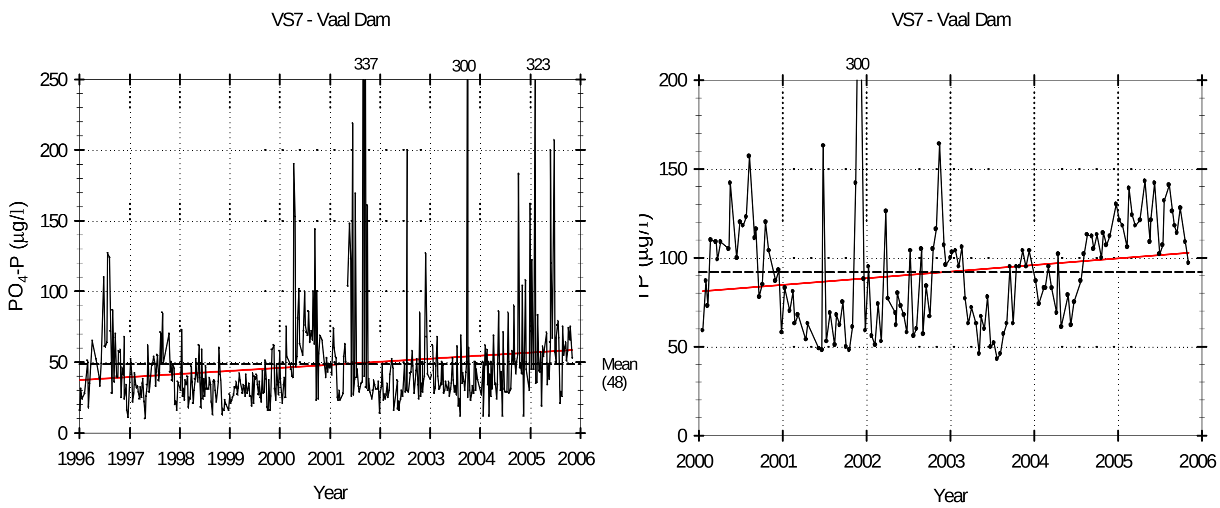


Figure 70: Variation in total phosphorus (TP) concentration (µg/ℓ) in the Vaal Dam for the period 2000 – 2005

WATER QUALITY STATUS:
Eutrophic Status: Level 1

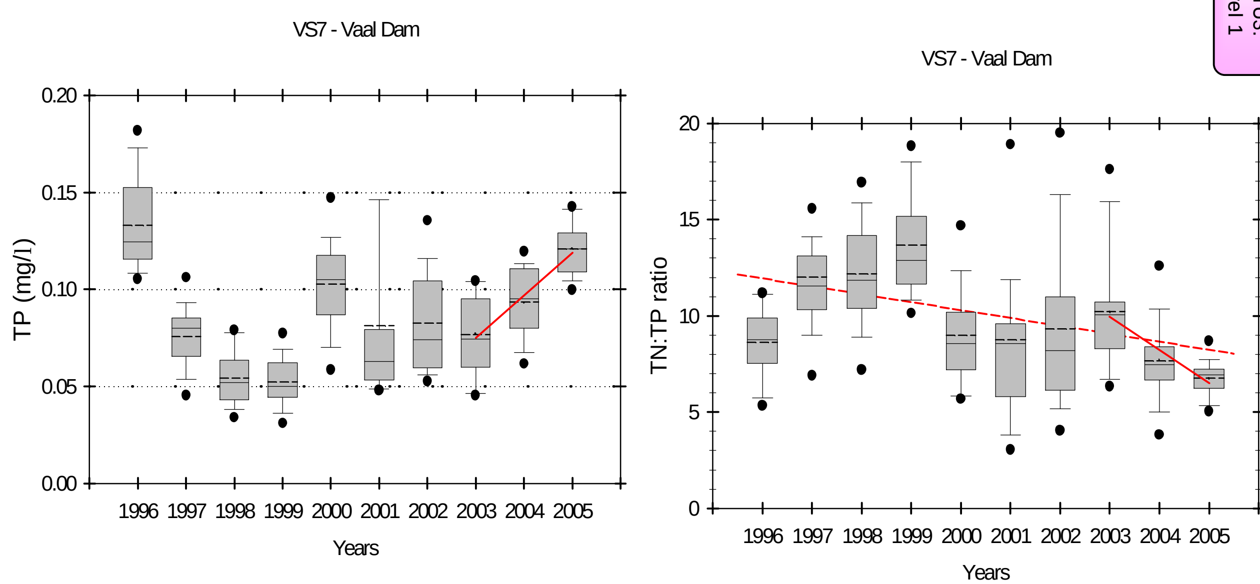


Figure 71: Box plot of total phosphorus (TP) concentration (mg/ℓ) and the TN:TP ratio in the Vaal Dam

The general increasing trend shown for phosphorus and chlorophyll-*a* concentration in the Vaal Dam is a matter of concern. Especially the high frequency and domination of Cyanobacteria (**Figure 74**) that could pose a tread to human health, because the Vaal Dam is the primary sources used by Rand Water for drinking water to some 10 million consumers within the supply area.

We do not know how much cyanobacterial toxin is accumulated under natural conditions in South African freshwater habitats, and what effects these toxins have on the organisms along the food chain.

The potential effects may be subtle – perhaps only a small reduction in growth rate, brood size, or body weight. However, in a complex and dynamic natural ecosystem, even small changes can be sufficient to cause a major decline in the survival of sensitive species.

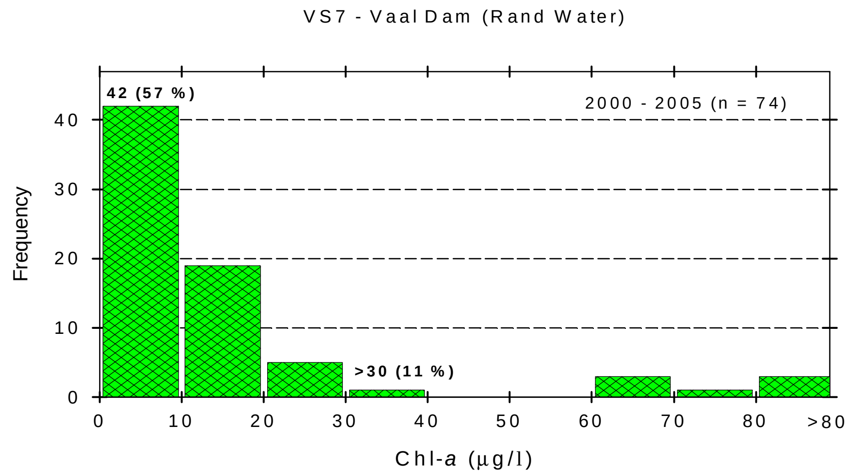


Figure 72: Frequency histogram of chlorophyll-*a* concentrations in the Vaal Dam 2000 – 2005

Based on the mean annual chlorophyll-*a* concentrations, the Vaal Dam can be classified as eutrophic (**Figure 73**).

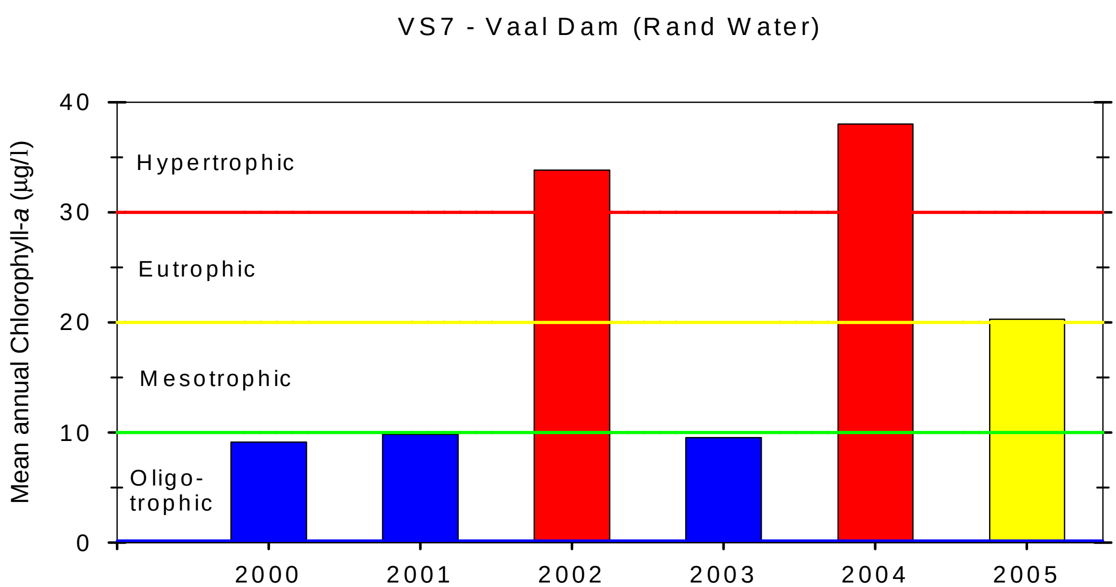


Figure 73: Bar chart of the trophic status of the Vaal Dam for the period 1996 – 2005

Figure 74: Cyanobacterial bloom (*Microcystis aeruginosa)* in the Vaal Dam (March 2002) – photo with permission from Rand Water

VS8 – Vaal Barrage

The Vaal Barrage is a popular recreational area in the middle Vaal River system. However, the Vaal Barrage is one of the 'hotspot' areas in the Vaal River because of the severe nutrient over-enrichment (eutrophication) and recent fish kills (January 2006). Water hyacinths (an indicator of eutrophication) has recently become a problem in the barrage (**Figure 75**).

Figure 75: Recreational activity and water hyacinths growth at the Vaal Barrage (30-05-2006)

The water quality in the Vaal Barrage is poor. The average phosphate concentration was high at 245 µg/ℓ, and a significant increase over the past 10 years was illustrated, *i.e.* about 30 µg/ℓ per annum (**Figure 76**). The nitrogen concentrations (DIN) were also the highest in the main stream river with a mean of 2.256 mg/ℓ and also show an increasing trend (**Figure 76**). The TDS was also high (mean 461 mg/ℓ) with relatively high sulphate concentrations (mean 140 mg/ℓ).

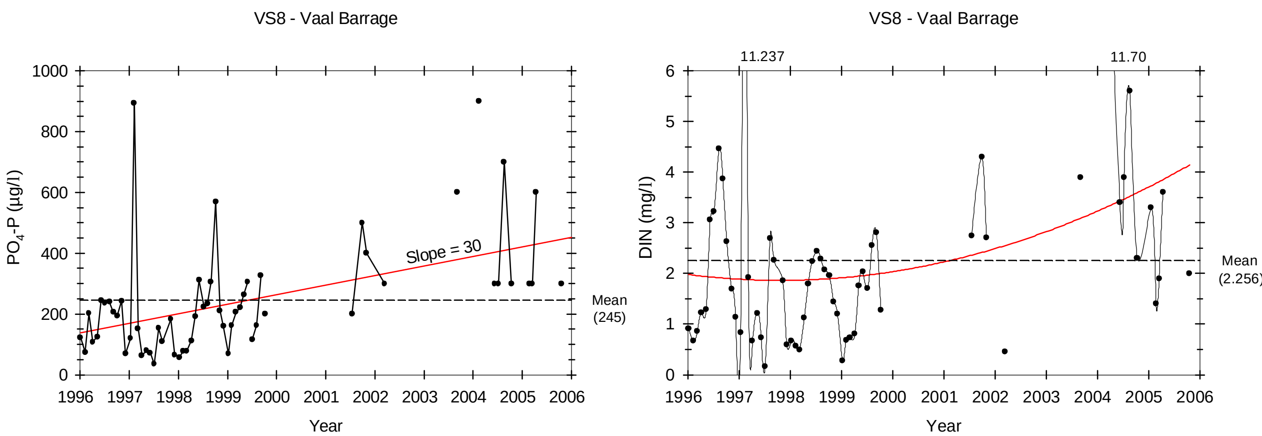


Figure 76: Variation in phosphate (µg/ℓ) and dissolved inorganic nitrogen (DIN) concentration in the Vaal Barrage during the past 10 years (1996 – 2005)

The average algal biomass in the Vaal Barrage was high (overall mean, 40 µg Chl-a/ℓ) and fall in the range of hypertrophic systems. The increasing trend in chlorophyll-***a*** concentrations (**Figure 77**) was associated with an increasing trend in phosphate concentrations (**Figure 78**).

There was also an increasing trend in the toxic algal cell in the Vaal Barrage water with a maximum of 40 000 cells/mℓ during February 2004 (**Figure 79**). A density of 100 000 cyanobacterial cells per ml (which is equivalent to approximately 50 µg/ℓ chlorophyll-***a*** if cyanobacteria dominate) is a guideline for moderate health alert in recreational waters (WHO, 1999).

The Cyanobacteria (*Anabaena* & *Microcystis*) usually dominates during the summer period (December to April; **Figure 80**) and centric diatoms (Bacilariophyceae, *Cyclotella* spp.) usually during winter – spring (June – November) (**Figure 80**).

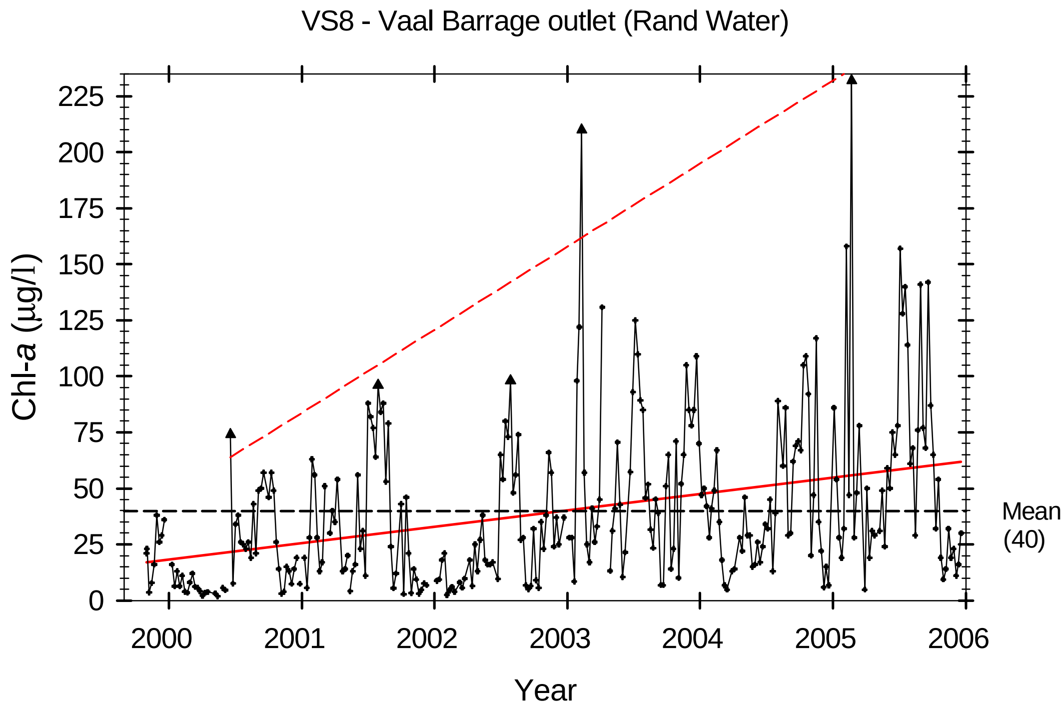


Figure 77: Variation in chlorophyll-a concentrations in the Vaal Barrage (1999 – 2005). An increasing trend was shown that indicates worsen eutrophication conditions (solid red line). The dashed line indicates the increasing trend in terms of peak concentrations.

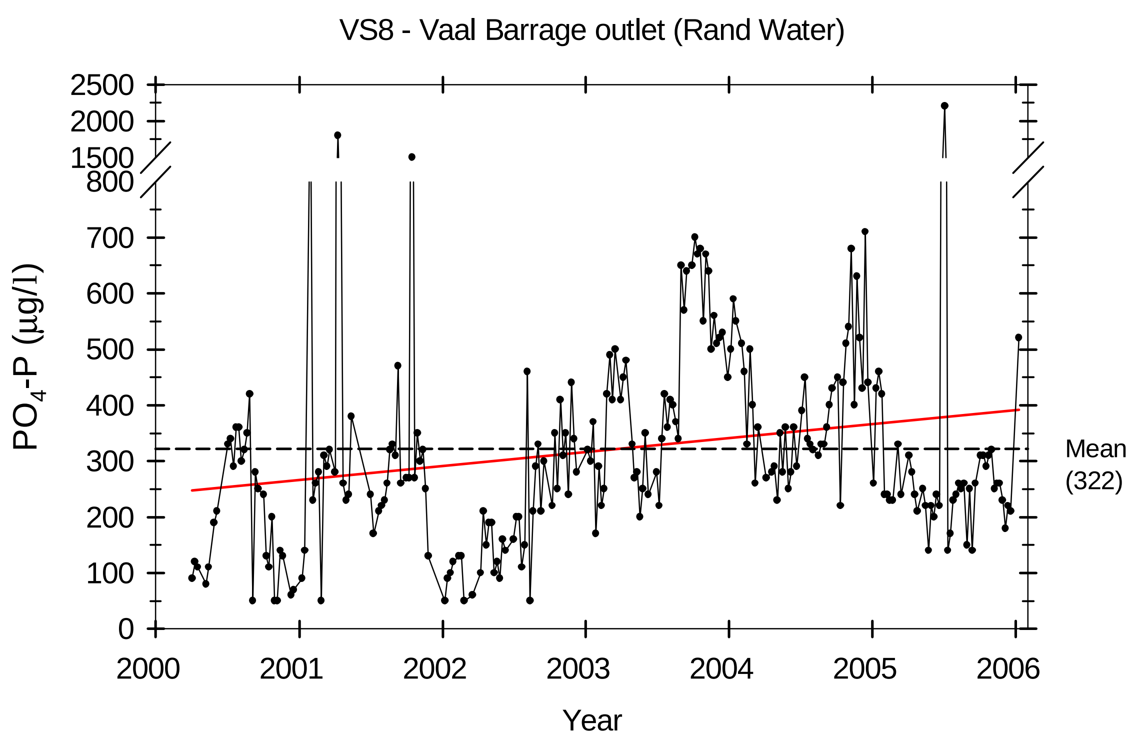


Figure 78: Variation in phosphate concentration (µg/ℓ) in the Vaal Barrage (2000 – 2005)

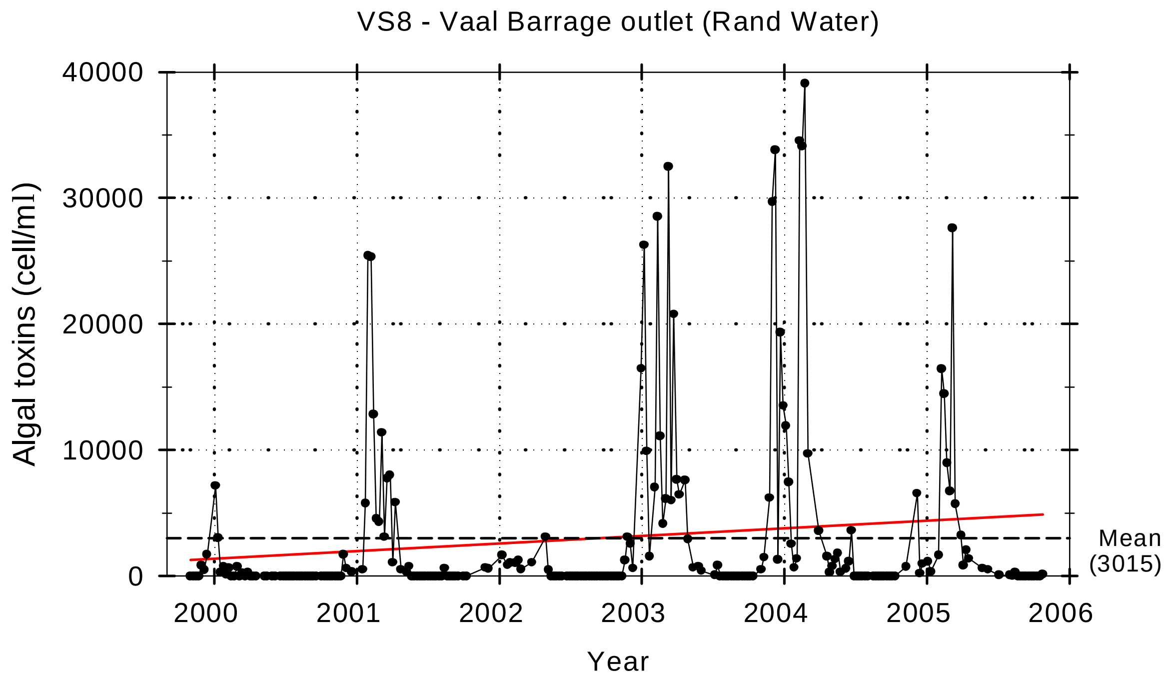


Figure 79: Variation in algal cell concentration that might produce algal toxins in the Vaal Barrage (2000 – 2005)

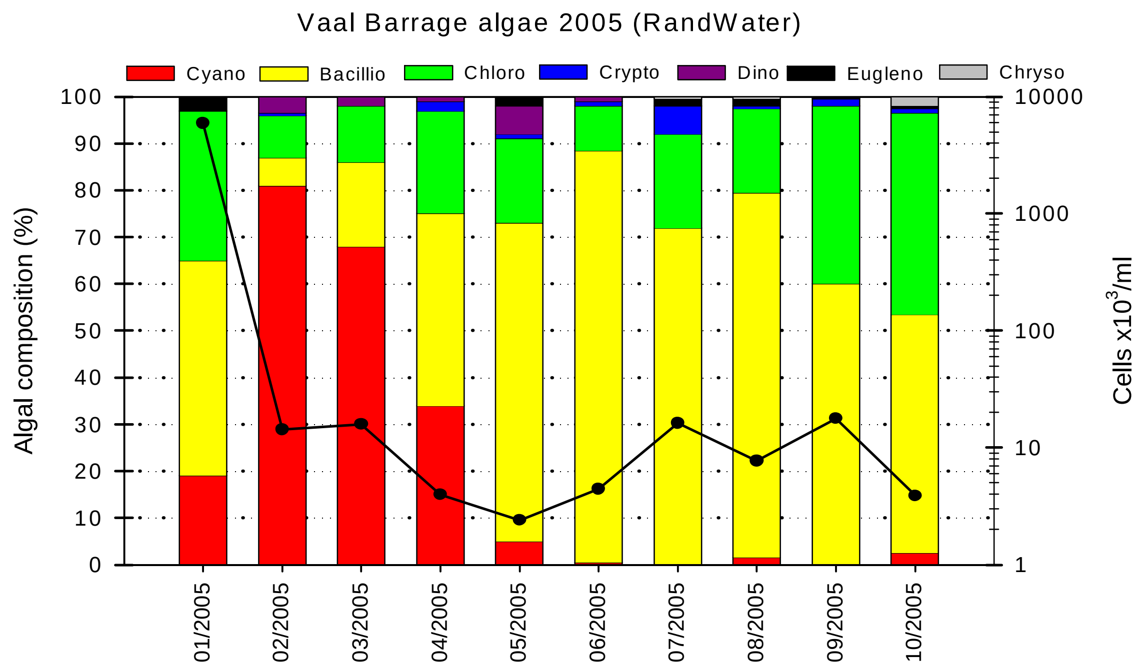


Figure 80: Algal composition (%) in the Vaal Barrage (2005) Cyanobacterial bloom during January, was dominated by Green algae *Microcystis*.

WATER QUALITY STATUS:
Eutrophic Status: Level 1

The average oxygen concentration in the Vaal Barrage was reasonably high (mean, 6.15 mg/ℓ, i.e. approximately 65 % saturation), and show an increasing trend, which is ascribed to the increasing phytoplankton biomass trend (**Figure 81**). Thus, the rate of oxygen production due to photosynthesis activity in the river appears to be much greater than the rate of oxygen consumption due to respiration.

However, DO concentrations <5 mg/ℓ, may adversely affect the functioning and survival of biological communities; Concentrations <4 mg/ℓ, usually cause hypoxia, i.e. physiological stressful for fish. DO concentrations <2 mg/ℓ may lead to the death of most fish. Decline in DO concentrations can also promote the formation of reduced compounds, such as hydrogen sulphide (H_2S), resulting in higher adverse effects on aquatic animals (Camargo & Alonso, 2006).

Thus, the very low concentrations (min, 0.5 mg/ℓ) occasionally recorded in the Vaal Barrage could result in fish-kills, typically as experienced during 2006.

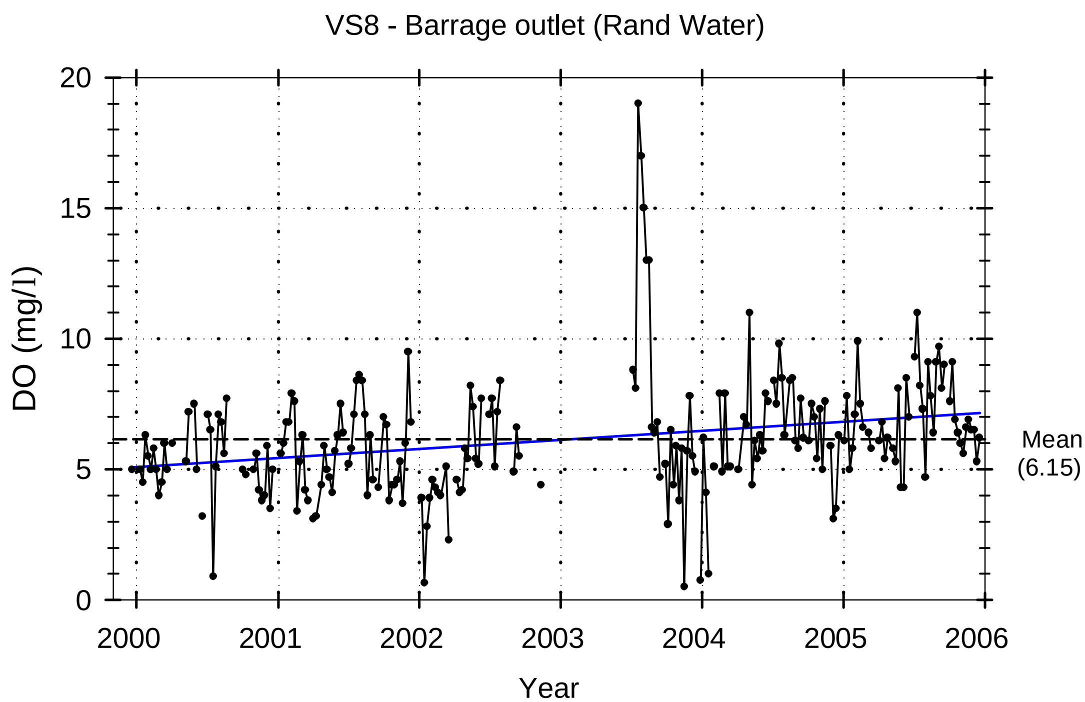


Figure 81: Variation in dissolved oxygen concentration in the Vaal Barrage (2000 – 2005)

The eutrophic condition in the Vaal Barrage has worsened significantly during the last six years (**Figure 82**). As a result of excessive nutrient loading, growth of algae progresses exponentially. The mean annual chlorophyll-*a* concentrations during the last three years in the Vaal Barrage were in the range of hypertrophic system, with concentration >30 µg/ℓ for more than 50 % of the time (**Figure 82**).

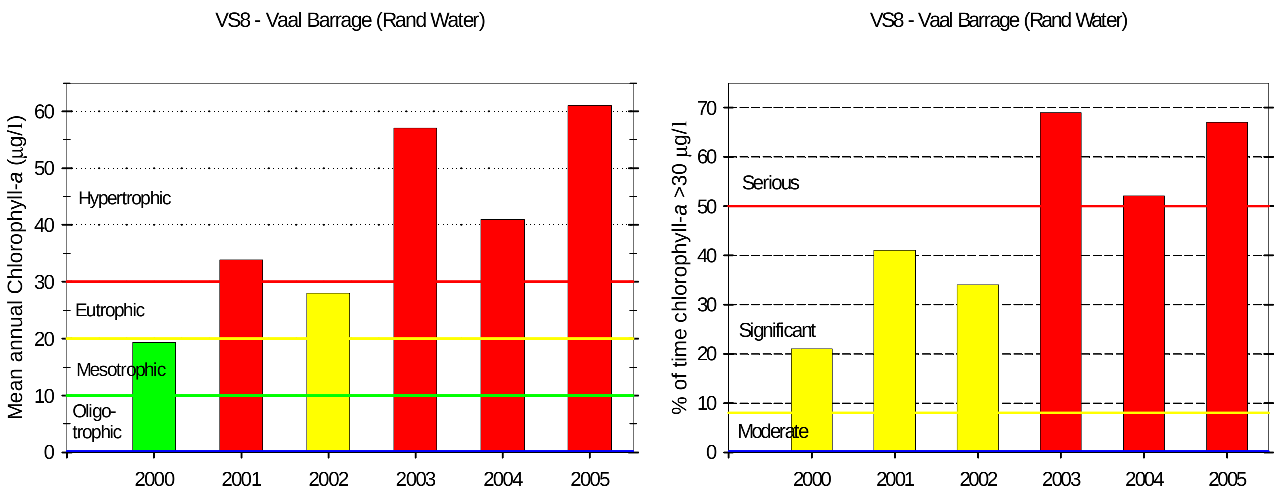


Figure 82: Trophic status (based on chlorophyll-*a* concentrations) and percentage of time that the chlorophyll-a concentration is more than 30 µg/ℓ in the Vaal Barrage during the past six years (2000 – 2005)

However, with the very high phosphate concentrations in the Barrage (mean, 322 µg/ℓ), much higher algal biomass was expected, but this could be ascribed to relatively short residence time in the Barrage. Steynberg (1986) calculated a retention time of between 8 to 17 days (av. 11.3) for the Vaal Barrage during the 1979 to 1985 period. While inflows often supply nutrients that enhance eutrophication, rapid flushing can reduce the time available for algal growth and result in less accumulation of biomass. Vollenweider (OECD, 1982) showed that if the flushing rate were faster than the algal growth rate, then the algae would be unable to grow to their maximum biomass and use up all the nutrients.

WATER QUALITY STATUS:
Eutrophic Status: Level 1

The pollutions levels are very high in the Vaal Barrage

<u>VS9 – Vaal River at Kromdraai – low water bridge</u>

The first monitoring point below the polluted Vaal Barrage is Kromdraai (VS9), which is about 125 km downstream. The phosphate concentrations were a little bit lower, but still high (mean 201 µg/ℓ) (**Figure 83**), however, surprisingly the dissolved nitrogen concentrations were significantly lower (mean, 0.95 mg/ℓ) (**Figure 83**) than at Vaal Barrage, *i.e.* about a 58 % decrease. The reduction in nitrogen concentrations is primarily ascribed to denitrification. The nutrients were still high enough to stimulate significant algal growth (**Figure 84**).

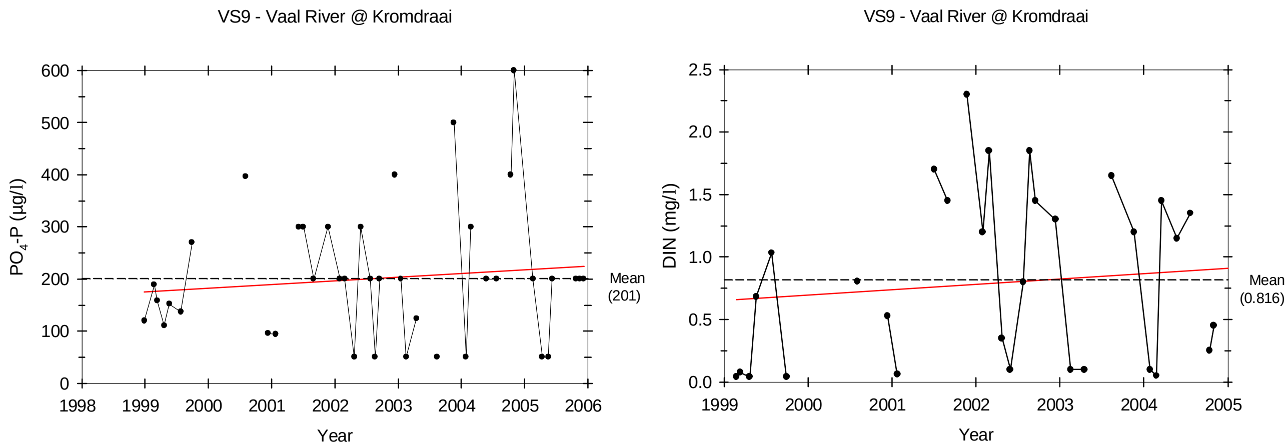


Figure 83: Variation in phosphate (µg/ℓ) and dissolved inorganic nitrogen (DIN) concentration in the Vaal River at Kromdraai during the past 8 years (1998 – 2005).

The higher alkalinity at Kromdraai (mean, 130 mg/ℓ) compared to 101 mg/ℓ at Vaal Barrage is associated with the highly effective denitrification process.

Figure 84: Algal growth in the Vaal River at Kromdraai (30/6/2006)

<u>VS10 – Vermaasdrift</u>

Vermaasdrift shows typical eutrophic characteristics. The phosphates were high (201 µg/ℓ) and shows an increasing trend over the 10 year period (**Figure 85**). The nitrate concentration was very high (mean, 0.880 µg/ℓ) (**Figure 86**). Unfortunately no ammonium concentrations were available at this point.

WATER QUALITY STATUS:
Eutrophic Status: Level 1

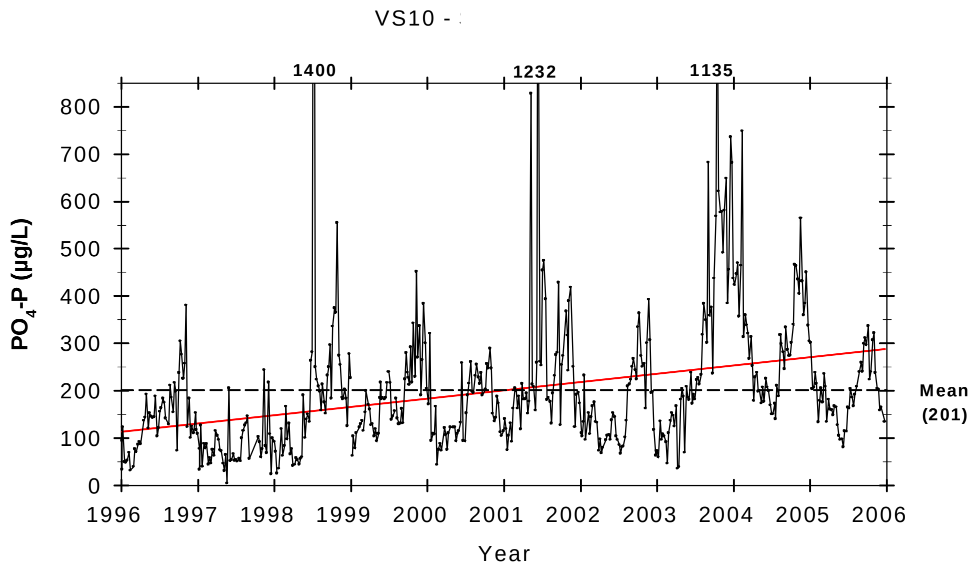
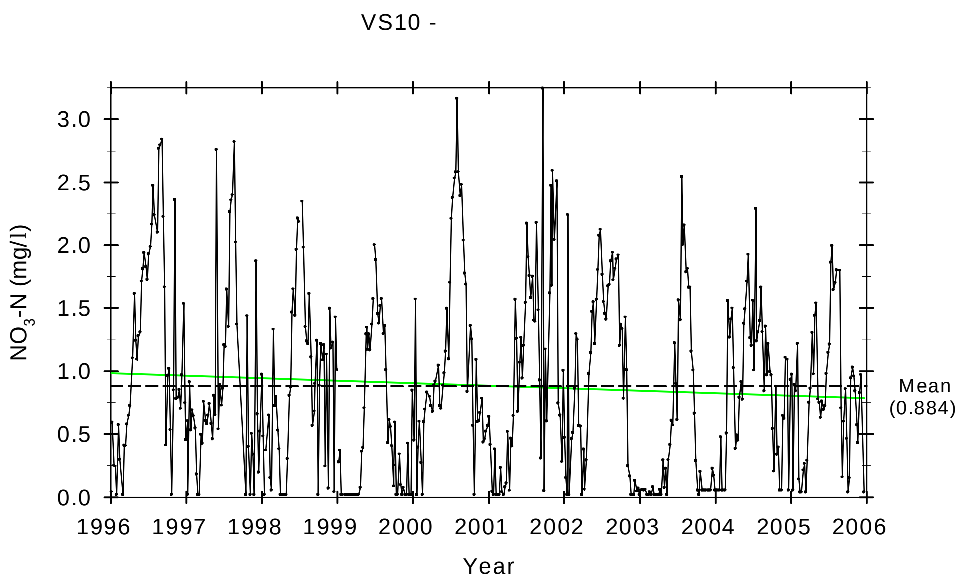


Figure 85: Variation in phosphate concentration (µg/ℓ) in the Vaal River at Vermaasdrift during the past 10 years (1996 – 2005).



WATER QUALITY STATUS: Eutrophic Status: Level 1

Figure 86: Variation in nitrate concentration (mg/ℓ) in the Vaal River at Vermaasdrift during the past 10 years (1996 – 2005)

<u>VS11 – Midvaal</u>

The general water quality at Midvaal was also poor with high phosphates (mean, 165 µg/ℓ), high inorganic nitrogen (mean DIN, 0.780 mg/ℓ) and high TDS concentrations (mean, 443 mg/ℓ), although a decreasing trend in the salts was observed during the last three years (**Figure 87**).

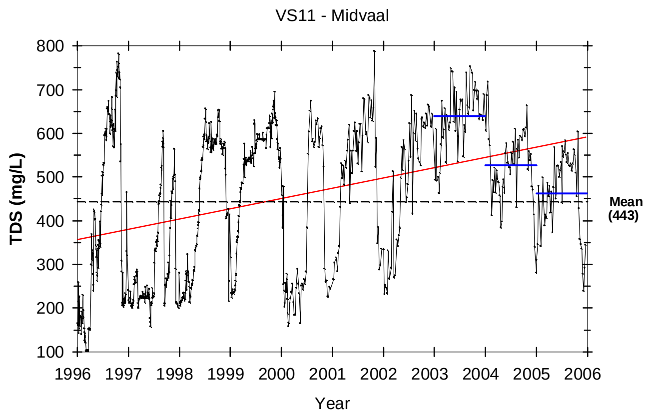


Figure 87: Variation in TDS (mg/ℓ) in the Vaal River at Midvaal during the past 10 years (1996 – 2005)

Limited information is available on the metals in the Vaal River system. However, data from the Midvaal Water Company indicate relative high manganese (Mn) concentrations (mean, 105 µg/ℓ). Manganese is an essential micronutrient for plants and animals, although high concentrations are toxic. The TWQR for aquatic ecosystems as per the SAWQGs is 180 µg/ℓ, which was frequently exceeded at Midvaal (**Figure 88**). The Mn concentrations show a seasonal change with the highest concentrations during the winter (**Figure 88**).

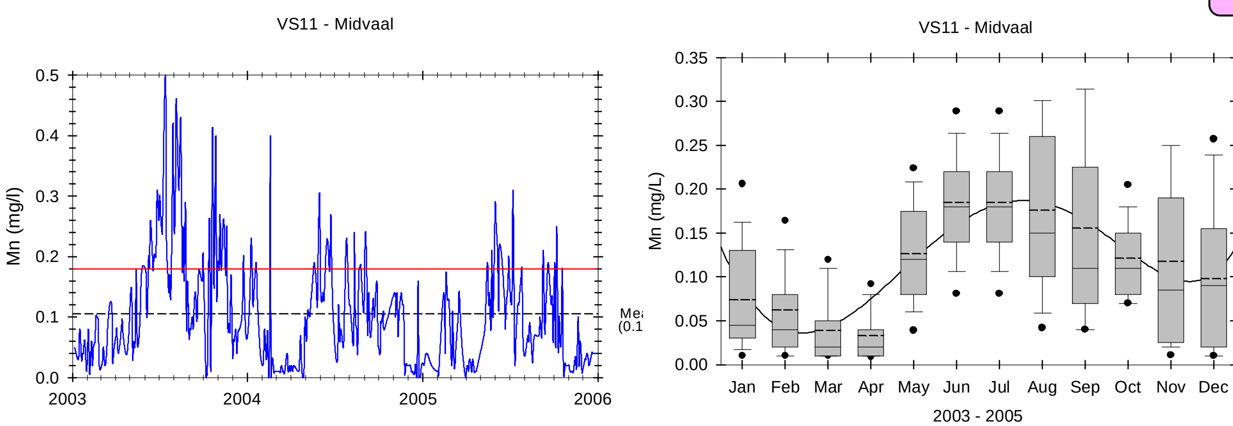


Figure 88: Variation in manganese concentration and a box plot of seasonal changes in the Vaal River at Midvaal during the past three years (2003 – 2005)

The dissolved organic carbon (DOC) concentrations at Midvaal were relatively high (mean, 7.05 mg/ℓ) and show an increasing trend (**Figure 89**). The high DOC concentrations could be ascribed to the general high algal biomass and other organic material in the water. High DOC is also associated with colour problems in drinking water, which is problem being faced by MidVaal Water Company at this point.

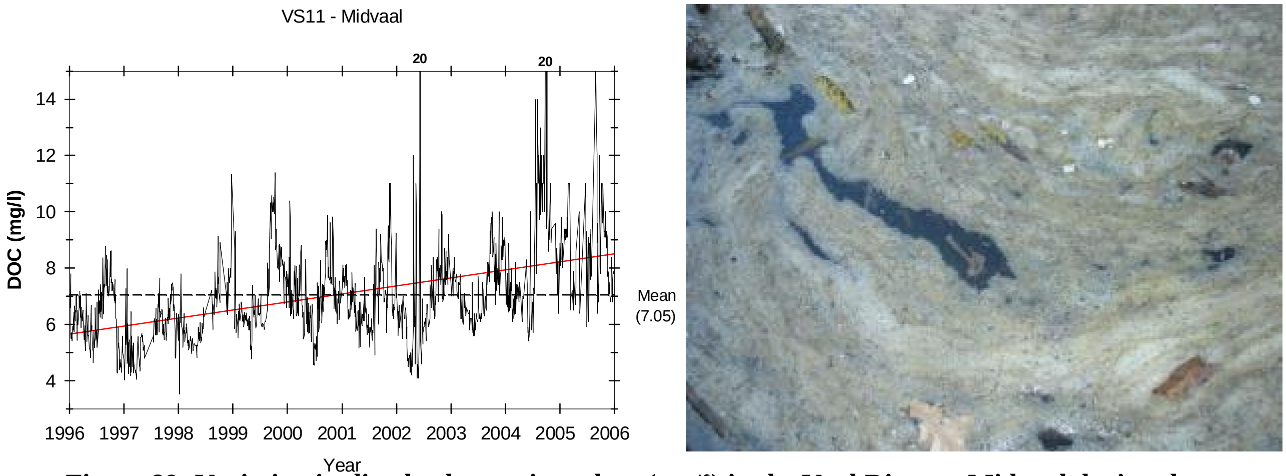


Figure 89: Variation in dissolved organic carbon (mg/ℓ) in the Vaal River at Midvaal during the past 10 years (1996 – 2005), and foam caused by high algal growth (1/6/2006).

Chlorophyll-***a*** concentrations at Midvaal (Stilfontein) were unfortunately only available until the end of 1999, when the Midvaal Water Company decided to measure only total chlorophyll concentrations, which is according to them, better from a water treatment point of view. However, the average chlorophyll-***a*** concentration during the period 1995 to 1999 was 40 µg/ℓ, which is associated with hypertrophic conditions. The chlorophyll concentrations apparently have even worsen during the following years – see increasing chlorophyll trend in **Figure 90**.

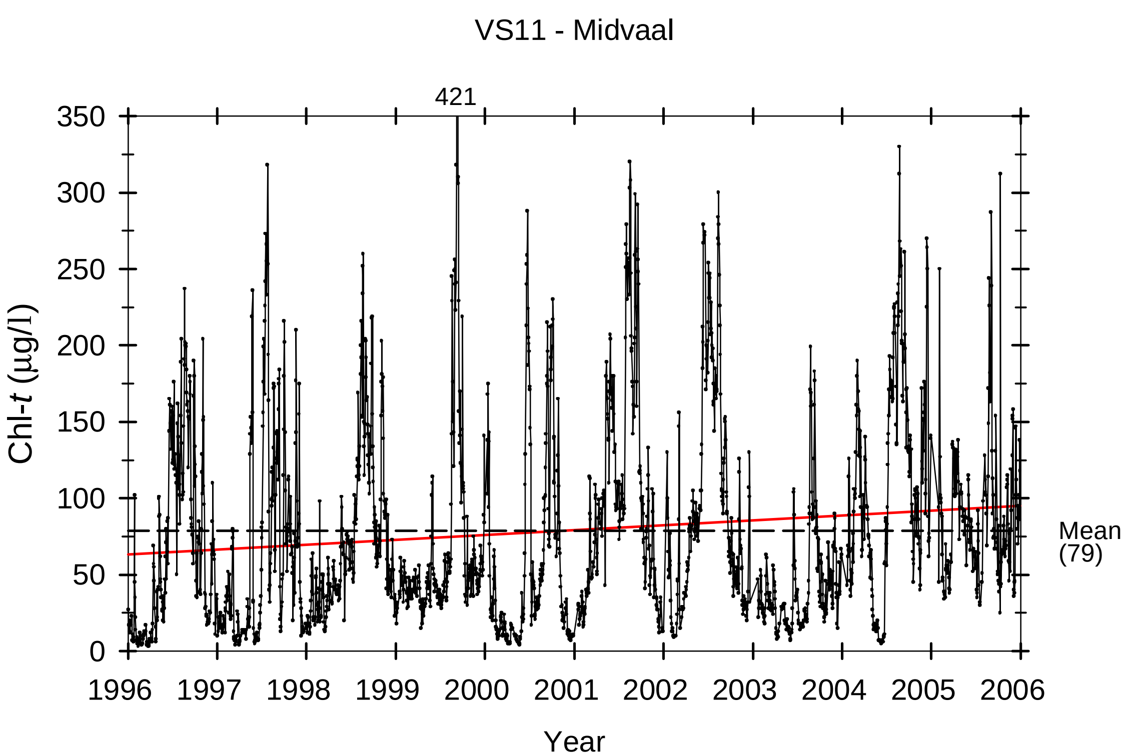


Figure 90: Variation in total chlorophyll concentrations (µg/ℓ) in the Vaal River at Midvaal Water Company (1996 – 2005)

The higher total chlorophyll concentrations (**Figure 90**) could be attributed to the higher phosphate concentrations and lower turbidity (**Figure 91**). This is in accordance with the general knowledge that higher nutrients (especially P) stimulate algal growth. Nitrogen apparently plays only a secondary role in the algal growth because the dissolved nitrogen in fact decreased over the same period.

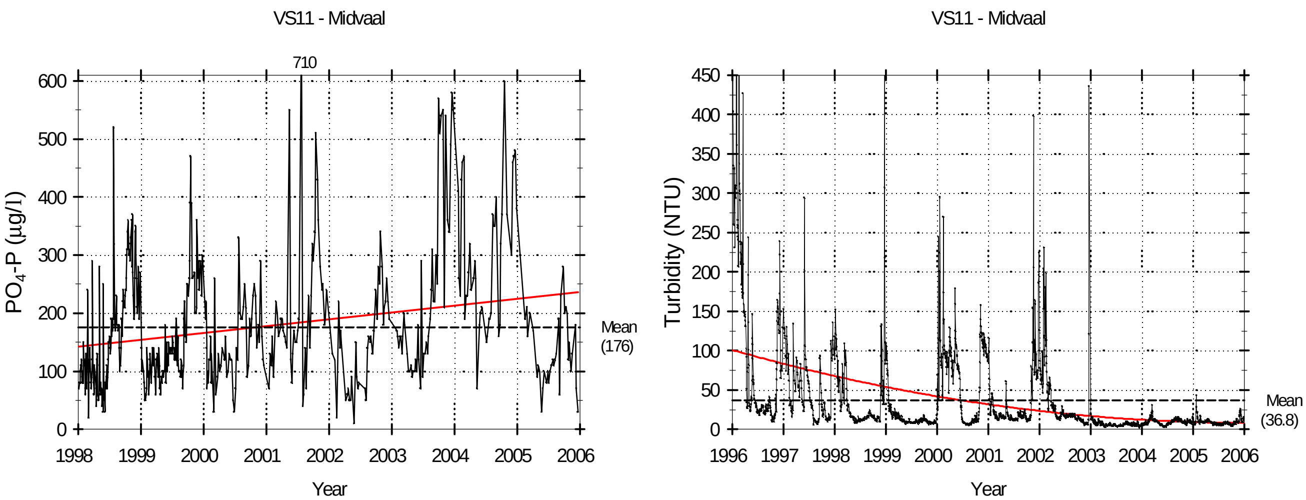


Figure 91: Variation in phosphate (PO_4-P) and turbidity (NTU) in the Vaal River at Midvaal

The Vaal River at Midvaal experienced hypertrophic conditions at least since 1995 with regular algal blooms (**Figure 92**).

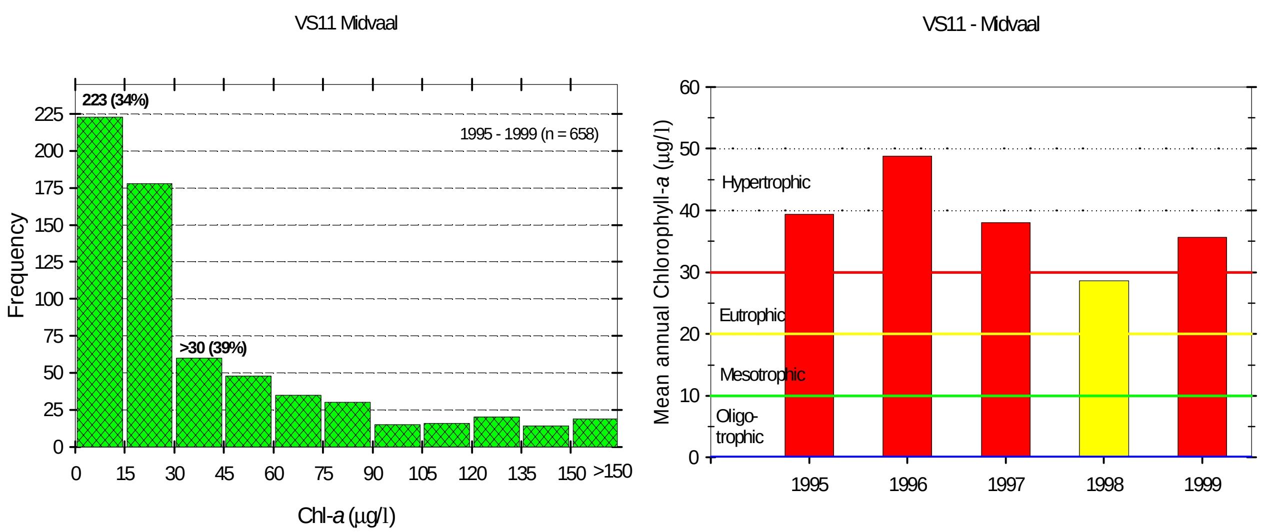


Figure 92: Frequency histogram of chlorophyll-a concentrations (left) and the annual trophic status in the Vaal River at Midvaal (1995 – 1999)

Midvaal also experience high dissolved organic carbon (DOC) concentrations (mean 7.05 mg/ℓ). These high levels are ascribed to the general high algal concentrations, because one by-product of dense algal blooms is high concentrations of DOC (**Figure 93**). When water with high DOC is disinfected by chlorination, potentially carcinogenic and mutagenic trihalomethanes (THMs) are formed (UNP, 2000). The density of algae and the level of eutrophication in the raw water supply have been correlated with the production of THMs (USEPA, 2000).

Figure 93: Scum and foam layer of algae at Midvaal Water Company intake tower with close-up picture (2/6/2006) – visible symptoms of eutrophication

WATER QUALITY STATUS:
Eutrophic Status: Level 1

VS12 - Orkney bridge

The phosphate concentrations were still high at Orkney (mean of 170 µg/ℓ). The dissolved salts were also high and show an increasing trend (**Figure 94**).

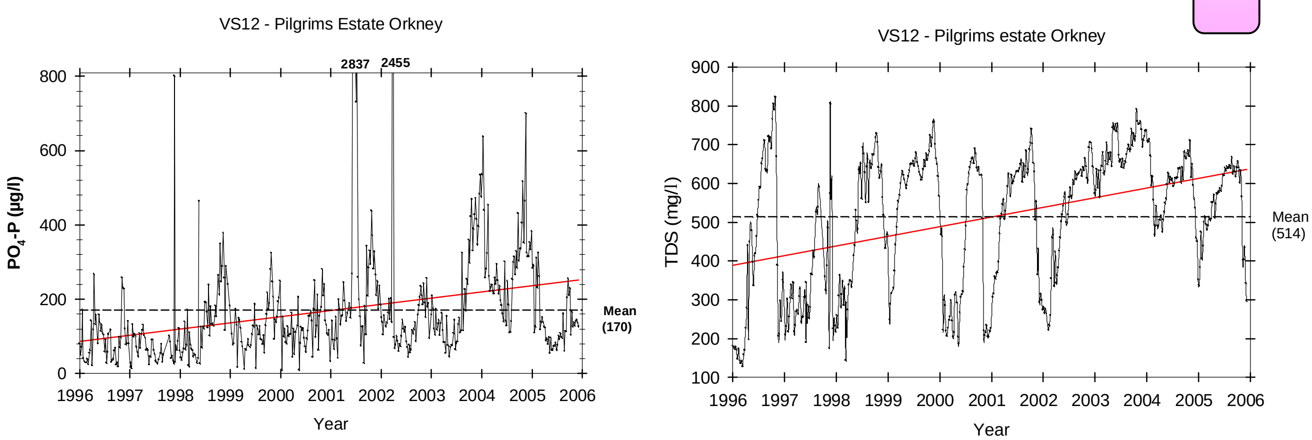


Figure 94: Variation in phosphate (µg/ℓ) and total dissolved salts (TDS) concentration in the Vaal River at Orkney during the past 10 years (1996 – 2005)

However, the nitrate concentrations are decreasing, while the alkalinity is increasing, a phenomenon noticed at various points in the middle Vaal reach – relationship explained earlier (**Figure 95**).

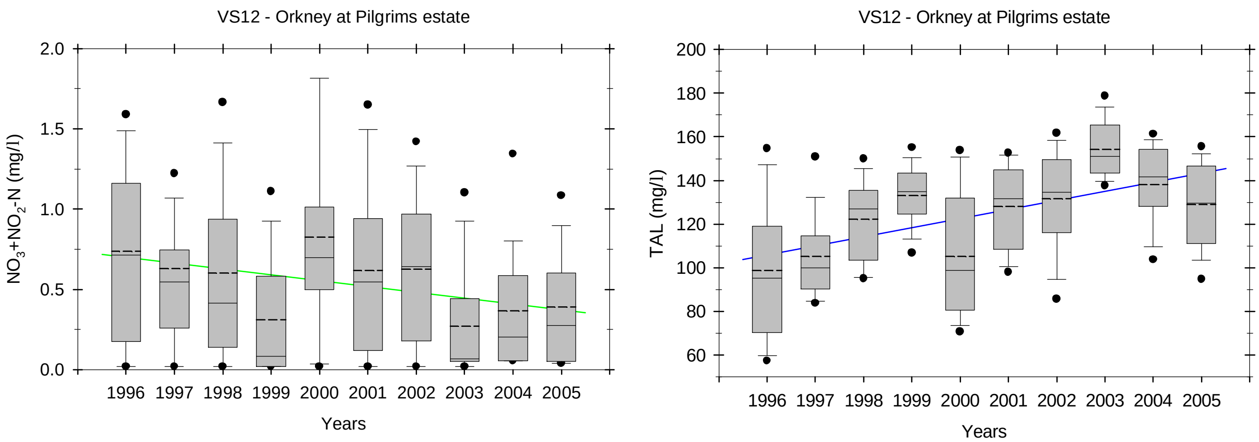


Figure 95: Box plots of the nitrate and total alkalinity concentration (mg/ℓ) in the Vaal River at Orkney during the past 10 years (1996 – 2005)

VS13 – Regina Weir

No data on nutrients were available for this point.

VS14 – Balkfontein (At Klipplaatdrift)

The water quality conditions at Klipplaatdrift was very much the same as the upstream point (Midvaal), *i.e.* high phosphates (mean, 120 µg/ℓ) and high dissolved nitrogen compounds (mean - 0.583 mg/ℓ) which show increasing trend lines (**Figure 96**).

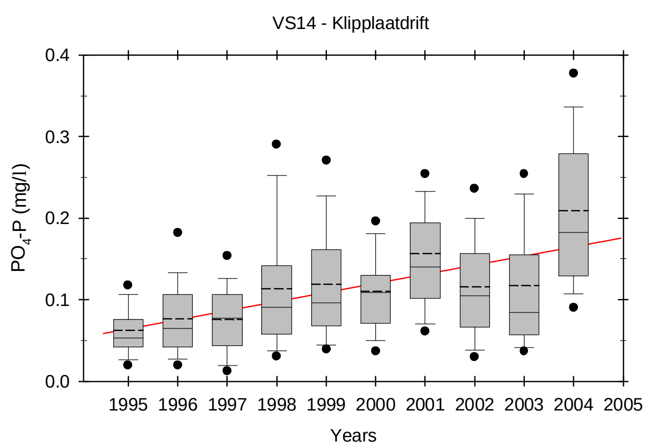


Figure 96: Variation in phosphate (µg/ℓ) concentration in the Vaal River at Klipplaatdrift during a 10 years period (1995 – 2004)

The high nutrients support generally high algal biomass with associated high pH values (**Figure 97**).

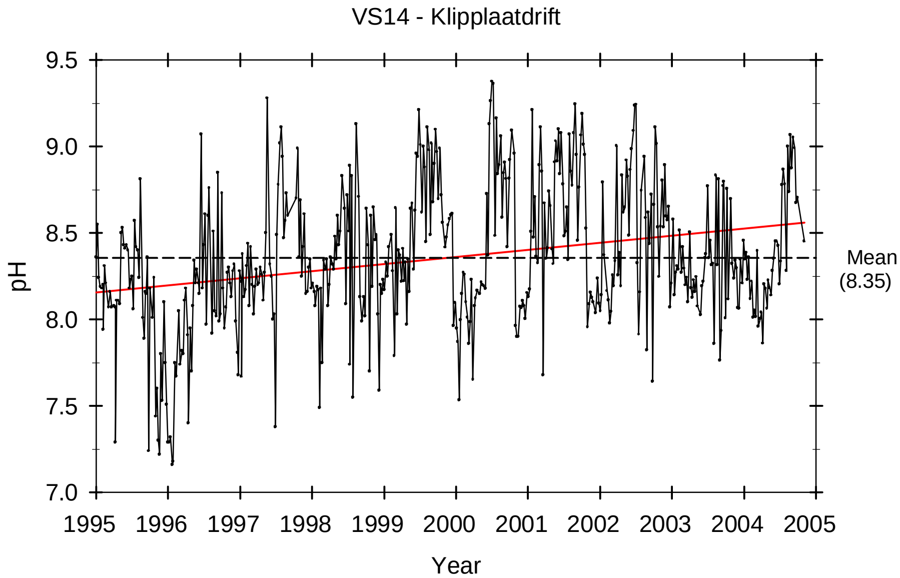


Figure 97: Variation in pH values in the Vaal River at Klipplaatdrift during the past 10 years (1995 – 2004)

The chlorophyll-***a*** concentrations at Balkfontein from 1999 to 2006 (unfortunately an incomplete data set) were also high (mean 45 µg/ℓ) and in the same range as at Midvaal (**Figure 98**). The average chlorophyll-***a*** concentration at Balkfontein for the period 1992 to 1997 was also 45 µg/ℓ, which could possibly indicates that the algal biomass stabilise at this level. However, the gap in the data set probably under-estimate the average concentration, because the average for 2005 – 2006 was 52 µg/ℓ. The increasing phosphate concentration at Klipplaatdrift (only about 1 km downstream of Balkfontein) suggests that an increase in algal biomass can be expected in the future.

WATER QUALITY STATUS:
Eutrophic Status: Level 1

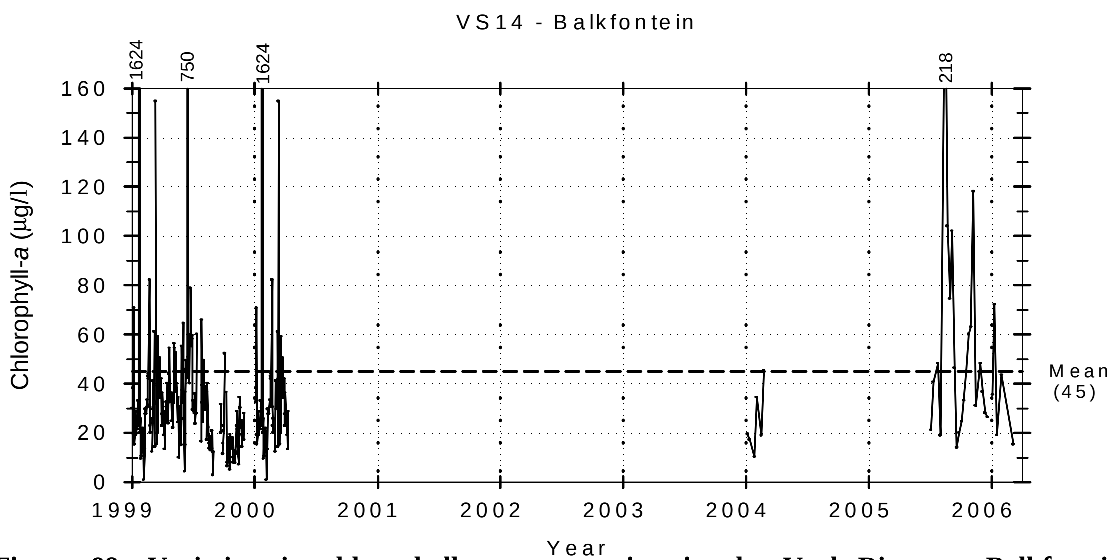


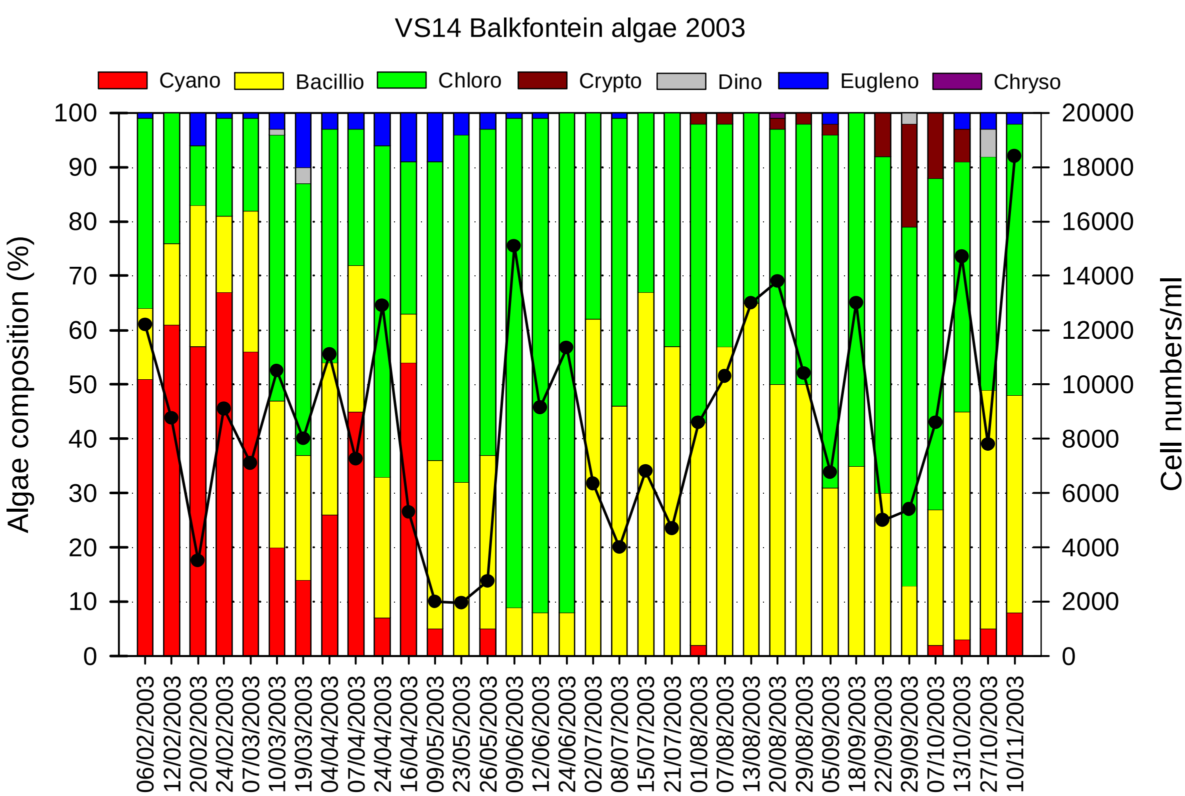
Figure 98: Variation in chlorophyll-a concentration in the Vaal River at Balkfontein (Bothaville)

Diatoms (primarily *Cyclotella* and *Thalassiosira* spp.) and green algae (primarily *Chlorella* sp. and *Chlamydomonas* spp) were always present in the algal assemblage of the Vaal River at Balkfontein, and dominate from May to December 2003 (**Figure 99**). Green algae are capable of tolerating wider environmental variability than other algal groups (Janse van Vuuren & Pieterse, 2005).

Cyanobacteria was absent in the Vaal River at Balkfontein during a study period 1986 to 1989, which was ascribed to the high inorganic N:P ratio (average 57) in the water (Roos & Pieterse, 1996).

During 2003 Cyanobacteria (mainly *Oscillatoria simplicissima*) was dominant during February and March (**Figure 99**). The manifestation of Cyanobacteria during the last few years in the middle Vaal River could be ascribe to higher phosphate concentrations, lower DIN:DIP ratios and lower discharge rates in the river.

The average DIN:DIP ratio during the last 10 years was relatively low at 5.7 and is decreasing. Together with decreasing flow conditions, favours the development of cyanobacteria.



WATER QUALITY STATUS:
Eutrophic Status: Level 1

Figure 99: Algal composition (%) in the Vaal River at Balkfontein (2003)

Dominant algal species recorded at Balkfontein during the last two years were: *Cyclotella* sp. and *Melosira* sp. (Diatoms), *Chlamydomonas* sp. (green algae), and *Oscillatoria* sp. (cyanobacteria) (**Figure 100**). Blooms of cyanobacteria and other algae in reservoirs and in river waters may impede coagulation and filtration, causing coloration and turbidity of water after filtration.

Figure 100: Thick foam scum in settling tanks of Sedibeng Water purification plant associated with a diatom (*Stephanodiscus* sp.) bloom in the Vaal River at Balkfontein (3/6/2006). The dark red-brown colour is partially attributed to the diatoms and the chemicals (ferrichloride) added to the water

One of the major consequences of eutrophication is the algal related water purification and water quality problems associated with high algal concentrations in the raw water. Based on the high annual chlorophyll-***a*** concentrations at Balkfontein (mean, 45 µg/ℓ), the trophic status of the Vaal River in this point is classified as hypertrophic (**Figure 101**).

Figure 101: Final effluent water from Sedibeng Water purification plant (3/6/2006) – note the green colour of the water because of high residual algal concentrations (chlorophyll-*a* concentration >1 µg/ℓ)

VS15 – Upstream Bloemhof Dam

No data available for this point (new monitoring point)

VS16 – Bloemhof Dam (Downstream weir)

The average phosphate concentration in Bloemhof Dam was low (mean of 31 µg/ℓ) and show no clear seasonal changes (**Figure 102**). However, the dam experiences frequent algal blooms and intense growth of water hyacinths.

Bloemhof Dam experience frequent algal blooms, dominated mainly by cyanobacteria (blue-green algae) and diatoms (**Figure 103**). It is also well-known that the dam experienced intensive growth of water hyacinths during the past ten years. Thus, the low phosphate concentrations in Bloemhof Dam are probably because of a biogenic uptake by the high concentration of algae and macrophytes in the lake.

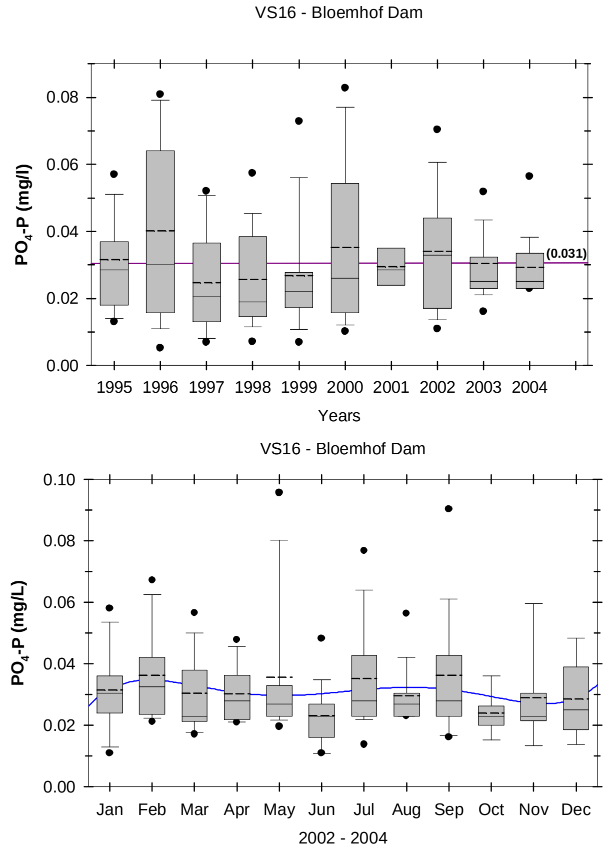


Figure 102: Box plots of the phosphates concentrations (annual and seasonal variation) in Bloemhof Dam during the past 10 years (1995 – 2004)

The dominant algal species were: during summer (November to May) *Microcystis, Oscillatoria* and *Anabaena* sp. (Cyanobacteria); during winter (June to August) centric diatoms (Cyclotella spp) (**Figure 104**).

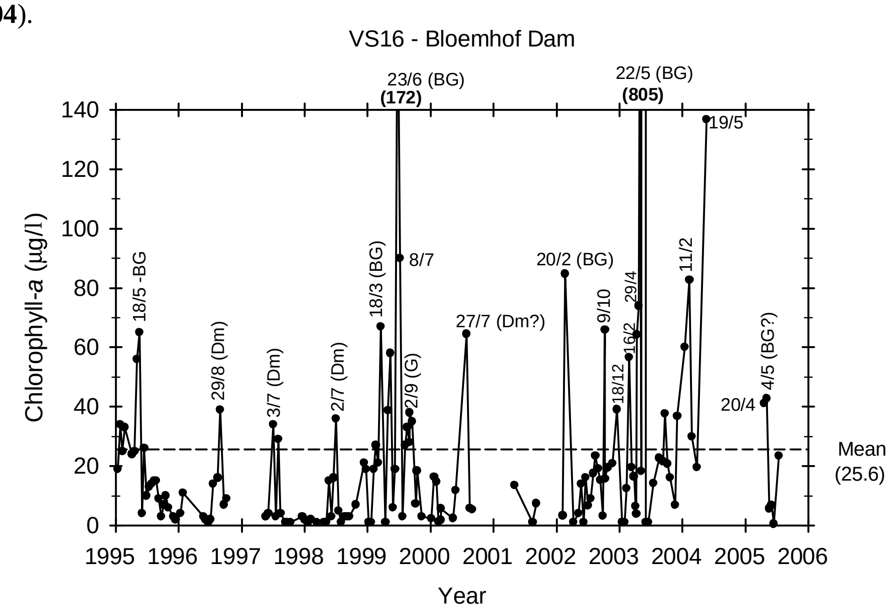
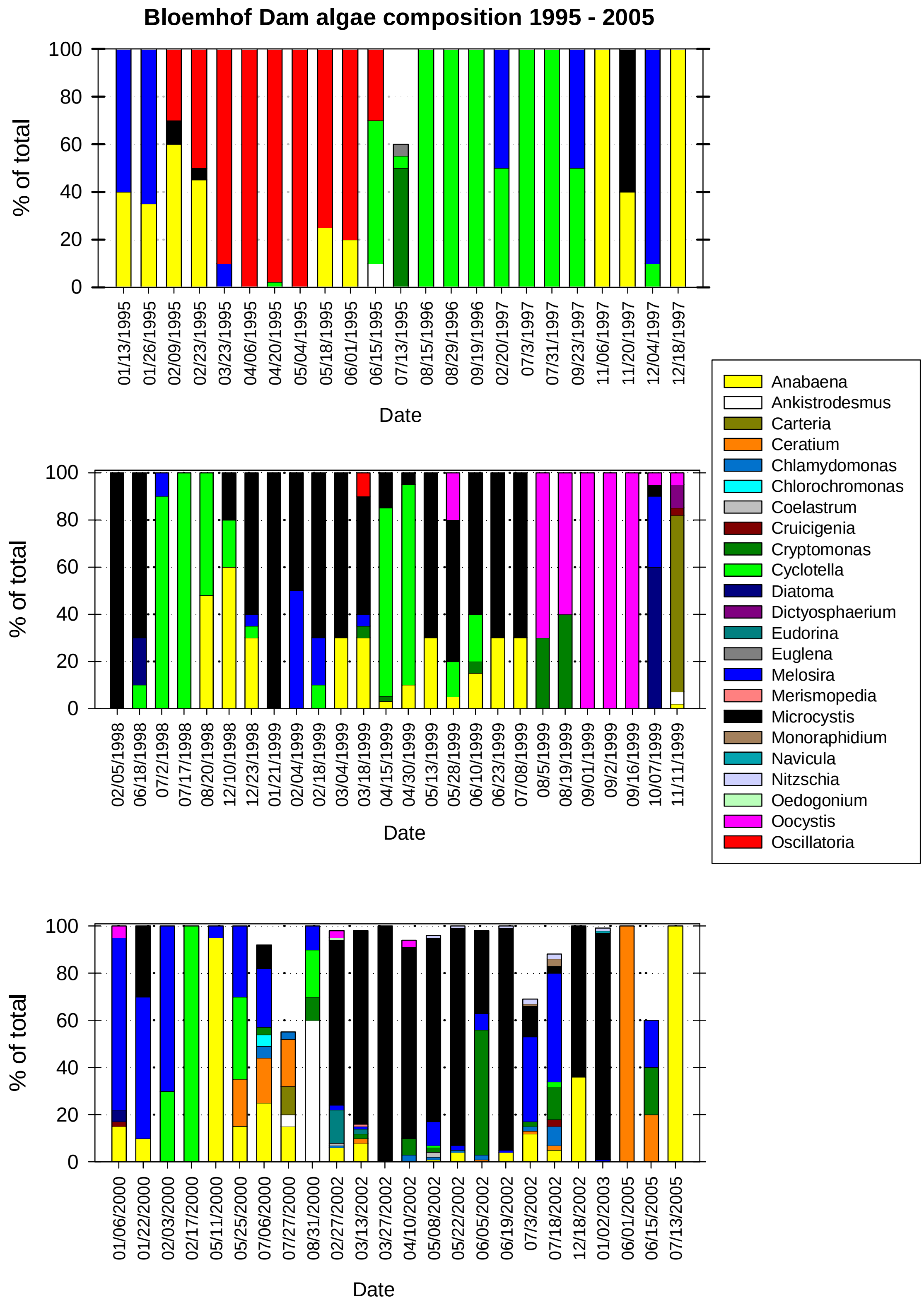


Figure 103: Variation in chlorophyll-a concentration in the Bloemhof Dam. The specific date and dominant algal composition for peak concentrations are also shown. BG = blue-green algae; Dm = diatoms; G = green algae.



WATER QUALITY STATUS:
Eutrophic Status: Level 1

Figure 104: Species composition (%) in Bloemhof Dam (1995 – 2005)

The severity of algal blooms varies from year to year depending on the climate conditions. Blooms tend to be worst in particularly dry summers or during droughts, and least severe in wetter summers. In general, there is a tendency for productivity to be correlated negatively with the depth of a lake (UNP, 2000). Thus, the decreasing dam levels in Bloemhof Dam (2002 to 2004) could also partially explain the increasing chlorophyll concentrations in the dam – see red trend line in **Figure 105**.

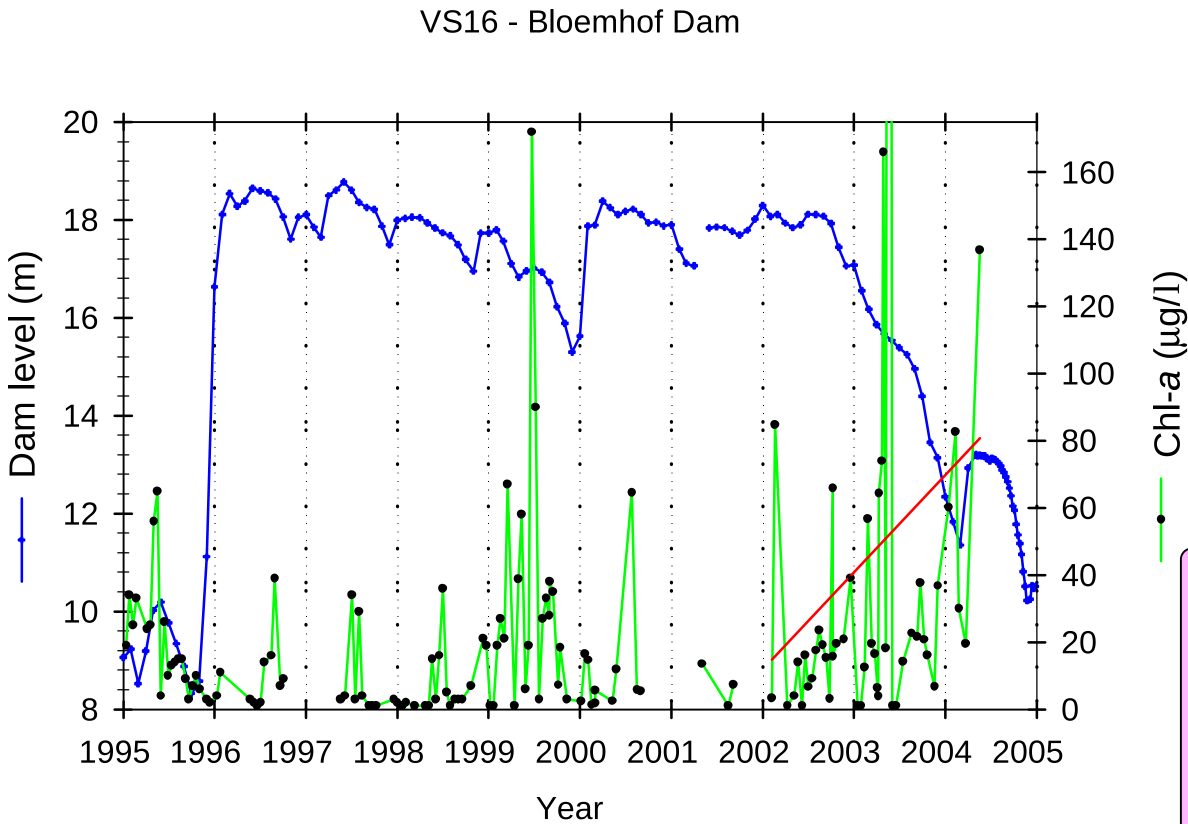


Figure 105: Variation in dam level and chlorophyll-a concentration in the Bloemhof Dam. The drop in dam level during 2002 to 2004 was associated with an increase in chlorophyll-a concentrations.

WATER QUALITY STATUS:
Eutrophic Status: Level 1

Based on the last three years, Bloemhof Dam is classified as hypertrophic (**Figure 106**). The eutrophic status during 2005 is questionable because the data was unfortunately limited to six measurements only during the year.

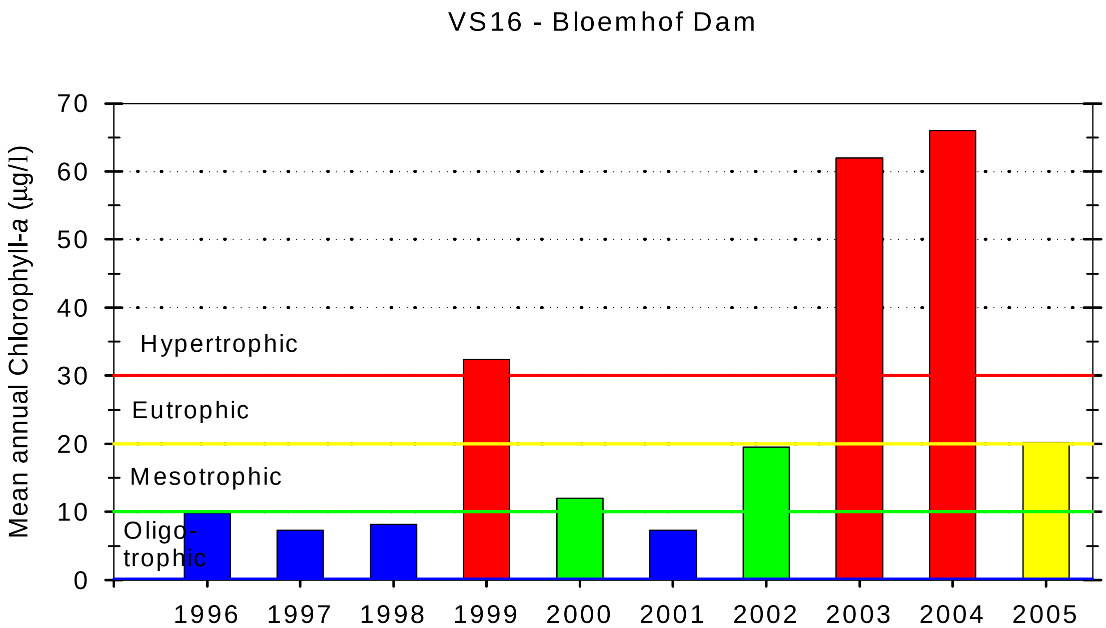


Figure 106: Annual trophic status of Bloemhof Dam for period 1996 to 2005

VS17 – Vaalharts Weir

The phosphates concentration in the Vaalharts weir were also low (mean, 36 µg/ℓ)(**Figure 107**), but the significant growth of water hyacinths show signs of eutrophication (**Figure 108**). The DIN (mean, 0.192 mg/ℓ) was relatively low.

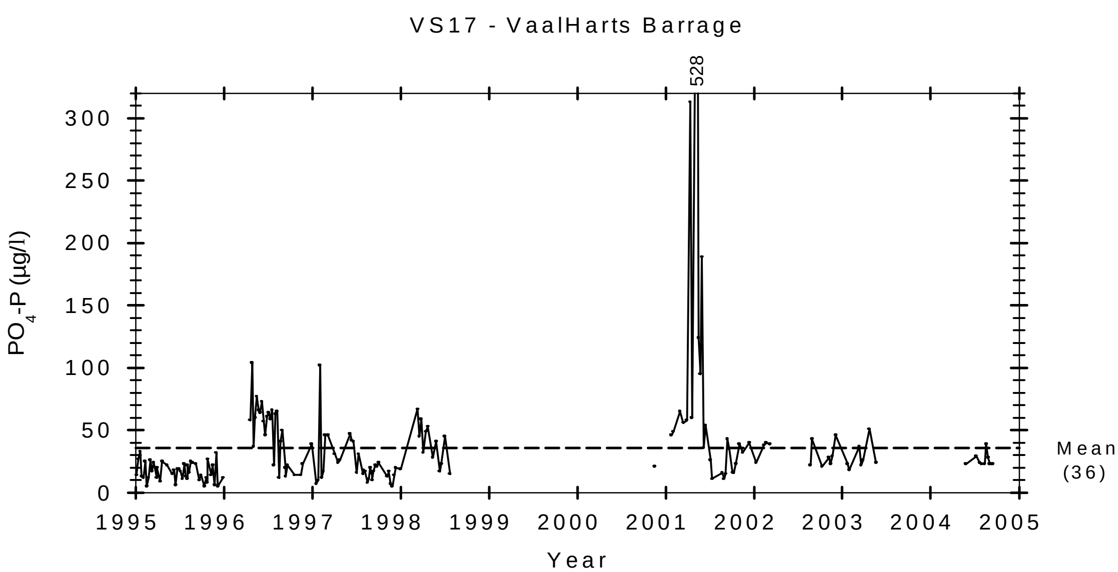


Figure 107: Variation in phosphate concentration (µg/ℓ) in the Vaalharts weir during the past 10 years (1996 – 2005)

Figure 108: Water hyacinths growth in Vaalharts weir in the Vaal River (3/6/2006)

VS18 – Vaal River at De Hoop

The dissolved nitrogen concentrations at this point, VS 18 (**Figure 109**) decreased from 1996 and the phosphate concentrations are relatively low (mean, 33µg/ℓ) and show no significant trend over the study period (**Figure 110**).

Figure 109: A recent photograph of the weir (3/6/2006)

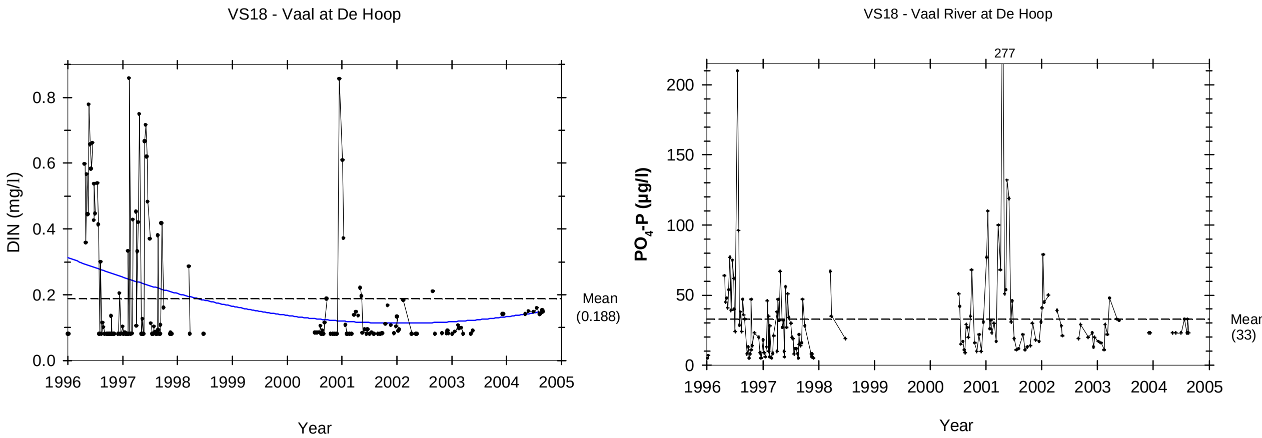


Figure 110: Variation in dissolved inorganic nitrogen (mg/ℓ) and phosphate concentration (µg/ℓ) in the Vaal River at De Hoop during the past 10 years (1996 – 2005)

VS19 – Schimidtsdrift

The water chemistry at Schimdsdrift was very similar to the upstream point at De Hoop, with low phosphate concentrations being recorded (**Figure 111**).

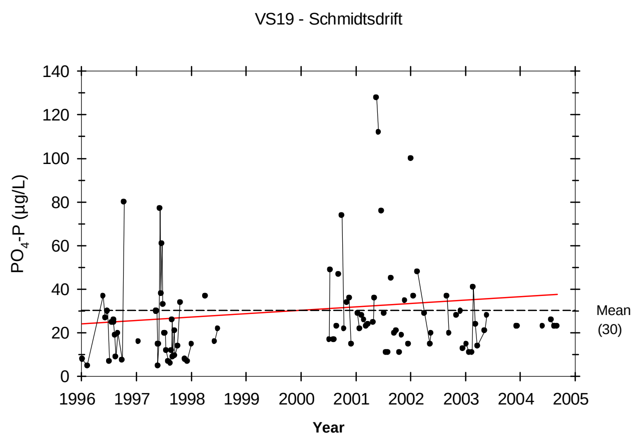


Figure 111: Variation in phosphate (µg/L) concentration in the Vaal River at Scmidtsdrift during the past 10 years (1996 – 2005)

VS20 – Douglas Barrage

The phosphate concentration at Douglas Barrage (VS20) was also relatively low (mean, 31 µg/ℓ) and shows only a slight increasing trend over the last nine years (1996 – 2004). However, if one considers the change over a longer period, 26 years in this case, the increase in phosphate concentrations are markedly significant, *i.e.* about 300 % increase (**Figure 112**).

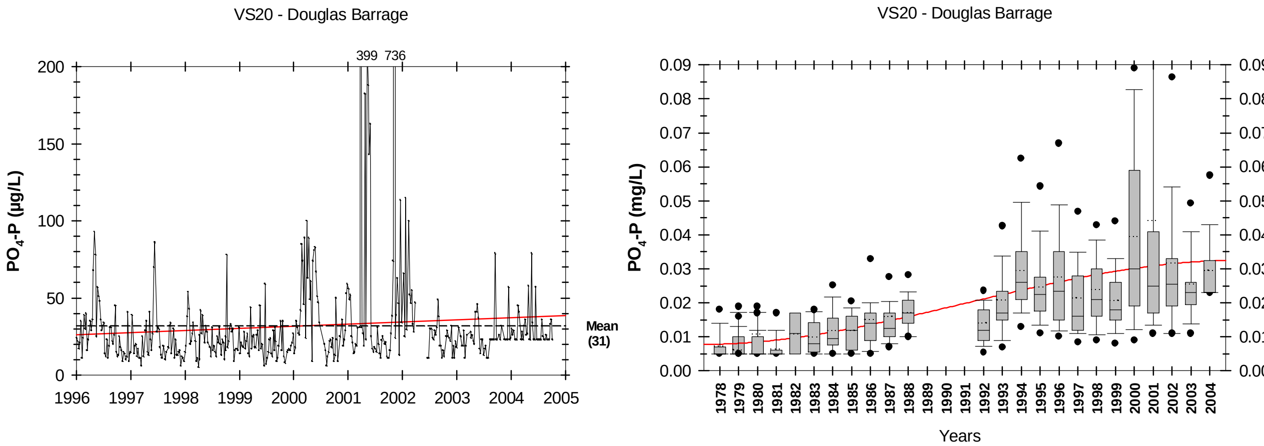
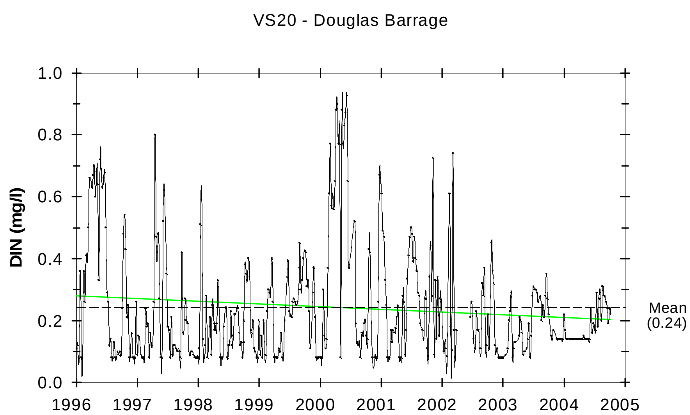


Figure 112: Variation in phosphate concentration (µg/ℓ) in the Vaal River at Douglas Barrage during the past 10 years (1996 – 2005) and a box plot of concentration changes during the past 26 years.

The DIN concentration was relatively low (mean of 0.24 mg/ℓ) and shows a slight decreasing trend during the period 1996-2005 (**Figure 113**).



WATER QUALITY STATUS:
Eutrophic Status: Level 1

Figure 113: Variation in dissolved inorganic nitrogen (mg/ℓ) concentration in the Vaal River at Douglas Barrage during the past 10 years (1996 – 2005)

The chlorophyll-*a* data for the Douglas Barrage is unfortunately limited to a few analyses per annum that were recorded. The problem with only a few determinations is that potential algal blooms could be missed and not recorded.

However, the average chlorophyll-***a*** concentration during the past six years was low at 7.6 µg/ℓ, with only one recording more than 30 µg/ℓ (**Figure 114**). Seventy three percent of the samples analysed has chlorophyll-a concentrations less than 10 µg/ℓ .

The low chlorophyll-a concentrations could be expected because of the low phosphorus concentrations, i.e. phosphate, mean 31 µg/ℓ and especially the low TP, mean 61 µg/ℓ (**Figure 115**).

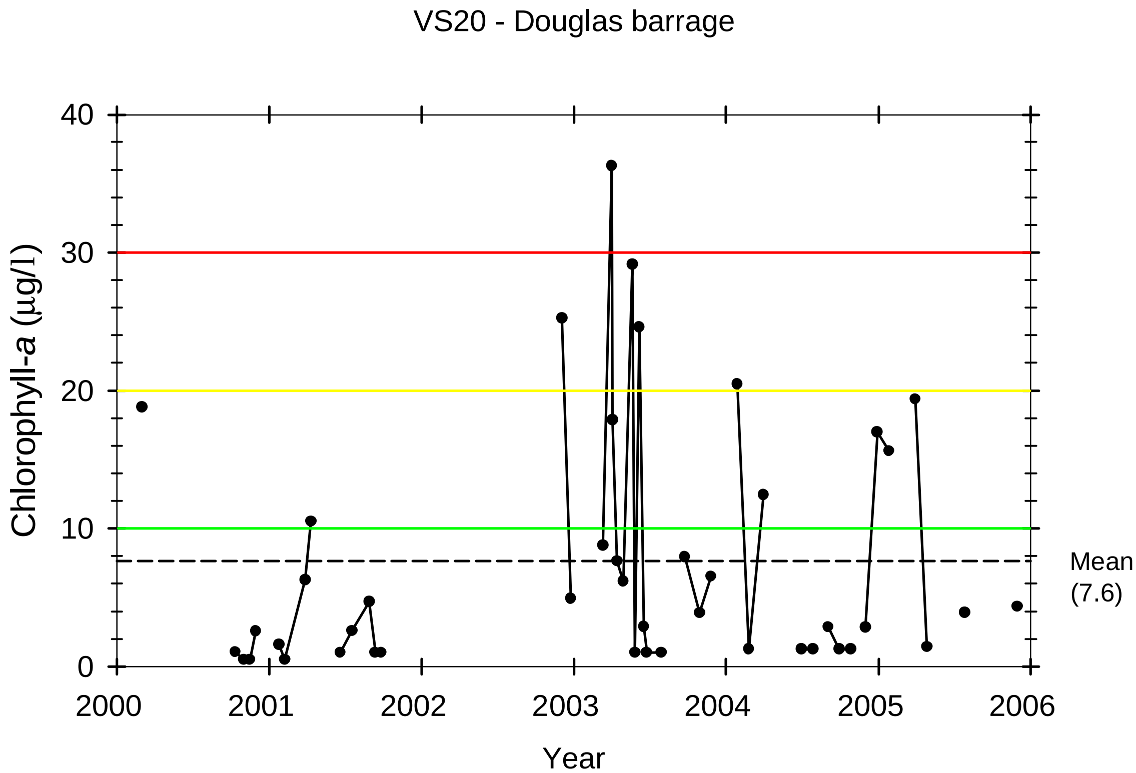


Figure 114: Variation of chlorophyll-a concentration in the Douglas Barrage during the period 2000 – 2005

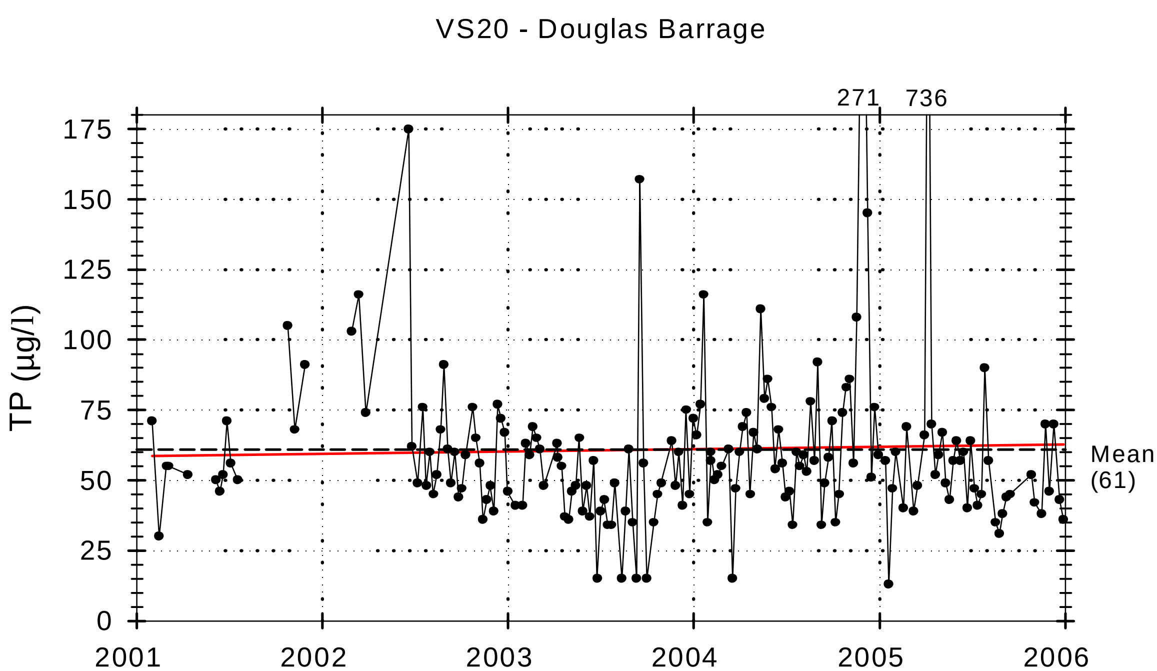


Figure 115: Variation in total phosphorus (TP) concentration (µg/ℓ) in the Vaal River at Douglas Barrage (2001 – 2005)

WATER QUALITY STATUS:
Eutrophic Status: Level 1

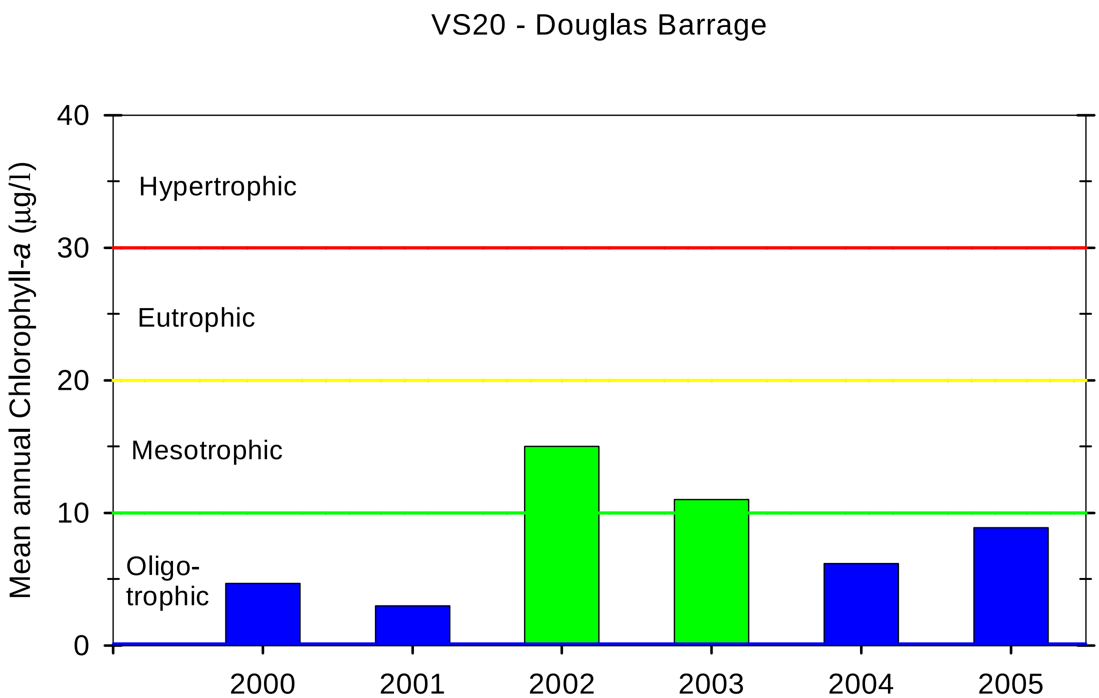


Figure 116: Trophic status in the Douglas Barrage based on chlorophyll-a concentrations for the period 2000 – 2005

The trophic status of the Douglas Barrage is oligo-mesotrophic (**Figure 116**), however, the data is based on limited chlorophyll-***a*** determinations (**Figure 114**).

The fairly good water quality at Douglas Barrage is partially ascribed to the influence of low nutrient water that is transferred from the Orange River to the barrage for irrigation purposes.

6.7 Microbiological Status

An attempt to assess the water quality status of the Vaal River System with regard to microbiological quality – specifically faecal coliforms was made. However due to the very limited microbiological monitoring data available it was not possible to generate an overview status of the entire system. The National Microbiological Monitoring programme (NMMP) of the DWAF was initiated in 2003 and only focuses on hotspot areas for now, the Vaal River not being one of them. The only catchment in the Vaal River System selected as a priority area as part of the NMMP is C81F. This area had a major shortage of proper sanitation infrastructure. The area mainly falls within the old Qwa Qwa area and include towns and settlements like Phuthaditjaba, Witsieshoek, Thababosiu, Mafikeng and Monontsha.

Some data was obtained from Midvaal Water which gives an indication of the microbiological quality of the water at VS11 (Midvaal).

Information on the current microbiological quality of the Vaal Barrage catchment (VS7 and VS 8) (October 2006) courtesy of Rand Water, was obtained from the website; www.reservoir.co.za.

6.7.1 Midvaal (VS11)

Total plate counts or heterotrophic plate counts detect a wide range of bacteria, which are omnipresent in nature. These counts are used to indicate the general microbial quality of water. At Midvaal, the bacterial concentrations (total plate count) increased significantly during 2005, which indicate sewage pollution and improper disinfection of treated sewage effluents (**Figure 117**). This situation is symptomatic of the general non-compliance of sewage works discharges.

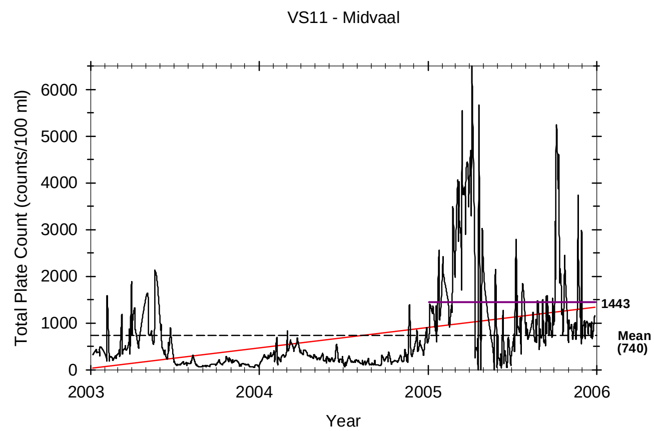


Figure 117: Total plate count in the Vaal River at Midvaal during the past 10 years (1996 to 2005)

6.7.2 Vaal Barrage Catchment (VS7 and VS8)

Microbiological quality of the water in the Vaal River downstream Vaal Dam and in the Vaal Barrage in October 2006 indicate faecal coliform counts in the range of 10-130 counts/100ml (**Figure 118**). However, while this quality does not pose a threat to health of water users, Rand Water does indicate that this quality shows a deterioration compared to counts of previous months. While the quality of the Vaal River at Vaal Barrage does not appear to be significantly impacted in terms of sewage pollution, the tributary catchments of the Vaal Barrage reflect high faecal coliform counts, indicating serious problems of non-compliance of the sewage works, the Klip River and Rietspruit catchments being cases in point (**Figure 118**).

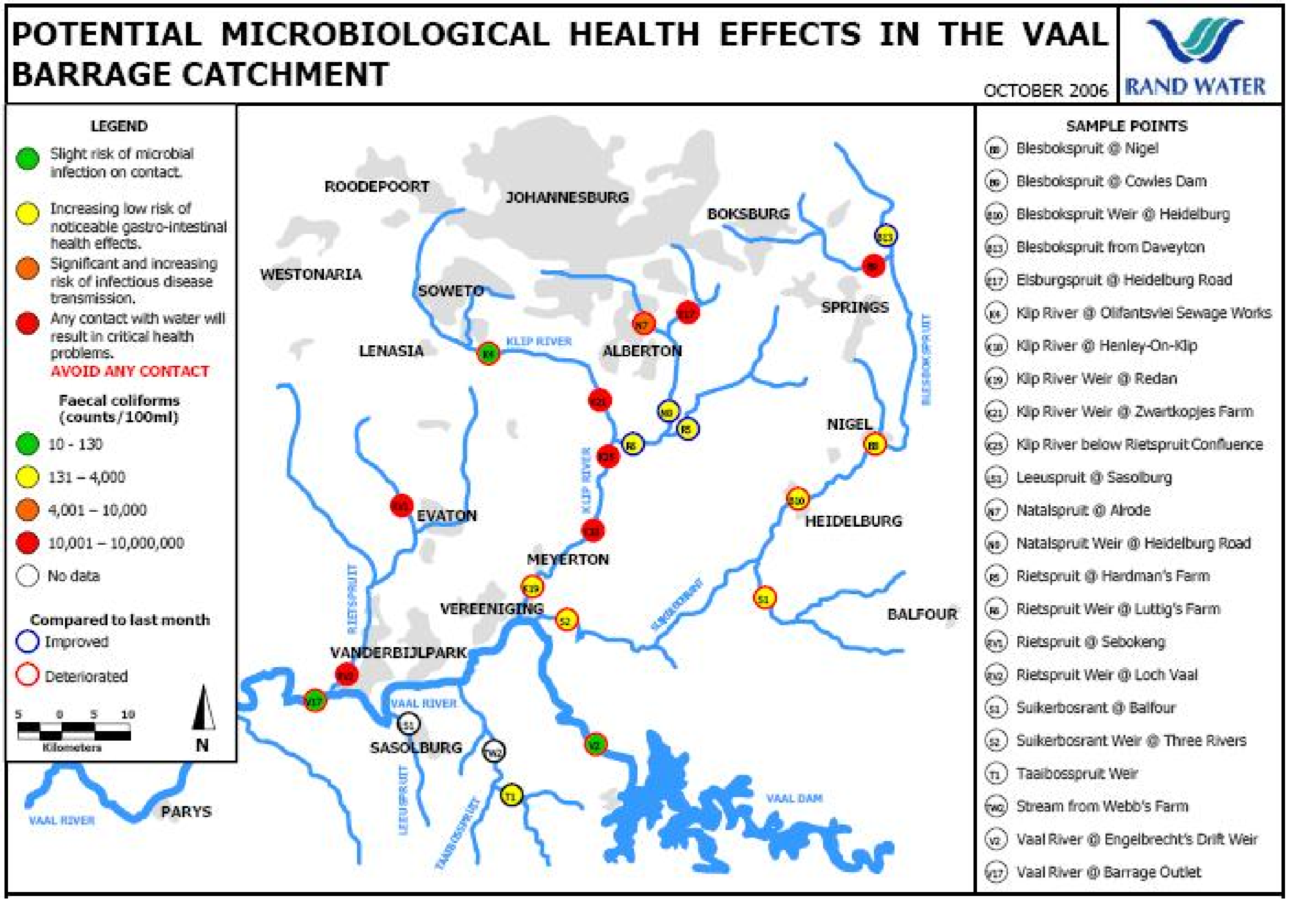


Figure 118: Indication of microbiological water quality in the Vaal Barrage catchment (VS7 and VS8) for October 2006 (Courtesy of Rand Water – obtained from www.reservoir.co.za)

WATER QUALITY STATUS:
Microbiological Status: Level 1

6.8 Current Status and Water Quality trends identified on the Major Tributaries of the Vaal River: Level 2 Strategic monitoring points

The water quality in the Vaal River main stem is to a large extent characteristic of the contributing tributaries that confluence with it along its length. An overview assessment was thus also done of the major tributaries to identify the extent of their potential impacts on the Vaal River. The tributaries were assessed at the level 2 strategic monitoring points identified for the study. The points and their locations are listed in **Table 47** and shown on **Figure 27**.

The assessment of the water quality at the level 2 points was done in terms of a sub-catchment perspective. The sub-catchments include:

- Grootdraai Dam
- Vaal Dam
- Vaal Barrage
- Downstream Vaal Barrage
- Middle Vaal River
- Bloemhof Dam
- Harts River
- Douglas Barrage,

as indicated on **Figure 119**.

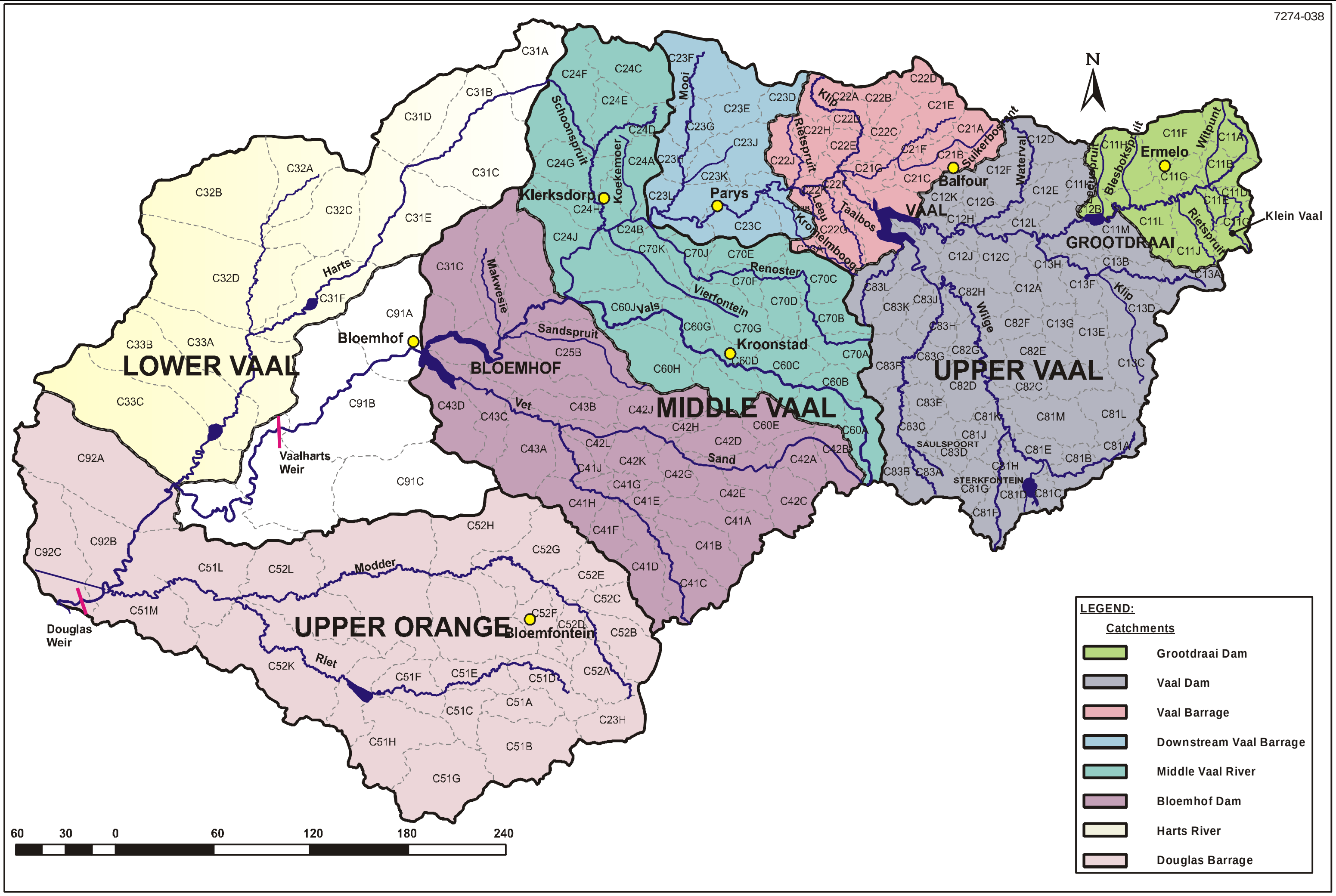


Figure 119: Sub-catchment areas in terms of which Level 2 monitoring points on tributaries where assessed

WATER QUALITY STATUS:
Level 2 Points: Tributaries

6.8.1 Grootdraai Sub-catchment

The tributaries of the Vaal River in the Grootdraai Dam sub-catchment include:

- Witpuntspruit
- Klein Vaal
- Rietspruit
- Blesbokspruit, and
- Leeuspruit

The water quality in these tributaries vary to a great degree, with the concentrations at some points exceeding their RWQOs and others having fairly good water quality. In addition the transfer of fairly good quality water from the Heyshope (Usutu to Mhlatuze WMA) and Zaaihoek (Thukela WMA) Dams into these part of the catchment is also affecting the water quality of the Grootdraai Dam.

The water quality of the tributaries are discussed below.

Witpuntspruit (L2-VS3-1)

Witpuntspruit is close to the Camden coal fired power station and joins the Vaal River in the upper section close to the source of the Vaal River. It is appears to be contaminated by acid mine drainage. This is inferred by the low pH values (mean, 4.4) and high sulphate concentrations (average of 1 013 mg/ℓ) – refer to **Figure 120**. The dissolved salts (TDS) concentration (average of 1 241 mg/ℓ) is dominated by high sulphate concentration, ***i.e.*** average 81 %. These concentrations exceed the unacceptable concentration levels of RWQOs for this sub-catchment and for the Vaal River (>162 mg/ℓ for TDS and > 30 mg/ℓ for sulphate) and thus some intervention must be sought if the RWQOs are to be met. In addition the acid mine drainage impacts need to be addressed in the local water quality management plan for the sub-catchment. However, the TDS and sulphate concentrations were significantly lower during the last two years (**Figure 120)**.

The concentration of cations (Na^+, Mg^{2+}, and K^+) were relatively low and the negative sulphate ions (SO_4^{2-}) were probably balanced by hydrogen ions (H^+), originating from the acid mine drainage, therefore the inverse relationship between SO_4^{2-} and pH (**Figure 121**).

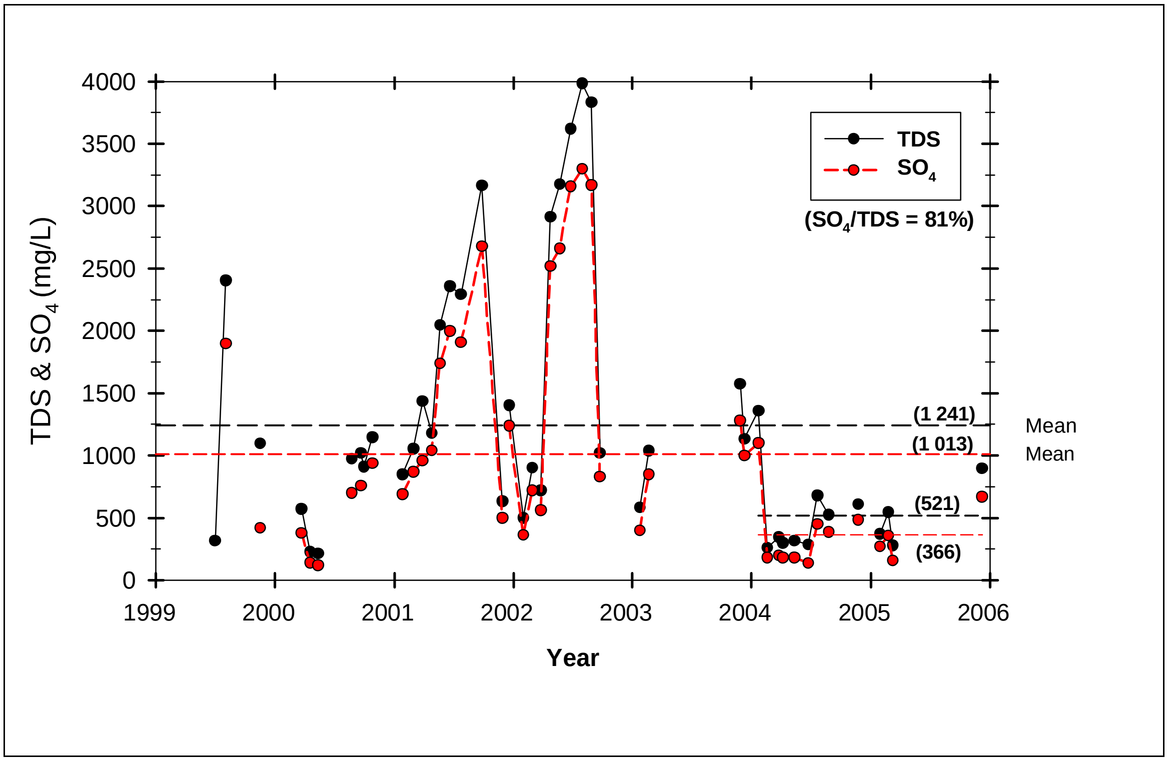


Figure 120: Variation in TDS and sulphate concentrations in Witpuntspruit from 1999 to 2005

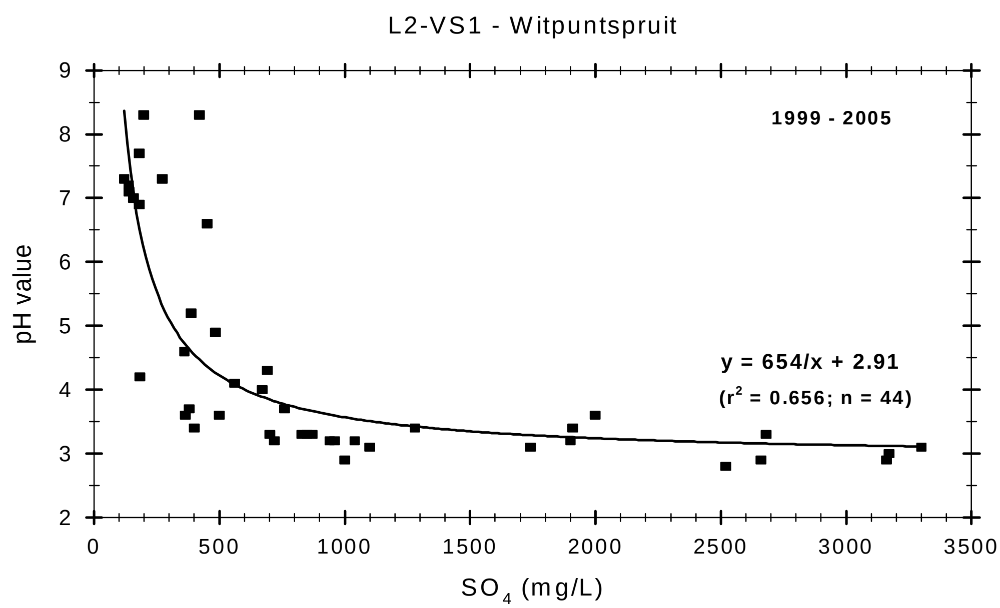


Figure 121: Relationship between sulphate concentrations and pH in Witpunt spruit during the period 1999 to 2005

The phosphate and DIN concentrations on the Witpuntspruit are high, mean 0.195 mg/ℓ and 1.275 mg/ℓ respectively. The ammonium (NH_4) concentrations were relatively high and makes up, on average, 75 %

of the total dissolved nitrogen, which indicates strong inhibition of nitrification (i.e. the convertion of NH_4 to NO_3), perhaps due to the low pH values. These concentrations also border on the unacceptable RWQO level concentrations for this catchment and thus require some management intervention.

Figure 122: Witpunt Spruit, a tributary of the Vaal River (29/5/2006)

Klein Vaal River (L2-VS4-1)

The physical and chemical data at this monitoring point is limited and scattered over the last two years. However, from this data and general observations in the field, it was clear that the water quality of the Klein Vaal River is very good with low TDS (mean of 195 mg/ℓ), low phosphate (0.05 mg/ℓ) and fairly low DIN concentrations (mean of 0.283 mg/ℓ) – **Figure 123** and **Figure 124** .

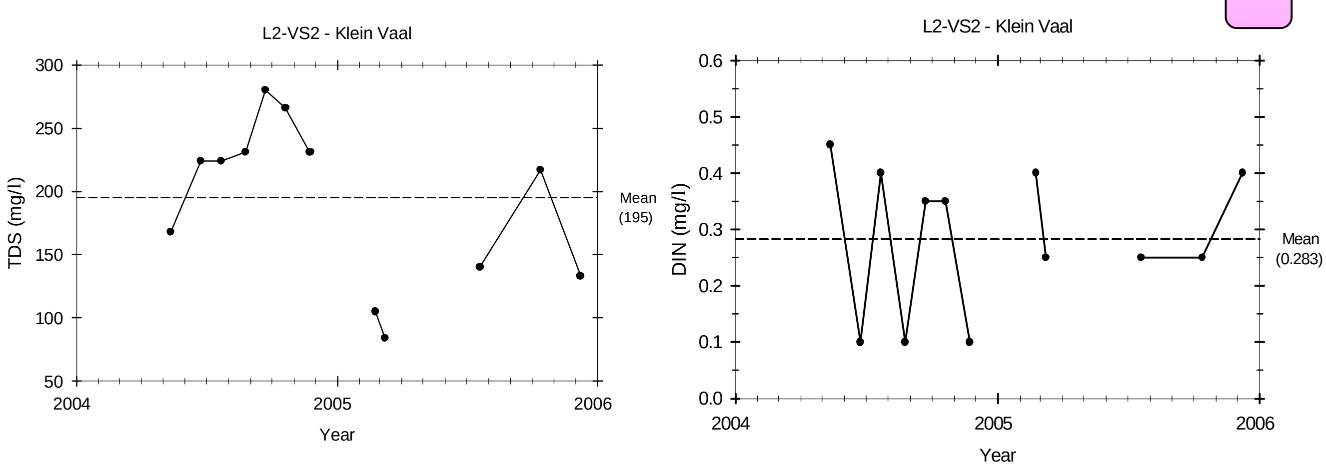


Figure 123: Variation in TDS and dissolved inorganic nitrogen (DIN) concentrations (mg/ℓ) in Klein Vaal River from 2004 to 2005

Figure 124: The general water quality conditions in the Klein Vaal were good with clear water, high dissolved oxygen and no excessive algal growth or water hyacinths (29/5/2006)

Rietspruit at N11 bridge (L2-VS4-2)

The average TDS concentration at this level 2 point on the Rietspruit was fairly low (average of 177 mg/ℓ), but the phosphate and dissolved inorganic nitrogen concentrations were relatively high, mean of 81 µg/ℓ and 0.444 mg/ℓ respectively (**Figure 125**). However, the phosphate concentration was during the last year at the detection level of 50 µg/ℓ (**Figure 126**). A concentration value of 1 600 µg/ℓ was rejected as an outlier.

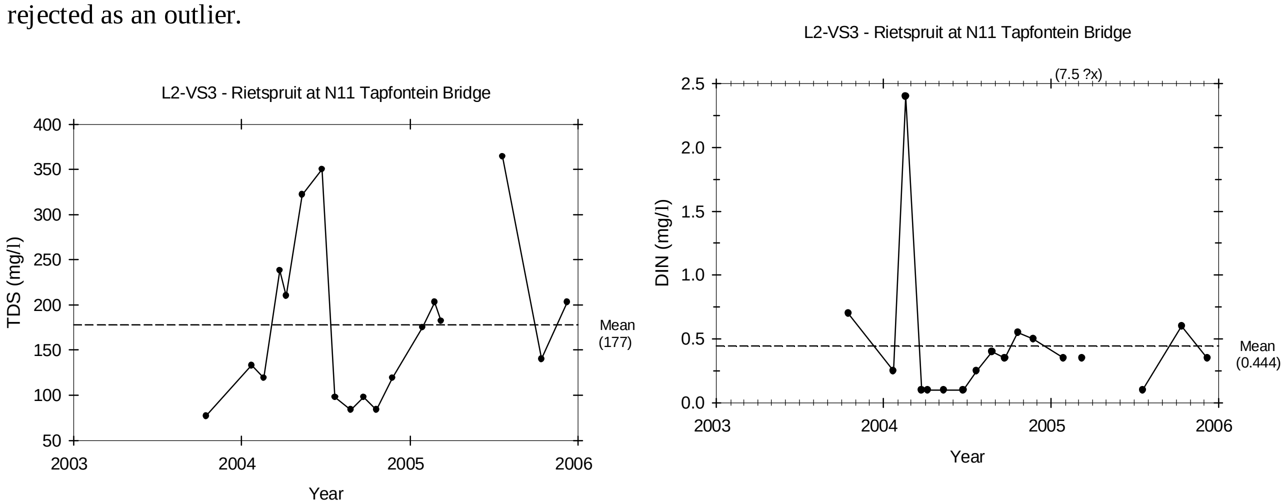


Figure 125: Variation in TDS and dissolved inorganic nitrogen (DIN) concentrations in Rietspruit from 2004 to 2005

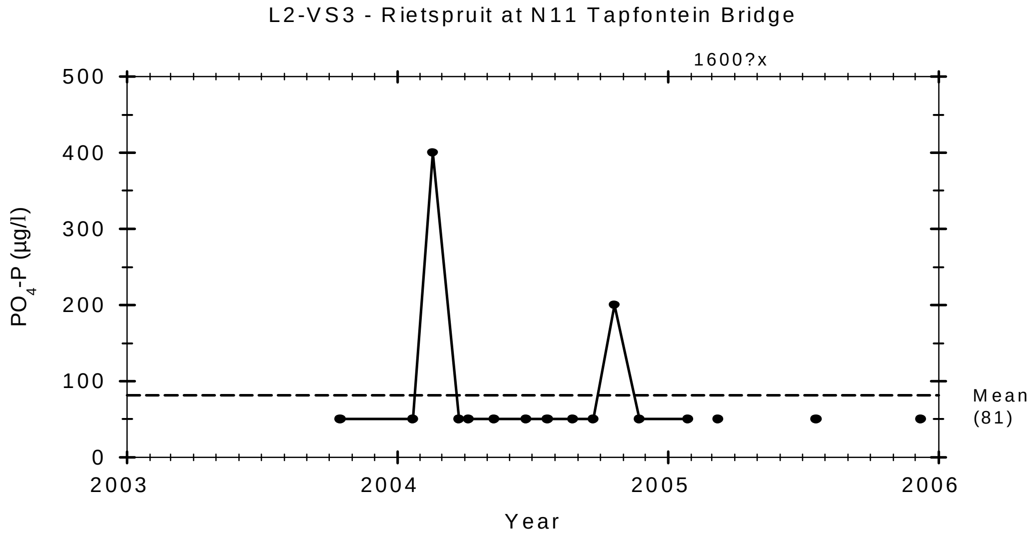


Figure 126: Variation in phosphate concentrations (µg/ℓ) in the Rietspruit from 2004 to 2005

The Vaal River at point VS4 (R35 Bloukop Bridge) does exhibit a slight exceedance of the acceptable RWQO concentration for TDS, which could be a result of the localized impact of the Rietspruit. This impact is probably attributable to the coal mines in the area (as sulphate concentrations are also high - refer to **Figure 127**). This tributary does not comply to the sub-catchment RWQOs or to those of the Vaal River for TDS or sulphate. The concentrations of 177 mg/ℓ (TDS) and 38 mg/ℓ (sulphate) exceed the unacceptable RWQOs level concentrations (which are >162 mg/ℓ for TDS and > 30 mg/ℓ for sulphate), which indicates that there is a likelihood that some of this impact is transferred to the Vaal River.

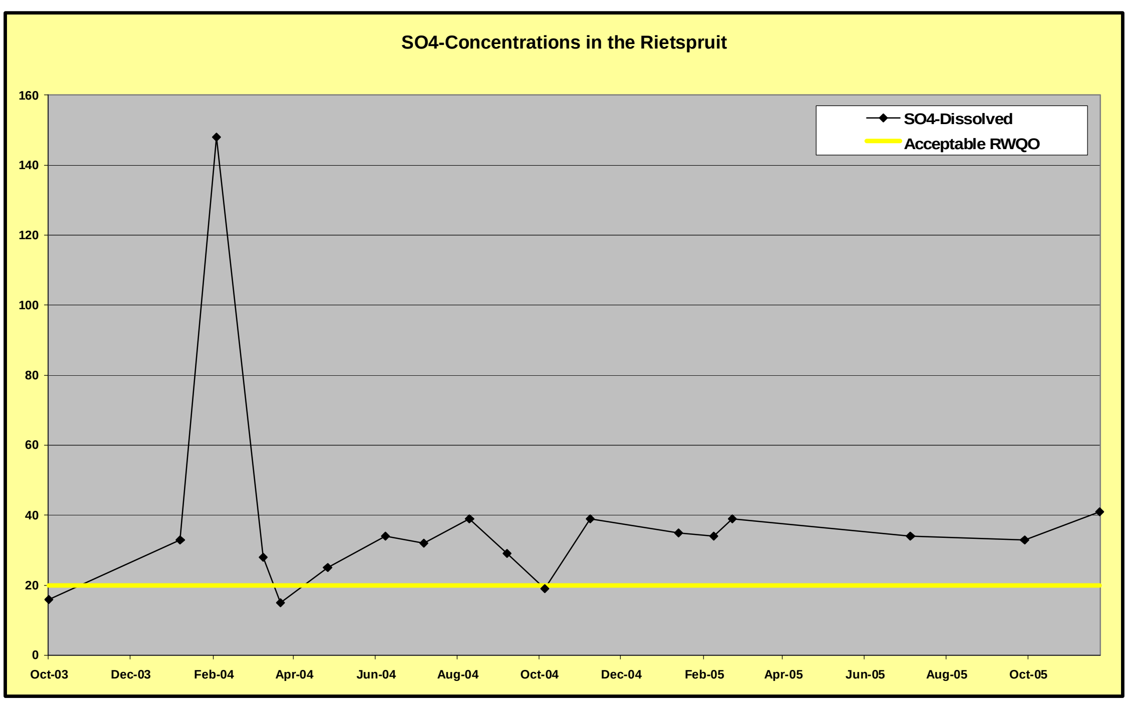


Figure 127: Variation in sulphate concentration in the Rietspruit from 2003 to 2005

The concentrations of phosphate and nitrogen are within the acceptable to tolerable RWQO range for the tributary and the Vaal River, and at this stage do not pose any serious threat to the water quality in the Vaal River.

Blesbokspruit at R39 bridge (L2-VS5-1)

The assessment of the water quality in the Blesbokspruit indicated TDS levels to be significantly higher than the other upstream points (average of 341 mg/ℓ; EC = 52.3mS/m)(**Figure 128**). These concentrations significantly exceed the acceptable RWQO concentration for TDS set for the tributary (>210 mg/ℓ). These levels of TDS also exceed the Vaal River RWQO which is set at the same concentration. From the assessment of the data clear cyclical seasonal patterns in the TDS concentrations are seen, with higher concentrations being associated with lower flows in the drier winter months (June to October). This is seen for the other macro ions as well, such as sulphate.

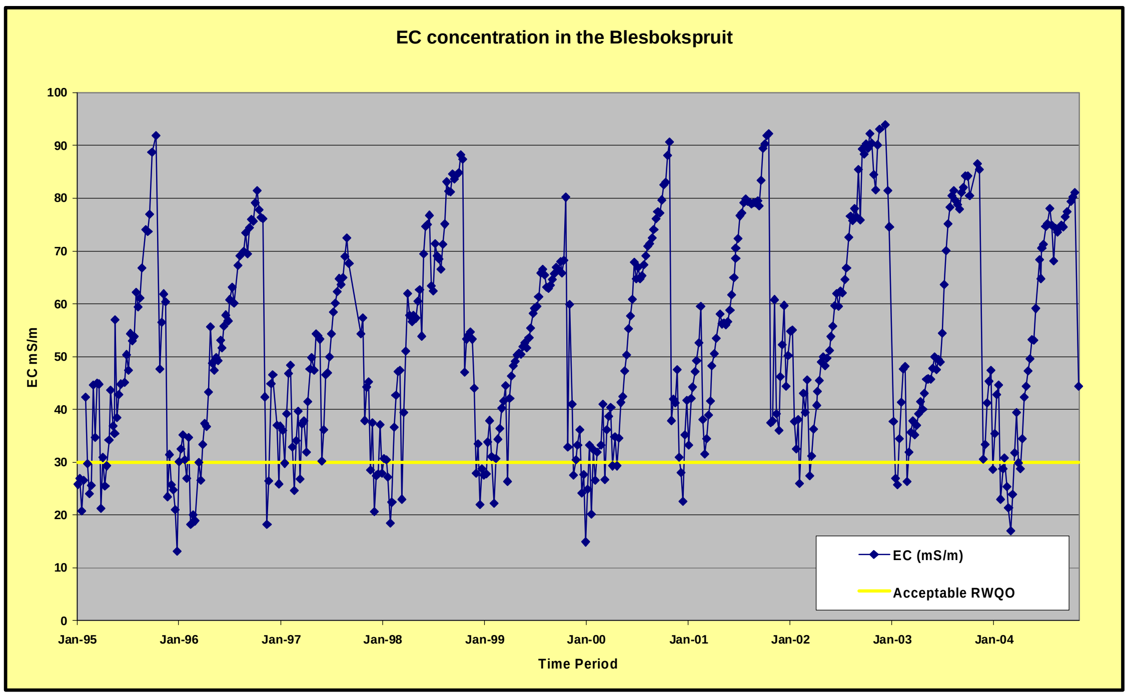


Figure 128: EC concentrations in the Blesbokspruit from 1995 to 2004

These high TDS concentrations and associated sulphate concentrations could be attributable to the contribution from the coal mines in the Ermelo area. This is an issue for this sub-catchment. The impact of the high concentration winter flows from the Blesbokspruit is attenuated in the Grootdraai Dam due to mixing with the good quality runoff from other parts of the catchment, the good quality summer flows and water transferred into the catchment from Zaaihoek Dam.

The Blesbokspruit was also characterised by high phosphate concentrations (average of 303 µg /ℓ), as well as fairly high nitrogen concentrations (**Figure 129** and **Figure 130**) which indicates sewage and possible agricultural pollution and can contribute significantly to the nutrient enrichment of the Vaal River.

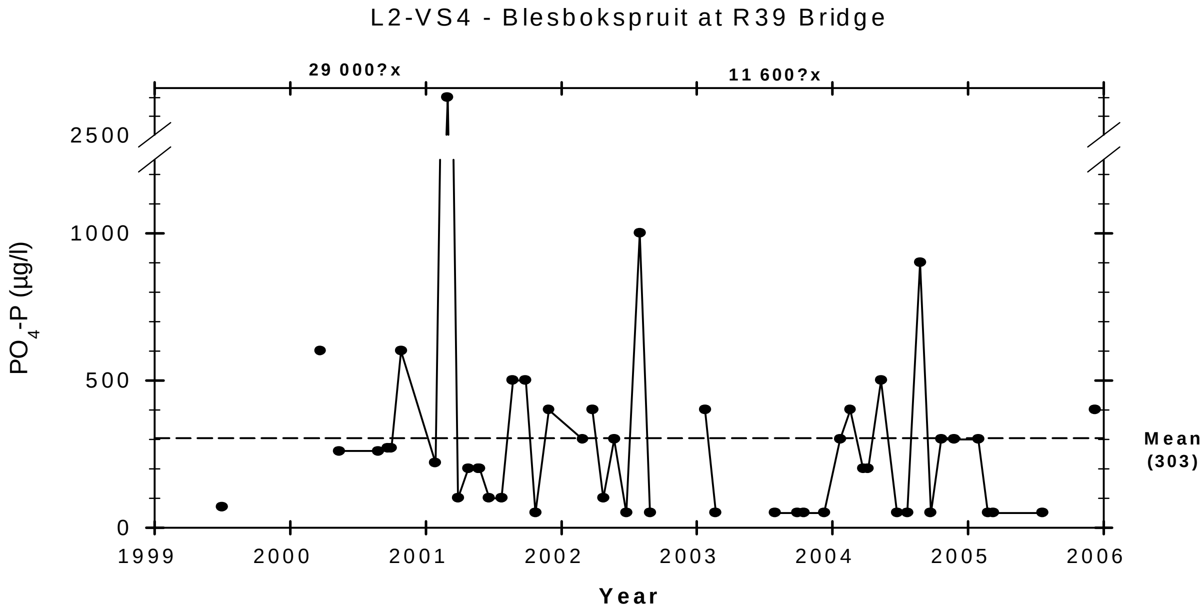
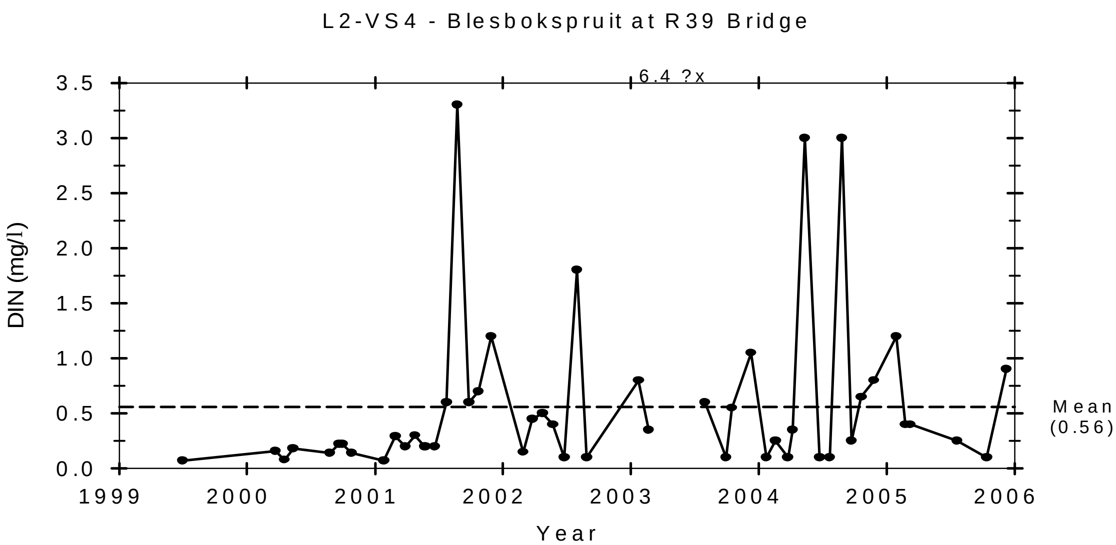


Figure 129: Variation in phosphate concentrations (µg/ℓ) in the Blesbokspruit from 1999 to 2005



WATER QUALITY STATUS: Level 2 Points: Tributaries

Figure 130: Variation in dissolved inorganic nitrogen concentrations in the Blesbokspruit from 1999 to 2005

These phosphate concentrations are above the acceptable level RWQO concentrations for phosphate set for the Blesbokspruit and the Vaal River (0.25 mg/l). The current concentrations while not yet posing a threat to the Vaal River require some intervention to ensure concentrations are managed to the acceptable RWQO concentration levels (0.05 to 0.25 mg/l) to ensure limited threat in the long term. The current situation requires an intervention strategy to manage the the impact of the sewage works in the area, as they appear to have high phosphate levels in their final sewage effluent.

<u>Leeuspruit at Welbedacht (L2-VS5-2)</u>

The Leeuspruit tributary drains into Grootdraai Dam. The nutrient levels in Leeuspruit were found to be high (phosphate- mean 161 μg/ℓ and DIN- 0.525 mg/ℓ) **(Figure 131).** The high nutrients trigger the cyanobacterial (*Microcystis* sp.) bloom observed at the end of May 2006 (**Figure 132**). The turbidity of the water was high, but the cyanobacteria form gas vacuoles and float at the surface thereby overcome the light limitation caused by high suspended solids that restrict light penetration.

However, the continuous inflow of such nutrient rich water into Grootdraai Dam will increase the nutrient levels and increase the probability of algal blooms in the dam over the long-term.

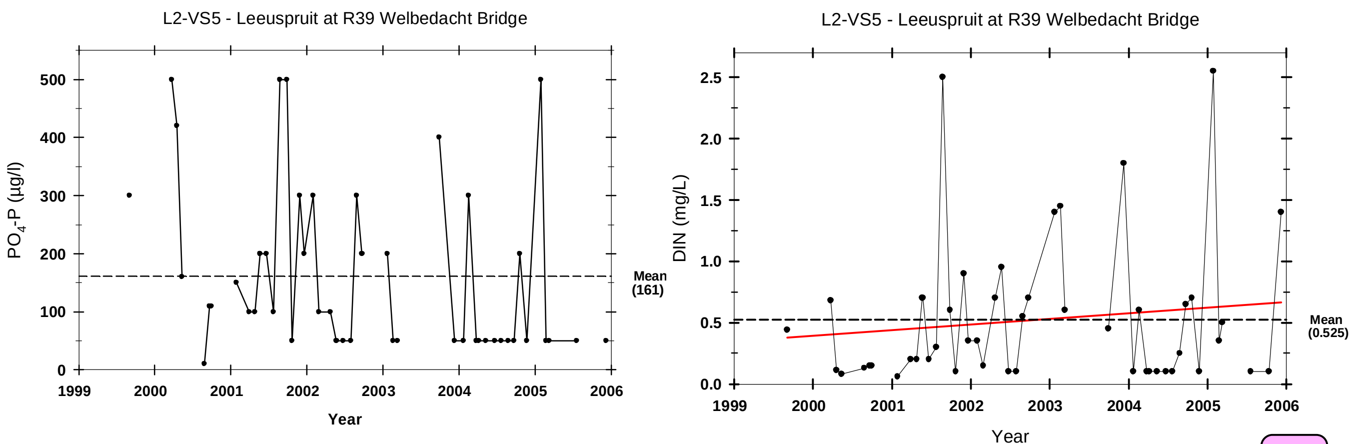


Figure 131: Variation in phosphate and dissolved inorganic nitrogen (DIN) concentrations in Leeuspruit from 1999 to 2005

While these levels of nutrients do not exceed the RWQO level concentrations set for the Leeuspruit, they still need to be monitored to ensure that they do not become a problem. This will include stricter controls being placed on the sewage treatment plants in the area (e.g. Bethal, Tutukani and those at the New Denmark Colliery).

Figure 132: An algal bloom in the Leeuspruit, 29 May 2006

The TDS concentrations in the Leeuspruit were also found to be very high (average 468 mg/l ; EC of 72 mS/m) (**Figure 133**). These concentrations exceed the unacceptable level RWQO levels for the Leeuspruit and Vaal River.

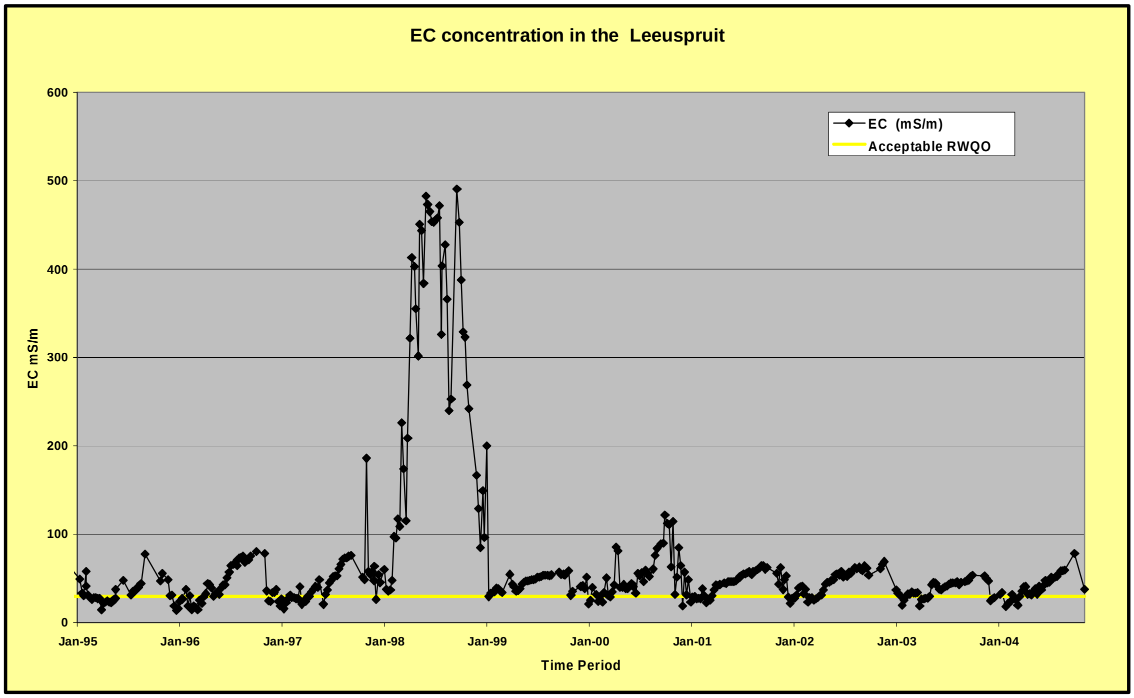


Figure 133: EC concentrations in the Leeuspruit from 1995 to 2004

The impact of the Leeuspruit is not seen in the Vaal River because of the attenuating effect of Grootdraai Dam. However the current status of the tributary requires a localized management strategy. It is probable that the current impacts originate from the collieries and power station in the area as well as from the sewage treatment plants.

Grootdraai Dam is of strategic importance as it supplies water to power stations as well as Sasol, thus the water quality needs to be maintained at an acceptable level. However if the the impact of the Leeuspruit and Blesbokspruit are not managed these tributaries could have long term consequences for Grootdraai Dam, which is currently experiencing some decline in water quality.

6.8.2 Vaal Dam Sub-catchment

The tributaries of the Vaal River in the Vaal Dam sub-catchment include:

- Klip River (Free State)
- Waterval River, and
- Wilge River

The water quality in these tributaries also vary to a great degree, with the Waterval exhibiting the poorest water quality and the other two being of fairly good water quality. The impact of the Waterval River is seen in the Vaal River mainstem at point VS6 (at Villiers). High TDS concentrations and total phosphorus concentrations were observed indicating the impact. However this impact on the Vaal River main stem is diluted by the good quality water from the Wilge and Klip Rivers. The water quality in the Wilge River is influenced by discharges of transferred water from the Thukela River and from the Katse Dam in Lesotho.

Klip River (L2-VS6-1)

No data was available.

Wilge River (L2-VS7-1)

The Wilge River is an important tributary to the Vaal Dam as it transports water transferred from Katse Dam *via* the Lesotho Highlands project and the Thukela River via the Sterkfontein Dam into the Upper Vaal WMA.

The phosphate concentrations in the Wilge River were low (mean, 52 µg/ℓ), however, frequently high concentrations (spikes) possibly indicative of spillages from sewage works upstream (**Figure 134**). These concentrations, with the exception of the high concentrations, are within the RWQOs for phosphate for the sub-catchment and that for the Vaal River.

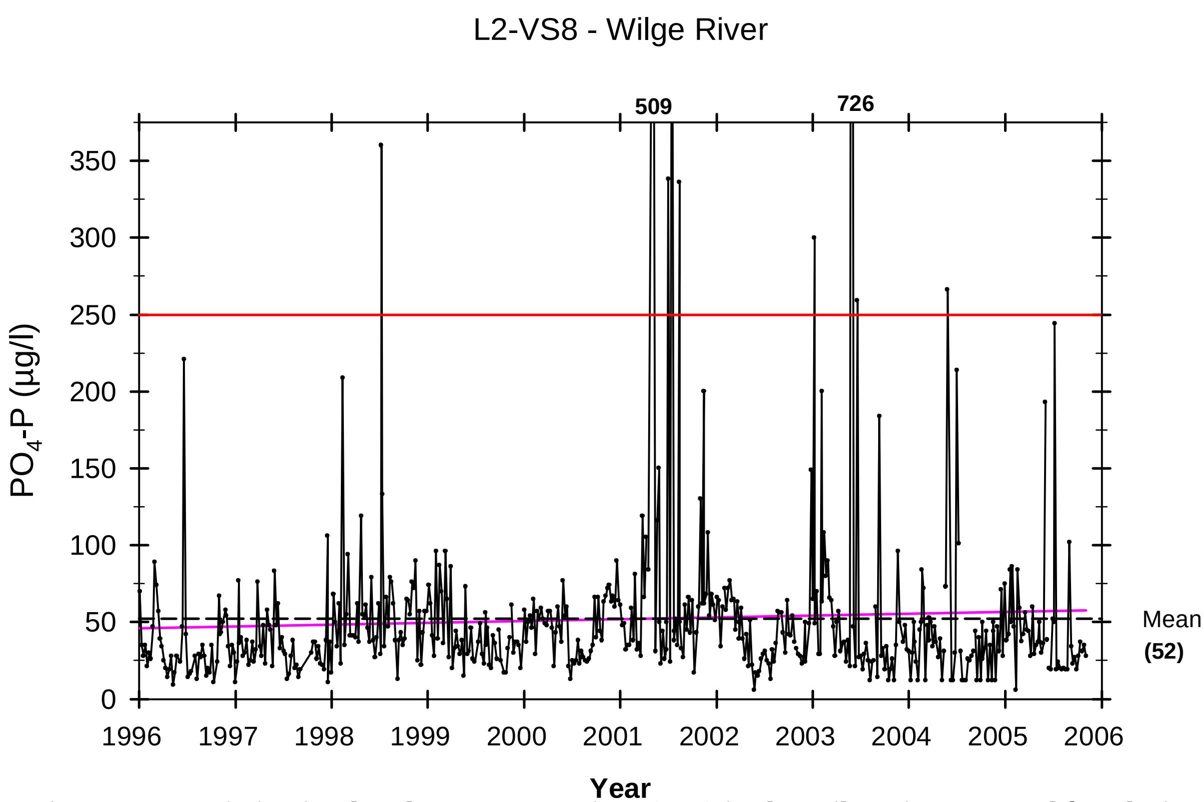


Figure 134: Variation in phosphate concentrations (µg/ℓ) in the Wilge River at Frankfort during the past 10 years. The red line indicates the concentration associated with hypertrophic waters.

The influence of the Lesotho Highlands Water Project is clearly illustrated in the changes in the TDS concentrations. The TDS concentrations in the Wilge River start to decrease significantly from 1998 when the start of the water releases from Katse Dam began (**Figure 135**). A further decrease was observed from 2003, possibly because of three dry years during which the water in the Wilge River was dominated by water from Katse Dam with a low TDS (**Figure 135**). The total drop in TDS concentrations since the start of the water transfer scheme was about 50 %, *i.e.* from an average of 161 to 80 mg/l.

The current TDS status of the Wilge River is well within the RWQOs set for the sub-catchment and the Vaal Dam. However as discussed above this situation is as a result of the water releases from Katse Dam.

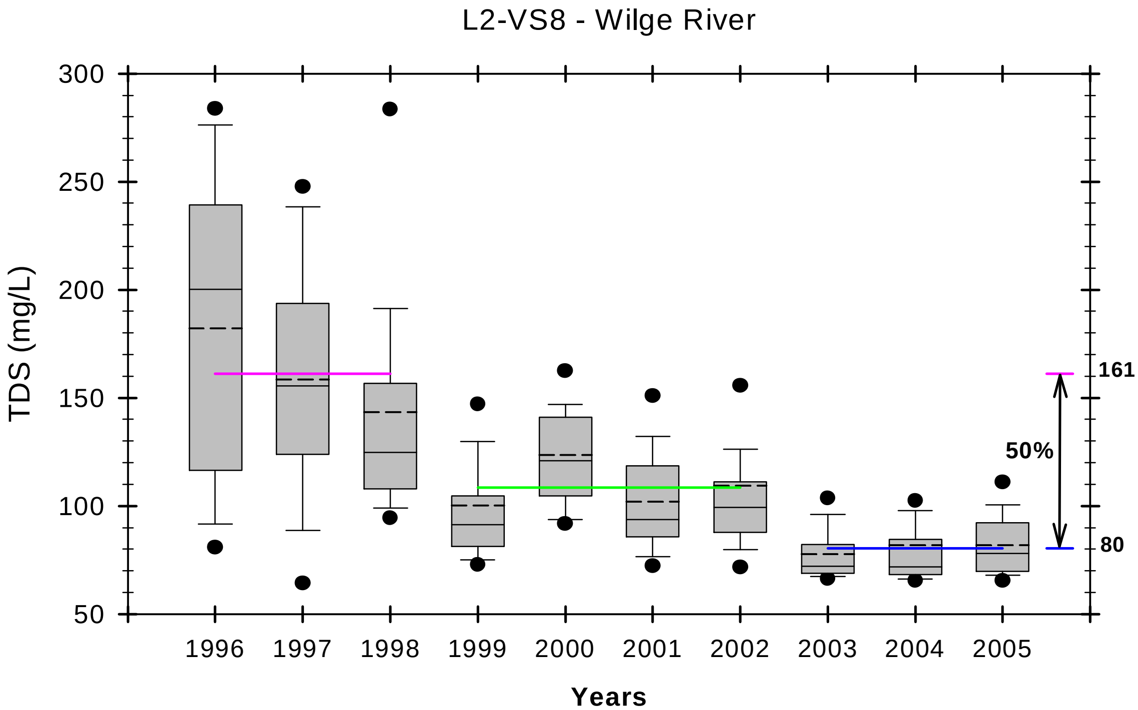


Figure 135: Box and whisker plot of the TDS concentrations (mg/ℓ) in the Wilge River at Frankfort during the last 10 years. The mean TDS concentration decreased by 50 % since the releases from Katse Dam started in 1998

However, it is not only the TDS concentration that decreased, but the seasonal variation almost disappears with the constant water release from Katse Dam (**Figure 136**). The ecological impact of this phenomenon is unknown.

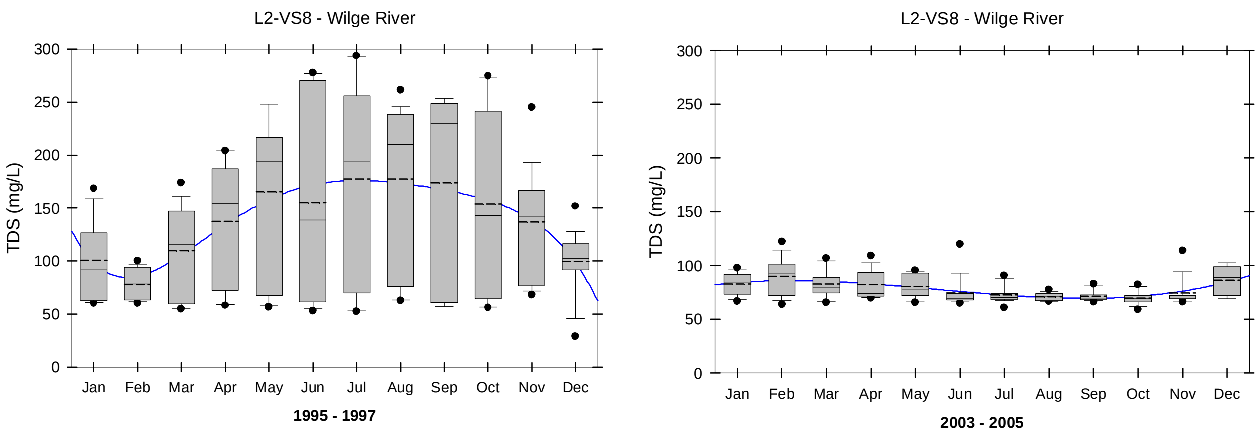


Figure 136: Box plot of the monthly TDS concentrations in the Wilge River at Frankfort before (1995 – 1997) and after (2003 – 2005) water releases from Katse Dam

Waterval River (L2-VS6-2)

The nitrogen and phosphorus concentrations in the Waterval River were high and show an increasing trend (**Figure 137**). The inorganic nitrogen was dominated by ammonium (73 % of DIN), which indicates a high organic load and slow nitrification, which could be because of low dissolved oxygen concentrations. An ammonium concentration of 25.2 mg/ℓ was rejected as an outlier.

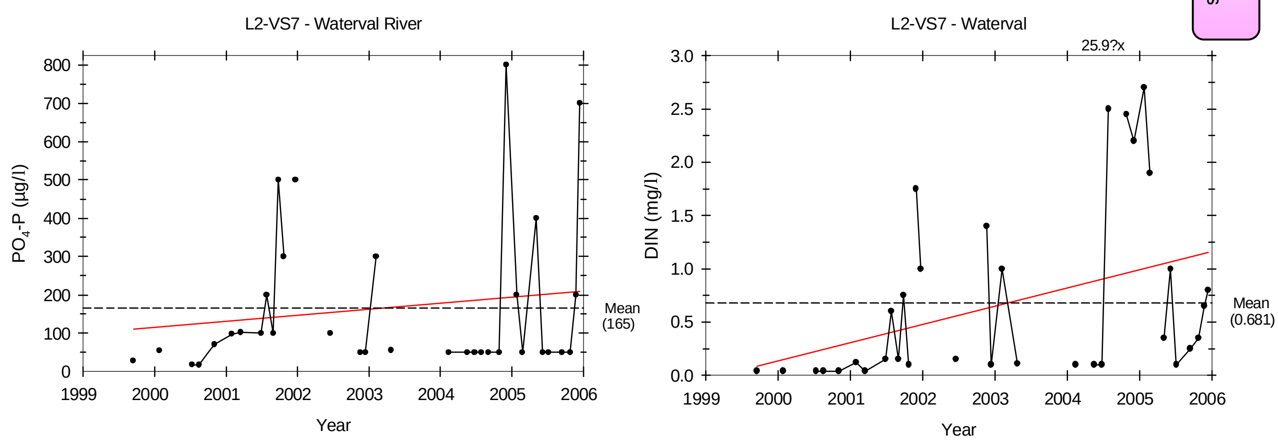


Figure 137: Variation in phosphate concentration (µg/ℓ) and dissolved inorganic nitrogen (DIN) concentrations in Waterval River from 1999 to 2005

The concentrations of nutrients observed are within the limits for RWQOs (tolerable range) for the Waterval sub-catchment, and for the Vaal River. However the situation does create localized impacts in the tributary (**Figure 138**).

Figure 138: Mats of filamentous algae in the Waterval River. Note also the foam that indicates sewage contamination (29/5/2006)

The EC concentrations observed in the Waterval River are high – average of 55 mS/m (approximate TDS concentration of 358 mg/l) when compared to the water quality in the rest of the Vaal Dam catchment. (**Figure 139**). These concentrations exceed the levels observed in the upper part of the WMA in the Grootdraai Dam catchment and thus account for the peak in TDS seen at Level 1 point VS6 (at Villiers). This observation indicates that the Waterval River is impacting on the Vaal River. The situation is not surprising as the Waterval catchment is highly industrialized, being home to the Sasol Two and Three complexes, Evander Gold Mine, Sasol mining as the major impactors, as well as the Evander and Secunda towns. These areas are the pollution sources that could be resulting in the situation being observed in the Waterval River. In this case as well, if the situation is not managed, the consequences could be felt in the Vaal Dam over the long term.

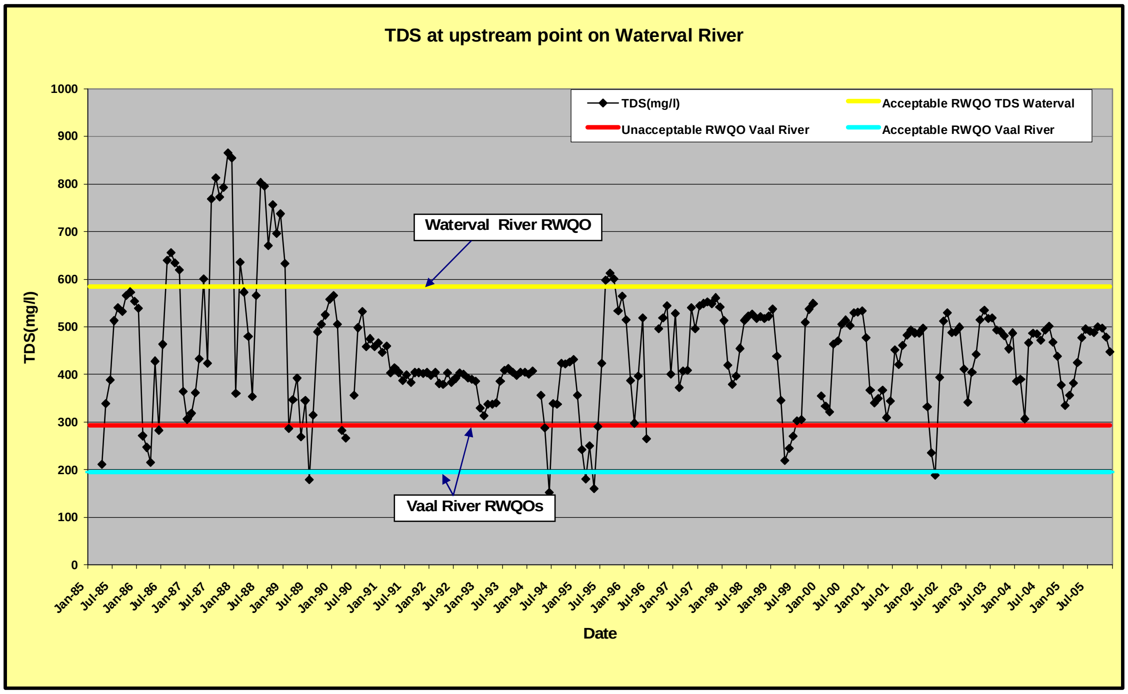


Figure 139: EC concentrations observed in Waterval River between 1998 and 2005

A further issue with respect to this tributary is the non-alignment between the RWQOs of the sub-catchment and that of the Vaal River as seen in **Figure 139**. The RWQOs for the Waterval River are less stringent which accommodates the needs of the users in the catchment, however they need to be integrated with those of the Vaal River to ensure the needs of downstream users in the Vaal System are also met. Is it unsustainable to rely on the water quality from the rest of the Vaal Dam catchment to ameriolate this situation.

6.8.3 Vaal Barrage Sub-catchment

The tributaries in the Vaal Barrage sub-catchment include the:

- Suikerbosrant River
- Klip River
- Taaibosspruit
- Rietspruit
- Leeuspruit, and
- Kromelmboogspruit.

The Vaal River is impacted upon to a great degree by the major tributaries in the sub-catchment. This is reflected in the significant increase in the TDS concentration at point VS8 from VS7 observed in the Vaal River main stem. Some of the tributaries are heavily impacting on the Vaal Barrage as they carry large pollution loads from the heavily urbanised and industrialised areas in the PWV area. The Suikerbossrant, Klip and Rietspruit are the major sources of impact with the Taaibosspruit and Leeuspruit carrying some pollution. The Kromelmboogspruit do not appear to have a significant impact.

Suikerbosrant River (L2-VS8-1)

The Suikerbosrant and its major tributary the Blesbokspruit drain the East Rand area of Johannesburg. The Suikerbosrant River was found to carry a high nitrogen (nitrates and ammonium) load (**Figure 140**). The mean DIN concentration for the last four years was 0.990 mg/ℓ, which is significantly higher than the previous five years. This sudden increase is possibly associated with increased sewage flows, of poorer quality.

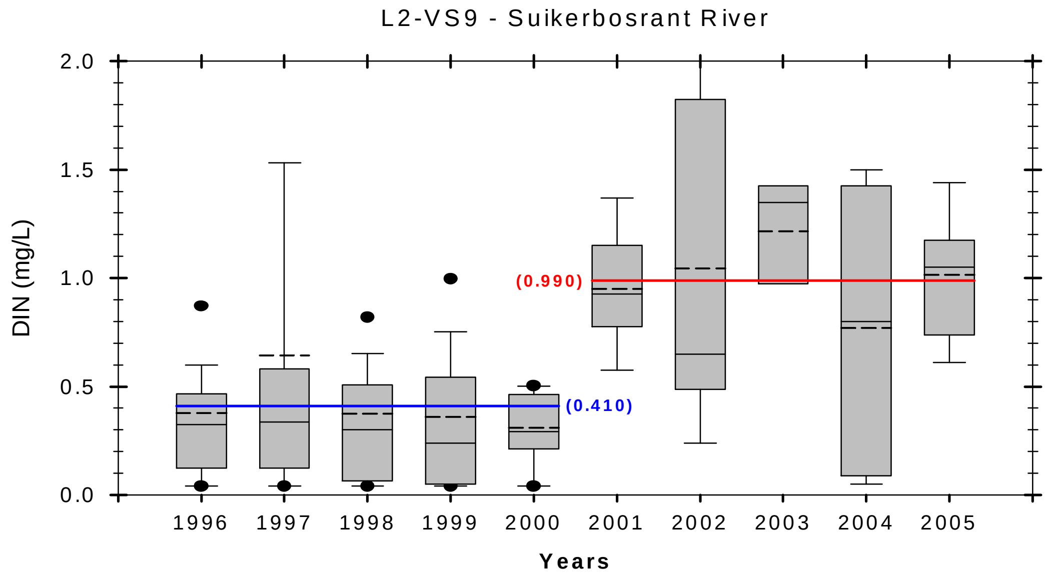


Figure 140: Box plot of DIN concentrations in Suikerbosrant River during the last 10 years

However, the phosphate concentration in this tributary was found to be relatively low, with a mean 91 µg/ℓ.

The comparison of the current concentrations of nitrogen and phosphate in the tributary to the applicable RWQOs for the sub-catchment show that they comply, however if these concentrations are compared to the RWQOs for the Vaal River they are found to be in the unacceptable level concentration range, indicating non-compliance.

The dissolved salts in the Suikerbosrant River were also found to be extremely high (mean of 1055 mg/ℓ; **Figure 141**). The TDS concentrations were also found to exhibit a cyclical seasonal pattern (**Figure 142**), with concentrations peaking during the dry winter months when flows are low.

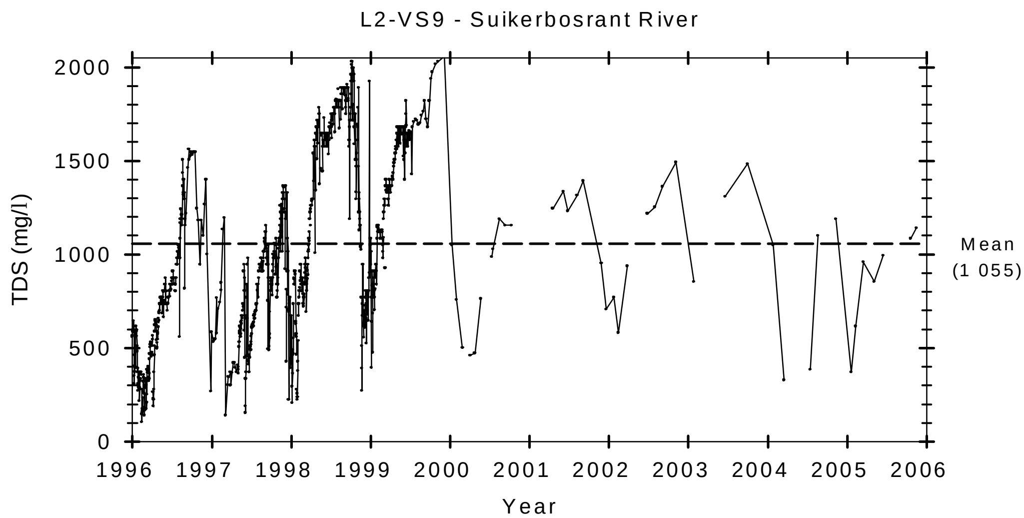


Figure 141: Variation in TDS concentrations (mg/ℓ) in Suikerbosrant River during the last 10 years

The extremely high TDS concentrations do not comply with the RWQOs of the sub-catchment nor to those of the Vaal River. The major sources of pollution in the sub-catchment include a number of sewage works and industries and mines, with the mine water effluent currently being discharged from Grootvlei Mine being a major contributor (75 Ml/day). However the large amount of sewage effluent that originates in the sub-catchment is also a key contributor. The impacts from this tributary are being felt by the Vaal Barrage as well as by downstrean users. This tributary catchment requires an intervention strategy if the situation in the Vaal Barrage is to be alleviated.

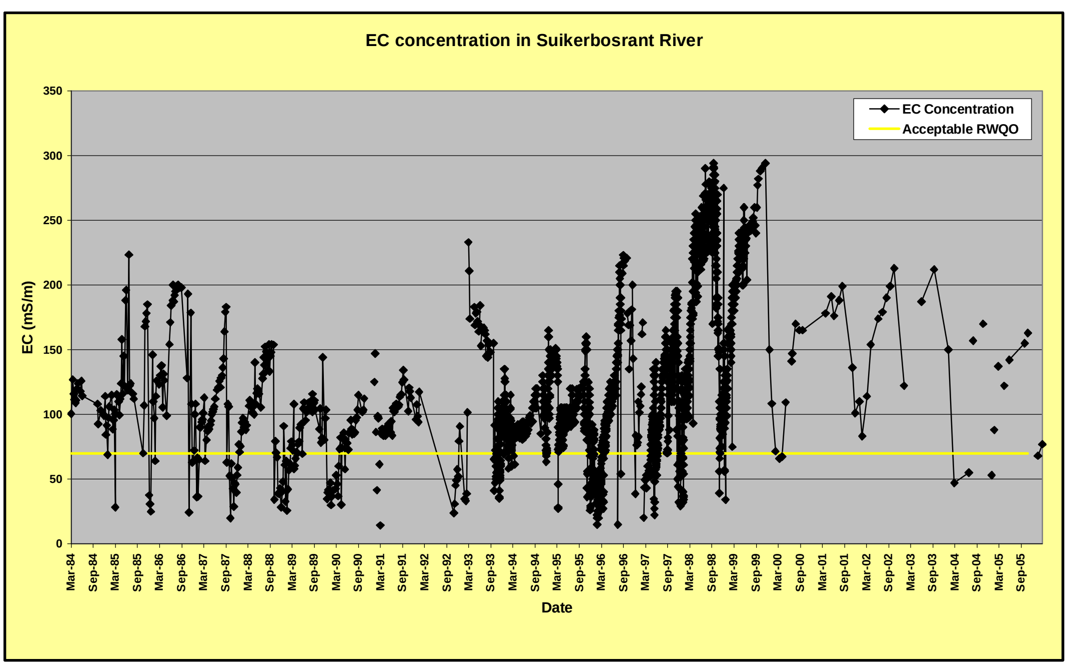


Figure 142: Time series plot of the EC concentrations in the Suikerbosrant its high salt concentrations

Klip River (L2-VS8-2)

The Klip River drains the Greater Johannesburg region, which includes some heavily urbanised and industrialised areas (including Soweto, Lenasia, Eldorado Park, Germiston, Boksburg). The water quality in the Klip River is very poor, *i.e.* high dissolved salts (mean of 546 mg/ℓ) (especially high sulphates, mean of 167 mg/ℓ), and very high nutrients. The nitrate and ammonium concentrations (DIN) in the Klip River were exceptionally high (mean of 4.12 mg/ℓ). These high nutrient levels can be considered to contribute significantly to the nutrient enrichment of the Vaal River (**Figure 143**) experienced at Vaal Barrage.

The overall phosphate concentration in the Klip River was also very high (738 µg/ℓ), however, the average for the last two years was lower (mean, 480 µg/ℓ), but still unacceptably high (**Figure 144**).

Here again while the above concentrations of nutrient water quality variables comply to RWQOs set for the Klip River sub-catchment, they do meet the more stringent requirements set for the Vaal Barrage, which seems to typical for this sub-catchment.

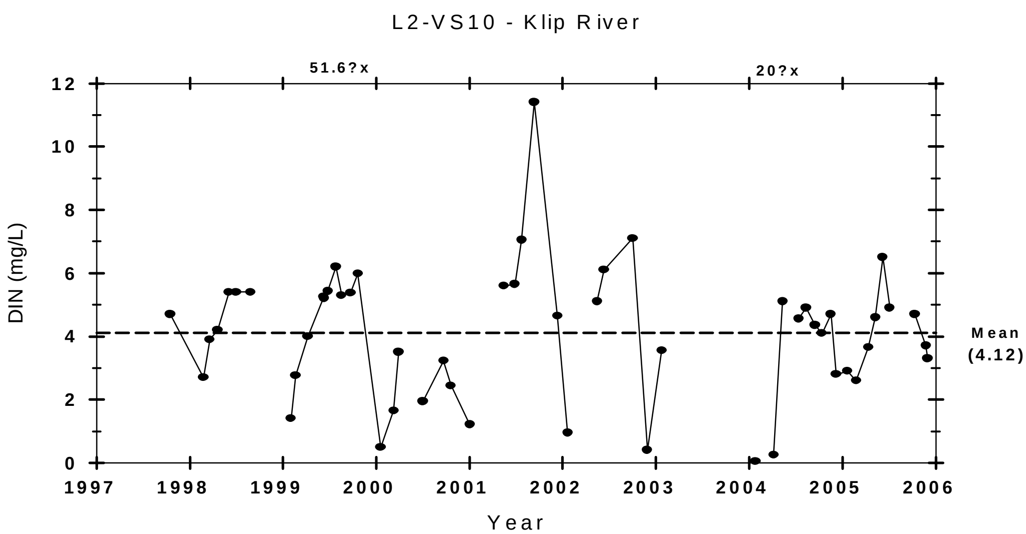


Figure 143: Variation in dissolved inorganic nitrogen (DIN) concentrations in Klip River from 1997 to 2005

WATER QUALITY STATUS: Level 2 Points: Tributaries

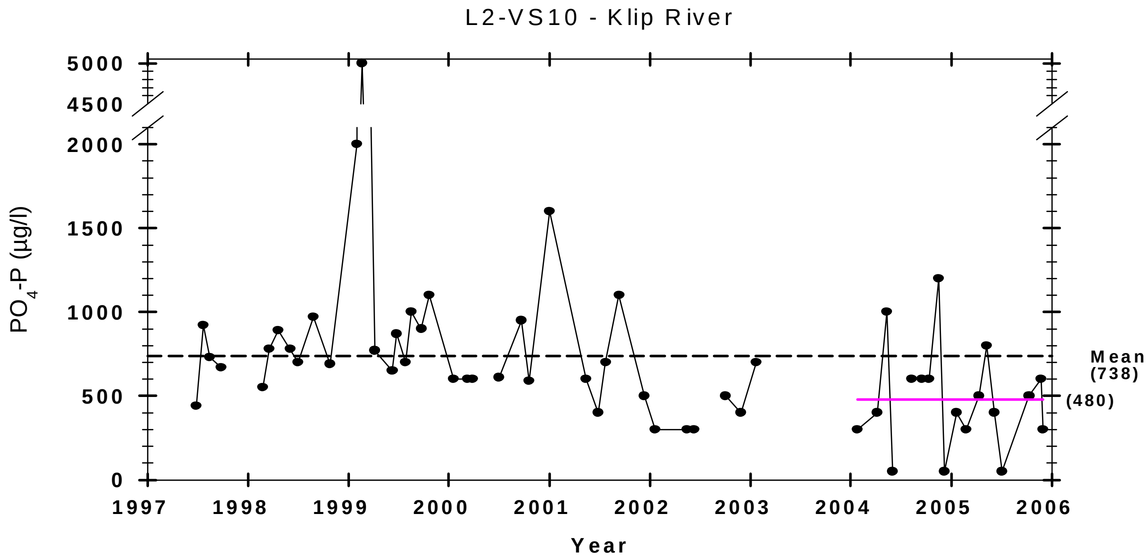


Figure 144: Variation in phosphate concentrations in the Klip River from 1997 to 2005

A similar situation is observed with respect to TDS, with average concentrations of 550 mg/l being observed (**Figure 145**). As for the nutrients, these TDS concentrations meet the RWQOs requirements for the tributary but not for the Vaal Barrage (**Figure 145**).

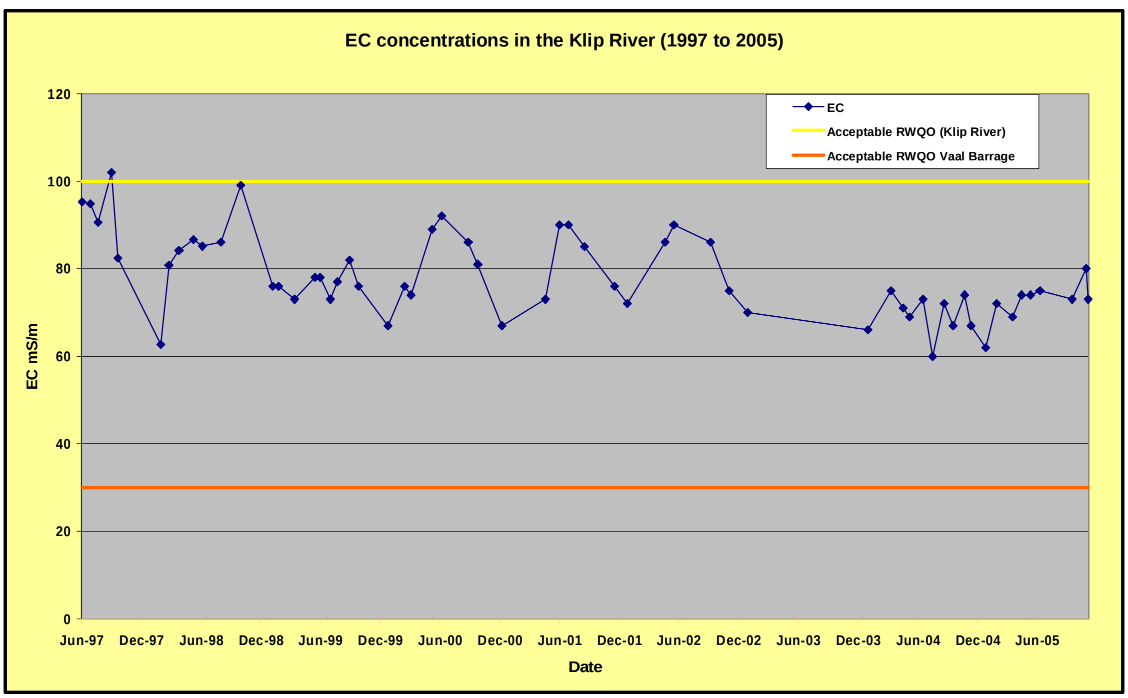


Figure 145: Time series plot of EC concentrations in observed in the Klip River

Taaibosspruit (L2-VS8-3)

The Taaibosspruit tributary drains the Sasolburg industrial complex and the surrounding areas. The TDS concentrations for this tributary were also found to be fairly high (average of 299 mg/ℓ; EC of 46 mS/m) (**Figure 146**). These concentrations are attributable to specific pollutions sources in the catchment related to the industrial activity in the area. The concentrations of sulphate and chloride mirror the patterns observed in TDS. However these concentrations are still within the acceptable level RWQO concentration for TDS for the tributary catchment, and within the tolerable range for the Vaal River at Vaal Barrage.

The phosphate concentrations in the tributary were found to be fairly high (average levels of 0.53 mg/l) (**Figure 147**) which indicates pollution sources from the upstream part of the catchment. It is apparent that phosphate is a problematic pollutant in the tributary catchment, which could be attributed to sewage pollution from inadequate operation of sewage treatment works, sanitation systems as well as from urban and industrial runoff.

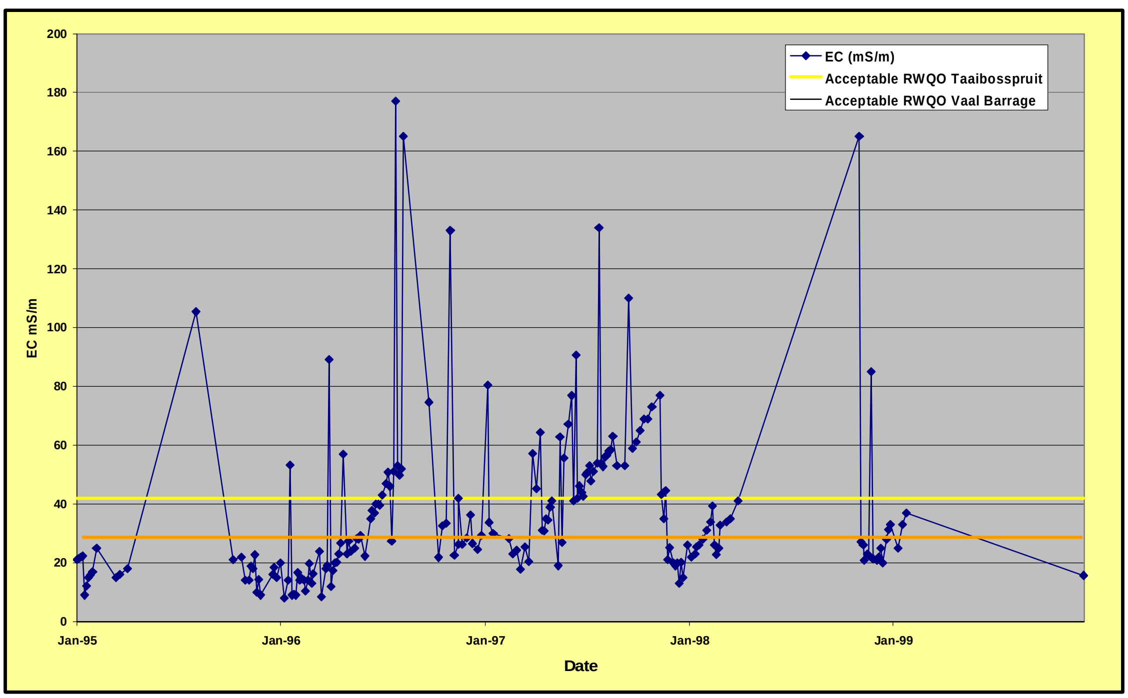


Figure 146: EC concentrations observed in the Taaibosspruit between 1995 and 2000

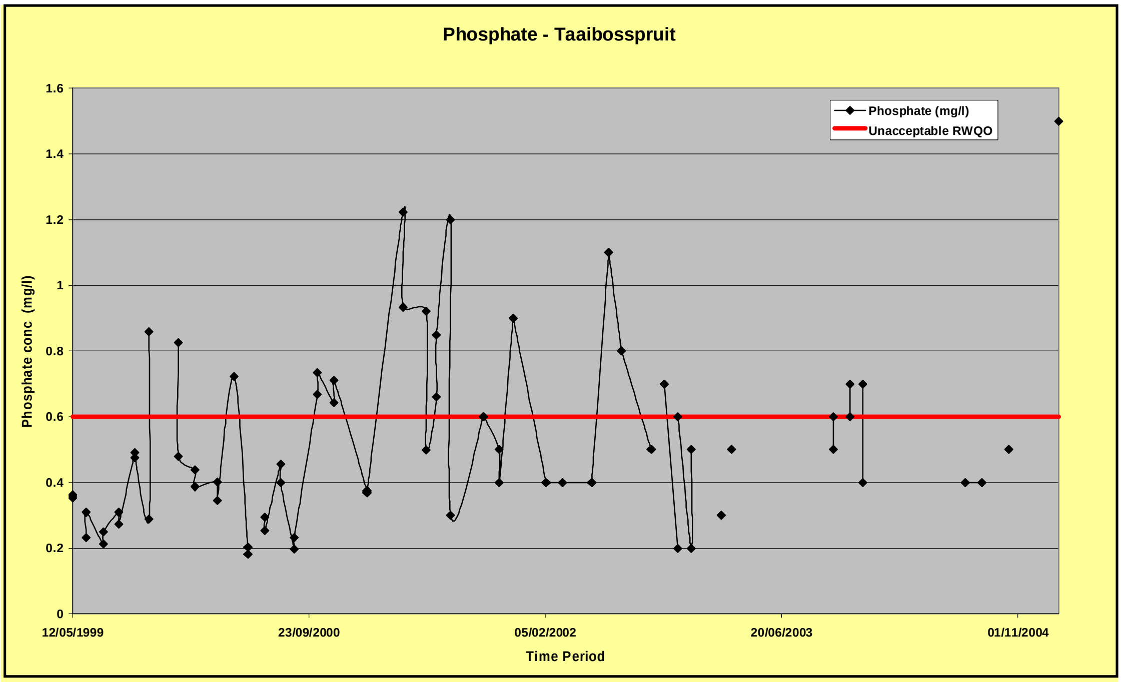


Figure 147: Phosphate concentrations observed in the Taaibosspruit between 1999 and 2004

<u>Leeuspruit (L2-VS8-4)</u>

The nutrients in Leeuspruit were generally high (phosphate mean, 234 µg/ℓ; DIN mean 0.661 mg/ℓ) (**Figure 148**). The TDS concentrations were also high (average of 429 mg/ℓ; EC of 66 mS/m).These impacts could largely be attributable to the Sasol One complex located in the sub-catchment. However, the load from the Leeuspruit is low compared to the Vaal Baarage and has a relatively small impact on the Vaal Barrage (**Figure 149**).

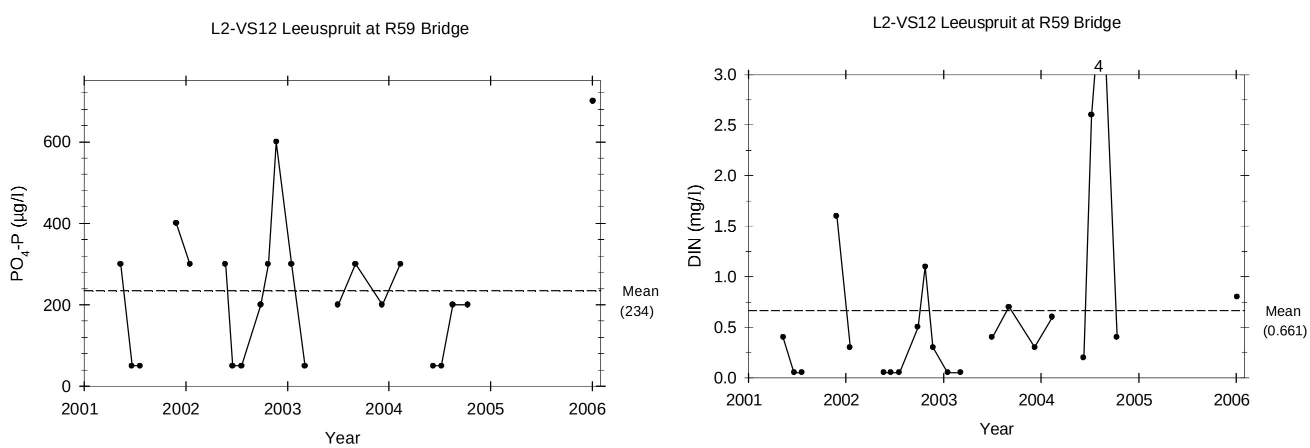


Figure 148: Variation in phosphate concentration (µg/ℓ) and dissolved inorganic nitrogen (DIN) concentrations in Leeuspruit from 2001 to 2005

Figure 149: Leeuspruit drains from Sasolburg

Rietspruit (L2-VS8-5)

The water quality of Rietspruit is very poor and falls in the hypertrophic range. The dissolved nitrogen concentrations were exceptionally high (highest in the Vaal River system; mean, 7.35 mg/ℓ). The phosphate concentrations were also generally high and are still increasing, especially during 2004 and 2005, which is a matter of concern for the Vaal Barrage eutrophication levels (**Figure 150**).

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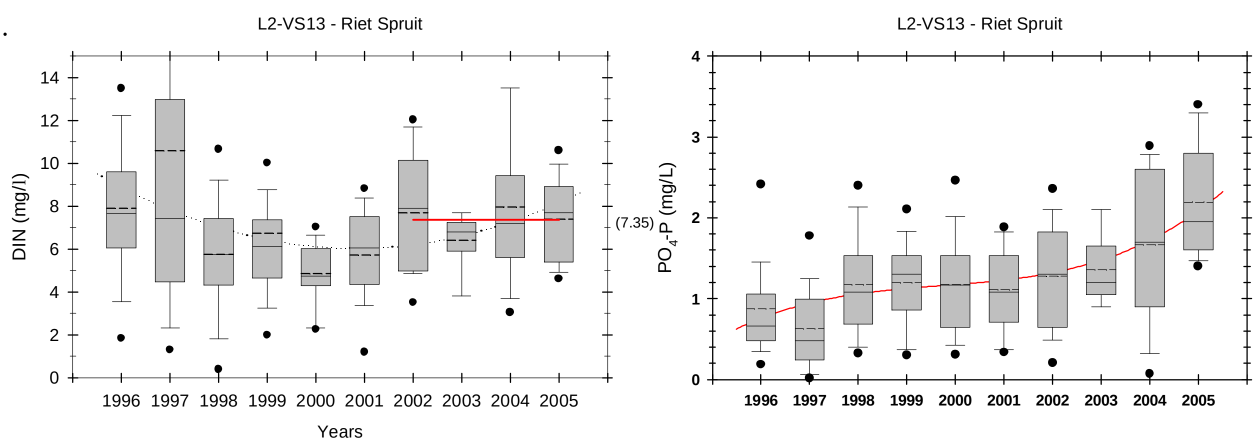


Figure 150: Box plot of the dissolved inorganic nitrogen and phosphate concentrations in Rietspruit (1996 – 2005)

The high nutrient concentrations stimulate algal growth – see the brown biofilm scum on rocks (**Figure 151**).

Figure 151: Algal biofilms in Rietspruit (30/5/2006)

The average dissolved salts concentration in Riet Spruit was high (625 mg/ℓ), but the concentrations seems to decrease during the last five years (**Figure 152**). Seasonal cyclical patterns are observed with respect to these concentrations, with higher dissolved salts observed during the winter months when rainfall is low (**Figure 153**).

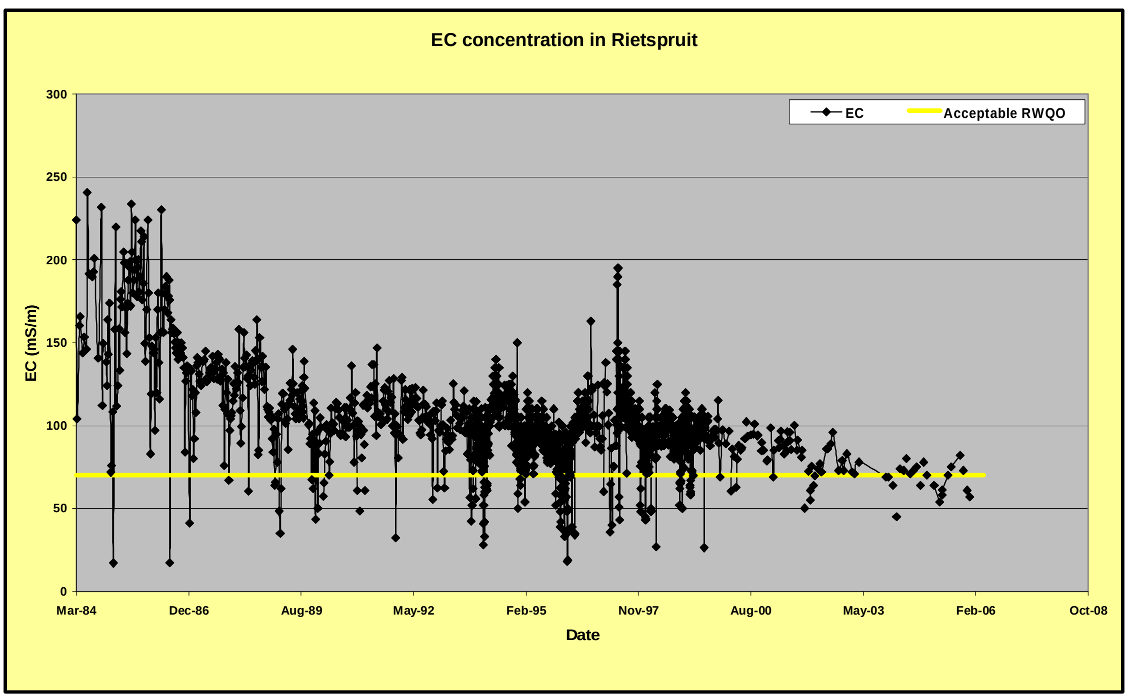


Figure 152: EC concentrations observed in the Rietspruit between 1984 and 2006

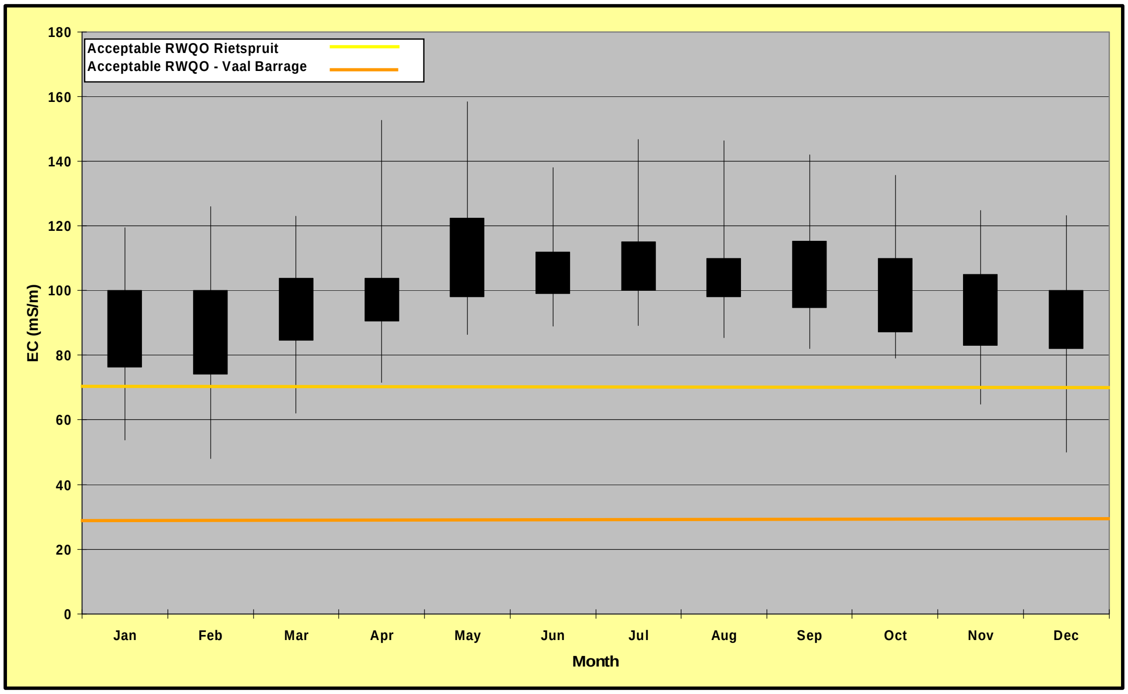


Figure 153: Box and whisker plot of the EC concentrations in the Rietspruit depicting the seasonal cyclical pattern

The concentrations of the nutrients and dissolved salts observed in the Rietspruit either exceed the RWQOs or border on the unacceptable level concentrations for the Rietspruit, and thus can be considered to be issues of concern for the tributary catchment. However these concentrations exceed the RWQOs set for the Vaal Barrage and thus the Rietspruit is contributing to the poor water quality situation observed at the Vaal Barrage.

Kromelmboogspruit (L2-VS8-6)

Current data is insufficient to make any useful conclusions.

6.8.4 Downstream Vaal Barrage Sub-catchment

The Mooi River is the only major tributary in this sub-catchment.

The assessment indicates that the Mooi River is a possible contributing tributary to the deteriorating water quality in the Vaal River downstream of Vaal Barrage. The Mooi river sub-catchment land use is heavily impacted by extensive mining activity and urbanized areas (Far West Rand Basin and numerous sewage treatment plants). These activities cumulatively discharge large quantities of mine water and sewage effluent that eventually drain into the Vaal River.

Mooi River (L2-VS9-1)

The N:P ratios in Mooi River are extremely low (mean DIN:DIP, 1.3; mean TN:TP, 1.4) because of a very high phosphorus concentrations (895 µg/ℓ). The nitrogen concentrations were relative low (mean, 0.854 mg/ℓ) and fluctuate significantly (**Figure 154**). The situation allows for algal growth which could become a problem for the tributary (**Figure 155**).

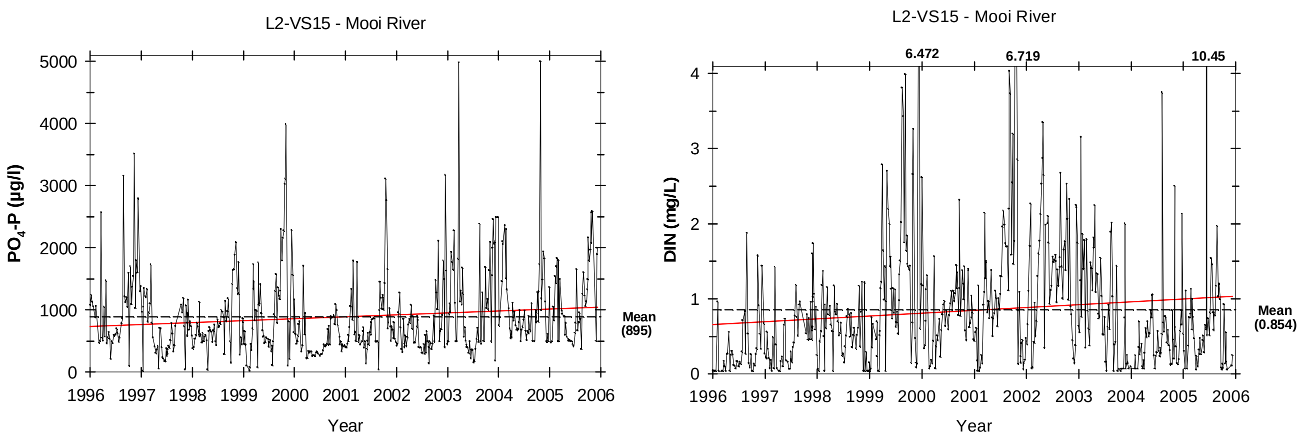


Figure 154: Variation in phosphate and dissolved inorganic nitrogen concentrations in the Mooi River from 1996 to 2005

Figure 155: The flow in the Mooi River was high, the water was clear, but because of the high nutrients algal growth on substrates was excessive and negatively influence habitat for macro-invertebrates (2/6/2006).

In terms of dissolved salts, TDS concentrations were also found to be high (average of 488 mg/l; EC of 75 mS/m) (**Figure 156**). These concentrations were found to exceed the RWQOs for the tributary catchment and the Vaal River (seen at VS 10) which highlights this tributary as a key area requiring attention.

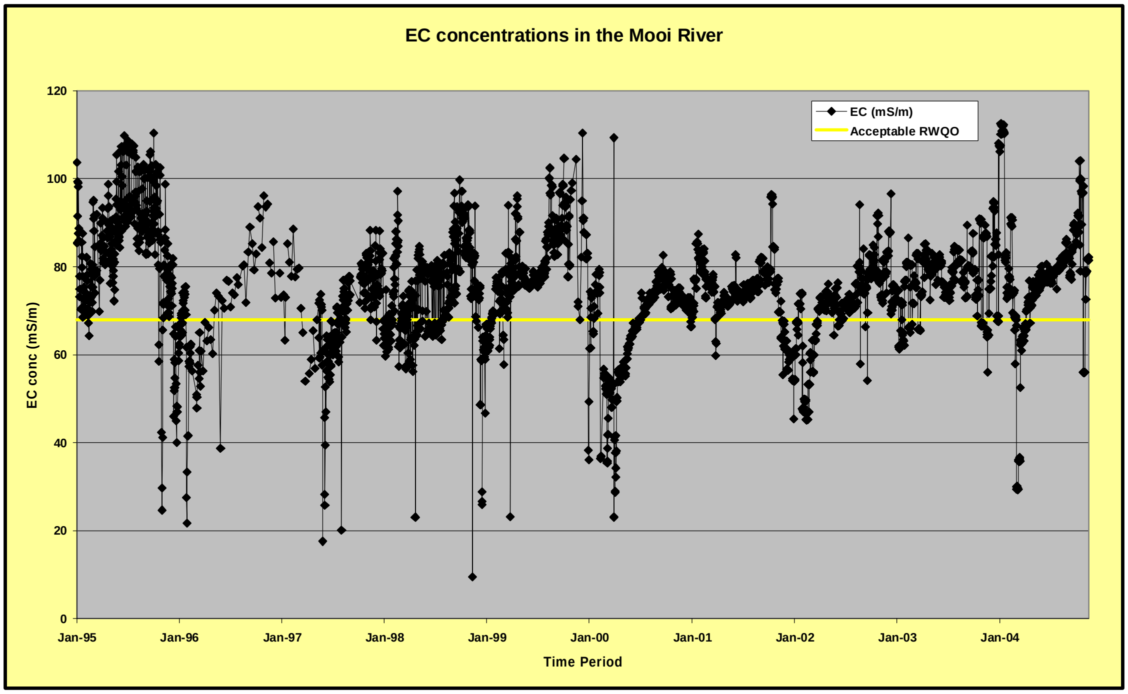


Figure 156: EC concentrations observed in the Mooi River between 1995 and 2005

The sulphate concentrations in the river were found to within the RWQO acceptable concentration level (average of 104 mg/l) (**Figure 157**). This situation is found to be surprising, as one would expect higher concentrations due to the extensive mining that occurs in the upper part of the catchment (large quantities of mine water discharges). The dissolved salts also display seasonal trends with higher concentrations observed during the winter periods when the flows in the river are low. (refer to **Figure 158** and **Figure 159**).

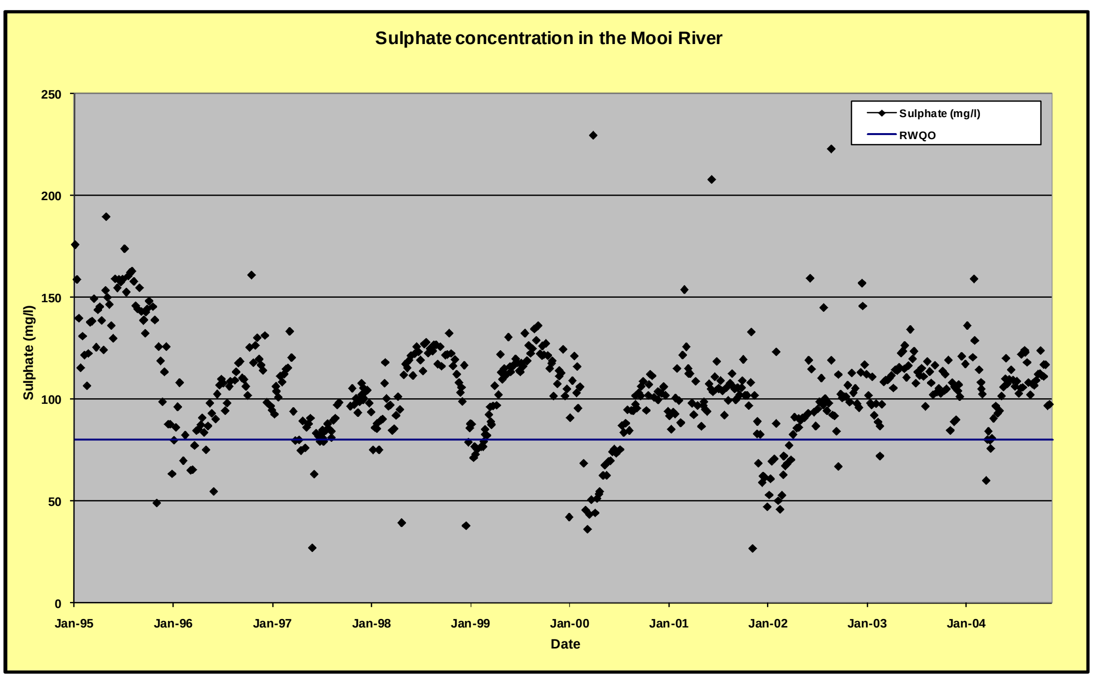


Figure 157: Sulphate concentrations observed in the Mooi River between 1995 and 2005

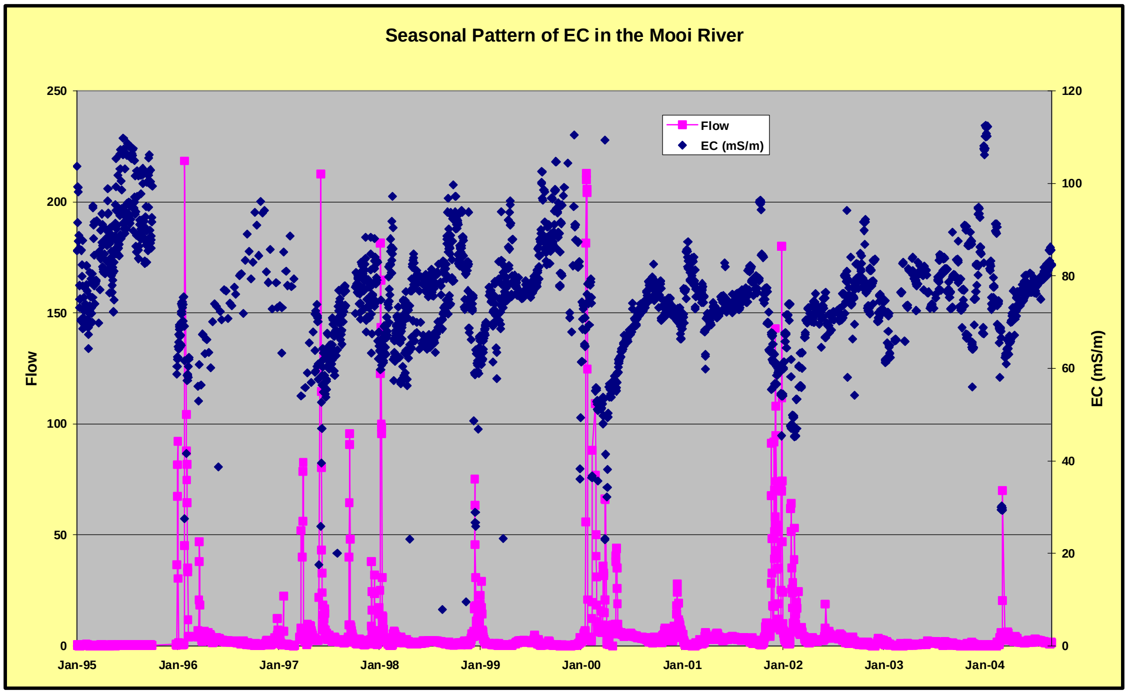


Figure 158: EC concentrations in the Mooi River depicting the seasonal cyclical pattern

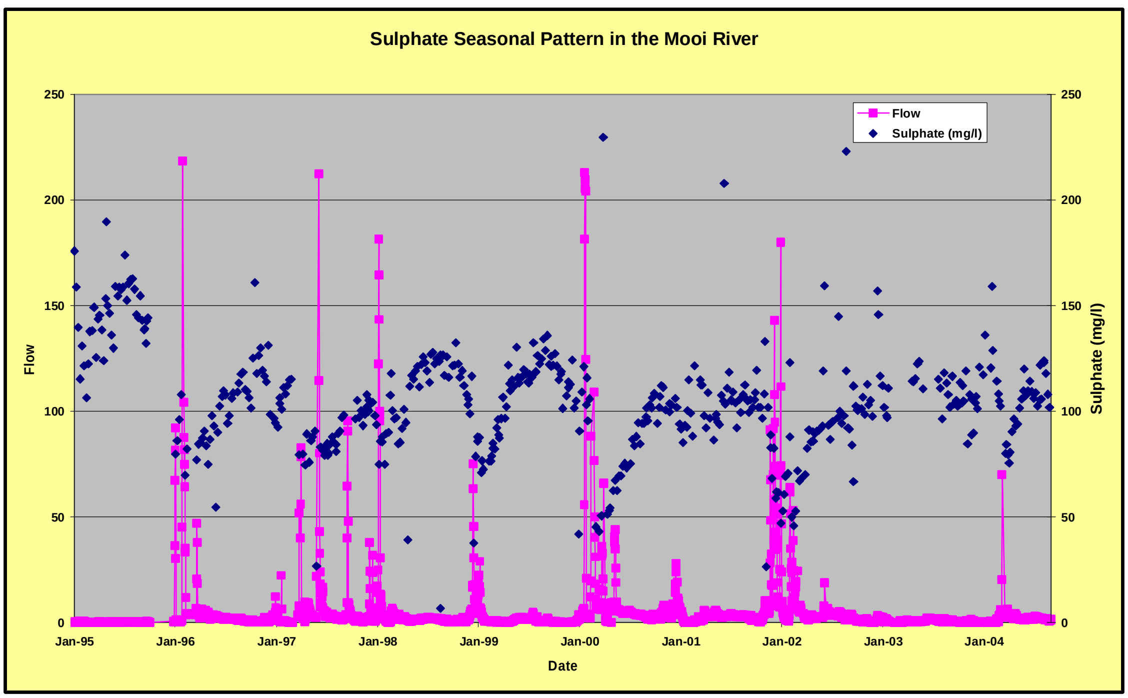


Figure 159: Sulphate concentrations in the Mooi River depicting the seasonal cyclical pattern

6.8.5 Middle Vaal River Sub-catchment

The tributaries of the Middle Vaal River sub-catchment include:

- Renoster
- Koekemoerspruit
- Vierfontein
- Schoonspruit, and
- Vals River

The water quality in these tributaries varies to a great degree, with some having high concentrations and others fairly good water quality. However their collective impact on the Vaal main stem River is felt as the water quality in the Middle Vaal River is of fairly poor quality, exhibiting salinity and eutrophication problems. Bloemhof Dam alleviates this situation by aatenuating the water quality. The tributaries of concern are the Koekemoerspruit, Schoonspruit, Vierfontein and to some extent the Vals River.

The water quality in the tributaries is discussed below.

Renosterspruit (L2-VS10-1)

The nutrient concentrations and dissolved salts in the Renosterspruit were relatively low and indicate fair water quality conditions (**Figure 160**). However, the visual appearance of the spruit was not good and shows poor conditions, *i.e.* milky turbid water and algal growth on the rocks (**Figure 161**).

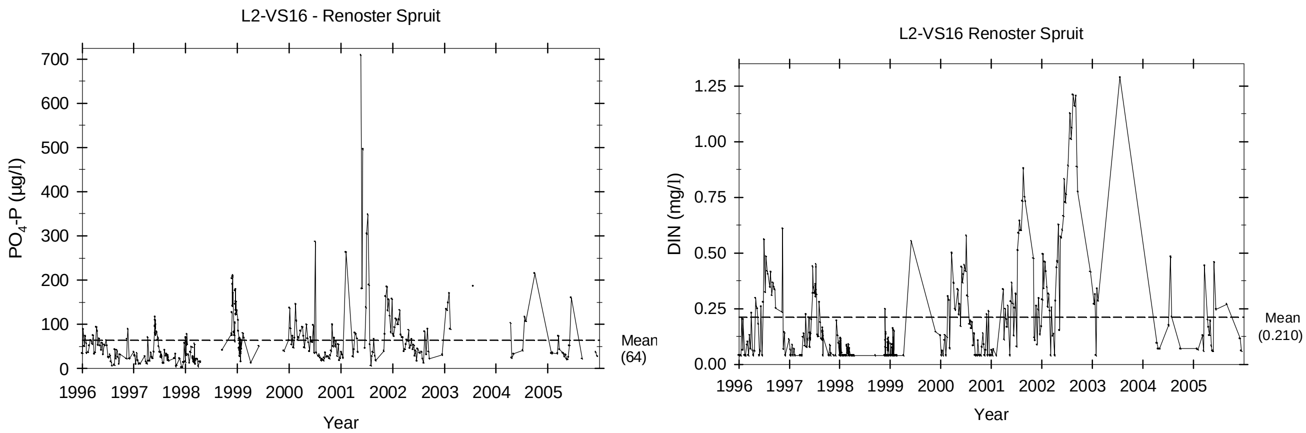


Figure 160: Variation in phosphate and dissolved inorganic nitrogen concentrations in the Renosterspruit from 1996 to 2005

Figure 161: Appearance of the Renosterspruit (milky turbid water)

The average TDS concentration in this tributary was found to be approximately 176 mg/l (EC = 27 mS/m) (**Figure 162**) which indicates fairly good water quality. The dissolved salts also display a seasonal pattern as seen in **Figure 162** . The water quality variables comply with the RWQOs set for the sub-catchment and are within those limits set for the Vaal River. However the RWQOs of the tributary catchment are the 95th percentile values of current status and thus comply, while the RWQOs of the Vaal River were set based on current status and user requirements, and does not include an improved water quality RWQO target concentration.

The Renosterspruit appears to have very limited impact on the Vaal River.

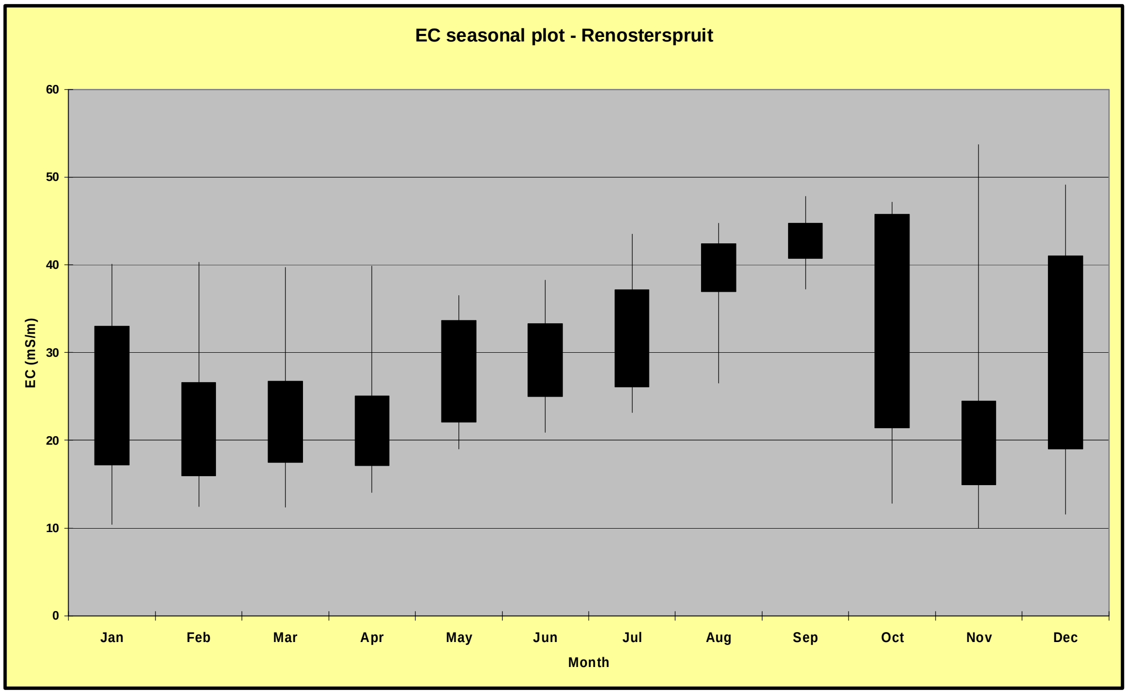


Figure 162: Box plots of EC concentrations in the Renosterspruit depicting the seasonal pattern

<u>Koekemoerspruit (L2-VS11-1)</u>

Koekemoerspruit shows severe signs of eutrophication with extremely high phosphate (mean of 1081 µg/ℓ; **Figure 163**) and nitrogen concentrations (4.11 mg/ℓ; **Figure 164**). The N & P concentrations have increased significantly since 2002 and indicate possible sewage spills and non-compliant sewage effluent discharges. These concentrations exceed the RWQOs set for the tributary and that of the Vaal River. It is apparent that this tributary could be contributing to the eutrophication problem being experienced in the Middle Vaal River.

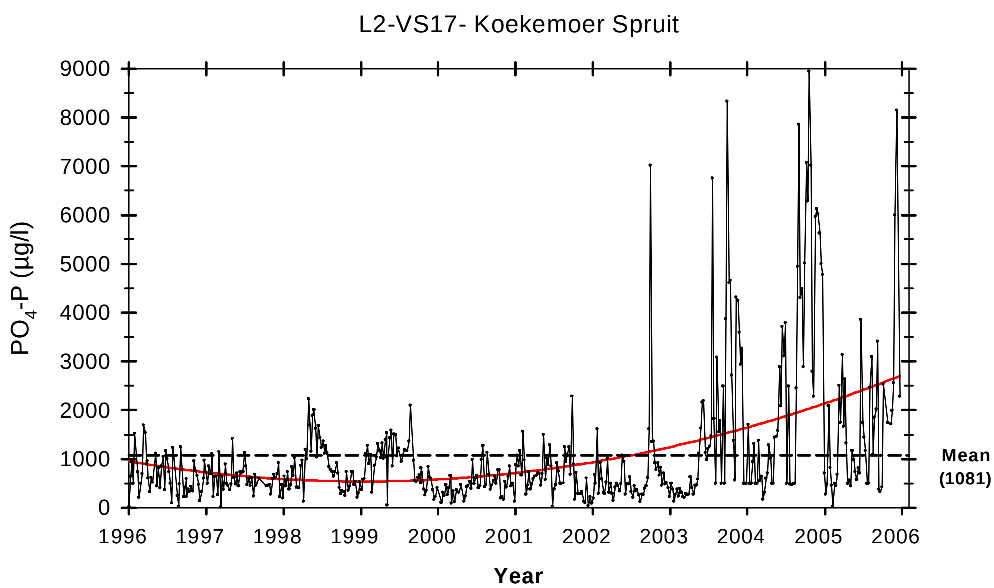


Figure 163: Variation in phosphate concentrations in Koekemoerspruit from 1996 to 2005

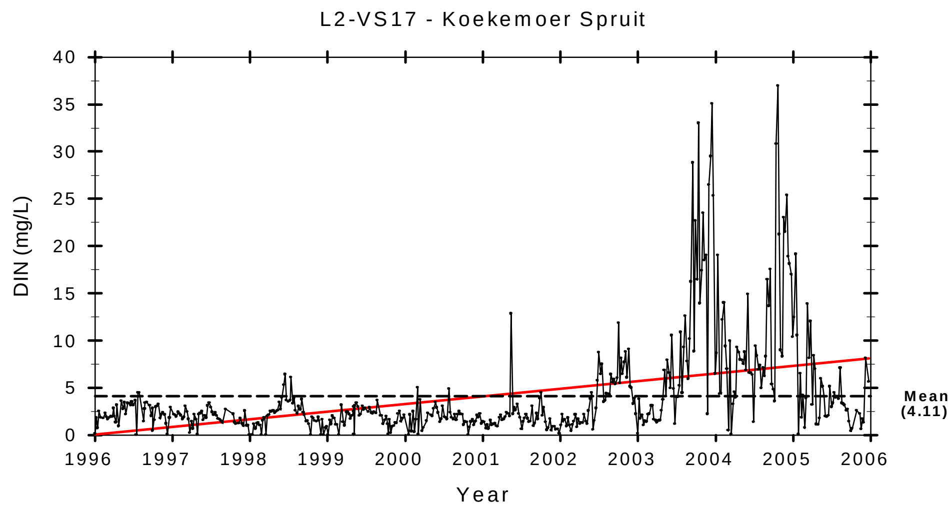


Figure 164: Variation in dissolved inorganic nitrogen concentrations in Koekemoerspruit from 1996 to 2005

The TDS concentrations in Koekemoerspruit were also extremely high and ranged between 31 and 1806 mg/ℓ (mean of 1 213 mg/ℓ). The concentrations exceed the RWQOs set for the catchment and the Vaal River. This situation reflects a cause for concern. These high concentrations of dissolved salts are due to discharges from the mining industry. Currently large quantities of mine water are discharged into the Koekemoerspruit.

It is apparent that the Koekemoerspruit is impacting on the Vaal River as a slight increase in TDS is observed at VS11 after the confluence of this tributary.

Vierfontein (L2-VS12-1)

This is a new monitoring point with only three data points. Unfortunately no phosphate data or dissolved salts data was available for this tributary. However, strong algal growth suggests high phosphate concentrations (**Figure 165** and **Figure 166**).

Figure 165: Algal growth at Vierfonteinspruit (2/6/2006)

Figure 166: Benthic algal growth in Vierfonteinspruit (2/6/2006)

The Vaal River does display a rise in TDS concentration between points VS11 and VS12 which is the reach within which the Vierfontein confluences (the only tributary). It is therefore believed that this tributary could be impacting on the Vaal River.

Schoonspruit (L2-VS13-1)

The N and P concentrations from 1995 to 1999 were extremely high (mean, 3.25 mg/ℓ; 9.57 mg/ℓ repectively). However, the concentrations decreased significantly to lower levels since 2000, but are increasing again (**Figure 167**). The reason for the sudden decrease is unknown.

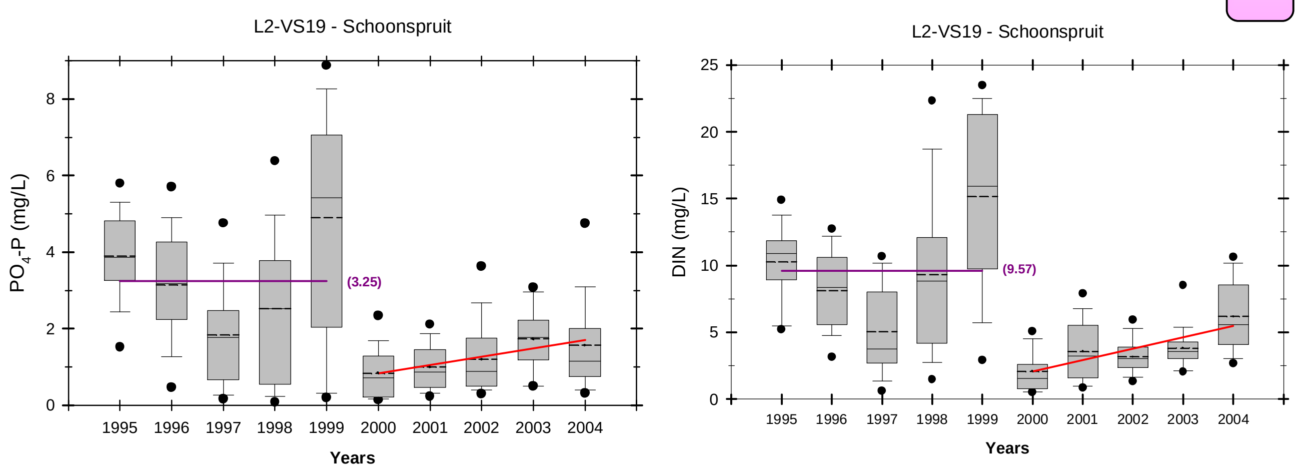


Figure 167: Box plots of phosphate and DIN concentrations in Schoon Spruit from 1995 to 2005

The algal growth observed in the Schoonspruit (**Figure 168**) is indicative of the high nitrogen and phosphate concentrations present.

Figure 168: Benthic algal growth in the Schoonspruit (2/6/2006)

The present concentrations of nitrogen and phosphate exceed the RWQOs for the tributary and that of the Vaal River. This current situation requires a sub-catchment intervention strategy to manage and improve the situation.

The dissolved salts concentrations were also extremely high (mean, 676 mg/ℓ; EC of 104 mS/m) (**Figure 169**).

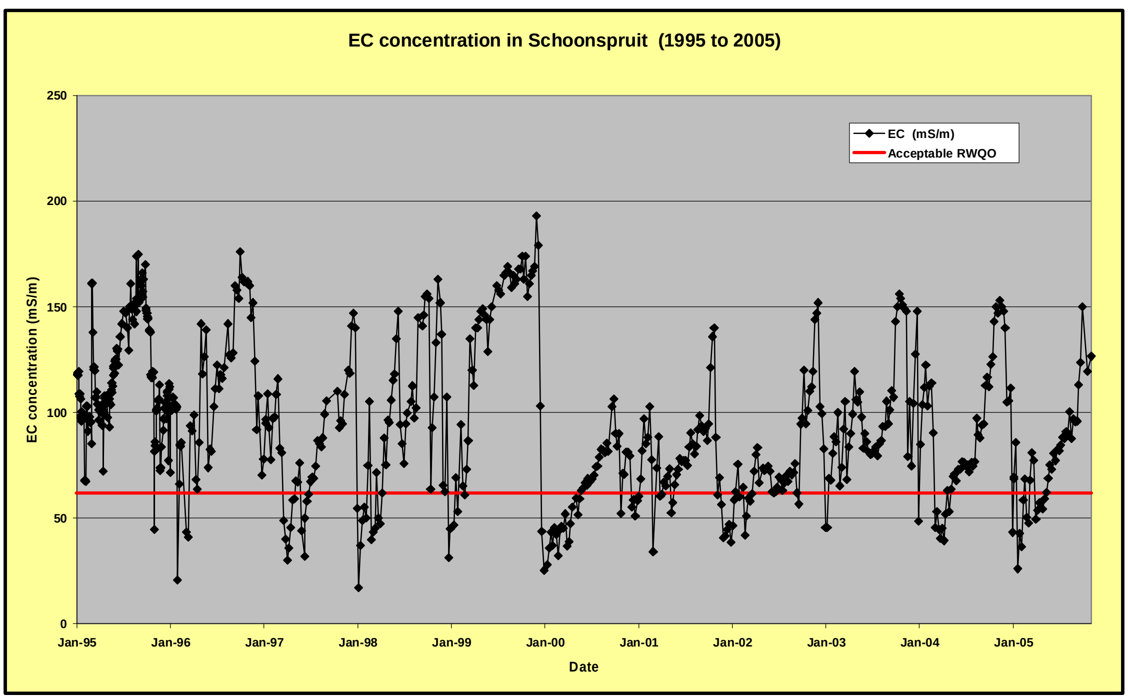


Figure 169: EC concentrations observed in the Schoonspruit between 1995 and 2005

The current TDS concentrations exceed the RWQOs for the Schoonspruit and the RWQOs that apply to the Vaal River. It is evident that these high levels of TDS are impacting on the Vaal main stem, as the high concentrations in TDS are observed in the Middle Vaal River continue to point VS13 (located below the Schoonspruit tributary confluence with the Vaal River). The dissolved salt concentrations are also related to seasonal flow patterns, with peak concentrations occurring during winter periods (**Figure 170** and **Figure 171**).

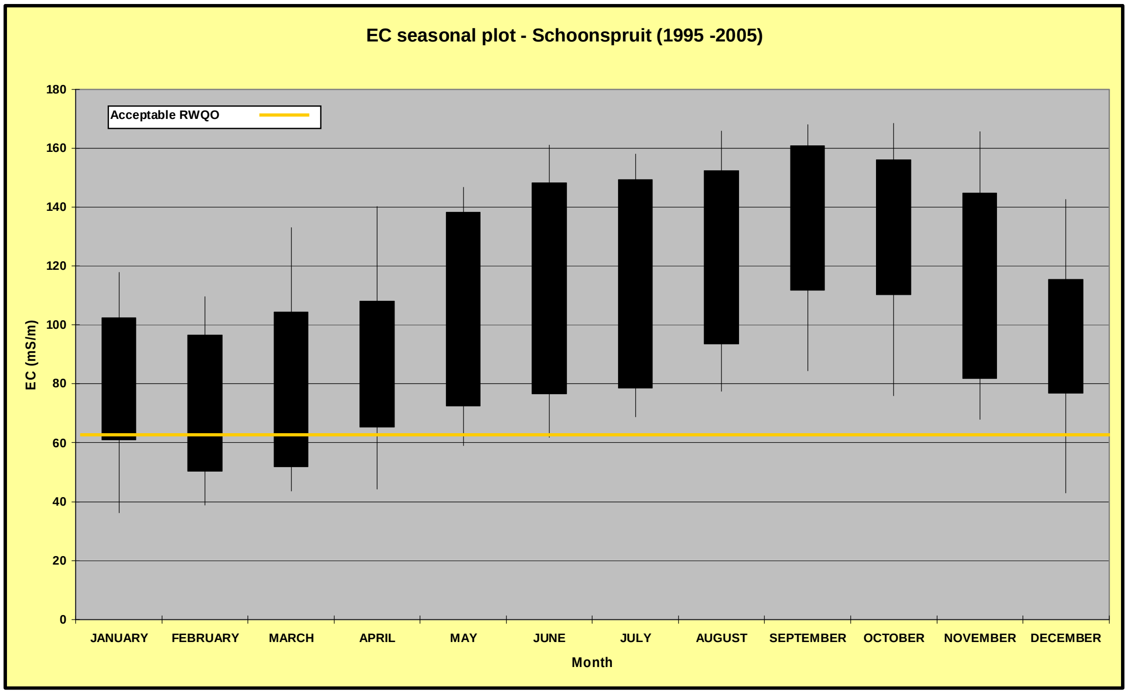


Figure 170: Box plots of EC concentrations in the Schoonspruit depicting a seasonal pattern

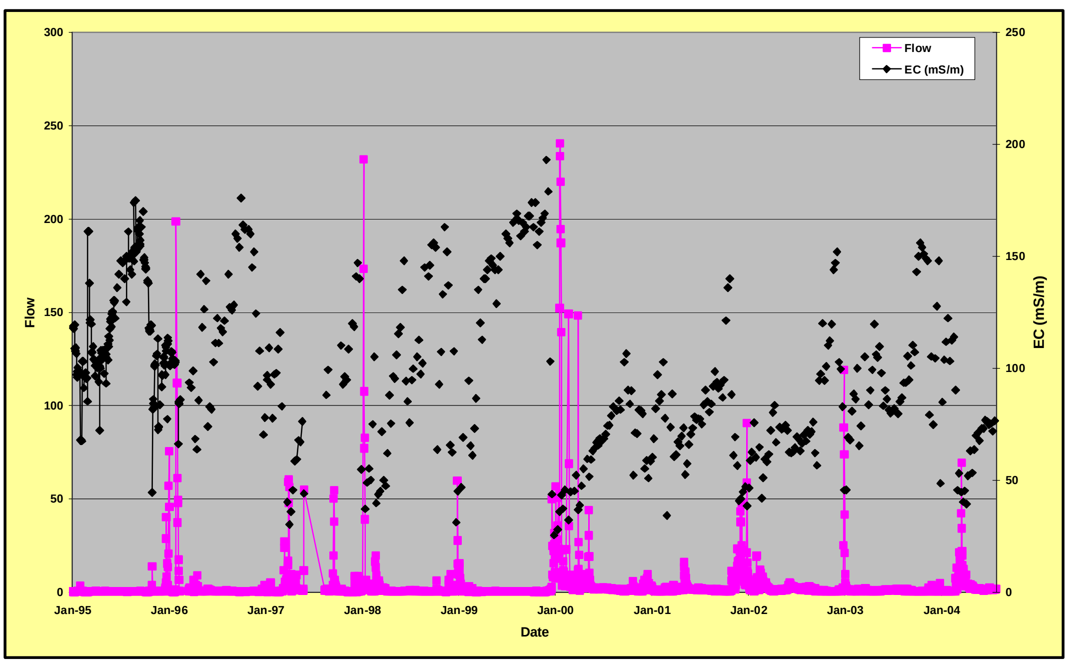


Figure 171: EC concentrations in the Schoonspruit in relation to flow depicting the seasonal pattern

Average concentrations of 168 mg/l for sulphate were observed. Although these levels were within the acceptable level RWQO concentration of the catchment (200mg/l) and that of the Vaal River (250mg/l) it is a fairly high in stream concentration indicative of mining pollution sources in the catchment.

It is apparent the the Schoonspruit tributary does impact on the Middle Vaal River with its high salt loads and nutrient concentrations. This sub-catchment requires a management strategy to deal with these issues and to address the pollution sources, thereby minimizing its contribution to the Vaal River.

Vals River (L2-VS14-1)

The nutrient concentrations (nitrogen and phosphate) in the Vals River are high and show a significant increasing trend during the last two years (**Figure 172 and Figure 173**).

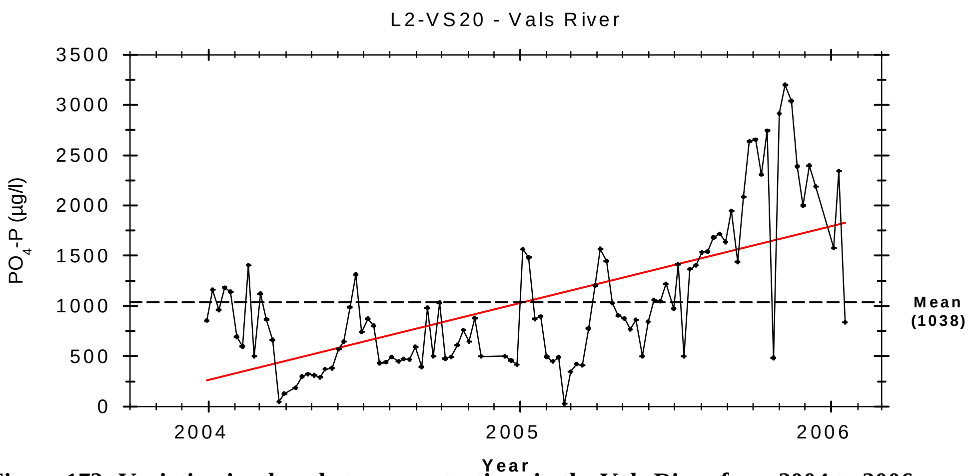


Figure 172: Variation in phosphate concentrations in the Vals River from 2004 to 2006

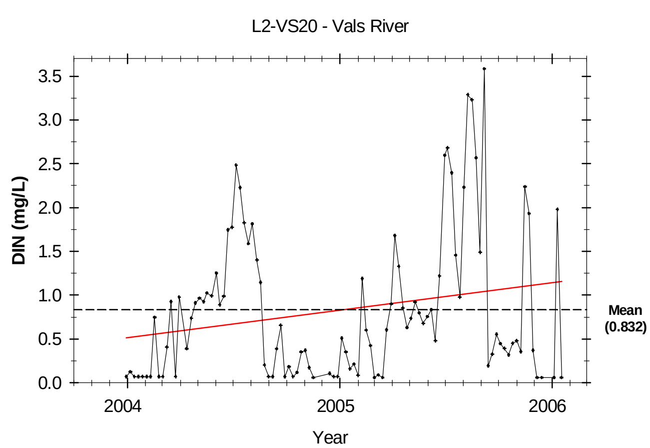


Figure 173: Variation in DIN concentrations in the Vals River from 2004 to 2006

The TDS concentrations in the Vals River are also fairly highly (mean 467 mg/l) and display a seasonal pattern (**Figure 174**). The high concentrations are indicative of pollution sources in the tributary catchment - possibly related to agricultural activities.

While the concentrations observed are high for dissolved salts and nutrients in terms of a water quality perspective they are within the RWQOs for the sub-catchment and the Vaal River. It is evident that the Vals River is impacting on the Vaal River to some extent as water quality observed at point VS14 (Balkfontein) remains of poor quality.

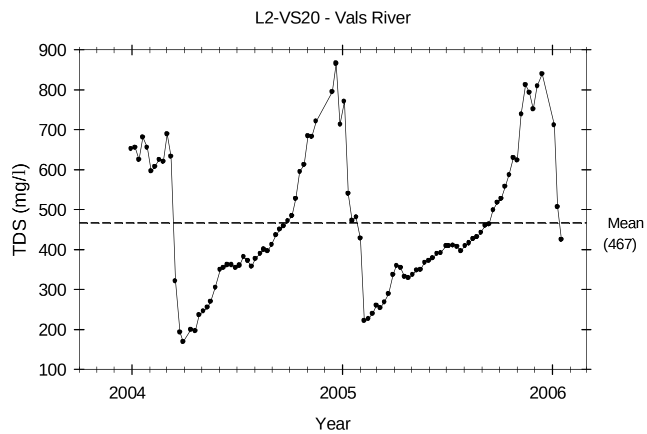


Figure 174: TDS concentrations in the Vals River from 2004 to 2006

6.8.6 Bloemhof Dam Sub-catchment

The tributaries of the Bloemhof Dam sub-catchment include:

- Sandspruit
- Makwassie, and
- Vet Rivers.

The water quality in these tributaries appear to be fairly good. The tributaries however need to be monitored to ensure that they do not have long term impacts on Bloemhof Dam.

<u>Makwassiespruit (L2-VS15-1)</u>

The phosphate (mean, 60 µg/ℓ) and inorganic nitrogen (0.113 mg/ℓ) concentrations in Makwassie spruit were relatively low, but the phosphates show an increasing trend (**Figure 175** and **Figure 176**). These concentrations are within the RWQOs for the Makwassiespruit but exceed the RWQOs for the Vaal River. The increasing trend in phosphate needs to be monitored to ensure that the situation is managed and does not pose a future threat to water quality. As no monitoring data is available for point VS15 on the Vaal River at this stage (new monitoring point) it is not evident as to whether the nutrient levels of the Makwassiespruit are contributing any substantial pollution load.

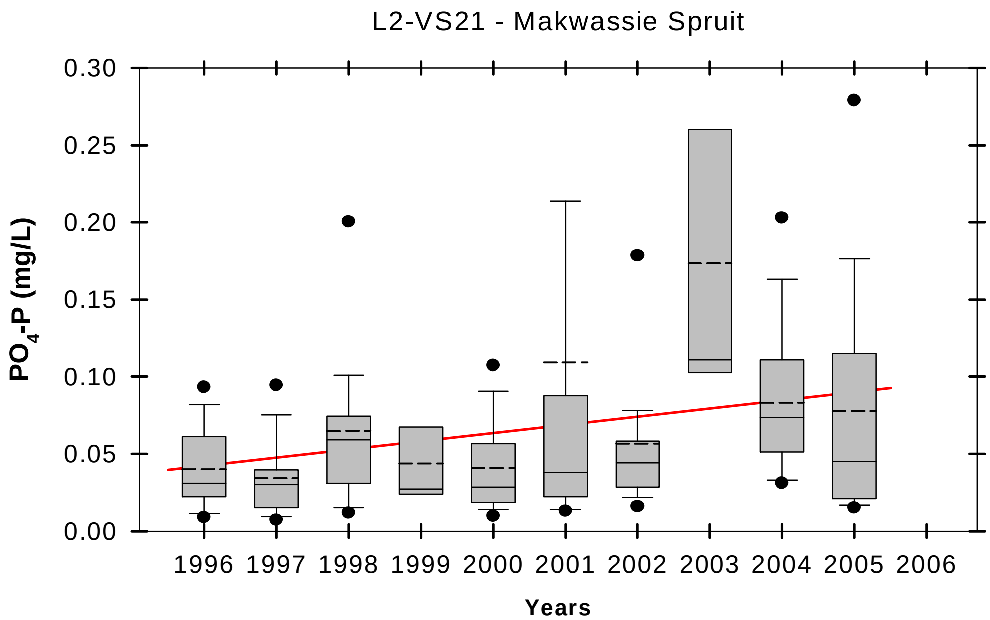


Figure 175: Variation in phosphate concentrations in Makwassie Spruit from 1996 to 2005

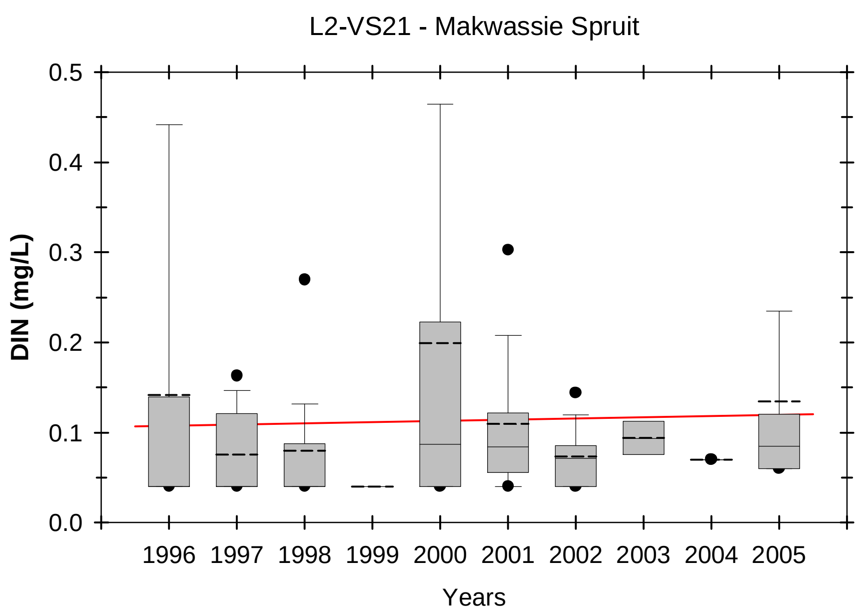


Figure 176: Variation in DIN concentrations in Makwassiespruit from 1996 to 2005

The TDS concentrations observed in the Makwassiespruit were of acceptable quality (average of 280mg/l) (**Figure 177**), and display a seasonal pattern (increasing during the drier winter months). This concentration is within the RWQOs for the sub-catchment and the Vaal River. As there is very limited activity in the area, it is unclear what the source of these dissolved salts could be. However the impact of Makwassiespruit on the Vaal River is believed to be limited.

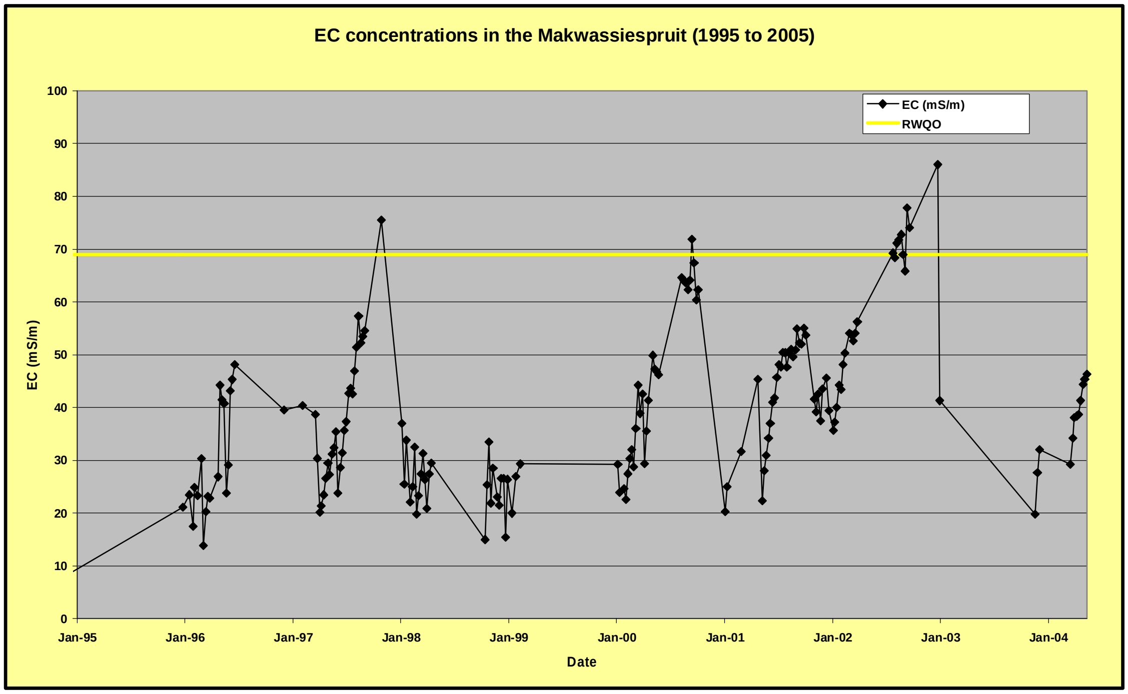


Figure 177: EC concentrations observed in the Makwassiespruit between 1995 and 2005

Sandspruit (L2-VS15-2)

The data in Sandspruit was scattered and highly variable (**Figure 178**). However, indications are that the water quality is decreasing significantly during the last few years. However, it is not apparent that the Sandspruit has any impact on the Vaal River.

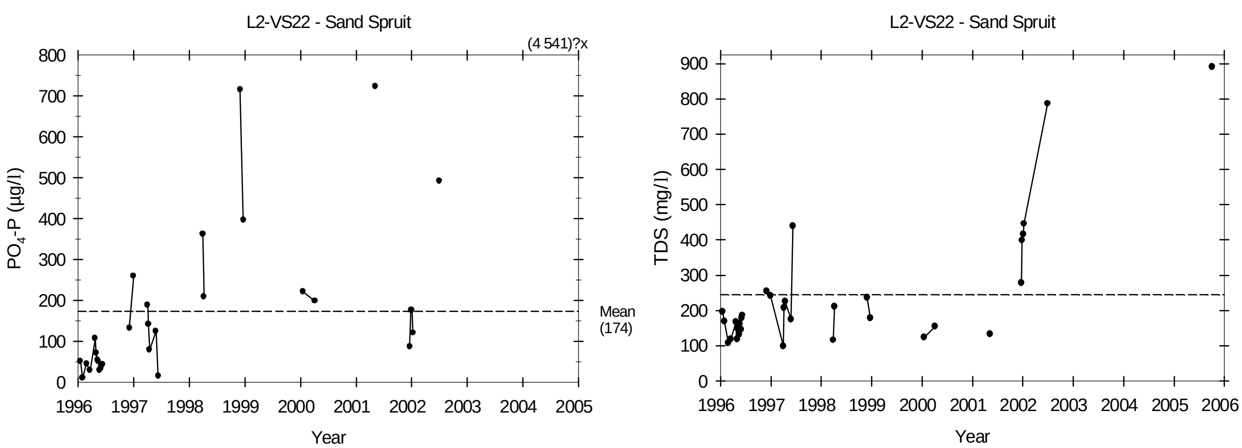


Figure 178: Variation in phosphate and salts concentrations in Sandspruit from 1996 to 2005

Figure 179: Sandspruit has clear water and filtered through a natural wetland area (3/6/2006)

<u>Vet River (L2-VS16-1)</u>

The average phosphate concentration in the Vet River was fairly high (mean, 75 µg/ℓ), but the nitrogen concentrations were very low (mean, 0.170 mg/ℓ) (**Figure 180** and **Figure 181**). However, both N & P was surprisingly low during the last four years (2001 to 2004).

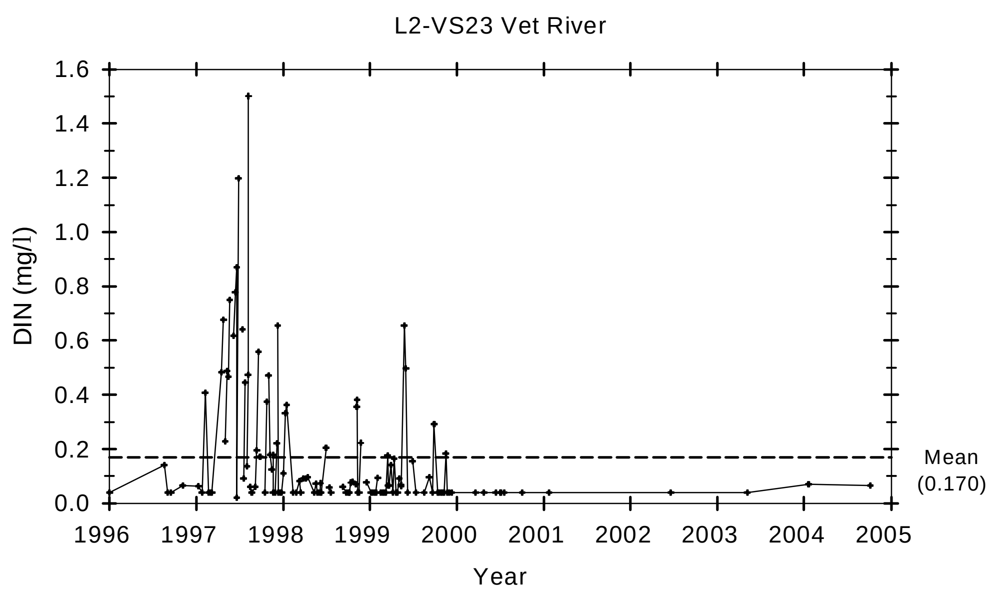


Figure 180: Variation in dissolved inorganic nitrogen concentrations in the Vet River from 1996 to 2005

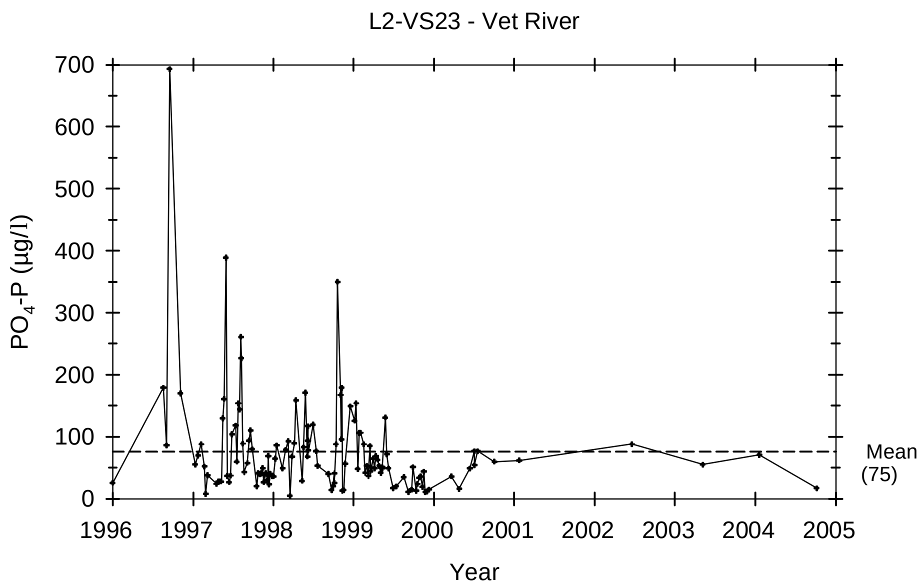


Figure 181: Variation in phosphate concentrations in the Vet River from 1996 to 2005

The TDS concentration in the tributary was fairly high (mean of 412 mg/ℓ). This is probably attributable to the impacts of the agricultural activities in the upper parts of the catchment.

The concentrations of the nutrients and salts are within the RWQOs for the Middle Vaal River. However the extent of the impact of the Vet River, if any, is not seen, as it is diluted by the water in Bloemhof Dam into which it flows. However this situation needs to be closely monitored to ensure that the water quality of Bloemhof Dam does not deteriorate.

6.8.7 Harts River Sub-catchment

The Harts River catchment includes the Harts River as the only tributary to the Vaal River. The Harts River as a tributary, does impact on the Vaal River as it carries large quantities of high salt load return flows from the Vaalharts Irrigation Scheme.

Harts River (L2-VS19-1)

The Harts River was characterized by very high dissolved salts (mean of 1 118 mg/ℓ), which has increased significantly during the last three years (**Figure 182**). The increased concentrations could partially be ascribed to very low flow conditions associated with a three years drought, thus a limited dilution of salts.

However, the phosphate and nitrogen concentrations were relatively low, *i.e.* 33 µg/ℓ and 0.362 mg/ℓ respectively.

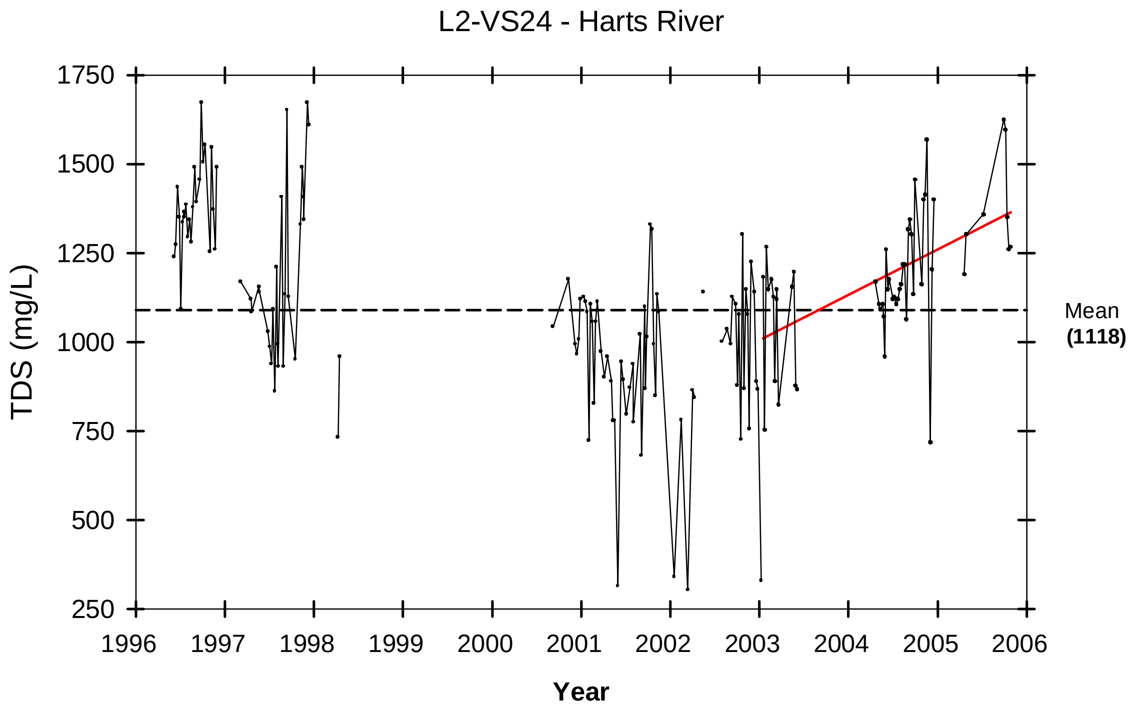


Figure 182: Variation in dissolved salts concentrations in the Harts River from 1996 to 2005

The impact of the Harts River is felt by the Vaal River, as an increase in TDS concentrations is seen at point VS19 (at Schmidtsdrift). The Harts is considered to have a major impact in terms of salt loads and thus an intervention strategy is required in the sub-catchment to manage the current practices.

6.8.8 Douglas Barrage Sub-catchment

The Riet River is the only tributary flowing into Douglas Barrage (most downstream point of Vaal River).

The impact of the Riet River is not clearly evident as it flows directly into Douglas Barrage which itself is of poor water quality as it acts as a "salt sink" for the entire Vaal River System. However the good water quality coming in from the Orange River through the pipe into Douglas Barrage also masks the situation. However the Riet River does appear to be an impacted tributary carrying a fair amount of salt load.

Riet River (L2-VS20-1)

The phosphate (mean, 23 µg/ℓ) concentrations in Riet River is relatively low, however it shows a gradual increasing trend over the last 15 years (**Figure 183**), which could be attributable to increasing activity in the catchment. However the concentrations are within the RWQO for the Vaal River and at this stage pose no real threat to water quality.

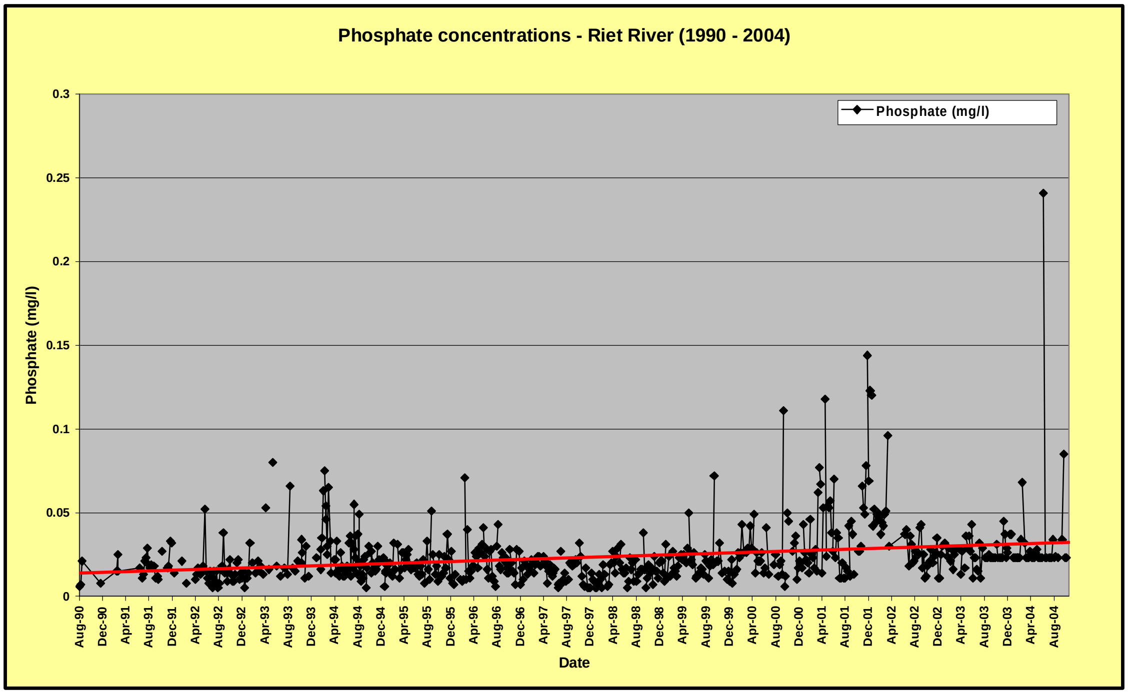


Figure 183: Variation in phosphate concentrations in the Riet River from 1990 to 2004 indicating increasing trend

Dissolved salt concentrations in the Riet River were found to be very high (average TDS of 956 mg/l; EC = 137 mS/m; **Figure 184**). This situation is definitely a cause for concern. A possible source could be the major agricultural activity that occurs in the catchment. This concentration exceeds the RWQO of 840mg/l set for TDS in the Lower Vaal WMA. Thus some source intervention is required at a sub-catchment level in order to alleviate the situation at Douglas Barrage.

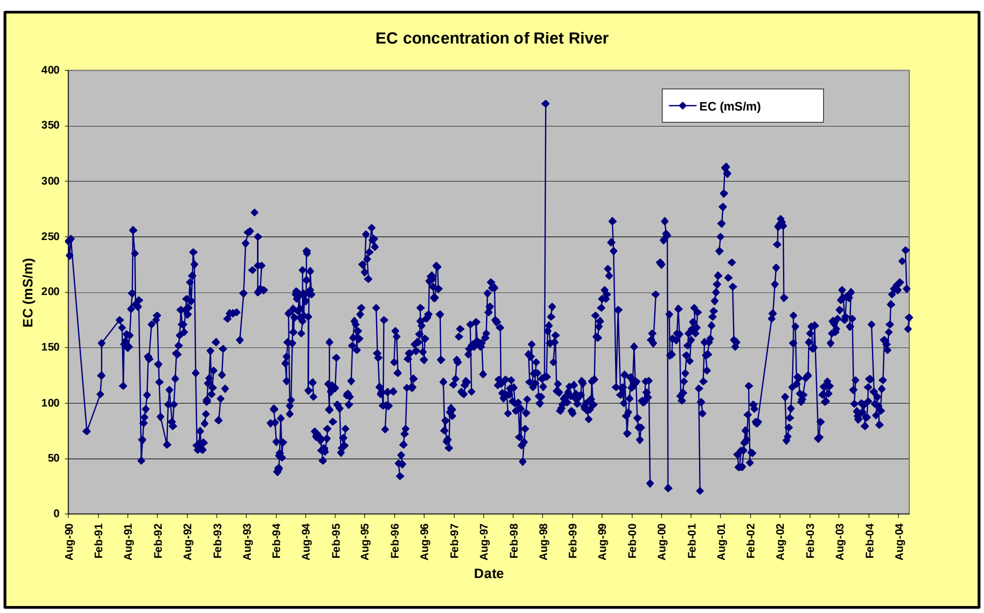


Figure 184: Dissolved salts concentrations as EC in the Riet River from 1990 to 2004

6.9 General Flow characteristics of the Vaal River

Discharge and water velocity have been proved to be important variables influencing water chemistry and river phytoplankton. The discharge in the Vaal River has decreased significantly during the last ten years, ***i.e.*** from an annual average of about 80 m^3/s to less than 10 m^3/s (**Figure 185**). If discharge in a river is reduced, instream concentrations of water quality variables, as well as values of physical variables, will change. The average flow during this period from the Vaal Dam was about 60 m^3/s and increase to about 80 m^3/s at Orkney, after which it decreased downstream and was only about 18 m^3/s at Schmidtsdrift. The flow patterns at the different monitoring point follows the same pattern (**Figure 186**).

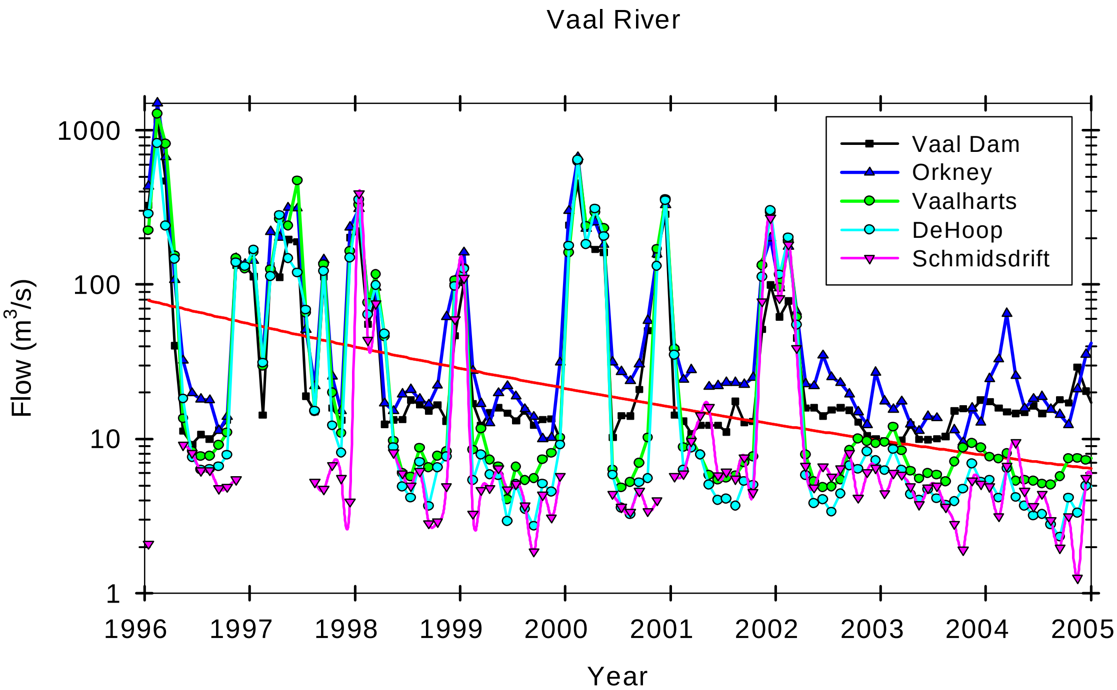


Figure 185: Variation in flow (monthly averages - m^3/s) in the Vaal River (main stream) during the last 10 years (1996 – 2005)

The flow in the Vaal River is regulated, yet highly seasonal, with the low flow during the winter and early spring months (***i.e.*** May to October), e.g. reflected by the flow at Orkney (**Figure 186**).

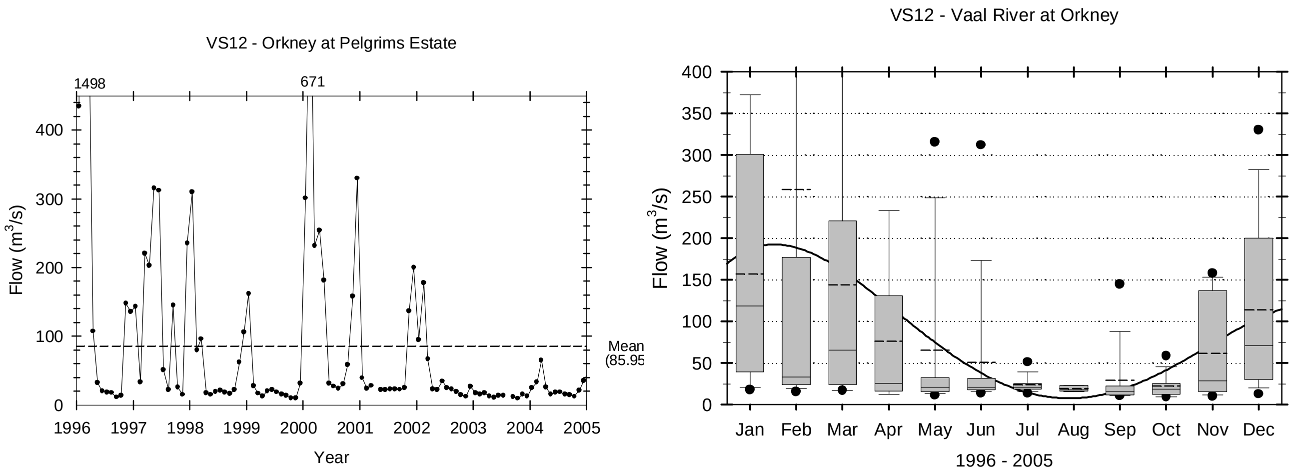


Figure 186: Annual variation in flow (monthly averages, m^3/s) and a box plot of seasonal variation in the Vaal River at Orkney during the last 10 years (1996 – 2005)

However, the dam level in Grootdraai Dam fluctuates significantly (**Figure 187**), whilst the level in Vaal Dam and Bloemhof Dam were more stable.

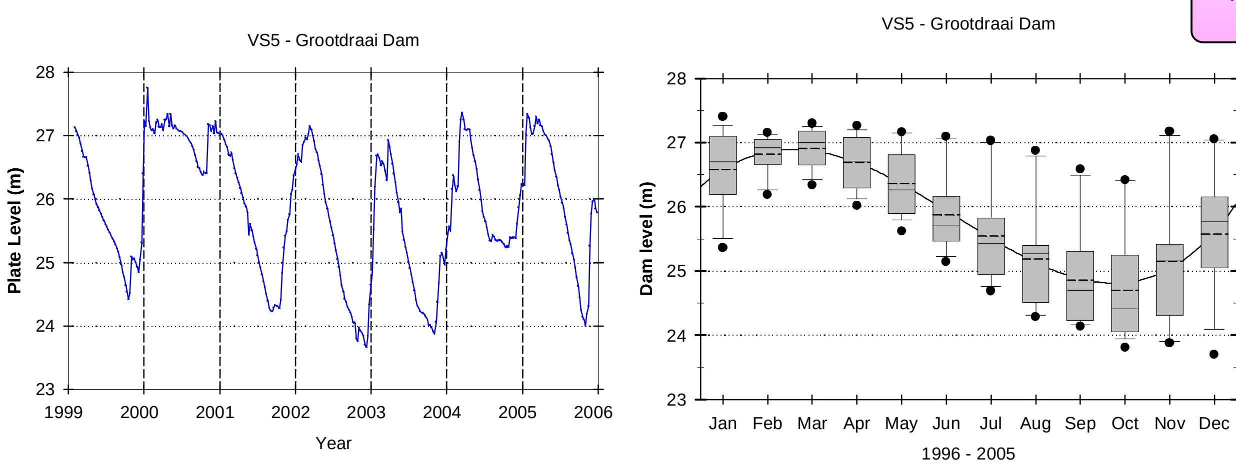
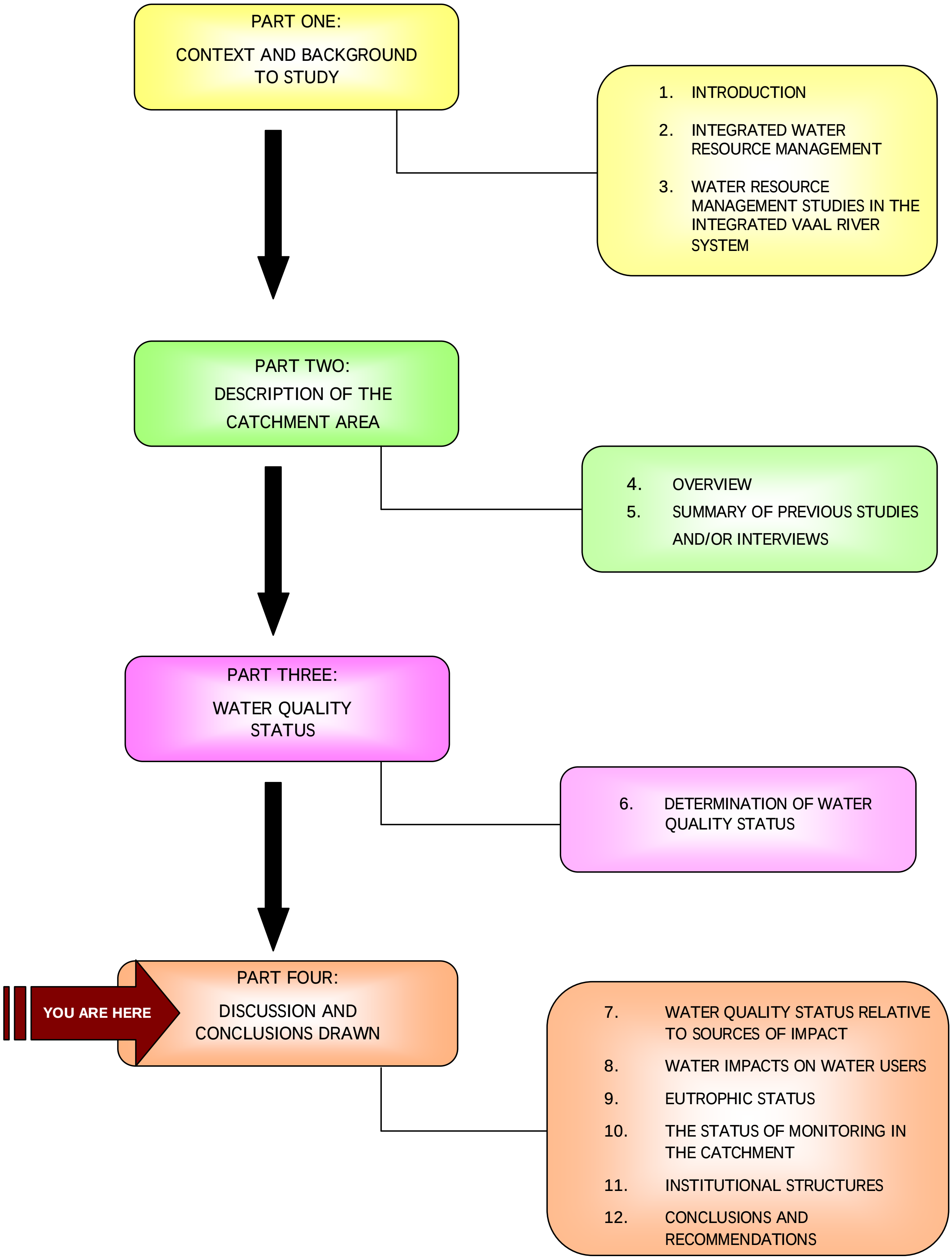


Figure 187: Annual variation in dam level (m) and a box plot of seasonal variation in the Grootdraai Dam during the last seven years (1999 – 2005)

STRUCTURE OF THE REPORT



PART FOUR
DISCUSSION AND CONCLUSIONS DRAWN

This part of the report discusses the following aspects with respect to the current water quality status observed in the Vaal River System:

- Water quality status relative to sources of impacts
- Water quality status relative to water user requirements
- Eutropohic status

7 WATER QUALITY STATUS RELATIVE TO SOURCES OF IMPACTS

7.1 Context

The patterns of water quality changes along the length of a river and with the flow of groundwater (through space) are related to (i) the spatial variability of the natural background soil and geological materials and rainfall, and (ii) the spatial location of point and non-point anthropogenic pollution sources. It is therefore important to relate water quality status to known sources that contribute to the water quality load, to ensure that the most adequate management intervention is applied. This therefore involves reconciling identified water quality problems with specified pollution sources, or identifying discrepancies that exist that do not necessarily link to the impacts of known land uses in the catchment. Based on the current water quality status reflected in the Part 3 of the report water quality problems linked to possible sources of impacts and stressed areas/catchments were identified/confirmed.

7.2 Issues identified as possible threats to the Vaal River System

The water quality data used for this study has come from different sources, varies in analysis, sampling frequencies, suite of variables analysed, analytical methodologies, and time periods. The lack of a holistic and an integrated system water quality monitoring programme has made it difficult to compare the water quality trends in the Vaal River System. Taking these limitations into account the data has however been used to determine the downstream trends along the Vaal River and to correlate these trends with either the flows of the confluencing tributaries, diffuse impacts or the decants and effluents being released into the rivers in the system. For the purposes of this part a water quality problem is defined as follows: “A problem is considered a water quality related issue when a re-evaluation of management options/intervention or application of treatment technology is required”.

The water quality issues of the Vaal River System are related essentially to salinisation and eutrophication, which have been confirmed as the the two critical challenges facing the sustainability of the system. Microbiological pollution is also an emerging problem, however this is related to more localised areas.

Deterioration of the water quality of the water resources in the system, is mainly attributable to the following land use impacts:

- Wastewater treatment works discharges (from the numerous small towns and urbanised areas within the catchment area, many of which are non compliant to the wastewater discharge standards and licence conditions);
- Mining pollution (point decants from dewatering and diffuse pollution originating from mining areas and tailings dams);
- Urban run-off (arising from the highly urbanised areas within the catchment with formalised and informal settlements);
- Irrigation return flow (originating from large irrigated areas within the system which carry fertilisers and high salt loads through leaching);
- Industrial pollution (originating from direct discharges to the water resource and from diffuse pollution at the numerous industrial complexes within the catchment area).

These major land use impacts vary in scale and intensiveness along the length of the Vaal River. The key areas where these land use impacts are felt the greatest in the Vaal River are the Vaal Barrage, Middle Vaal River (through the KOSH area) and the reach after the confluence of the Harts River (Vaalharts irrigation scheme). The reach of the Vaal River just downstream of the confluence of Waterval River also accepts a fair amount of impact and although does not reflect a significant problem at this stage, it could become one in future if the quality of Vaal Dam water deteriorates, and is not able to assimilate this load. However, in terms of the approach to water quality management source directed controls should predominate and the principles of waste minimisation, pollution prevention, and the precautionary principle should always underlie decision-making.

7.2.1 Wastewater Discharges

The persistent discharge of treated sewage is one of the most obvious sources of degradation of urban freshwater ecosystems (Luger & Brown, 2004). However, these relatively constant impacts are exacerbated by emergency events like intermittent spillages of raw sewage due to power failures, pump or pipe failures or blockages, and inadequate hydraulic capacity during high rainfall events.

The Vaal River system is receiving large volumes of sewage effluent, between 500 and 540 milliom m^3/a. The problem of non compliant discharges from wastewater treatment works and poorly managed sewage reticulation systems is a critical issue in the Vaal River System which is typical of many of the sub-catchments in all the WMAs. The impact of these non-compliant wastewater discharges from the wastewater treatment plants is considered to be a major contributor to salinity, eutrophication and microbiological problems currently observed. The sewage works in many of the smaller towns are inadequate and are in a poor state. While the larger treatment plants *e.g.* those of Johannesburg Water and ERWAT generally comply with their discharge standards, there appears to be a general trend in the discharge of poor quality effluent from sewage treatment plants from the smaller municipalities to the water resources in the system. In the Upper Vaal WMA the total effluent return flow from wastewater treatment plants to the river system is 295,5 x $10^6 m^3$/a (DWAF, 2002a), and in the Middle Vaal the total effluent return flow from wastewater treatment plants is estimated to be 472 x $10^6 m^3$/a. The Lower Vaal does not include any significant discharges.

In the Upper Vaal WMA, the this situation of poor quality sewage effluent is typical of towns in the Wilge, Grootdraai to Vaal Dam, Suikerbosrand, Klip (Gauteng), Vaal Dam to Vaal Barrage, Mooi, and Vaal Barrage to Mooi sub-catchments. In the Middle Vaal and Lower Vaal WMAs and Modder Riet catchments, all the sub-catchments are experiencing water quality issues related to this problem. This situation is largely to poor management, poor planning, lack of resources and capacity, inadequate skilled personnel and the lack of prioritising wastewater treatment as an issue within local government planning. The non-compliance of these discharges needs to be dealt with through regulatory, participatory and co-operative mechanisms.

7.2.2 Mining

Throughout most of the Upper and Middle catchment area there are areas that are experiencing threats to water quality due to some type of mining activity, which pose both short and long term risks. In the Upper Vaal, the Suikerbosrand and Kilp River (Gauteng)(Vaal Barrage area) and Mooi sub-catchments are two key areas of concern, where mining is contributing to salinity. This is attributable to mine decants and run-off diffuse pollution as well as seepage. Grootvlei Mine in the Suikerbosrand catchment is pumping approximately 76 Ml/day of underground mine water into the Blesbokspruit. ERPM Gold Mine (20Ml/day), Western Areas Gold Mine (21Ml/day) and Durban Roodepoort Deep discharge effluent, which drains to the Vaal Barrage. The mining areas of the West Rand and Far West Rand (Mooi River sub-catchment) e.g. Randfontein Estates Gold Mine (10Ml/day), Kloof Gold Mine (34Ml/day), Doornfontein Gold Mine, Driefontein Gold Mine (26Ml/day), Anglogold (Western Deep Levels), Deelkraal and Blyvooruitzicht Gold Mine (10ML/day) amongst others, are all either pumping mine water or discharging effluent into the tributaries of the Vaal River. Many of these activities have led to elevated salinity levels in the major tributaries of the Mooi River *viz.* Mooirivierloop, Wonderfonteinspruit, Loopspruit (DWAF, 2006b). The cumulative impact of the above is seen by the high salts loads in the area downstream of Vaal Barrage. Two other areas in the Upper Vaal WMA are possibly experiencing some impact of mining activity however it is not as extensive as that of the Vaal Barrage and Downstream of the Barrage. These areas are the Waterval catchment where Evander Gold Mining Operations and Sasol Coal mining operations are located. There are also coal mining activities in the Bethal and Ermelo area which are affecting the water quality in the Vaal River upstream of Grootdraai Dam. There activities probably provide some explanation for the peaks in salinity seen at monitoring points VS4 and VS6.

In the Middle Vaal WMA, the Schoonspruit and Koekemoerspruit sub-catchments are impacting on water quality, with large mine dewatering and diffuse pollution from tailings dams, e.g. the Stilfontein Gold Mine is releasing 37 ML/day of untreated water into the Koekemoerspruit, and the slimes dams of New Machavie Mine and Hartebeesfontein mine, and AngloGold Vaal River Operations are polluting the water resources of the sub-catchments and the Vaal River (DWAF, 2002d). Buffelsfontein Gold Mine is also discharging effluent into the Koekemoerspruit. High salinity levels are also experienced in the Schoonspruit River. In the Vierfontein sub-catchment there are also issues of water quality relating to mining activity impacts, with the Vierfontein Colliery decanting 3ML/day into the Vierfonteinspruit. A further concern is the presence of mine dumps in close proximity to the northern bank of the Vaal River which could be adding diffuse salinity impacts to the Vaal River. The cumulative impact of these sources contribute to the increase in TDS concentrations seen in the Middle Vaal River (at VS12), and identifies this stretch of the Vaal River as a key area requiring focus. Gold mining in the Welkom-Virginia area elevates the salinity of the Lower Sand River below Allemanskraal Dam (DWAF 2002e) however this impact is assimilated by the Vet River and Bloemhof Dam.

The situation in the Lower Vaal is concentrated on the upper reaches of the Harts River. This mining impact is related to diamond digging which is contributing to sedimentation.

7.2.3 Urban run-off

While the water quality impact of diffuse pollution arising from urbanised areas is not easily quantifiable and difficult to regulate, it is none the less a problem that needs to be addressed, especially in the Upper Vaal WMA where urbanisation is expanding at a rapid rate (Pretoria, Witwatersrand, Vereeniging Area). Runoff from unserviced or underserviced dense settlements, runoff from urban areas and storm-water run-off from industrialised areas within the urban areas can carry high pollutant loads. It is estimated that the run-off generated in the Upper Vaal WMA amounts to about 111,4 x $10^6 m^3/a$ (from total urban area of 1 035km^2 in WMA) and that generated by the Middle Vaal WMA is 13,8 x $10^6 m^3/a$ (from total urban area of 252km^2 in WMA) (DWAF, 2002a and 2002b). This situation is contributing to salinity, eutrophication and public health problems that are being observed in the water resources of the system, especially that of the Vaal Barrage which drains the Greater Johannesburg and Vanderbijlpark-Vereeniging area, the area downstream of Vaal Barrage (draining the West Rand) and to some extent the Middle Vaal River (draining the KOSH area). The run-off from the mining areas in the catchment can carry high sediment loads, high salt loads and typical mine related water quality issues such as (metals and sulphates) if not managed correctly. This situation is again typical of the Vaal Barrage, area downstream of the Vaal Barrage and the Middle Vaal River, as the key areas of concern. Another area where the impact of urbanisation is felt on the system, however to a lesser degree is the Secunda/Evander area. However this by no means implies that other urbanised areas in the system are well managed, rather the intensity of those impacts is small on the system as a whole. However what should be borne in mind is that in the Vaal River System, this run-off with wastewater discharges supplements the base flow of the Vaal River, which supports downstream users. Thus it is important that the quality of this run-off is maintained at an acceptable level that does not compromise downstream use to a large degree.

A further problem which could be emerging between points VS4 and VS6, and VS7 and VS8 (Grootdraai Dam and Vaal Dam catchments) is atmospheric deposition, which could be a further contributing factor to the salinity load. This aspect may require further investigation to determine the true extent of the impact, as long term consequences could impact on the strategic water users, who depend on good quality water with low TDS and sulphate levels.

The current infrastructure in place in many of the towns in the WMAs appears to be overloaded and with the rapid expansion and growth, the situation appears to have become critical at a service delivery level. The issue needs to be addressed through co-operative governance mechanisms between the Department, and the different spheres of the appropriate government departments, with specific emphasis on planning at local government level.

7.2.4 Industrial Pollution

The impact on the water quality of the system by industrial pollution is most significant in the Upper Vaal WMA, where the most concentrated industrial activity is found. The impacts are associated with direct effluent discharges and to surface run-off from industrial complexes. The Vaal Barrage in addition to the the salinity problems experiences eutrophication problems as well. This situation can be managed through regulatory instruments such as water use licences. However there needs to be the revival of compliance monitoring to achieve success.

The sub-catchments of concern are the Grootdraai to Vaal Dam, Vaal Dam to Vaal Barrage, Mooi, Klip, Suikerbosrand and Vaal Barrage to Mooi sub-catchments, where the problem appears to surface more significantly, eventually emanating in the Vaal Barrage. The Sasol industrial complex in Secunda could be a contributor to the high TDS levels seen at VS6. The other key sub-catchment of concern is Vaal Dam to Vaal Barrage (Vaal Barrage especially with industries such as Sappi and Sasol Sasaolburg). The major industrial complexes in the PWV area could be significantly contributing to the problems being experienced in the Vaal Barrage. This includes direct discharges into the Vaal River e.g from Sasol, or from surface run-off from the numerous complexes in the sub-catchments. However the industries appear to be the most regulated and co-operative of the water users with regard to wastewater discharges.

7.2.5 Agricultural Activities

The impacts of agricultural activities predominate in the Middle and Lower Vaal WMAs, where this land use is more extensive. The Lower Vet River could be contributing saline irrigation return flows to Bloemhof Dam, from the Sand-Vet irrigation scheme, however this impact is masked by the dilution capacity of the dam. Similarly the Riet River is also contributing to the TDS loads at Douglas Barrage, by irrigation return flows from the Modder Riet Catchment, however here again the analysis of the water quality data does not indicate a significant impact if compared to water quality in the Douglas Barrage and the impact of the Harts River. However, this impact should not be ignored but rather managed by catchment interventions.

The greatest impact of irrigation return flows on the Vaal River in terms of salinity is from the Vaalharts Irrigation scheme. The water quality of the system is being affected by the high salt loads and nutrient loads in the irrigation return flows from Harts sub-catchment area. Due to a build up salinity being experienced in the soils of the Vaalharts scheme, it is accepted practise to apply extra irrigation water to leach these salts out of the soil. This results in salt loads in these return flows being as high as 1500mg/l in the Harts River downstream of the irrigation scheme which impacts on the Douglas Weir. There is further concentrating of salts in Spitskop Dam due to evaporation.

The salinity load emanating from the Vaal River catchment is low as the system is managed to keep the discharge volumes from Douglas Barrage to a minimum, as a result the load from the Vaal River is assimilated by the Orange River before being used by irrigation schemes in the Lower Orange WMA. Thus the salinity problem lies more at Douglas Barrage than downstream in the Orange River. In addition to the salinity loads in the return flows, fertilisers are also applied, which add to the nutrient loads in the return flows as well. The nutrients have resulted in the growth of algae in the Spitskop Dam, which has been cited as the source of the algae (especially the blue-green form) found in the main stem of the Orange River in the Lower Vaal WMA (DWAF, 2004d). The Harts sub-catchment is a key area requiring attention from a water quality management perspective and requires some intervention (e.g. use of Taung Dam), as irrigators are actively trying to flush salts out of the soil. The current situation is an inevitable cost of large-scale irrigation. The aim should therefore be to not let the water quality deteriorate any further.

A further issue in the Vaalharts irrigation scheme is the large losses between the amount of water transferred from the Vaalharts weir on the Vaal River and the quantity irrigated – It is estimated that only 51% of the water diverted from the Vaal River reaches the irrigated crops (DWAF, 2002c). If this transfer scheme is optimised, more water could be available to dilute the irrigation return flows leaving the scheme.

7.2.6 Future predicted impacts

- A key issue related to mining activities in the Upper and Middle Vaal WMAs is the management of the mine decants after the closure of the mines. At present it is unclear where expected decant points are and what the volumes will be, and the expected quality of the decants. This issue is of long-term significance which requires intervention in the short term.
- The proposed mining prospects envisaged in the Grootdraai and Vaal Dam catchmernts due to the recommissioning of Camden and Grootvlei power stations could contribute further impact to the system. If the mining activities are not controlled or properly managed the impacts in the Ermelo area could be further compounded.
- The failure to achieve closure and rehabilitation of tailings dams could possibly impact on the water resources of the system.
- Lack of action to address the state of disrepair, inadequate capacity and general non-compliance to discharge standards of the wastewater treatment works in many of the towns in the system could result in a major catastrophe that causes greater pollution and more public health problems (waterborne diseases) in the surface water resources.
- Failure to ensure integrated planning at Provincial and Local Government level, with regards to development and infrastructure planning could also result in further increase in polluted stormwater run-off entering the water resources of the Vaal River System. This situation is also dependent on adequate delivery of services which includes sanitation services.
- The extent of air pollution impacts on the Vaal River needs to be determined, in order to quantify the impact on the water resources. The atmospheric deposition monitoring data is not readily available at present. This data needs to be made available to assess the problem in the future. The

Department needs to collaborate with the Department of Environmental Affairs and Tourism to ensure compliance air quality monitoring and reporting is practiced and that regulatory measures are adequately enforced.

- The deterioration in the quality of the water at Grootdraai Dam and Vaal Dam impact on strategic users and the cross WMA transfer of water.
- Organic loads in the Middle Vaal River
- Reserve Determinations could impact on the current operation of the system which could affect the blending and dilution option currently being implemented in the Vaal Barrage.
- The water quality of the Grootdraai Dam and the Vaal Dam is influenced by water transferred into the Vaal River catchment. Deterioration of the water quality of the contributing catchments would result in the deterioration of the water quality in the receiving water bodies.

8 WATER QUALITY IMPACTS ON WATER USERS

A range of water related problems are currently being experienced by water users in the Vaal River System due to the current water quality status that prevails. For the purposes of this discussion a problem is considered a water related issue if it requires or will require a re-evaluation of management options or application of treatment technology.

8.1 Domestic Water Use

Problems are being experienced in the treatment and supply of raw water to potable standards by the major water suppliers in the system. Problems are being experienced at various stages of the treatment process such as the raw water intakes, the treatment plant or the distribution system. Nutrient enrichment currently observed in the the Vaal River System, is considered to be an expensive problem as it has increased treatment required for drinking water.

8.1.1 Sulphate and chloride

Sulphate and chloride at high concentrations in domestic water are the primary determinants associated with accelerated corrosion. At concentrations above 200mg/l of either sulphate or chloride corrosion problems can be expected. Sulphate at these concentrations can also have human health effects and aesthetic effects (slight salty taste and diarrhoea in sensitive individuals). Concentrations of sulphate as high as 250 mg/l were recorded at Orkney and at Balkfontein, and concentrations above 200mg/l were also observed at Vaal Barrage, downstream Vaal Barrage and at Midvaal. However these occurrences were found to occur only 5- 10% of the time. The middle Vaal River could thus be a potential problem area in terms of high sulphate concentrations. These concentrations are generally localized and are caused by sulphate pollution of mining activities in the region. The contributions from agricultural activities are as yet not quantified.

In the reaches below the Harts River chloride is a significant part of the TDS, originating from agricultural return flow from the Harts River and Modder Riet Catchments. The chloride concentration at Douglas weir is as high as 180 mg/l, which exceeds the 100mg/l TWQR for domestic use (DWAF: SAWQGs, 1996).

It is expected that these elevated values of sulphate and chloride has and will result in corrosion problems, which if not already happened will translate into replacement costs for municipalities. These elevated concentrations of sulphate and chloride are also associated with aesthetic problems in potable water.

8.1.2 Managanese

Data from the Midvaal Water Company indicate relatively high manganese (Mn) concentrations (mean, 105µg/ℓ). Manganese is an essential micronutrient for plants and animals, although high concentrations are toxic. The TWQR for aquatic ecosystems as per the SAWQGs is 180 µg/ℓ, which was frequently exceeded at Midvaal (in the range of 200-500µg/ℓ). The Mn concentrations show a seasonal change with the highest concentrations during the winter. The high manganese concentrations result in increased treatment costs, as well impacts on the distribution system. A potential for the managanese problem also exists at Sedibeng Water.

8.1.3 Dissolved Ogranic Carbon

The dissolved organic carbon (DOC) concentrations at Midvaal were relatively high (mean, 7.05 mg/ℓ) and show an increasing trend. The high DOC concentrations could be ascribed to the general high algal biomass and other organic material in the water. High DOC is also associated with colour problems in drinking water, which is problem being faced by MidVaal Water Company at this point.

8.1.4 Algae

One of the major consequences of eutrophication is the algal related water purification and water quality problems associated with high algal concentrations in the raw water. The presence of microscopic algae in the treatment and supply of potable water for domestic use mainly cause interference with the treatment process and distribution system. In addition algae may also pose a health hazard and impair the aesthetic quality of potable water supplied. Water Boards frequently struggle with effective purification of water to drinking standard levels with high costs; treatment cost could increase by more than 45 % at high cyanobacterial cell concentration

Midvaal Water, Rand Water and Sedibeng Water are experiencing problems with the treatment of raw water abstracted from the Vaal River due to the presence of algae, however moreso Midvaal Water and Sedibeng Water, as the middle Vaal River to Bloemhof Dam is considered to be hypertprohic. The algal blooms that dominate the Vaal River sysem include Diatoms (*Cyclotella* spp. or *Melosira* sp.) and Cyanobacteria, especially *Microcystis* and *Anabaena* species. Theses vary in occurrence through the system and are generally seasonal with Diatoms usually dominating during the winter months, June - September, and cyanobacteria during summer months, January – May. Algal related problems have presented many challenges to the scientific and engineering community and result in increased purification cost. For example, treatment costs increase by approximately R4.22/Mℓ (over the mean treatment cost of R25/Mℓ), if the *Anabaena* counts in the raw water entering Durban Heights Waterworks were 6 000 cell/mℓ causing taste and odour problems (Harding & Paxton, 2001).

Increased potential of toxic algal blooms is another water quality concern that exists. Cyanobacterial blooms, often including species such as *Microcystis* species that can be toxic to man, biota, livestock and wildlife. The production of the toxins by the algae also pose a threat and could involve additional water treatmeat ranging from granular activated carbon filtration, followed by reverse osmosis, to more elaborate treatment including membrane filtration (WHO, 1999). *Microcystis aeruginosa, Oscillatoria* spp., and *Anabaena floss-aqua* have regularly been recorded in the Vaal River and the probability for toxic algal blooms are high.

Taste and odour problems are a common symptom of eutropohic waters worldwide. Blooms of nuisance algae have an effect on the taste and odour of water in potable water supplies. A wide variety of odorous compounds maybe detected, however the most common compounds are Geosmin and MIB, which causes earthy or musty off-flavours in water. Cyanobacteria are known to produce Geosmin. Eutrophic water supply systems frequently experience taste and odour problems, which has been found to be the case for the Vaal River.

Taste and odour problems in drinking water is thus a big concern for water companies in the Vaal River system, for example Rand Water experienced severe taste and odour problems associated with cyanobacterial blooms in the Vaal Dam during 2005 (Swanepoel, 2006). Control measures by water purification plants to remove taste and odour are usually expensive. Water boards are reluctant to implement expensive control measures when the ecological, environmental and health details of these compounds remain unknown.

However, consumers' demands for high quality water will remain or increase. Taste and odour events erode consumer confidence in municipal drinking water supplies leading to a rise in the use of bottled water.

8.1.5 Water Hyacinths (Macrophytes)

Macrophytes – free floating plants are also a common problem in the Vaal River System, and a another problem facing water treatment. The dominant macrophyte is the water hyacinth in the Vaal River which is a typical indicator of eutrophication. Water Hyacinths has been a nuisance in the Vaal River since 1985. The frequency and intensity of algal blooms are increasing in the Vaal River.

Water hyacinth has been observed in the Vaal Barrage, at Midvaal and Balkfontein and at Bloemhof Dam. The Department has developed guidelines for the removal and management of water hyacinth.

8.2 Industrial Water Use

The problems experienced by the major industrial users are also related to increase in treatment costs especially with regard to the high TDS concentrations and in some cases the nuisance algal blooms, and water hyacinths. Some problems experienced are corrosion and scaling which are of major importance to industrial users, especially those employing elevated temperatures for processes such as steam generation; increased waste generation and deterioration in effluent quality. The poor water quality of the Vaal Barrage is limiting its use by potential users due to the high salt load and eutrpohication problems. Industrial users such as Sasol, Mittal Steel and Eskom (Lethabo Power Station) rely on Vaal Dam water due to the high macro ion content present in the Vaal Barrage water.

Sasol (Sasolburg) has incurred treatment costs by abstracting water from the Vaal Barrage. Sasol has now stopped abstracting from the Barrage due to the deterioration in water quality. This has therefore added further demand on Vaal Dam.

8.3 Agricultural Water Use

8.3.1 TDS

The high TDS concentrations in the middle and lower Vaal River is a potential threat to the agricultural sector, as it could be impacting on crop production. High TDS waters are known to reduce the yields of crops and eventually limit the range of crops that can be grown. The salinity of the water in the area downstream of Vaal Barrage averages about 400-450 mg/l TDS which exceeds the TWQR of 260 mg/l for irrigation of salt sensitive crops (DWAF: SAWQGs, 1996). While the salt sensitivity of a crop type varies, and determines the salinity levels in the irrigation water that can be tolerated, many agricultural users in the Vaal River System downstream of Vaal Barrage have been impacted in terms of crop yield or in terms of irrigation systems and soil salinity, due to the current salt levels. Many of the users in the Harts River system are also impacted by the saline waters. The water quality of the return flows are also affected by the quality of the water supplied.

The macro ions chloride and sodium specifically are problematic for agricultural use. Chloride specifically impacts on certain crop types such as fruits, vines and citrus. High levels of chloride are found in the Lower Vaal River, as high as 180 mg/l. These concentrations exceed the TWQR of $\leq$100 mg/l for irrigation (DWAF: SAWQGs, 1996).

8.3.2 Algae

The presence of the nuisance algal problems is a potential problem which could impact on the supply of water for irrigation. The distribution of nutrient rich water can impact on the efficient abstraction, transfer, pumping, calibration of weirs and distribution of irrigation water, which could result in losses from canals. These impacts could have economic implications on agricultural users.

A further problem of algae present in irrigation waters is that it could affect the efficiency of the irrigation system used, for example drip irrigation systems can become blocked. While the exact impact of the algae present in the Vaal River on irrigation systems has not been determined it is believed that it could present a problem in the future.

Water hyacinth also have potential to interfere with pumping and pumping capacity along the Vaal River, which could be a problem for agricultural water in the lower Vaal River.

8.4 Recreational Water Use

The recreational potential of the Vaal River is being impacted upon/adversely affected specifically by the eutrophication problems being observed, specifically at the major impoundments, e.g at Vaal Barrage and at Bloemhof Dam. Apart from the aethestic impacts in some instances contact recreation is restricted due to the potential health effects.

In the Vaal Barrage and at Midvaal some areas are also impacted by microbiological pollution which is also impacting on the recreational use of the Vaal River.

8.5 Aquatic Ecosystem and Biota

While the aquatic ecosystem and biota is not a water user *per se*, but inherently components of the water resource, it is important nevertheless to highlight the issues being faced by the ecological system with respect to the current water quality in the Vaal River.

The exact sensitivity and current health status of the aquatic ecosystem is not fully known at this time. It is accepted that the ecosystem has been severely altered due to the high regulation of and development in the system, in particular the high return flows from the wastewater treatment plants. The extent of the ecosystem modification and the suitability of the RWQOs set have on the aquatic ecosystem still needs to be determined. The implementation of a structured biomonitoring programme and the results of the Comprehensive Reserve determination process that has been recently initiated by the Department will soon provide an understanding of the current situation in the system with regard to the aquatic ecosystem as a user.

However based on the current assessment the following issues and concerns can be raised:

- *Lower biodiversity and dominant biota change*: The phytoplankton species composition in the Vaal River has shifted towards cyanobacteria – excluding other algae.
- *DO levels in the hypolimnion of the dams and weir pools*: DO depletion in the water-column; anoxic conditions may develop in hypolimnion. Oxygen concentrations are not regularly measured in the Vaal River, however, indications are that the concentrations are usually relatively high (>60 %).
- *Concerns about elevated metals and its effects on fish and other biota*: The concentrations of metals in the Vaal River is generally high, particular potential problems are high Aluminium, Copper, Nickel, Lead and Zinc.
- *Increased probability of fish kills*: Frequent fish kills have occurred in the Vaal River, *e.g.* kill during January and June 2006 in the Vaal Barrage area

9 EUTROPHIC STATUS

Eutrophication of inland waters ranks as one of the most widespread environmental problems worldwide. It has many significant and negative ecological, health and economic impacts on the use of a primary and finite resource, the water. The sources of toxic pollutants to lakes and rivers are usually material derived from human activities.

Algae respond to eutrophication by the development of massive populations, including blooms, scums and mats. Such mass populations are increasingly attracting the attention of environment agencies, water authorities, and human and animal health organizations, since cyanobacteria can present a range of amenity, water quality treatment problems, and hazards to human and animal health (Codd *et al.*, 1999).

Sewage effluent is one of the most common type of pollution found in urban rivers. Both the quality and quantity of effluent result in various impacts on the receiving freshwater environment. The ecological integrity of the Vaal River has been changed significantly, consequently, the key ecological processes and species composition is probably not comparable to that of natural habitats within the region.

It has become clear in the literature of the last decade that the earlier generalisation that phosphorus is limiting in freshwater systems whereas nitrogen limits primary production in marine and estuarine systems is an oversimplification. Numerous studies make it clear that nitrogen can be as important as phosphorus in driving the development of algal blooms in freshwaters at particular times of year. The current consensus in Australia is that both nitrogen and phosphorus, rather than just one supposedly limiting nutrient, need to be considered when developing management strategies to reduce nutrient inputs to waters (Davis & Koop, 2006).

Impoundment and large abstractions from the Vaal River reduces the flushing rate and increase the residence time of algae in the impounded water enabling them to take advantage of the growth conditions that are often more suitable in the pools than in the flowing river. In addition, the reduced flushing rate decreases the mixing intensity and increases the likelihood of temperature stratification. Reduced water mixing advantages buoyant, bloom-forming cyanobacteria because they are able to float towards the well-illuminated surface layers.

The phytoplankton biomass in the middle Vaal River has increased extensively over the last 30 years. For example, in 1973, 93 % of samples from the Vaal Barrage had chlorophyll concentration levels below 5 µg/ℓ, by 1982, 87 % of samples had chlorophyll concentration levels exceeding 15 µg/ℓ, while 34 % of the samples exceeded 35 µg/ℓ (DWAF, 1986). During 2005, 92 % of samples had chlorophyll concentrations levels exceeding 15 µg/ℓ, while 58 % of the samples exceeded 35 µg/ℓ. The average concentration during 2005 was 62 µg/ℓ and a maximum of 232 µg/ℓ, dominated by cyanobacteria, was recorded in the Vaal Barrage during January 2005.

Algal growth in the Vaal River is probably limited by light during the late summer (rainy season, with high flow, high turbidity), but the decrease in flow and turbidity during the winter period improves the underwater light climate, thereby lifting the light limitation and permitting vigorous algal growth, mainly diatoms that are well adapted to low water temperatures. Centric diatoms generally favour temperatures below 15 °C (Jansen van Vuuren & Pieterse, 2005).

In the Vaal River, diatoms blooms have occurred during winter and spring which coincided with low flow conditions, high inorganic N:P ratios, high salts, low turbidity, thus high underwater light climate, and long residence times.

Cyanobacterial blooms usually occur during late spring and summer, coinciding with high temperatures (>20 °C), low inorganic N:P and low salt levels. Bloom formation can be avoided by measures which address their growth requirements, i.e. plant nutrients and light, which is strongly regulate by flow conditions.

It is generally recognised that an increase in nutrient loading is a prerequisite of increased eutrophication in rivers.

The whole middle section of the Vaal River, i.e. from the Vaal Barrage to Bloemhof Dam (about 425 km river length, i.e. about 35 % of the whole river) is classified as hypertrophic (**Table 49**).

The fact the Vaal River at Douglas is classified as Oligotrophic indicates that the river has a self-purification capacity to absorb pollutants and can be restored to lower eutrophication levels. However, the transfer of Orange River water (lower nutrients) to Douglas Barrage and the abstraction for irrigation result in relatively short residence times which probably contributes significantly to the better water quality and thus low algal biomass (Chlorophyll-***a***).

The resource water quality objective (RWQO) in terms of phosphates, stated for the Vaal Barrage (50 µg/ℓ) are unrealistically low and should be revised. Based on the relationship between phosphorus and chlorophyll in the Barrage, the following concentration values are proposed:

Ideal: <50 µg/ℓ

Acceptable: 50 – 100 µg/ℓ (currently set at <30 µg/ℓ)

Tolerable: 100 – 150 µg/ℓ (currently set at 30 – 50 µg/ℓ);

Unacceptable: >150 µg/ℓ (currently >50 µg/ℓ)

Table 49: Summary of the Trophic Status of Vaal River impoundments (averages for the last three years)

Dam name	Mean TP (µg/ℓ)	Potential for algal productivity	Mean annual Chl-*a* (µg/ℓ)	% of Chl-*a* >30 µg/ℓ	Nuisance value of algal bloom productivity	Trophic status
Grootdraai	55	Significant	8	5 %	Moderate	Oligotrophic
Vaal Dam	97	Significant	23	14 %	Significant	Eutrophic
Vaal Barrage	~400	Serious	53	63 %	Serious	Hypertrophic
Midvaal*[1]	340	Serious	35	34 %	Significant	Hypertrophic
Balkfontein*[2]	~160	Serious	52	66 %	Serious	Hypertrophic
Bloemhof	100	Significant	55	35 %	Significant	Hypertrophic
Douglas Barrage	60	Significant	8.5	2 %	Moderate	Oligotrophic

*[1] based on 1997 – 1999 data; *[2] based on 2005 – 2006 data

The Trophic Status Index (TSI) Carlson's values for chlorophyll-*a* concentrations in the Vaal River indicate eutrophic conditions for the whole system (**Figure 188**). The TSI values for the TP concentrations were either eutrophic or hypertrophic. However, it is unrealistic to put the Vaal Barrage with high nutrient concentrations and frequent algal blooms in the same category as Douglas Barrage with low nutrients, clear water and no algal blooms. Therefore, the trophic state index of Carlson (1977) is not recommended for the Vaal River.

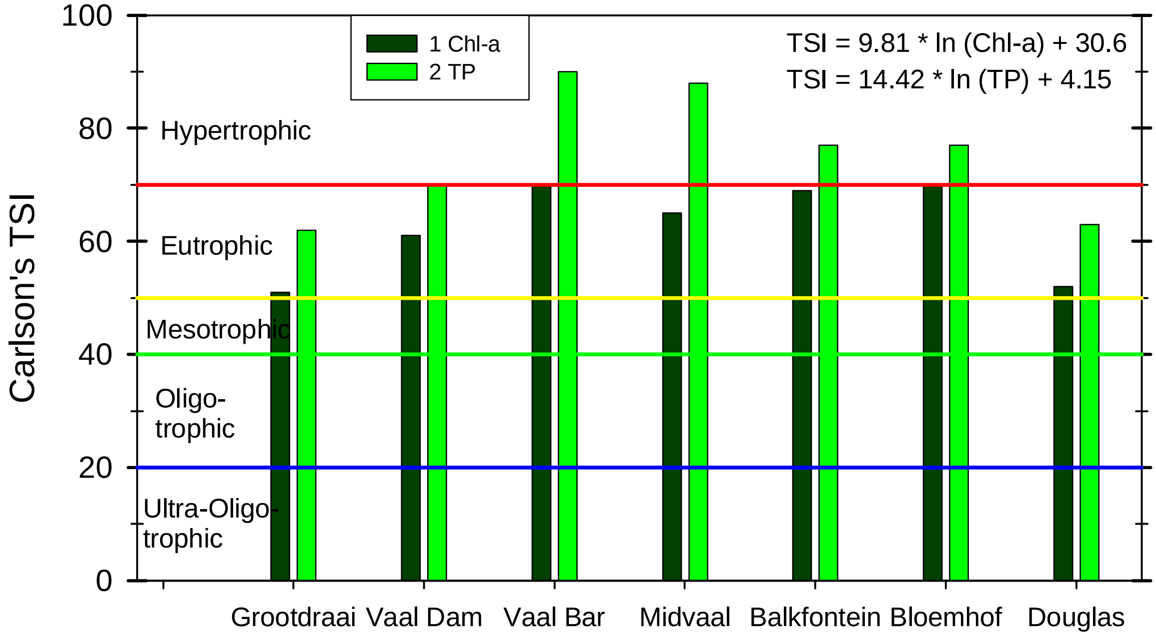


Figure 188: Carlson's Trophic State Index (TSI) values for chlorophyll-a and total phosphorus concentration at six monitoring points in the Vaal River system.

9.1.1 Ecological implications

- Phosphorus (P) plays a major role in biological metabolism and is a common growth-limiting factor for phytoplankton in lakes and rivers. Consequently, the high concentrations of P (mostly as phosphate) in the Vaal River, promotes the excessive growth of algae.

- In general, the discharge of treated wastewater into aquatic systems results in a reduction in species diversity (high species diversity is indicative of a healthy, functioning system), and an increase in biomass of pest species.

- Phytoplankton species composition changes in response to eutrophication. Blooms of cyanobacteria are a clear sign of eutrophication, which has become more intensive during the last 10 years in the Vaal River.

- The most frequent cyanobacterial species observed in the Vaal River were *Anabaena*, *Microcystis aeruginosa*, and *Oscillatoria* spp. *Microcystis aeruginosa*, and *Oscillatoria spp.* were the predominant species in enriched freshwater reservoirs throughout the world (Moreno et al., 2005).

- High dissolved salts concentrations (>700 mg/ℓ) in the Vaal River could be the tipping factor that may shift the algal composition in favour of undesirable species such as the highly toxic cyanobacterium, *Cylindrospermopsis rasciborskii*, that was already observed in the lower part of the Vaal River and Orange River.

- The presence of substances that are not removed during the sewage treatment process, such as drugs (e.g., heart and blood medication, hormonal treatments, oral contraceptives), domestic cleaners and various industrial chemicals, all of which may have subtle, but significant, effects on an ecosystem.

Note: A detailed Vaal River Eutrophication Status Report has been produced in support of this status assessment report. It contains much detail, includes background information, principles and concepts, gives further explanations, scenarios and discusses the eutrophication issues in more depth. While this report has drawn on the Eutrophication Status Report, if the reader is interested in the detail he/she is referred to the detailed report: "Vaal River Eutrophication Status". Draft 3. November 2006 - by Jan C. Roos.

10 THE STATUS OF MONITORING IN THE CATCHMENT

The design and implementation of effective monitoring networks and repository databases to ensure adequate quantification of the balance between sustainable water use and protection of water resources is pivotal to ensure that the goals of water resource management are being achieved in a catchment. Extensive and reliable information regarding stream flow, in-stream water quality and discharge loads, is essential to readily identify and prioritise problem areas and assess the water resource situation. It was therefore of importance to assess the existing water quality monitoring systems active in the Vaal River System with the objectives of (i) evaluating the monitoring systems in place and (ii) identifying key information gaps.

In this report, the gaps are identified and recommendations made on improving the monitoring network. A monitoring programme will be developed as part of this study and will be presented as a stand alone report.

10.1 Current Monitoring

Data used in this study has been obtained from different organizations that have in-stream monitoring programmes in the system. They include:

- DWAF, Directorate Resource Quality Services
- DWAF Gauteng Regional Office
- DWAF Free State Regional Office
- Rand Water
- Midvaal Water
- Sedibeng Water

The majority of the data was obtained from Departmental databases, with only limited information being obtained from the Water Boards based on specific requests. Midvaal Water supplied the most data with limited data from the other two Water Boards. It was evident that each organization had its own programme which served its purposes, with no integration with the others. The Departmental monitoring programmes and that of the Water Boards are briefly discussed below.

10.1.1 Department of Water Affairs and Forestry

The Department as the regulator monitors the water quantity and quality in the Vaal River System. A National monitoring system is currently in place and is coordinated by the Department's Resource Quality Services. All data collected for the National monitoring programmes are stored on the Department's database and information management system*, i.e.* the Water Management System (WMS). In some instances the Directorate Hydrological Information and/or the Regional Offices collect the samples for the RQS for the National monitoring programmes. The Regional Offices also have their own regional water quality monitoring programmes for which they are the lead agents.

These programmes are not always integrated into the WMS. The Gauteng Regional Office has an extensive water quality monitoring programme in place which supports the national programme, while the Free State Regional Office has recently initiated a regional monitoring programme, which is not yet integrated into the National system, as WMS is not yet used by the Region. The Northern Cape Regional Office has also recently initiated a regional monitoring network which has some integration with the National system be it to a minimal degree.

The Gauteng Regional Office's monitoring network also includes monitoring stations that monitor the wastewater discharges from point sources. This network is a compliance monitoring network to assist the Gauteng Regional Office in determining if industries, mines, wastewater treatment plants, etc. in the catchment are complying with the discharge standards stipulated in their water use authorisations. However during data gathering many of the datasets for dischargers did not volumes available. The data sets in the database were not always complete or up to date. The supply of data is dependent both on the water users themselves and Department's own compliance monitoring network, thus the heart of the problem lies primarily with the Department not updating the WMS on receipt of the data as its own compliance monitoring provides data even if the water users don't. With regard to this situation the industries in the catchment did indicate that they did in fact diligently submit their data to the Department as and when required.

10.1.2 Rand Water, Midvaal Water, Sedibeng Water

Limited information was made available regarding the monitoring programmes of the Water Boards. Rand Water and Sedibeng Water were not willing to share much information. Requests for data from Rand Water were at a cost.

Midvaal Water has a monitoring programme with sampling points in the Koekemoerspruit and the Vaal River. Samples are taken on a weekly basis and analysed on site by their own laboratory. Variables analysed range between physical parameters, metals, micro and macro elements, organics, nutrients, biological parameters and faecal coliforms.

There is no alignment to the Departmental monitoring system, or between the different Water Boards themselves.

10.1.3 Inadequacies and gaps identified

The following gaps and inadequacies were identified during this task with regard to water quality monitoring and monitoring programmes:

- There are differences in:
  - Variables analysed
  - Time periods and scales of the monitoring

- Analytical methods
- Laboratories used for the analysis
- Differences in data collection and storage formats

- There is a lack of integration between the monitoring programmes of the National Programme and Regional Offices. There is also a lack of integration among the three Regional Offices with regards to the monitoring programmes and monitoring. There is at present no co-ordination between the RQS and the Departmental Regional Offices regarding the location of monitoring stations, sampling frequency and analyses performed.
- There is also no integration or co-operation between the Department and the Water Boards with regard to monitoring of the Vaal River. Efforts are duplicated, uncoordinated and isolated.
- Data from the monitoring stations have in many instances proved to be incomplete (information gaps) or insufficient (limited data sets). The data sets were fragmented and their reliability was questionable.
- Monitoring stations were not always suitably located and thus in some instances the most downstream point on the tributaries were too high up in the catchment. Thus the lower catchment impacts were thus not accounted for.
- With regard to salinity, the Gauteng Regional monitoring programme monitors EC, while the National programme and that of the Free State Region monitors TDS.
- Analysis of data between various monitoring stations is not always possible because of differing water quality variables analysed and discrepancies in the analytical techniques used by different testing laboratories.
- The water quality monitoring variables currently analysed is largely concentrated on chemical constituents. At present very little information is available of the aquatic health of the water resources of the catchment.
- Available Departmental data varies in completeness, accuracy and reliability, which have resulted in difficulty in isolating and quantifying specific pollution sources.
- Not all monitoring points include flow measurements which limited the extent of water quality analysis at some points, and the determination of loads.
- No validation processes are in place to verify the data that has been captured (no validation of methods, sampling, analysis, etc.). This therefore sometimes raises questions about the validity of the data that is available on the Department databases.
- Limited continuous monitoring of water quality is practised in the Vaal River and its tributaries. In impacted catchments the continous monitoring of key water quality variables such as EC is needed for use with the flow monitoring stations to accurately assess the loads and compliance with RWQOs.

10.2 Recommendations with regard to interventions and actions needed

There exists a need to integrate and improve the monitoring network in the Vaal River System to adequately address the information needs.

- With the strategic monitoring points, Level 1 and Level 2 having been confirmed through this task, a comprehensive and integrated monitoring programme for these points can be agreed upon between the RQS and Regional Offices, which would serve the needs of the Vaal River System. The current "fragmented" programmes can be built upon to ensure that all the monitoring points deliver the same information needs, as required, in a consistent and co-ordinated manner. This would include agreement on the suite of variables, sampling frequency, time periods, analysis methods, etc.
- The location of the monitoring gauges, especially those at level 2 points must be reviewed to ensure that they in fact are located at the most downstream point just before confluence with the Vaal River. There also needs to be monitoring gauges installed in the upper reaches of all the tributaries to determine background qualities.
- Water quality monitoring must be consistently carried out at all monitoring points according to the agreed upon monitoring programme to enable all strategic points to build up credible data sets. This is specifically needed for the Middle Vaal River (points VS9 to VS 15), and for many of the tributaries (level 2 points). Consideration should be given to continuous monitoring of flow and water quality wherever possible.
- To maximise the monitoring in the system, the Department and the Water Boards, and other key water users should co-ordinate their monitoring programmes/sampling programmes to support effective and efficient capacity and resource utilisation. The Department and the Water Boards should also enter into co-operative agreements regarding sharing of water quality information (free of charge).
- The water quality monitoring variables currently analysed is largely concentrated on chemical constituents. The monitoring system therefore needs to be extended to include biological and microbiological parameters, as well as metals. Chlorophyll a and total phosphorus, total nitrogen, chemical oxygen demand and dissolved oxygen levels should also be included as variables to be monitored.
- The Department should adopt the monitoring of either TDS or EC for the entire system. Both variables could be monitored however it should be consistent through the Vaal River System.
- Stream flow monitoring must be resumed and/or initiated at all Level 1 and 2 water quality monitoring points to allow for trend analysis and determination of loads.
- Data capturing needs to be improved as many of the stations are missing recent monitoring data, or have gaps of a few years in the information.
- The standard WMS database should be used by all Departmental Offices to ensure consistency in storage, format and analysis. In this regard there should be maintenance of the central water

quality database that would hold all the data from the Level 1 and 2 strategic monitoring points in the Vaal River System.

- Compliance monitoring and the capturing of compliance data should be revitalised/re-emphasised, in order to determine the true extent of the impacts on the water resources of the Vaal River System. This would include monitoring of the point source discharges from mines, industries, wastewater treatment works, irrigation canals, etc. that report to the Vaal River or to its major tributaries.
- It is also important to install air quality monitoring devices especially in the Vaal Dam and Grootdraai Dam catchments in order to start determining the impact of atmospheric deposition on the water quality.
- The monitoring needs can be phased into immediate, medium term and long term plans to ensure that the information needs are achieved.

11 INSTITUTIONAL STRUCTURES

Water resource management in a catchment and water quality management as a component thereof is highly dependent and closely linked to the land use practices and physical developments and the consequent modifications that these have on the land phase and the hydrological cycle (DWAF, 2003). However many of these land uses and developments are beyond the statutory control of the Department and involve various other institutions. In addition to these other regulatory institutions, the water interest stakeholder sectors in the catchment are also responsible for the activities in the catchment and how they impact on the water resources. These water interest stakeholder sectors also have interest in the water quality, or are affected by the water quality and the way it might be managed. Thus one of the best ways of understanding water related issues in the catchment is by engaging the people and the institutions who perceive them, who are affected by them or who can contribute to improving the situation. Thus the development and implementation of a water quality management plan for a catchment is highly dependent on a process of collaboration, consultation and joint undertakings between different organs of state, various institutions and all water interest stakeholder sectors. All these institutions and groupings need to play a role and accept responsibility in the process surrounding the management of water resources in the catchment. Sound institutional structures are essential for a catchment like the Vaal River System that is highly regulated, heavily utilized and heavily impacted, and central to the economy of the country.

11.1 Water Management Institutions

The NWA provides for the establishment of a number of statutory water management Institutions (WMIs) to facilitate local stakeholder participation in water resource management. Each of these has a different purpose and is best suited to perform a specific set of functions. They include the following:

- *Catchment management agency* (CMA)- is responsible for planning and implementation of WRM within a WMA in line with the CMS.

- *Catchment management committee* (CMC) - may be established by a CMA, in order to perform specific delegated functions within a specified area.

- *Water user association* (WUA) - may be established as a cooperative association of water users to undertake water-related activities on a local scale for their mutual benefit.

- *Advisory committee* (AC) is established by the Minister to provide him/her with advice or perform functions in a specified area.

These institutions above are statutory and are established by the Minister and must satisfy certain requirements stipulated in the NWA.

Catchment forums

Catchment forums have been and are being used extensively by the Department to involve stakeholders in decisions about water resources management. These forums have now become important bodies representing stakeholders in the establishment of CMAs, and are envisaged to play an active role in assisting these CMAs after their establishment. Catchment forums are particularly important in the development of the CMS, to address local priority water resource management issues, but also provide a vehicle to facilitate the coordination and/or integration of water resource management with spatial planning and land use management.

Catchment forums are not formally established under the NWA, although the Minister may make regulations for consultative forums, in terms of Section 90(1)(b) of the NWA.

11.1.1 Catchment Management Agencies

At present, CMAs have not been established in any of the WMAs of the Vaal River System. The Departmental Regional Offices, Gauteng Region, Free State Region and Northern Cape Region serve as the CMAs until CMAs have been established for the Upper, Middle and Lower Vaal WMAs, as well as for the Upper Orange. Processes are underway to initiate the establishment of the CMA for the Upper Vaal WMA, however the establishment of CMAs for the other WMAs are still estimated to be about 5 years away (**Table 50**).

Table 50: CMA Establishment process (DWAF, WISA 2006)

WATER MANAGEMENT AREA	ESTABLISHED COMMITTEES/STRUCTURES TO SUPPORT CMA ESTABLISHMENT	TARGETS FOR THE ESTABLISHMENT OF THE CMA	
		PROPOSAL DEVELOPMENT	COMPLETION
UPPER VAAL	*Upper Vaal River Reference Group* *Vaal Dam Catchment Executive Committee* *Vaal Barrage Catchment Executive Committee* *Kromdraai Catchment Executive Committee*	2007/08	2010
MIDDLE VAAL WMA	*Schoonspruі/Koekemoerspruit Steering Committee* *Sand-Vet Catchment Management Committee*	*New Processes* (still to be initiated 2009/2010)	Unknown (Beyond 2012)
LOWER VAAL WMA	*None at present*		
UPPER ORANGE WMA	*Modder Riet Catchment Forum*	Beyond 2012	

The committees/structures established to support the CMA for the Upper Vaal WMA are listed in **Table 50**. However it must be recognised, that the other WMIs are established based on the specific needs identified or specific water resource functions that must be performed. Their non-existence could merely imply that there is no need for them at this stage as the water resource management issues in the catchment do not warrant their establishment.

11.1.2 Catchment Forums

There are 13 catchment management forums present in the Upper Vaal WMA, 2 in the Middle Vaal WMA and a forum for the Modder Riet catchment (**Table 51**). The Lower Vaal WMA has no established catchment management forums yet.

Table 51: Catchment Forums active in the Vaal River System

<table>
<tr><th>Upper Vaal WMA</th><th>Middle Vaal WMA</th><th>Modder Riet Catchment</th></tr>
<tr><td>Grootdraai Catchment Forum</td><td rowspan="13">Schoonspruit/Koekemoer Catchment Forum

Sand-Vet Catchment Forum</td><td rowspan="13">Modder Riet Catchment Forum</td></tr>
<tr><td>Vaal Dam Catchment Forum</td></tr>
<tr><td>Klip River (Free State) Catchment Forum</td></tr>
<tr><td>Waterval Catchment Forum</td></tr>
<tr><td>Wilge River Catchment Forum</td></tr>
<tr><td>Vaal Barrage Catchment Forum</td></tr>
<tr><td>Rietspruit Catchment Forum</td></tr>
<tr><td>Blesbokspruit Catchment Forum</td></tr>
<tr><td>Klip River (Gauteng) Forum</td></tr>
<tr><td>Mooi River Forum</td></tr>
<tr><td>Upper Wonderfonteinspruit Catchment Forum</td></tr>
<tr><td>Lower Wonderfonteinspruit Catchment Forum</td></tr>
<tr><td>Loopspruit Catchment Forum</td></tr>
</table>

These forums comprise interested and concerned stakeholders, as well as major water users, contributing their time and resources to ensure that water resource management issues are addressed. The catchment forums include a range of stakeholders including non-governmental organisations, catchment based organisations, other governmental departments, local authorities, provincial departments, water users, and various other organizations that are interested. Problems with representivity, participation and sustainability threaten their existence. These forums will play a central role to the CMA establishment processes, and in the implementation of CMSs and water quality management plans. These bodies could be used to achieve various water quality management goals.

11.1.3 Water User Associations

Irrigation Boards and government water schemes are currently being transformed into WUAs within the various WMAs. This process will continue and these institutions will eventually adopt their roles in terms of the NWA. The following irrigation boards, schemes and controlled areas exist in the Vaal River System (DWAF, 2002a,b &c):

<u>Upper Vaal WMA:</u>

- Mooi Government Water Scheme
- Klipdrift Management Board
- Vyfhoek Management Board
- Vaal Government Water Control Area

- Rietpoort Irrigation Board
- Koppieskraal Irrigation Board

Middle Vaal WMA

- Sand Vet Government Water Scheme (Sand)
- Sand Vet Government Water Scheme (Vet)
- Vet Government Water Scheme
- Renoster Government Water Scheme
- Weltevrede Management Board
- Vaal River Government Water Control Area
- Klerksdorp Irrigation Board

Lower Vaal WMA

- Vaalharts Irrigation Scheme
- Vaal Gamagara Regional Water Supply Scheme
- Douglas Irrigation Scheme
- Harts River Government Water Scheme

Modder-Riet Catchment

- Riet River Government Water Scheme
- Modder and Lower Riet Rivers Irrigation Scheme

11.1.4 Other Institutions

Water Boards

The following Water Boards exist in the Vaal River System. They are important institutional bodies in terms of being major water users in the system, and play a key support role to the Department in terms of monitoring of water resources, information gathering and involving the public.

Upper Vaal WMA	Middle Vaal WMA	Lower Vaal WMA	Modder Riet Catchment
Rand Water	Midvaal Water	Kalahari East Water Board	Bloem Water
Sedibeng Water (supply to QwaQwa area only)	Sedibeng Water	North West Water Supply Authority	

Municipalities

The municipalities are important institutional structures in the Vaal River System as they are responsible for water services provision and wastewater treatment. These institutional bodies are critical role players in addressing the problems currently being experienced with wastewater treatments works in the various sub-catchments within the system. They will have to be engaged through co-operative government structures as well as through the water management institutions and catchment forums, if the objectives of water resource management are to be achieved. The municipalities (metropolitan and district category) that have jurisdiction within the study area include the following:

Upper Vaal WMA:

- City of Johannesburg Metropolitan Municipality
- Ekurhuleni Metropolitan municipality
- Sedibeng District Municipality
- West Rand District Municipality
- Govan Mbeki District Municipality
- Northern Free State District Municipality
- Thabo Mofusanye District Municipality
- Southern District Municipality
- Gert Sibande District Municipality

Middle Vaal WMA:

- Lejweleputswa District Municipality
- Northern Free State District Municipality
- Southern District Municipality

Lower Vaal WMA:

- Frances Baard District Municipality
- Kgalakgadi District Municipality
- Siyanda District Municipality

Upper Orange WMA:

- Motheo District Municipality

12 CONCLUSIONS AND RECOMMENDATIONS

This status assessment has highlighted the issues that are of relevance to the development of the integrated water quality management plan for the Vaal River System into the future.

12.1 Summary of the situation as it exists

From this water quality status assessment task, a spectrum of problems have been identified with regard to the current water quality in the Vaal River. Some issues are related to the whole length of the Vaal River while others are of a localised nature. This study has confirmed that increase in salinity (and related macro ions) has had the greatest impact on the usage of the water in the Vaal River. The increase in TDS and concomitant increase in constituents such as chloride and sulphate has major implications on domestic, industrial and agricultural water use. The occurrence of microbiological pollutants as localised problems are also an emerging concern, as well elevated levels of certain metals. Eutrophication is the other key water quality problem in the Vaal River System. This problem has resulted in excessive algal blooms and growth of water hyacinth. Eutrophication impacts have resulted in economic implications for users and large expenditure to control it. The effect of the extensive algal blooms and biomass upon water treatment processes and quality of potable may yet increase in significance.

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 levels are high. Of further concern is the impact of the high TDS concentrations on downstream water users below the Vaal Barrage and those abstracting from the Barrage.

Specific catchments are of concern as well in terms of their contributions 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. These catchments must ensure the development of water quality management strategies to manage the impacts originating from them, thereby alleviating the stress currently being placed on the Vaal River.

It is apparent that the status quo in terms of land based activities and water use practices cannot continue unabated as they have. Water users, major role players and the Department have to all start taking responsibility where required, to ensure the situation does not worsen, and to ensure sustainable use of the water resources. While it is accepted that socio-economic development is needed in South Africa, with the Vaal River System being a key area for this, it cannot occur at the expense of the water resource system. However this is the current situation as far as water quality is concerned. While it is also accepted that the Vaal River is highly regulated and a “hard-working” river, current unsustainable and uncontrolled practices will surely have long term consequences for future generations.

While water resource management plans are required in the Vaal River System, the situation is of a broader nature requiring much integrated and developmental planning with different tiers of the relevant government departments and various role players.

12.2 Focus areas requiring intervention

The following specific areas require some degree of immediate intervention to ensure the sustainability of the water resources in the Vaal River System:

- **Data collection, handling and management**

  The water quality data of the surface water resources data captured by the Department for the system, although exhibiting some gaps, is available and useable. However, data of the water users in the system especially wastewater discharge information from mines and wastewater treatment plants is extremely difficult to obtain, even though this is a reporting requirement of the water use authorisation.

  It is thus important that data gathering and handling and monitoring receive a high priority as such information forms the basis for water quality management within the system. This applies to all historical and future water resources related data.

- **Lack of alignment between RWQOs**

  While the effort to develop RWQOs is recognised, and the achievements made thus far especially in the Upper Vaal WMA is considered progressive, much of it has happened in isolation of the wider WMA and the Vaal River system contexts. The status assessment task has identified a lack of alignment between RWQOs between WMAs and between tributary catchments and the Vaal River. Thus while catchment objectives are being met those of the Vaal River and cascading WMAs are not. In many instances the objectives set for the identified variables of concern in the Vaal River are at a more stringent level than those of tributary catchment thereby resulting in the tributaries not meeting the management objective of the Vaal River. This is especially true for the Grootdraai to Vaal Dam reach (Waterval sub-catchment) and the Vaal Barrage reach (Klip, Rietspruit, Leeu/Taaibosspruit and Suikerbosrand/Blesbokspruit sub-catchments) of the Vaal River. In the Middle Vaal WMA, only specific variables are not aligned to the main stem objectives (ammonia and phosphate). Compliance with current RWQOs set in the Vaal River will therefore require the Vaal River having capacity available to assimilate the loads from the tributary catchments. In addition the deterioration of the water resources in some catchments of the system as well as in certain reaches of the Vaal River warrant an evaluation of RWQOs to determine their current applicability, appropriateness and effectiveness in achieving the desired water quality. This issue however is to be addressed in task 4, and will eventually result in an integrated approach.

- **Impacts of the mining activities and mine closure**

  The management of mining activities in the system is crucial to the management of water quality both in the short term to alleviate the current salt loads being released and long term to manage the impacts of mine closure and mine decants. While the complex dynamics of this situation is accepted in terms of maintaining base flows in the system, permitting active mining, and promoting wider socio-economic imperatives, a major intervention in terms of current mining development practices is required if the situation in the Vaal Barrage and Middle Vaal River is to be alleviated.

Of further concern is the final decant points within the system once all the mines within this area close and pumping ceases. This is unknown at this stage but will have future ramifications for all surrounding catchments. Closure plans need to be developed by the mines.

- **Management of wastewater treatment works discharges**

  As previously discussed, the lack of compliance of wastewater discharges from the many smaller wastewater treatment plants in the system to discharge standards is deeply concerning. This situation appears to be continuing unabated, and until such time as this matter is addressed by all the role players at the appropriate levels, water quality management goals will not be achieved. The Vaal Barrage water quality cannot be maintained or improved if this aspect is not prioritised by the local authorities of the smaller towns. The Department needs to develop an intervention strategy as this is a problem throughout the Vaal River System and in other WMAs as well.

- **Urbanisation**

  This focus area is linked to the above issue of wastewater treatment works to some degree, however it also related to the uncontrolled development and urban sprawl that is being experienced in many of the urbanised centres of the Vaal Barrage, Mooi River and Middle Vaal River catchment areas. Lack of, poor and improper planning is leading to large quantities of pollutants entering stormwater return flows which are draining to various tributaries that report to the Vaal River. This aspect as well requires an integrated planning approaches that need to be taken up with the appropriate structures if the situation is meant to improve.

- **Vaal Barrage**

  The Vaal Barrage is a key area in the system from a water quality management perspective that requires specific interventions that relate to the focus areas discussed above. If the issues in the Vaal Barrage can be addressed to some degree this will benefit downstream users and decrease the requirement for good quality water from Vaal Dam for dilution.

- **Middle Vaal River**

  While many of the water quality problems in the Middle Vaal River originate in the Vaal Barrage, this river reach is impacted on by the KOSH area. It is thus another key area of concern in the system that needs immediate intervention to alleviate some of the current stress being experienced.

- **Vaalharts Irrigation Scheme**

  The Vaalharts irrigation scheme and the Harts River Catchment need a management strategy to optimise water use and reduce the impact of irrigation return flows. While the impact of this activity is not felt beyond Douglas Barrage, it is unsustainable to continue current practices, as it does not support the principles of water quality management. The intervention strategy will require water quantity, WCWDM and water quality approaches. By improving water quality, the water may be made available to other users in the WMA.

- **Research needs**

  Making decisions with imperfect and incomplete information is never easy, and carries with it considerable risk. With funding the necessary research, it is quite possible to reduce the risks of decisions by improving our knowledge base, and especially extending our long-term studies in the Vaal River system.

  Water is fundamental resource for South Africa, and pricing mechanisms are a fundamental tool in water resource management. If we seek to develop the necessary knowledge to arrest the degradation of the river system, we need to commit more resources to understanding the functioning of aquatic ecosystems. This includes long-term research, which is not being adequately undertaken at present. The cost of research to enable the river systems to be managed in an ecological sustainable fashion should be seen as one of the costs of supplying water.

  Filling key knowledge gaps, include:

  - The sediments in the Vaal River are believed to play an important role in nitrogen removal *via* denitrification; apparently a N sink of thousands of kilogram being removed annually, and should be investigated. There is also insufficient knowledge of the behaviour of P in streams and rivers.

  - Improve our understanding of algal toxin impacts. Cyanotoxins are known to bioaccumulate in common aquatic vertebrates and invertebrates, including fish, mussels and zooplankton. Consequently, there is a considerable potential for toxic effects to be magnified in aquatic food chains. Thus, ecological studies should be undertaken to determine the bioaccumulation of algal toxins and the effect of these toxins on aquatic biota in the Vaal River. For assessing the health risk caused by cyanotoxins, an understanding of their persistence and degradation in aquatic environments is of crucial importance.

  - The detection and accurate quantification of cyanobacterial toxins are necessary to provide understanding of their occurrence and abundance and to contribute to the risk management of the Vaal River affected by cyanobacterial abundance. Research and development on methods for simple and rapid detection and treatment of algal toxins in surface waters should be given a high priority.

  - Biomonitoring – measurements of aquatic biota (mainly macro-invertebrates and fish), to identify structural or functional integrity of ecosystems, have gained acceptance for river assessment as part of the River Health Programme and should be implemented in the Vaal River system.

  - The use of alum, aluminium sulphate ($Al_2(SO_4)_3$), and calcium carbonate ($CaCO_3$) in streams or iron sulphate to reduce sediment equilibrium P concentrations and P availability requires further research on the effects of alum floc on stream habitat and biota.

  - We know that pesticide and herbicide contamination of our waters can lead to acute toxic effects on aquatic organisms. However, the extent of pesticide contamination of drinking water supplies in the Vaal River catchment is unknown and should be determined. Pesticide residue concentrations are usually low in drinking water. Nevertheless, there is some evidence that continued consumption of water containing low levels of pesticides can lead to chronic and sub-chronic illness and biological changes (Cooper *et al.*, 1996). This is a poorly researched area where evidence is not conclusive, and there have been no clinically detected effects in South Africa.

- The influence of saline groundwater on the water quality in the Vaal River should be investigated. Major saline groundwater intrusions greatly enhance the water-column clarification processes in the Murray-Darling River, which led to huge algal blooms (Oliver *et al.*, 1999).

- An accurate determination of the residence time of water in the Vaal River is important and necessary for a better understanding and management of the lotic ecosystem.

- Determine the Ecological Reserve for the Vaal River.

- **Monitoring:**

Strengthening of the water quality monitoring programme of the Vaal River is key requirement. The key for the success of these policies in providing solutions to the problems of pollution is the ability to conduct continuous and routine monitoring. Ideally, chlorophyll-*a* concentrations should be monitored weekly.

Usually, when fish kills occur, it is an emergency situation; indicating a severe environmental problem, such as low oxygen or a toxic chemical. To detect these emergency conditions, it is recommended that a computerised continuous monitoring of dissolved oxygen concentrations is implemented upstream and in the Vaal Barrage, which can serve as an early warning system.

- **Integrated management:**

Environmental and conservation issues need to be placed within the context of social and economic uses of the river by the community and therefore requires the perception of local residents, landowners, the water industry and other stakeholders to be taken into account. Science has an important role to play in the decision-making process.

Integrated management should be adaptive, constantly producing new mechanisms, ideas and tools. This can only be achieved with solutions and activities at the local level with political and managerial support. In this context education at all levels plays a fundamental and unique role. Public participation and awareness, practical focus, institutional capacity and articulation continuity, and adequate scope should be some of the essential components of integrated water management focusing on eutrophication, salinity and related issues.

12.3 Management strategies

An important rule for the management of freshwater ecosystems is to remember that the conditions, water quality and biota of any body of freshwater are the product and reflection of events and conditions in its catchment.

The effects of discharging treated sewage into freshwater ecosystems depend on the quality and quantity of the effluent, and on the condition, type, size, and resilience of the receiving ecosystems (Luger & Brown, 2002). Any discharge will result in some change in a receiving aquatic system, but different systems display different sensitivities and thus priority should be given to setting appropriate target effluent quality and quantity at each sewage works, and other point discharges based on an understanding of the resilience of, and the extent and relevance of impacts on the specific receiving environment. Phosphorus concentrations in streams generally show a sequential decrease with increasing distance from municipal WWTP effluent discharge (Haggard *et al.*, 2004).

Source reduction technologies are the only effective way of slowing water pollution from the many non-point sources such as agricultural run-off, and from point discharges such as industrial and mining wastewater.

The primary step in the reduction of eutrophication of a water body is to limit, divert or treat inputs of nutrients and associated particles (UNP, 2000). It is also the least costly way because it saves the cost of treating polluted discharge waters or cleaning up polluted natural waters. These technologies can be grouped under three broad categories, namely i) efficiency, ii) recycling, and iii) substitution.

The most effective way of treating highly saline discharges is source control, as once it enters the water resource system it is almost impossible to remove. Reduction at source may include a range of technologies however each bearing a varying degree of cost implications. However this cost needs to be measured up against the cost to the water resource.

12.3.1 Nutrient reduction

Control of eutrophication can only be reached effectively by drastic reduction of the total nutrient load of an overloaded water system. Controlling phosphorus should be the primary focus of any nutrient control strategy. Prevention is better than cure.

Although wastewater effluent is the principal contributor to the degradation of the Vaal River aquatic system, it is also one of the impacts that is most easy to mitigate. It is easy to focus on point sources because they are easily identified, measured, and susceptible to control by policies and regulation. Stormwater runoff from urban areas however also contributes to nutrient loading of the water resource system, and must also be targeted in terms of control and management.

Ugrading infrastructure:

Attention should be given by the municipalities to upgrade the sewerage infrastructures and minimise operational spillages. As a consequence, improved quality of the sewage effluent will contribute to the environmental sustainability of the Vaal River ecosystem.

Phosphate from sewage can be controlled in a number of ways in wastewater treatment works. Secondary treatment may remove about 30% – 40 % of phosphate present. However, more stringent control is provided by tertiary treatment, either biological (70% – 85 % removal depending on conditions), chemical (up to 95 % removal), or some combination of the two. A further regulatory control measure could be a limit on the use/manufacture of detergents containing phosphate. Manufacture of phosphate free detergents while involving significant investment onset will in the long term result in the elimination of the problems of trying to deal with their concentrations in wastewater.

However, internal loading (recycling) of N and P from sediments of lakes and reservoirs can sustain eutrophic conditions for long periods after external loading is reduced (UNP, 2000). Though, the effect in rivers could be less pronounced because on an annual basis, streams and rivers usually retain only a small fraction of the dissolved and particulate nutrients that enter the system (UNP, 2000).

Chemical treatment:

Sediments play a significant role in the process of eutrophication of water bodies. Control/recovery of nutrients inputs contained in the sediment may be delayed due to the elevated levels (UNP, 2000), but chemical remediation may be used to reduce sediment P flux.

The use of alum may be a viable option to treat and reduce elevated levels of readily exchangeable sediment P in impacted streams, such as downstream from WWTPs. Alum has successfully reduced P concentrations and loads in WWTP effluent and urban stormwater runoff (Harper, *et al.*, 1998). The addition of alum and $CaCO_3$ significantly reduced the sediment equilibrium P concentrations and readily exchangeable P, while increasing the ability of sediments to buffer increasing P loads (Haggard *et al.*, 2004).

However, P has been reduced by 96 % through the addition to the treatment process of ferrous chloride. Thus, alum or iron chloride treatment of streams may be feasible option to mitigate P release from benthic sediments after external P sources are reduced.

Biological filters:

Establishment of artificial wetlands at waste water treatment plants must seriously be considered – this ecological purification process is economical and could be a useful alternative way of treating sewage in rural areas, smaller towns and townships.

Establishment of riparian buffers for the control and mitigation the impact of non-point source pollutant loading (e.g. modern agriculture) into surface water. Numerous studies have shown the effectiveness of riparian buffers in reducing sediments, pathogen, and nutrient loads into surface and groundwater in agricultural catchments. A riparian buffer is defined as an area of permanent vegetation adjacent to a water body or wetland managed for the purpose of removing pollutants from runoff or groundwater. A wetland riparian system on the River Lambourn, a tributary of the River Kennet (tributary of Thames River, England), successfully removed up to 85 % of total nitrogen and up to 70 % of total phosphorus from runoff.

However, as point sources are brought under control, the relative contribution from diffuse sources can become increasingly important (Mainstone & Parr, 2002).

12.3.2 Flow manipulation

Flow manipulation appears to be a most promising area for management of eutrophication in rivers because it addresses both of the key drivers of algal blooms: water residence time and stratification (Davis & Koop, 2001, 2006). Much greater attention needs to be given to flow management to provide flushing flows, to reduce pollution levels, and endeavouring to provide flows that are closer to the natural situation. Based on the relationship between discharge, stratification, and bloom formation, three strategies to minimize the occurrence or impacts of cyanobacterial blooms in weir pools are suggested.

<u>Discharge volume:</u>

River flows can be used to break the stratification in weir pools and so remove the advantage that buoyant nuisance species of algae possess as well as preventing anoxic conditions from becoming established in bottom waters. This technique has been trialled with success in some inland rivers of the Murray-Darling catchment (Webster ***et al.***, 2000; Davis & Koop, 2006).

Sherman ***et al.*** (1998) found that there was a threshold flow of approximately 1 000 Mℓ/d (depth-average velocity = 6 cm/s) that governed the thermal stratification ; flow/velocities less than this corresponded to persistent stratification and a surface mixed layer typically 1 – 2 m deep, whereas greater flow/velocities caused complete mixing of the water-column at least once per day. Increase in discharge to more than 1 500 Mℓ/d produced complete mixing of the water-column (Webster ***et al.***, 2000). Flows >4 000 Mℓ/d kept the weir pool well mixed at all times (Sherman ***et al.***, 1998).

In the Vaal River, a minimum discharge of 2 500 – 3 000 Mℓ/d (30 – 35 m^3/s) from the Barrage during summer is suggested to prevent cyanobacterial blooms in the middle section of the river. Maintaining reasonable flow rates in the Vaal River is also important for the ecology processes in the system. The average discharge from the Vaal Barrage during the last four years was 25 m^3/s, with the median at 20 m^3/s.

<u>Pulsed discharge:</u>

The maintenance of the discharge at a volume sufficient to destroy persistent stratification during the summer may require the release of more water than is available or more than is economically feasible. However, it may be possible to minimise near-surface cyanobacterial accumulations by pulsing the discharge on a periodic basis (Webster ***et al.***, 2000).

A discharge pulse of sufficient size and duration to cause complete mixing of the water column would also mix the algae uniformly. If the pulse were to be repeated before the cyanobacteria have the opportunity to float back into the euphotic zone, then their growth advantage would be reduced. A second benefit of a pulsed discharge strategy is that it would cause reoxygenation of bottom waters in the weir pool if they had been significantly depleted of oxygen by respiration processes in the sediments and bottom waters. The desired time between discharges pulses to control cyanobacterial blooms is about 3 days (Webster ***et al.***, 2000).

Based on the above field studies, a discharge of 3 500 – 4 500 Mℓ/d (~40 – 50 m^3/s) every 3 – 5 days are suggested for the Vaal River during bloom forming periods. Under these conditions the flow velocity would probably be >0.75 m/s, which means that the flow in the river will change from laminar to turbulent flow with the appropriate effect.

Flush discharge:

Diatoms usually form winter blooms and cyanobacteria summer blooms. Once a bloom has developed (>100 µg/ℓ), a flush discharge of 7 500 ± 1 000 Mℓ/d (~75 – 100 m^3/s) for 3 days from the Barrage would probably be sufficient to dilute and flush the bloom to acceptable concentration levels (Chlorophyll-***a*** <50 µg/ℓ). Use of this strategy depends on the availability of water.

Artificial destratification:

Artificial destratification was observed to reduce the internal nutrient load by about 85 % and algal biomass was much lower during the years following artificial destratification (NEMP, 2000). Because buoyant cyanobacteria are favoured by stable water column conditions, a management technique for preventing cyanobacterial blooms in weir pools in the Vaal River could be artificial destratification. Several studies have shown that artificial mixing prevents nuisance blooms of cyanobacteria in hypertrophic lakes and chlorophyll concentrations were also much lower in the mixed lakes (Visser ***et al.***, 1996; Donnelly ***et al.***, 1998).

12.3.3 Salinity reduction

While parts of the the Vaal River System exhibits high levels of salinity, it is believed that the peak of the problem has been largely reached. Thus what is now required is fervent control and reduction measures to ensure that the impacts can be alleviated and mitigated where possible. While economic growth and development in the system is expected to occur, it is expected that the salinity loads will not increase massively as this development is not expected to involve major industrial developments or mine development. Much of the projected development in the WMAs is expected to focus on the tertiary economy – *viz.* service related industries. Currently a "handle" on the system has been achieved and current modelling systems in place are adequate to predict system behaviour – which at this stage does not indicate any further significant risk. The issue at hand is thus implementation of measures to deal with the current high salinity concentrations and to manage any further deterioration.

Under current trends, future system wide salinity impacts will be small and thus it will be feasible to contain or reduce them at the major 'hotspot' areas within the catchment. The high cost of salinity prevention and rehabilitation will however be a major determining factor in the protection or remediation of water resources in the catchment.

The current situation requires that in different parts of the Vaal River System, decisions will need to be made regarding three approaches to salinity management:

- To attempt to reverse it;

- To limit its rate of increase; or
- To let it take its course.

A "business as usual" approach is no longer acceptable. Control of the rise in salt loads in tributary catchments and that of the system at large, is required to protect the water resources and aquatic ecosystems at agreed levels, and to ensure the requirements of agricultural, domestic, industrial and recreational users are met.

Salinity is best managed at source, and in most cases with point discharges being key contributors to the problem in the Vaal River, effective results are achieved through policy and regulation. However any significant improvement to the current salinity levels observed in the system will require ardent efforts by dischargers to manage the problem at source. Drainage from irrigated areas (non-point sources), are also key contributers to the salt loads in the Vaal River, and management measures have to be implemented to manage this run-off from these areas (especially in the Lower Vaal River). The use of appropriate and effective management practices for both point and non-point source impacts will be the driving force in managing salinity impacts.

While it is envisaged that the implementation of the Waste Discharge Charge System (WDCS) as a regulatory measure would provide an incentive for improved source management, any concerted effort to prevent any further deterioraton of the Vaal River will require a strategic approach that encompasses various aspects to address the problems of salinity at hand. These include amongst others:

- Implementation of highly focussed programmes at catchment or sub-catchment level such as increased regulatory control, improved catchment drainage initiatives, salinity monitoring programmes, treatment schemes; mitigation measures, etc.
- A targeted approach is expected to achieve better results sooner and with more dramatic outcomes than if funds and efforts are spread out resulting in slow and insignificant salinity improvements;
- Management solutions need to be big enough to ensure the efforts focussed on salinity reduction meet the desired salinity targets. The effects on the system need to be substantial enough to warrant the effort and cost implications;
- The solutions adopted must take into account economic, social and ecological impacts, of both technical/scientific and engineering approaches for salinity reduction or containment;
- Working in government-private partnerships, catchment partnerships, local communities, co-operative governance, industry and local government "teams" are central to achieving any significant changes to current salinity levels;
- Support to research and development programmes and initiatives into treatment technologies and approaches that focus on salinity control and reduction is required.

Some control of salinity maybe achieved through the following measures and consideration of the above-mentioned aspects must be taken in account when the final options are determined:

Regulatory Control

The continued application of source control measures through water use authorisations, Environmental Management Programme Reports and Environment Impact Assessment processes, is a easy way to to identify, measure, and monitor impacts. Regulatory control could imply stricter wastewater discharge standards dependent on the “salinity load targets” set for the sub-catchment/Vaal River. This would be dependent on the RWQOs established and on the objectives of the CMS for each WMA.

In addition economic incentives such as the WDCS or similar systems could also form the basis of the regulatory control for management of salinity.

Greater enforcement and compliance monitoring is required by the regulator if changes are to be seen. The lack of or decrease in “policing” and monitoring is partly responsible for the non-compliance that is observed..

Mitigatory Measures (Treatment)

A possible option to manage the current salinity loads would be investments in treatment schemes. Treatment of saline waters is expensive, with high capital and operating costs, however this option becomes more viable if regional schemes/catchment schemes are considered. Desalinasition is a consideration however the costs-benefits to the users and the system still need to be quantified. The treatment and handling of the brine also becomes an issue. However such schemes must be justified in terms of the benefit derived in terms of the water resource, and costs incurred.

Reuse and recycling

The reuse of mine water and the recycling of wastewater plant effluent is becoming a sustainable option to supplementing the water demands of many users. This option is becoming very favourable especially with regards to neighbouring WMAs that are currently water stressed (Olifants and Corocodile-West Marico). Here again, the recovery of pumping and treatment costs would be the determining factor.

The possible use of recycled water for the development of resource poor farming projects is a further management option to be considered. This option supports the National imperative of poverty eradication and links to the principle of sustainable management.

An important consideration in the reuse and recycling of wastewater discharges is their possible impact to the system in terms of reduced return flows. This would be a critical factor in the overall water balance of the system, as much of the downstream flow is dependent on return flows.

Continued dilution

Salinity levels of the Vaal River can continue to be managed by the current dilution rule, where water is released from Vaal Dam to maintain the levels of TDS at 600 mg/l in Vaal Barrage and in the downstream WMAs. This option although is to some extent alleviating the situation it is not well regulated or managed and is not reaching the desired objective. In addition, the release of good quality water is considered to be unsustainable, and the RWQO of 600 mg/l of TDS is also considered unfair to downstream users, in terms of meeting their water quality requirements.

The possibility of diluting TDS concentrations below 600mg/l, versus the status quo will be investigated, to determine the benefits to the system.

12.4 Relationship to future tasks

The results of this status assessment task, although forming a basis for all future tasks, has direct linkages to the following future tasks:

- Task 3: Salinity Balance
- Task 4: Integration of RWQOs
- Task 6: Evaluation of Management options
- Task 7: Monitoring Programme.

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14 GLOSSARY OF TERMS

Alkalinity The buffer capacity of a water body.

Allocatable water quality The maximum worsening change in any water quality attribute away from its present value that maintains it within a pre-determined range reflecting the desired future state (typically defined by resource quality objectives). If the present value is already at or outside the pre-determined range, this indicates that none is allocatable and that (a) reduced pollution loads relating to the affected attribute(s) and/or (b) remediation of the resource may be necessary.

Assimilative capacity This represents the ability of the receiving environment to accept a substance without risk

Bioaccumulation Build up of a pollutant in the body of an aquatic organism by uptake food of and directly from surrounding water.

Biological diversity It refers to the variety of elements at different levels of biological organisation, ranging from genetic through population, community, and ecosystem to landscape levels that characterize natural ecosystems.

Biota The sumof living organisms of any designated area.

Catchment In relation to a watercourse or watercourses or part of a watercourse, means the area from which any rainfall will drain into the watercourse or watercourses or part of a watercourse, means the area form which any rainfall will drain into the watercourse or watercourses or part of a watercourse, through surface flow to a common point or common points.

Cyanobacteria A division of photosynthetic bacteria, formerly known as blue-green algae, that can produce strong toxins.

Denitrification The biological reduction of NO_3 or NO_2 or gaseous nitrogen oxides.

Diffuse sources See non-point sources

DO Dissolved oxygen concentration in water (mg/ℓ or % saturation).

Ecological integrity (health) The ‘health’ or condition of an ecosystem. i.e. the ability of the ecosystem to support and maintain key ecological processes and organisms so that their species composition, diversity and functional organisations are as comparable as possible to those occurring in natural habitats within a region.

Euphotic zone Is defined at the depth at which light intensity of the photoynthetically active spectrum (400-700nm) equals 1% of the subsurface light intensity. Thus the zone in which photosynthesis can occur.

Eutrophication The process of enrichment of waters with plant nutrients, primarily phosphorus, causing abundant aquatic plant and algal growth.

Fitness for use A scientific judgement, involving objective evaluation of available evidence, of how suitable the quality of water is for its intended use or for protecting the health of aquatic ecosystems.

Heavy metals Metallic elements with high atomic weights e.g copper, mercury, chromium, cadmium, arsenic or lead. Heavy metals can damage living things at low concentrations and tend to accumulate in the food chain.

Internalisation of externalities Externalities, also called external costs, spill-overs or social costs, are costs generated by a producer but paid for by someone else. A typical example is a water user that discharges polluted water into a stream. The downstream user may then need to treat the water before it can be used. This treatment in effect means that the downstream user is paying the production costs of the upstream user. Internalising these externalities means the polluter should be responsible for these costs.

MIB 2-methylisoborneol, an odorous compound produced by algae and fungi.

Monitoring The measurement, assessment and reporting of selected properties of water resources in a manner that is focussed on well-defined objectives. These monitoring objectives should also be clearly linked to water resource management objectives.

Nitrate reduction The conversion of nitrate to ammonium ($NO_3 \rightarrow NH_4$).

Nitrification The biological oxidation of ammonium to nitrate ($NH_4^+ \rightarrow NO_3$) with nitrite (NO_2) as an intermediate in the reaction sequence.

Non-point sources Diffuse discharges that over large areas and multi-point sources

Pollution Defined by the National Water Act as the direct or indirect alteration of the physical, chemical or biological properties of a water resource so as to make it:

(1) Less fit for any optimal water use for which it may reasonably be expected to be used, or

(2) Harmful or potentially harmful to (a) the welfare, health or safety of human beings, (b) any aquatic or non-aquatic organisms, (c) the resource quality or (d)

to property.

Point sources Direct discharges through discrete conveyance systems to water bodies.

Preliminary classification An interim classification of a water resource established din the absence of the formal classification system required by Section 12 of the National Water Act. A preliminary classification is permitted in terms of Section 14.

Preliminary resource quality objectives An interim resource quality objective established in the absence of the formal classification system required by Section 12 of the National Water Act. Preliminary resources quality objectives are permitted in terms of Section 14.

Retention/Residence Time Is the time required for the water to move through the lake or time to fill the lake, or to replace all the water in the lake

Reserve Defined by the National Water Act as the quantity and quality of water required:

1. to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act (Act No. 108 of 1997), for people who are now or who will in the reasonably near future, be (a) relying upon, (b) taking water from or (c) being supplied from, the relevant water source; and
2. To protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource.

Resource quality Includes all aspects of water quantity, water quality and aquatic ecosystem quality, the latter including the quality of in-stream and riparian habitats and aquatic biota.

Resource quality objectives (RQOs) Numeric or descriptive (narrative) goals for resource quality within which a water resource must be managed. These are given legal status by being published in a government Gazette.

Resource water quality objectives (RWQOs) Spatially and temporally incremental in-stream (or in-aquifer) water quality objectives that:

1. Give effect to the water quality component RQOs and
2. May equal these gazetted RQOs but are more often set at a finer resolution (spatial or temporal), and
3. Dictate the tolerable level of impact collectively produced by upstream users.

Salinisation Is the process by which the concentration of dissolved solids in inland waters is increased.

Stakeholder	An individual, group or organisation that has an interest in, or is affected by, an initiative and who may therefore affect the outcome of an initiative.
Stressed water resource	A water resource for which the demand for benefits exceeds the supply. This can apply to either the quantity of water or the allocatable water quality.
Sustainability	"… to meet the needs of the present without compromising the ability of future generations to meet their own needs."
TDS	Total dissolved solids – a measure the inorganic salts (and organic compounds) dissolved in water.
Toxicant	A chemical capable of producing an adverse response (effect) in a biological system at concentrations that might be encountered in the environment, seriously injuring structure or function or producing death. Examples include pesticides, heavy metals and biotoxins.
TSS (SS)	Total suspended solids concentration is a measure of the amount of material suspended in water, which includes a wide range of sizes of material, from cooloids (0.1 µm) through to large organic and inorganic particulates.
Waste	Defined by the National Water Act as including any solid material or material that is suspended, dissolved or transported in water (including sediment) and which is spilled or deposited on land or into a water resource in such volume, composition or manner as to cause, or to be reasonably likely to cause, the water resource to be polluted.
Watercourse	Defined by the National Water Act as a river or spring, a natural channel in which water flows regularly or intermittently, a wetland, lake or dam into which, or from which, water flows and any collection of water that the Minister may declare to be a watercourse. Furthermore, reference to a watercourse includes, where relevant, its bed and banks.
Wastewater Treatment Plant (WWTP)	Any device or system used to treat (including recycling and reclamation) either domestic wastewater or a combination of domestic wastewater and industrial waste of a liquid nature.
Water quality	The physical, chemical, radiological, toxicological, biological and aesthetic properties of water that (1) determine its fitness for use or (2) that are necessary for protecting the health of aquatic ecosystems. Water quality is therefore reflected in (a) concentrations of substances (either dissolved or suspended), (b) physicochemical attributes (e.g. temperature), (c) levels of radioactivity and (d) biological responses to those concentrations,

	physicochemical attributes or radioactivity.
Water resource	Defined by the National Water Act including a watercourse, surface water, estuary or aquifer.
Water Use Authorisation	An entitlement to undertake a water use in terms of the National Water Act (Act No. 36 of 1998). An authorisation may be a water use license, permissible under a general authorisation, an existing lawful water use, or a Schedule I water use.

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APPENDIX A

SUMMARY INFORMATION FROM PREVIOUS WATER QUALITY STUDIES

List of previous studies that were consulted for the status assessment task and IWQMP Study as a whole

No	Title	Document No	Author	Date
1	**Vaal River Water Quality Management Study**			
1.1	Practical Implications of the Blending Option	P C000/00/2885	Stewart Sviridov & Oliver	1985
1.2	Optimum utilisation of purified effluent in the region north of the Witwatersrand	P C000/00/3185	Stewart Sviridov & Oliver	1985
1.3	Water Quality Modelling of the Vals and Renoster Rivers	P C000/00/8688	Stewart Sviridov & Oliver	1988
1.4	Evaluation of the flow, water quality and atmospheric deposition networks in the upper Vaal catchment	P C000/00/8889	Stewart Sviridov & Oliver	1988
1.5	Preliminary investigation of the cost of reducing peak TDS concentrations in the supply to the Western Transvaal Regional Water Company, OFS Goldfields Water Board and Kimberley Municipality by means of desalination	P C000/00/8588	Stewart Sviridov & Oliver	1988
1.6	Preliminary estimation of the impact of air pollution on the water quality in the Vaal Dam	P C000/00/8989	Stewart Sviridov & Oliver	1989
1.7	A 1989 review of the report by JJC Heynike for the purpose of cost benefits analysis by the Department of Water Affairs and Forestry		SRK Consulting	1989
1.8	Preliminary evaluation of options for improving the Quality of the Water Supplied to Christiana	PC 000/00/9189	Stewart Sviridov& Oliver	November 1989
1.9	Blending options for the Western Transvaal Regional Water Company and the OFS Goldfields Water Board based on Rietfontein Dam and Klipbank Dams	PC 000/00/8788	Stewart Sviridov& Oliver	July 1989
1.10	Kromdraai Dam Option	P C000/00/9089	Stewart Sviridov & Oliver	1990
1.11	Summary of the data acquisition and assimilation carried out by the consultants for the southern PWV catchment	P C000/00/10190	Stewart Sviridov & Oliver	1991
2	**Vaal River System Analysis Update**			

No	Title	Document No	Author	Date
2.1	Vaal River System Analysis Update: Hydro-salinity model calibration: Upper Vaal catchment	P C000/00/18096	BKS/Stewart Scott/ Ninham Shand	1998
2.2	Vaal River System Analysis Update: Hydro-Salinity Model Calibration: Vaal Barrage Catchment	PC 000/00/18196	DWAF	April 1998
2.3	Vaal River System Analysis Update: Hydro-salinity model calibration: Middle Vaal catchment	P C000/00/18296	BKS/Stewart Scott/ Ninham Shand	1999
Other Reports				
3	An assessment of water related problems of the Vaal River between Barrage and Douglas Weir	TR 121	DWAF	
4	Surface Water Quality of South Africa (1979 – 1988) Volume 3: Drainage Region C and D	(TR 145)	DWAF	1990
5	An investigation of a New Operating Strategy for the Vaal River System: The potential effects on the eutrohpication of the Middle Vaal River (Vol.2)	NC 200/00RPQ/2790	G Quibell	March 1991
6	The development of techniques for the evaluation and effective management of surface and groundwater contamination in the Orange Free State Goldfields	WRC Report No 224/1/92)	Institute for Ground Water Studies – University of the OFS	1992
7	Assessment of the feasibility and impact of alternative water pollution control options on TDS Concentrations in the Vaal Barrage and Middle Vaal	WRC Report No.326/1/93	JAC Cowan & P Skivinngton	Sep 1993
8	Vaal River Liason Forum	C000/00/0193	DWAF	1993
9	Vaal River – Life Blood of a Nation		DWAF	1993
10	Middle Vaal River Catchment. Water Quality Management Plan. Situation Analyses of Eutrophication related Water Quality	E/C200/00/0191	DWAF	January 1995
11	Vaal Barrage Catchment - Water Quality Management Plan Phase 1: Scoping Report	WQ C220/00/01/96	Rand Water & DWAF	April 1996
12	Water Quality Impact Assessment of Johannesburg's Southern Wastewater Treatment Works on the Klip River: Evaluation of the Quantity and Quality of purified effluent discharged from Johannesburg's Southern Drainage Basin Wastewater Treatment Works (Volume 4)	WW C0065-04-00-0896	Pulles Howard and de Lange, Greater Johannesburg Transitional Metropolitan Council and Stewart	August 1996

No	Title	Document No	Author	Date
			Scott	
13	Water Quality Impact Assessment of Johannesburg's Southern Wastewater Treatment Works on the Klip River: Land Use/ Diffuse Pollution Source Relationships(Part 1), Klip River Water Quality Situation Analysis (Part 2), Point and Diffuse Source Pollution load projections (Volume 6)	WW C0065-06-00-0896	Pulles Howard and de Lange, Greater Johannesburg Transitional Metropolitan Council and Stewart Scott	August 1996
14	Mooi river Catchment Management Study: Phase 1 - Situation Analyses	16/14/231/1	DWAF	October 1998
15	Development of a Waste Water Quality Management Plan for the Klip River Catchment: Phase 1 - Situation Analysis	WQ C221/3/1	DWAF	August 1999
16	A Catchment Management Plan for the Schoonspruit and Koekermoerspruit Catchments. Phase 1: Surface Water		Pulles, Howard and De Lange	March 2002
17	Catchment Management Strategy for the Modder and Riet Rivers (Water quality Assessment) Draft Report	Draft	BKS	May 2002
18	Upper Vaal WMA: Water Resources Situation Assessment	P WMA 08/000/00/0101	Stewart Scott	July 2002
19	Middle Vaal WMA: Water Resources Situation Assessment	P WMA 09/000/00/0101	Stewart Scott	August 2002
20	Lower Vaal WMA: Water Resources Situation Assessment	P WMA 10/000/00/0101	Stewart Scott	November 2002
21	Upper Vaal WMA: Overview of Water Resources Availability and Utilisation	P WMA 08/000/00/0203	BKS	September 2003
22	Middle Vaal WMA: Overview of Water Resources Availability and Utilisation	P WMA 09/000/00/0203	BKS	September 2003
23	Lower Vaal WMA: Overview of Water Resources Availability and Utilisation	P WMA 10/000/00/0203	BKS	September 2003
24	Internal Strategic Perspective for the Vaal River System: Overarching	P RSA C 000/00/0103	PDNA,WRP, WMB and Kwezi-V_3	March 2004
25	Internal Strategic Perspective for the Upper Vaal WMA	P WMA 08/000/00/0304	PDNA, WRP, WMB, and Kwezi-V_3	March 2004
26	Internal Strategic Perspective for the Middle Vaal WMA	P WMA 09/000/00/0304	PDNA, WRP, WMB, and Kwezi-V_3	July 2004
27	Internal Strategic Perspective for the Lower Vaal WMA	P WMA 10/000/00/0304	PDNA, WRP, WMB, and Kwezi-V_3	October 2004
28	Grootdraai Catchment Water Quality Situation Assessment (Draft)	5005/6965/2/W	Golder Associates	February 2006
Study Reports still to be obtained				

No	Title	Document No	Author	Date
1	Sand Vet Study Report	Draft		
2	Modder Riet CMS	Draft		
3	Waterval Situation Assessment	Draft		

A SUMMARY OF PREVIOUS STUDIES/REPORTS

This report lists the recommendations that were made in previous studies done on the Vaal River System as captured in various reports. However, where it is known that further action did take place a note is given in *italic font* to explain the current status of the particular recommendation.

The studies that are summarised in this Chapter are as listed below:

- Vaal River Water Quality Management Study
- Issues from several Water Quality Studies and reports.

1 VAAL RIVER WATER QUALITY MANAGEMENT STUDY

1.1 Practical Implications of the Blending Option

- The study recommended the blending option of water from the Vaal Dam and Vaal Barrage in order to prevent the TDS concentration of water supplied to consumers from rising above a set standard (proposed at 300mg/l).

This recommendation has been implemented, however the current set standard of TDS of 600 mg/l needs to be relooked at. This is needed to benefit the water users in the Middle Vaal catchment.

1.2 Water Quality Modelling of the Vals and Renoster Rivers

- A general recommendation was made regarding the modelling of river flows and water qualities *viz.* to model both simultaneously to enable the identification of inherent problems in the flow data, which are not evident when runoff is being modelled in isolation

This recommendation has been implemented in terms of the Integrated Vaal River System Water Resources Planning Model (WRPM) that has been configured to simulate both water quantity and salinity (TDS).

1.3 Evaluation of the flow, water quality and atmospheric deposition networks in the upper Vaal catchment

- The report contains detailed recommendations for improving the streamflow and water quality monitoring network in the Upper Vaal catchment. These recommendations are listed in order of priority. Some recommendations for upgrading the atmospheric deposition monitoring network have also been included.

Recommendations on the different monitoring networks must be reviewed to determine what measures have been taken and those that could still be adopted for the catchment. The monitoring of atmospheric deposition appeared to be of specific concern.

1.4 Preliminary estimation of the impact of air pollution on the water quality in the Vaal Dam

- The study proved to have various recommendations regarding the impact of atmospheric deposition on the Vaal Dam. These included:
  - The improvement of the database (as recommended by the study 'Evaluation of the flow, water quality and atmospheric deposition networks in the upper Vaal catchment' – listed above);
  - Improvement of the estimation of atmospheric deposition loads;
  - Determination of the fate of atmospherically deposited pollutants;
  - The undertaking of further modelling studies (short term and long term); and
  - The undertaking of a multi-disciplinary research project to understand the effect of atmospheric pollution on the water resources of the Vaal Dam catchment. It was recommended that this study should bring together the disciplines of hydrological, water quality and atmospheric modelling, and that of soil chemistry.

The impact of atmospheric deposition in the Vaal catchment needs to be given further consideration.

1.5 Kromdraai Dam Option

- The objective of the study was to:

Determine the improvement in the mineral water quality of the Middle Vaal by considering the option of building on a new dam on the Vaal River on the farm, Kromdraai; and

ii. To determine the improvement in water quality if the entire PWV demand was drawn directly from the Vaal Dam with no recycling of effluent.

The recommendations emanating from the study included the following:

- The system operation should be improved (further model simulation to develop operating rules);
- There should be phasing of the LHWP (model simulations should be carried out to determine delay of later phases of LHWP);
- The cost of implementation of the dam option must be re-evaluated;
- Modelling should be undertaken to determine the likely eutrophic status and its effect further downstream;
- Conjunctive use should be considered;
- Verification of the estimates of the costs associated with salination of the water supply to urban and industrial consumers should be undertaken, and
- The PWV zero recycling option should not be implemented.

1.6 Optimum Utilisation of Purified Effluent in the Region North of the Witwatersrand

- This report assessed the economic attractiveness of five options for the recycling of treated sewage effluent for domestic use, *via* the Vaal Dam. This was to make a realistic comparison between the Lesotho Highlands Water Project (LHWP) and alternative augmentation schemes for the Vaal Dam.

  Based on a number of assumptions, it was concluded that the fifth option was the most cost effective. This option is described below:

  - "Option 5 entails the commissioning in 1999 of a pipeline to convey Johannesburg Northern Sewage Works effluent to a tributary of the Kip River, followed in 2000 by a second pipeline transferring Kempton park effluent to the Blesbokspruit. The purpose of the scheme is to delay (by two years relative to Option 1) the commissioning dates for phases IB, II and III of the LHWP (The consultants were instructed to assume that the commissioning date of Phase IA is fixed at 1995). In all other respects, Option 5 is identical to Option 1 (*i.e.* blending of Vaal Dam and Vaal Barrage water to prevent peak TDS concentrations in the RWB (Rand Water Board) supply water from exceeding 300 mg/ℓ."

1.7 Preliminary Investigation of the Cost of reducing peak TDS concentrations

- This report was a desk study on the feasibility of reducing the salinity of water using reverse osmosis (RO) at the raw water intakes of the Western Transvaal Regional Water Company, the OFS Goldfields Water Boards and the Kimberley Municipality.
  - The study could not demonstrate conclusively that treatment using RO was beneficial to consumers and thus no recommendations were made.

1.8 Summary of the data acquisition and assimilation carried out by the consultants

- The study looked into the areas of overlap between the DWAF and the consultants, Stewart, Sviridov and Oliver with regards to the acquisition and assimilation of streamflow, water abstraction, effluent return flow and water quality data collected for the Vaal River Salinity Study.
- The report includes main types of data collected by Stewart, Sviridov and Oliver; the areas of overlap of data collection programmes and identifies those data items only collected by Stewart, Sviridov and Oliver,
- No recommendations were made.

2 VAAL RIVER SYSTEM ANALYSIS UPDATE: HYDRO-SALINITY MODEL CALIBRATION: MIDDLE VAAL CATCHMENT

2.1 UPPER VAAL CATCHMENT

- The objective of re-calibrating the WQT model for the Upper Vaal catchment was successfully achieved. The study made the following recommendations aimed at improving the confidence with which the salinity regime of the Upper Vaal catchment can be simulated:
  - Improvement of monitoring systems;
  - Improvement of models;
  - Improvement of hydrological modelling;
  - Modelling of the effect of atmospheric deposition; and
  - Additional investigations needed into the significance of diffuse pollution in the Blesbokspruit and Kafferspruit catchments.

2.2 MIDDLE Vaal catchment

- The study included the following conclusions:
  - Data inconsistencies and geographical limitations proved to be a problem.
  - Calibration of the sub-catchments proved to be difficult in many cases, due to a lack of adequate flow and water quality data or to the dolomitic nature of the catchments and the influences of the gold mines.
  - Releases from the Vaal Barrage exert an enormous influence on the hydro-salinity regime of the Middle Vaal, both in terms of flow and salt load.
  - Calibration of the hydrological model showed a poor fit between observed releases from Vaal Barrage and Bloemhof Dam and better results were achieved at the main observation points using simulated Barrage outflows.
  - Successful calibrations were achieved at critical gauges in the system and results were adequate for the purpose of simulating general trends in the salinity regime of the Middle Vaal catchment.

3 SURFACE WATER QUALITY OF SOUTH AFRICA: VOLUME 3: DRAINAGE REGION C AND D

- This report presents an overview of the quality of South Africa's water resources in terms of the water quality variables, TDS, sodium adsorption ration, pH and phosphate between the period 1979 –1988
- Although no specific recommendations were made, the following conclusions were drawn:

- The surface water quality for drainage region C was suitable for most uses in terms of TDS and irrigation quality in the south-eastern parts of the drainage region (included the Vaal River catchment upstream of the Vaal Dam [C100], the Vet river catchment [C400], the Renoster river catchment [C700] and the Wilge river catchment [C800]).
- In the Harts river catchment (C300) and parts of the Vaal river catchment between the Bloemhof Dam and the Vaal Dam (C210, C220, C230) the water proved to be only marginally suitable for use in terms of TDS. The irrigation quality thus proved to be problematic as well.
- In terms of pH the water in the entire C drainage region appeared to be suitable for most uses.
- Phosphate concentrations proved to problematic in the Suikerboschrand River (C210) and upstream of the Vaal Barrage (C220).
- In general the surface water quality of drainage region D was found to be suitable for most uses in terms of TDS, pH and irrigation quality.

The above conclusions need to be verified to confirm their applicability in the current situation.

4 THE DEVELOPMENT OF TECHNIQUES FOR THE EVALUATION AND EFFECTIVE MANAGEMENT OF SURFACE AND GROUNDWATER CONTAMINATION IN THE ORANGE FREE STATE GOLDFIELDS

- Some conclusions derived from the study included the following:
  - Contamination of surface and subsurface water resources by municipal, industrial and mining activities, throughout the area has taken place and is currently still happening. The current situation has improved though due to preventative actions being taken by responsible organizations.
  - Contamination of ground water resources is generally contained within close proximity of the polluting sites. Although the risk of pollution in the Orange Free State Gold Fields is relatively large due to the abundance of pollution sources, the vulnerability of ground water resources in this region is relatively small due to favourable geological conditions.
  - Evaporation pans and dams currently pose a large pollution potential. Currently the spread of pollution around the slimes dams appear to be limited, however they do pose a long-term pollution threat.
  - Detailed geohydrological investigations as well as risk assessment of environmental effects will have to be done.
- Recommendations proposed in the report are as follows:
  - The implementation of pollution prevention measures in future (better planning)
  - There should be more emphasis on financial provisions by mines for remediation measures;
  - There should be more effective implementation of the legislation.

5 VAAL RIVER LIASON FORUM

This report contains a collection of papers presented at the Vaal River Liaison Forum on the 16 November 2003 (Riviera International Hotel).

Various aspects were discussed, with the issues relating to water quality summarized below (conclusions drawn):

- Need effective WQM policy to meet the challenge of maintaining fitness for use of the country's water resources.
- The management plan for the Vaal system must take account of both yield and water quality and address the system as a whole.
- Investigations into the impact of atmospheric deposition on the Upper Vaal catchment must be undertaken.
- The viability of the 600 mg/l Barrage blending option as a solution for the Middle Vaal needs to be determined and compared with the Rietfontein and Klipbank Dam options.
- The effect of the evaporation concentration in the 280km long river reach between the Vaal Barrage and the Goldfield Water raw intakes need to be investigated.
- The influence of other sources of dissolved solids (effluents and dewatering of mines) will have to be studied in greater detail.
- The return flows must also be investigated.
- The salt balance of the Vaalharts irrigation scheme must be quantified.
- Other approaches to preventing salt from entering the Vaal river system to be considered – stricter effluent standards; direct reclamation of saline effluents and separation and disposal of highly saline effluent streams in evaporation pans. – Need to consider economic impacts of these measures
- Impact of water quality in Vaal River system on neighbouring catchments must be taken into consideration when developing a management strategy (could have international consequences – Vaal River System – Crocodile River – Limpopo River).

Options to manage eutrophication in the Middle Vaal River must be investigated.

APPENDIX B

RESOURCE WATER QUALITY OBJECTIVES OF THE SUB-CATCHMENTS IN THE UPPER VAAL WMA

Level 1: Sub-unit 1 - Grootdraai catchment (VS1, VS2 and VS3)

Variable	Measured as	Ideal	Acceptable	Tolerable	Unacceptable
Conductivity	mS/m	< 10	10 - 15	15 - 25	> 25
Alkalinity ($CaCO_3$)	mg/l	< 20	20 - 45	45 - 75	> 75
pH	pH units				< 6.4 & > 8.5
Phosphate (PO_4)	mg/l	< 0.05	0.05 - 0.08	0.08 - 1	> 1
Sulphate (SO_4)	mg/l	< 10	10 - 20	20 - 30	> 30
Nitrate (NO_3)	mg/l	< 0.05	0.05 - 0.25	0.25 - 0.50	> 0.50
Ammonia (NH_4)	mg/l	< 0.02	0.02 - 0.5	0.5 - 1	> 1
SAR		< 4	4 - 8	8 - 12	> 12
Chloride (Cl)	mg/l	< 10	10 - 15	15 - 20	> 20
Chemical Oxygen Demand (COD)	mg/l	< 10	10 - 15	15 - 25	> 25

Level 1: Sub-unit 2 - Grootdraai catchment (VS4)

Variable	Measured as	Ideal	Acceptable	Tolerable	Unacceptable
Conductivity	mS/m	< 15	15 - 30	30 - 50	> 50
Alkalinity ($CaCO_3$)	mg/l	< 40	40 - 70	70 - 100	> 100
pH	pH units				< 6.4 & > 8.5
Phosphate (PO_4)	mg/l	< 0.05	0.05 - 0.25	0.25 - 0.50	> 0.50
Sulphate (SO_4)	mg/l	< 15	15 - 35	35 - 50	> 50
Nitrate (NO_3)	mg/l	< 0.05	0.05 - 0.25	0.25 - 0.50	> 0.50
Ammonia (NH_4)	mg/l	< 0.02	0.02 - 0.5	0.5 - 1	> 1
SAR		< 4	4 - 8	8 - 12	> 12
	mg/l	< 10	10 - 20	20 - 30	> 30
Chemical Oxygen Demand (COD)	mg/l	< 10	10 - 20	20 - 35	> 35

Level 1: Sub-unit 3 - Vaal Dam (VS 5 and VS6)

Variable	Measured as	Ideal	Acceptable	Tolerable	Unacceptable
Ammonia (NH_4)	mg/l	< 0.2	0.2 - 0.5	0.5 - 1.0	> 1.0
Chemical Oxygen Demand (COD)	mg/l	< 10	10 - 15	15 - 20	> 20
Chloride (Cl)	mg/l	< 25	25 - 50	50 - 75	> 75
Conductivity	mg/l	< 10	10 - 30	30 - 45	> 45
Faecal coliforms	per 100 ml	< 10	10 - 60	60 - 120	> 120
Fluoride (F)	mg/l	< 0.05	0.05 - 0.20	0.20 - 0.40	> 0.40
M - Alkalinity ($CaCO_3$)	mg/l	< 40	40 - 75	75 - 120	> 120
Nitrate (NO_3)	mg/l	< 0.1	0.1 - 0.2	0.2 - 0.3	> 0.3
pH	pH units	6.5 - 8.5			< 6.5 & > 8.5
Phosphate (PO_4)	mg/l	< 0.05	0.05 - 0.25	0.25 - 0.50	> 0.50
SAR		< 4	4 - 8	8 - 12	> 12
Sulphate (SO_4)	mg/l	< 20	20 - 45	45 - 70	> 70

Level 1: Sub-unit 4 - Vaal Barrage (VS7 and VS8)

Variable	Measured as	Ideal	Acceptable	Tolerable	Unacceptable
Physical					
Conductivity	mS/m	< 18	18 - 30	30 - 70	> 70
Dissolved Oxygen (O_2)	mg/l		> 6	5 - 6	< 5
pH	mg/l	7.0 - 8.4	6.5 - 8.5	9.0 - 9.0	< 6.0 & > 9.0
Suspended Solids	mg/l	< 20	20 - 30	30 - 55	> 55
Organic					
Atrazine	ug/l	< 5	5 -10	10 - 20	> 20
Chemical Oxygen Demand (COD)	mg/l	< 10	10 - 20	20 - 30	> 30
Phenols	mg/l		< 0.01	0.01 - 0.1	> 0.1
Macro Elements					
Aluminium (Al)	mg/l		< 0.3	0.3 - 0.5	> 0.5
Ammonia (NH_4)	mg/l		< 0.5	0.5 - 1.0	> 1.0
Chloride (Cl)	mg/l	< 5	5 - 50	50 - 75	> 75
Fluoride (F)	mg/l	< 0.19	0.19 - 0.70	0.70 - 1.00	> 1.00
Iron (Fe)	mg/l		< 0.5	0.5 - 1.0	> 1.0
Magnesium (Mg)	mg/l	< 8	8 - 30	30 - 70	> 70
Manganese (Mn)	mg/l		< 0.15	0.15 - 0.20	> 0.20
Nitrate (NO_3)	mg/l	< 0.5	0.5 - 3.0	3.0 - 6.0	> 6.0
Phosphate (PO_4)	mg/l		< 0.03	0.03 - 0.05	> 0.05
Sodium (Na)	mg/l	< 15	15 - 50	50 - 100	> 100
Sulphate (SO_4)	mg/l	< 20	20 - 100	100 - 200	> 200
Bacteriological					
Faecal coliforms	counts/100 ml		< 126	126 - 1000	< 1000
Biological					
Daphnia	% survival	100	90 - 100	80 - 90	< 80

Level 1: Sub-unit 5 - Downstream Vaal Barrage (VS9)

Variable	Measured as	Ideal	Tolerable
Conductivity	mS/m	30	68
Sodium (Na)	mg/l	40	50
Sulphate (SO_4)	mg/l	80	140
Chloride (Cl)	mg/l	50	50
Nitrate (NO_3)	mg/l	0.7	0.7
Phosphate (PO_4)	mg/l	0.077	0.2
Boron (B)	mg/l	0.12	0.2
Fluoride (F)	mg/l	0.5	0.5
Manganese (Mn)	mg/l	0.1	0.15
Phenols	mg/l	0.004	0.01
pH	pH units	6.5 - 8.4	6.5 - 8.4
Ammonia (NH_4)	mg/l	0.015	0.07
Iron (Fe)	mg/l	0.1	0.2
Aluminium (Al)	mg/l	0.03	0.15

Level 1: Sub-unit 6 – Middle Vaal (VS10 to V15)

Variable	Measured as	Acceptable
Physical		
Conductivity	mS/m	90
pH	pH units	6.5 - 8.4
Suspended Solids	mg/l	75
Organic		
Chemical Oxygen Demand (COD)	mg/l	75
Macro Elements		
Aluminium (Al)	mg/l	0.01
Ammonia (NH_4)	mg/l	0.1
Chloride (Cl)	mg/l	100
Nitrate (NO_3)	mg/l	3
Phosphate (PO_4)	mg/l	0.03
Sodium (Na)	mg/l	70
Silica (diatoms)		To be determined
Sulphate (SO_4)	mg/l	250
Total Dissolved Salts (TDS)	mg/l	630
Bacteriological		
Faecal coliforms	counts/100 ml	1
Biological		
Daphnia	% survival	90 - 100
Algae	mg/l Chl-a	0.001*

* to be confirmed through eutrophication assessment task

Level 1: Sub-unit 7 - Lower Vaal (VS 16 - VS 20)

Variable	Measured as	Acceptable
Physical		
Conductivity	mS/m	120
pH	pH units	6.5 - 8.4
Suspended Solids	mg/l	75
Organic		
Chemical Oxygen Demand (COD)	mg/l	75
Macro Elements		
Aluminium (Al)	mg/l	0.01
Ammonia (NH_4)	mg/l	0.1
Calcium (Ca)	mg/l	53
Chloride (Cl)	mg/l	100
Magnesium (Mg)	mg/l	41
Nitrate (NO_3)	mg/l	3
Phosphate (PO_4)		0.04
Sodium (Na)	mg/l	70
Sulphate (SO_4)	mg/l	250
Total Dissolved Salts (TDS)	mg/l	840
Bacteriological		
Faecal coliforms	counts/100 ml	1
Biological		
Daphnia	% survival	90 - 100
Algae	mg/l Chl-a	0.001*

* to be confirmed through eutrophication assessment task

Level 2: Sub-unit 1 - Vaal Origin

Variable	Measured as	Ideal	Acceptable	Tolerable	Unacceptable
Conductivity	mS/m	< 10	10 - 15	15 - 25	> 25
Alkalinity ($CaCO_3$)	mg/l	< 20	20 - 45	45 - 75	> 75
pH	pH units				< 6.4 & > 8.5
Phosphate (PO_4)	mg/l	< 0.05	0.05 - 0.08	0.08 - 1	> 1
Sulphate (SO_4)	mg/l	< 10	10 - 20	20 - 30	> 30
Nitrate (NO_3)	mg/l	< 0.05	0.05 - 0.25	0.25 - 0.50	> 0.50
Ammonia (NH_4)	mg/l	< 0.02	0.02 - 0.5	0.5 - 1	> 1
SAR		< 4	4 - 8	8 - 12	> 12
Chloride (Cl)	mg/l	< 10	10 - 15	15 - 20	> 20
Chemical Oxygen Demand (COD)	mg/l	< 10	10 - 15	15 - 25	> 25

Level 2: Sub-unit 2 - Schulpspruit

Variable	Measured as	Ideal	Acceptable	Tolerable	Unacceptable
Conductivity	mS/m	< 10	10 - 15	15 - 25	> 25
Alkalinity ($CaCO_3$)	mg/l	< 20	20 - 45	45 - 75	> 75
pH	pH units				< 6.4 & > 8.5
Phosphate (PO_4)	mg/l	< 0.05	0.05 - 0.08	0.08 - 1	> 1
Sulphate (SO_4)	mg/l	< 10	10 - 20	20 - 30	> 30
Nitrate (NO_3)	mg/l	< 0.05	0.05 - 0.25	0.25 - 0.50	> 0.50
Ammonia (NH_4)	mg/l	< 0.02	0.02 - 0.5	0.5 - 1	> 1
SAR		< 4	4 - 8	8 - 12	> 12
Chloride (Cl)	mg/l	< 10	10 - 15	15 - 20	> 20
Chemical Oxygen Demand (COD)	mg/l	< 10	10 - 15	15 - 25	> 25

Level 2: Sub-unit 3 - Blesbokspruit

Variable	Measured as	Ideal	Acceptable	Tolerable	Unacceptable
Conductivity	mS/m	< 15	15 - 30	30 - 50	> 50
Alkalinity ($CaCO_3$)	mg/l	< 40	40 - 80	80 - 120	> 120
pH	pH units				< 6.4 & > 8.5
Phosphate (PO_4)	mg/l	< 0.05	0.05 - 0.25	0.25 - 0.50	> 0.50
Sulphate (SO_4)	mg/l	< 15	15 - 35	35 - 50	> 50
Nitrate (NO_3)	mg/l	< 0.05	0.05 - 0.25	0.25 - 0.50	> 0.50
Ammonia (NH_4)	mg/l	< 0.02	0.02 - 0.5	0.5 - 1	> 1
SAR		< 4	4 - 8	8 - 12	> 12
Chloride (Cl)	mg/l	< 25	25 - 50	50 - 70	> 70
Chemical Oxygen Demand (COD)	mg/l	< 10	10 - 20	20 - 35	> 35

Level 2: Sub-unit 4 - Leeuspruit

Variable	Measured as	Ideal	Acceptable	Tolerable	Unacceptable
Conductivity	mS/m	< 15	15 - 30	30 - 50	> 50
Alkalinity ($CaCO_3$)	mg/l	< 40	40 - 70	70 - 100	> 100
pH	pH units				< 6.4 & > 8.5
Phosphate (PO_4)	mg/l	< 0.05	0.05 - 0.25	0.25 - 0.50	> 0.50
Sulphate (SO_4)	mg/l	< 15	15 - 35	35 - 50	> 50
Nitrate (NO_3)	mg/l	< 0.05	0.05 - 0.25	0.25 - 0.50	> 0.50
Ammonia (NH_4)	mg/l	< 0.02	0.02 - 0.5	0.5 - 1	> 1
SAR		< 4	4 - 8	8 - 12	> 12
Chloride (Cl)	mg/l	< 10	10 - 20	20 - 30	> 30
Chemical Oxygen Demand (COD)	mg/l	< 10	10 - 20	20 - 35	> 35

Level 2: Sub-unit 5 - Klip River Catchment (Free State)

Variable	Measured as	Ideal	Acceptable	Tolerable	Unacceptable
Ammonia (NH_4)	mg/l	< 0.2	0.2 - 0.5	0.5 - 1.0	> 1.0
Chemical Oxygen Demand (COD)	mg/l	< 10	10 - 15	15 - 20	> 20
Chloride (Cl)	mg/l	< 25	25 - 50	50 - 75	> 75
Conductivity	mg/l	< 10	10 - 30	30 - 45	> 45
Faecal coliforms	per 100 ml	< 10	10 - 60	60 - 120	> 120
Fluoride (F)	mg/l	< 0.05	0.05 - 0.20	0.20 - 0.40	> 0.40
M - Alkalinity ($CaCO_3$)	mg/l	< 40	40 - 75	75 - 120	> 120
Nitrate (NO_3)	mg/l	< 0.1	0.1 - 0.2	0.2 - 0.3	> 0.3
pH	pH units	6.5 - 8.5			< 6.5 & > 8.5
Phosphate (PO_4)	mg/l	< 0.05	0.05 - 0.25	0.25 - 0.50	> 0.50
SAR		< 4	4 - 8	8 - 12	> 12
Sulphate (SO_4)	mg/l	< 20	20 - 45	45 - 70	> 70

Level 2: Sub-unit 6 - Waterval River Catchment

Variable	Measured as	Ideal	Acceptable	Tolerable
Conductivity	mS/m	40	90	370
pH upper	pH units	8.4	9	10
pH lower	pH units	6.5	5	4
Nitrate (NO_3)	mg/l	0.5	2.5	10
Fluoride (F)	mg/l	0.7	1	1.5
Sulphate (SO_4)	mg/l	60	100	200
Sodium (Na)	mg/l	50	100	200
Potassium (K)	mg/l	25	50	100
Magnesium (Mg)	mg/l	23	50	70
Calcium (Ca)	mg/l	80	150	300
Chloride (Cl)	mg/l	75	150	300
Ammonia (NH_4)	mg/l	0.025	0.3	0.8
Nitrite	mg/l	0.06	0.25	5
Orthophosphate	mg/l	0.005	0.025	0.25
Total Hardness	CaCO3 mg/l	200	300	600
Sodium Adsorption Ratio	units	3	6	12
Faecal Coliforms	CFU/100ml	1	600	2000

Level 2: Sub-unit 7 - Wilge River

Variable	Measured as	Ideal	Acceptable	Tolerable	Unacceptable
Conductivity	mS/m	< 10	10 - 30	30 - 45	> 45
Alkalinity ($CaCO_3$)	mg/l	< 30	30 - 80	80 - 120	> 120
pH	pH units	> 6.4 - 8.5	> 6.4 - 8.5	> 6.4 - 8.5	> 6.4 - 8.5
Phosphate (PO_4)	mg/l	< 0.05	0.05 - 0.15	0.15 - 0.3	> 0.3
Sulphate (SO_4)	mg/l	< 5	5- 10	10 - 15	> 15
Nitrate (NO_3)	mg/l	< 0.1	0.1 - 0.2	0.2 - 0.3	> 0.3
Ammonia (NH_4)	mg/l	< 0.05	0.05 - 0.1	0.1 - 0.2	> 0.2
Fluoride (F)	mg/l	< 0.05	0.05 - 0.1	0.1 - 0.2	> 0.2
Chloride (Cl)	mg/l	< 5	5 - 10	10 - 15	> 15
Chemical Oxygen Demand (COD)	mg/l	< 5	5 - 15	15 - 25	> 25

Level 2: Sub-unit 8 - Blesbokspruit Catchment

Variable	Measured as	Ideal	Acceptable	Tolerable	Unacceptable
Physical					
Conductivity	mS/m	< 45	45 - 70	70 - 120	> 120
Dissolved Oxygen (O_2)	mg/l		> 6	5 - 6	> 5
pH	mg/l	6.5 - 8.5			< 6.5 & > 8.5
Suspended Solids	mg/l	< 20	20 - 30	30 - 55	> 55
Organic					
Chemical Oxygen Demand (COD)	mg/l	< 20	20 - 35	35 - 55	> 55
Macro Elements					
Aluminium (Al)	mg/l		< 0.3	0.3 - 0.5	> 0.5
Ammonia (NH_4)	mg/l	< 0.1	0.1 - 1.5	1.5 - 5.0	> 5.0
Chloride (Cl)	mg/l	< 80	80 - 150	150 - 200	> 200
Fluoride (F)	mg/l	< 0.19	0.19 - 0.70	0.70 - 1.00	> 1.00
Iron (Fe)	mg/l	< 0.1	0.1 - 0.5	0.5 - 1.0	> 1.0
Magnesium (Mg)	mg/l	< 8	8 - 30	30 - 70	> 70
Manganese (Mn)	mg/l	< 0.2	0.2 - 0.5	0.5 - 1.0	> 1.0
Nitrate (NO_3)	mg/l	< 0.5	0.5 - 3.0	3.0 - 6.0	> 6.0
Phosphate (PO4)	mg/l	< 0.2	0.2 - 0.4	0.4 - 0.6	> 0.6
Sodium (Na)	mg/l	< 70	70 - 100	100 - 150	> 150
Sulphate (SO_4)	mg/l	< 150	150 - 300	300 - 500	> 500
Bacteriological					
Faecal coliforms	counts/100 ml		< 126	126 - 1000	> 1000
Biological					
Daphnia	% survival	100	90 - 100	80 - 90	< 80

Level 2: Sub-unit 9 - Klip River Catchment (Gauteng)

Variable	Measured as	Ideal	Acceptable	Tolerable	Unacceptable
Physical					
Conductivity	mS/m	< 80	80 - 100	100 - 150	> 150
Dissolved Oxygen (O_2)	mg/l		> 6	5 - 6	< 5
pH	mg/l	6.0 - 9.0			< 6.0 & > 9.0
Suspended Solids	mg/l	< 20	20 - 30	30 - 55	> 55
Organic					
Chemical Oxygen Demand (COD)	mg/l	< 15	15 - 30	30 - 40	> 40
Macro Elements					
Ammonia (NH_4)	mg/l	< 0.5	0.5 - 1.5	1.5 - 4.0	> 4.0
Chloride (Cl)	mg/l	< 50	50 - 75	75 - 100	> 100
Fluoride (F)	mg/l	< 0.19	0.19 - 0.70	0.70 - 1.00	> 1.00
Iron (Fe)	mg/l	< 0.5	0.5 -1.0	1.0 - 1.5	> 1.5
Manganese (Mn)	mg/l	< 1	1.0 - 2.0	2.0 - 4.0	> 4
Nitrate (NO_3)	mg/l	< 2	2.0 - 4.0	4.0 - 7.0	> 7
Phosphate (PO_4)	mg/l	< 0.2	0.2 - 0.5	0.5 - 1.0	> 1.0
Sodium (Na)	mg/l	< 50	50 - 80	80 - 100	> 100
Sulphate (SO_4)	mg/l	< 200	200 - 350	350 - 500	> 500
Bacteriological					
Faecal coliforms	counts/100 ml	< 1000	1000 - 5000	5000 - 10 000	> 10 000
Biological					
Daphnia	% survival	> 95	95 - 90	90 - 80	< 80

Level 2: Sub-unit 10.1 - Taaibosspruit Catchment

Variable	Measured as	Ideal	Acceptable	Tolerable	Unacceptable
Physical					
Conductivity	mS/m	< 42	42 - 60	60 - 70	> 70
Dissolved Oxygen (O_2)	mg/l		> 6	5 - 6	< 5
pH	mg/l		7.0 - 8.5	7.0 - 9.0	< 7.0 & > 9.0
Suspended Solids	mg/l	< 27	27 - 50	50 - 90	> 90
Organic					
Chemical Oxygen Demand (COD)	mg/l	< 10	10 - 15.0	15 - 20	> 20
Macro Elements					
Aluminium (Al)	mg/l	< 0.15	0.15 - 0.50	0.50 - 1.00	> 1.00
Ammonia (NH_4)	mg/l	< 0.25	0.25 - 0.50	0.50 - 1.00	> 1.00
Chloride (Cl)	mg/l	< 50	50 - 60	60 - 75	> 75
Fluoride (F)	mg/l	< 0.40	0.40 - 0.70	0.70 - 1.00	> 1.00
Iron (Fe)	mg/l	< 0.4	0.4 - 0.5	0.5 - 0.8	> 0.8

Magnesium (Mg)	mg/l	< 8	8 - 30	30 - 70	> 70
Manganese (Mn)	mg/l	< 0.2	0.2 - 0.5	0.5 - 1.0	> 1.0
Nitrate (NO_3)	mg/l	< 0.5	0.5 - 3.0	3.0 - 6.0	> 6.0
Phosphate (PO_4)	mg/l	< 0.2	0.2 - 0.4	0.4 - 0.6	> 0.6
Sodium (Na)	mg/l	< 70	70 - 100	100 - 150	> 150
Sulphate (SO_4)	mg/l	< 150	150 - 300	300 - 500	> 500
Bacteriological					
Faecal coliforms	counts/100 ml		< 126	126 - 1000	> 1000
Biological					
Daphnia	% survival	100	90 - 100	80 - 90	< 80

Level 2: Sub-unit 10.2 - Leeuspruit Catchment

Variable	Measured as	Ideal	Acceptable	Tolerable	Unacceptable
Physical					
Conductivity	mS/m	< 45	45 - 70	70 - 120	> 120
Dissolved Oxygen (O_2)	mg/l		> 6	5 - 6	< 5
pH	mg/l	6.5 - 8.5			< 6.5 & > 8.5
Suspended Solids	mg/l	< 20	20 - 30	30 - 55	> 55
Organic					
Chemical Oxygen Demand (COD)	mg/l	< 20	20 - 35	35 - 55	> 55
Macro Elements					
Aluminium (Al)	mg/l		< 0.3	0.3 - 0.5	> 0.5
Ammonia (NH_4)	mg/l	< 0.1	0.1 - 1.5	1.5 - 5.0	> 5.0
Chloride (Cl)	mg/l	< 80	80 - 150	150 - 200	> 200
Fluoride (F)	mg/l	< 0.19	0.19 - 0.70	0.70 - 1.00	> 1.00
Iron (Fe)	mg/l	< 0.1	0.1 - 0.5	0.5 - 1.0	> 1.0
Magnesium (Mg)	mg/l	< 8	8 - 30	30 - 70	> 70
Manganese (Mn)	mg/l	< 0.2	0.2 - 0.5	0.5 - 1.0	> 1.0
Nitrate (NO_3)	mg/l	< 0.5	0.5 - 3.0	3.0 - 6.0	> 6.0
Phosphate (PO_4)	mg/l	< 0.2	0.2 - 0.4	0.4 - 0.6	> 0.6
Sodium (Na)	mg/l	< 70	70 - 100	100 - 150	> 150
Sulphate (SO_4)	mg/l	< 150	150 - 300	300 - 500	> 500
Bacteriological					
Faecal coliforms	counts/100 ml		< 126	126 - 1000	> 1000
Biological					
Daphnia	% survival	100	90 - 100	80 - 90	< 80

Level 2: Sub-unit 10.3 - Kromelemboogspruit Catchment

Variable	Measured as	Ideal	Acceptable	Tolerable	Unacceptable
Physical					
Conductivity	**mS/m**	< 18	18 - 30	30 - 70	> 70
Dissolved Oxygen (O_2)	mg/l		> 6	5 - 6	< 5
pH	mg/l	7.0 - 8.4	6.5 - 8.5	9.0 - 9.0	< 6.0 & > 9.0
Suspended Solids	mg/l	< 27	27 - 50	50 - 90	> 90
Organic					
Chemical Oxygen Demand (COD)	mg/l	< 10	10 - 20	20 - 30	> 30
Macro Elements					
Aluminium (Al)	mg/l		< 0.3	0.3 - 0.5	> 0.5
Ammonia (NH_4)	mg/l		< 0.5	0.5 - 1.0	> 0.1
Chloride (Cl)	mg/l	< 5	5 - 50	50 - 75	> 75
Fluoride (F)	mg/l	< 0.19	0.19 - 0.70	0.70 - 1.00	> 1.00
Iron (Fe)	mg/l		< 0.5	0.5 - 1.0	> 1.0
Magnesium (Mg)	mg/l	< 8	8 - 30	30 - 70	> 70
Manganese (Mn)	mg/l		< 0.15	0.15 - 0.20	> 0.20
Nitrate (NO_3)	mg/l	< 0.5	0.5 - 3.0	3.0 - 6.0	> 6.0
Phosphate (PO_4)	mg/l		< 0.03	0.03 - 0.05	> 0.05
Sodium (Na)	mg/l	< 15	15 - 50	50 - 100	> 100
Sulphate (SO_4)	mg/l	< 20	20 - 100	100 - 200	> 200
Bacteriological					
Faecal coliforms	counts/100 ml		< 126	126 - 1000	< 1000
Biological					
Daphnia	% survival	100	90 - 100	80 - 90	< 80

Level 2: Sub-unit 11 - Rietspruit Catchment

Variable	Measured as	Ideal	Acceptable	Tolerable	Unacceptable
Aluminium (Al)	mg/l	< 0.15	0.15 - 0.30	0.30 - 0.50	> 0.50
Ammonia (NH_4)	mg/l	< 0.25	0.25 - 5.0	5 - 10	> 10
Chemical Oxygen Demand (COD)	mg/l	< 20	20 - 30	30 - 55	> 55
Chloride (Cl)	mg/l	< 50	50 - 100	100 - 150	> 150
Conductivity	mg/l	< 30	30 - 70	70 - 100	> 100
Faecal coliforms	per 100 ml	< 131	131 - 4000	4000 - 10 000	> 10 000
Fluoride (F)	mg/l	< 0.2	0.2 - 0.4	0.4 - 0.8	> 0.8
Iron (Fe)	mg/l	< 0.1	0.1 - 0.5	0.5 - 1.0	> 1.0
Manganese (Mn)	mg/l	< 0.1	0.1 - 0.3	0.3 - 0.5	> 0.5
Nitrate (NO_3)	mg/l	< 1	1 - 3	3 - 6	> 6
pH	pH units	6.5 - 8.5			< 6.5 & > 8.5

Phosphate (PO_4)	mg/l	< 0.25	0.25 - 0.50	0.50 - 1.00	> 1.00
Sodium (Na)	mg/l	< 40	40 - 70	70 - 100	> 100
Sulphate (SO_4)	mg/l	< 100	100 - 200	200 - 300	> 300

Level 2: Sub-unit 12 - Mooi River

Variable	Measured as	Water Quality Objective
pH	pH units	8
Conductivity	mg/l	57
Total Dissolved Salts (TDS)	mg/l	370.5
Ammonia (NH_4)	mg/l	0.03
Nitrate (NO_3)	mg/l	0.3
Fluoride (F)	mg/l	0.25
Sodium (Na)	mg/l	47
Magnesium (Mg)	mg/l	30
Phosphate (PO_4)	mg/l	0.4
Sulphate (SO_4)	mg/l	75
Chloride (Cl)	mg/l	36
Calcium (Ca)	mg/l	47
Aluminium (Al)	mg/l	0.18
Manganese (Mn)	mg/l	0.03
Iron (Fe)	mg/l	0.35

Level 2: Sub-unit 13 - Middle Vaal, Schoonspruit and Koekemoerspruit Catchments

Variable	Measured as	Ideal	Acceptable	Tolerable	Unacceptable
pH	pH units	6.5 - 8.5			< 6.5 & > 8.5
Sulphate (SO_4)	mg/l	< 100	100 - 200	200 - 400	> 400
Total Dissolved Salts (TDS)	mg/l	< 200	200 - 400	400 - 600	> 600
Sodium (Na)	mg/l	< 70	70 - 100	100 - 200	> 200
Chloride (Cl)	mg/l	< 50	50 - 100	100 - 150	> 150
Manganese (Mn)	mg/l	< 0.05	0.05 - 0.1	0.1 - 0.3	> 0.3
Magnesium (Mg)	mg/l	< 30	30 - 100	100 - 500	> 500
Aluminium (Al)	mg/l	< 0.15	0.15 - 0.30	0.30 - 0.5	> 0.5
Ammonia (NH_4)	mg/l	< 0.25	0.25 - 1.0	1.0 - 5.0	> 5.0
Phosphate (PO_4)	mg/l	< 0.2	0.2 - 0.4	0.4 - 1.0	> 1.0
Faecal coliforms	counts/100 ml	< 150	150 - 200	200 - 1000	> 1000
Fluoride (F)	mg/l	< 0.7	0.7 - 1.0	1.0 - 2.0	> 2.0
Nitrate (NO_3)	mg/l	< 0.2	0.2 - 1.0	1.0 - 3.0	> 3.0
Iron (Fe)	mg/l	< 0.1	0.1 - 0.5	0.5 - 1.0	> 1.0
SAR		< 1.5	1.5 - 3.0	3.0 - 5.0	> 5.0

Level 2: Sub-units 14,15,16,17 and 18

Rhenoster/Vierfontein (14), Vals (15), Makwassie (16), Sandspruit (17) and Sand/Vet (18) Catchments

Variable	Units	Acceptable Range					
Management Unit		13	14	15	16	17	18
Nitrate	(mg/l)	0.2-1.0	0.6	2.0	3.5	0.9	Awaiting RWQOs from study
Ammonia	(mg/l)	0.25 -1.0	0.15	0.15	0.14	0.2	
Sulphate	(mg/l)	100-200	40	120	38	60	
Chloride	(mg/l)	50-100	30	100	52	107	
EC	(mS/m)	31-62	45	98	69	94	
TDS	(mg/l)	200-400	293	637	449	611	
Phosphate	(mg/l)	0.2-0.4	0.2	1.0	0.1	0.4	

Level 2: Sub-units 19 and 20

Harts (19) and Modder Riet (20) Catchment

Variable	Units	Acceptable Range:	
Management Unit		**19**	**20**
Nitrate	(mg/l)	3	Awaiting RWQOs from study
Ammonia	(mg/l)	0.1	
Sulphate	(mg/l)	250	
Chloride	(mg/l)	100	
EC	(mS/m)	120	
TDS	(mg/l)	840	
Phosphate	(mg/l)	0.04	

APPENDIX C

RESULTS OF ANALYSIS OF THE PRELIMINARY WATER QUALITY ASSESSMENT CONDUCTED DURING INCEPTION PHASE TO IDENTIFY VARIABLES OF CONCERN

Identification of water quality variables of concern

During the inception phase of the study the following was undertaken, in order to identify the water quality variables of concern and areas of focus of the study,:-

- The resource water quality objectives (RWQO) that have been set for the Vaal River System were collected by using the Rand Water web site, contact with the staff at the Regional Offices of the Department and by means of water quality situation assessment reports. The RWQO define categories of water quality as ideal, acceptable, tolerable and unacceptable. If RWQO are not available at certain points, the most sensitive user requirements based on the South African water quality guidelines (SAWQGs) were used as the ideal water quality.

- The water quality data from the Department's databases was accessed for key points on the main tributaries of the Vaal and along the main stem of the Vaal River. The water quality data was used to determine the in-stream water quality status of various water quality variables. The spread of the in stream water quality data analysed was represented as box and whisker plots which were based on the 5^{th}, 25^{th}, 50^{th}, 75^{th} and 95^{th} percentile data values.

- The in-stream water quality status of the variables was then compared to the available RWQOs to determine the water quality variables of concern.

- The water quality variables of concern that have been identified from this process are total dissolved solids (electrical conductivity), sulphate and nutrients as they relate to eutrophication and dissolved organic carbon. The percentiles are plotted as box and whisker plots alongside the RWQO's in Figures 1, 2 and 3 below, for sulphate, phosphate and EC (indicative of TDS) respectively. These plots allow the measured instream water quality to be compared to the RWQOs and highlight the extent of the compliance.

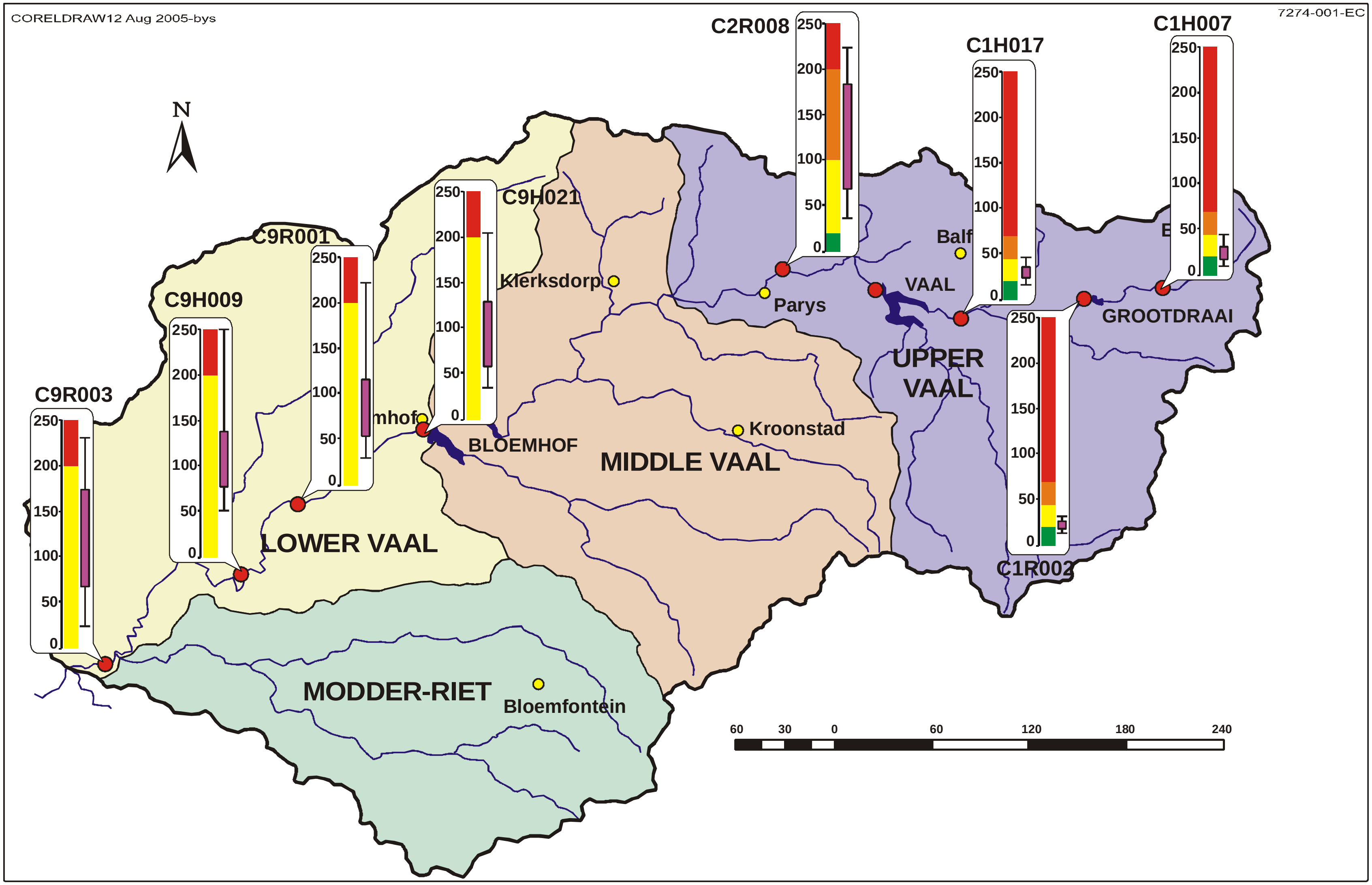

Figure 1: **In-stream water quality status of sulphate along the Vaal River compared to the RWQOs**

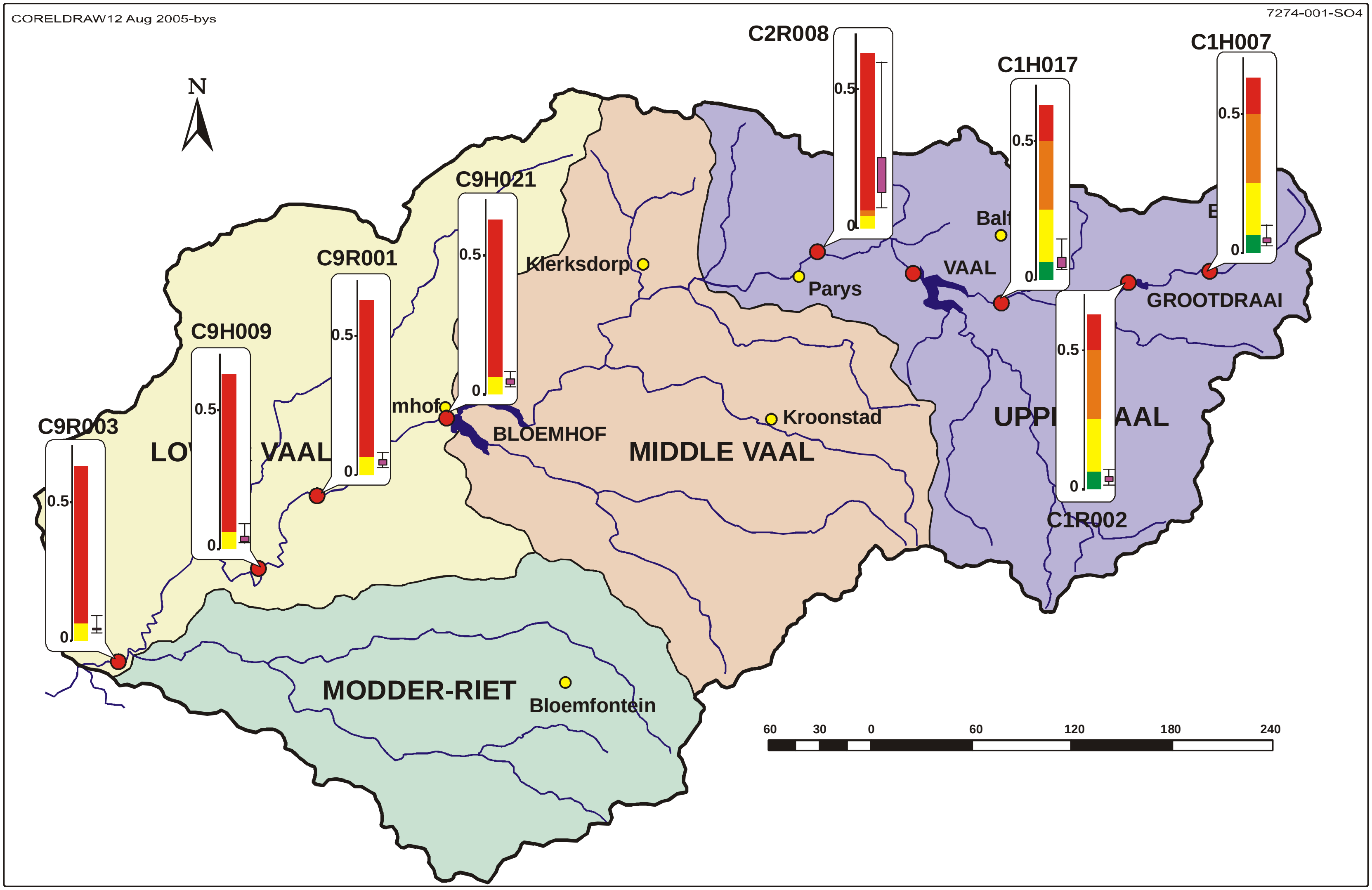

Figure 2: In-stream water quality status of phosphate along the Vaal River compared to the RWQOs

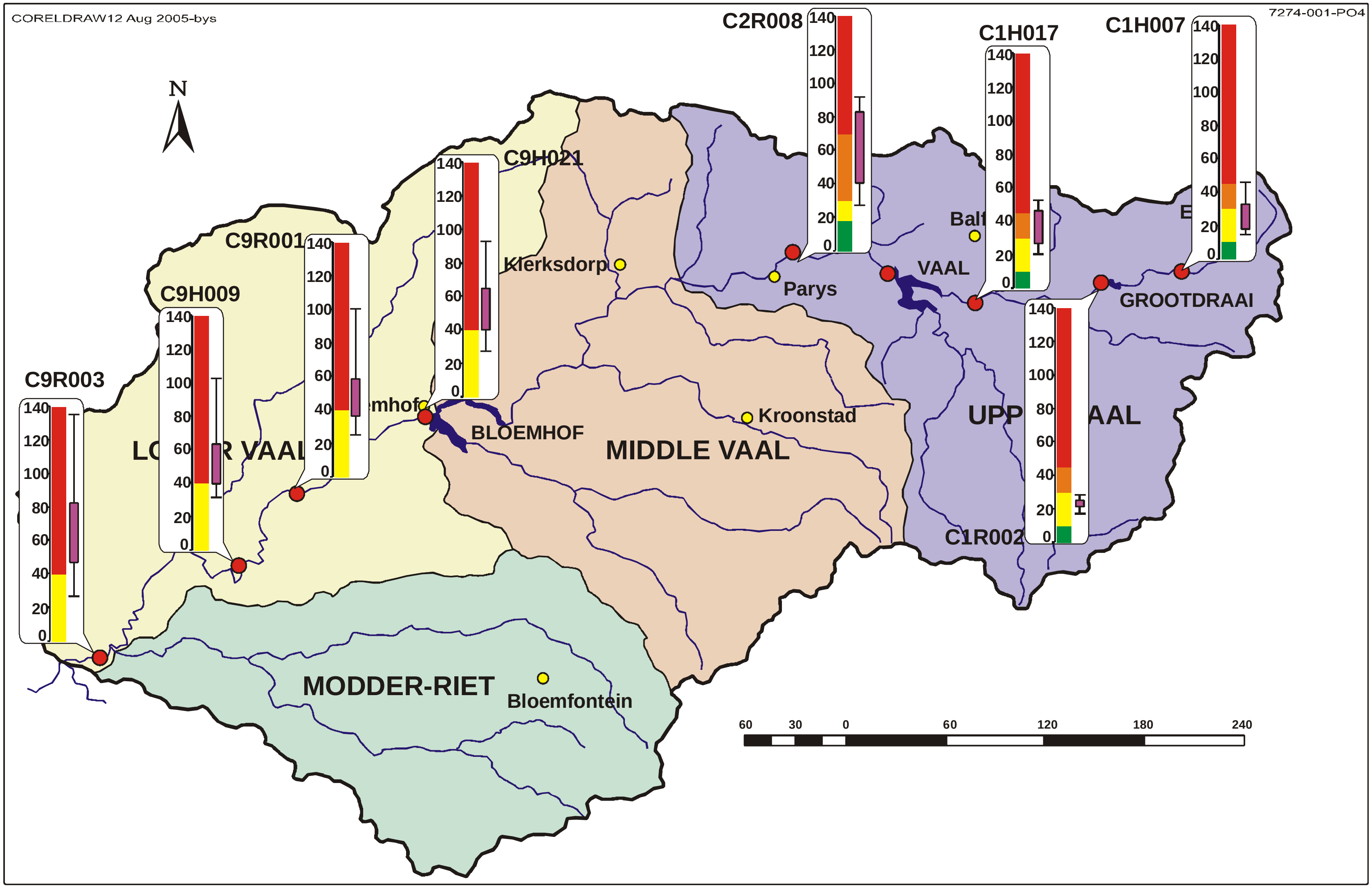

Figure 3: **In-stream water quality status of electrical conductivity along the Vaal River compared to the RWQOs**

APPENDIX D

PROCESS OF DENITRIFICATION AND AN EXAMPLE RELATED TO THE VAAL RIVER SYSTEM

Denitrification

Denitrification is the biological reduction of NO_3^- or NO_2^- to N_2 or gaseous nitrogen oxides. The process is performed by heterotrophic bacteria (such as *Pseudomonas fluorescens*) from all main proteolitic groups. Denitrification is the second step in the nitrification-denitrification process: the conventional way to remove nitrogen from sewage and municipal wastewater.

Denitrification proceeds through some combination of the following steps:

Nitrate → nitrite → nitric oxide → nitrous oxide → dinitrogen gas

Or expressed as a redox reaction:

$$2NO_3^- + 10\bar{e} + 12H^+ \rightarrow N_2 + 6H_2O$$

The Vaal River example:

In the Vaal River, the average $NO_3 + NO_2$ –N concentration drops from 2.015 mg/ℓ at the Vaal Barrage to 0.705 mg/ℓ at Kromdraai (below Parys), which is about 125 km (river length) downstream. This means that about 1.310 mg N/ℓ has 'disappeared' from the system over this distance. This loss of nitrogen could be explained by either assimilation by algae and macrophytes, absorbed by the sediments, or being converted to nitrogen gas through denitrification. Rivers are believed to play an important role in nitrogen removal via denitrification.

If we assume low flow condition (10 m^3/s) in the Vaal River, with about 0.25 m/s flow velocity, it will take the water 5.8 days to move from the Vaal Barrage to Kromdraai. Thus, the nitrogen reduction rate is approximately 0.225 mg N/ℓ/d. With a discharge rate of 10 m^3/s, the water volume that moves pass a point is 864 Mℓ/d (10 000 X 60 X 60 X 24), therefore 195.145 kg N/d is removed from the river between these two points, i.e. 71 228 kg N/a. With a total bottom area of approximately 18.75 Mm^2, (125 km x 150 m) the nitrogen removal rate is about 10.41 mg N/m^2/d, which is the same order of denitrification rates reported in the literature, e.g. Richardson ***et al.***, (2004) reported for the upper Mississippi values between 4.8 and 96 mg N/m^2/d.

The river downstream of the Vaal Barrage is apparently 'ideal' for denitrification because it has been shown that denitrification rates in the sediment was correlated positively with nitrate concentrations in the water-column (which is high at the Barrage) and higher in shallow waters –the Vaal River is extraordinary wide (365 m at Parys bridge) and shallow in the Parys area (**Figure 189**).

Figure 189: A section of the Vaal River at Parys bridge

Conclusion: Rivers are believed to play an important role in nitrogen removal via denitrification. Denitrification is apparently a very important sink for nitrogen in the Vaal River.

However, high flow (>250 m^3/s) or flood condition (>1 000 m^3/s), have a major impact on the alkalinity levels in the river, by reducing it significantly (**Figure 190**). Every time after a flood, the TAL in the river system is reset to a lower level (but not as low as the previous), followed by a gradual build-up (**Figure 190**)

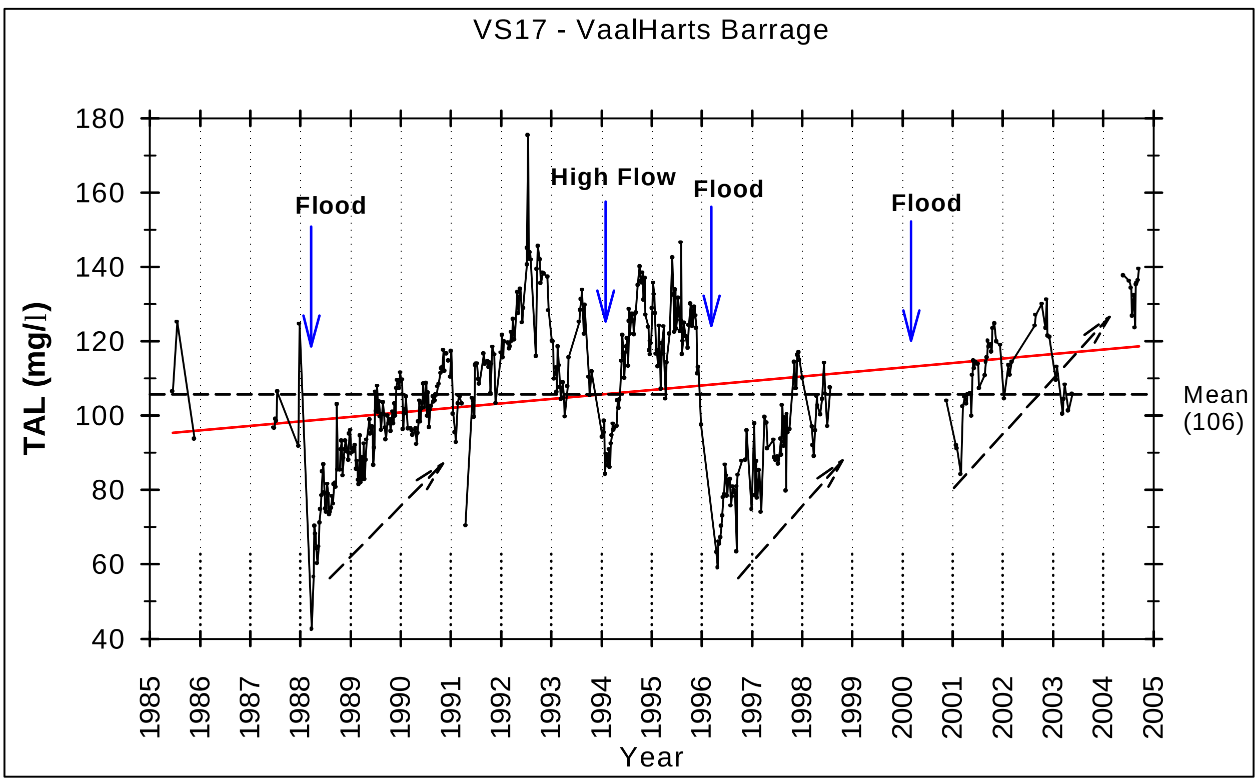

Figure 190: Annual variation in total alkalinity in the Vaalharts Barrage during the last 20 years (1985 to 2005)