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ASSESSMENT OF APPROACHES TO DETERMINE THE WATER QUALITY STATUS OF SOUTH AFRICAN CATCHMENTS

BY

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DECLARATION

I hereby declare that this is an authentic record of work and has not in its entirety, nor in part, previously formed for the award of any degree of this or any other University. Wherever use is made of others' work, it is acknowledged in the text.

Moleboheng Wilhelmina Mosoa

2013

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Assessment of approaches to determine the water quality status of South African catchments

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MSc: Water Resource Management

SUMMARY

The paradigm shift in water quality management of South African water resources was based on current international trends. This significant move was from a previous emphasis on source management to a focus on finding a balance between water resource protection and water use. The current approach requires that water quality and quantity should be maintained for sustainable functioning of both the natural aquatic environment and socio-economic development. This approach has placed the assessment of water quality status as a key decision tool in water quality management.

Various assessment tools have been utilized to quantify the quality of South African water resources. In this study we assessed the compatibility of some of the methodologies that have been used in the Department of Water Affairs to determine and report on the water quality status of the resource. During the assessment the context and manner in which these methodologies can be utilized in water quality management were also addressed

The Compliance Evaluation and Fitness for use categorization methodologies are both used to describe the water quality threshold of potential concern when dealing with the resource. **Compliance Evaluation methodology** uses a pass or fail assessment, while the **Fitness**

for use categorization methodology uses a scaled approach allowing for the assessment of gradual change in the system. The out puts of these two methodologies, the Resource Water Quality Objectives and Fitness for use categories/ classes have both been used in the department as benchmarks to describe the current water quality status

The assessment of the two methodologies indicated that there are similarities in the approaches and the principles behind the two processes. The observation of the results, however, indicated differences in the manner of presentation of the results, the interpretation of the outcome and in how water quality management measures that needs to be implemented are linked.

Both methodologies are easy to apply when conducting water quality status assessments. However, the two methodologies are not sufficient on their own when making decisions on water quality management. It was concluded that although the compliance evaluation methodology can play a pivotal role when setting end of pipe standards, the process needs to consider the gradual changes of water quality in the river system in order to enable instigation of different water quality management measures at appropriate levels. Further it was recommended that with some modification the two approaches can be applied to assess water quality to support adequate water quality management decisions at various levels.

GLOSSARY OF ACRONYMS

ARMCANZ	Agriculture and Resources Management Council of Australia and New Zealand
ANZECC	Australian and New Zealand Environment and Conservation Council
CMS	Catchment Management Strategy
CWA	Clean Water Act of 1972
DWA	Department of Water Affairs
EPA	Environmental Protection Agency
EVs	Environmental Values
IWRM	Integrated Water Resource Management
LIMCOM	Limpopo basin is specifically managed by the Limpopo Watercourse Commission of 2003
LA	Load Allocation
NWA	National Water Act 36 of 1996
NEMA	National Environmental Management Act No. 107 of 1998
NPDES	National Pollutant Discharge Elimination System
NWP	National Water Policy
NWQMS	National Water Quality Management Strategy
NWRS	National Water Resource Strategy
POPs	Persistent organic pollutants
PCBs	Polychlorinated biphenyls
RWQO(s)	Receiving or Resource Water Quality Objective(s)
RDM	Resource Directed Measures
RQO	Resource Quality Objectives
RU	Resource Unit

SDCs	Source Directed Controls
SAWQG(s)	South African Water Quality Guideline(s) of 1996
TWQR	Target Water Quality Range
TDML	Total Maximum Daily Loads
WLA	Waste Load Allocation
WMS	Water Management System
WRM	Water Resource Management
WRCS	Water Resource Classification System
WMA	Water Management Area
WQO	Water Quality Objectives
UES	Uniform Effluent Standards

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CHAPTER 1: INTRODUCTION

1 INTRODUCTION

1.1 Background

South Africa's growing population and socio economic development trends are threatening water availability and quality. Trends in anthropogenic impacts such as intensive agriculture, large industrial developments including mining, power generation and urbanisation, exert pressure on the quality of the country's water resources (Ashton *et al,* 2008). Most of these fast growing water uses are found to be upstream of large rivers and dams, thus their effluent discharges and return flows have significant impacts on water resources (Oberholster *et al* 2008b). The deterioration in the water resource quality has major consequences for the aquatic ecosystem, human health and other water users. Some of the common water quality problems experienced in the country include increased salinity, heavy metals, toxic organics (POPs, PCBs), hydrocarbons, nutrients, organic matter, pathogens and sedimentation. (Quibell *et al*, 2000).

Moreover deteriorating water quality threatens to undermine economic growth and development. Factors that have been implicated in the cause of this decline in water quality include poor governance, poor intergovernmental co-operation, lack of technical capacity, poor water quality management and lack of compliance to license conditions by some of the water users (CDE, 2010).

1.2 The history of water quality management in South Africa

The need for suitable water quality management in South Africa was recognised before the promulgation of Water Act (Act 54 of 1956). Prior to the promulgation of the Water Act, water quality was managed by tribal laws where people were required to wash downstream of the drinking water collection point. Later the prevention of discharge of waste to surface water was recognised as a water quality management tool and was acknowledged as a legislative requirement in the Public Health Act of the Union of South Africa (Act 36 of 1919). The Act mandated the Department of Public Health to employ the best known and practicable methods for the disposal of sewage, hence giving officers of the department the responsibility to prevent discharge of sewage effluent into the water resources.

Post 1950, industrialization related to mining played a major role in water quality. This change brought the realisation that effluent reuse should be considered as a source of water supply due to increasing water demands in the country (Van der Merwe and Grobler, 1990). The Act of 1956 required that the effluent be treated before disposal to its original water resource. This led to the establishment of Uniform Effluent Standards which comprised the General Standards and the Special Standards of which the effluent were required to comply with (WRC, 1995). The later amendments to this act gave the Department of Water Affairs (DWA) more powers in terms of water quality management and the ability to address activities which could lead to water pollution.

In the past 20 to 30 years there has been tremendous evolution in water quality management approaches. South Africa adopted international trends and moved from simply addressing pollution control issue to performing water quality management as an integral part of water resource management. The change occurred during the 1980s and early 1990s when the deteriorating water quality of the water resources prompted the then Department of Water Affairs and Forestry to revise their water quality management approach. The new approach led to the adoption of the concept of Receiving or Resource Water Quality Objectives (RWQOs) and the pollution prevention approach for hazardous pollutants. Ultimately the Department advocated for the following set of tools for water quality management: Source reduction; Application of minimum Uniform Effluent Standards (UES); Waste load allocation based on RWQOs; and Exemption from the minimum standards if the water body had enough assimilative capacity.

After a long process of consultation the National Water Act 36 of 1998 (NWA) came into effect in 1998. NWA Act recognised the need for the sustainable use of water for the benefit of all users and the protection of the resource. To achieve this, the Act prescribes a series of measures which are to be developed within the context of the National Water Resource

Strategy (NWRS) and Catchment Management Strategy (CMS). In particular the Act provides for:

- The development of a Classification System for water resources
- The setting of a Management Class
- Determination of the Reserve and
- The setting of Resource Quality Objectives

The NWA states that the purpose of Resource Quality Objectives (RQOs) is to establish comprehensible water quality management targets that relate to the clear relevant water resources. Further according to the act the minister is obliged to determine the RQOs in order to achieve a balance between the water resource protection and sustainable water resource use. Since the RQOs provides for the maintenance of the established management class of the resource, it may be set to satisfy the maintenance of the concentrations of quality and volume and flow of quantity of the aquatic ecology, the distribution thereof, and improvement or maintenance of instream habitat. The RWQOs can also be established to instigate and reinforce the regulation or prohibition of in stream or land-based activities which may affect the quantity and quality of the water resource. Management of water quality requires that threshold of potential concern be established as a benchmark but also as a means to make decision on where and when to apply particular water quality measures (McLoughlin *et al.*, 2011).

1.3 Resource Water Quality Objectives

The RWQOs represent water quality management goals and are a component of RQOs. Together with other components relating to the protection of the water resource, RWQOs contribute to the derivation of RQOs. Typically RQOs must provide the framework for the RWQOs. The RWQOs are described as numeric in stream water quality targets typically set at a finer resolution (spatial or temporal) than RQOs that provide greater detail to base the water quality management decisions (DWAF, 2006a).

The RWQOs approach to water quality management assumes that the resource have an assimilative capacity. The assimilative capacity is the capacity of the resource to dilute or degrade pollutants with little or no effect to other water users of a particular water resource (WRC, 1995).

Setting of RWQOs requires one to determine the current and future desires of water users for a management unit or river reach. The approach makes provision for the following five water users: Domestic, Aquatic Ecology, Agricultural, Industrial and Recreational water users. The water quality constituents of concern are determined based on the relevant water users. Further, a range should be defined for each of the water quality constituents. The information on the water quality requirements for the five water users can be obtained from individual water users or from DWAs' set of South African Water Quality Guidelines of 1996 (SAWQG). The SAWQG provides generic information on the water quality requirements for each of the uses described.

When employing the SAWQG, the RWQOs are set so they fall either within or outside the Target Water Quality Range (TWQR). TWQR is the range where the concentration of the water quality constituent has no effect on the intended use. When setting RWQOs one must consider the following aspects which play a pivotal role in water quality catchment assessment:

a. Other DWA water quality management policies;
b. Natural characteristics of a catchment;
c. Current water quality of the resource;
d. Sensitivity of downstream users to water quality changes;
e. Available technology for treatment of effluent for the mitigation of effects of deteriorating water quality and
f. Other options of providing alternative water supply for affected users.

1.4 Fitness for use categorization

It is essential to note that the water quality requirements of the four water uses and the requirements for protecting aquatic ecosystems form the basis for the evaluation of fitness for use of water. The fitness for use of water is the decision on the suitability of the quality of water for its intended use or for protecting the health of aquatic ecosystems (DWA, 1996). To make a decision on fitness for use of water the following processes need to be conducted prior to assigning a fitness for use range:

a. Firstly it is imperative for the uses to be characterised from a water quality perspective. This is done by determining the purpose for which the water is to be used. The uses can be characterised into four water users, namely domestic, agriculture, industrial and recreational water use. Although the aquatic ecosystem is part of the resource it is also regarded as a water user and is the fifth water user in this regard. However if required these uses can be divided into sub categories.
b. Secondly one is required to identify and/or determine the water quality requirements of the intended uses;
c. Thirdly one should obtain information on the key constituents and parameters which determine the fitness of water for the intended uses;
d. Fourthly one needs to establish effects and the magnitude of the possible effects of the prevailing water quality on the intended uses and
e. One should determine whether the effect of water quality on particular water users and their undesirable effects can be mitigated.

The water quality in a specific resource can range from being ideal and completely fit for use to being entirely unfit for use. The expression of fitness for use is usually allocated the following narrative description.

i. *Ideal*: Is the desirable water quality which is completely fit for its intended use; and is within the TWQR.

ii. *Acceptable*: The concentration of the water quality constituent is tolerable with low effect on the intended user.
iii. *Tolerable*: Usually for a limited time period only, over a long period the concentration of the water quality constituent can have adverse effects on the intended water user.
iv. *Unacceptable for use*: The concentration can produce chronic effects on the water user.
v. *Completely unfit for use*: The concentrations of the water quality constituents can result in death of the water user (DWA, 1996)

The process of making a decision on the fitness for use of water by a water user and the setting of RWQOs for the water body is interconnected. The decision of fitness for use and its categorisation is a judgment call on the desirability and acceptability of water that has a certain impact on a particular water user(s). The process of setting RWQOs, in the formulation of RQOs is an evolving process that takes into consideration not only the water quality requirements of the users but it also considers the economic, social, political, legal and technological considerations. Currently these two approaches are used in the Department of Water Affairs to quantify the water quality status of the water resources in South Africa.

1.5 Problem Statement

1.5.1 Background

Reports on poor water quality in the Crocodile (West) catchment has affected the functioning of the aquatic environment (Van Ginkel et al, 2000). Discharges from waste water treatment works, and excessive nutrient loads from agricultural return flows have impacted reservoirs and rivers where cyanobacteria and other water quality issues dominate. Some of the impacted dams in the catchment are Roodeplaat, Rietvlei, Hartbeespoort and Klipvoor Dams (DWAF, 2004b, Van Ginkel *et al*, 2000, Oberhouser *et al*, 2008a).

1.5.2 Main problem Statement

There are two approaches that can be used to quantify water resource quality and determine whether the water is fit for its intended use. This can either be done by using the compliance determination that depicts a pass or fail approach or by using a fitness for use categorization that shows a scaled descriptive approach. Both these approaches have been used by the Department of Water Affairs for the assessment of water quality. This study seeks to assess the compatibility of the approaches, and the context in which each approach can be employed based on a case study performed in the Crocodile West Catchment. The study will also recommend ways in which the approaches can be employed and improved to provide valuable information when developing management plans and reconciliation strategies for water resource usage and water availability.

The scaled approach or fitness for use categorisation methodology provides the judgment on fitness of water for the intended use based on TWQR. In this case a set of statistical values representing the current water quality is compared to previously defined ranges and arrives at a single narrative description which defines the fitness of water for the intended use and is expressed as: *Ideal, Acceptable, Tolerable, Unacceptable* or *Unfit for use*. This approach was previously used in the assessment of water quality for other catchments (DWA, 2009a; DWA, 2011)

For the fail or pass approach or the compliance evaluation methodology, a set of statistical values representing historical and current water quality is compared to the range of predefined water quality criteria. Ultimately one arrives at a maximum value which represents the RWQO. In this case the water quality is defined by the compliance to this maximum value, and the current water quality will either be compliant or non-compliant to the maximum limit (DWA, 2009b; DWA, 2009c).

1.6 Aims and objectives of the study

1.6.1 Overall aim

The overall aim of this study is to assess and compare the two methodologies that have previously been used in DWA to perform water quality situation assessments. A water quality situation analysis will be conducted for the Crocodile West River main stream located in Crocodile West catchment and will be based on the physico-chemical properties of the water body.

1.6.2 Objectives

The study address the following objectives

a. To determine water quality status of the water resource by the use of the two methodologies;
b. To establish the differences/similarities of the two approaches for the quantification of water quality and recommend the context at which each approach can be used.

1.6.3 Approach

To address the main research problem, the study requires setting of water quality management targets at selected monitoring points. The approach will assess both the methodology for compliance evaluation and the methodology for determining the fitness for use categories. The results for the two methodologies will be assessed and compared. Compliance to RWQOs and fitness for use classification will be compiled and a report on the prevailing water quality status of the resource will be provided. During the study the following tasks need to be performed:

i. Setting of TWQR
ii. Since no RWQOs were available at the time of writing the report, the process will include setting of preliminary RWQOs and fitness for use categories at selected water quality monitoring points in the Crocodile West Catchment.
iii. Determination of the compliance status and fitness for use at selected water quality monitoring points in the Crocodile West catchment area.

iv. Comparison of the two methodologies.

The process of quantification will consider only the monitoring points located on the Crocodile West River (Level 1 Monitoring point). A monitoring point selection process will be conducted based on data availability from the Department of Water Affairs' Water Management System (WMS). The data available in the system is based on the samples collected and analysed by Resource Quality Services and some of DWA's Regional Offices. The water quality information to be utilized for the assessment is purely based on the National Chemical Monitoring Programmer.

1.6.4 Limitations and assumptions of the study

a. The monitoring selection for this study is purely data driven. However completeness of data will be conducted during the assessment.
b. The data for the study is retrieved from the Department's Water Resource Management (WMS) which is a water quality data base. No specific statistical programme will be used during this exercise.
c. Where necessary Microsoft Excel functions will be used for visual/ graphical presentation of data and information.
d. The study will review the current existing approaches, protocols and guidelines for the determination of the water quality status assessments used in some of the studies within the department in the planning environment.
e. The research is not funded by any sponsor or organization; therefore it is an effort of a researcher Water Resource Management student (WRM) from a tertiary institution.

CHAPTER 2: TRENDS IN WATER QUALITY MANAGEMENT

2 TRENDS IN WATER QUALITY MANAGEMENT

Experts in water resource management have come to the realisation that water quality management is more complex than water quantity management (Biswas *et al*., 2011*;* DWA, 2004a). This complexity is illustrated by the level of detail of data requirements for water quality management which far supersede that of water quantity in both space and time. To avoid this complication, historically more attention was shifted to water quantity management as a primary tool for water resource management.

In recent years many researchers have identified poor water quality as a global problem (Brown and Froemke, 2012). Some of the major water quality problems experienced globally are the incidents of eutrophication of water bodies; increasing trends of salinisation; microbiological and pathogenic contamination; radio nucleotides; and persistent organic pollutants (UNEP, 2008.). Global awareness of water pollution implications has changed the course of water resource management. Where previously water quality management implied source pollution control, with particular reference to discharge effluents from waste water treatment works, in recent years water quality management is regarded as an essential component of Integrated Water Resource Management (UNEP/ WHO, 1997).

Water resource management authorities in co-operation with other public and private institutions from other countries are developing water quality objectives to establish threshold values for water quality management over a certain period. These threshold values provide the basis for instigating regulation of pollution control and the application of control measures for the prevention and reduction of adverse water quality impacts on the water resources. This paradigm shift has been applied in Canada, United Kingdom, United States of America, Australia and South Africa. In this chapter we will explore the literature review of the current legislations, policies and approaches employed in water quality management in Australia, United states of America, and South Africa while those for other countries are explained elsewhere outside this thesis (http://www.env.gov.bc.ca accessed 26 July 2012; Everard M, 1994)

2.1 Water quality management in Australia

2.1.1 Water quality management legislation and policy

The Department of Sustainability, Environment, Water, Population and Communities is responsible for the implementation of the environmental policies in Australia. The key water resource management legislations in Australia are the Water Act 2007 and Water Amendment Act 2008.

The mechanism for water quality management is conducted through the implementation of the National Water Quality Management Strategy (NWQMS) (ANZECC & ARMCANZ, 2000). Previously, this strategy was endorsed by the former Agriculture and Resources Management Council of Australia and New Zealand (ARMCANZ) and the former Australian and New Zealand Environment and Conservation Council (ANZECC) (ANZECC & ARMCANZ, 1994). The current development of the strategy is overseen by the ministerial councils of Environment Protection and Heritage the Natural Resource Management and the National Health and Medical Research.

The implementation bodies of the strategies vary between the different states. The following states make up the Australian Capital Territory: Western Australia; Northern Territory; Southern Australia; Queensland; New South Wales Victoria and Tasmania. Although the government is the central administrator of the Water Act and the Strategy, the Environmental Protection Agency (EPA) act as the environmental regulator in some of these states, holding a statutory authority within the government. In such cases the EPA provide independent environmental advice to the government.

The National Water Quality Management Strategy comprises three key components relevant to achieving the primary objective of sustainable water resource usage in Australia. The components defined in the strategy are nationally agreed policies, processes and guidelines. The policy components outlines principles and approaches used to achieve sustainable water resource usage; the processes describe the manner in which objectives of the policy can be achieved through implementation while the guidelines address specific issues pertaining to the water quality status or management and monitoring, review processes and implementation approaches (ANZECC & ARMCANZ, 2000).

2.1.2 Water quality management approaches

A range of measures and approaches are used in the protection and restoration of water resources in Australia. The applied approaches include regulatory approaches, market based approaches and waste water disposal approaches. However, the role of technology plays an essential role in the application of most approaches. Some of the key elements for water quality management in Australia pertain to the control of diffuse source pollution and point source discharges.

2.1.2.1 Source pollution management

As part of a waste minimization policy, preventative approaches are employed to ensure reduction of pollution at source. Different measures are applied for the management of source and diffuse pollution. In Australia most of the diffuse sources are attributed to agricultural and urban runoff. Though it is difficult to manage diffuse source mainly because of the complexity in applying direct measures for the control of source pollution, the implementation of best management practices in order to reduce the impacts on water quality is essential (Al Bakri D *et al*. 1999). The main point source pollutions are attributed to industries and municipal treatment works. This type of source pollution is controlled with the application of license discharge limits. The intention of the predetermined limits on the licenses is to ensure the success in attaining water quality management goals which are also known as Water Quality Objectives. These license discharge limits conforms to certain minimum technology-based performance criteria which ensures that the discharge is able to meet the in-stream water quality targets. The limits are usually specified water quality guidelines.

Monitoring and modeling of water resources is conducted in order to verify the significant potential effects that the technology-based guidelines or standards can have on the assimilative capacity of the resource. The basis for this assessment is usually based on the comparison of water quality to the Water Quality Objectives (WQO). Water Quality Objectives are numerical concentration limits or narrative statements that support and protect the beneficial uses of water at a particular site (ARMCAN and ANZECC 1998). The development of water quality objective is particularly based on water quality guidelines but is highly influenced by socio-economic and political constraints. In the event water quality objectives cannot be met, stricter source controls are applied.

The determination of Water Quality Objectives usually considers the current environmental conditions, economic prospects as well as the continuing social practices in the region. The WQOs consider the five environmental values (EVs) that are of benefit to the public. These beneficial uses include in stream water quality users such as the ecosystem, recreational and aesthetics, drinking water and industrial water (EPA Victoria, 1999). Water Quality Objectives are a set of criteria that is used as a means to protect the beneficial uses from pollution. The determination of EVs and Water Quality Objectives supports the planning and management of the water resources (DEWHA, 2008).

2.1.2.2. Development of water quality objectives

Historically, guideline values were a standard value which indicated a pass or fail state of water quality. This was the maximum limit at which ecological health was likely to be compromised (ARMCANZ & ANZECC, 1994). Australians have adopted a risk based approach in developing the water quality objectives (ANZECC & ARMCANZ, 2000; EPA Victoria, 2003). Although the objectives consider other beneficial uses, the objectives are based on the ecological goals and the health of the aquatic environment which is regarded as pivotal. For the purpose of setting Water Quality Objectives the ecosystem is regarded as the most sensitive beneficial use, implying that the objectives are designed to protect the aquatic environment (Goudey, 1999). The water quality objectives for ecosystem protection are divided into nutrients objectives; objectives for rivers and streams and biological objectives.

The objectives for nutrients are provided as concentrations rather than loads. Selected variables for nutrient measurement are total phosphorus (TP) and total nitrogen (TN). The objectives for rivers and streams are determined for a set of key indicators of ecosystem health that can provide a measure of deterioration of water resources attributed to human activity. Essential parameters for this purpose are pH, dissolved oxygen, turbidity and salinity (EPA, 2003). The Water Quality Objectives are regionalized meaning that the state is subdivided into homogeneous segments. The segments define geographical areas within which the same objectives of environmental quality apply. The objectives are set for each segment, with the level tailored to the ecological potential of the segment under current and future developments. Previously these regions were based on the land use with the exception of the aquatic ecosystem. Current regionalization applied in developing objectives for rivers and streams is macro-invertebrate based (biological). This current approach is based on the biological regions produced for the purpose of developing biological objectives for streams across Victoria as indicated by Wells *et al*., 2002 and Barton and Metzeling 2003. The regions slightly differ for different types of objectives e.g. the region for nutrient objectives might slightly differ from the regions for water quality objectives for rivers and streams.

2.2 Water Quality Management in the United States of America

2.2.1 Water quality management legislation and policy

The early resolution to address water quality in the United States (US) was first enacted through the promulgation of Water Pollution Control Act of 1948. Several amendments to the water law occurred through the years resulting in the development of Federal Water Pollution Control Act of 1956 and the Water Quality Act of 1965. This Act was amended, resulting in the endorsing of Clean Water Act of 1972 (CWA of 1972). The CWA of 1972 was further strengthened through the enactment of the Water Quality Act of 1987.

CWA was developed with the purpose of restoring and maintaining the integrity of the water resources in the United State and to enhance their ability to support its beneficial uses. All the amendments through from the Federal Water Pollution Act to the Water Quality Act of 1987 are collectively referred to as the Clean Water Act (CWA) and it is the main legislation for surface water quality protection in the United States (Hanmer, 1989). The Clean Water Act is administered by the federal government and its implementation is over seen by the US Environmental Protection Agency (USEPA). The Act endorses a range of regulatory approaches which are enshrined in the water quality policy and regulations.

2.2.2 Water quality management approaches

As the implementation body of the Clean Water Act the USEPA has established a number of regulations and programmes that are endorsed as part of water quality approaches in the Clean Water Act. These measures include the water quality-based control program and the technology-based limits. The technology based programme promotes the employment of the best available treatment technology that is economically viable for industrial users and waste water treatment works. The water quality based programmes deals with measures that address the in stream water quality. The measures comprises of National Pollutant Discharge Elimination System (NPDES) permits; nonpoint source programs; oceans and wetlands programs; and source water protection; EPA standards and criteria program; water quality monitoring and Total Maximum Daily Loads (TMDLs) (Cech, 2005).

In the United States the main regulatory support tools underpinning water quality protection and management are water quality standards and criteria. By virtue of seeing the execution of these regulatory mechanisms, USEPA have established a Water Quality Standard Hand book as a guideline for the implementation of the Water Quality Standard Regulation (40 CFR 131) (www.water epa.gov accessed 30 July 2012).

2.2.2.1. Water Quality Criteria

The first set of Water Quality Criteria in the United States was published in 1952 followed by a number of revisions which were required to reflect and incorporate advances in scientific knowledge (McKee *et al.*, 1963). The Water Quality Criteria are concentration limits assigned to particular chemicals or conditions in a water body. The criteria are either numeric or narrative or can be both and they are expressed as variable concentrations or as narrative statements. The criteria are intended to protect the aquatic ecosystem and the water users that may directly or indirectly depend on the aquatic ecosystem (Bauer *et al.,* 1999). The derivations of criteria are based on the hazard and risk assessment procedures, while scientific observations of the response of a test organism to particular non persistent or biomagnified compounds are conducted to establish acute or chronic effects. Although Water Quality Criteria are particularly established for the aquatic ecosystem and for human health effects there are no specific criteria for wildlife. Investigation shows that the criteria for human health is not restrictive enough for the protection of the most sensitive wild life species, This is because the criteria for human health assumes restrictive human consumption which cannot be assumed for wildlife (Ludwig *et al,* 1993).

The criteria for the protection of the aquatic ecosystem includes the aquatic life criteria which is based on chemical concentration constituents of the resource; the biological criteria which is based on the type and number of organisms present in the water resource and the type of the habitat; the nutrients criteria to mitigate excessive algal growth is based on the control of substances that promote growth of benthic algae such as phosphorus, nitrogen and available chlorophyll (Dodds *et al,* 2000). The microbial criteria are considered in order to combat human health effects. The latter criterion takes into account the level of pathogens in water used for human consumption and exposure during recreational activities (Dufour, 1984).

2.2.2.2. Water Quality Standards

In the United States Water Quality Standards are used to define goals for a water resource. This is done by describing the designated uses of the resource, setting the water quality criteria to protect those uses, and establishing water quality requirements to protect that particular resource from pollution. The Water Quality standards also consist of anti degradation policies which serve the purpose of establishing water quality management goals and provide the regulatory tools for establishing relevant treatment controls and strategies (USEPA, 2003). These anti-degradation policies play a pivotal role when developing waste load allocations, Total Daily Maximum Load (TDML) and National Pollutant Discharge Elimination System (NPDES) permits.

In the United States the designated uses of the water resource include the water for the purpose of public water supply, for propagation of fish, shell fish and wild life, for recreation, agriculture, industry, and other uses which the government may regard as important (Water Quality Standards Regulation on November 8, 1983 (54 F.R. 51400). Moreover, the developments of standards make provision for the maintenance of downstream standards.

2.2.2.3. Total Maximum Daily Load (TMDL)

A TMDL is a calculation of the measure of the assimilative capacity as loads for a particular pollutant in a water resource. The available load is further allocated among various sources of that pollutant. The TMDL process plays a key role in water quality improvement because it links the development and implementation of control actions to the achievement of water quality standards. According to the CWA, the TMDL is implemented through the National Pollutant Discharged Eliminating System (NPDES). For the purpose of implementing the system Pollutant sources are characterized as either point and non point sources where the former receive a Waste Load Allocation (WLA) and later receive a Load Allocation (LA). TMDLs can be developed by simple mass balance calculations, however depending on the complexity of the catchment water quality mathematical modelling approach can be used. Factors that determines the approach that can be used for TMDL depend on the type of the resource, is it a highly utilized river or not, flow conditions, and type of pollutant causing the impairment.

Total Maximum Daily Load is determined for those water resources that display signs of water quality stress and when determining the total maximum daily load for a particular water quality variable one is required to identify the possible sources that contribute to the impact. Further an allowable load is allocated to each source. The allocation requires each of the sources to reduce their pollutant contributions into the system hence reducing the water quality impacts on the water resource. However, because both anthropogenic and natural factors can impact the water resource the natural background sources such as the geology and topography of the catchment; seasonal variations and the allowable amount of substance in the resource are considered when developing an allocation plan (Langseth *et al*., 2011). The development of TMDL is also driven through public participation Figure 2.1 depicts the approach for water quality management using the TMDL approach.

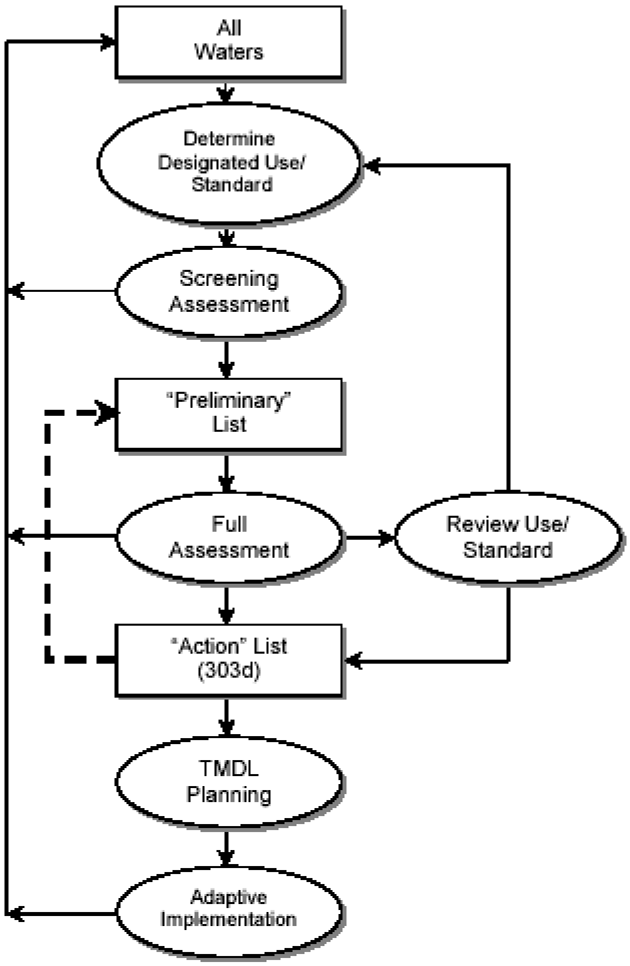

Figure 2.1: The framework for Water quality management in the United States (National Research Council, 2001)

2.3 Water quality management in South Africa

2.3.1 South African environmental legislation

As with other international countries that moved from source control and management to integrated water resource management, water quality management in South Africa transformed over the years. The Constitution is the supreme law in the Republic of South Africa. The Bill of Rights echoes the right of everyone to have the environment protected for the benefit of present and future generations (The Constitution of the Republic of South Africa, Act No.: 108 of 1996, Chapter 2: Bill of Rights). This provision accentuated the need for environmental law reform in the country. The National Environmental Management Act No. 107 of 1998 (NEMA) is the overarching legislative tool governing environmental use and management in South Africa.

Other resource management laws contain sets of management principles relating to the specific resource which is the subject of the law.

The review of the environmental law in the country led to the development of the National Water Policy which was endorsed through the promulgation of the NWA. The NWA is the legislation governing South African water resource. Together with other complementary legislations such as the Water Service Act No. 108 of 1997 and National Forestry Act No. 84 of 1998 they are the legislative tools regulating use of the water resources. The cooperative governance of the National Environmental Act, National Water Act and Water Service Act is deemed crucial for the successful water resource management in the country (DWA, 2004b).

2.3.2 Water quality management legislation and policy

The process of reviewing the national water law resulted in the formulation of the National Water Policy (NWP) which was adopted by the cabinet in 1997. The fundamental principles and objectives of the Constitution are endorsed in the National Policy. The primary principles underlying the policy are the equal availability of water for every citizen for current and the future generations. The policy grants everyone a right to water for basic human needs and water for sustaining environmental functioning. The water required for basic human needs and environmental or ecological functioning is termed The Reserve (DWAF, 1998). The implementation mechanism for the NWP is both the National Water Act 36 of 1998 and Water Service Act 108 of 1997.

The principal purpose of the NWA is to ensure water resource protection for the ultimate purpose of securing water for sustainable development and use. The NWA gave legal standing of the National Water Policy by proclaiming three management functions of sustainable use and protection of water resources, efficient water use and equitable access to available water (DWA, 1998).

NWA emphasises on the requirement to protect water resources by declaring that “The protection of water resources is primarily related to their use, development, conservation, management and control" (DWA, 1998). In view of the socio developmental needs in the country, the Act accepts that rivers require a different status of protection. To acknowledge this reality the Act requires the following measures to be put in place to ensure ample protection of all water resources:

- The water resource to be classified according to the National Water Resource Classification System, and provide a Management Class for that particular water resource.
- The Reserve to be determined for human and ecological requirements.
- The Resource Quality Objectives to be described, in order to be able to maintain the class of the resource.

As the organ of state the Minister of the Department of Water Affairs is required to give effect to the implementation of these measures progressively in the context of National Water Resource Strategy (NWRS) and Catchment Management Strategies (CMS) (DWA 1998).

2.3.3 Water resource management strategies and approaches

The NWRS and CMS serve as the framework for decision making which water management institutions and water users must adhere to. The purpose of the NWRS is to establish the procedures and strategies which facilitate decision-making to promote values that are enshrined in the NWA. The NWRS outlines tools for the minister relating to the realisation of the purpose of the Act within the framework of the existing relevant government policies. These tools include water resource management strategies, objectives, plans, guidelines and procedures (DWA, 2004a).

The principles for Integrated Water Resource Management (IWRM) are embraced in NWRS and NWA (WRC, 2006). The NWRS acknowledges the requirement for the integration of different components of the water resource in order to achieve IWRM and prescribes approaches in which the IWRM can be achieved in the country. In the light of integrated water resource management, The Strategy prescribes Source Directed Controls (SDCs) and

Resource Directed Measures as complementary strategies for the protection of water resources (DWA, 2004a).

2.3.3.1. Source Directed Controls (SDCs)

The SDCs are regulatory measures for pollution sources. These measures define limits that must be imposed on the water user in order to meet the management goals. The water user sectors implements the measures for incremental improvement of the resource in order to control impacts prior to the impact actually reaching the resource to ensure the protection of the resource. The National Water Resource Strategy describes a number of regulatory management instruments and approaches for the protection of water resources. The approaches include the combination of precautionary approach, pollution prevention, remediation, water allocation, differentiation approach and water use which is controlled by licensing (WRC, 2008).

2.3.3.2. Resource Directed Measures

Resource protection encompasses the Classification System for the water resources, determination of the Reserve, determination of Resource Quality Objectives and Source Control Measures (SCM) (DWA, 1998). The relationship between RDM and SCM is as depicted in Figure 2.2.

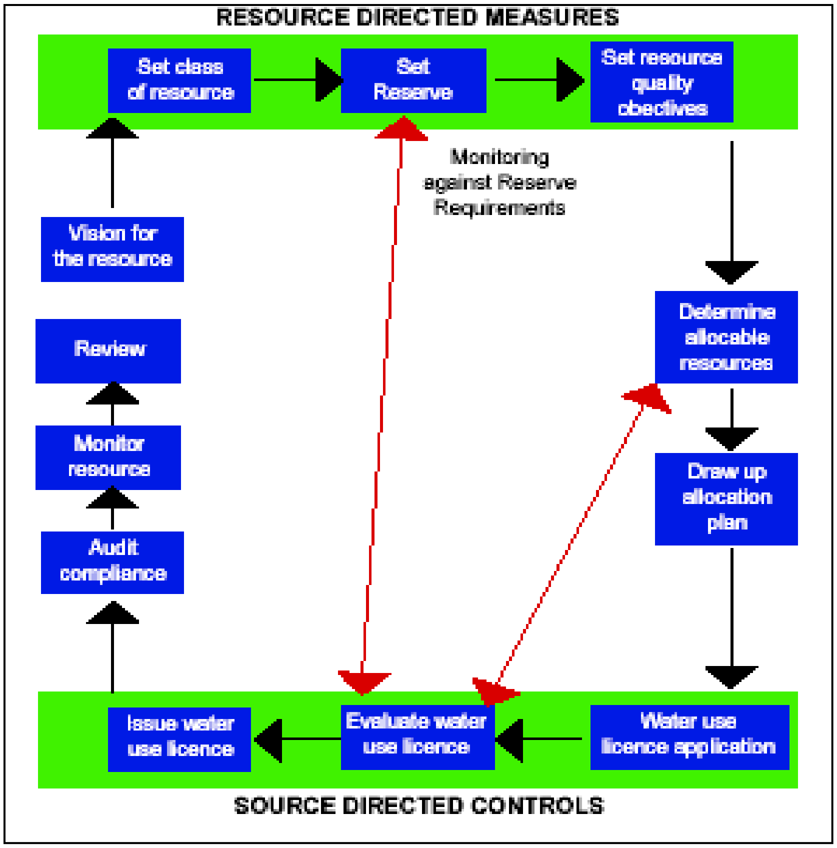

Figure 2.2: Measures for the protection of water resources (DWA, 2010b)

a. Classification

The classification process attempts to harmonize the ecological sustainability of water resources with social and economic needs. To address these three conflicting goals Water Resource Classification process is required to be transparent drive the process through public participation. It is clear that because of the conflicting nature of the goals tradeoffs between these three spheres of developmental needs are necessary. This requires that the valuation methods for determining balance and tradeoffs for optimal use to be fair. The process has to be consistent in characterization of the class and providing solutions that can be evaluated at a national level. Water Resource Classification System (WRCS) is required to provide a framework for sustainable use of water resources (Water Wheel, 2008).

By virtue of their ecological importance some water resources may require a high level of protection, while others may serve for developmental and economic growth needs. WRCS categorizes water resources according to specific classes. Each Class represent a management vision of a particular catchment by taking into account the current state of the water resource (Dollar *et al,* 2007).

The WRCS comprises of three water resource classes, reflecting a shift from resources that will be minimally used, to resources that are heavily used by taking into consideration the socio-economic needs of all water resource users (Table 2.1). The system provides the description of desired condition of the resource, and the extent at which it can be used sustainably by balancing economic, social and ecological developmental needs in the catchment. The level of protection is determined by the three spheres of developmental needs. Ultimately increase in the protection is reciprocal to increase restrictions in water resource usage. This might result in prohibition of certain types of water uses in the catchment.

The classification of water resources represents the first stage in the water resource protection process which ultimately results in the determination of the quantity and quality of the water required for ecosystem functioning as well as maintaining economic activity that relies on a particular water resource. The procedure for the determination of a water resource class comprises of a seven step process (Dollar *et al* 2007; Joubert *et al*, 2007). The process of classification first defines the status quo of the water resource (or part thereof) in terms of the ecological and biophysical elements. Subsequent to this a consultative process is then embarked upon, whereby the classification system is used considering the ecological, social and economic aspects, to define a future desired state. Ultimately the configuration of the Class of the resource is gazetted.

The Management Class and the RQOs are the consecutive outputs of the gazzetted classification and Resource Quality Objectives processes. The two processes are only conducted for those water resources that are regarded to be of significant value. The management Class and RWQOs can be conducted for rivers, wetlands, estuaries, and aquifers.

These determined Class and Objectives are binding on all authorities and institutions exercising any power or performing any duty under the NWA. Further the Management Class informs the determination of the allocatable portion of a water resource for use.

Table 2.1: Management classes of water resources

Class	Type of water resource
Class I	Water resource that is minimally used & the overall ecological condition of that water resource is minimally altered from its pre-development condition.
Class II	Water resource is one which is moderately used & the overall ecological condition of that water resource is moderately altered from its predevelopment condition.
Class III	Water resource is one which is heavily used and the overall ecological condition of that water resource is significantly altered from its predevelopment condition.

b. The Reserve

Under NWA there is a provision of the determination of the Human needs Reserve and the Ecological Reserve. The Human Needs Reserve is quality and quantity of water required for current and future water supply from the relevant resources (DWA, 1998). This portion of water for “The Reserve” is required to fulfil basic human needs by securing a basic water supply for consumption, as prescribed under the Water Service Act 108 of 1997.

Moreover the legislation has focused on the establishment of the Ecological Reserve policy. However the intent thereof is not explicitly described (Van Wyk et al, 2006). Consequently this has led to misconceptions by the resource beneficiaries that the Ecological Reserve is intended merely for conservation purposes. The Ecological Reserve is the quantity and quality of water that needs to be reserved for the protection and maintenance of the aquatic ecosystems to acquire sustainable use of the resource. The protection of the aquatic ecosystem is therefore intended to ensure the sustainability of the ecosystem goods and services and the distribution of resource related benefits in society. The methodologies for the determination of the Reserve particularly the water quality methods, have undergone several reviews through the years, however they do not form part of the thesis and are explained elsewhere in literature (Palmer, 2004).

c. Resource Quality Objectives

The function of the RQOs determination is to balance the requirements of the environment with those of the ecosystem within the framework of the WRCS. The RQOs are narrative and qualitative they can also be quantitative statements describing the overall objective for the catchment or Resource Unit (RU). RQOs are aligned with the vision and are necessary to achieve the vision for the water resource and are less subject to change as the understanding of the ecosystem changes (Palmer et al, 2004).

The narrative RQOs are supported by numerical limits which are quantitative descriptors of the different components of the resource such as water quality, quantity, habitat and biota. However these quantitative descriptors are not gazetted as they are subject to change with better scientific knowledge (Harris *et a*l, 1999).

The RQOs are essential measure for maintaining the Management Class of the particular significant water resource. The process of the setting RQOs follows a seven steps process which include the definition and selection of Resource Units; establishment of a vision; selection of indicators for monitoring; development of narrative and numerical limits; stakeholder consultation and gazetting of the RQOs. Following gazetting of the RQOs the process is followed by monitoring and compliance to measure performance in management of the water resource (DWA, 2011). The RQOs provide limits/boundaries from which it can be deduced as to whether the resource is stressed by existing management practices or not. Water resource management strategies such as Catchment Management Strategies and water quality allocation plans as basis of Source Management Objectives, are guided by the RQOs. It is crucial to be aware that the RQOs relate to management of water resources through the implementation of Source Directed Controls.

d. Resource Water Quality Objectives

By virtue of integrating the different components of the water resource, Integrated Water Resource Management resulted in the development of Resource Water Quality Objectives (RWQO) approach (Van der Merwe and Grobler, 1990). Resource Water Quality Objectives (RWQOs) are clear goals or numerical concentrations relating to the quality of the water resource. The Objectives are required to be quantifiable, measurable verifiable and enforceable (Harris *et a*l, 1999). They are objectives for controlling impacts on the water resource through SDC regulatory measures (UNEP/WHO, 1997). RWQOs are the water quality components of the RQOs outlining the user's water quality requirements as well as discharge requirements with respect to the particular water resource Figure 2.3.

Apart from providing a basis for water quality input to RQOs, the RWQOs are a prerequisite when planning for water quality. They provide a basis for conducting water quality reconciliation, water quality allocation and benchmarking during water quality foresights and determination of the level of water quality stress (WRC, 2008). They allow for water quality scenario analysis and strategy establishment. RWQOs are descriptive or quantitative, spatial or temporal, and allows for the realisation of the catchment vision by giving effect to the water quality component of the gazetted (RQOs) (DWA, 2006a). The RWQOs are usually set at a finer resolution with monitoring points located at a closer proximity than RQOs. This is in order to provide greater detail upon which to base the decision making in water quality management.

RWQOs' approach focuses on harmonising the conflicting interests between the various water use requirements relative to the assimilative capacity of the resource. This approach is set up in such a way that it considers effects of an individual as well as the combined effects of the different discharges into a water body. It also consider the sensitivity of the in stream water users. Further, the approach enables an overall limit on levels of contaminants within a water body to be set according to the quality required by the water users in the catchment (DWA, 2011).

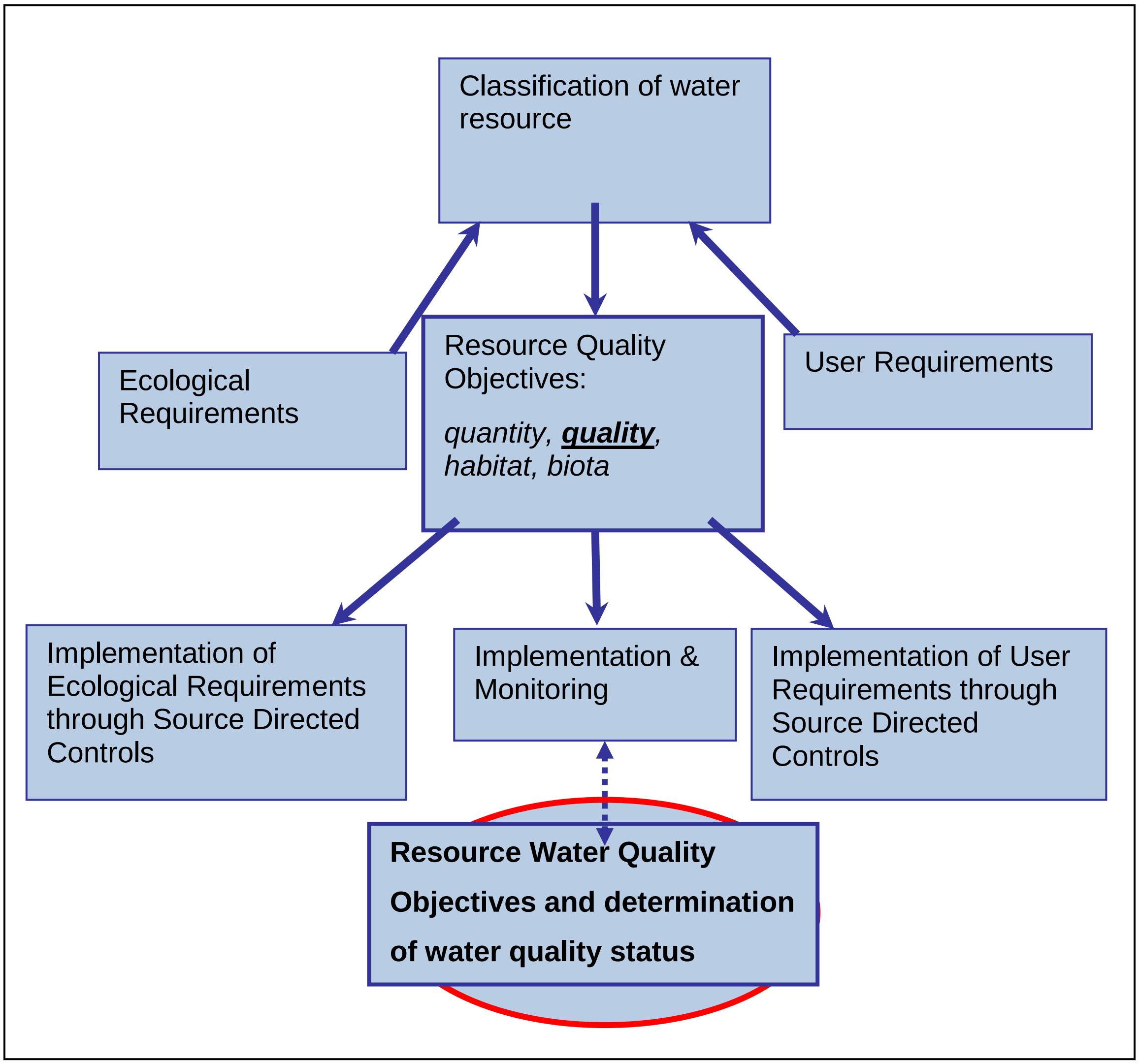

Figure 2.3: The link between Classification, Resource Quality Objectives, Source Directed Controls and RWQOs (adopted with modification from DWA, 2011).

The NWA allows for the setting of Preliminary RQOs for the water resources before the formal classification system has been established and the objectives may be revised once the final classification system is in place. Hence preliminary RWQOs can be set for the water resource. Although setting of the RWQOs is a participatory process, It is not the responsibility of individual water users to comply with the set Objectives but that of the regulator (in this case the minister) to ensure that the water resource is fit for use (DWA, 1998).

In setting RWQOs, the water resource manager strives to achieve a balance between protecting the water resource for the downstream users and allowing use and development of the water resource upstream of the river reach selected for the RWQOs (Figure 2.4). For the downstream water users, the focus is on protecting the water quality in order to ensure a healthy functional aquatic ecosystem, while also meeting the water quality requirements of the other recognised water user groups (domestic, agricultural, industrial, recreation and aquatic ecosystems) downstream of the RWQOs point (Van Wyk *et al*, 2002). However, the selected RWQO might also restrict the type and extent of water use upstream of the point. Water uses refer to those described in Section 21 of the NWA and includes uses such as the discharge of water containing waste which uses the assimilative capacity of the resource and taking water from a water resource which affect the dilution capacity of the water resource (DWAF, 2006a).

In terms of DWAF policy the RQOs and related RWQOs will be used as the basis for the setting of waste discharge standards (Section 26[h] of the NWA) and waste discharges charges in each catchment (DWA, 2007). Thus the setting RQOs and RWQOs become central to balancing the needs of the upstream “impactors” with downstream user requirements. The methodology for setting the RWQOs is described in detail in the following chapter.

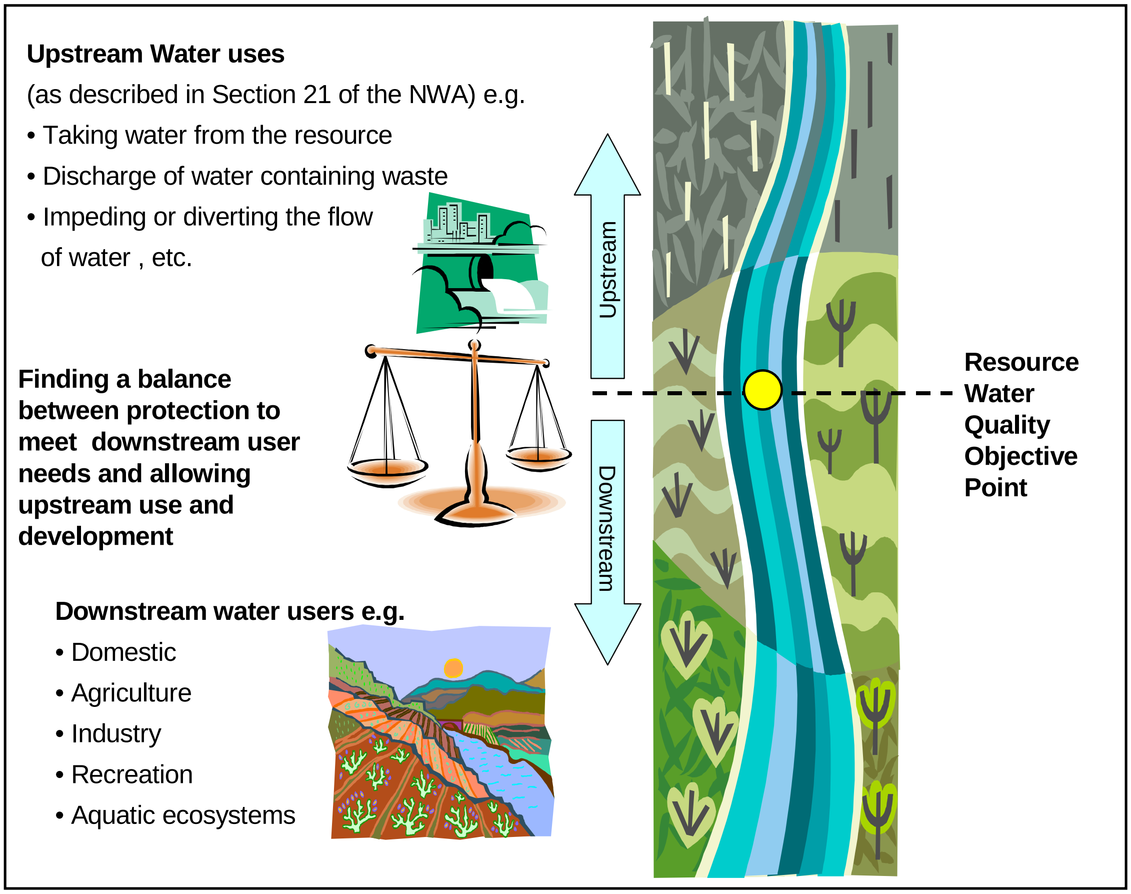

Figure 2.4: Balancing the needs of downstream water users with upstream water use and development (DWAF, 2006a).

DWA has developed a set of water quality guidelines which give a general perspective on the water quality criteria for the five recognised water user groups namely: domestic, agricultural, industrial, recreation and aquatic ecosystems. South African Water Quality Guidelines (SAWQGs) are a set of water quality criteria which constitute the basic reference when determining the water quality requirements for various water users (DWA, 1996). These criteria include those for the aquatic environment which were reached by achieving a consensus between water quality specialists (Zokufa et al, 2001). Currently this criterion is used as basic water use requirements. Although fairly generic, the SAWQGs are the primary input information used when setting RWQOs.

CHAPTER 3: METHODOLOGY AND APPROACHES FOR THE DETERMINATION OF WATER QUALITY STATUS USING RWQOs AND FITNESS OF WATER FOR USE

3 METHODOLOGY AND APPROACHES FOR THE DETERMINATION OF WATER QUALITY STATUS USING RWQOS AND FITNESS OF WATER FOR USE

3.1 Background

Water resource management is underpinned by the principle of sustainable development which originates from the realization that the natural resource base can pose ecological limits to economic development. This principle considers the interactions between the economic, social and ecological spheres and seeks to achieve a balance between these three spheres through objective governance. The South African Constitution clearly states that reasonable legislative measures are required to secure ecological sustainability through justifiable economic and social development when using the country's natural resources. The constitutional requirement is enacted and effected by the legislation dealing with natural resources which include the National Water Act 36 of 1998.

In the National Water Act, sustainable development is enabled through balancing water resource protection and water use. Resource protection emphasizes the implementation of necessary management measures to maintain and improve the reliability of water resources. This is done in terms of the water quantity and quality components as well as the ability to provide ecological goods and services in a sustainable manner. As a result, the Department of Water Affairs decided that the deterioration of water quality beyond the current status should not be allowed in order to ensure meeting the minimum requirements of current and future users.

Currently managers apply the Integrated Water Resource Management model (Plan, Do, Check and Act approach) as shown in Figure 3.1. This model requires the manager to monitor and audit the progress of instituted actions, to frequently review the processes involved and is dependent on detailed planning to be successful. Planning typically includes the development of the implementable water quality management strategies. For such strategies the current water quality status is assed as the assessment forms the basis for the development of management goals. Classification of the system and setting of Resource Quality Objectives as well as the development of water quality allocation plan and source control measures also have to be addressed to achieve management aspirations.

A three tier decision making hierarchical structure is currently used during the development of water quality management plans. This framework is shown in Figure 3.2. During the initial step, water quality management targets are required. These targets are based on the current water quality status, and the ability to assess the quality status is therefore extremely important (DWA, 2006c).

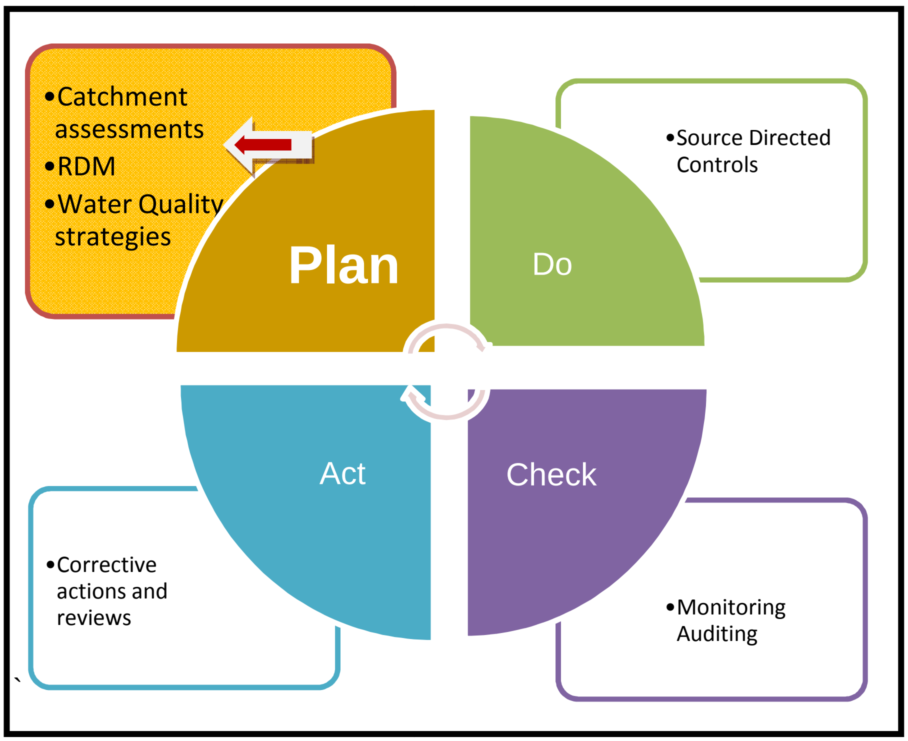

Figure 3.1: Structure showing the business process for Integrated Water Quality Management model (adopted with changes from DWA, 2006c).

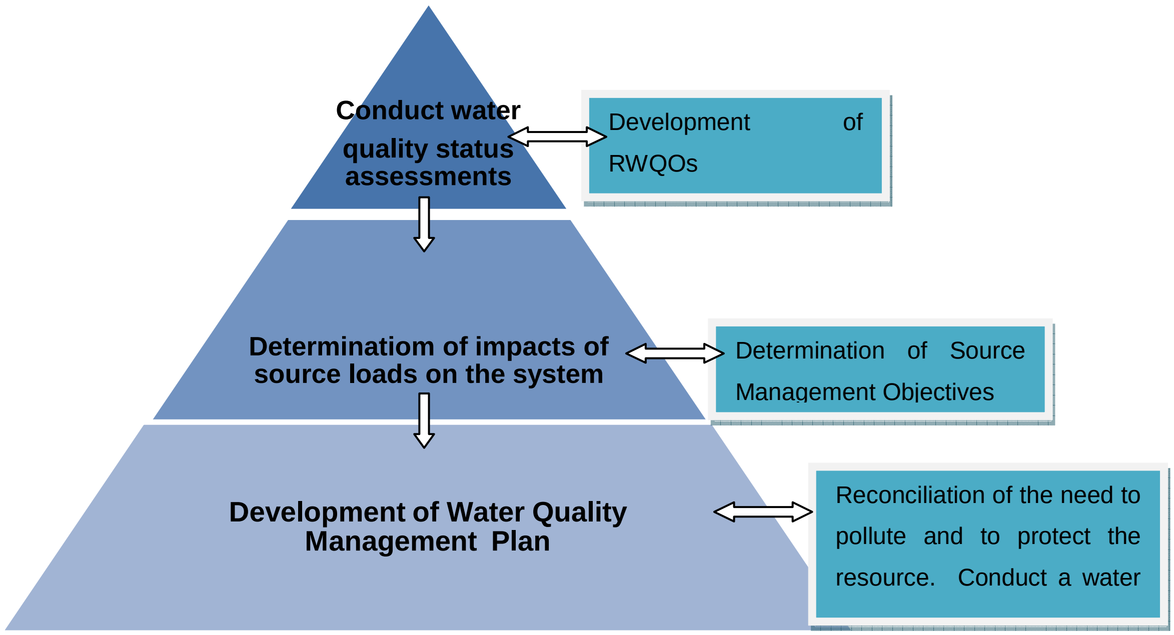

Figure 3.2: Structure showing hierarchy of water quality management decision making used during planning phase.

3.2 Methodologies for the Water Quality status assessment

Currently the Department of Water Affairs uses different approaches to assess the water quality status. In this chapter two of these approaches will be compared using information from the Crocodile West River catchment. In the first methodology **Compliance evaluation** methodology the assessment is based on compliance to pre-set numerical values or RWQOs. These numerical values are the maximum limits required for the sustainable use of the water resource. The methodology considers the current status and the historical status of the resource. The approach do data assessment considers the 95 percentile of over a five year period as the upper limit for a variable of concern with the exception of Orthophosphate. The fifth percentile represents the lower limit particularly for pH as indication of acidity of water.

Water quality status does not necessarily have to be measured against a single value but could also be assessed according to ranges that define the effect of water quality on different water users. This forms the approach for the **Fitness for use classification** method. The methodology considers the median, 75 percentile and the 95 percentile as the basic data assessment ranges. These water quality ranges are combined to give the description of a water quality assessment category. The approaches to the two methodologies are depicted in Figure 3.3 and they are discussed in detail in the following sub sections.

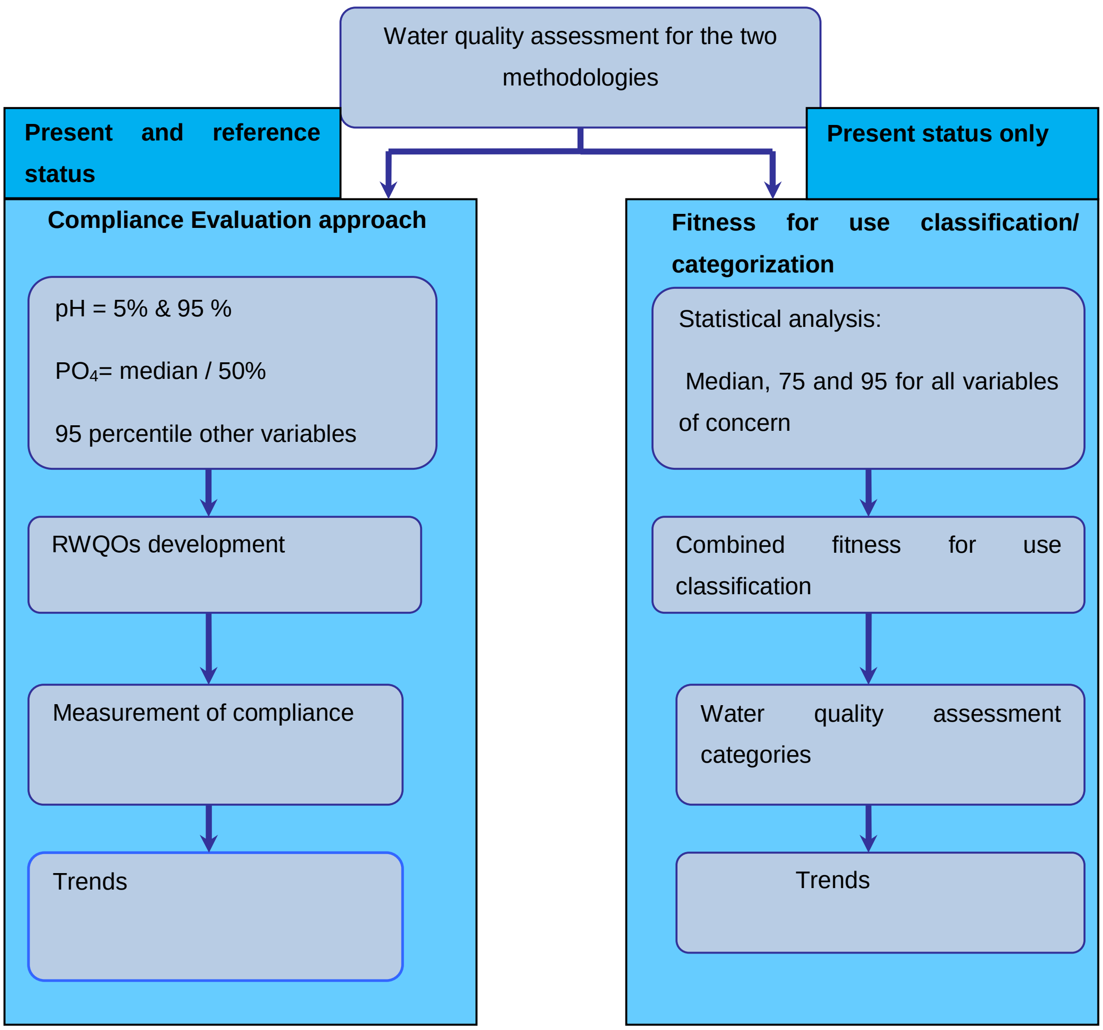

Figure 3.3: Schematic diagram depicting the approaches for the compliance evaluation and fitness for use classification methodologies

3.2.1 Criteria for evaluation of the Compliance evaluation and Fitness for use classification methodologies)

In order to have an objective evaluation of the two approaches it was necessary to set the criteria which will be used to compare the two approaches. It was decided that the approaches:

a. must be simple;
b. must be reproducible and
c. must factor in sustainable water resource management by catering for the protection of the water resources as well as social and the economic use /development; and must allow for the assessment of fitness for use and analysis of the trends.

3.2.2 Water Quality Assessment

Step 1: Catchment assessment

During this phase of water quality status assessment the catchment vision, as well as the management targets for the water resource needs to be clearly identified. The boundaries of the catchment to be assessed have to be determined and if necessary the catchment might need to be divided into smaller homogeneous management areas. Attention is also given to the natural features and characteristics of the catchment area that might impact or affect the water quality of the water resource. The assessment also takes note of the current known water quality issues and the anthropogenic sources of pollution. Ultimately the natural and the anthropogenic processes occurring in the catchment should be understood and must be linked to the water quality impacts that are observed (DWA, 2003b).

Step 2: Identify current and future water uses

To assess the water quality of a stream the specific water users needs to be identified in order to determine whether the water is suitable for their purposes. The study will identify the water users that are currently and will in future be abstracting and using water from the river. The identification of the water users will be done through review of available literature and the knowledge of the catchment. These water users will be clustered into groups similar to those identified by the SAWQG (DWA, 1996).

Step 3: Determine the water use requirements

After identifying water users in the catchment one has to determine their water quality requirements. The process of determining water use requirements can be an intensive process of interviews and public consultation, however for the purpose of this thesis it will be based on the water quality requirements previously determined by the SAWQG Volume 1 to 7 (DWAF, 1996). These guidelines describe the effects that the changes in water quality will have on the particular water users.

The SAWQG make provision for five water user categories, namely domestic, recreation, industrial (category 1 to 3), agricultural (irrigation, livestock watering and aquaculture), and the aquatic ecosystem. However, only the relevant water quality guidelines that are applicable to the catchment area will be considered. The guidelines provide a description of the effect that water quality will have on the user and do not provide an interpretation of whether these values are acceptable or not. The cut-off values for the different fitness-for-use categories will have to be set based on these guidelines.

Step 4: Determine the variables of concern

When determining the variables for concern it is important to consider both in stream water use requirements to cater for abstracting water users as well as the need to discharge water containing waste into the resource. This is in order to take cognisance of cause and possible effects/symptoms of the water quality variable (Quibell *et al*, 1997).

Although a long list of variables can be compiled, inclusion of the variables will only be possible if the required data is available. For this study the best available data at the time of this study will be sourced from the Department of Water Affairs.

Step 5: Identify monitoring point location

Ideally suitable monitoring points will be selected to determine the status. The suitability of the monitoring points depends on their location in relation to upstream impacts and downstream water users (DWA, 1996). The location of a selected monitoring point is critical because it is used as a point of departure when seeking to achieve a balance between the protection of the resource for downstream users and allowing certain water use activities upstream of the monitoring point. Only those monitoring points where a minimum of 25 measurements are present during the selected period will be considered for further assessments.

Step 6: Verify water quality data availability

The data to be used during the assessment will be obtained from the National Chemical Monitoring Programme. When developing RWQOs, it is required that the current as well as the reference or historical water quality should be considered. In this study, the current water quality will be based on the most resent five year data set. For a reference it is customary to refer to the most pristine conditions of the resource. Due to the lack of such data, the first five years of data dating since the inception of the monitoring programme will be used to represent the historical conditions of the resource. The Fitness for use categorisation/classification methodology considers the current status as a point of departure.

In order to ensure that there is sufficient sets of data to produce reliable statistical values we will confirm completeness of the data sets. Once the completeness of data has been determined the statistical data will be produced by using the Water Management System statistical function.

3.2.3 Fitness for use categorisation

For the Fitness of use approach, the water quality is categorised into specified target ranges called fitness for use categories. This section will describe the process followed to develop the fitness for use categories and determine the associated water quality ranges. In order to arrive at the fitness for use categories the previous 6 steps are conducted. The steps include:

a. Catchment assessment
b. Identify current and future water uses
c. Determine the water use requirements
d. Determine the variables of concern
e. Identify monitoring points location
f. Verify of water quality data

During the latter part of the assessment the subsequent steps are as follows:

Step 7: Setting of fitness for use categories

After identifying the water use requirement in step 3, the fitness for use approach focuses on the development of water quality categories instead of a single compliance value to describe the effect of changes in water quality levels on water users. The cut-off values for the fitness for use categories are described per user and per variable. In this approach, based on the SAWQG (1996) the fitness-for-use range is divided into four sections which are classified as four categories, ranging from *Ideal* to *Unacceptable*. These categories are described as:

- *Ideal* : the user of the water is not affected in any way;
- *Acceptable* : slight to moderate problems are encountered;
- *Tolerable* : moderate to severe problems are encountered; and
- *Unacceptable*: Severe health impact will be encountered

For ease of interpretation the fitness for use ranges are colour coded as shown in Table 3.1.

Table 3.1: Colour codes assigned to fitness for use

Fitness for use range	Colour code
Ideal	Blue
Acceptable	Green
Tolerable	Yellow
Unacceptable	Red

Step 8: Current Water quality data assessment.

This methodology uses non-parametric statistics to calculate the variability, which allows the calculation of the percentage of time for which a value was not exceeded. In this case the 5th, 50th or median, 75th and the 95th percentiles are used to assess the current water quality status. The 95th percentile value thus referring to a value that was not exceeded for 75 percent of the data points. The inter-quartile range (the values between the 25th percentile and the 75th percentile) indicate the central tendency, as the values fall between these two values for 50 percent of the time (Van Veelen, 2002).

Step 9: Combined fitness for use classification/Water quality assessment category

During this step the Fitness for use will be determined in terms of the relevant water users (domestic, agriculture, industry, recreation and the aquatic ecosystem/ ecological Reserve) and is based on the statistical calculations described in the previous step.

Thereafter, the fitness for use ranges are further grouped and analysed to come up with a single water quality assessment category. The water quality assessment categories describe the effect of the overall water quality on the users also in terms of *Ideal, Acceptable, Tolerable* or *Unacceptable*. The assessment categories are depicted in Table 3.2.

Table 3.2.: Water Quality Assessment categories

Fitness for use range in which the variables falls			**Water quality assessment category**	**Colour code**
Median	**75th percentile**	**95th percentile**		
Ideal	Ideal	Ideal	Ideal	Blue
Ideal	Ideal	Acceptable	Acceptable	Green
Ideal	Acceptable	Acceptable		
Acceptable	Acceptable	Acceptable		
Ideal	Ideal	Tolerable		
Ideal	Acceptable	Tolerable	Tolerable	Yellow

Acceptable	Acceptable	Tolerable		
Acceptable	Tolerable	Tolerable		
Tolerable	Tolerable	Tolerable		
Any other combination			Unacceptable	Red

3.2.4 Compliance Evaluation

In order to determine water quality compliance status of the resource it is necessary to have a set of targets or management objectives. In this approach the RWQOs are used as the management targets. At the time of writing this thesis RWQOs were not available for the targeted catchment, it was deemed necessary to develop a set of RWQOs. This section will therefore cover both the setting of RWQOs as well as how the compliance status of the resource is determined.

For the Compliance Evaluation approach, the RWQOs are set and water quality is categorised as compliant and non compliant to the RWQO. To arrive at the compliant status the first 6 steps described at section 3.2.2 are conducted. The steps include:

a. Catchment assessment
b. Identify current and future water uses
c. Determine the water use requirements
d. Determine the variables of concern
e. Identify monitoring points location
f. Verify of water quality data

During the latter part of the assessment the subsequent steps are as follows:

Step 7: Setting RWQOs

For the purpose of setting RWQOs the statistical values to be determined will include the 5th percentile as a lower limit for pH, the 50th percentile for phosphates and 95th percentile for other physico-chemical parameters. The verified data sets are used in the RWQOs model. The model compares the reference and current data to water quality guidelines and recommend objective based on the most sensitive user. In cases where the current water quality status of the resource is poorer than the suggested water quality value based on the most sensitive user, the tolerable limit will be selected as the proposed RWQO. In cases where the current status is better than the proposed water quality value, the current concentration will be used as the proposed RWQO in order to prevent further deterioration of the water resource. The future water uses also have to be factored into the final set of RWQOs to allow for further socio-economic development in the catchment.

Step 8: Compliance status determination

The final step in the approach is to determine compliance of the water quality as measured against the set RWQOs using a colour coding system. Blue will represent a compliant status. This implies that the current status for a particular variable is suitable for use and hence can cause no detrimental effect on the identified water users. The colour red implies that the water is not compliant and the use of this water without treatment is associated with risks to the water users.

3.2.5 Comparison of methodologies.

For the purpose of addressing the aim of the study, the results for each of the methodologies will be interpreted in the context of the approach used. The comparison will be based on the interpretation of the colour codes of the data. Finally, recommendations for the use of these approaches will be given. The study will also give suggestion on further research questions for future studies.

CHAPTER 4: WATER QUALITY STATUS OF THE CROCODILE WEST RIVER IN THE CROCODILE WEST AND MARICO WATER MANAGEMENT AREA.

4 WATER QUALITY STATUS OF THE CROCODILE WEST RIVER IN THE CROCODILE WEST AND MARICO WATER MANAGEMENT AREA

4.1 Background to the study area

The Crocodile West River is one of the most polluted rivers in South Africa. This is substantiated by the extent of eutrophic water bodies in the Crocodile West catchment as reported by several studies (Van Ginkel, 2001; Van Ginkel, 2004; DWA, 2007). At the time of writing of this thesis, the implementation of Resource Directed Measures was still underway in the Department of Water Affairs.

The aim of this chapter is to implement two approaches used in determining the water quality status of the resource. This will be done by employing management objectives or levels for threshold of potential concern in the Crocodile West River. The determination of water quality status is relevant when establishing the extent of water quality problems in the river system and determining the downstream water quality impact. The thesis uses the South African Water Quality Guidelines (SAWQG 1996) as the foundation for the setting the management objectives and thresholds.

4.1.1 The scope of the study area

The study area comprises of the entire length of the Crocodile West River (Figure 4.1). The river originates from Gauteng Province in the Witwatersrand mountain range. It is the main stream flowing through the Crocodile West and Marico Water Management Area (WMA 3). The Marico River joins the Crocodile West River before joining Limpopo River, which finally discharges into the Indian Ocean in Mozambique. Apart from the upper area of the WMA which is located in the Gauteng Province, the other portions of the catchment fall in two other provinces (Figure 4.1) The northeast portion is situated in the Limpopo Province and the central part of the WMA is located in the North West Province (DWAF, 2004b).

The Crocodile West River is highly influenced by the flows from its tributaries. The major tributaries draining into the Crocodile (West) River are the Jukskei, Hennops, Pienaars, Sand, Magalies, Elands and Bierspruit. The Crocodile (West) catchment is divided into four sub-areas which are the Elands, Apies/Pienaars and Upper and Lower Crocodile (West) sub-Areas.

4.1.2 Description of the Sub-Areas of the Crocodile West Catchment

The Upper Crocodile Sub-Area [Tertiary drainage region A21]

This upper catchment is located upstream of the confluence of Crocodile West River and the Elands River. The rivers and their tributaries included in the sub-area are: Bloubankspruit, Magalies and Sterkstroom on the left bank and J Jukskei and Hennops on the right bank of the Crocodile West River. The major towns in the area include the northern suburbs of Johannesburg, parts of Kempton Park and Krugersdorp. Hartbeespoort and Roodekopjes dams are located in this part of the catchment.

Apies /Pienaars Sub-Area [Tertiary drainage region A23]

The rivers in this catchment consist of Pienaars River and its tributaries which joins the Crocodile (West) River below the Elands River, the Moretele, Tlholwe and Apies River. The towns of Pretoria and Bela-Bela are the mainly urban and industrial areas in the catchment. The major dams in the sub-area are the Klipvoor and Roodeplaat dams located on the Pienaars River.

Elands Sub-Area [Tertiary drainage region A22]

The catchment consists of the Elands River and its tributaries such as the Koster, Selons and Hex rivers. The catchment consists mainly of rural areas and the only major city in this drainage region is Rustenburg. Mining of platinum and the platina group are dominant land uses in this sub-catchment. Major dams in the catchment include the Bospoort dam located on the Hex River and the Vaalkop dam located on the Elands River.

Lower Crocodile Sub-Area (Tertiary drainage region A24)

The sub-area comprises of the lower portions of the Crocodile (West) Catchment downstream of the confluence of the Crocodile (West) and Elands Rivers. This part of the river is fed by two major tributaries, the Sand River and Bierspruit. The major town located in this part of the catchment is Thabazimbi. After passing Thabazimbi the river meanders through an area with small villages before its confluence with the Marico River. The main water use in this sub-catchment is irrigation.

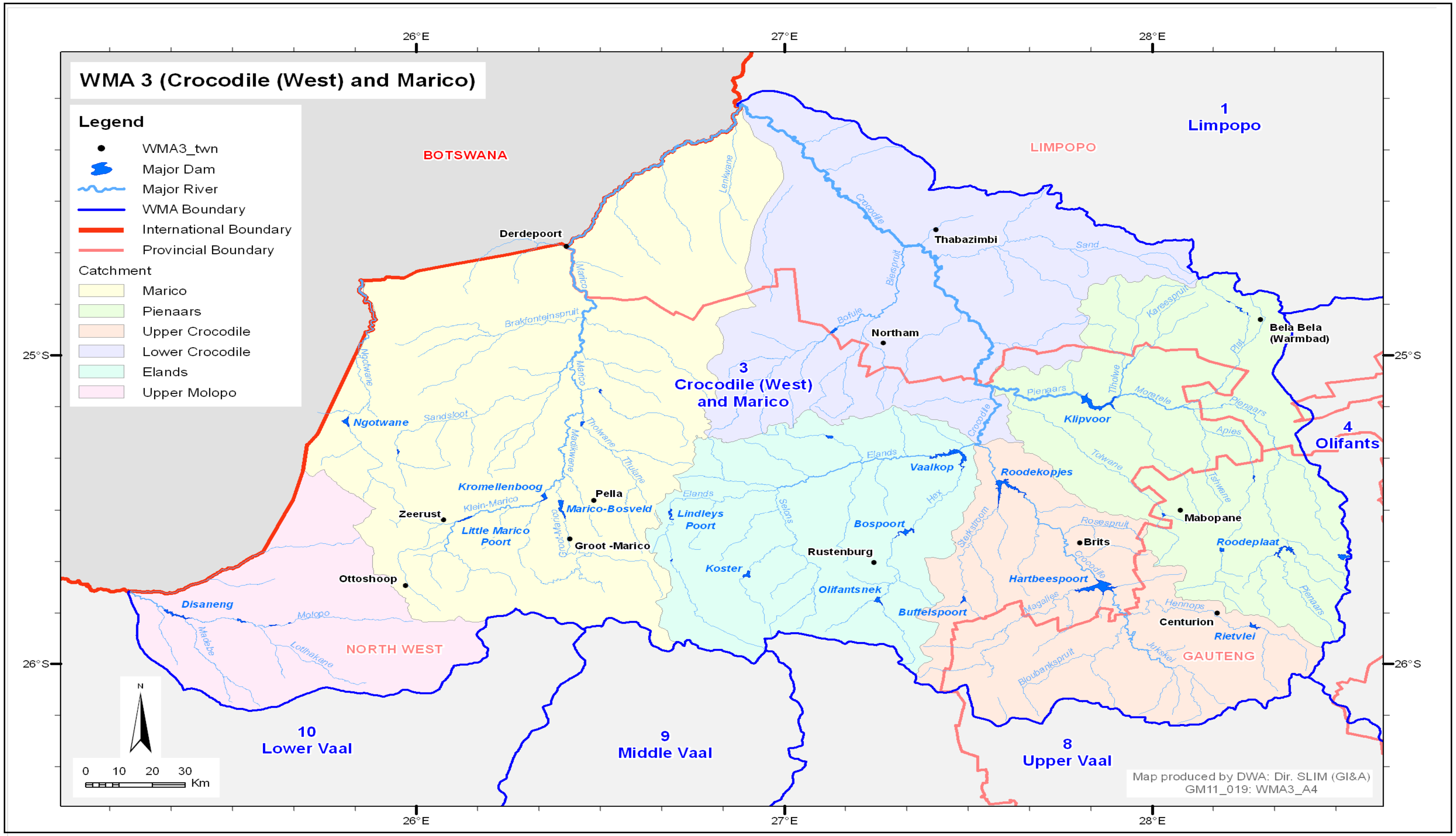

Figure 4.1: The individual sub-areas in the Crocodile (West) Marico catchment Water Management Area (WMA)

4.2 Natural features and characteristics of the WMA

4.2.1 Climate and rainfall

The climatic condition of the catchment is temperate, varying from semi arid in the east to dry in the west. Rainfall is seasonal, with the Mean Annual Rainfall (MAR) ranging from 400 to 800 mm. The MAR decreases from the eastern to the western side of the catchment. The mean annual temperature ranges between 18℃ and 20℃, with maximum temperatures during January and minimum during July (DWA, 2004a).

4.2.2 Topography and geology

The topography of the area is generally flat with undulated hills towards the Marico catchment. The main topographical features of the WMA are the Witwatersrand, Magaliesberg, Waterberg and Pilanesberg mountains. The geology varies resulting in different soil types and rich mineral deposits. The dominant Bushveld Igneous Complex in the north of Magaliesberg is the area richest in minerals. As a result a number of platinum and platina group mines have existed in the area. The catchment is located on dolomitic rock (DEAT 2005).

4.2.3 Conservation and protected areas

A number of ecologically important areas have been proclaimed in the catchment including the Bafokeng Tribal Area, the Pilanesberg Nature reserve and the Cradle of Humankind Heritage site

4.2.4 Ecology

a) Aquatic ecology

The ecology of the catchment is in a poor state (DEAT, 2005). This is due to the highly developed nature of the catchment. Pollution sources from surrounding land uses contribute to the poor water quality evident in most of the streams in the catchment. The pollution is threatening the in wetland the catchment. Many of these wetlands have not been formally characterised, consequently they lack protection status.

b) Implementation of RDM

During the writing of the thesis a preliminary Intermediate Ecological Reserve was still in progress for selected water resources in the WMA. To understand how the water quality of the system responds to changes, an assessment of the water quality component of the Reserve was conducted although not finalised. (draft DWA, 2010 (Reserve study) At the time of writing of the thesis the classification of the catchment resources was still in its early stages and the Determination of the Resource Quality Objectives for the Crocodile catchment have not taken place. This study will therefore utilize the currently best available information.

4.3 Sources of pollution and drivers of water quality in the Crocodile West catchment

The Crocodile (West) catchment is a highly developed catchment and land use development contribute extensively to the state of the water resources (Morrison *et al*., 2001; Oberholster and Ashton, 2008a; Oberholster *et al.,* 2008b). The development in the area is associated with a number of pollution sources that are contributing to the reduced levels in water quality. The development upstream of the catchment also contributes to the water pollution experienced in the rivers. The poor water quality and its implication to water users in the catchment is a major concern (Roux and Oelofse, 2010). Table 4.1 summarises the major water quality concern and issues, cause and the implications thereof to the users.

Table 4.1: Summary of the water quality concerns in the Crocodile West catchment

Water quality concern	Drivers and consequences
Eutrophication	Mainly caused by discharges from waste water treatment works and intensive agriculture with its associated use of fertilizer. Eutrophic water bodies result in the presence and increased algal growth and toxic algae; escalating costs of water treatment to water users; taste and smell of drinking water are affected; clogging of irrigation canals and pipes; and impacts on recreational water use.

Microbial contamination	Caused by discharges from waste water treatment works and informal dense settlements. Affect human health during recreational use, washing and bathing.
Turbidity	Main cause in this catchment is the informal dense settlements; Urbanisation; mining; agriculture and point source discharges. Turbidity of the water resource causes dam sedimentation; increased water treatment costs and clogging of irrigation canals.
Salts	The main source is waste water treatment works; mining (active and abandoned sites); and intensive agricultural and irrigation. Presence of high salt concentrations increase water treatment costs; cause soil salinity; and promote irrigation system clogging.

4.3.1 Urban discharges and sewage spills

The biggest impacts on water quality in the area are made by the large scale water and land users. The sprawling urban areas in the south-east of the catchment and escalated waste problems contribute to poor water quality downstream. The discharges from sewage works are also a major contributing factor as local authorities struggle to comply with discharge standards. This is evident through the eutrophication problems being experienced in the local dams. Other contributing factors to the poor water quality include industries and old abandoned mines.

4.3.2 Agricultural return flows

Fertilizers and pesticides present in runoff from agricultural land end up in the streams. This is evidently having a negative impact on the water resources in the catchment. The fertilizers contribute to the increased nutrient levels in the water resources (Walmsley, 2000) but the exact extent of this impact has not been quantified yet.

4.3.3 Use of Return flows

The Vaal River system is indirectly linked to the Crocodile River West system through the distribution of drinking water by Rand Water. The treated effluent discharges from Tshwane and the northern suburbs of Johannesburg contribute large volumes of water to the Crocodile River West catchment (DWA, 2004b).

4.3.4 Mining

Gold mines in the area have been closed. However, acid water decanting from these mines has attributed to the water quality problems in the river. Of late, the uncontrolled discharge of contaminated water from defunct mines operations has been recognised as the biggest threat to the water resources and environment (Pulles et al., 2005, DEAT, 2006).

4.4 Water users in the study area

Water quality requirements vary for each particular use. In order to determine the water quality requirements in a catchment it is important to identify which water users in the catchment are likely to be affected by the water quality of a particular river. The determination of water users within a catchment is therefore the point of departure for setting RWQOs. The specific water users for the Crocodile (West) catchment was determined through literature review. The water uses are described in the following section.

4.4.1 Agriculture

a) Irrigation

Irrigation is the largest water use sector within the catchment. Various types of crops such as vegetables are produced in the catchment (DEAT, 2005). These include citrus and subtropical fruits, sunflower, soy beans, cotton and tobacco. The sensitivity of the different crops to water quality varies and water users may be impacted in variety of ways as a result of water quality changes (DWA, 1996).

The area north west of Johannesburg but, south of the Magaliesberg Mountain has limited irrigation activities. However, extensive irrigation takes place downstream of the

Hartbeespoort dam and the area is renowned for its citrus and high value market garden crops. Further downstream of Hartbeespoort dam but south of Thabazimbi along the Crocodile there is irrigation of crops such as maize, wheat and fodder.

b) Live stock watering

Livestock are more resilient to poor water quality changes than humans and do adapt to a gradual change in water quality. However, it is imperative that the requirements of livestock are taken into consideration when determining fitness for use in order to cater for stock and game farming that is taking place in the catchment.

4.4.2 Domestic

The Crocodile catchment is more urbanised than the rest of the WMA. The majority of the population is located in Northern Johannesburg and Pretoria followed by the settlements next to the Apies/ Pienaar and the Elands rivers (DWA, 2004b). Smaller settlements are found in the Lower Crocodile sub-area. Domestic water services in the more densely settlements such as Pretoria and Johannesburg are provided by the district and local municipalities through Rand Water whereas Magalies Water provides basic services to some of the rural communities. Most of the rural communities, however, depend on ground water as their main source of domestic water. Domestic water use in this study therefore, mainly focuses on those small holdings that do not have access to treated water supplies but use water directly from the resource after primary treatment.

4.4.3 Industry, mining and power generation

Industrial water use refers to various industrial processes taking place in other industries, mining and power generating. These water processes include cooling, steam production, process water, wash water, product water as in beverages, and water used for fire protection (DWAF, 1996). Most of the industrial activities in this catchment support mining, agriculture as well as food processing industries. Large industries are situated in the city of Johannesburg and Pretoria where most of the economic activities in the Crocodile West catchment are taking place. Some of the industries receive their water from the municipal water supply but most industries treat their own water to the required level before use. Although this is the case, it is a requirement of the NWA that all legal water use is catered for when determining the resource directed measures.

The mining industry is an important sector in the catchment and makes a large contribution to the economy. There are extensive platinum and platina group mining activities around the perimeter of the Bushveld Igneous Complex, north and east of Rustenburg. The platinum mines extend to the Mabopane–Centurion Development Corridor. In the Upper catchment of the Crocodile West River there are open cast stone and sand quarries as well as platinum and chrome mining activities (DWA, 2004a).

The power stations located in the catchment are situated in Kempton Park, Pretoria West and Rooiwal power stations. All these power station receive treated effluent from adjacent sewage works. These power stations are therefore not directly impacted by the water quality in the river.

4.4.4 Recreation

Recreational water use refers to those activities taking place in or around the river whereby health impact, human safety, aesthetic impacts and economic impacts might occur due to poor water quality. The most important recreational water uses that are taken into consideration are boating and fishing. The indirect aesthetics impact of the water is also important in areas around the Hartbeespoort Dam where there is a large concentration of weekend and holiday homes.

4.4.5 Aquatic ecology

The protection of the aquatic ecology is important. Although it is a part of the resource the aquatic ecology is considered as a water user in order to cater for the water requirements of the natural aquatic ecology.

4.4.6 International Water use

The Crocodile West Marico WMA is linked to the Limpopo Basin. The Crocodile River does not necessarily transcend the boundaries of neighbouring countries, but it has an impact on the water uses of the related countries as it eventually flows into the Limpopo

River which is an international river. The international rivers are guided by agreements. The Limpopo basin is specifically managed by the Limpopo Watercourse Commission of 2003 (LIMCOM). Currently there are not specific International water quality requirements related to Crocodile West River.

4.5 Data availability

4.5.1 Data selection

The best available data was obtained from DWA- Water Management System (WMS). The monitoring points are shown by the WMS identity code and monitoring station description. All the monitoring points selected are located on the Crocodile (West) River and are part of the National Chemical Monitoring Programme of the Department Water Affairs). Table 4.2 provides more details on the selected monitoring points. Figure 4.2 and Figure 4.3 are the map and schematic diagram representing the location of the monitoring points along the Crocodile West River.

Table 4.2: Selected monitoring points along the Crocodile (West River)

Monitoring point identification number as per WMS	Monitoring Point Description as per WMS	Latitude	Longitude	Drainage Region Name
90164	A2H012 KALKHEUWEL 493 JQ ON KROKODILRIVIER	-25.810483	27.909552	A21H
90167	A2H019Q01 ROODEKOPJES DAM ON CROCODILE RIVER: DOWN STREAM WE	-25.403611	27.574778	A21K
90190	A2H045 VLAKFONTEIN 494 JQ DWJ31 ON KROKODILRIVIER	-25.892644	27.914367	A21H
90192	A2H048 KROKODILPOORT 418 JO /THABA MOYA ON KROKODILRIVIER	-25.573269	27.75445	A21J
90194	A2H050 ZWARTKOP 250 JQ HOI-HOI AT HOI-HOI ON KROKODILRIVIER	-25.99136	27.84208	A21E

90195	A2H051 VAN WYKS RESTANT 182 IQ AT MULDERSDRIFT ON KROKODILRI	-26.03311	27.84269	A21E
90203	A2H059 VAALKOP 192 JQ AT ATLANTA ON KROKODILRIVIER	-25.20639	27.558	A24A
90204	A2H060Q01 CROCODILE RIVER AT NOOITGEDACHT	-25.062222	27.521111	A24B
90214	A2H083Q01 HARTBEESPOORT DAM ON CROCODILE RIV: DOWN STREAM WE	-25.724722	27.85	A21H
90233	A2H132 HAAKDOORNDRIFT 373 KQ @ PAUL HUGO DAM ON KROKODILRIVI	-24.69514	27.40906	A24H

Historical and current data was sourced from WMS to represent the current and reference status of the resource. The present status at the sampling point was based on the data from 2006 to 2011. The statistical data sets used to show current status are shown in Appendix A. Ideally the reference conditions should be an indication the natural state of the river. However, due to data limitations the reference condition did not represent an actual natural river state, but rather the best available data to show a minimally impaired baseline state. The reference state was represented by a period of 2000 to 2004. The data sets used are shown in Appendix A.

The data was first checked for completeness to ensure that there was sufficient data to produce reliable values. For this purpose time series graphs were produced for each of the selected monitoring points as shown in the example (Figure 4.4). The remainder of the graphs are shown in Appendix B. The time series graphs for all variables indicated that all data sets were sufficient enough for the purpose of setting RWQOs.

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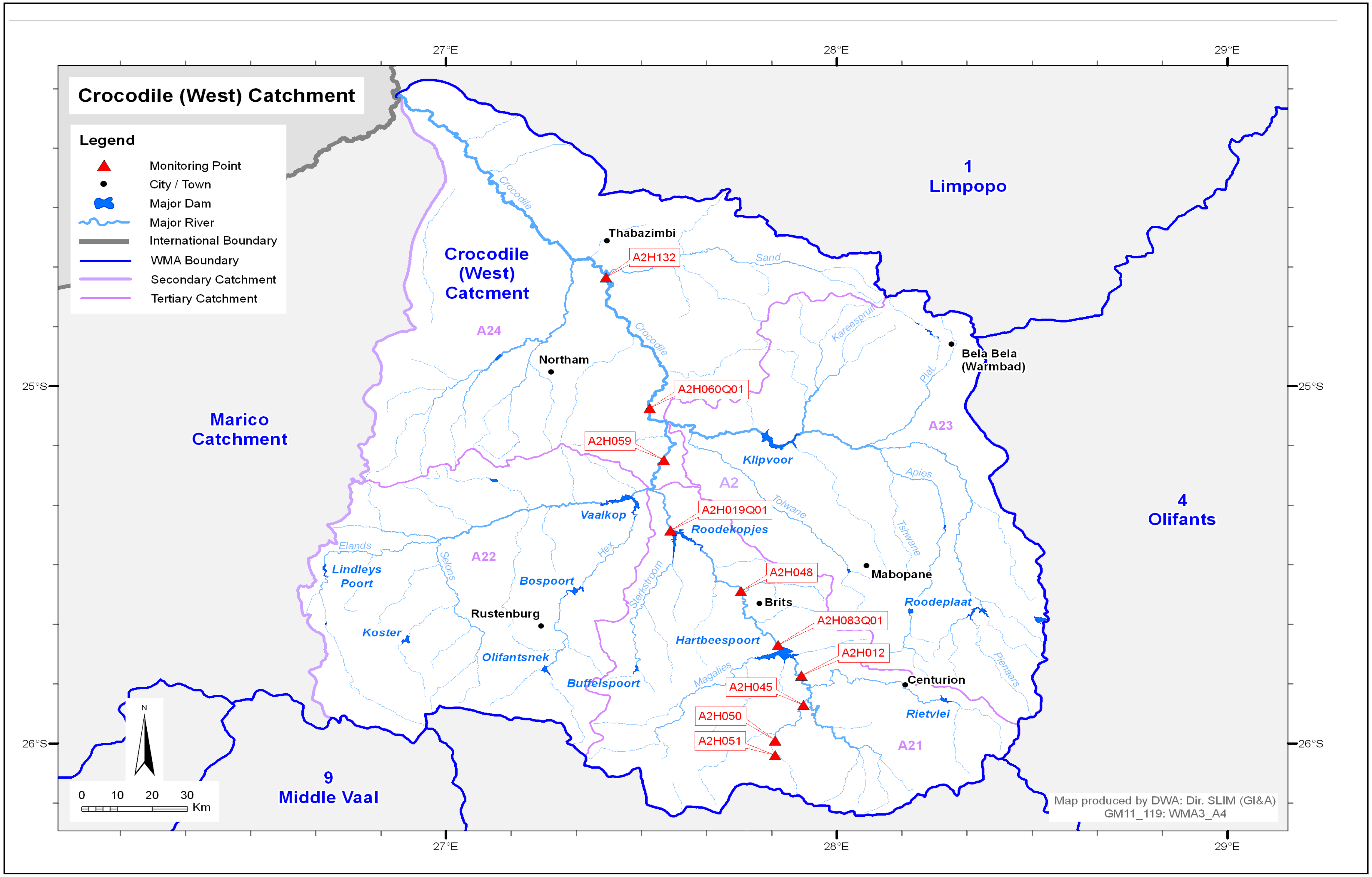


Figure 4.2: Map depicting the location of selected monitoring points along the Crocodile West River.

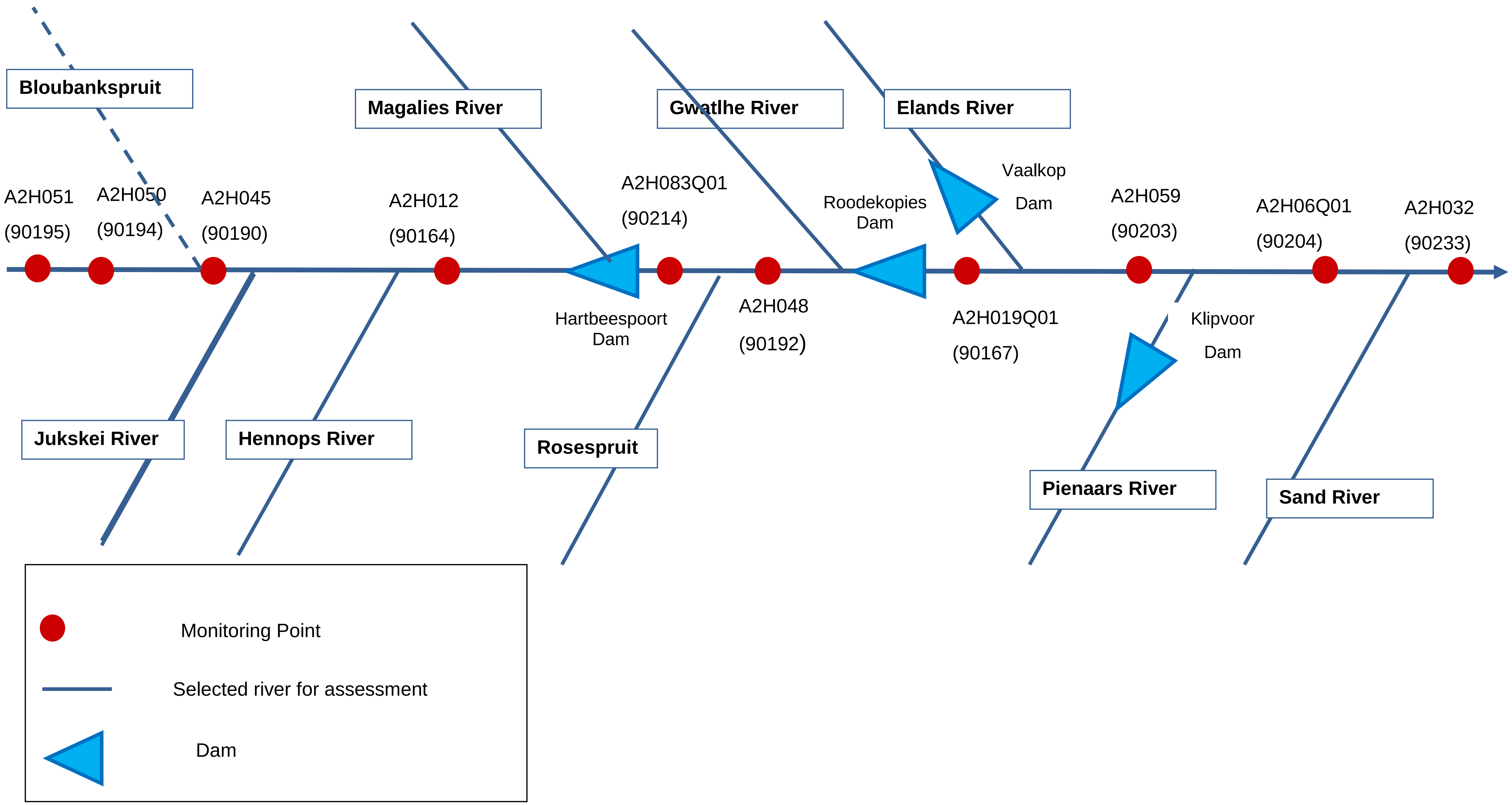


Figure 4.3: Diagram of the Crocodile (West) River main stream (level 1) monitoring points.

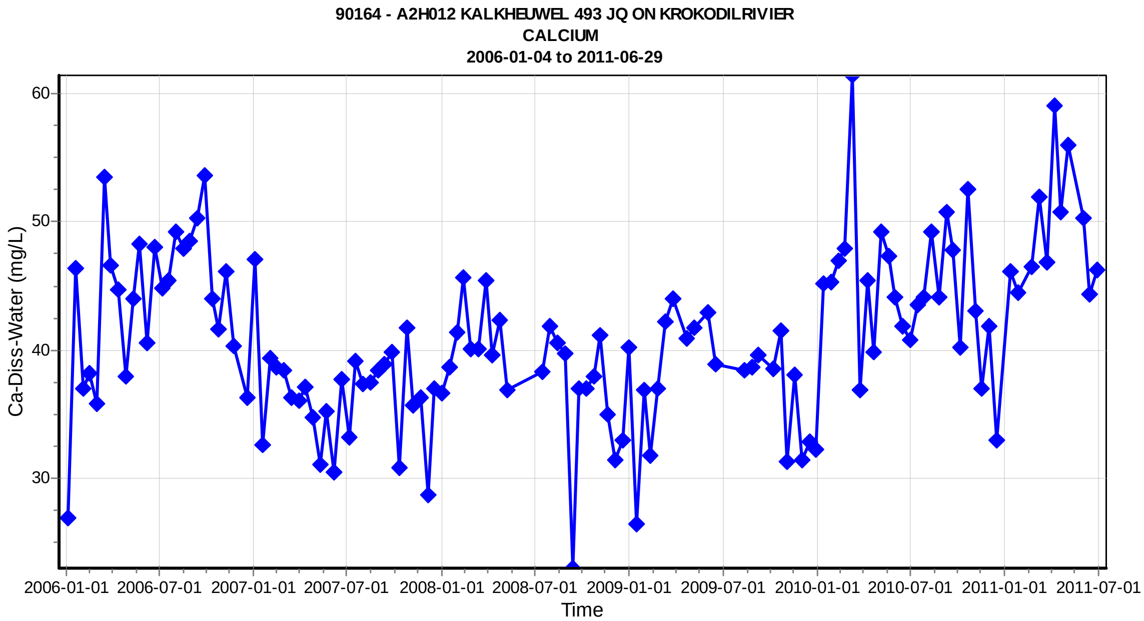


Figure 4.4: Time series graph depicting the details of calcium concentrations at monitoring point A2H012 along the Crocodile (West) River.

4.5.2 The selection of water use requirements.

The Crocodile West catchment is mainly characterised by the water user categories described on Table 4.3. The categories of the water users are based on those listed in the SAWQG (DWA, 1996). The selected water users for the purpose of the assessment are indicated in Table 4.3.

Table 4.3: Selected water users included in the Crocodile West River assessment

Water Use	Description	Associated Variables of concern
Aquatic ecology	It is the water quality required to protect fresh water ecosystems. For the purpose of this study Aquatic Ecology SAWQG will be used as an alternative to the ecological subgroup of the Reserve. Impacts on Aquatic ecology relates to the distribution of the habitat and toxic effects of other constituents	pH, Temperature, Ammonia and Nitrate/Nitrite

Domestic use	It is the water intended for human consumption, bathing and performance of other household errands. This also caters for the Basic Human Needs which is a subgroup of the Reserve. The acceptability of domestic water is judged by acceptability of human health effects and effects on the aesthetics of water. The water has to be free from odour, suspended solids and must have acceptable taste.	EC/TDS, pH, turbidity, Calcium Magnesium, Fluoride, Nitrate/Nitrite, Sulphate and Faecal coliforms as indicators of possible pathogenic contamination
Agriculture - Irrigation	It is the water primarily used for crop production. The problem associated with irrigation relate to the effect on soil and on crops/plants. The effect on soil can affect the permeability of soil. The effect on crops relates to the insufficient water absorption due to high salt concentration	EC/ TDS, pH, SAR Sulphate and Fluoride, Sulphate
Agriculture – Stock watering	It is the water required for consumption by live stock.	The variables similar to that for Domestic use, since water is fit for domestic use it should be fit for live stock watering.
Industrial use	Water required for industrial processes that utilize domestic water as the baseline minimum water quality requirement. The processes might require minimum water treatment to achieve the desired water quality. The processes include water required for production of beverages and dairy products.	The water required for the industrial use varies between industries. The water quality parameters that are required are a wide spectrum however in the thesis we will only consider the following: TDS, pH, turbidity, Sulphate, Magnesium, Potassium, and Calcium.
Recreation – Intermediate contact	Recreational water is the water required for activities such as water-skiing and angling. Recreational activities are dominant in the Crocodile West catchment. Some recreational activities are at the dams such as Hartbeespoort Dam catchment while others are taking place in the	pH, turbidity, and odour, colour and litter and faecal coliforms as indicators of pathogenic contamination

	tributaries of the main stream. The acceptability of water used for recreation is judged by the health effects and effect on the aesthetic of the water resource.	

The main stream of the Crocodile West River is a river of international importance because it is a tributary of the Limpopo which is shared by South Africa, Botswana, Zimbabwe and Mozambique. The river fall under the Limpopo basin, and is governed by international agreements. However in this case there are no international water quality requirements related to the applicable international agreements. Hence on the Limpopo as a whole, no water quality requirements for this water use were included in this study

4.5.3 Selection of variables of concern

The water quality variables were selected by considering the development objectives of the area; variables for which the identified water users were likely to be impacted by and the possible limitations on data sets. The natural characteristics of the catchment and land use information were also considered. Although large sets of variables are available on the database the assessment will only address the selected physico-chemical parameters of concern (Table 4.4).

Table 4.4: Variables selected for the Crocodile West river assessment

Variable	Variable description	Units
Physical parameters		
pH	pH	units
Chemical parameters		
Ammonia (NH_3-N)	Ammonia un-ionized 25℃	mg/l
Calcium (Ca)	Calcium, dissolved	mg/l
Chloride (Cl)	Chloride, dissolved	mg/l
Fluoride (F)	Fluoride, dissolved	mg/l
Magnesium (Mg)	Magnesium, dissolved	mg/l
Potassium (K)	Potassium, dissolved	mg/l
Sodium (Na)	Sodium, dissolved	mg/l
SO_4	Sulphate, dissolved	mg/l
TDS/DMS	Dissolved major salts,	mg/l
Nutrient parameters		
NO_2 And NO_3	Nitrate + nitrite nitrogen, dissolved	mg/l
PO_4-P	Ortho phosphate as phosphorus, dissolved	mg/l

4.5.4 Description of the variables of concern

a) Physical variables

i. pH

The pH of water is a measure of the acid-base equilibrium for dissolved compounds. The adverse effects of pH result from the solubilisation of toxic heavy metals and the protonation or deprotonation of other ions (DWAF: Ecosystems, 1996). pH is therefore used as an indicator of acidity or alkalinity of the water, which provides an indication of possible corrosive properties of the water. Health impacts are normally limited to irritation of mucous membranes or the eyes when swimming. The aquatic ecosystem is only affected by significant deviations from the natural background value.

b) Chemical variables

i. Ammonia

Total ammonia is used as an indicator of the presence of ammonia which is highly toxic to benthic or aquatic biota even at low concentrations that are difficult to measure. Ammonia has no effect on water users such as domestic use and irrigation. Ammonia is typically converted to nitrate/nitrite by bacteria that occur naturally in the water bodies.

ii. Calcium

Mineral deposits of calcium, an alkaline earth metal, are common, usually as calcium carbonate, phosphate or sulphate. Calcium occurs naturally in varying concentrations in most waters and, together with magnesium, is one of the main components of water hardness. Soft waters contain low, while hard waters contain high concentrations of calcium. Calcium is an essential element for all living organisms and is an important constituent of the bony skeleton of mammals, which consists of phosphates of calcium. At high concentrations calcium has aesthetic impacts such as scaling in domestic appliances and the impairment of soap lathering.

iii. Chloride

Chloride is an indicator of salty taste, and corrosiveness towards household appliances and irrigation equipment. Effects of salinity on the aquatic ecosystem are detected long before chloride itself becomes problematic (DWA, 1996). High chloride is problematic when irrigating deciduous trees such as citrus, where chloride build up in the leaves can result in leave chlorosis due to poor water absorption.

iv. Fluoride

Fluoride is present in many foods. Drinking water is estimated to contribute between 50% - 75% of the total dietary fluoride intake of adults (DWA, 1996). In domestic water supplies as well as industrial supplies used in the food and beverage industries, the fluoride concentration in the water should not exceed 0.7 mg/l.

v. Magnesium

Magnesium is an essential element for plants and most other living organisms, as it is a component of chlorophyll and important enzyme co-factors. Together with calcium, magnesium contributes towards scaling problems caused by deposits of carbonates in appliances using heating elements and hot water plumbing systems. It can also inhibit the lathering of soap which results in scum formation.

vi. Potassium

High concentrations of potassium are typically found in runoff from irrigated lands and at fertilizer production plants. It is also found in domestic waste water as a result of the relatively high concentration of potassium in urine. At high concentrations potassium imparts a bitter taste to water, and consumption can induce nausea and vomiting. Healthy humans are insensitive to any harmful effects caused by potassium, but electrolyte disturbances can occur, particularly in infants or patients with kidney pathologies and as such are on a potassium-restricted diet.

vii. Sodium

Sodium is highly soluble in water and mainly occurs as sodium chloride, but sometimes also as sodium sulphate, bicarbonate or nitrate. Sodium is found in industrial waste such as brine which contains high levels of sodium. It is also present in domestic waste water and irrigation return flows. Crops are sensitive to high sodium levels which can cause low crop yields and deterioration in the quality of the crops.

viii. Sulphate

Sulphate is a common constituent of surface waters due to the solubilisation of mineral sulphates such as calcium sulphate in soil and rock. High concentrations of sulphates are typically associated with acid mine drainage and industries using sulphuric acid or sulphates such as tanneries and textile mills. Effects of high concentration of dissolved sulphates in streams are destructive to the aquatic habitat. High concentrations of sulphate on drinking water can have laxative effects to sensitive individuals such as children, ill and elderly people (WHO, 2004)

ix. Total Dissolved Solids (TDS)

The Total Dissolved Solids (TDS) are a measure of the combined quantity of various inorganic and small amounts of organic matter present in solution. The principal constituents are usually calcium, magnesium, sodium, and potassium cat ions and carbonate, hydrogen carbonate, chloride, sulfate, and nitrate anions. TDS concentration is directly proportional to the Electrical Conductivity (EC) of water. EC is routinely used as an estimate of the TDS concentration (DWAF, 1996). TDS and EC are used as indicators of the salinity of the water, which affects both domestic use as well as irrigation. High salinity can have a devastating effect on the aquatic ecosystem if it deviates far from the natural background value.

c) Nutrients

i. Nitrite (NO_2)/Nitrate (NO_3)

Inorganic nitrogen present in water includes compounds such as ammonia, ammonium, nitrite and nitrate. Ammonia (NH_3) and ammonium (NH_4) are the reduced forms of inorganic nitrogen and their relative portions in water are regulated by water temperature and pH. Nitrite (NO_2) is the inorganic intermediate and nitrate (NO_3), the more stable of the two is the end product of the oxidation of organic nitrogen and ammonia. Nitrate is abundant in soil and water environment. It can also serve as an indication of contamination from human activities in the catchment, particularly the discharge of treated waste water. Due to their co-occurrence and rapid inter conversion, nitrite and nitrate are measured and considered together (DWAF, 1996). Nitrate/Nitrite (NO_3/NO_2) may affect human health, and nitrite has a toxic effect on aquatic organisms, particularly those organisms that breathe under water.

ii. Phosphate (PO_4)

Phosphorus occurs as organic and inorganic forms, and is present in water as dissolved and/or particulate species. In unimpacted waters, phosphorus is readily utilized by plants and converted into cell structures. Natural sources of phosphorus include the weathering of rocks and the subsequent leaching of phosphate salts into surface waters, in addition to the decomposition of organic matter. Elevated levels of phosphorus emanate from point-source discharges such as domestic and industrial effluents, and from diffuse sources (non point sources). Non point sources include atmospheric precipitation, urban runoff, and drainage from agricultural land, in particular from land on which fertilizers have been applied.

Phosphorus concentrations are usually determined as orthophosphates, total inorganic phosphate or total dissolved phosphorus (which includes organically bound phosphorus and all phosphates). Phosphate has no direct effect on the use of water, but is an indicator of contamination from activities in the catchment such as waste water discharge and fertilizers from agricultural activities. Phosphorus is considered to be the principle nutrient controlling the degree of eutrophication in aquatic ecosystems.

4.5.5 Water Quality Guidelines

The South African Water Quality Guidelines of 1996 are used as the basis for setting RWQOs. The guidelines were identified for the water use and variable of concern. DWA, 1996 makes provision for the following water quality guidelines domestic, aquatic ecosystems, irrigation, livestock, industry and recreationas outlined on Table 4.3. The Water Quality Guidelines for the selected variables of concern are indicated in Table 4.5. The ranges used to define the state of water indicating the level of protection are described as *Ideal, Acceptable and Tolerable*. Any value above the tolerable range is regarded as *Unacceptable*.

Table 4.5: User specific water quality guideline values.

Ecological									
Variable	**Units**	**Ideal**		**Acceptable**				**Tolerable**	
Ammonia (NH_3-N)	**mg/l**	**<**	0.015	0.015 to	0.044	0.044 to	0.073	0.073 to	0.1

Calcium (Ca)	**mg/l**								
Chloride (Cl)	**mg/l**								
Fluoride (F)	**mg/l**	<	1.5	1.5 to	2.51	2.51 to	3.52	3.52 to	3.54
Magnesium (Mg)	**mg/l**								
NO_2 and NO_3	**mg/l**								
pH (Upper)	**Units**	<	8	8 to	8.8	8.8 to	9.2	9.2 to	10
pH (Lower)	**Units**	>	6.5	6.5 to	5.9	5.9 to	5.6	5.6 to	5
Potassium (K)	**mg/l**								
PO_4-P	**mg/l**	<	0.005	0.005 to	0.015	0.015 to	0.025	0.025 to	0.125
Sodium (Na)	**mg/l**								
SO_4	**mg/l**								
TDS	**mg/l**								
Basic Human Needs									
Variable	**Units**	**Ideal**		**Acceptable**		**Tolerable**		**Unacceptable**	
Ammonia (NH_3-N)	**mg/l**								
Calcium (Ca)	**mg/l**	<	80					>	80
Chloride (Cl)	**mg/l**	<	200					>	200
Fluoride (F)	**mg/l**								
Magnesium (Mg)	**mg/l**	<	100					>	100
NO_2 and NO_3	**mg/l**							>	
pH (Upper)	**Units**	<	9.5					>	9.5

pH (Lower)	**Units**	>	5					<	5
Potassium (K)	**mg/l**	<	150					>	150
PO4-P	**mg/l**								
Sodium (Na)	**mg/l**	<	200					>	200
SO_4	**mg/l**	<	400					>	400
TDS	**mg/l**	<	1000					>	1000
Domestic use									
Variable	**Units**	**Ideal**		Acceptable		Tolerable		Unacceptable	
Ammonia (NH_3-N)	**mg/l**								
Calcium (Ca)	**mg/l**	<	10	10 to	150	150 to	300	>	300
Chloride (Cl)	**mg/l**	<	100	100 to	200	200 to	600	>	600
Fluoride (F)	**mg/l**	<	0.7	0.7 to	1	1 to	1.5	>	1.5
Magnesium (Mg)	**mg/l**	<	70	70 to	100	100 to	200	>	200
NO_2 and NO_3	**mg/l**	<	6	6 to	10	10 to	20	>	20
pH (Upper)	**Units**	>	9.5	9.5 to	10	10 to	10.5	>	10.5
pH (Lower)	**Units**	<	5	5 to	4.5	4.5 to	4	<	4
Potassium (K)	**mg/l**		25	25 to	50	50 to	100	>	100
PO_4-P	**mg/l**								
Sodium (Na)	**mg/l**	<	100	100	200	200 to	400	>	400

				to					
SO_4	**mg/l**	<	200	200 to	400	400 to	600	>	600
TDS	**mg/l**	<	450	450 to	1000	1000 to	2400	>	2400
Agriculture - Stock watering									
Variable	**Units**	**Ideal**		Acceptable		Tolerable		Unacceptable	
Ammonia (NH_3-N)	**mg/l**								
Calcium (Ca)	**mg/l**	<	1000	1000 to	1500	1500 to	2000	>	2000
Chloride (Cl)	**mg/l**	<	1000	1000 to	1750	1750 to	2000	>	2000
Fluoride (F)	**mg/l**	<	2	2 to	4	4 to	6	>	6
Magnesium (Mg)	**mg/l**	<	500	500 to	750	750 to	1000	>	1000
NO_2 and NO_3	**mg/l**								
pH (Upper)	**Units**								
pH (Lower)	**Units**								
Potassium (K)	**mg/l**								
PO_4-P	**mg/l**								
Sodium (Na)	**mg/l**	<	2000	2000 to	2250	2250 to	2500	>	2500
SO_4	**mg/l**	<	1000	1000 to	1250	1250 to	1500	>	1500
TDS	**mg/l**	<	1000	1000	2000	2000	3000	>	3000

				to		to			
Agriculture - Irrigation									
Variable	**Units**	**Ideal**		Acceptable		Tolerable		Unacceptable	
Ammonia (NH_3-N)	**mg/l**								
Calcium (Ca)	**mg/l**								
Chloride (Cl)	**mg/l**	<	100	100 to	137.5	137.5 to	175	>	175
Fluoride (F)	**mg/l**	<	2	2 to	8.5	8.5 to	15	>	15
Magnesium (Mg)	**mg/l**								
NO_2 and NO_3	**mg/l**								
pH (Upper)	**Units**		8.4	8.4 to	8.4	8.4 to	8.4	>	8.4
pH (Lower)	**Units**		6.5	6.5 to	6.5	6.5 to	6.5	>	6.5
Potassium (K)	**mg/l**								
PO_4-P	**mg/l**								
Sodium (Na)	**mg/l**	<	70	70 to	92.5	92.5 to	115	>	115
SO_4	**mg/l**								
TDS	**mg/l**	<	260	260 to	1755	1755 to	3510	>	3510
Industrial Category 3									
Variable	**Units**	**Ideal**		Acceptable		Tolerable		Unacceptable	
Ammonia	**mg/l**								

(NH_3-N)									
Calcium (Ca)	**mg/l**								
Chloride (Cl)	**mg/l**	<	100	100 to	150	150 to	200	>	200
Fluoride (F)	**mg/l**								
Magnesium (Mg)	**mg/l**								
NO_2 and NO_3	**mg/l**								
pH (Upper)	**Units**	<	8	8 to	9	9 to	10	>	10
pH (Lower)	**Units**	>	6.5	6.5 to	5.75	5.75 to	5	<	5
Potassium (K)	**mg/l**								
PO_4-P	**mg/l**								
Sodium (Na)	**mg/l**								
SO_4	**mg/l**	<	200	200 to	250	250 to	300	>	300
TDS	**mg/l**	<	450	450 to	800	800to	1600	>	1600
Recreation – Intermediate contact									
Variable	**Units**	**Ideal**		Acceptable		Tolerable		Unacceptable	
Ammonia (NH_3-N)	**mg/l**								
Calcium (Ca)	**mg/l**								
Chloride (Cl)	**mg/l**								
Fluoride (F)	**mg/l**								

Magnesium (Mg)	**mg/l**								
NO_2 and NO_3	**mg/l**								
pH (Upper)	**Units**	<	8.5	8.5 to	8.75				
pH (Lower)	**Units**	>	6.5	6.5 to	5.75				
Potassium (K)	**mg/l**								
PO_4-P	**mg/l**								
Sodium (Na)	**mg/l**								
SO_4	**mg/l**								
TDS	**mg/l**								

4.6 Fitness for use classification and categorisation approach

The approach that is documented in DWA report: Water Quality Assessment Report for the study updating of the hydrology and yield analysis of the Marico River catchment (DWA, 2009b; DWA, 2010c; DWA, 2006a - b) was used as the basis for the analysis.

4.6.1 Determining the fitness for use categories and combined fitness for use classification

The statistical values for the 5th, 50th percentile, 75thand 95th percentiles were compared to the Water quality criteria shown in Table 4.5. Each water quality criterion is divided into four sections or categories, ranging from ideal to unacceptable. The categories are described as follows:

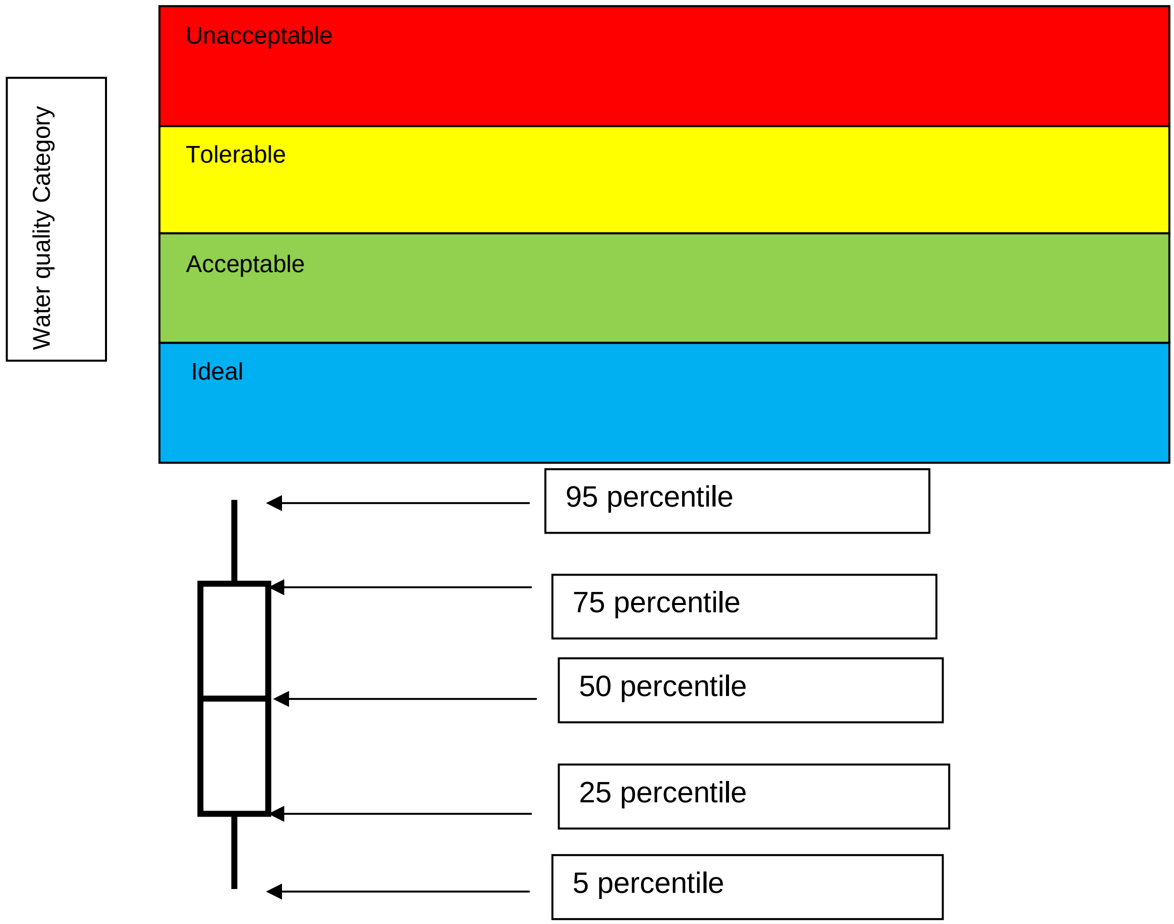
Ideal: The user of the water is not affected in anyway

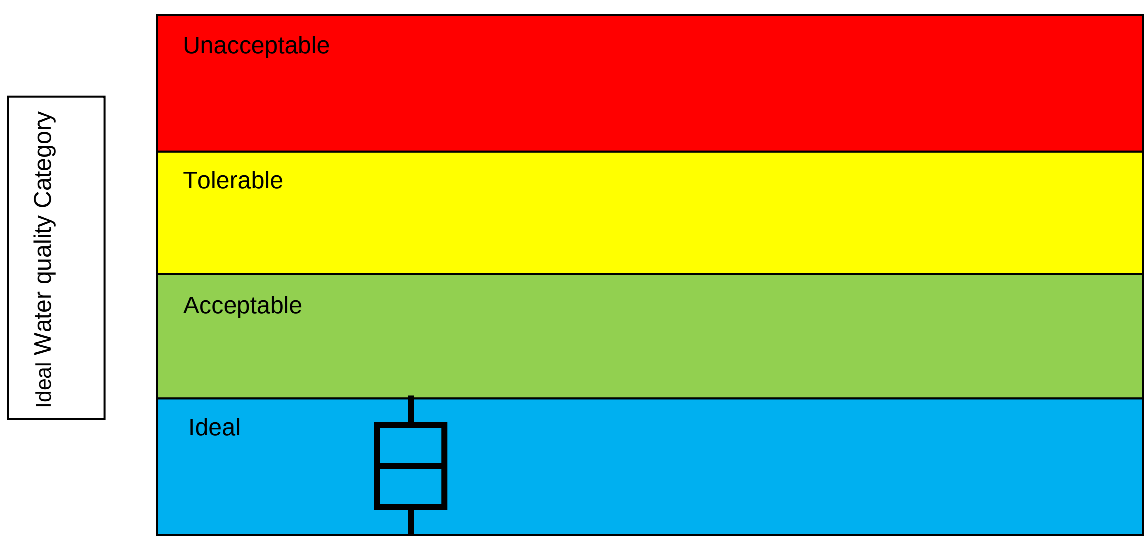
Acceptable: Slight to moderate problems are encountered

Tolerable: Moderate to severe problems are encountered

Unacceptable: The water cannot be used under normal circumstances.

For ease of interpretation during the assessment of the water quality, the fitness for use categories are colour coded as indicated in Figure 4.5. Figure 4.5 and Table 4.6 show the combined fitness for use categories. The categories for each variable are defined per water use (Table 4.5). To arrive at a category the different user requirements were reconciled. For reconciliation, the most sensitive user requirements are a representative of the combined fitness for use which defines the category. Further the categories were assigned a colour code as shown on Figure 4.5 and Table 4.6.


Water quality Category
Unacceptable
Tolerable
Acceptable
Ideal
95 percentile
75 percentile
50 percentile
25 percentile
5 percentile


Ideal Water quality Category
Unacceptable
Tolerable
Acceptable
Ideal

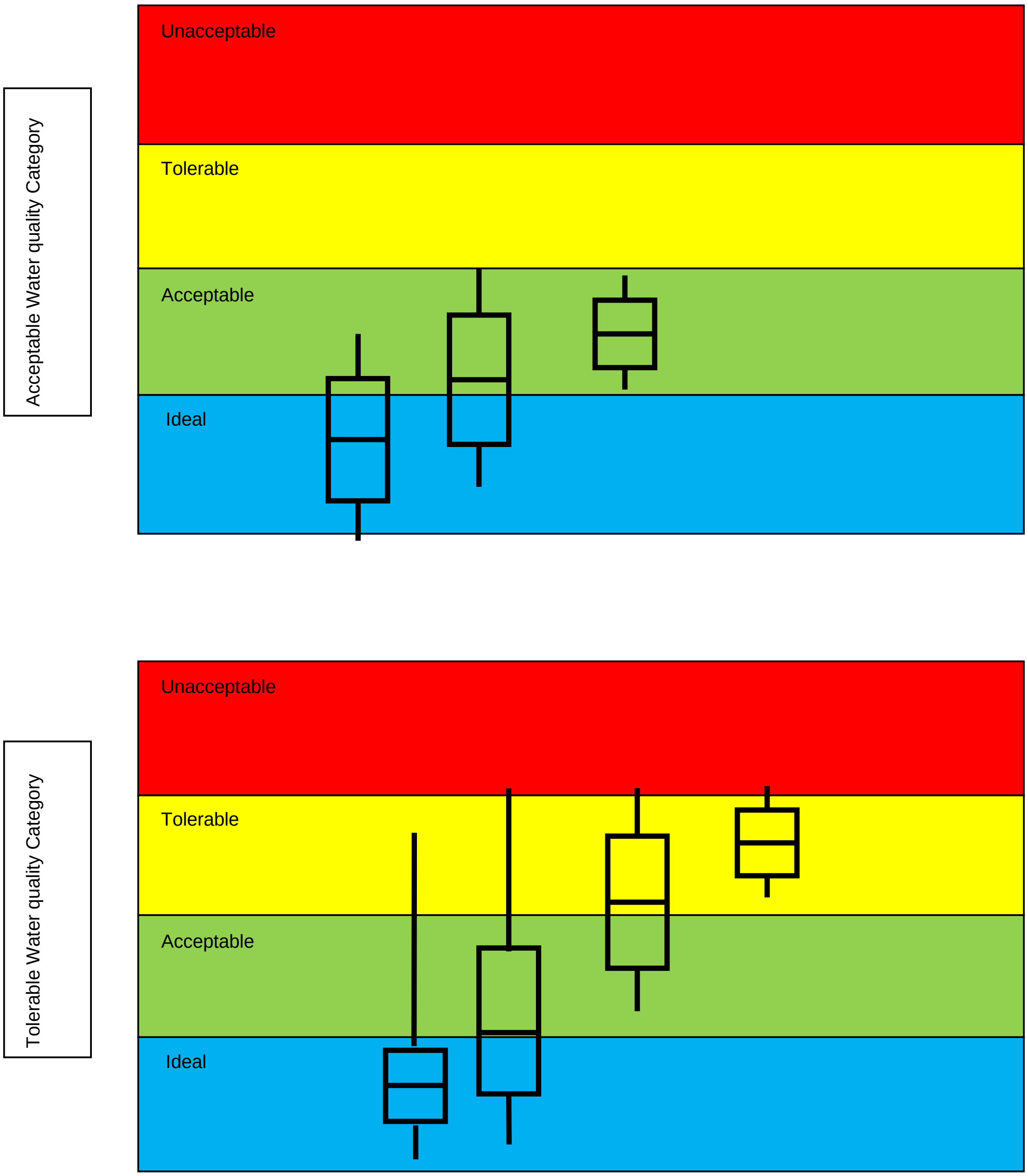


Figure 4.5: The graphical representation of the colour codes for fitness for use categories

Table 4.6: Description and colour codes for the fitness for use categories

Fitness for use range in which the variables falls			Water quality assessment category	Colour code
Median/ 50th percentile	75th percentile	95th percentile		
Ideal	Ideal	Ideal	Ideal	Blue
Ideal	Ideal	Acceptable	Acceptable	Green
Ideal	Acceptable	Acceptable		
Acceptable	Acceptable	Acceptable		
Ideal	Ideal	Tolerable		
Ideal	Acceptable	Tolerable	Tolerable	Yellow
Acceptable	Acceptable	Tolerable		
Acceptable	Tolerable	Tolerable		
Tolerable	Tolerable	Tolerable		
Any other combination			Unacceptable	Red

4.6.2 Assigning of the assessment categories

Data used for the assessment was extracted from WMS data base. The current water quality state was arrived at by calculating 5th, 50th 75th and the 95th percentile values for all variables selected at each sampling point (Appendix A). The values were then compared to the cutoff values presented in Table 4.5 and the colour codes were assigned. Based on the colour codes, an overall water quality assessment category was assigned to each variable at that particular monitoring point. Table 4.7 depicts the result of assessment for monitoring point A2H012. The water quality assessment results for other selected monitoring points are shown in Appendix C.

Table 4.7: Fitness for use categories for monitoring point A2H012 KALKHEUWEL 493 JQ ON KROKODILRIVIER

Monitoring point ID	Stats of	N	P5	P75	P95	Mean	Water Quality Assessment Category & colour coding
90164	Ca-Diss-Water	128	31.153	45.43275	51.57665	41.06386	A
90164	Cl-Diss-Water	125	38.5982	61.036	100.2426	59.7909	A
90164	DMS-Tot-Water (Total Dissolved Solids: TDS)	82	308.3995	439.4865	498.9121	411.0311	T
90164	F-Diss-Water	95	0.1607	0.2845	0.3943	0.271789	I
90164	K-Diss-Water	129	6.14	9.769	11.1848	8.652915	I
90164	Mg-Diss-Water	127	10.5253	17.4275	21.3828	16.09832	I
90164	Na-Diss-Water	122	32.72055	54.65375	68.67245	50.20236	I
90164	NH_3(25)-Union-Diss-W	131	0	0.024	0.0635	0.015115	A
90164	NO_3+NO2-N-Diss-Water	100	2.205	5.818	6.9272	4.98026	A
90164	pH- Lower limit	136	7.41975	8.122	8.36875	7.904801	I
90164	pH- Upper limit	136	7.41975	8.122	8.36875	7.904801	A
90164	PO_4-P-Diss-Water	131	0.2955	0.956	1.71	0.811809	U
90164	SO_4-Diss-Water	132	35.79795	57.956	72.0802	52.37276	I

4.6.3 Results and discussion for the Fitness for use classification and categorisation approach

Calcium and magnesium are the main components of water hardness. According to the assessed data calcium for the selected monitoring points along the Crocodile (West) River is acceptable, while magnesium is in the Ideal category. This implies that the water in this catchment is likely to be slightly hard. This will cause noticeable but not major aesthetic effects associated with scaling in domestic appliances and the impairment of soap lathering. The main water hardness driver in this case is calcium since it is in the acceptable category. Although the water body does not require any management action with regard to magnesium the situation must be monitored to ensure that it does not deteriorate. Calcium should be strictly monitored and management actions should be implemented if the situation deteriorates.

Sodium mainly occurs as sodium chloride, sodium sulphate, bicarbonate or nitrate. Most of the assessed monitoring points are on *Ideal* category for sodium with the exception of A2H048 (90192), A2H059 (90203), A2H060Q01 (90204) and A2H132 (90233) which are in *Acceptable* category.

None of the water users in this catchment are affected to a large degree. If the quality remains stable or if it improves no major management actions are required except to monitor that the situation does not deteriorate. When monitoring shows a deteriorating state of sodium which may affect the yield and quality of sensitive agricultural crops strict point source management will need to be implemented in the following sectors: industry, local government specifically the waste water treatment works and informal settlements. The diffuse sources such as the return flows from agricultural irrigation will have to be addressed in the event of deteriorating trends of water quality with regard to sodium.

As an indicator of saltiness, chloride is on *Ideal* category for most of the monitoring points in the Crocodile West River. However the data indicate that the monitoring points A2H012 (90164); A2H048 (90192); A2H059 (90203); A2H060Q01(90204) and A2H132 (90233) are on *Acceptable* category, indicating that there could be local problems with regard to the chloride input in some portions of the river. The data indicates that the situation is currently under control and only requires monitoring that verify that the quality does not deteriorate. In the event that the quality shows an upward trend the action will need to be taken to address the water quality in the system as high chloride concentration can be toxic to plants due to poor water absorption. In domestic use water with high chloride concentration can cause corrosion of house hold appliances and cause drinking water to taste salty.

The situation for sulphate in the Crocodile West catchment is *Ideal.* Water quality management should strive to maintain this state as. The only management option at this point is to monitor the situation and ensure that it does not deteriorate.

Dissolved Major Salts (DMS) or Total Dissolved Solids (TDS) is mostly *Acceptable* with the exception of monitoring point A2H051 (90195) which is in the *Ideal* condition*,* In this category most of the water users such as domestic use as well as irrigation and the ecology are not noticeably affected as the is currently under control and only requires monitoring to ensure that the water quality does not deteriorate. However in the event that the water quality shows an upward deteriorating trend actions will have to be executed to address the water quality in the system.

The Crocodile West River is in *Ideal* category for with respect to fluoride, potassium and magnesium. These water quality parameters only require to be monitored to ensure that the situation remains stable and does not deteriorate. No effects are expected on the Ecological, domestic, industrial and agricultural irrigation.

The water quality condition for ammonia in the Crocodile West River ranges from I*deal* to *Unacceptable* category. The situation presented by monitoring point A2H012 (90164), A2H01Q01 (90167) and A2H132 (90233) is *Acceptable* while monitoring point A2H083Q01 (90214) is in a *Tolerable* state and A2H048 (90192) falls in the *Unacceptable* category. The effects of high ammonia can affect human health and the aquatic ecosystem. The other forms of inorganic nitrogen which are nitrate and nitrite are mostly in the *Ideal state* with the exception of monitoring point A2H012 (90164) which are in the *Acceptable* state. The water quality of the river requires some intervention since some of the portions of the river are already in the unacceptable state.

The crocodile West River is mostly in an *Unacceptable* state with regard to Phosphate. Approximately 90% of the monitoring points fall outside the tolerable fitness for use category (Figure 5.6). Although phosphate on its own has no direct effect on the water use it is an indicator of contamination from mainly waste water discharges and fertilizers from agricultural activities. High phosphorus concentrations are considered to be the principle cause of eutrophication in the water resources. An immediate intervention is required to address the water quality deterioration that is already in the water resource. This might require a number of interventions such as source management as well as resource remediation. Water resource remediation is considered as one on the most expensive methods to address this issue. The increase in phosphorus concentrations in water resources increases the growth of phosphate-dependent organisms, such as algae which ultimately disrupts the aquatic environment.

The pH of water is a measure of the acid-base equilibrium for dissolved compounds. The adverse effects of pH result from the solubilisation of toxic heavy metals and the protonation or deprotonation of other ions (DWAF: Ecosystems, 1996). pH is therefore used as an indicator of acidity or alkalinity of the water, which provides an indication of possible corrosive properties of the water. Health impacts are normally limited to irritation of mucous membranes or the eyes when swimming. The aquatic ecosystem is only affected by significant deviations from the natural background value

As an indicator of acidity or alkalinity of water the data shows that the state of water quality in the Crocodile West ranges from acceptable to unacceptable alkalinity. Although alkaline water has less effect than acidic water, hard water can impart in appropriate soda like taste. The water quality in the Crocodile West requires management actions to address high alkalinity

Based on the analysis of the data, orthophosphate falls within the *Unacceptable* fitness for use category for all the selected monitoring points evaluated for the river. This is evident in the eutrophic conditions of some of the major dams in the catchment. The other variables of concern in the Crocodile (West) River is alkalinity, where the fitness for use categories varied between *Acceptable* to *Unacceptable*. Ammonia ranges from *Ideal* to *Unacceptable*. Monitoring point A2H048 (90192) was the only point with an *Unacceptable* designation which could be attributed to the discharges from the nearby town of Brits. The percentage summary for the fitness for use categories are shown in Figure 4.6.

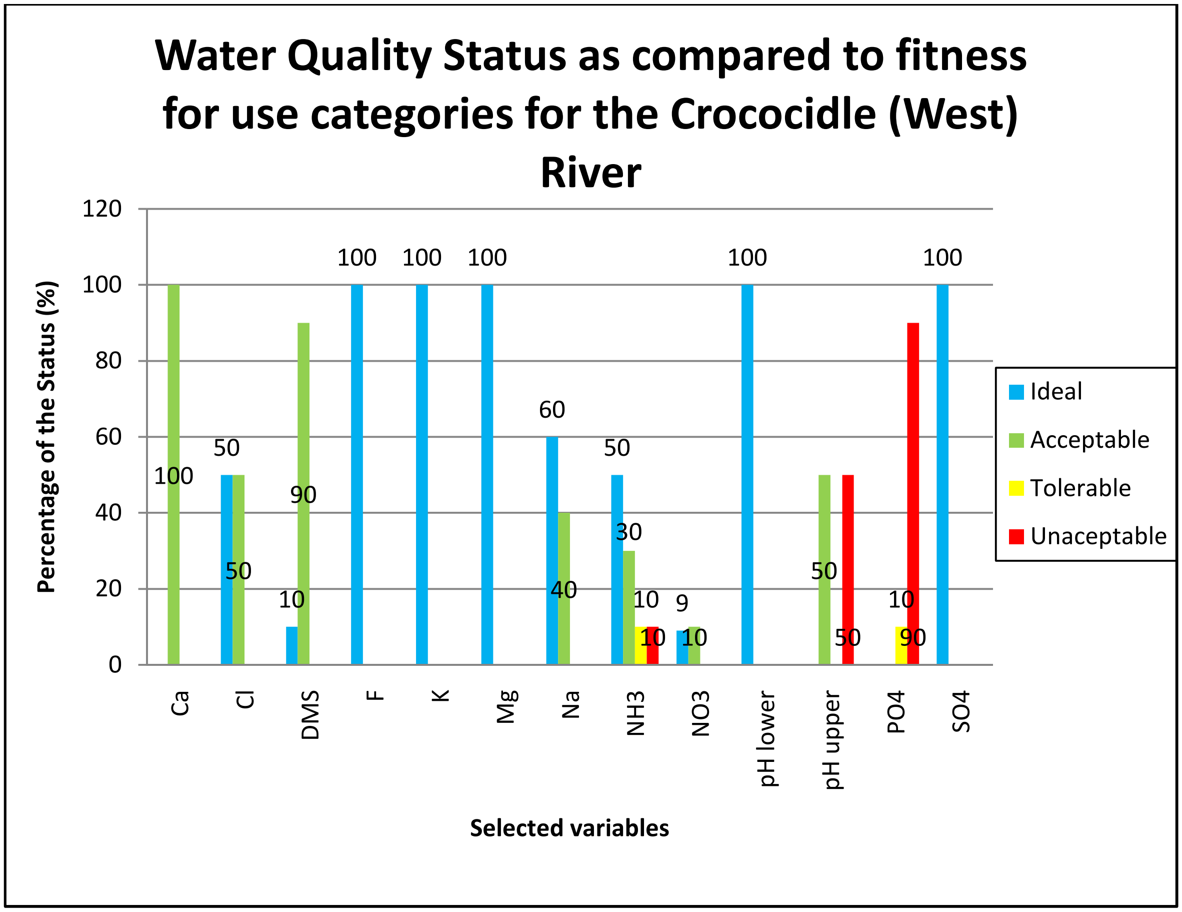


Figure 4.6: Graph summarizing the fitness for use categories of the monitoring points along the Crocodile (West) River for each of the variables of concern.

4.7 Compliance Evaluation Approach

4.7.1 The level of protection for the water resource

The methodology and approach used for the Compliance Evaluation approach is discussed elsewhere in literature (DWAF 2006a-c; DWA, 2009a; DWA, 2009c and Hughes, 2005. RWQOs Model DWAF was utilized to determine to determine the RWQOs for each river reach of the Crocodile West River.

As a prerequisite this approach requires that the management vision of the catchment be established. Visioning is a process of identifying the current and future water use requirements and the desired state of the catchment. The process is driven by catchment stakeholder engagement. Since no visioning was conducted for the purpose of the thesis, the vision for this catchment was obtained from the Internal Strategic Perspective document and the National Water Resource Strategy of 2004 (DWA, 2004a, (DWA, 2004b).

The purpose of water quality management as described in the thesis is to ensure that where necessary, acceptable water quality is maintained in the Crocodile (West) River and to prevent further deterioration of the resource. Where required the poor water quality to be improved to acceptable state. This will be achieved by assigning a certain level of protection to the water resource. For the purpose of this thesis the level of protection is guided by the need to ensure a balance between socio-economic development and the protection of the resource as described in Strategy 2.2 of the ISP (DWA, 2004b). The descriptions of the Sustainable Ecological Categories for the assessment of the surface water resources are provided in Table 4.8; the Present Ecological State was based on the current water quality status of the river. The ecological integrity status for the assessment of the Crocodile West River was adopted from the RWQOs model (Table 4.9).

The determination of the RWQOs is to ensure the suitability of water for intended uses. Each user sector has different water quality requirements and user conflicts may occur in a single catchment. The desired water user's category can be described in terms of quantitative and descriptive information goals. In the Crocodile West River Catchment the acceptable water is a basic requirement for most of the fundamental water uses in the catchment. The selected water uses in the catchment include the existing and future water users' categories as indicated in Table 4.3. Retrospectively Table 4.10 shows the selected water users and the level of protection required for each water resource reach and/ or selected monitoring point. The assigned level of protection can be described *as Ideal (I), Acceptable (A) or Tolerable (T)*. However it is not desirable to manage the resource at tolerable conditions but the tolerable condition can be assigned temporarily where the resource can be improved to acceptable conditions.

Table 4.8: Ecological Categories for the assessment of the ecological integrity of

surface water resources

Category	Ecological Integrity Status	Description of the Ecological Integrity Status
A	Unmodified, natural	The resource has not been exploited
B	Modified	Resource with small change of natural habitat and biota. The ecosystem functions are still the same.
C	Moderately Modified	There is a change in biota and habitat but the basic ecosystem functions are still the same
D	Largely Modified/ Heavily Used	There are large changes in natural habitat, biota and basic ecological functions

Table 4.9: Recommended Ecological Categories for each of the monitoring points

Quaternary Drainage region		Ecological Importance and Sensitive Categories (EISC)	Present Ecological State Categories (PESC)	Recommended Ecological Categories (REC)
A21H	Crocodile	Moderate	Class C: Moderately modified	Class B
A21K	Sterkstroom	Moderate	Class C: Moderately modified	Class B
A21J	Crocodile	Moderate	Class C: Moderately modified	Class B
A21E	Crocodile	Moderate	Class C: Moderately modified	Class B
A24 A	Crocodile	Moderate	Class D: Largely modified	Class B
A24B	Crocodile	Moderate	Class D: Largely modified	Class B
A24H	Crocodile	Moderate	Class D: Largely modified	Class C

Table 4.10: The level of protection for water users at selected monitoring points

Water Users and level of protection at different sites in the Crocodile River mainstream and tributaries-level 1 and 2															
RWQOs Sample site	**Domestic use**			**Irrigation**			**Livestock Watering**			**Industrial Use (Category 3)**			**Recreational Intermediate**		
	I	A	T	I	A	T	I	A	T	I	A	T	I	A	T
Crocodile West river															
A2H051		√			√			√			√			√	
A2H050		√			√			√			√			√	
A2H045		√			√			√			√			√	
A2H012		√			√			√			√			√	
A2H083Q01		√			√			√			√			√	
A2H048		√			√			√			√			√	
A2H019Q01		√			√			√			√			√	
A2H059		√			√			√			√			√	
A2H060Q01		√			√			√			√			√	
A2H132		√			√			√			√			√	

4.7.2 Water quality statistical analysis

The present state and the reference state (Appendix B) was used as input data in the current version of the RWQOs model. The percentile values used for each variable are 95^{th} percentiles for salts and 50^{th} percentile for nutrients concentrations. The 5^{th} percentile of the pH data represents the lower limit and the 95^{th} percentile the upper limit (Table 4.11).The model compares the data for each variable to the water user requirements (Table 4.5) and provides the cut off values for *Ideal, Acceptable and Tolerable* and recommends a maximum value that can be applied for the management of the resource. The recommended RWQOs are defined by the most sensitive water user requirements within the desired management class.

Table 4.11: Percentiles used for the setting of RWQOs for different variables

Variable Name	Variable Abbreviation	P5	P50/Mean	P95
Calcium	Ca-Diss-Water			X
Chloride	Cl-Diss-Water			X
Fluoride	F-Diss-Water			X
Potassium	K-Diss-Water			X
Magnesium	Mg-Diss-Water			X
Sodium	Na-Diss-Water			X
Ammonium Nitrogen	NH3(25)-Union-Diss-W			X
Nitrate+Nitrite nitrogen	NO3+NO2-N-Diss-Water			X
pH as indicator of acidity	pH-Diss-Water Lower	X		
pH as indicator of alkalinity	pH-Diss-Water Upper			X
Orthophosphate as phosphorus	PO4-P-Diss-Water		X	
Sulphate	SO4-Diss-Water			X
Dissolved major salts	DMS-Tot-Water / (Total Dissolved Solids: TDS)			X

Table 4.12 depicts the preliminary RWQOs set for the monitoring point A2h012 and the compliance of the current status to the set objectives as an assessment status. The RWQOs were set for all selected motoring points and the information is available in Appendix D. To arrive at the final RWQOs, the outputs RWQOs from the model were adjusted based on stricter water quality requirements and catchment knowledge. A motivation for the adjustment is supplied in the associated tables.

For interpretation of results, excel spread sheet was utilized to perform an assessment of the compliance status and produce the graphs (Figure 4.7 and Figure 4.8). To enable better interpretation of the results, percentage compliance and graphical representation of the results were produced. The percentage compliance is indicated by a histogram (Figure 4.7) and the spatial variation of variables is indicated by line diagrams (Figure 4.8). Figure 4.7 shows that most of the variables of concern comply with the set RWQOs. Phosphate is an exception where 90 percent of the monitoring points do not comply. Furthermore 50 percent of the monitoring points do not comply with the Upper limit of pH followed by 0 percent of the monitoring points that do not comply to the RWQOs set for the Ammonia. Figure 4.8 The RWQOs for the monitoring points have been imposed as a red line across the distance plot to indicate the compliance at each monitoring point. The statistics used are the 5th, 50th and 95th percentile values for the selected monitoring points. Further information is available in Appendix E.

Table 4.12: RWQOs and compliance status quo for monitoring point: 90164: A2H012 KALKHEUWEL 493 JQ ON KROKODILRIVIER.

	Reference status (2000 to 2004)			Present status (2006 to 2011)						
Stats of	P5	P50	P95	P5	P50	P95	RWQOs Model 4.2.0.3	**Affected User**	**Recomm-ended RWQOs**	***Reason for adjustment***
90164: A2H012 KALKHEUWEL 493 JQ ON KROKODILRIVIER										
Ca-Diss-Water	31.20775	40.148	50.40575	31.153	40.3215	51.57665	80	**Dom**	**80**	
Cl-Diss-Water	33.349	52.155	73.52	38.5982	55.98	100.2426	137.5	**Dom AIr In3**	**100**	*ideal for domestic and agriculture*
DMS-Tot-Water	287.0105	416.755	455.4265	308.39945	412.227	498.9121	800	**Air**	**500**	*acceptable for Industrial use Cat 3*
F-Diss-Water	0.22575	0.2645	0.34	0.1607	0.27	0.3943	1	**Dom**	**0.7**	
K-Diss-Water	6.186	9.031	11.5295	6.14	8.645	11.1848	50	**Dom**	**25**	*Ideal for Domestic use*
Mg-Diss-Water	11.01825	16.314	21.1645	10.5253	15.387	21.3828	100	**Dom**	**70**	*Ideal for domestic use*
Na-Diss-Water	28.61275	45.7985	63.5965	32.72055	49.709	68.67245	92.5	**Air**	**70**	*Ideal for Agriculture Irrigation*
NH3(25)-Union-Diss-W	0	0.002	0.01425	0	0.005	0.0635	0.044	**EWQG**	**0.044**	
NO3+NO2-N-Diss-Water	2.2	4.576	6.22225	2.205	5.216	6.9272	10	**Dom**	**10**	
pH-Diss-Water	7.394	8.153	8.40675	7.41975	7.9675	8.36875	8.4	**BHN In3**	**8.4**	

(Upper)										
pH-Diss-Water (Lower)	7.394	8.153	8.40675	7.41975	7.9675	8.36875	6.5	**BHN AIr In3**	**6.5**	
PO4-P-Diss-Water	0.138	0.347	0.74175	0.2955	0.717	1.71	0.015	**EWQG**	**0.125**	*Strict-relaxed to a tolerable state*
SO4-Diss-Water	40.805	56.7005	70.7435	35.79795	52.026	72.0802	250	**Dom In3**	**200**	

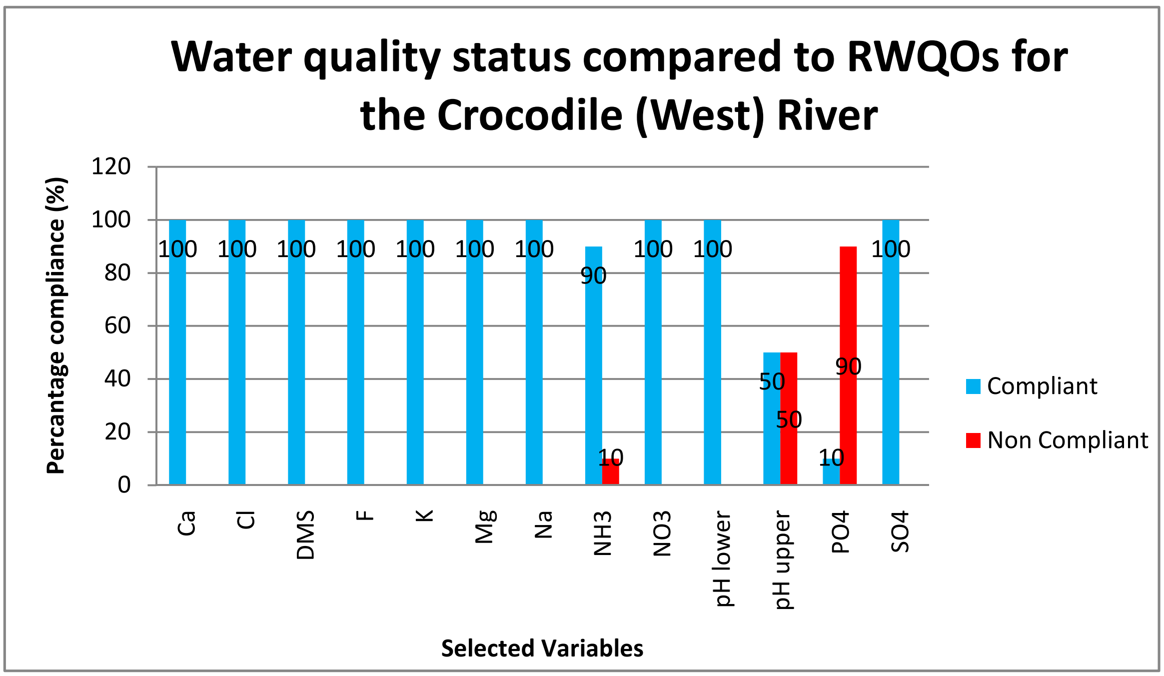


Figure 4.7: Graph summarizing the compliance status (expressed as a percentage) of all monitoring points when compared to the RWQOs for the Crocodile West River.

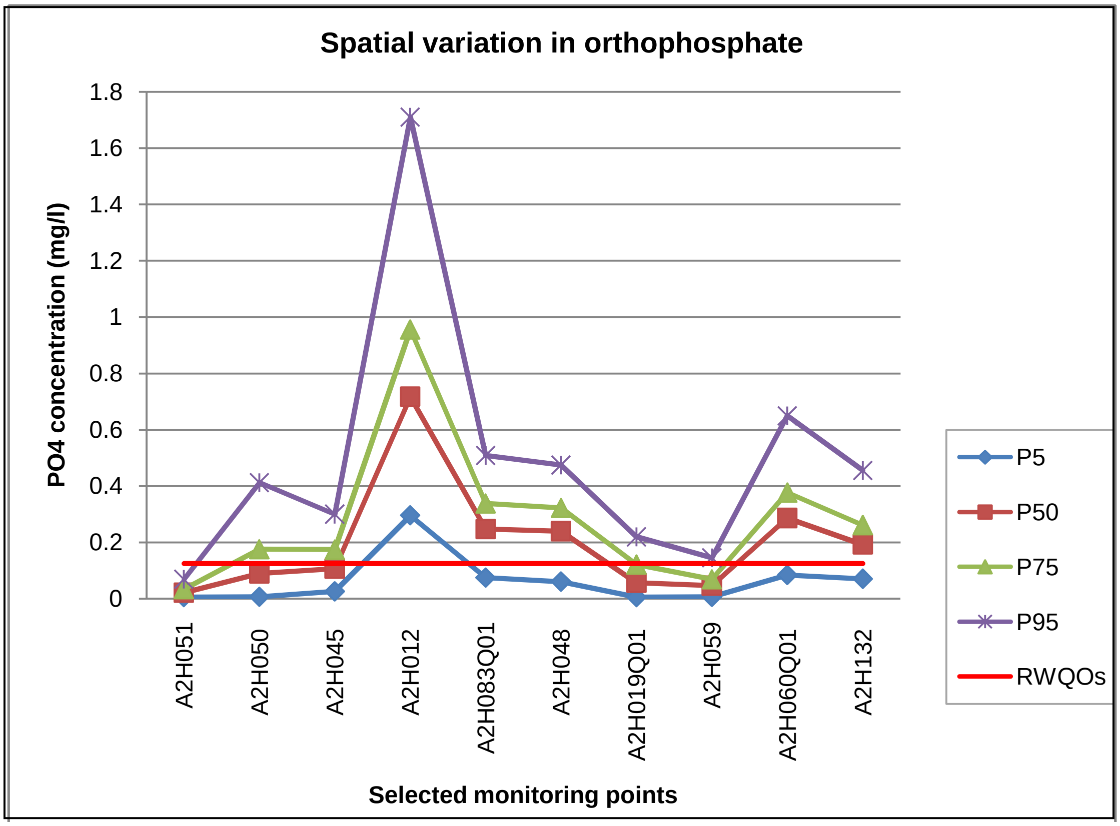


Figure 4.8: The spatial variation of orthophosphate values at selected monitoring points.

4.7.3 Discussion of the results per water quality variable

The compliance status quo revealed that the nutrient loading in the Crocodile West River is unacceptably high. The elevated concentration level of nutrients in the system is beyond the set RWQOs. Particularly the concentration levels of orthophosphate in the system exceed the recommended preliminary RWQOs 0.125 mg/l that correspond to the cut off value for category D of Ecological Water Requirements of the model (DWA, 2006a-c). Approximately 90% of the monitoring points along the river do not comply with the RWQO (Figure 4.7). This implies that the system does not have any more assimilative capacity for phosphate loading. The main sources of orthophosphate are municipal waste water treatment works and Agricultural return flows. This increased concentration of orthophosphate is a cause of concern in the catchment (DWA, 2004a and b).

The status quo for ammonium nitrogen is 90 percent compliant with the recommended preliminary RWQOs of 0.044mg/l. The RWQOs corresponds to category B of the Ecological Water Quality Requirements. The exception is monitoring point A2H048 which is located below the town of Brits. This monitoring site is non compliant with the set RWQOs. Main sources of ammonia are municipal waste water treatment works, fertilizer application, and intensive livestock farming. Some quantity of ammonia can be released from industries to enter the water resource. Ammonia is toxic to benthic or aquatic and control of the ammonium releasing activities is essential in the catchment.

The status of alkalinity in the Crocodile West River is 55 percent compliant to the RWQOs. Fifty percent of the monitoring points along the Crocodile West River comply with the set preliminary RWQOs of 8.4 pH units. However monitoring sites situated below Hartbeespoort Dam, monitoring points A2H083Q01, A2H048, A2H019Q01 exceed the set preliminary RWQOs of 8.4 pH units. Monitoring point A2H060Q01 and A2H132 located in the Lower Crocodile West catchment does not comply with the objectives.

There is slight increase in salinity in the Crocodile West. Although current status for most of the monitoring sites complies with the set RWQOs for the Dissolved Major Salts or Total Dissolved Solids, the concentrations for chloride are higher than the set RWQOs. The monitoring sites situated after the confluence of Crocodile with Hennops River A2H083Q01, below Brits Town A2H048 do not comply with the set RWQOs, However most of the cat ions such as calcium, magnesium, potassium, sodium, sulphate and other anions are within the recommended RWQOs.

4.8 Comparison of results for the two approaches to the development of resource water quality objectives

To recapitulate the objectives of the study, the Department of Water Affairs has used several approached to determine and report on the water quality of their surface resources. Amongst numerous methodologies the Department of Water Affairs have employed the **Fitness for use Classification/Categorisation** and **Compliance Evaluation** as some of the key tools to report on water quality in the planning studies.

This thesis was conducted to identify the differences and/ or similarities between the two aforementioned approaches that have been utilized by The Department to determine water quality objectives of the resources and explore the manner in which the approaches have been used to report on the fitness of water for intended uses in the catchment.

It was found during the study that the two approaches have several similarities. The approaches were simple and reproducible under the same conditions when conducting data analysis and water quality reporting. In both approaches one can employ the same data and information of water user requirements as the basis for the determination of water quality objectives. In this instance the information on water user requirements were represented by the Target Water Quality Ranges sourced from the SAWQG of 1996. By representing the broader sphere of water users in the catchment both the approaches attempt to achieve a balance between the socio economic development and the protection of the water resource that play a pivotal role in South African water resource management (DWA, 2004b). In varying manner and degrees both approaches benefit water resource management by accentuating and highlighting the areas of water quality concern.

Though the results from both studies contribute significantly to the reporting of water quality, there were apparent differences that were observed in the approaches. Apart from the aforementioned similarities, some of the assessment results for the approaches evidently demonstrate that the **Fitness for use Classification/ Categorisation** provides a range that contributes a fitness for use category. In this instance the current water quality status is compared to fitness for use categories namely, *Ideal, Acceptable, Tolerable and Unacceptable*. Ultimately the current water quality status is defined by an overall category. Respectively **Compliance Evaluation** approach allocates a numerical range serving as a maximum limit to which the current water quality status is compared to establish compliance status. The assigned or recommended limit falls within a particular target water quality range. Finally the current water quality status is reported as either compliant or non-compliant with the recommended preliminary RWQOs.

The Fitness for use Classification/Categorisation approach demonstrates that the approach test a set of data in a consistent and unbiased manner. It takes into consideration the full range of fitness for use by utilizing the 5th percentile, the median/ 50 percentile, 75 and the 95 percentiles of each variable of concern in a particular stretch of a resource. This is to ensure that the full time span of the water quality of the resource is been tested in the same way that a single sample would be checked for fitness-for-use.

Compliance Evaluation approach applies a conservative approach towards determining the objective for a particular stretch of the river. To arrive at the compliant status of the resource the **Compliance Evaluation approach** considers the 5th percentile value as the Lower limit or the, 50th or 95th percentile values as the upper limit for the present status depending on the variable assessed. Apart from the present status it considers the reference condition of the water quality variable(s) monitoring point assessed before assigning recommended RWQOs value.

The two approaches take cognisance of the ecological water quality requirements. In the absence of the Reserve, both approaches utilize the SAWQG Aquatic Ecosystems as the best available information to cater for the ecological water quality requirements (DWA, 2006a and b). In the event that the Reserve is available, the methodology for the determination of RWQOs is required to consider the Reserve requirements. This requirement provides an allowable water quality range to maintain or improve the aquatic environment. Although this concept was not tested in the two approaches, both approaches cater for the reserve in different ways. The **Fitness for use Classification/Categorisation** approach caters for three categories the, *Ideal, Acceptable and Tolerable* where the values beyond the *Tolerable* conditions are regarded as *Unacceptable.* This will make it difficult to apply the concept of the Reserve within the approach itself and hence require that the Reserve be catered for and analysed separately. This will make the process complex. The **Compliance Evaluation** approach caters for the Reserve value that can be easily substituted by the Reserve values in the RWQOs model. This makes the methodology simpler and requires less effort when conducting data analysis for water quality assessments.

Additionally, the ideology behind the concept of the Compliance Evaluation approach is to allow one to be able to impose the monthly hydrological flows on the RWQOs model. This is to allow the model to assign an estimate of the allocatable loads within the system and provide allowable end of pipe concentrations. This information is relevant in determining the estimated assimilative capacity of the water resource and they are applicable when conducting source control measures such as licensing of water containing waste and application of the Waste Discharge Charge System (WRC, 1995 DWA, 2006a-c; DWA, 2012).

In many instances the results from both approaches emphasize on similar water quality issues and concern in a water quality reach (refer to Appendix F). Occasionally the emphasis is distorted and obscured by the different reporting approaches. For instance the current water quality according to the two approaches for monitoring site A2H012 which is situated downstream of the confluence with Hennops River. The Fitness for use Classification/Categorisation results show that all water quality variables on monitoring site A2H012 comply with respective RWQOs with the exception of Orthophosphate that will require serious water resource management actions and intervention. Orthophosphate concentration levels according to the results is the only variable of great concern while other water quality variables are either on Ideal or Acceptable conditions. The Acceptable category mainly requires that the water quality and the trends at the monitoring site should be monitored and assessed regularly. **Compliance Evaluation** approach shows that there are three variables of concern, the chloride, Ammonia and Orthophosphate. The results are indicative of the water quality threshold that cannot be exceeded. In this instance, the results show that the water quality of the system with regard to the three variables is been compromised.

The reasons for the differences can be attributed to the fact the ranges for the **Fitness for use Classification/Categorisation** approach are scaled description of the water quality. The water quality can be assigned any of the four categories that are established on the basis of the suitability of water for intended uses. The categories illustrate the various ranks where the water quality can be is evaluated against. The category is defined by a combination of the 50, 75 and the 95^{th}. The **Compliance Evaluation** methodology is a pass or fail/comply/do not comply approach. The approach assigns a maximum limit that the current water quality is required to comply with. If the current water quality status exceeds the maximum limit, the management actions must be instigated to prevent further water quality deterioration of the water resource. The recommended maximum limit can either be an upper and/ or a lower level that the water quality in the water quality reach is required to comply with. The Compliance Evaluation approach applies a conservative technique. Thus the approach suggests a maximum limit based on either the 5^{th}, 50^{th} or 95^{th} percentile.

Table 4.13: Comparison of the current water quality status reporting as per Fitness for use Classification/ Categorization and Compliance Evaluation for monitoring point A2H012.

Monitoring point ID	Stats of	Fitness for use Classification/Categorization	Compliance Evaluation
90164: A2H012	Ca-Diss-Water	A	51.57665
90164: A2H012	Cl-Diss-Water	A	100.2426
90164: A2H012	DMS-Tot-Water or	T	498.9121
90164: A2H012	F-Diss-Water	I	0.3943
90164: A2H012	K-Diss-Water	I	11.1848
90164: A2H012	Mg-Diss-Water	I	21.3828
90164: A2H012	Na-Diss-Water	I	68.67245
90164: A2H012	NH3(25)-Union-Diss-W	A	0.0635
90164: A2H012	NO3+NO2-N-Diss-Water	A	6.9272
90164: A2H012	pH-Diss-Water Lower	I	8.36875
90164: A2H012	pH-Diss-Water Upper	A	7.41975
90164: A2H012	PO4-P-Diss-Water	U	0.717
90164: A2H012	SO4-Diss-Water	I	72.0802

Clearly the two approaches are comparable however because the **Fitness for use Classification/Categorisation** concentrate more on the scaled approach of water quality reporting and **Compliance Evaluation** give a conservative approach where a maximum value is utilized as a management objective to be complied to address different purposes, the **Fitness for use Classification/Categorisation** is addressing where the system is in terms of water that is available for different uses, while the **Compliance Evaluation** approach addresses compliant status to the maximum limit or water quality management objectives.

4.9 Recommendations for the setting of RWQOS and questions for further research.

Although the two approaches provide information in different manners it is evident that both approaches are valuable in the process of setting RWQOs. When assessing the current water quality it is essential that one looks at the complete spread of the data which is provided for by looking at the summary of the data set (box and whiskers plot with 5, 50, 75 and 95 percentiles). However at this stage only the 5 for pH, 50 for orthophosphate and 95 percentile for other variables is been considered when setting the RWQOs. Clearly the approach is essential in establishing the water quality status quo of the resource. The details of the status quo can provide a good input in the finalisation of the objective and determination of the management plan or strategy development.

It is important to consider that when setting RWQOs one needs to apply a conservative approach, hence the objectives should be informed by the 95 percentile. The provision of a maximum limit is essential in order for one to be able to assess if the particular objective is complied with. In the future when The Ecological and Basic Human needs Reserves are integrated, the setting of RWQOs and their maximum values will have to form part of the water uses in the catchment. In such a situation The Reserve, either the Ecological or/ and Basic Human Needs, might be the most sensitive user and their maximum limit might be considered to determine the single cut-off values of the river reach. It is therefore recommended that both approaches be integrated in such a way that the fitness for use provides input to the determination of the final RWQOs. The approaches can be integrated and used in conjunction to provide a complete representation of the status quo and the compliance of the water resource to the RWQOs.

Clearly **Fitness for use Classification/Categorisation** put emphasis on ensuring completeness of data and exclusion of bias when assessing data. This is done by considering the 5, 50, 75 and 95 percentiles when assessing data. This information is necessary in determining the water quality status quo, and hence can be integrated into **Compliance Evaluation**. The **Fitness for use Classification/Categorisation** approach can play a pivotal role in identifying the gaps in water quality data and in highlighting the scaled approach of the fitness of water for use.

Compliance Evaluation is a conservative technique of assigning level of compliance to the water resource. The approach checks both historical and present data before assigning a cut-off value. However the short coming of the approach is that the data can be regarded as being biased since it considers only the worst case scenario (95 percentile) without evaluating or comparing this to other scenarios of importance (5, 50 and 75 percentiles).

The approach will be thorough if the data could be checked in an unbiased approach by considering the entire box and whiskers plot as a first step of assessing the status quo of the resource. The main steps for **Compliance Evaluation** include the following:

a. Delineation of the Resource Units (RU)

b. Determining the status quo

c. Determination of the water user requirements
d. The Determination or setting of the RWQOs
e. Resource Water Quality Objectives Model

f. Employing a conservative approach and providing the recommended RWQOs
g. Compliance management

Fitness for use Classification/Categorisation can be utilized for the determination of the status quo which is important in establishing and identifying the variables of concern in the catchment.

The setting of the RWQOs is an essential water resource management decision making tool that is required in the development of the management plans /strategies and ultimately RWQOs informs the manager as to whether the Management Class of the resource is been maintained or is it improving. It is therefore imperative to have complete and detailed information and data on the study area. The RWQOs model requires input on the management class and Ecological and basic Human Needs. The implementation of this Resource Directed Measures has recently started. It is recommended that the methodology and approaches for the determination of RWQOs be aligned with other resource directed measures in order to draw appropriate and required information from other parts of the RDM.

Compliance Evaluation approach makes allowance for a desktop and a comprehensive setting of RWQOs depending on data availability. However there is no clear distinction between the data period used for the purpose of setting RWQOs and data period required for the purpose of water quality assessment or status quo assessment, thus different approaches employ various time periods (WRC, 1995; DWA 2009c). It is recommended that the water quality managers and researchers set scientifically and simple to apply guidelines on the employment of water quality data set.

When employing **Compliance Evaluation** approach, some of the current/ reference status are two or three times less than the recommended cut-off values, it is recommended that a scientifically correct process be set to refine the recommended RWQOs further to prevent pollution of the current water quality while allowing for development. The RWQOs of potassium is provided as an example (refer to Table 4.12 and Appendix D).

When a decision needs to be made on how to maintain RWQOs one needs to determine the effluent quality targets. The effluent quality targets are required to ensure that the downstream RWQOs are complied with given the dynamics of hydrology, numerous point and non point pollution sources and other system complexities. To quantify their decision water quality managers are required to conduct “what if?” scenarios to verify the effectiveness of catchment management strategies aimed at improving the in stream water quality. For this purpose the simulation model should be able to indicate if the assigned RWQOs are realistic and if it is achievable.

Previously, the Department of Water Affairs has utilized many other simulation models particularly for eutrophication and salinity modelling. Due to the complex nature of water quality there is no single overarching model that will assist with the management of water resources. It is recommended that a guideline be developed to qualify the goals for employing a water quality modeling in the quantification of RWQOs. The guideline should give an indication of the scenarios where a water quality model can and should be used and the types of questions that can be posed. The model should be able to test if the recommended objective are realistic for the particular water quality reach; Indicate what happens downstream of the RWQOs particularly after land development that is likely to influence the quality of the water resource, additionally it should be able to evaluate the implications of water use licenses applications on the water quality and compliance to the RWQOs; The modeling should cater for a range of water quality variables and integration with water quality.

4.10 Conclusion

An understanding of the methodology for determining the Resource Water Quality Objectives in South Africa was conducted by reviewing available literature. It has been shown how the two applicable approaches for determining the current water quality status by the use of the Resource Water Quality Objectives principles compares with each other: that although the two approaches are significantly applicable in water quality management, both approaches show the success and failures of previous and current water quality management by highlighting the areas where water quality has been impacted on by land use. It has been shown that the approaches although using the same information, they are different and are applicable under different circumstances.

The fact that the **Fitness for use Classification/Categorisation** approach provides the status indicates that the methodology is important for the purpose of water resource management. The need for an approach that indicates compliance of the water resource to a set of management goals and to provide for the determination of the allocation of water quality for the purpose of further source directed controls such as Waste Discharge Charge System is also of importance.

According to the results the methodology is similar in many aspects such as the core methodology and the principles behind the process of water quality management and reporting. However, there are several difference which are attributed to the manner in which the water quality is been reported for instance the **Fitness for use Classification/ Categorization** approach presents a scaled approach for describing the current status of the water resource. While the **Compliance Evaluation** approach illustrates a pass or fail grading on the water resource and the assessment of complete data set by employing 5^{th}, 50^{th}, 75^{th} and 95^{th} for the **Fitness for use Classification/ Categorisation** and the employment of a conservative approach in the **Compliance Evaluation**. However, the differences can be addressed and the recommendations to address and strengthen the methodology for the determination of the current status and setting of RWQOs is been provided in the previous section.

It is concluded that the approaches are comparable in adding value to water quality management, however they address different needs in the management hierarchy of decision making. Both the methodologies play an essential role in setting the RWQOs and water quality reporting purposes with the adoption of some of the recommendations given in section 4.9.

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5 REFERENCES

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APPENDIX A:

DATA USED FOR DATA ANALYSIS

		Reference status					Present/current status				
Monitoring Point Name	Stats of	N	P5	P50	P95	Mean	N	P5	P50	P95	Mean
A2H012	Ca-Diss-Water	236	31.20775	40.148	50.40575	40.27696	128	31.153	40.3215	51.57665	41.06386
A2H012	Cl-Diss-Water	236	33.349	52.155	73.52	54.35916	125	38.5982	55.98	100.2426	59.7909
A2H012	DMS-Tot-Water	236	287.0105	416.755	455.4265	401.5446	82	308.3995	412.227	498.9121	411.0311
A2H012	F-Diss-Water	236	0.22575	0.2645	0.34	0.271246	95	0.1607	0.27	0.3943	0.27179
A2H012	K-Diss-Water	236	6.186	9.031	11.5295	9.000636	129	6.14	8.645	11.1848	8.652915
A2H012	Mg-Diss-Water	236	11.01825	16.314	21.1645	16.4665	127	10.5253	15.387	21.3828	16.09832
A2H012	Na-Diss-Water	236	28.61275	45.7985	63.5965	45.96042	122	32.72055	49.709	68.67245	50.20236
A2H012	NH_3(25)-Union-Diss-W	236	0	0.002	0.01425	0.00536	131	0	0.005	0.0635	0.015115
A2H012	NO_3+NO_2-N-Diss-Water	236	2.2	4.576	6.22225	4.441131	100	2.205	5.216	6.9272	4.98026
A2H012	pH	236	7.394	8.153	8.40675	8.06328	136	7.41975	7.9675	8.36875	7.904802
A2H012	PO_4-P-Diss-Water	236	0.138	0.347	0.74175	0.391822	131	0.2955	0.717	1.71	0.811809
A2H012	SO_4-Diss-Water	236	40.805	56.7005	70.7435	56.20891	132	35.79795	52.026	72.0802	52.37276
A2H012	TAL-Diss-Water	236	93.51325	130.926	157.4773	129.6284	129	89.8082	125.213	150.5618	125.6142
A2H019Q01	Ca-Diss-Water	131	27.696	34.224	46.083	35.48394	128	30.0007	36.341	47.28225	37.06495
A2H019Q01	Cl-Diss-Water	131	45.4425	65.413	97.116	67.81201	130	56.8003	68.5025	88.0443	69.73655
A2H019Q01	DMS-Tot-Water	131	364.2295	441.479	574.502	451.3621	85	357.7452	428.263	517.4922	434.4657
A2H019Q01	F-Diss-Water	131	0.2725	0.345	0.4835	0.361061	89	0.2558	0.324	0.4354	0.338652
A2H019Q01	K-Diss-Water	131	5.568	7.732	9.563	7.635832	129	6.146	7.472	9.2462	7.533512

A2H019Q01	Mg-Diss-Water	131	19.0485	25.686	34.317	26.18086	128	17.71545	23.214	29.962	23.54308
A2H019Q01	Na-Diss-Water	131	34.536	51.232	79.4185	54.06108	126	42.47525	53.1045	68.97925	53.98937
A2H019Q01	NH_3(25)-Union-Diss-W	131	0.001	0.016	0.045	0.017603	128	0.001	0.018	0.06965	0.026
A2H019Q01	NO_3+NO_2-N-Diss-Water	131	0.055	0.202	1.5445	0.452687	117	0.04	0.675	2.4358	0.835821
A2H019Q01	pH	131	7.7675	8.259	8.5035	8.188199	134	7.71335	8.163	8.423	8.120149
A2H019Q01	PO_4-P-Diss-Water	131	0.012	0.026	0.065	0.034657	130	0.005	0.056	0.2194	0.079746
A2H019Q01	SO_4-Diss-Water	131	55.627	72.14	100.7215	75.36947	130	51.94985	63.2145	79.18975	64.01141
A2H045	Ca-Diss-Water	168	29.88405	43.5985	49.55665	42.26485	129	31.4024	41.953	57.9374	42.93971
A2H045	Cl-Diss-Water	168	22.79595	35.708	48.5796	35.69883	166	27.988	40.881	50.225	39.94717
A2H045	DMS-Tot-Water	168	277.2498	393.8375	439.1728	380.6427	82	296.1694	392.1985	481.1689	390.4885
A2H045	F-Diss-Water	168	0.1	0.169	0.223	0.168786	89	0.1066	0.183	0.2842	0.188281
A2H045	K-Diss-Water	168	2.72025	3.6065	5.31225	3.762929	127	3.7	4.578	5.8081	4.603409
A2H045	Mg-Diss-Water	168	16.6687	24.623	28.5373	23.85215	127	16.4796	22.15	31.7224	22.24856
A2H045	Na-Diss-Water	168	17.6299	26.646	36.67005	26.5877	125	19.7	32.895	40.232	31.73961
A2H045	NH_3(25)-Union-Diss-W	239	0.001	0.004	0.0111	0.004619	170	0.00045	0.004	0.033	0.008094
A2H045	NO_3+NO_2-N-Diss-Water	239	1.4639	3.318	4.5132	3.253594	155	1.2	2.688	3.8626	2.580897
A2H045	pH	239	7.9325	8.197	8.4286	8.184276	178	7.3	8.1	8.3932	7.999247
A2H045	PO_4-P-Diss-Water	239	0.0459	0.122	0.1994	0.123975	172	0.0251	0.1065	0.3	0.12543
A2H045	SO_4-Diss-Water	168	38.7659	58.471	74.44	57.92476	165	44.7062	59.586	138.7896	67.34855
A2H048	Ca-Diss-Water	238	28.03185	52.7445	68.36695	50.28946	130	33.7875	45.982	62.8578	47.31448

A2H048	Cl-Diss-Water	238	41.5657	84.722	117.8036	79.98686	132	50.51205	69.7915	112.1262	74.92369
A2H048	DMS-Tot-Water	237	340.2378	613.171	763.7108	569.807	87	354.0645	510.464	727.6581	518.5068
A2H048	F-Diss-Water	238	0.247	0.286	0.354	0.290193	91	0.239	0.292	0.406	0.309044
A2H048	K-Diss-Water	238	4.67555	6.069	8.2142	6.206223	130	5.76025	7.2025	9.3264	7.285108
A2H048	Mg-Diss-Water	238	18.6241	38.6605	51.76595	36.16627	129	15.07	24.083	43.3636	26.46125
A2H048	Na-Diss-Water	238	33.0973	60.5235	88.9593	59.07233	124	39.22065	54.464	80.7249	56.6848
A2H048	NH_3(25)-Union-Diss-W	237	0.001	0.007	0.0464	0.012658	128	0.001	0.031	0.2766	0.064977
A2H048	NO_3+NO_2-N-Diss-Water	238	0.0644	1.671	2.85305	1.656635	110	0.51575	2.378	4.20175	2.396091
A2H048	pH	238	7.76355	8.3145	8.7042	8.29716	134	7.6572	8.151	8.46725	8.114649
A2H048	PO_4-P-Diss-Water	238	0.025	0.073	0.22115	0.099143	132	0.06015	0.2395	0.47395	0.273121
A2H048	SO_4-Diss-Water	237	53.505	104.078	142.3512	97.80605	130	49.14965	62.711	112.4424	72.43195
A2H050	Ca-Diss-Water	165	18.0546	24.155	31.3304	24.5676	130	21.4734	26.8075	35.2485	27.28409
A2H050	Cl-Diss-Water	165	22.5462	38.674	67.0668	40.71906	132	22.82405	38.5145	56.95205	38.93399
A2H050	DMS-Tot-Water	165	200.3134	265.456	343.3906	268.5986	87	204.4215	286.782	362.2213	281.1271
A2H050	F-Diss-Water	165	0.159	0.197	0.2734	0.205109	94	0.1027	0.206	0.35815	0.219936
A2H050	K-Diss-Water	165	4.0178	6.561	11.3346	6.920194	131	3.908	6.7	9.3035	6.512046
A2H050	Mg-Diss-Water	165	6.9814	11.405	14.8644	11.23216	131	8.1155	10.855	16.2225	11.35973
A2H050	Na-Diss-Water	165	16.7372	29.66	56.1096	31.92542	125	16.944	32.64	49.6114	33.34314
A2H050	NH_3(25)-Union-Diss-W	237	0	0.002	0.014	0.005038	129	0	0.003	0.02	0.006054
A2H050	NO_3+NO_2-N-Diss-Water	237	0.7836	2.861	5.316	2.96838	102	0.9213	2.731	4.5627	2.714039
A2H050	pH	237	7.4402	7.927	8.1934	7.898616	132	7.4291	7.8875	8.2238	7.868652
A2H050	PO_4-P-Diss-Water	237	0.0432	0.152	0.3946	0.190051	132	0.006	0.089	0.41145	0.150159

A2H050	SO_4-Diss-Water	165	17.614	25.931	37.4244	26.95907	132	21.42255	28.603	41.4495	29.69727
A2H051	Ca-Diss-Water	167	14.1064	19.427	22.8031	19.22125	87	17.7569	21.825	25.5038	21.84594
A2H051	Cl-Diss-Water	167	11.4713	15.608	20.363	15.80684	87	13.2228	19.003	28.6405	19.59738
A2H051	DMS-Tot-Water	167	138.3832	180.648	213.1514	179.9331	65	154.6988	187.619	221.3348	188.6972
A2H051	F-Diss-Water	167	0.1	0.158	0.2272	0.160988	68	0.08425	0.161	0.30745	0.172559
A2H051	K-Diss-Water	167	1.5906	2.595	4.3461	2.723252	87	1.7518	2.682	3.9612	2.71254
A2H051	Mg-Diss-Water	167	7.5007	10.931	14.2023	10.93428	86	8.29875	12.3325	16.4495	12.51469
A2H051	Na-Diss-Water	167	7.1225	10.586	13.9202	10.56033	84	7.642	10.2585	13.85695	10.3951
A2H051	NH_3(25)-Union-Diss-W	239	0	0.004	0.013	0.005636	85	0.001	0.004	0.0144	0.005588
A2H051	NO_3+NO_2-N-Diss-Water	239	0.055	0.717	1.3346	0.693402	80	0.3867	0.8025	1.613	0.863413
A2H051	pH	239	7.5855	8.016	8.4146	8.00367	94	7.48785	7.9225	8.3251	7.889255
A2H051	PO_4-P-Diss-Water	239	0.012	0.03	0.0731	0.047163	87	0.0053	0.021	0.0689	0.027747
A2H051	SO_4-Diss-Water	167	8.3848	13.515	20.7322	14.06462	87	11.5872	15.641	24.7065	16.52353
A2H059	Ca-Diss-Water	162	28.40205	40.706	53.4641	40.82549	131	32.178	41.377	55.109	42.40366
A2H059	Cl-Diss-Water	162	44.03505	67.2165	143.1676	74.80394	129	62.6766	82.733	116.8916	88.17826
A2H059	DMS-Tot-Water	162	332.8085	473.536	696.1299	481.3662	83	375.1213	490.414	683.4267	507.0533
A2H059	F-Diss-Water	162	0.309	0.377	0.5526	0.397012	92	0.28455	0.371	0.4797	0.374446
A2H059	K-Diss-Water	162	4.86685	6.3435	8.00145	6.402272	132	5.89775	7.346	8.7206	7.528227
A2H059	Mg-Diss-Water	162	16.78735	27.414	40.26985	27.50257	130	18.1817	25.7865	36.83185	26.28695
A2H059	Na-Diss-Water	162	32.6776	52.175	96.84385	56.66598	128	46.615	61.8665	90.43495	64.12189
A2H059	NH_3(25)-Union-Diss-W	225	0.001	0.004	0.014	0.005453	128	0.001	0.005	0.01765	0.007016
A2H059	NO_3+NO_2-N-Diss-Water	225	0.1934	0.526	1.681	0.664258	119	0.282	0.822	2.0529	0.92574
A2H059	pH	225	7.9742	8.24	8.5016	8.235844	135	7.6733	8.134	8.3921	8.109015

A2H059	PO_4-P-Diss-Water	225	0.012	0.029	0.1154	0.049991	132	0.006	0.046	0.145	0.055849
A2H059	SO_4-Diss-Water	162	50.40075	73.8195	110.5651	75.50361	131	55.8685	74.604	101.5315	75.77511
A2H060Q01	Ca-Diss-Water	227	28.4926	40.189	48.1577	39.62215	127	28.7219	40.715	49.377	39.71984
A2H060Q01	Cl-Diss-Water	227	40.3886	68.27	106.41	70.72159	124	44.5771	70.9875	103.1031	72.42995
A2H060Q01	DMS-Tot-Water	227	329.816	484.38	630.5353	484.4741	84	319.0108	469.494	638.8132	471.6696
A2H060Q01	F-Diss-Water	227	0.3433	0.43	0.5837	0.440877	90	0.333	0.42	0.559	0.421411
A2H060Q01	K-Diss-Water	227	5.3521	7.632	11.1987	7.973749	129	6.1216	7.877	10.9652	8.07576
A2H060Q01	Mg-Diss-Water	227	15.1733	25.181	35.6602	25.18167	125	15.52	23.383	35.0392	23.78766
A2H060Q01	Na-Diss-Water	227	34.7527	56.806	91.7229	59.97674	120	38.27125	57.2335	89.9092	59.48181
A2H060Q01	NH_3(25)-Union-Diss-W	227	0.001	0.004	0.0147	0.005471	124	0.00015	0.003	0.017	0.006371
A2H060Q01	NO_3+NO_2-N-Diss-Water	227	0.02	0.266	1.1444	0.383991	118	0.04	0.481	1.50605	0.627288
A2H060Q01	pH	227	7.9981	8.288	8.6007	8.300106	132	7.55225	8.1905	8.4953	8.160182
A2H060Q01	PO_4-P-Diss-Water	227	0.0373	0.127	0.3358	0.149308	125	0.0838	0.286	0.6494	0.308424
A2H060Q01	SO_4-Diss-Water	227	43.1546	67.363	93.9618	67.83356	126	40.33275	59.8895	84.39475	61.47602
A2H083Q01	Ca-Diss-Water	132	24.22015	30.132	39.5446	30.51295	128	29.8869	37.681	43.06805	37.51413
A2H083Q01	Cl-Diss-Water	132	35.87945	47.089	57.29385	46.80601	132	43.0643	54.471	68.5467	55.69974

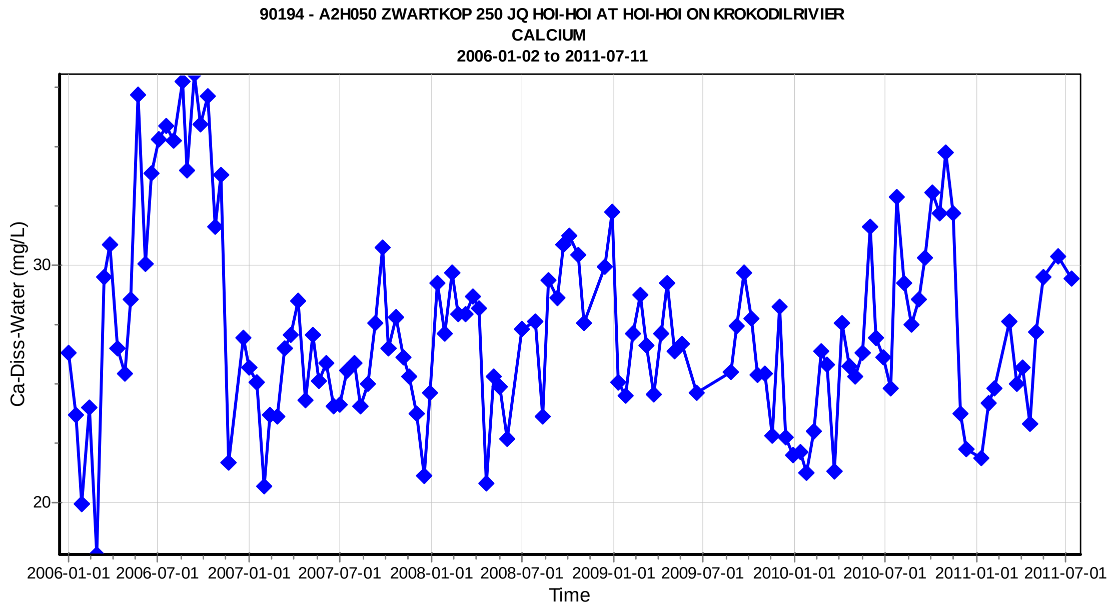
A2H083Q01	DMS-Tot-Water	132	311.5266	349.2215	380.0309	346.8619	87	315.5645	374.293	441.6529	375.6459
A2H083Q01	F-Diss-Water	132	0.242	0.279	0.34035	0.283538	91	0.2305	0.284	0.3745	0.291066
A2H083Q01	K-Diss-Water	132	5.8927	7.9855	9.7936	7.90028	129	6.329	7.774	9.6526	7.927892
A2H083Q01	Mg-Diss-Water	132	13.4618	17.095	20.3588	17.18389	128	12.64095	15.109	18.98635	15.33122
A2H083Q01	Na-Diss-Water	132	28.90345	37.9555	49.1511	39.00661	121	36.348	44.336	54.996	44.95341
A2H083Q01	NH_3(25)-Union-Diss-W	132	0	0.018	0.09445	0.027371	130	0.001	0.0255	0.0941	0.036446
A2H083Q01	NO_3+NO_2-N-Diss-Water	132	0.055	1.141	2.44955	1.172515	109	0.5572	1.543	3.08	1.598239
A2H083Q01	pH	132	7.57555	8.2835	8.75645	8.216265	135	7.6069	8.184	8.8712	8.21383
A2H083Q01	PO_4-P-Diss-Water	132	0.024	0.065	0.237	0.09322	131	0.074	0.247	0.508	0.270412
A2H083Q01	SO_4-Diss-Water	132	41.53465	50.1495	57.86575	50.32419	132	39.62625	47.374	53.7241	47.03154
A2H132	Ca-Diss-Water	96	30.3515	43.3015	54.38775	42.68908	119	29.4441	46.154	56.6104	44.40485
A2H132	Cl-Diss-Water	96	41.38575	76.3465	111.0893	76.95305	121	49.639	87.063	124.414	87.30747
A2H132	DMS-Tot-Water	96	335.7123	514.629	636.3473	505.333	71	328.445	526.407	672.5415	514.607
A2H132	F-Diss-Water	96	0.34525	0.4435	0.61025	0.45276	79	0.34	0.457	0.5932	0.457798
A2H132	K-Diss-Water	96	5.733	7.179	10.345	7.591479	119	6.2228	7.9	10.5155	8.095286
A2H132	Mg-Diss-Water	96	14.90625	27.5645	34.82025	27.17593	117	15.5478	26.82	37.8286	26.6186
A2H132	Na-Diss-Water	96	36.24825	60.7315	90.396	61.77554	114	39.06315	66.2705	87.1942	65.1483
A2H132	NH_3(25)-Union-Diss-W	119	0.001	0.004	0.0141	0.005235	121	0.001	0.003	0.022	0.05038
A2H132	NO_3+NO_2-N-Diss-Water	119	0.02	0.207	1.329	0.359311	99	0.04	0.599	1.7181	0.736485

A2H132	pH	119	7.9204	8.333	8.6032	8.304235	126	7.6315	8.2185	8.73275	8.189151
A2H132	PO_4-P-Diss-Water	119	0.018	0.064	0.1727	0.078412	121	0.07	0.192	0.455	0.217934
A2H132	SO_4-Diss-Water	96	45.2315	70.011	94.6715	70.42414	119	45.3874	69.554	104.018	69.71784

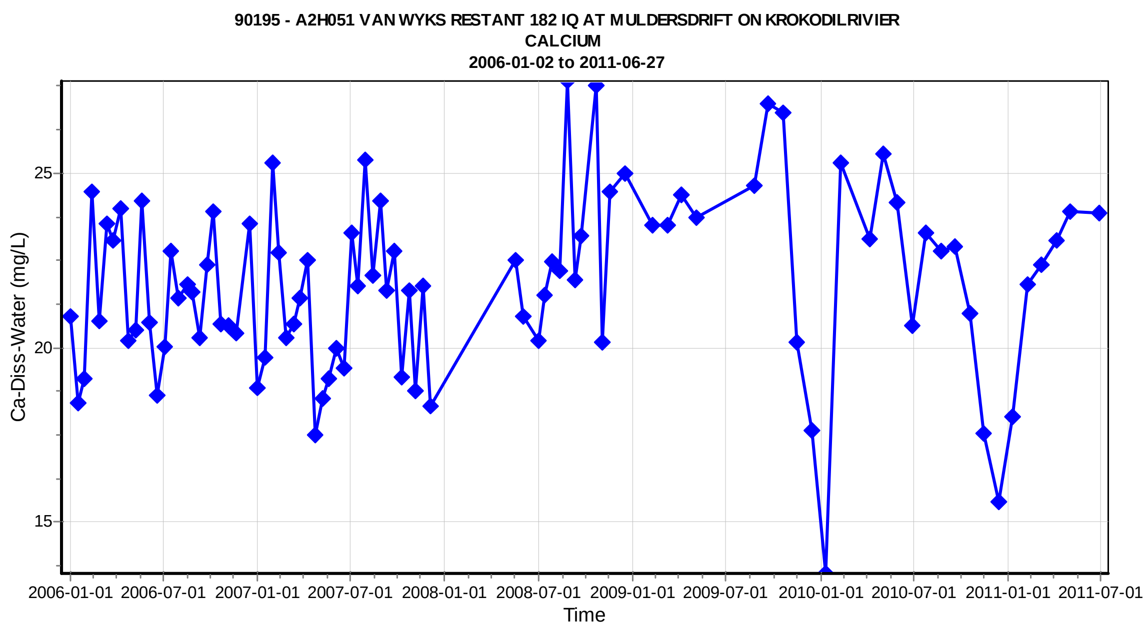
APPENDIX B:

ASSESSMENT FOR COMPLETENESS OF DATA

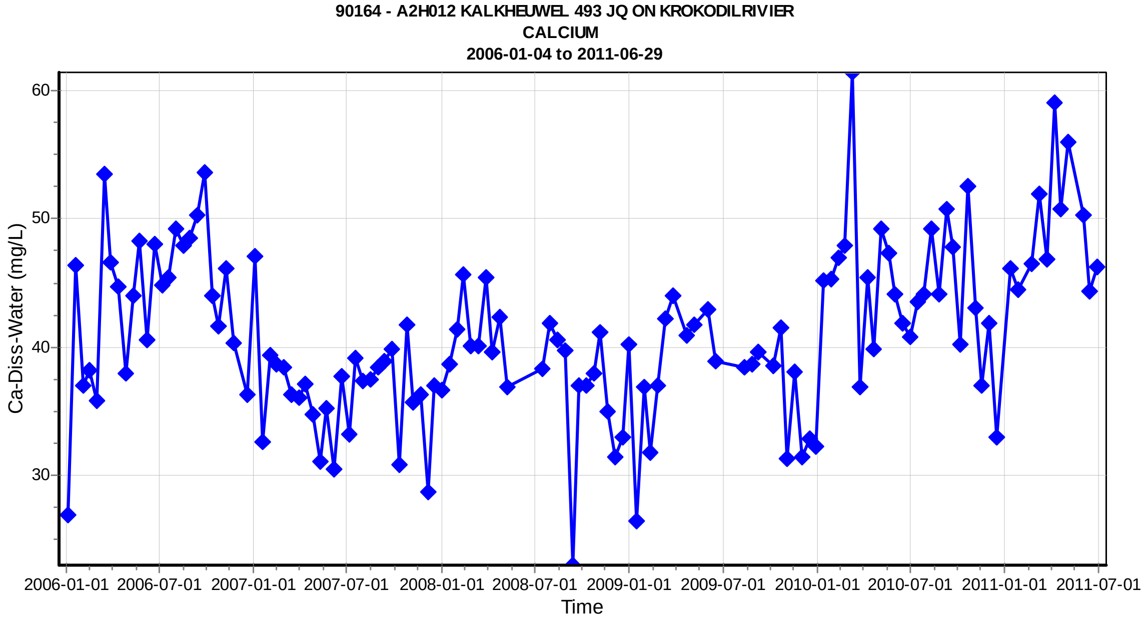
CALCIUM

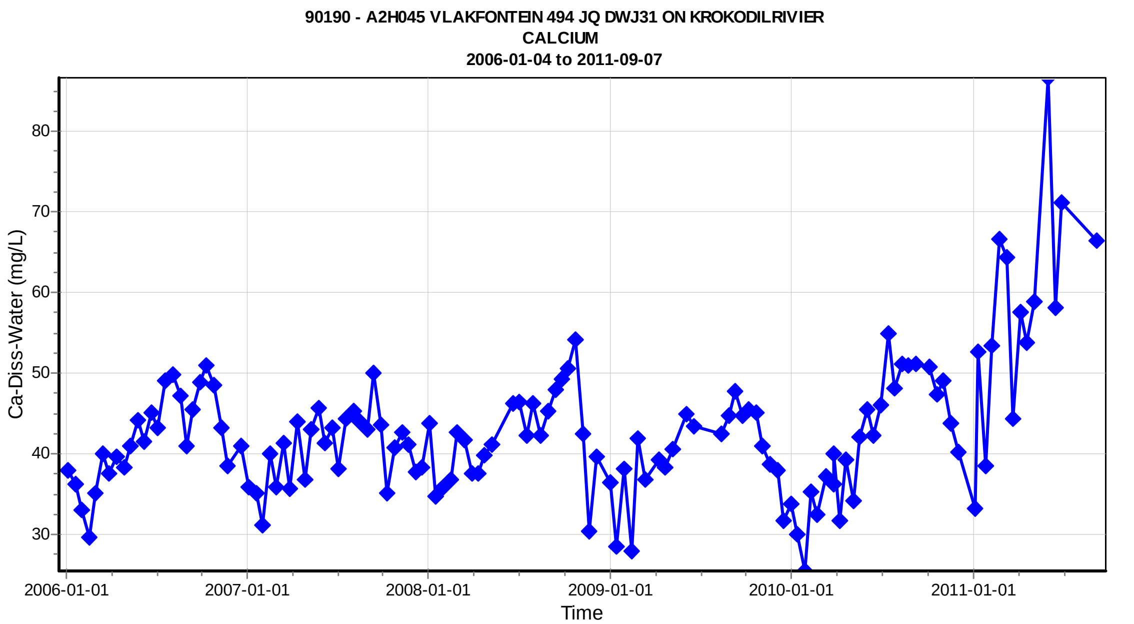


90194 - A2H050 ZWARTKOP 250 JQ HOI-HOI AT HOI-HOI ON KROKODILRIVIER
CALCIUM
2006-01-02 to 2011-07-11
Ca-Diss-Water (mg/L)
30
20
2006-01-01 2006-07-01 2007-01-01 2007-07-01 2008-01-01 2008-07-01 2009-01-01 2009-07-01 2010-01-01 2010-07-01 2011-01-01 2011-07-01
Time

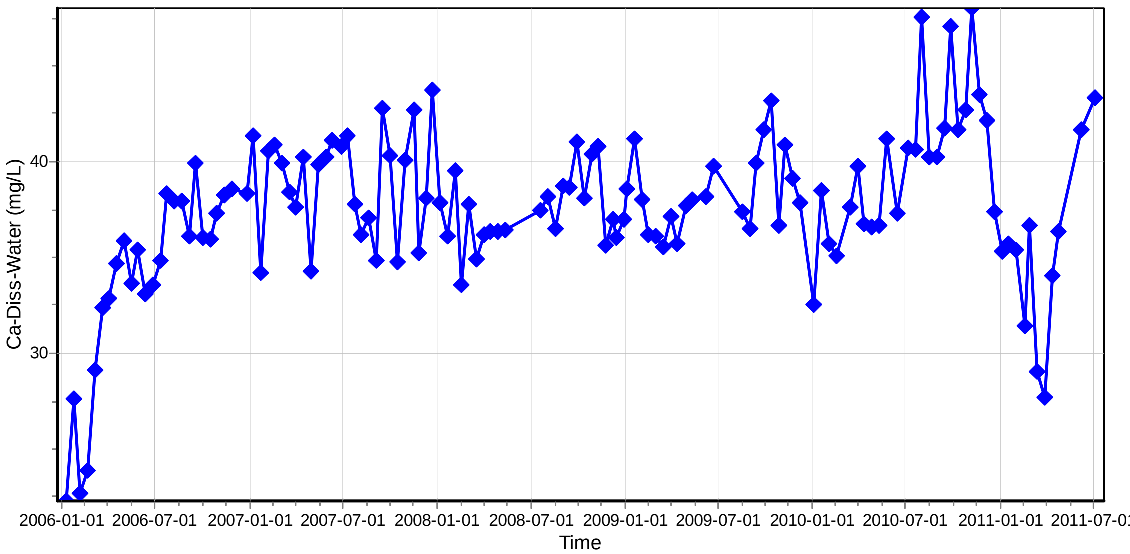


90195 - A2H051 VAN WYKS RESTANT 182 IQ AT MULDERSDRIFT ON KROKODILRIVIER
CALCIUM
2006-01-02 to 2011-06-27
Ca-Diss-Water (mg/L)
25
20
15
2006-01-01 2006-07-01 2007-01-01 2007-07-01 2008-01-01 2008-07-01 2009-01-01 2009-07-01 2010-01-01 2010-07-01 2011-01-01 2011-07-01
Time

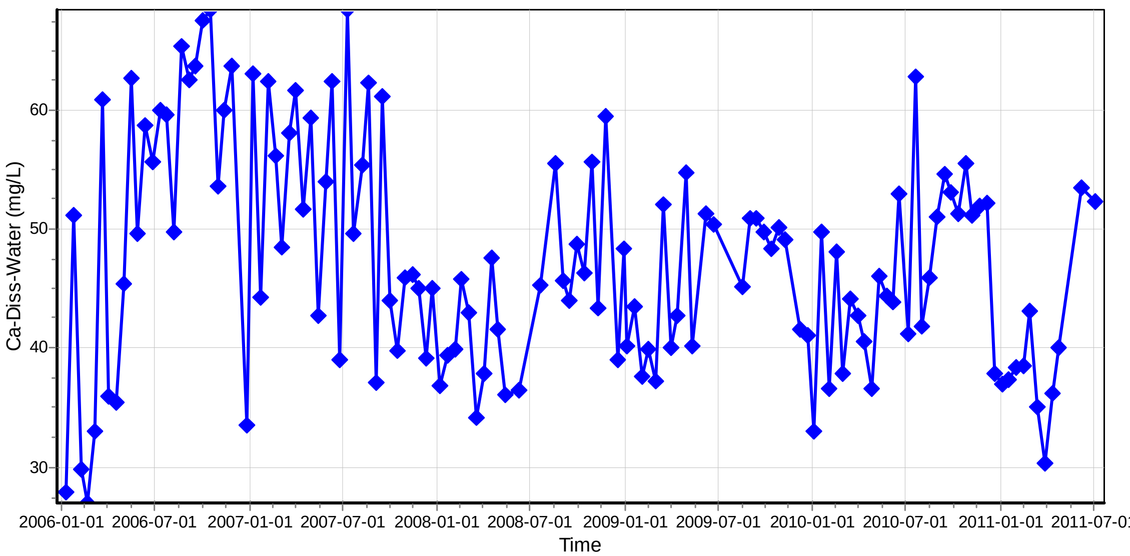

90164 - A2H012 KALKHEUWEL 493 JQ ON KROKODILRIVIER
CALCIUM
2006-01-04 to 2011-06-29
Ca-Diss-Water (mg/L)
60
50
40
30
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
2011-07-01
Time

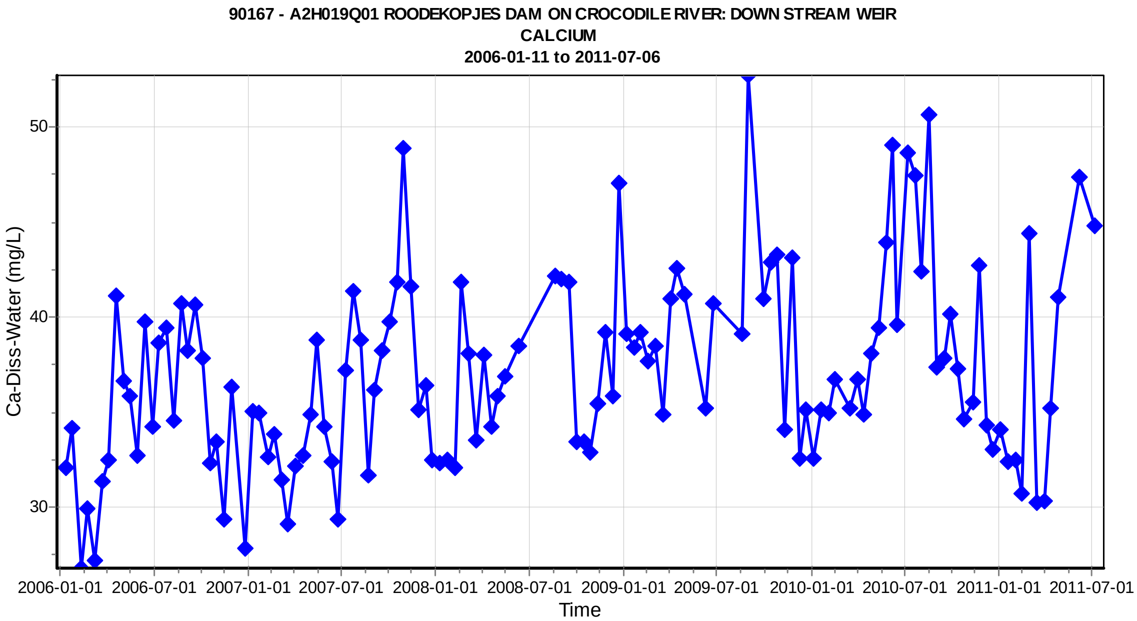

90190 - A2H045 VLAKFONTEIN 494 JQ DWJ31 ON KROKODILRIVIER
CALCIUM
2006-01-04 to 2011-09-07
Ca-Diss-Water (mg/L)
80
70
60
50
40
30
2006-01-01
2007-01-01
2008-01-01
2009-01-01
2010-01-01
2011-01-01
Time

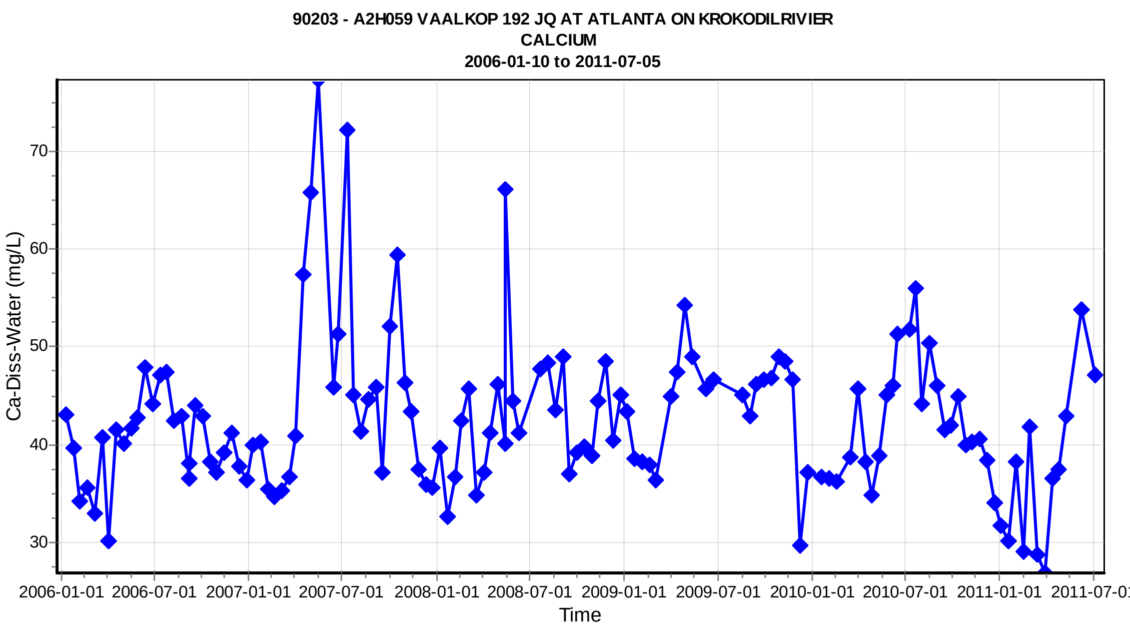
90214 - A2H083Q01 HARTBEESPOORT DAM ON CROCODILE RIV: DOWN STREAM WEIR
CALCIUM
2006-01-09 to 2011-07-04

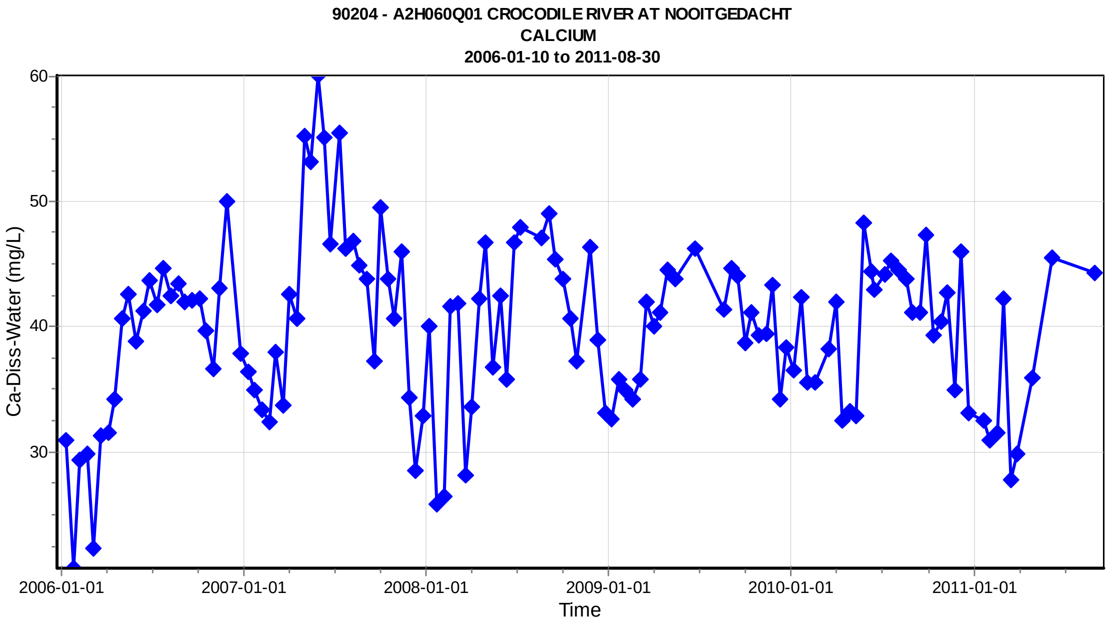


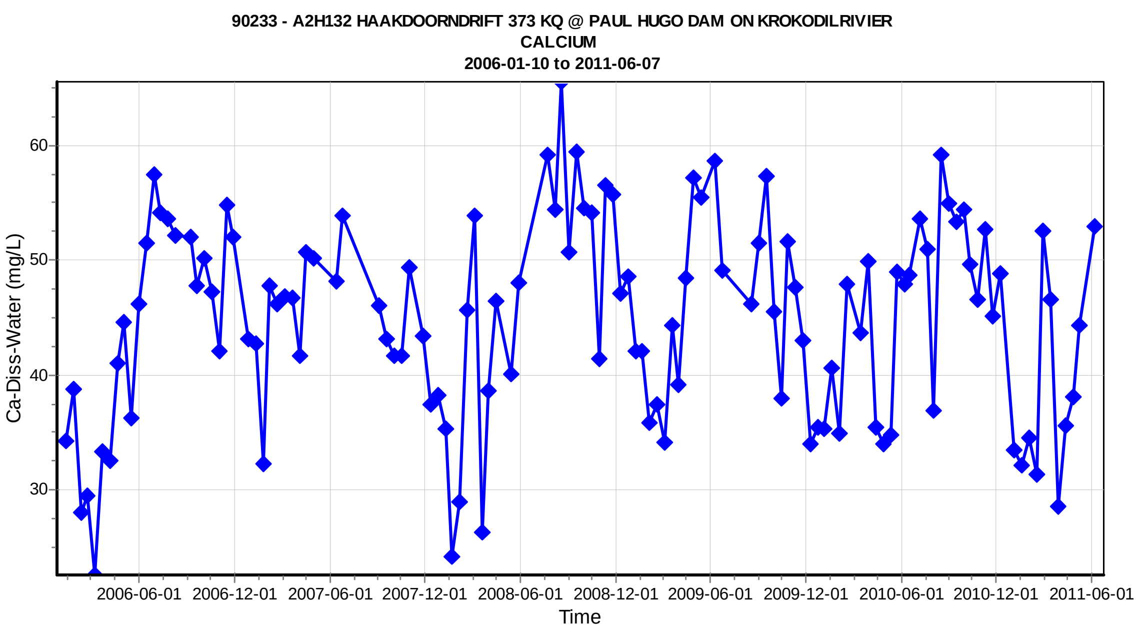
90192 - A2H048 KROKODILPOORT 418 JO /THABA MOYA ON KROKODILRIVIER
CALCIUM
2006-01-09 to 2011-07-04



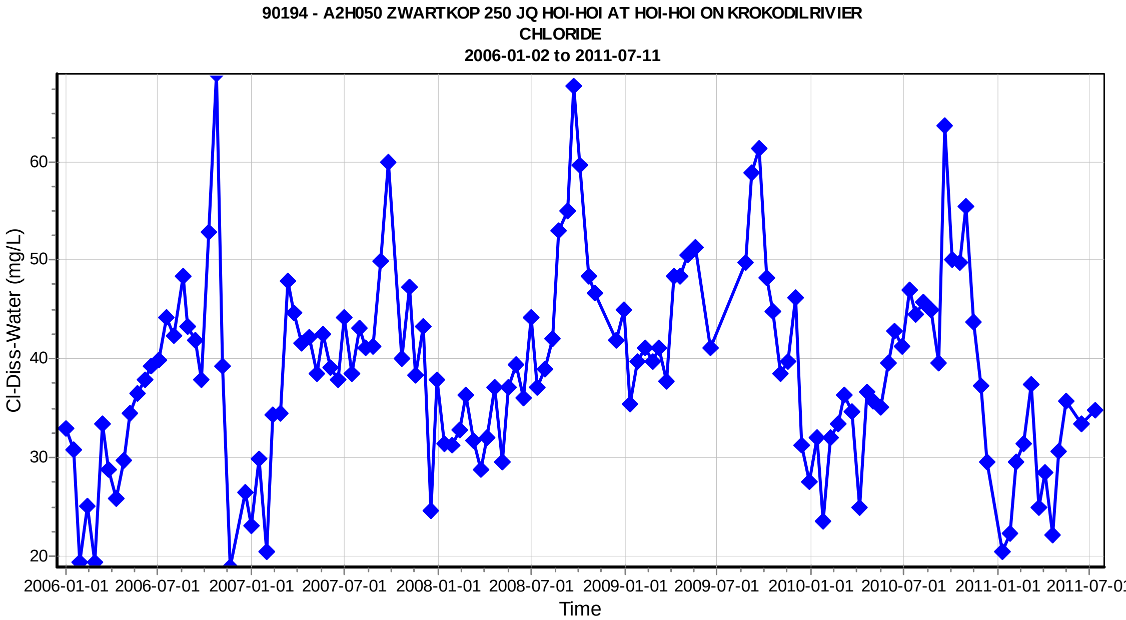

90167 - A2H019Q01 ROODEKOPJES DAM ON CROCODILE RIVER: DOWN STREAM WEIR
CALCIUM
2006-01-11 to 2011-07-06
Ca-Diss-Water (mg/L)
50
40
30
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
2011-07-01
Time

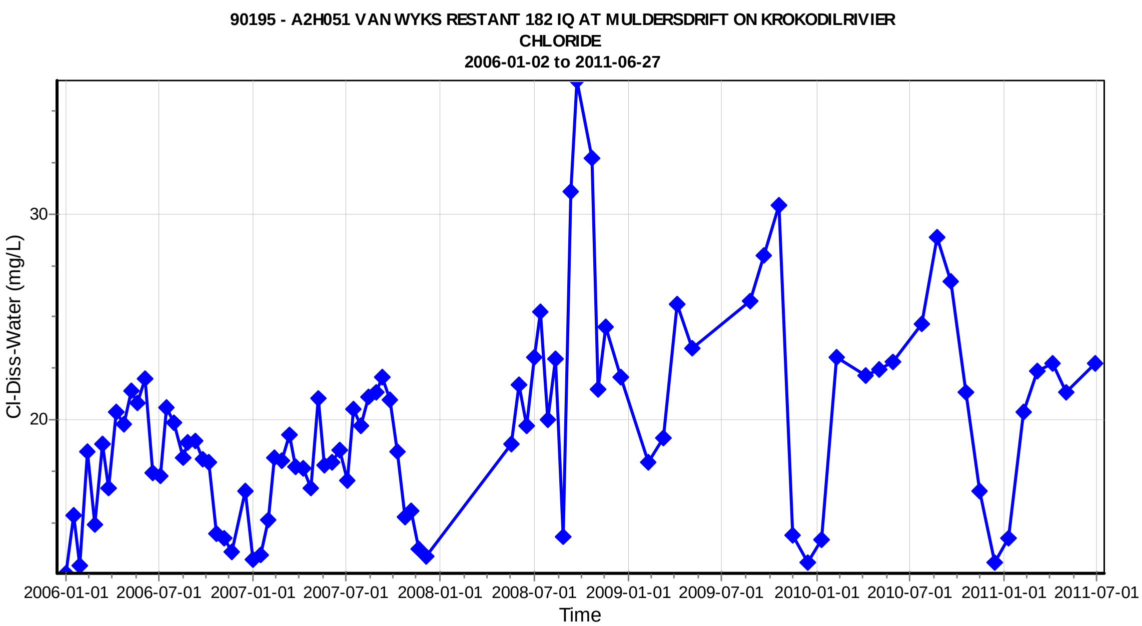

90203 - A2H059 VAALKOP 192 JQ AT ATLANTA ON KROKODILRIVIER
CALCIUM
2006-01-10 to 2011-07-05
Ca-Diss-Water (mg/L)
70
60
50
40
30
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
2011-07-01
Time

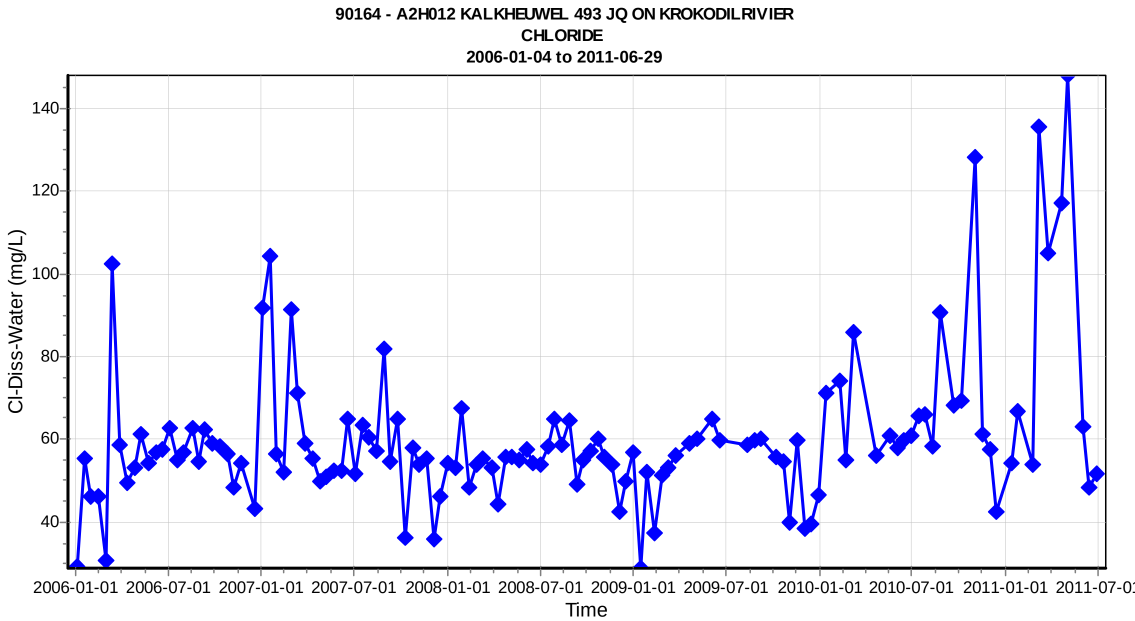

90204 - A2H060Q01 CROCODILE RIVER AT NOOITGEDACHT
CALCIUM
2006-01-10 to 2011-08-30
Ca-Diss-Water (mg/L)
60
50
40
30
2006-01-01
2007-01-01
2008-01-01
2009-01-01
2010-01-01
2011-01-01
Time

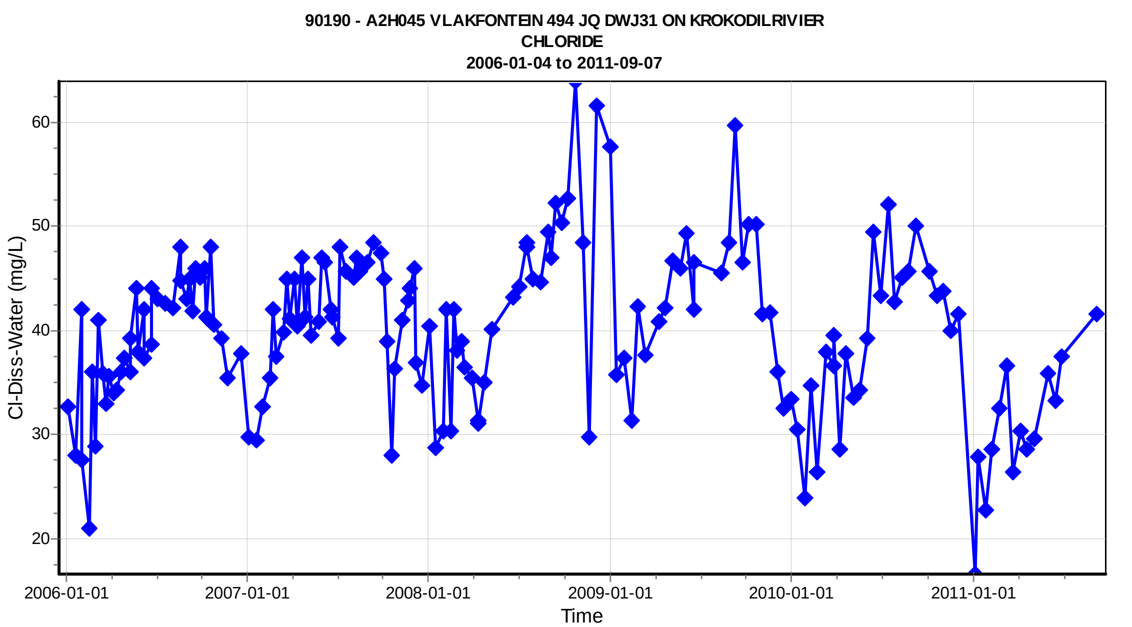

90233 - A2H132 HAAKDOORNDRIFT 373 KQ @ PAUL HUGO DAM ON KROKODILRIVIER
CALCIUM
2006-01-10 to 2011-06-07
Ca-Diss-Water (mg/L)
60
50
40
30
2006-06-01
2006-12-01
2007-06-01
2007-12-01
2008-06-01
2008-12-01
2009-06-01
2009-12-01
2010-06-01
2010-12-01
2011-06-01
Time

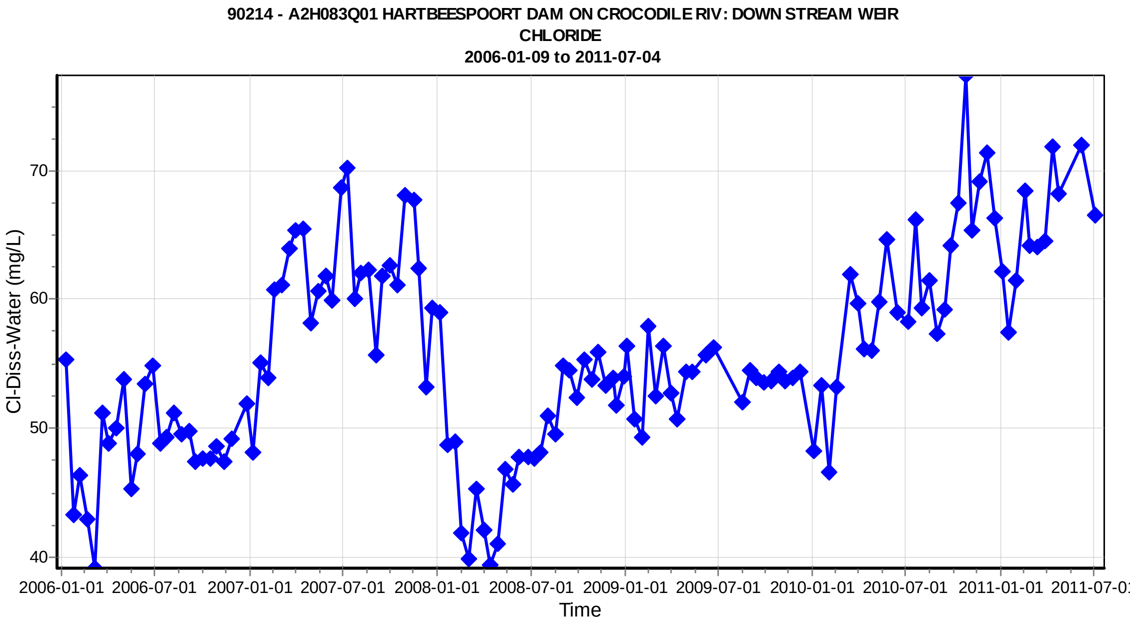
CHLORIDE

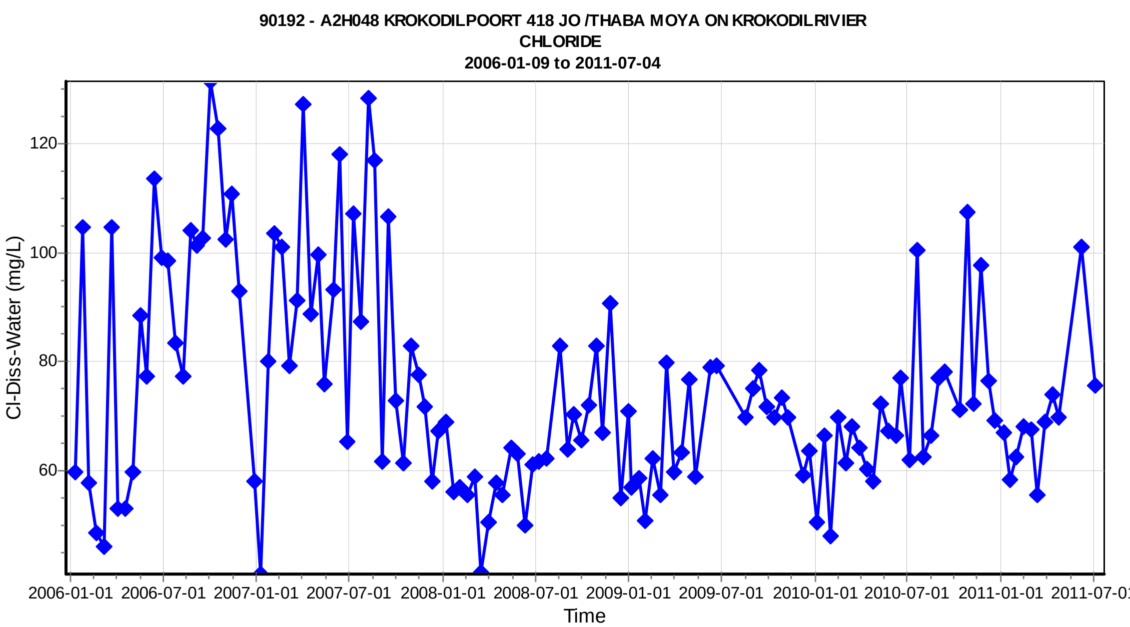

90194 - A2H050 ZWARTKOP 250 JQ HOI-HOI AT HOI-HOI ON KROKODILRIVIER
CHLORIDE
2006-01-02 to 2011-07-11
Cl-Diss-Water (mg/L)
20
30
40
50
60
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
2011-07-01
Time


90195 - A2H051 VAN WYKS RESTANT 182 IQ AT MULDERSDRIFT ON KROKODILRIVIER
CHLORIDE
2006-01-02 to 2011-06-27
Cl-Diss-Water (mg/L)
20
30
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
2011-07-01
Time


90164 - A2H012 KALKHEUWEL 493 JQ ON KROKODILRIVIER
CHLORIDE
2006-01-04 to 2011-06-29
Cl-Diss-Water (mg/L)
140
120
100
80
60
40
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
2011-07-01
Time


90190 - A2H045 VLAKFONTEIN 494 JQ DWJ31 ON KROKODILRIVIER
CHLORIDE
2006-01-04 to 2011-09-07
Cl-Diss-Water (mg/L)
60
50
40
30
20
2006-01-01
2007-01-01
2008-01-01
2009-01-01
2010-01-01
2011-01-01
Time


90214 - A2H083Q01 HARTBEESPOORT DAM ON CROCODILE RIV: DOWN STREAM WEIR
CHLORIDE
2006-01-09 to 2011-07-04
Cl-Diss-Water (mg/L)
70
60
50
40
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
2011-07-01
Time


90192 - A2H048 KROKODILPOORT 418 JO /THABA MOYA ON KROKODILRIVIER
CHLORIDE
2006-01-09 to 2011-07-04
Cl-Diss-Water (mg/L)
120
100
80
60
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
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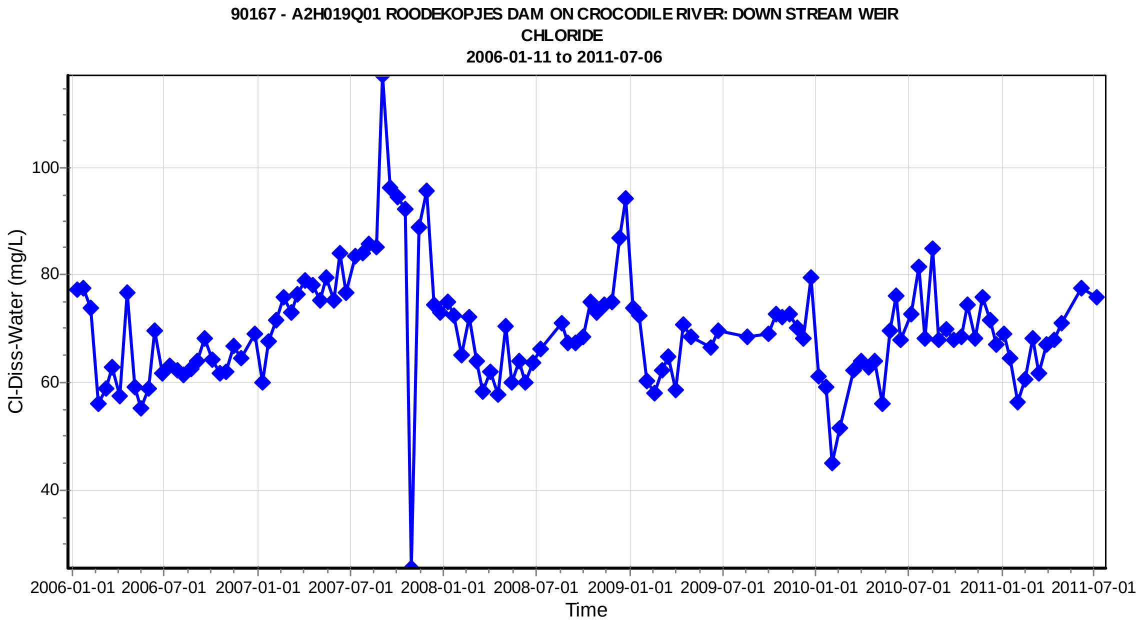
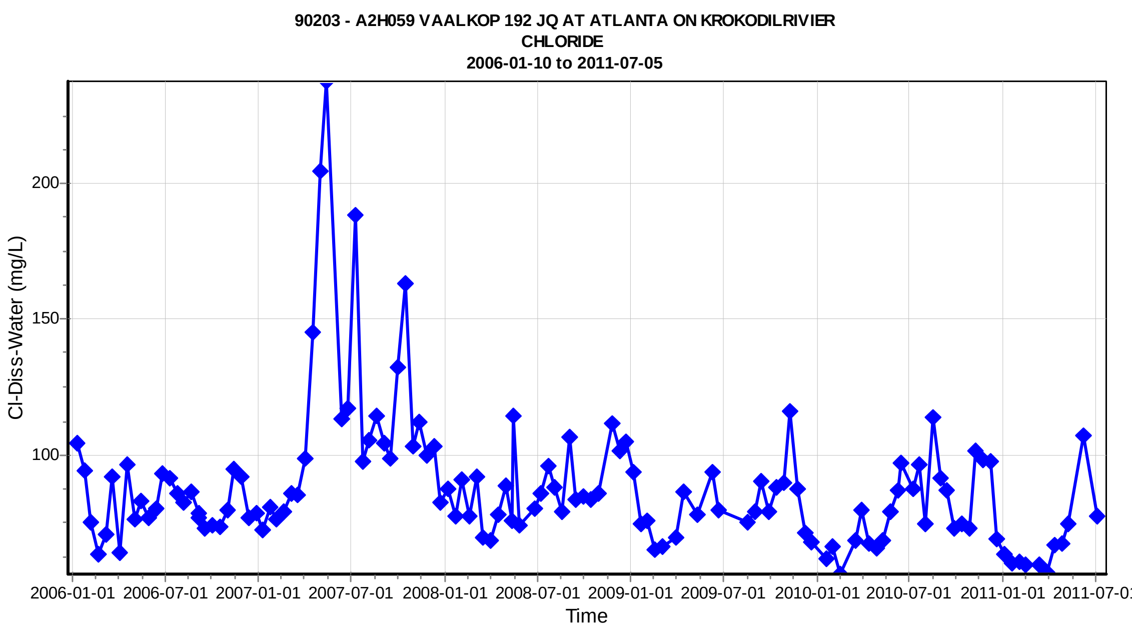
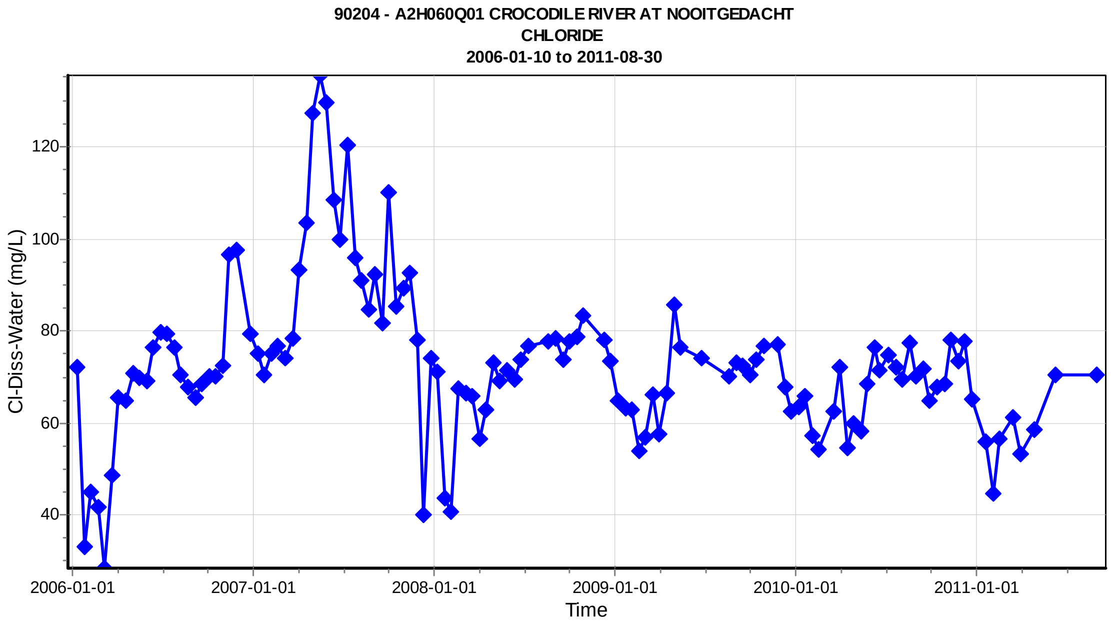
2011-01-01
2011-07-01
Time

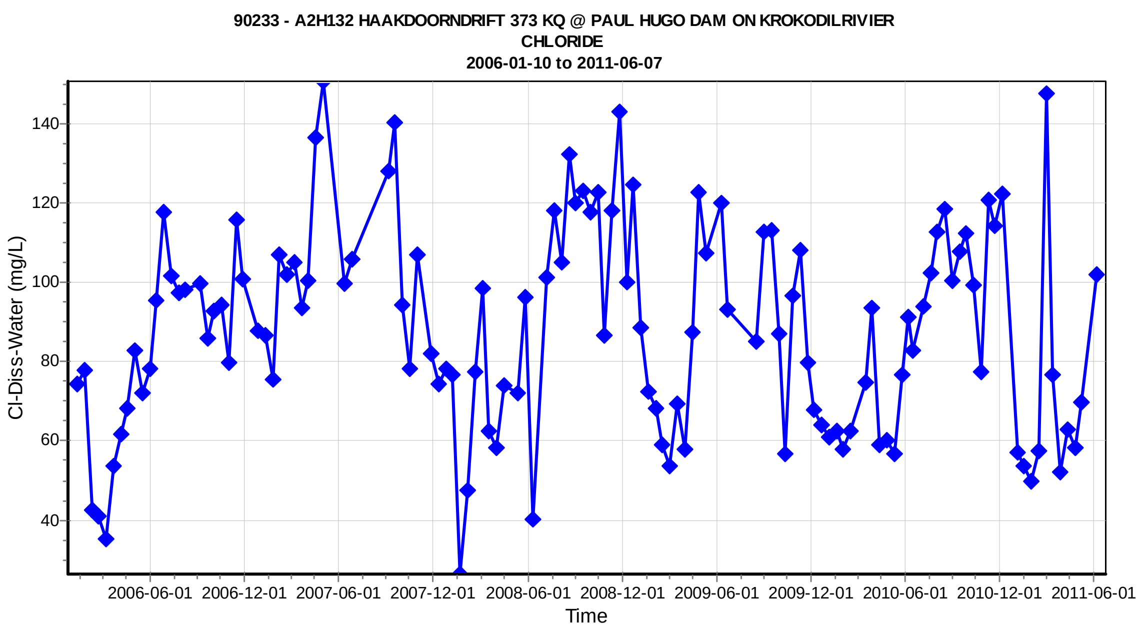


90167 - A2H019Q01 ROODEKOPJES DAM ON CROCODILE RIVER: DOWN STREAM WEIR
CHLORIDE
2006-01-11 to 2011-07-06
Cl-Diss-Water (mg/L)
100
80
60
40
2006-01-01 2006-07-01 2007-01-01 2007-07-01 2008-01-01 2008-07-01 2009-01-01 2009-07-01 2010-01-01 2010-07-01 2011-01-01 2011-07-01
Time

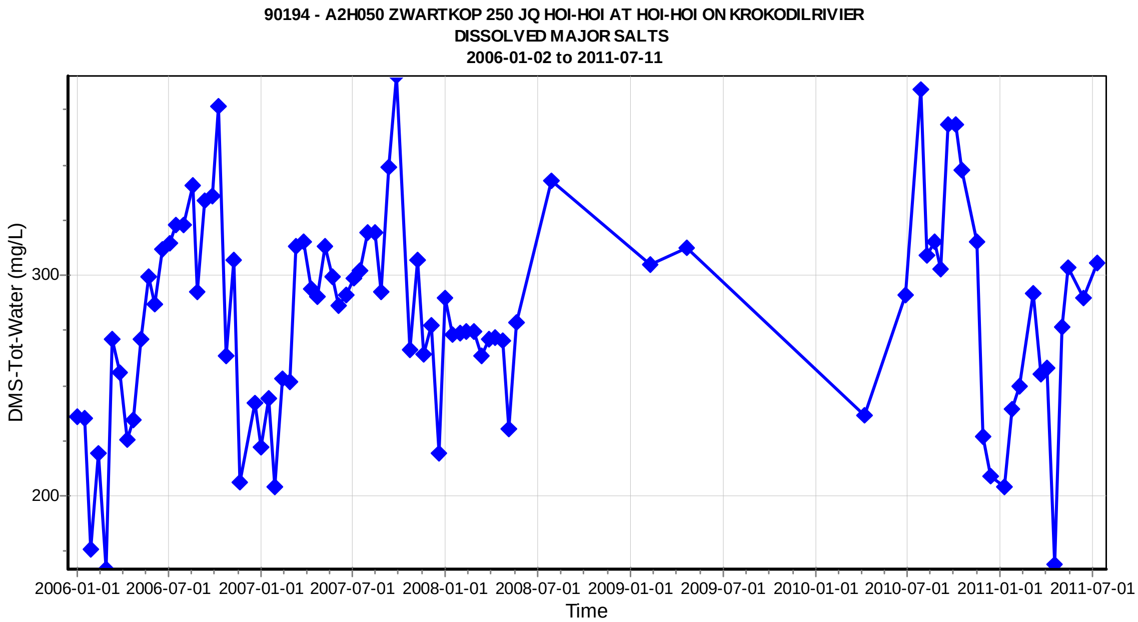


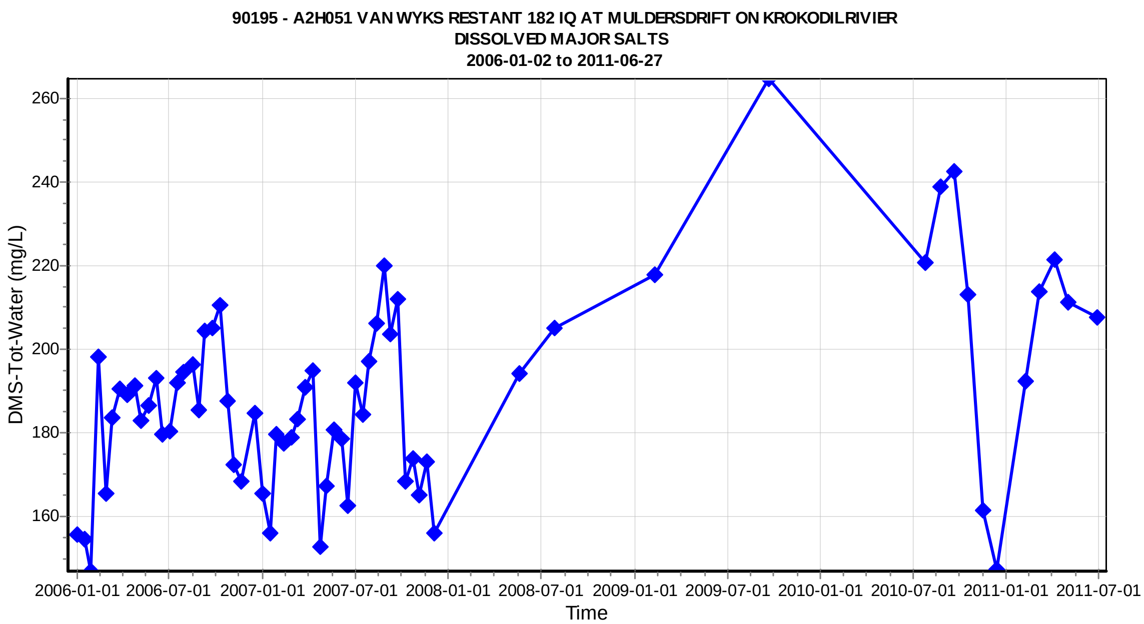
90203 - A2H059 VAALKOP 192 JQ AT ATLANTA ON KROKODILRIVIER
CHLORIDE
2006-01-10 to 2011-07-05
Cl-Diss-Water (mg/L)
200
150
100
2006-01-01 2006-07-01 2007-01-01 2007-07-01 2008-01-01 2008-07-01 2009-01-01 2009-07-01 2010-01-01 2010-07-01 2011-01-01 2011-07-01
Time

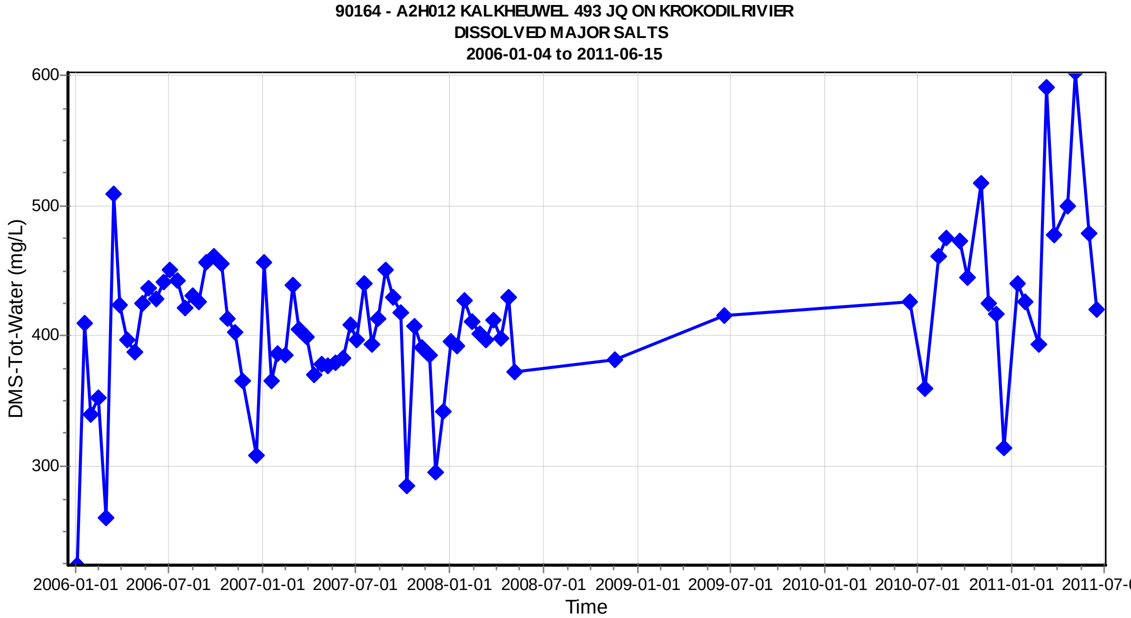

90204 - A2H060Q01 CROCODILE RIVER AT NOOITGEDACHT
CHLORIDE
2006-01-10 to 2011-08-30
Cl-Diss-Water (mg/L)
120
100
80
60
40
2006-01-01
2007-01-01
2008-01-01
2009-01-01
2010-01-01
2011-01-01
Time

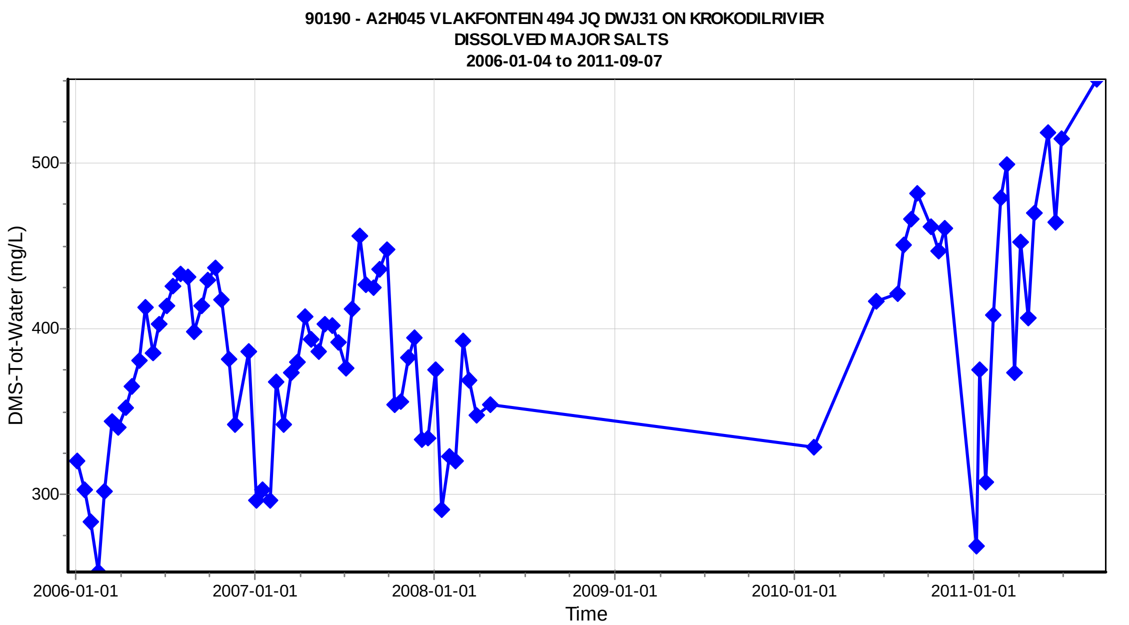

90233 - A2H132 HAAKDOORNDRIFT 373 KQ @ PAUL HUGO DAM ON KROKODILRIVIER
CHLORIDE
2006-01-10 to 2011-06-07
Cl-Diss-Water (mg/L)
140
120
100
80
60
40
2006-06-01
2006-12-01
2007-06-01
2007-12-01
2008-06-01
2008-12-01
2009-06-01
2009-12-01
2010-06-01
2010-12-01
2011-06-01
Time

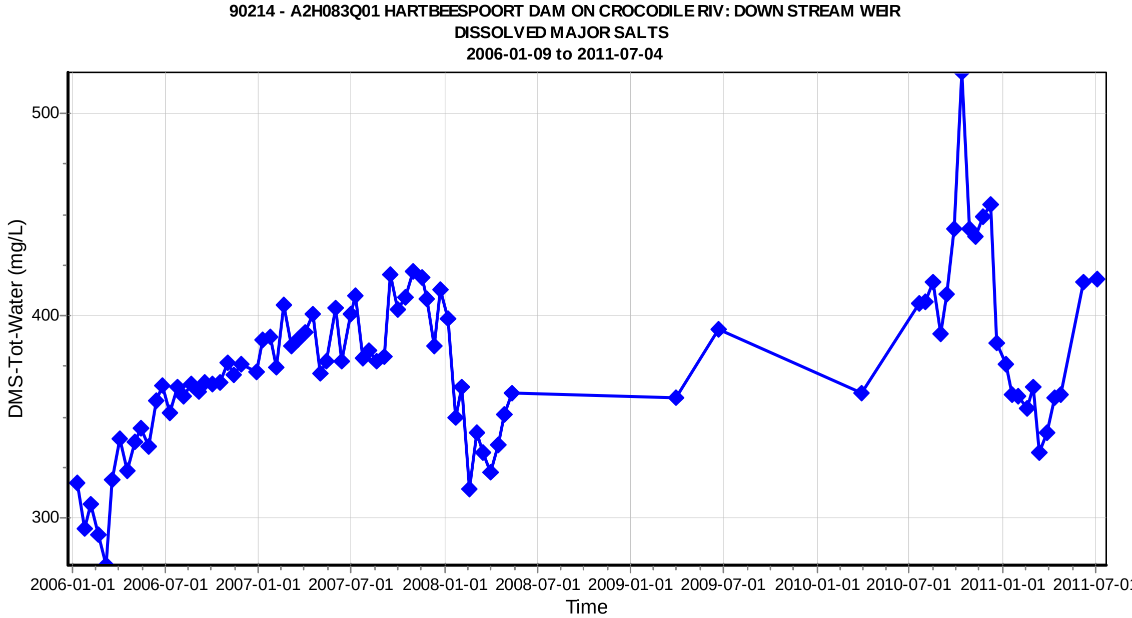
DISSOLVED MAJOR SLATS (DMS) / TOTAL DISSOLVED SALTS

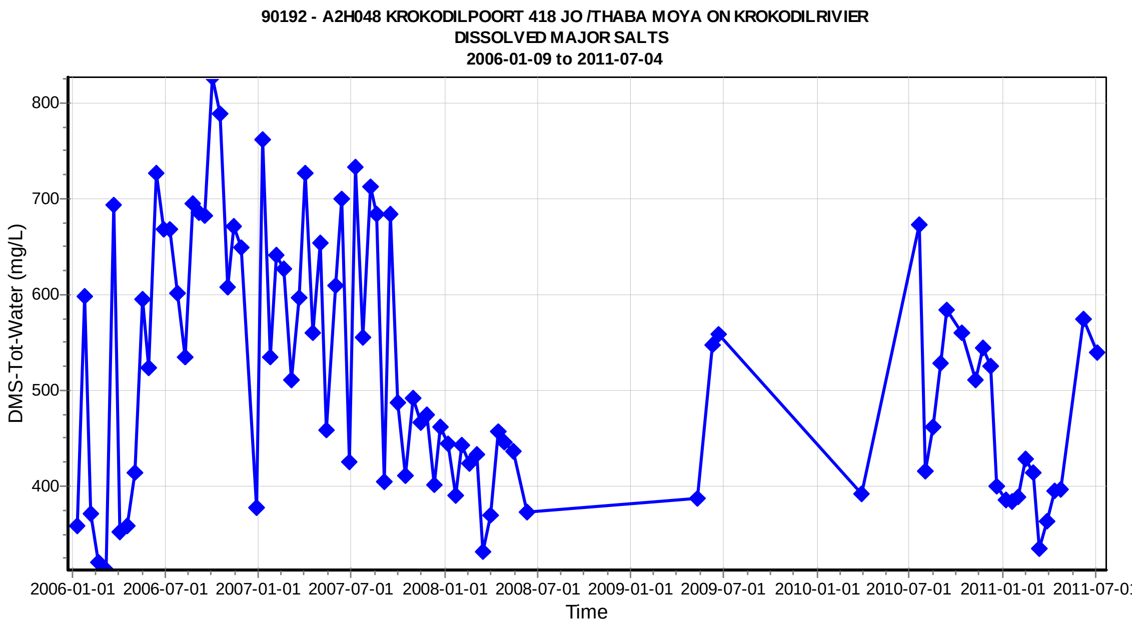





90164 - A2H012 KALKHEUWEL 493 JQ ON KROKODILRIVIER
DISSOLVED MAJOR SALTS
2006-01-04 to 2011-06-15
DMS-Tot-Water (mg/L)
600
500
400
300
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
Time


90190 - A2H045 VLAKFONTEIN 494 JQ DWJ31 ON KROKODILRIVIER
DISSOLVED MAJOR SALTS
2006-01-04 to 2011-09-07
DMS-Tot-Water (mg/L)
500
400
300
2006-01-01
2007-01-01
2008-01-01
2009-01-01
2010-01-01
2011-01-01
Time


90214 - A2H083Q01 HARTBEESPOORT DAM ON CROCODILE RIV: DOWN STREAM WEIR
DISSOLVED MAJOR SALTS
2006-01-09 to 2011-07-04
DMS-Tot-Water (mg/L)
500
400
300
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
2011-07-01
Time


90192 - A2H048 KROKODILPOORT 418 JO /THABA MOYA ON KROKODILRIVIER
DISSOLVED MAJOR SALTS
2006-01-09 to 2011-07-04
DMS-Tot-Water (mg/L)
800
700
600
500
400
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
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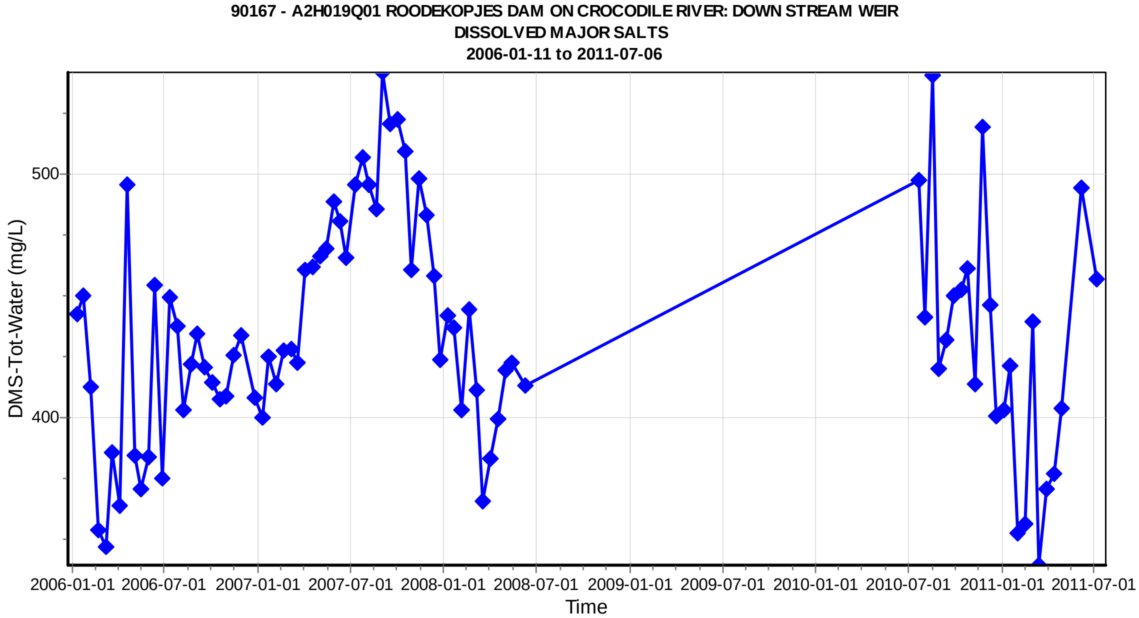
2011-01-01
2011-07-01
Time


90167 - A2H019Q01 ROODEKOPJES DAM ON CROCODILE RIVER: DOWN STREAM WEIR
DISSOLVED MAJOR SALTS
2006-01-11 to 2011-07-06
DMS-Tot-Water (mg/L)
500
400
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
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2010-01-01
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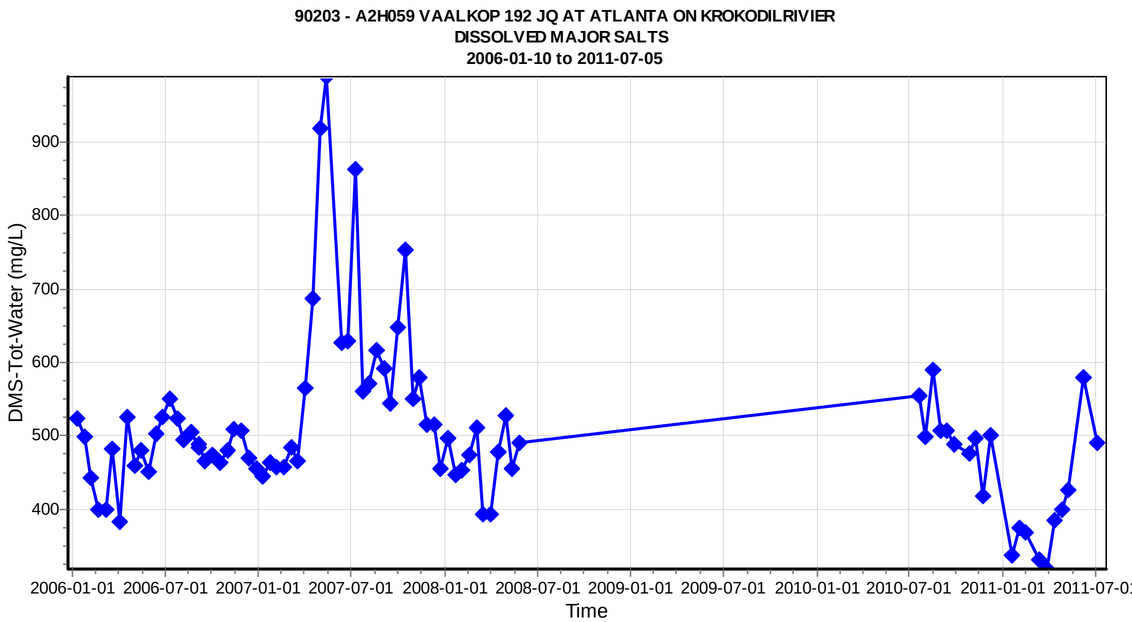
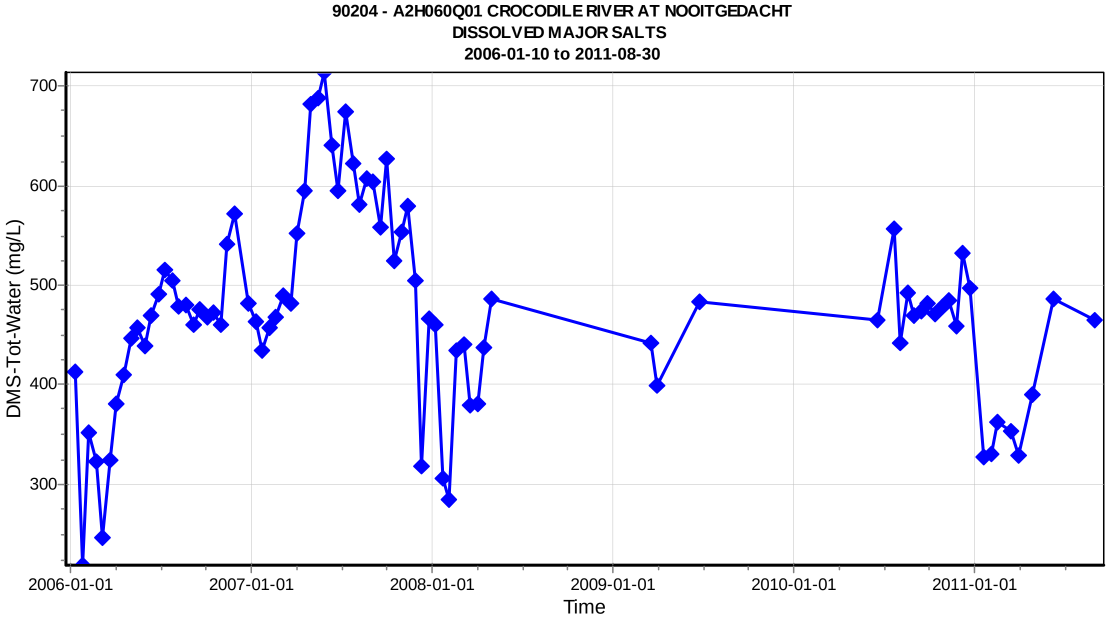
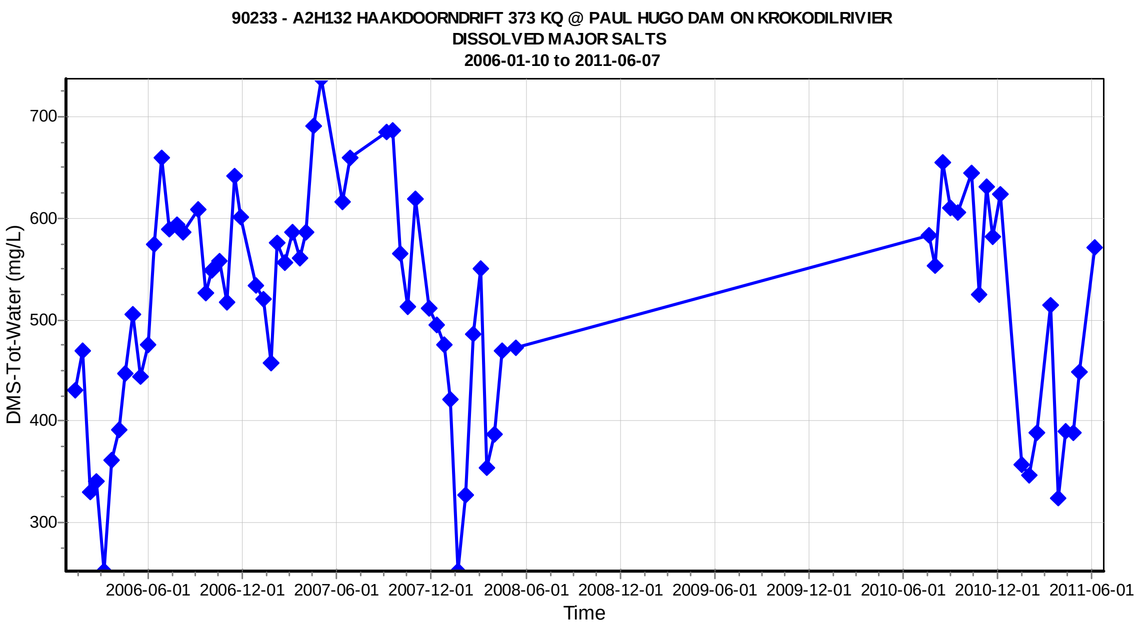
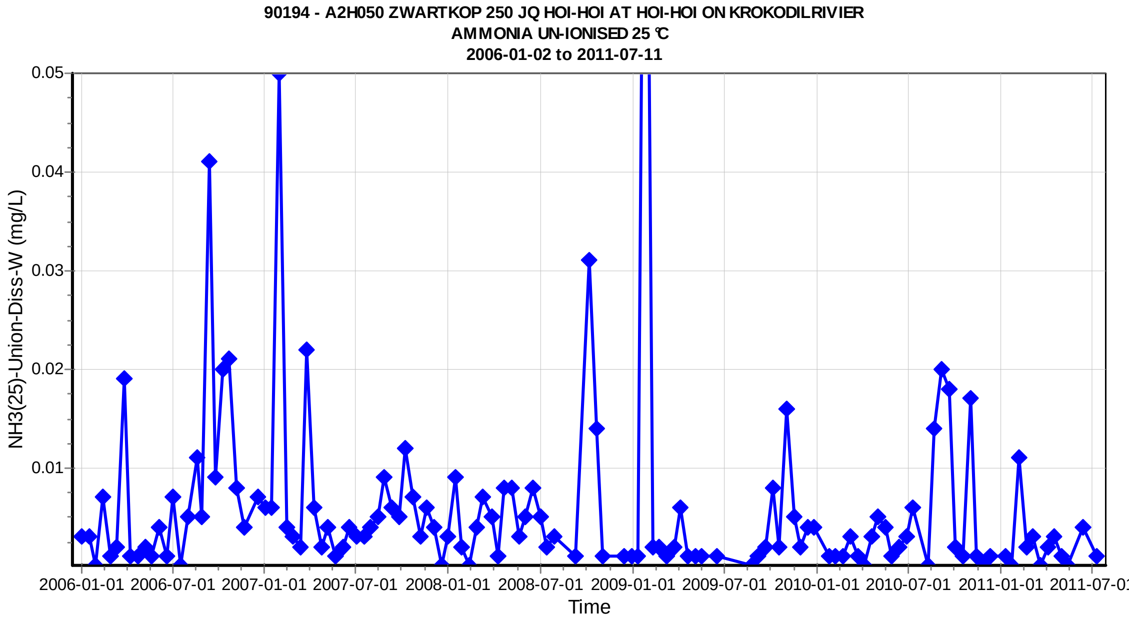
2011-01-01
2011-07-01
Time

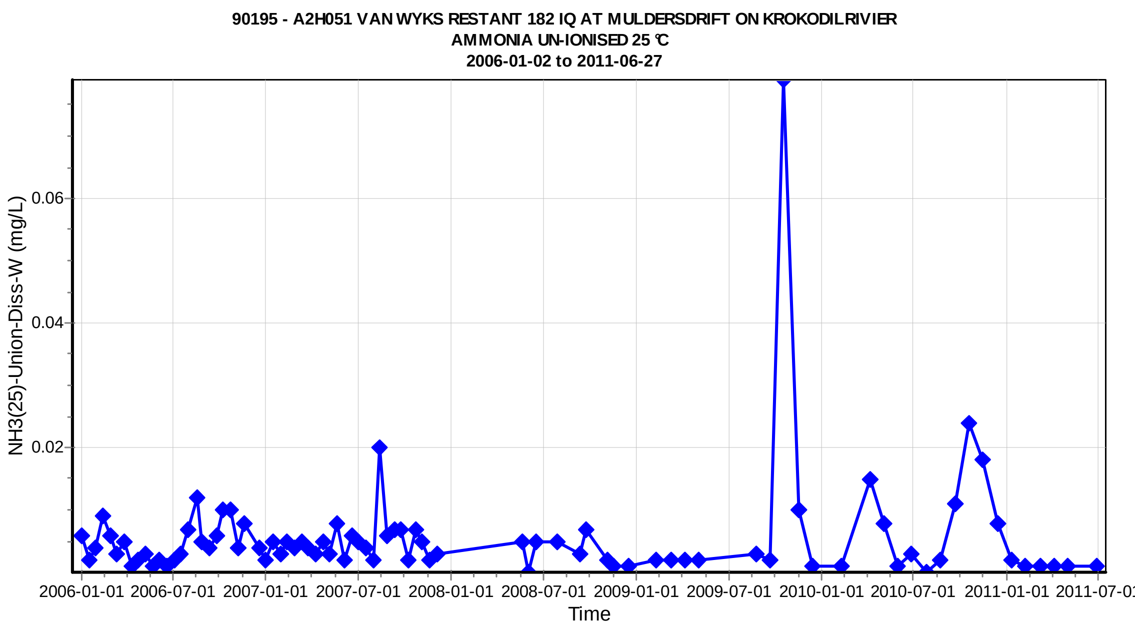

90203 - A2H059 VAALKOP 192 JQ AT ATLANTA ON KROKODILRIVIER
DISSOLVED MAJOR SALTS
2006-01-10 to 2011-07-05
DMS-Tot-Water (mg/L)
900
800
700
600
500
400
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
2011-07-01
Time


90204 - A2H060Q01 CROCODILE RIVER AT NOOITGEDACHT
DISSOLVED MAJOR SALTS
2006-01-10 to 2011-08-30
DMS-Tot-Water (mg/L)
700
600
500
400
300
2006-01-01
2007-01-01
2008-01-01
2009-01-01
2010-01-01
2011-01-01
Time

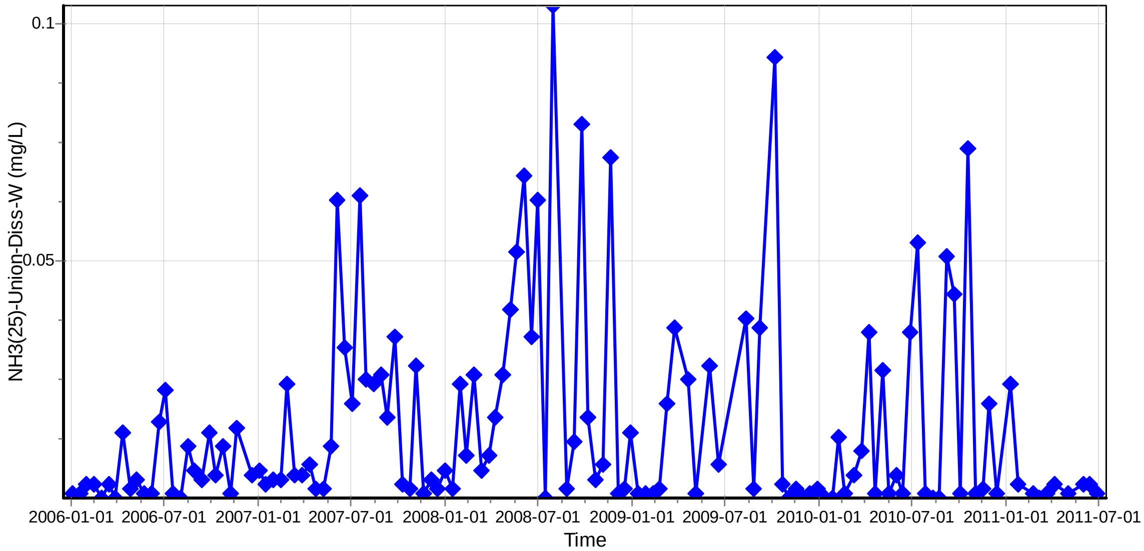

90233 - A2H132 HAAKDOORNDRIFT 373 KQ @ PAUL HUGO DAM ON KROKODILRIVIER
DISSOLVED MAJOR SALTS
2006-01-10 to 2011-06-07
DMS-Tot-Water (mg/L)
700
600
500
400
300
2006-06-01
2006-12-01
2007-06-01
2007-12-01
2008-06-01
2008-12-01
2009-06-01
2009-12-01
2010-06-01
2010-12-01
2011-06-01
Time

AMMONIUM

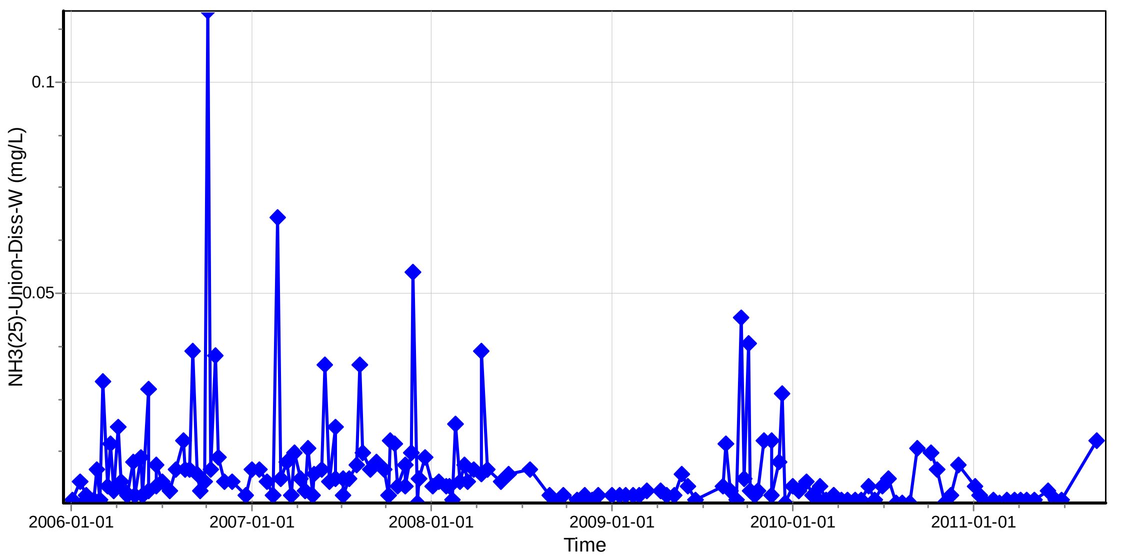

90194 - A2H050 ZWARTKOP 250 JQ HOI-HOI AT HOI-HOI ON KROKODILRIVIER
AMMONIA UN-IONISED 25 ℃
2006-01-02 to 2011-07-11
NH3(25)-Union-Diss-W (mg/L)
0.05
0.04
0.03
0.02
0.01
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
2011-07-01
Time

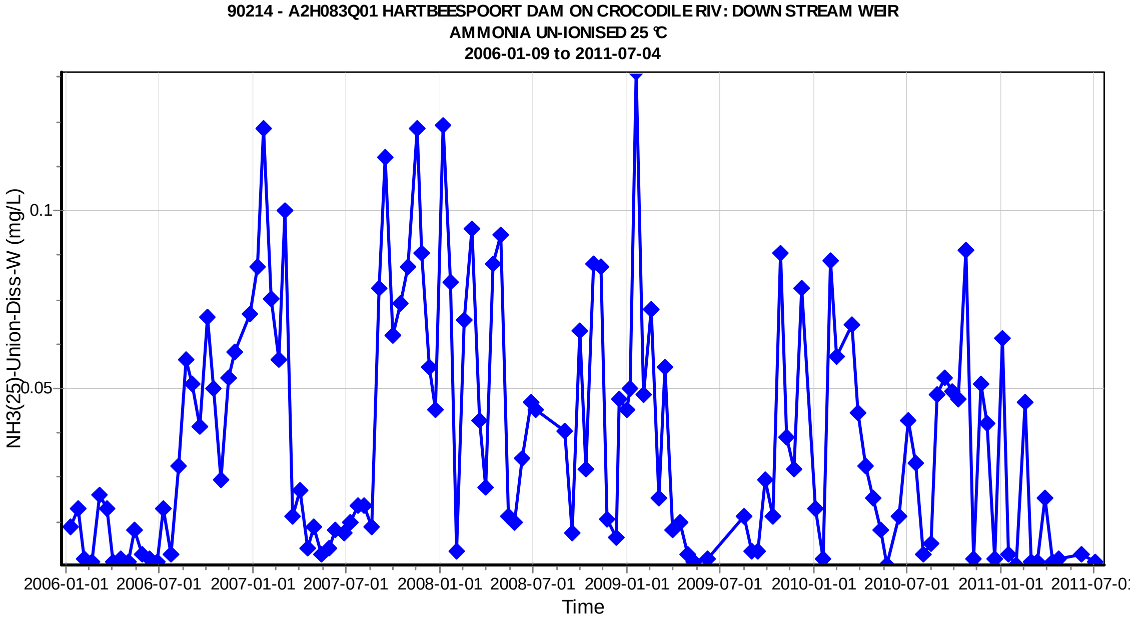

90195 - A2H051 VAN WYKS RESTANT 182 IQ AT MULDERSDRIFT ON KROKODILRIVIER
AMMONIA UN-IONISED 25 ℃
2006-01-02 to 2011-06-27
NH3(25)-Union-Diss-W (mg/L)
0.06
0.04
0.02
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
2011-07-01
Time

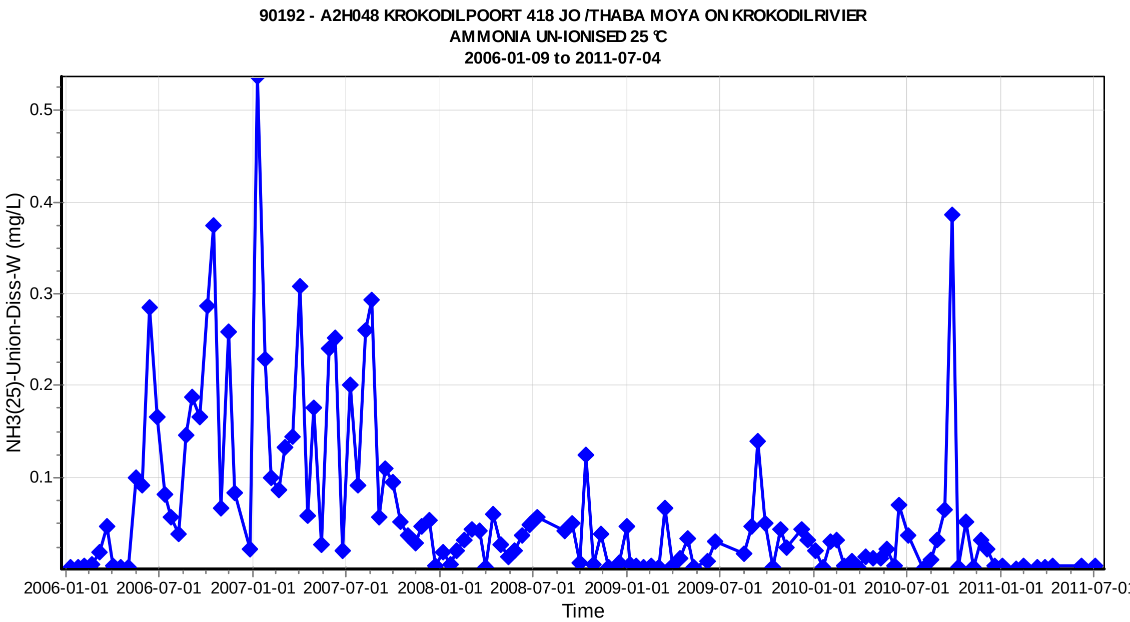
90164 - A2H012 KALKHEUWEL 493 JQ ON KROKODILRIVIER
AMMONIA UN-IONISED 25 ℃
2006-01-04 to 2011-06-29

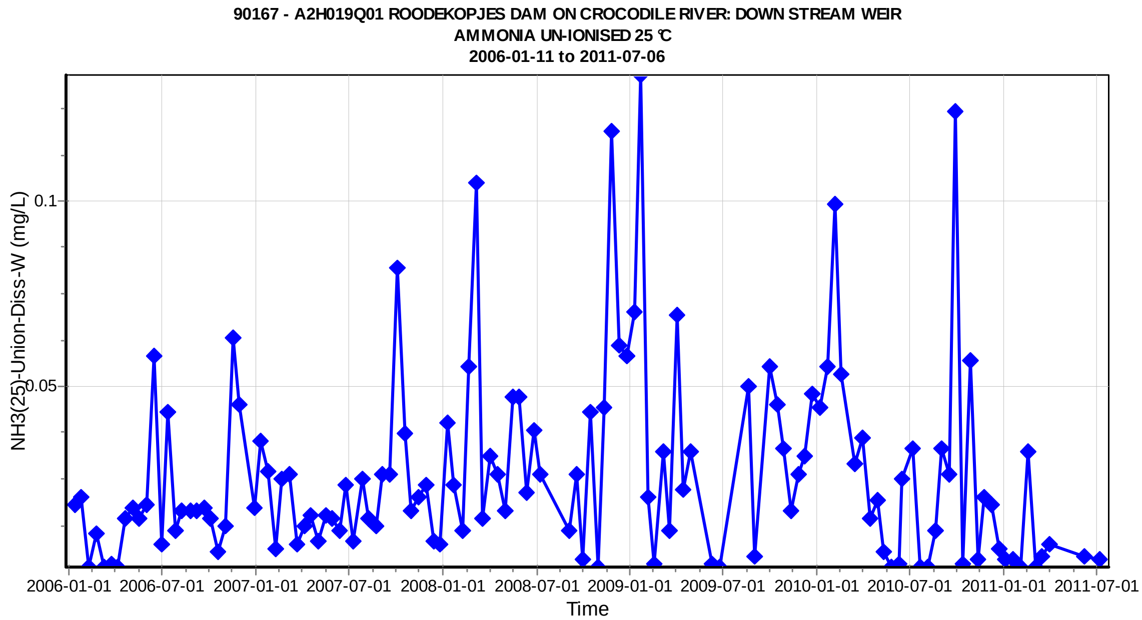


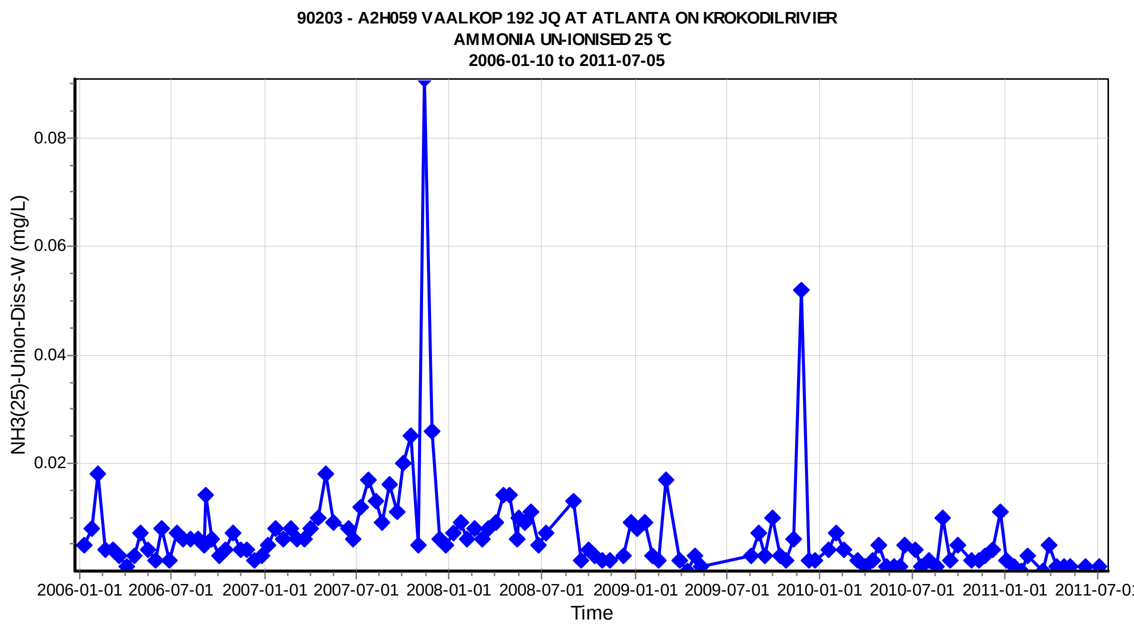
90190 - A2H045 VLAKFONTEIN 494 JQ DWJ31 ON KROKODILRIVIER
AMMONIA UN-IONISED 25 ℃
2006-01-04 to 2011-09-07



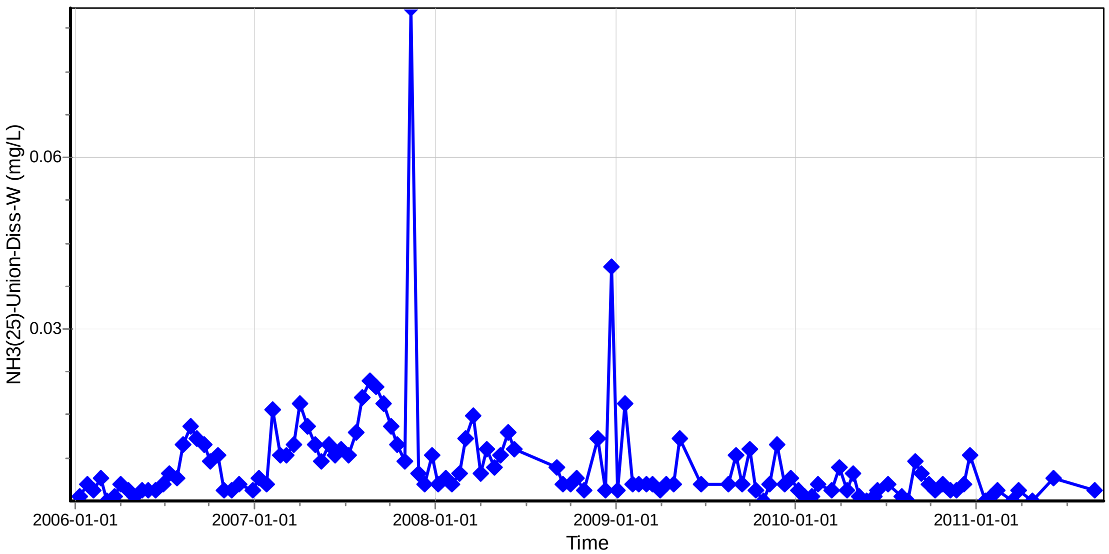

90214 - A2H083Q01 HARTBEESPOORT DAM ON CROCODILE RIV: DOWN STREAM WEIR
AMMONIA UN-IONISED 25 °C
2006-01-09 to 2011-07-04
NH3(25)-Union-Diss-W (mg/L)
0.1
0.05
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
2011-07-01
Time


90192 - A2H048 KROKODILPOORT 418 JO /THABA MOYA ON KROKODILRIVIER
AMMONIA UN-IONISED 25 °C
2006-01-09 to 2011-07-04
NH3(25)-Union-Diss-W (mg/L)
0.5
0.4
0.3
0.2
0.1
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
2011-07-01
Time

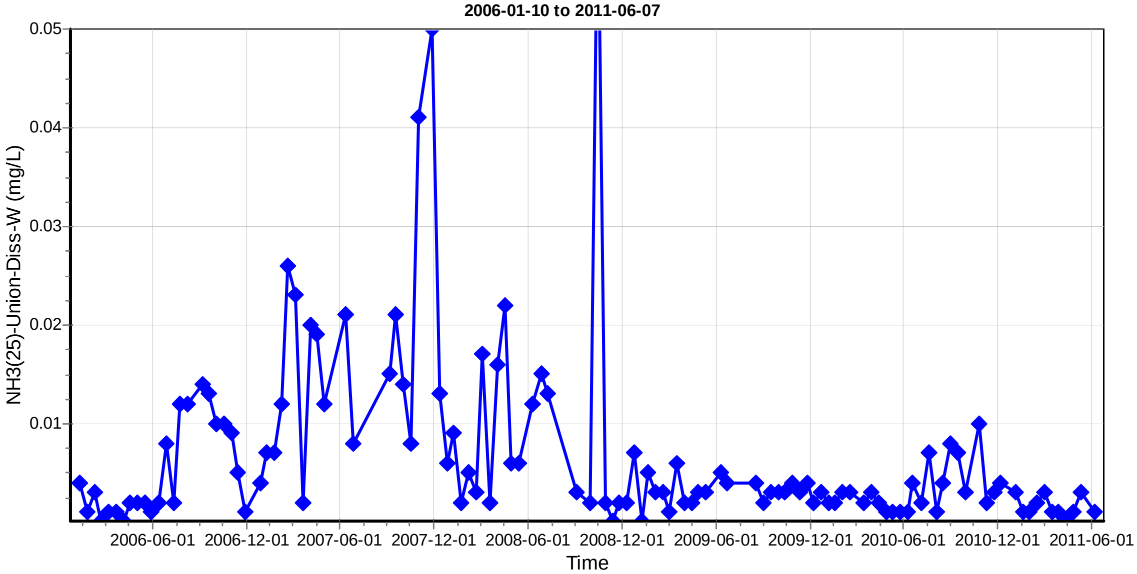

90167 - A2H019Q01 ROODEKOPJES DAM ON CROCODILE RIVER: DOWN STREAM WEIR
AMMONIA UN-IONISED 25 ℃
2006-01-11 to 2011-07-06
NH3(25)-Union-Diss-W (mg/L)
0.1
0.05
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
2011-07-01
Time


90203 - A2H059 VAALKOP 192 JQ AT ATLANTA ON KROKODILRIVIER
AMMONIA UN-IONISED 25 ℃
2006-01-10 to 2011-07-05
NH3(25)-Union-Diss-W (mg/L)
0.08
0.06
0.04
0.02
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
2011-07-01
Time

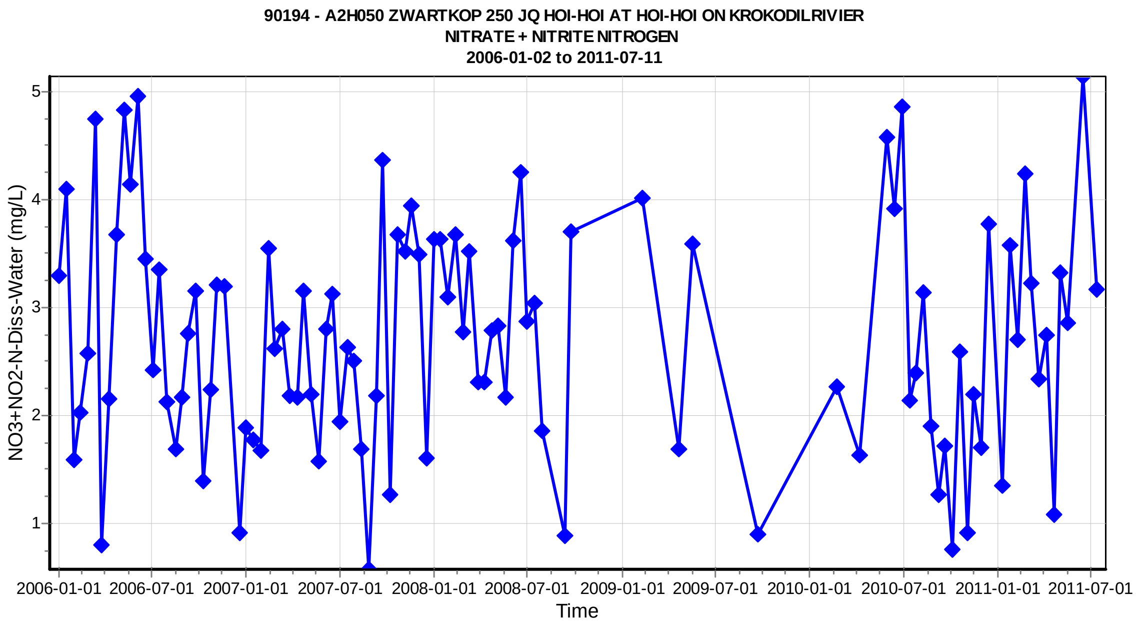
90204 - A2H060Q01 CROCODILE RIVER AT NOOITGEDACHT
AMMONIA UN-IONISED 25 ℃
2006-01-10 to 2011-08-30

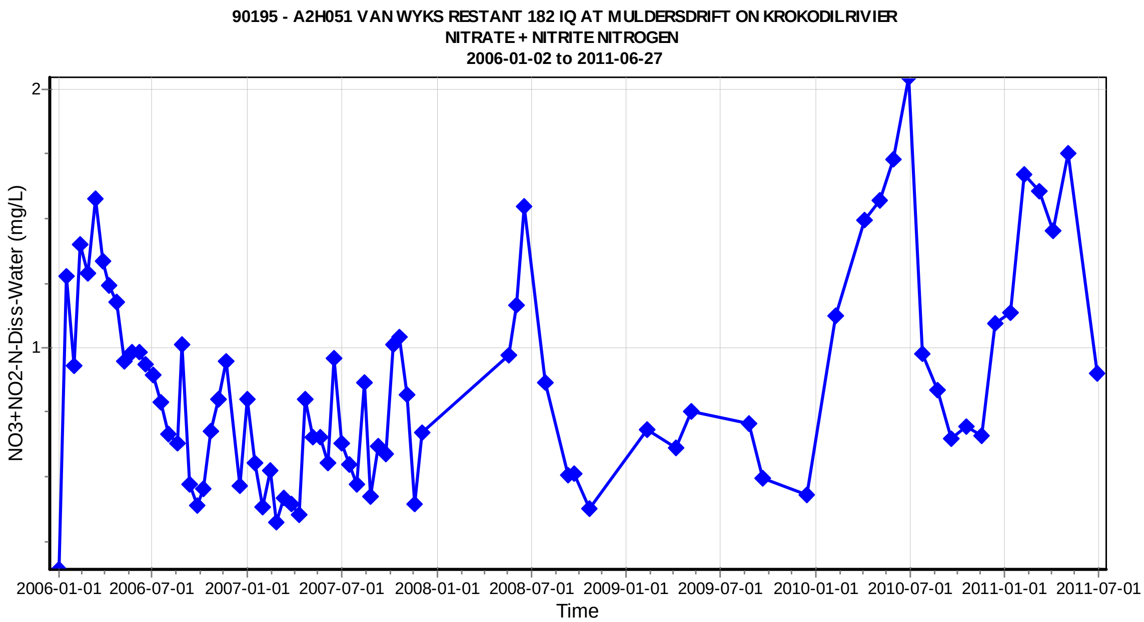


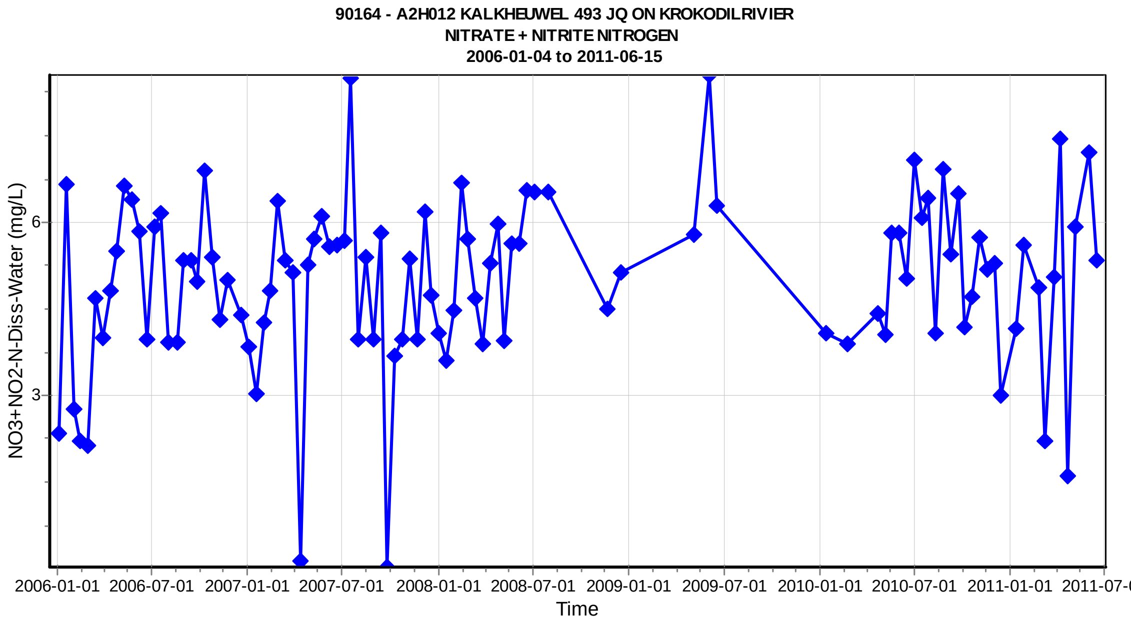
90233 - A2H132 HAAKDOORNDRIFT 373 KQ @ PAUL HUGO DAM ON KROKODILRIVIER
AMMONIA UN-IONISED 25 ℃
2006-01-10 to 2011-06-07

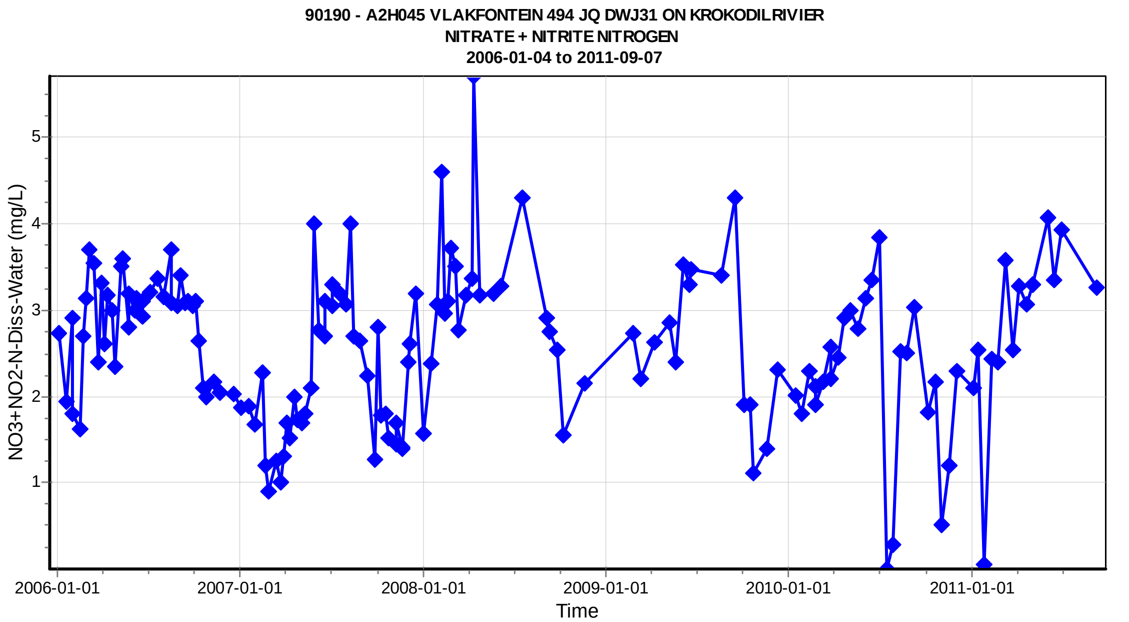


NITRATE NITRITE

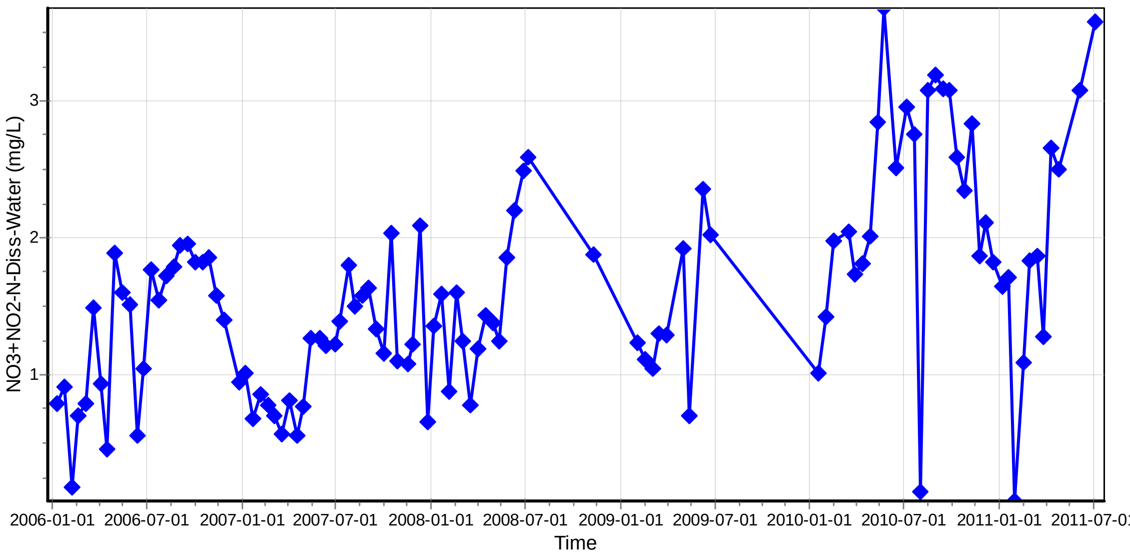




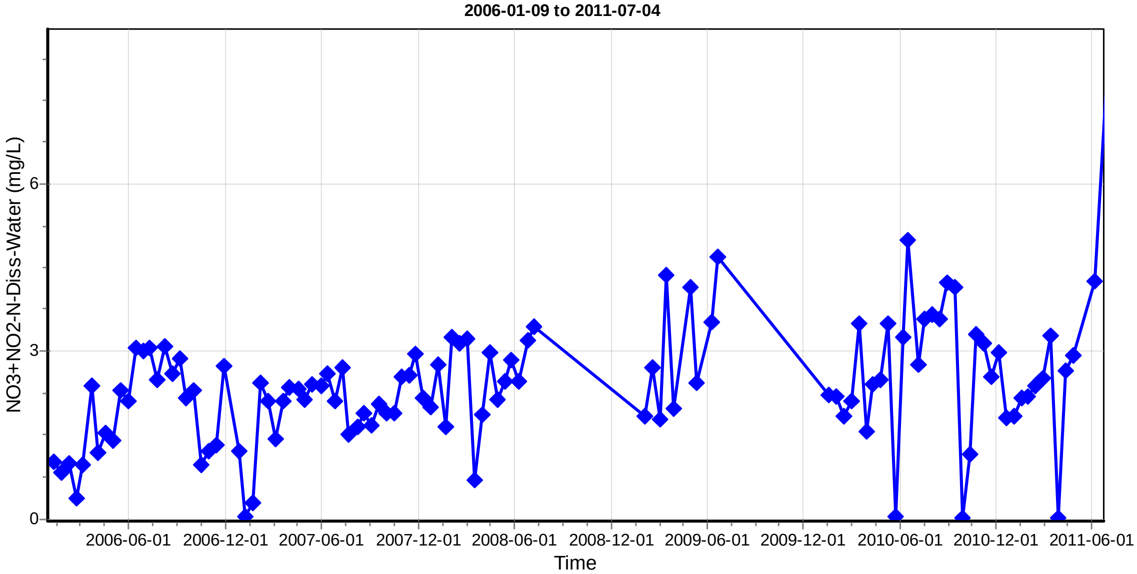

90164 - A2H012 KALKHEUWEL 493 JQ ON KROKODILRIVIER
NITRATE + NITRITE NITROGEN
2006-01-04 to 2011-06-15
NO3+NO2-N-Diss-Water (mg/L)
6
3
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
Time


90190 - A2H045 VLAKFONTEIN 494 JQ DWJ31 ON KROKODILRIVIER
NITRATE + NITRITE NITROGEN
2006-01-04 to 2011-09-07
NO3+NO2-N-Diss-Water (mg/L)
5
4
3
2
1
2006-01-01
2007-01-01
2008-01-01
2009-01-01
2010-01-01
2011-01-01
Time

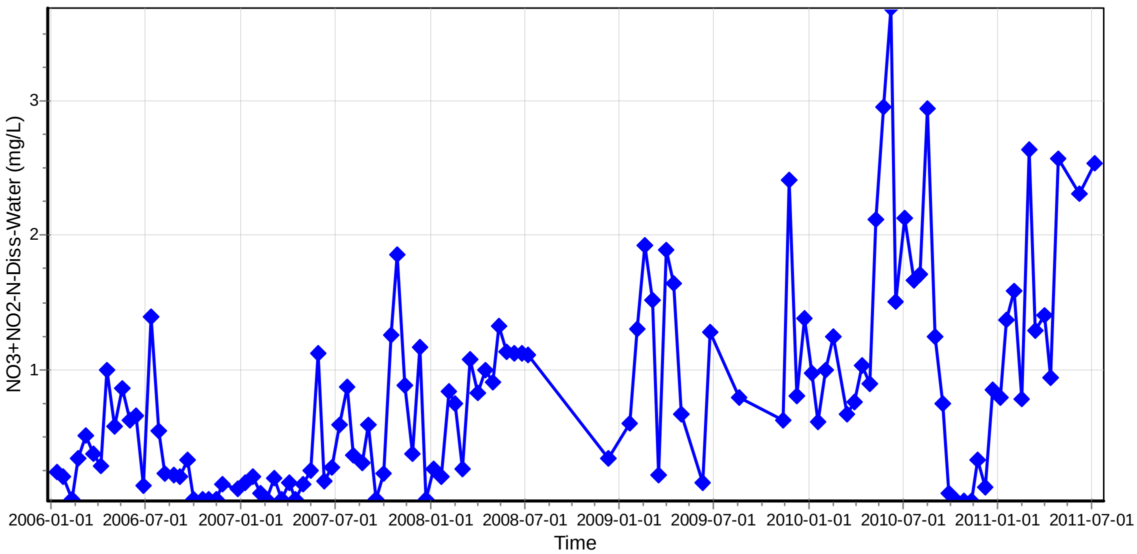
90214 - A2H083Q01 HARTBEESPOORT DAM ON CROCODILE RIV: DOWN STREAM WEIR
NITRATE + NITRITE NITROGEN
2006-01-09 to 2011-07-04



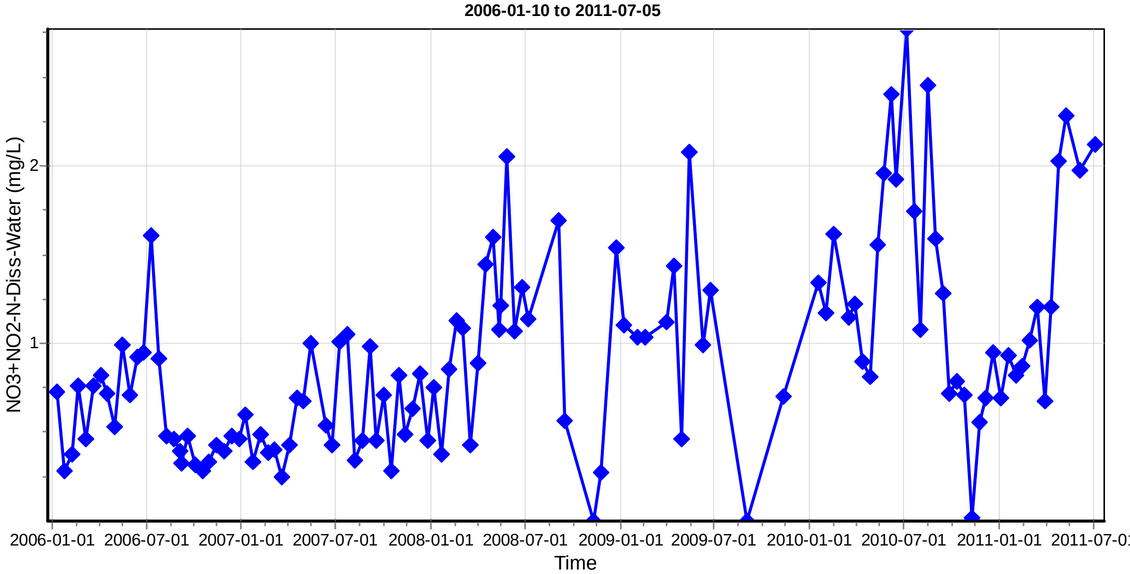
90192 - A2H048 KROKODILPOORT 418 JO /THABA MOYA ON KROKODILRIVIER
NITRATE + NITRITE NITROGEN
2006-01-09 to 2011-07-04

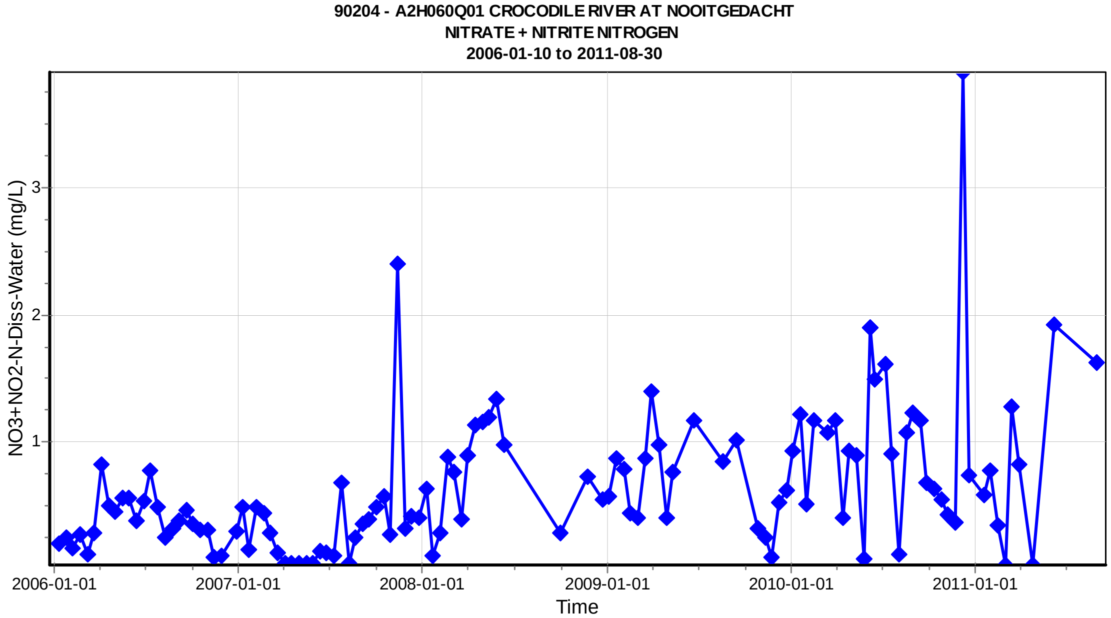


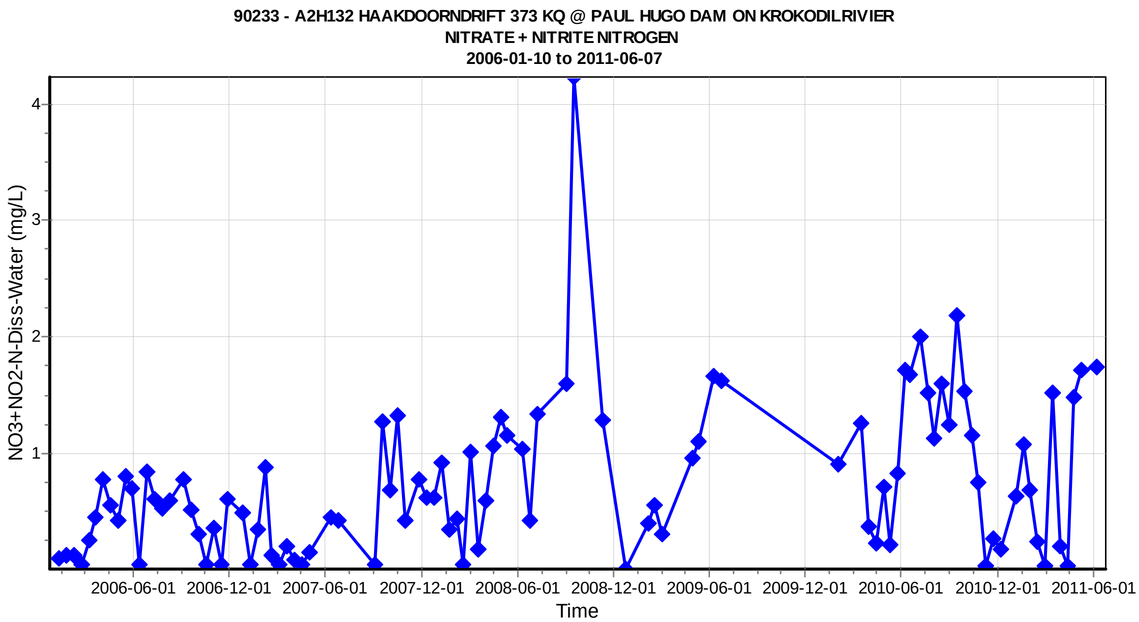
90167 - A2H019Q01 ROODEKOPJES DAM ON CROCODILE RIVER: DOWN STREAM WEIR
NITRATE + NITRITE NITROGEN
2006-01-11 to 2011-07-06



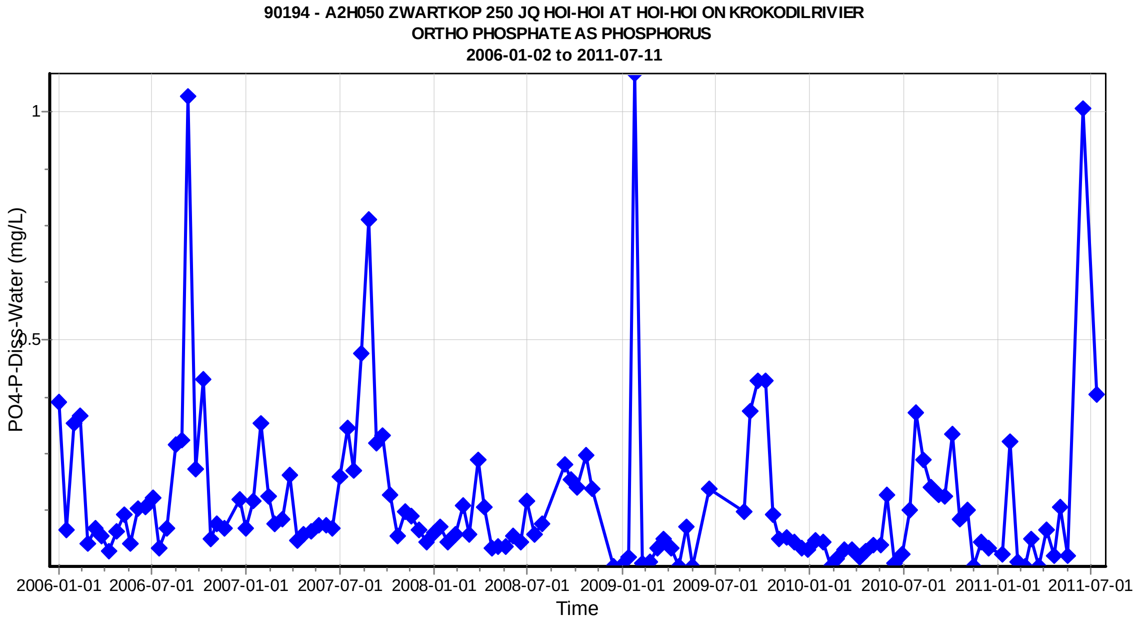
90203 - A2H059 VAALKOP 192 JQ AT ATLANTA ON KROKODILRIVIER
NITRATE + NITRITE NITROGEN
2006-01-10 to 2011-07-05

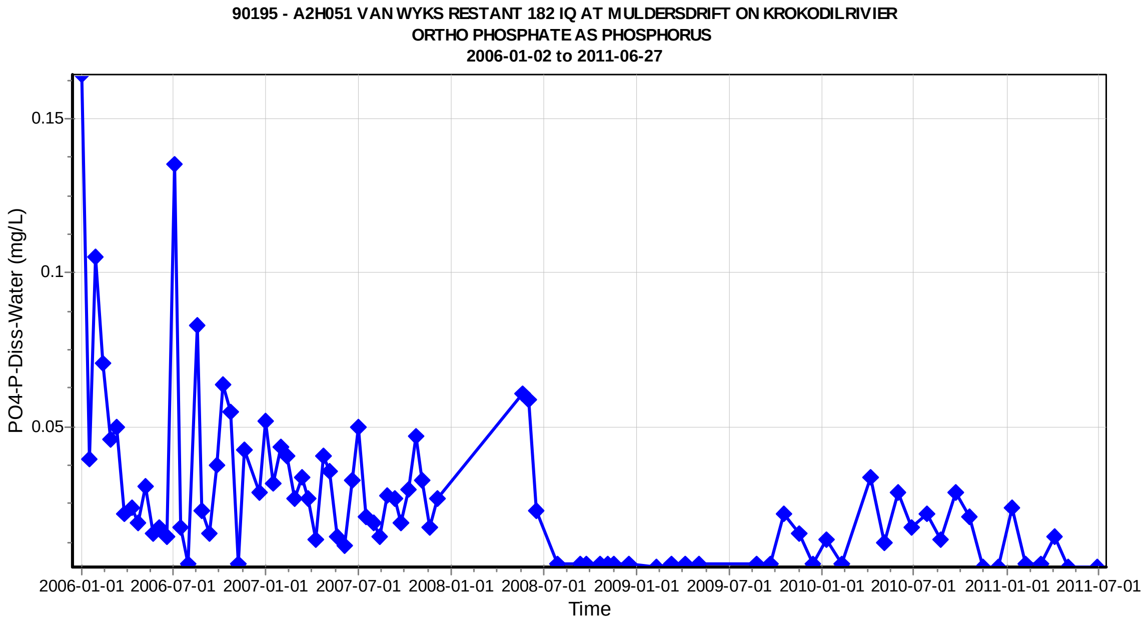


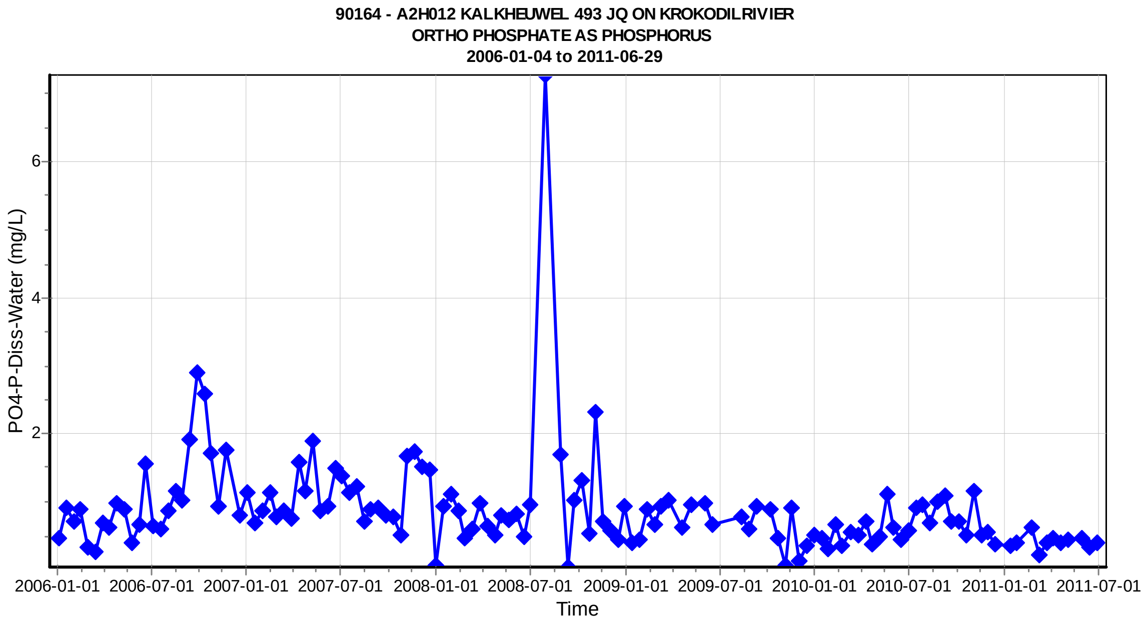

90204 - A2H060Q01 CROCODILE RIVER AT NOOITGEDACHT
NITRATE + NITRITE NITROGEN
2006-01-10 to 2011-08-30
NO3+NO2-N-Diss-Water (mg/L)
1
2
3
2006-01-01
2007-01-01
2008-01-01
2009-01-01
2010-01-01
2011-01-01
Time

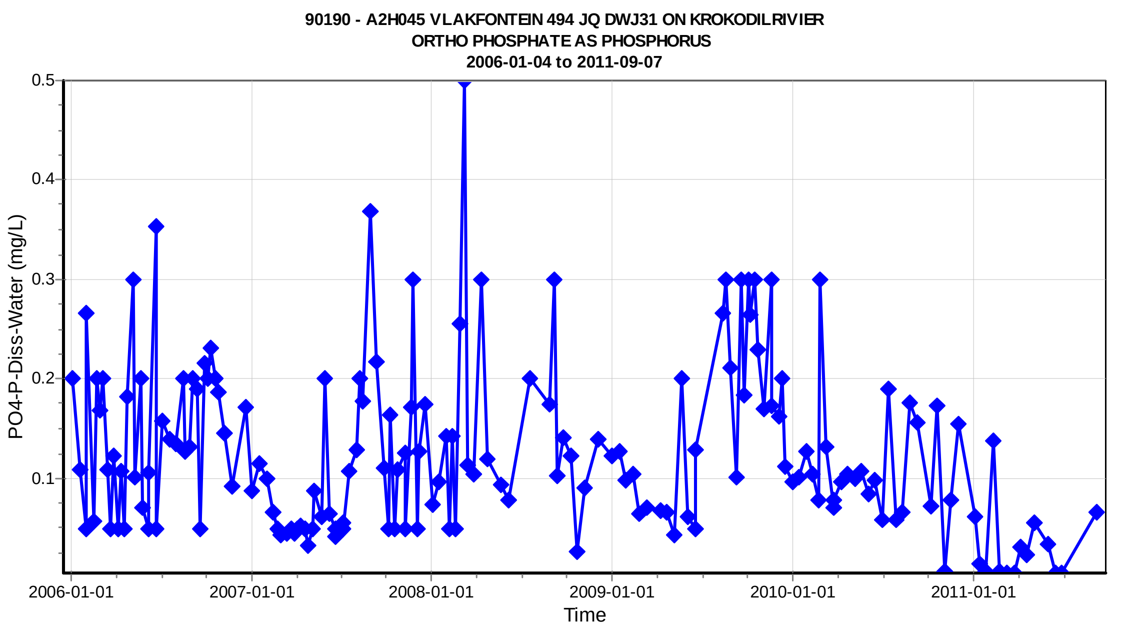

90233 - A2H132 HAAKDOORNDRIFT 373 KQ @ PAUL HUGO DAM ON KROKODILRIVIER
NITRATE + NITRITE NITROGEN
2006-01-10 to 2011-06-07
NO3+NO2-N-Diss-Water (mg/L)
1
2
3
4
2006-06-01
2006-12-01
2007-06-01
2007-12-01
2008-06-01
2008-12-01
2009-06-01
2009-12-01
2010-06-01
2010-12-01
2011-06-01
Time

ORTHO PHOSPHATE

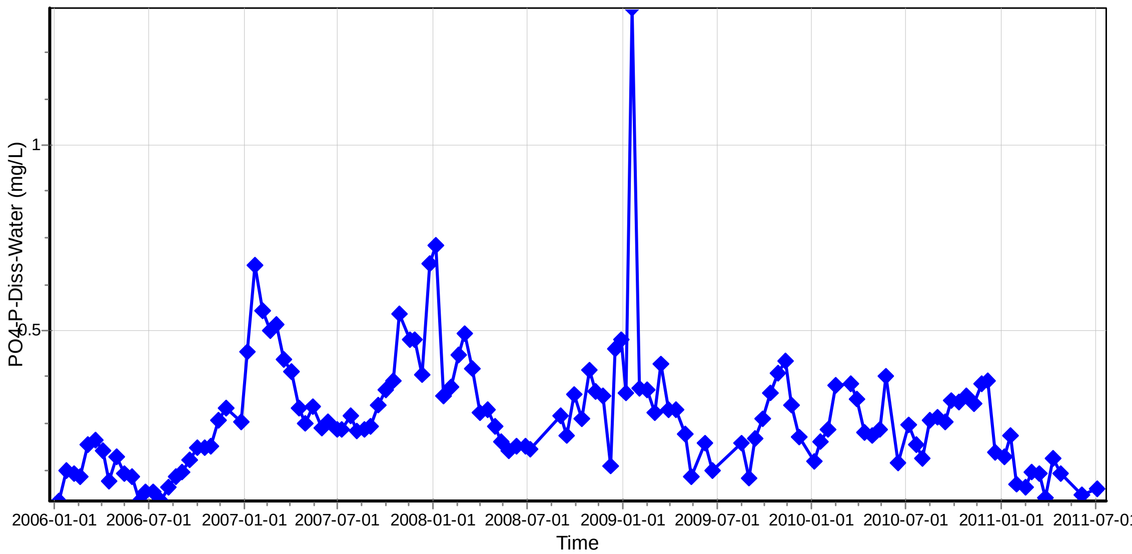




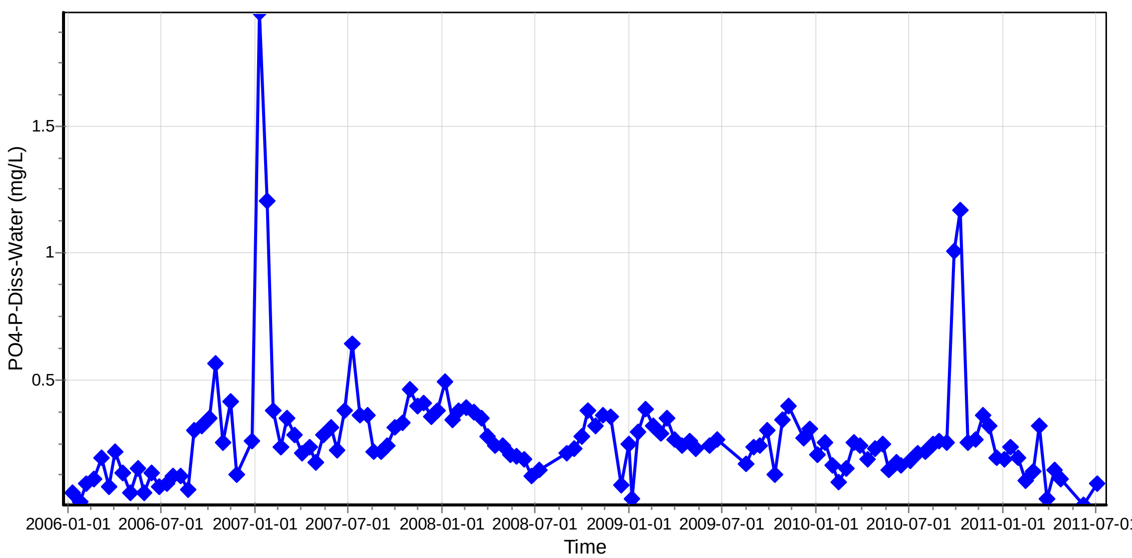

90164 - A2H012 KALKHEUWEL 493 JQ ON KROKODILRIVIER
ORTHO PHOSPHATE AS PHOSPHORUS
2006-01-04 to 2011-06-29
PO4-P-Diss-Water (mg/L)
2
4
6
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
2011-07-01
Time

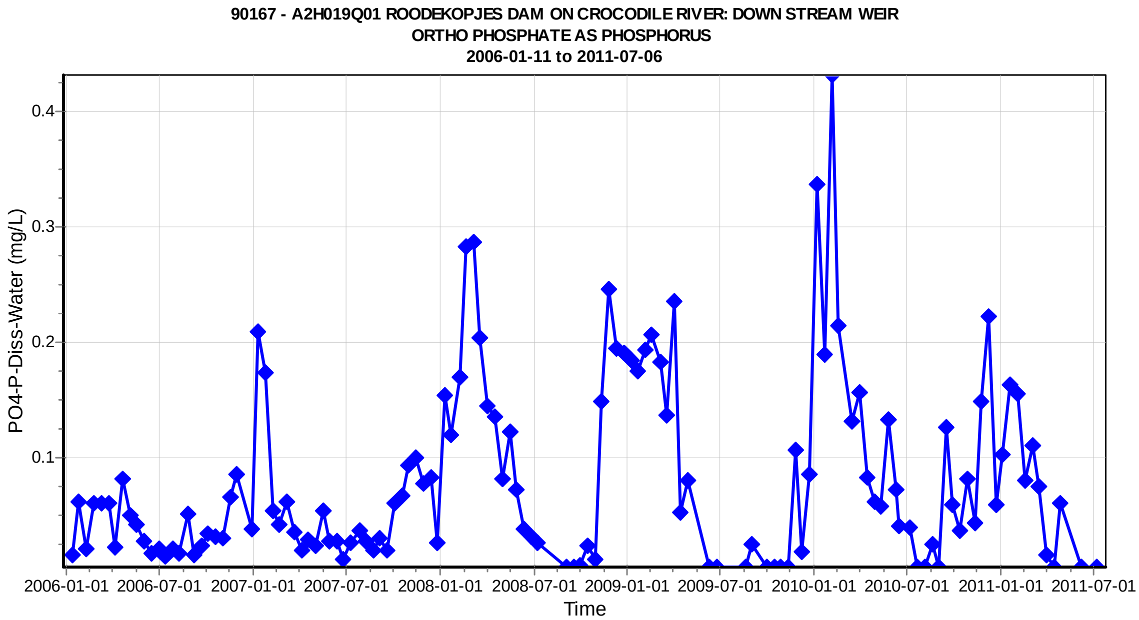

90190 - A2H045 VLAKFONTEIN 494 JQ DWJ31 ON KROKODILRIVIER
ORTHO PHOSPHATE AS PHOSPHORUS
2006-01-04 to 2011-09-07
PO4-P-Diss-Water (mg/L)
0.1
0.2
0.3
0.4
0.5
2006-01-01
2007-01-01
2008-01-01
2009-01-01
2010-01-01
2011-01-01
Time

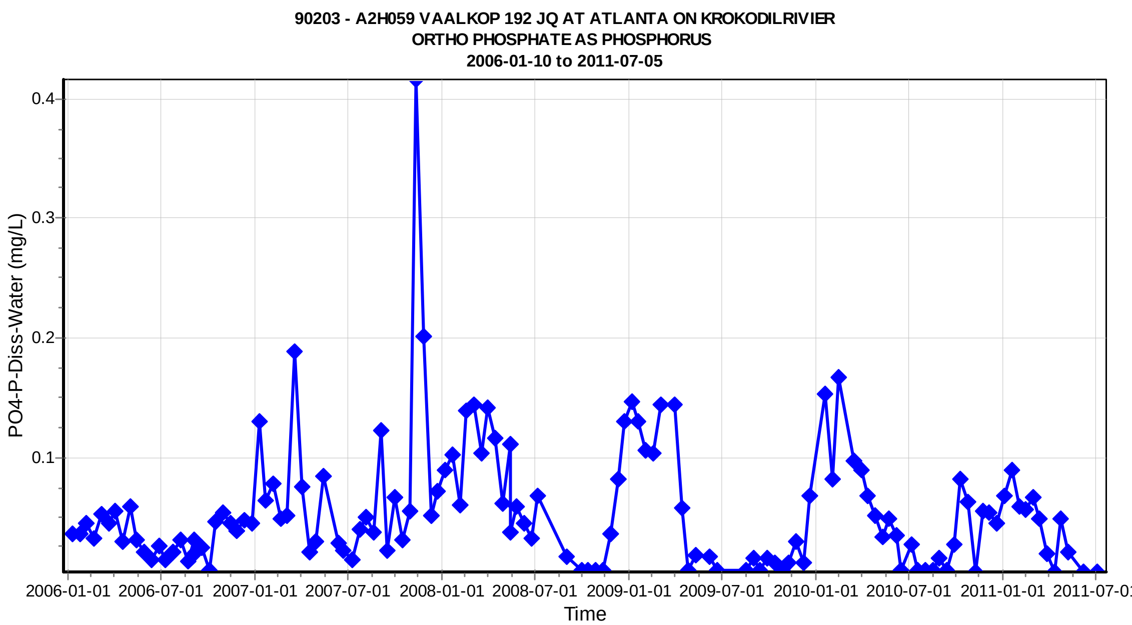
90214 - A2H083Q01 HARTBEESPOORT DAM ON CROCODILE RIV: DOWN STREAM WEIR
ORTHO PHOSPHATE AS PHOSPHORUS
2006-01-09 to 2011-07-04



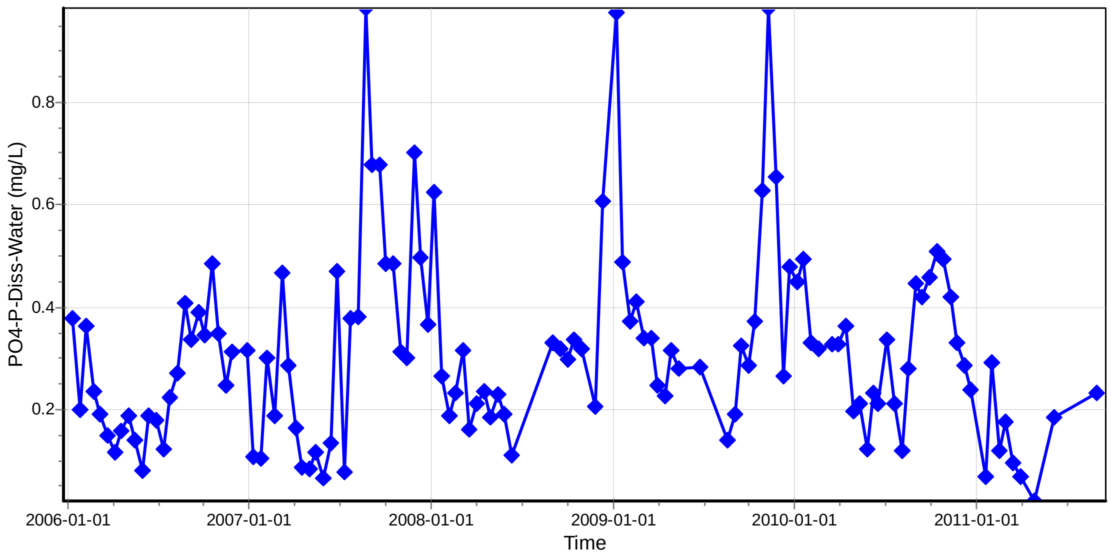
90192 - A2H048 KROKODILPOORT 418 JO /THABA MOYA ON KROKODILRIVIER
ORTHO PHOSPHATE AS PHOSPHORUS
2006-01-09 to 2011-07-04



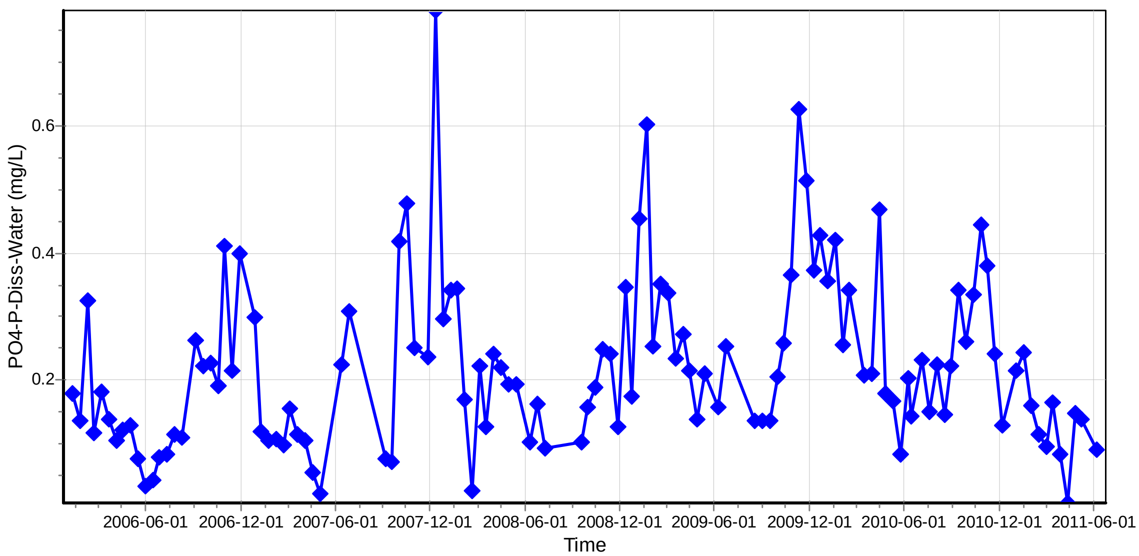

90167 - A2H019Q01 ROODEKOPJES DAM ON CROCODILE RIVER: DOWN STREAM WEIR
ORTHO PHOSPHATE AS PHOSPHORUS
2006-01-11 to 2011-07-06
PO4-P-Diss-Water (mg/L)
0.1
0.2
0.3
0.4
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
2011-07-01
Time


90203 - A2H059 VAALKOP 192 JQ AT ATLANTA ON KROKODILRIVIER
ORTHO PHOSPHATE AS PHOSPHORUS
2006-01-10 to 2011-07-05
PO4-P-Diss-Water (mg/L)
0.1
0.2
0.3
0.4
2006-01-01
2006-07-01
2007-01-01
2007-07-01
2008-01-01
2008-07-01
2009-01-01
2009-07-01
2010-01-01
2010-07-01
2011-01-01
2011-07-01
Time

90204 - A2H060Q01 CROCODILE RIVER AT NOOITGEDACHT
ORTHO PHOSPHATE AS PHOSPHORUS
2006-01-10 to 2011-08-30



90233 - A2H132 HAAKDOORNDRIFT 373 KQ @ PAUL HUGO DAM ON KROKODILRIVIER
ORTHO PHOSPHATE AS PHOSPHORUS
2006-01-10 to 2011-06-07



APPENDIX C:

WATER QUALITY ASSESSMENT RESULTS FOR FITNESS FOR USE CATEGORISATION METHODOLOGY

Monitoring point ID	Stats of	N	P5	P75	P95	Mean	Water Quality Assessment Category & colour coding
90167	Ca-Diss-Water	128	30.0007	40.25325	47.28225	37.06495	A
90167	Cl-Diss-Water	130	56.8003	75.0255	88.0443	69.73655	I
90167	DMS-Tot-Water (Total Dissolved Solids: TDS)	85	357.7452	461.368	517.4922	434.4657	A
90167	F-Diss-Water	89	0.2558	0.359	0.4354	0.338652	I
90167	K-Diss-Water	129	6.146	8.494	9.2462	7.533512	I
90167	Mg-Diss-Water	128	17.71545	25.449	29.962	23.54308	I
90167	Na-Diss-Water	126	42.47525	58.3355	68.97925	53.98937	I
90167	NH_3(25)-Union-Diss-W	128	0.001	0.0335	0.06965	0.026	A
90167	NO_3+NO_2-N-Diss-Water	117	0.04	1.247	2.4358	0.835821	I
90167	pH (Upper)		7.71335	8.25475	8.423	8.120149	U
90167	pH (Lower)	134	7.71335	8.25475	8.423	8.120149	I
90167	PO_4-P-Diss-Water	130	0.005	0.12125	0.2194	0.079746	U
90167	SO_4-Diss-Water	130	51.94985	70.12125	79.18975	64.01141	I

Monitoring point ID	Stats of	N	P5	P75	P95	Mean	Water Quality Assessment Category & colour coding
90190	Ca-Diss-Water	129	31.4024	45.793	57.9374	42.93971	A
90190	Cl-Diss-Water	166	27.988	45.0215	50.225	39.94717	I
90190	DMS-Tot-Water (Total Dissolved Solids: TDS)	82	296.1694	428.688	481.1689	390.4885	A
90190	F-Diss-Water	89	0.1066	0.201	0.2842	0.188281	I
90190	K-Diss-Water	127	3.7	4.9595	5.8081	4.603409	I
90190	Mg-Diss-Water	127	16.4796	24.198	31.7224	22.24856	I
90190	Na-Diss-Water	125	19.7	36.6	40.232	31.73961	I
90190	NH_3(25)-Union-Diss-W	170	0.00045	0.008	0.033	0.008094	I
90190	NO_3+NO_2-N-Diss-Water	155	1.2	3.163	3.8626	2.580897	I
90190	pH (Upper)		7.3	8.204	8.3932	7.999247	A
90190	pH(Lower)	178	7.3	8.204	8.3932	7.999247	I
90190	PO_4-P-Diss-Water	172	0.0251	0.17425	0.3	0.12543	U
90190	SO_4-Diss-Water	165	44.7062	66.972	138.7896	67.34855	I

Monitoring point ID	Stats of	N	P5	P75	P95	Mean	Water Quality Assessment Category & colour coding
90192	Ca-Diss-Water	130	33.7875	53.49725	62.8578	47.31448	A
90192	Cl-Diss-Water	132	50.51205	83.06325	112.1262	74.92369	A
90192	DMS-Tot-Water (Total Dissolved Solids: TDS)	87	354.0645	618.3925	727.6581	518.5068	A
90192	F-Diss-Water	91	0.239	0.3265	0.406	0.309044	I
90192	K-Diss-Water	130	5.76025	7.78225	9.3264	7.285108	I
90192	Mg-Diss-Water	129	15.07	33.058	43.3636	26.46125	I
90192	Na-Diss-Water	124	39.22065	62.319	80.7249	56.6848	A
90192	NH_3(25)-Union-Diss-W	128	0.001	0.0675	0.2766	0.064977	U
90192	NO_3+NO_2-N-Diss-Water	110	0.51575	2.9825	4.20175	2.396091	I
90192	pH (Upper)		7.6572	8.26975	8.46725	8.114649	U
90192	pH(Lower)	134	7.6572	8.26975	8.46725	8.114649	I
90192	PO_4-P-Diss-Water	132	0.06015	0.32225	0.47395	0.273121	U
90192	SO_4-Diss-Water	130	49.14965	84.58275	112.4424	72.43195	I

Monitoring point ID	Stats of	N	P5	P75	P95	Mean	Water Quality Assessment Category & colour coding
90194	Ca-Diss-Water	130	21.4734	29.405	35.2485	27.28409	A
90194	Cl-Diss-Water	132	22.82405	44.349	56.95205	38.93398	I
90194	DMS-Tot-Water (Total Dissolved Solids: TDS)	87	204.4215	311.9155	362.2213	281.1271	A
90194	F-Diss-Water	94	0.1027	0.235	0.35815	0.219936	I
90194	K-Diss-Water	131	3.908	7.5675	9.3035	6.512046	I
90194	Mg-Diss-Water	131	8.1155	12.4145	16.2225	11.35973	I
90194	Na-Diss-Water	125	16.944	41.6	49.6114	33.34314	I
90194	NH_3(25)-Union-Diss-W	129	0	0.006	0.02	0.006054	I
90194	NO_3+NO_2-N-Diss-Water	102	0.9213	3.51925	4.5627	2.714039	I
90194	pH (Upper)		7.4291	8.0265	8.2238	7.868652	A
90194	pH(Lower)	132	7.4291	8.0265	8.2238	7.868652	I
90194	PO_4-P-Diss-Water	132	0.006	0.1755	0.41145	0.150159	U
90194	SO_4-Diss-Water	132	21.42255	32.84225	41.4495	29.69727	I

Monitoring point ID	Stats of	N	P5	P75	P95	Mean	Water Quality Assessment Category & colour coding
90195	Ca-Diss-Water	87	17.7569	23.5655	25.5038	21.84594	A
90195	Cl-Diss-Water	87	13.2228	21.8605	28.6405	19.59738	I
90195	DMS-Tot-Water (Total Dissolved Solids: TDS)	65	154.6988	204.33	221.3348	188.6972	I
90195	F-Diss-Water	68	0.08425	0.1855	0.30745	0.172559	I
90195	K-Diss-Water	87	1.7518	3.085	3.9612	2.71254	I
90195	Mg-Diss-Water	86	8.29875	14.1	16.4495	12.51469	I
90195	Na-Diss-Water	84	7.642	11.6465	13.85695	10.3951	I
90195	NH_3(25)-Union-Diss-W	85	0.001	0.006	0.0144	0.005588	I
90195	NO_3+NO_2-N-Diss-Water	80	0.3867	1.05875	1.613	0.863413	I
90195	pH (Upper)		7.48785	8.00425	8.3251	7.889255	A
90195	pH (Lower)	94	7.48785	8.00425	8.3251	7.889255	I
90195	PO_4-P-Diss-Water	87	0.0053	0.034	0.0689	0.027747	T
90195	SO_4-Diss-Water	87	11.5872	18.1115	24.7065	16.52353	I

Monitoring point ID	Stats of	N	P5	P75	P95	Mean	Water Quality Assessment Category & colour coding
90203	Ca-Diss-Water	131	32.178	45.89	55.109	42.40366	A
90203	Cl-Diss-Water	129	62.6766	96.477	116.8916	88.17826	A
90203	DMS-Tot-Water (Total Dissolved Solids: TDS)	83	375.1213	526.661	683.4267	507.0533	A
90203	F-Diss-Water	92	0.28455	0.41825	0.4797	0.374446	I
90203	K-Diss-Water	132	5.89775	7.95125	8.7206	7.528227	I
90203	Mg-Diss-Water	130	18.1817	27.878	36.83185	26.28695	I
90203	Na-Diss-Water	128	46.615	67.46225	90.43495	64.12189	A
90203	NH_3(25)-Union-Diss-W	128	0.001	0.008	0.01765	0.007016	I
90203	NO_3+NO_2-N-Diss-Water	119	0.282	1.157	2.0529	0.925739	I
90203	pH (Upper)		7.6733	8.246	8.3921	8.109015	A
90203	pH (Lower)	135	7.6733	8.246	8.3921	8.109015	I
90203	PO_4-P-Diss-Water	132	0.006	0.069	0.145	0.055848	U
90203	SO_4-Diss-Water	131	55.8685	81.164	101.5315	75.77511	I

Monitoring point ID	Stats of	N	P5	P75	P95	Mean	Water Quality Assessment Category & colour coding
90204	Ca-Diss-Water	127	28.7219	43.8605	49.377	39.71983	A
90204	Cl-Diss-Water	124	44.5771	77.81125	103.1031	72.42995	A
90204	DMS-Tot-Water (Total Dissolved Solids: TDS)	84	319.0108	517.165	638.8132	471.6695	A
90204	F-Diss-Water	90	0.333	0.46475	0.559	0.421411	I
90204	K-Diss-Water	129	6.1216	8.745	10.9652	8.07576	I
90204	Mg-Diss-Water	125	15.52	25.917	35.0392	23.78766	I
90204	Na-Diss-Water	120	38.27125	64.35125	89.9092	59.48181	A
90204	NH_3(25)-Union-Diss-W	124	0.00015	0.008	0.017	0.006371	I
90204	NO_3+NO_2-N-Diss-Water	118	0.04	0.87725	1.50605	0.627288	I
90204	pH (Upper)		7.55225	8.314	8.4953	8.160182	U
90204	pH (Lower)	132	7.55225	8.314	8.4953	8.160182	I
90204	PO_4-P-Diss-Water	125	0.0838	0.377	0.6494	0.308424	U
90204	SO_4-Diss-Water	126	40.33275	68.053	84.39475	61.47602	I

Monitoring point ID	Stats of	N	P5	P75	P95	Mean	Water Quality Assessment Category & colour coding
90214	Ca-Diss-Water	128	29.8869	40.2675	43.06805	37.51413	A
90214	Cl-Diss-Water	132	43.0643	61.49925	68.5467	55.69974	I
90214	DMS-Tot-Water (Total Dissolved Solids: TDS)	87	315.5645	402.1045	441.6529	375.6459	A
90214	F-Diss-Water	91	0.2305	0.3035	0.3745	0.291066	I
90214	K-Diss-Water	129	6.329	8.625	9.6526	7.927891	I
90214	Mg-Diss-Water	128	12.64095	16.2065	18.98635	15.33122	I
90214	Na-Diss-Water	121	36.348	49.223	54.996	44.95341	I
90214	NH_3(25)-Union-Diss-W	130	0.001	0.058	0.0941	0.036446	T
90214	NO_3+NO_2-N-Diss-Water	109	0.5572	1.958	3.08	1.598239	I
90214	pH (Upper)		7.6069	8.4285	8.8712	8.21383	U
90214	pH (Lower)	135	7.6069	8.4285	8.8712	8.21383	I
90214	PO_4-P-Diss-Water	131	0.074	0.338	0.508	0.270412	U
90214	SO_4-Diss-Water	132	39.62625	50.62875	53.7241	47.03154	I

Monitoring point ID	Stats of	N	P5	P75	P95	Mean	Water Quality Assessment Category & colour coding
90233	Ca-Diss-Water	119	29.4441	50.85	56.6104	44.40485	A
90233	Cl-Diss-Water	121	49.639	105.091	124.414	87.30747	A
90233	DMS-Tot-Water (Total Dissolved Solids: TDS)	71	328.445	590.8865	672.5415	514.607	A
90233	F-Diss-Water	79	0.34	0.493	0.5932	0.457797	I
90233	K-Diss-Water	119	6.2228	8.722	10.5155	8.095286	I
90233	Mg-Diss-Water	117	15.5478	30.035	37.8286	26.6186	I
90233	Na-Diss-Water	114	39.06315	75.649	87.1942	65.1483	A
90233	NH_3(25)-Union-Diss-W	121	0.001	0.008	0.022	0.05038	A
90233	NO_3+NO_2-N-Diss-Water	99	0.04	1.1135	1.7181	0.736485	I
90233	pH (Upper)		7.6315	8.36875	8.73275	8.189151	U
90233	pH (Lower)	126	7.6315	8.36875	8.73275	8.189151	I
90233	PO_4-P-Diss-Water	121	0.07	0.261	0.455	0.217934	U
90233	SO_4-Diss-Water	119	45.3874	81.4185	104.018	69.71784	I

APPENDIX D:

WATER QUALITY ASSESSMENT RESULTS FOR COMPLIANCE EVALUATION METHODOLOGY.

	Reference status (2000 to 2004)			Present status (2006 to 2011)						
Stats of	**P5**	**P50**	**P95**	**P5**	**P50**	**P95**	**RWQOs Model 4.2.0.3**	**Affected User**	**Recom-mended RWQOs**	***Reason***
90167: A2H019Q01 ROODEKOPJES DAM ON CROCODILE RIVER: DOWN STREAM WE										
Ca-Diss-Water	27.696	34.224	46.083	30.0007	36.341	47.28225	80	**Dom**	**80**	
Cl-Diss-Water	45.4425	65.413	97.116	56.8003	68.5025	88.0443	137.5	**Dom AIr In3**	**100**	***ideal for domestic and agriculture***
DMS-Tot-Water	364.2295	441.479	574.502	357.7452	428.263	517.4922	800	**AIr**	**800**	
F-Diss-Water	0.2725	0.345	0.4835	0.2558	0.324	0.4354	1	**Dom**	**0.7**	
K-Diss-Water	5.568	7.732	9.563	6.146	7.472	9.2462	50	**Dom**	**25**	***Ideal for Domestic use***
Mg-Diss-Water	19.0485	25.686	34.317	17.71545	23.214	29.962	100	**Dom**	**70**	***Ideal for domestic use***
Na-Diss-Water	34.536	51.232	79.4185	42.47525	53.1045	68.97925	92.5	**AIr**	**70**	***Ideal for Agriculture Irrigation***
NH_3(25)-Union-Diss-W	0.001	0.016	0.045	0.001	0.018	0.06965	0.044	**EWQG**	**0.044**	
NO_3+NO_2-N-Diss-Water	0.055	0.202	1.5445	0.04	0.675	2.4358	10	**Dom**	**10**	
pH (Upper)	7.7675	8.259	8.5035	7.71335	8.163	8.423	8.4	**BHN In3**	**8.4**	
pH (Lower)	7.7675	8.259	8.5035	7.71335	8.163	8.423	6.5	**BHN AIr In3**	**6.5**	
PO_4-P-Diss-Water	0.012	0.026	0.065	0.005	0.056	0.2194	0.015	**EWQG**	**0.125**	
SO_4-Diss-Water	55.627	72.14	100.7215	51.94985	63.2145	79.18975	250	**Dom In3**	**200**	
90190: A2H045 VLAKFONTEIN 494 JQ DWJ31 ON KROKODILRIVIER										
Ca-Diss-Water	29.88405	43.5985	49.55665	31.4024	41.953	57.9374	80	**Dom**	**80**	
Cl-Diss-Water	22.79595	35.708	48.5796	27.988	40.881	50.225	137.5	**Dom AIr In3**	**100**	***ideal for domestic and agriculture***
DMS-Tot-Water	277.2498	393.8375	439.17275	296.1694	392.1985	481.1689	800	**AIr**	**500**	***acceptable for Industrial use Cat 3***

F-Diss-Water	0.1	0.169	0.223	0.1066	0.183	0.2842	1	**Dom**	**0.7**	
K-Diss-Water	2.72025	3.6065	5.31225	3.7	4.578	5.8081	50	**Dom**	**25**	***Ideal for Domestic use***
Mg-Diss-Water	16.6687	24.623	28.5373	16.4796	22.15	31.7224	100	**Dom**	**70**	***Ideal for domestic use***
Na-Diss-Water	17.6299	26.646	36.67005	19.7	32.895	40.232	92.5	**AIr**	**70**	***Ideal for Agriculture Irrigation***
NH_3(25)-Union-Diss-W	0.001	0.004	0.0111	0.00045	0.004	0.033	0.044	**EWQG**	**0.044**	
NO_3+NO_2-N-Diss-Water	1.4639	3.318	4.5132	1.2	2.688	3.8626	10	**Dom**	**6**	
pH (Upper)	7.9325	8.197	8.4286	7.3	8.1	8.3932	8.4	**BHN In3**	**8.4**	
pH (Lower)	7.9325	8.197	8.4286	7.3	8.1	8.3932	6.5	**BHN AIr In3**	**6.5**	
PO_4-P-Diss-Water	0.0459	0.122	0.1994	0.0251	0.1065	0.3	0.015	**EWQG**	**0.125**	
SO_4-Diss-Water	38.7659	58.471	74.44	44.7062	59.586	138.7896	250	**Dom In3**	**200**	
90192: A2H048 KROKODILPOORT 418 JO /THABA MOYA ON KROKODILRIVIER										
Ca-Diss-Water	28.03185	52.7445	68.36695	33.7875	45.982	62.8578	80	**Dom**	**80**	
Cl-Diss-Water	41.5657	84.722	117.8036	50.51205	69.7915	112.1262	137.5	**Dom AIr In3**	**100**	***ideal for domestic and agriculture***
DMS-Tot-Water	340.2378	613.171	763.7108	354.0645	510.464	727.6581	800	**AIr**	**500**	***acceptable for Industrial use Cat 3***
F-Diss-Water	0.247	0.286	0.354	0.239	0.292	0.406	1	**Dom**	**0.7**	
K-Diss-Water	4.67555	6.069	8.2142	5.76025	7.2025	9.3264	50	**Dom**	**25**	***Ideal for Domestic use***
Mg-Diss-Water	18.6241	38.6605	51.76595	15.07	24.083	43.3636	100	**Dom**	**70**	***Ideal for domestic use***
Na-Diss-Water	33.0973	60.5235	88.9593	39.22065	54.464	80.7249	92.5	**AIr**	**70**	***Ideal for Agriculture Irrigation***
NH_3(25)-Union-Diss-W	0.001	0.007	0.0464	0.001	0.031	0.2766	0.044	**EWQG**	**0.044**	
NO_3+NO_2-N-Diss-Water	0.0644	1.671	2.85305	0.51575	2.378	4.20175	10	**Dom**	**6**	
pH (Upper)	7.76355	8.3145	8.7042	7.6572	8.151	8.46725	8.4	**BHN In3**	**8.4**	
pH (Lower)	7.76355	8.3145	8.7042	7.6572	8.151	8.46725	6.5	**BHN AIr**	**6.5**	

								In3		
PO_4-P-Diss-Water	0.025	0.073	0.22115	0.06015	0.2395	0.47395	0.015	**EWQG**	**0.125**	
SO_4-Diss-Water	53.505	104.078	142.3512	49.14965	62.711	112.4424	250	**Dom In3**	**200**	
90194: A2H050 ZWARTKOP 250 JQ HOI-HOI AT HOI-HOI ON KROKODILRIVIER										
Ca-Diss-Water	18.0546	24.155	31.3304	21.4734	26.8075	35.2485	80	**Dom**	**80**	
Cl-Diss-Water	22.5462	38.674	67.0668	22.82405	38.5145	56.95205	137.5	**Dom AIr In3**	**100**	***ideal for domestic and agriculture***
DMS-Tot-Water	200.3134	265.456	343.3906	204.4215	286.782	362.2213	800	**AIr**	**450**	***Ideal for domestic use***
F-Diss-Water	0.159	0.197	0.2734	0.1027	0.206	0.35815	1	**Dom**	**0.7**	
K-Diss-Water	4.0178	6.561	11.3346	3.908	6.7	9.3035	50	**Dom**	**25**	***Ideal for Domestic use***
Mg-Diss-Water	6.9814	11.405	14.8644	8.1155	10.855	16.2225	100	**Dom**	**70**	***Ideal for domestic use***
Na-Diss-Water	16.7372	29.66	56.1096	16.944	32.64	49.6114	92.5	**AIr**	**70**	***Ideal for Agriculture Irrigation***
NH_3(25)-Union-Diss-W	0	0.002	0.014	0	0.003	0.02	0.044	**EWQG**	**0.044**	
NO_3+NO_2-N-Diss-Water	0.7836	2.861	5.316	0.9213	2.731	4.5627	10	**Dom**	**6**	
pH (Upper)	7.4402	7.927	8.1934	7.4291	7.8875	8.2238	8.4	**BHN In3**	**8.4**	
pH (Lower)	7.4402	7.927	8.1934	7.4291	7.8875	8.2238	6.5	**BHN AIr In3**	**6.5**	
PO_4-P-Diss-Water	0.0432	0.152	0.3946	0.006	0.089	0.41145	0.015	**EWQG**	**0.125**	
SO_4-Diss-Water	17.614	25.931	37.4244	21.42255	28.603	41.4495	250	**Dom In3**	**200**	
90195: A2H051 VAN WYKS RESTANT 182 IQ AT MULDERSDRIFT ON KROKODILRI										
Ca-Diss-Water	14.1064	19.427	22.8031	17.7569	21.825	25.5038	80	**Dom**	**80**	
Cl-Diss-Water	11.4713	15.608	20.363	13.2228	19.003	28.6405	137.5	**Dom AIr In3**	**100**	***ideal for domestic and agriculture***
DMS-Tot-Water	138.3832	180.648	213.1514	154.6988	187.619	221.3348	800	**AIr**	**260**	***Ideal for agric Irrigation***
F-Diss-Water	0.1	0.158	0.2272	0.08425	0.161	0.30745	1	**Dom**	**0.7**	

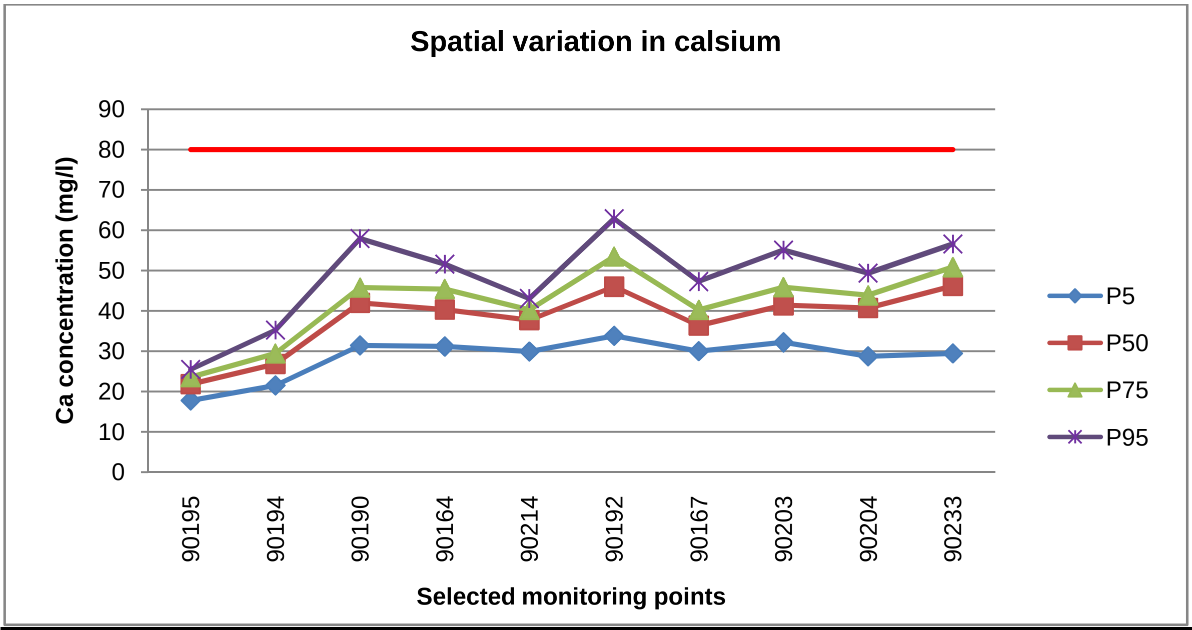
K-Diss-Water	1.5906	2.595	4.3461	1.7518	2.682	3.9612	50	**Dom**	**25**	***Ideal for Domestic use***
Mg-Diss-Water	7.5007	10.931	14.2023	8.29875	12.3325	16.4495	100	**Dom**	**70**	***Ideal for domestic use***
Na-Diss-Water	7.1225	10.586	13.9202	7.642	10.2585	13.85695	92.5	**AIr**	**70**	***Ideal for Agriculture Irrigation***
NH_3(25)-Union-Diss-W	0	0.004	0.013	0.001	0.004	0.0144	0.044	**EWQG**	**0.015**	***Category A for Ecological Water Requirements***
NO_3+NO_2-N-Diss-Water	0.055	0.717	1.3346	0.3867	0.8025	1.613	10	**Dom**	**6**	
pH (Upper)	7.5855	8.016	8.4146	7.48785	7.9225	8.3251	8.4	**BHN In3**	**8.4**	
pH (Lower)	7.5855	8.016	8.4146	7.48785	7.9225	8.3251	6.5	**BHN AIr In3**	**6.5**	
PO_4-P-Diss-Water	0.012	0.03	0.0731	0.0053	0.021	0.0689	0.015	**EWQG**	**0.125**	
SO_4-Diss-Water	8.3848	13.515	20.7322	11.5872	15.641	24.7065	250	**Dom In3**	**200**	
90203: A2H059 VAALKOP 192 JQ AT ATLANTA ON KROKODILRIVIER										
Ca-Diss-Water	28.40205	40.706	53.4641	32.178	41.377	55.109	80	**Dom**	**80**	
Cl-Diss-Water	44.03505	67.2165	143.16755	62.6766	82.733	116.8916	137.5	**Dom AIr In3**	**100**	***ideal for domestic and agriculture***
DMS-Tot-Water	332.80845	473.536	696.12985	375.1213	490.414	683.4267	800	**AIr**	**800**	
F-Diss-Water	0.309	0.377	0.5526	0.28455	0.371	0.4797	1	**Dom**	**0.7**	
K-Diss-Water	4.86685	6.3435	8.00145	5.89775	7.346	8.7206	50	**Dom**	**25**	***Ideal for Domestic use***
Mg-Diss-Water	16.78735	27.414	40.26985	18.1817	25.7865	36.83185	100	**Dom**	**70**	***Ideal for domestic use***
Na-Diss-Water	32.6776	52.175	96.84385	46.615	61.8665	90.43495	92.5	**AIr**	**70**	***Ideal for Agriculture Irrigation***
NH_3(25)-Union-Diss-W	0.001	0.004	0.014	0.001	0.005	0.01765	0.044	**EWQG**	**0.044**	
NO_3+NO_2-N-Diss-Water	0.1934	0.526	1.681	0.282	0.822	2.0529	10	**Dom**	**10**	
pH (Upper)	7.9742	8.24	8.5016	7.6733	8.134	8.3921	8.4	**BHN In3**	**8.4**	
pH (Lower)	7.9742	8.24	8.5016	7.6733	8.134	8.3921	6.5	**BHN AIr In3**	**6.5**	
PO_4-P-Diss-	0.012	0.029	0.1154	0.006	0.046	0.145	0.015	**EWQG**	**0.125**	

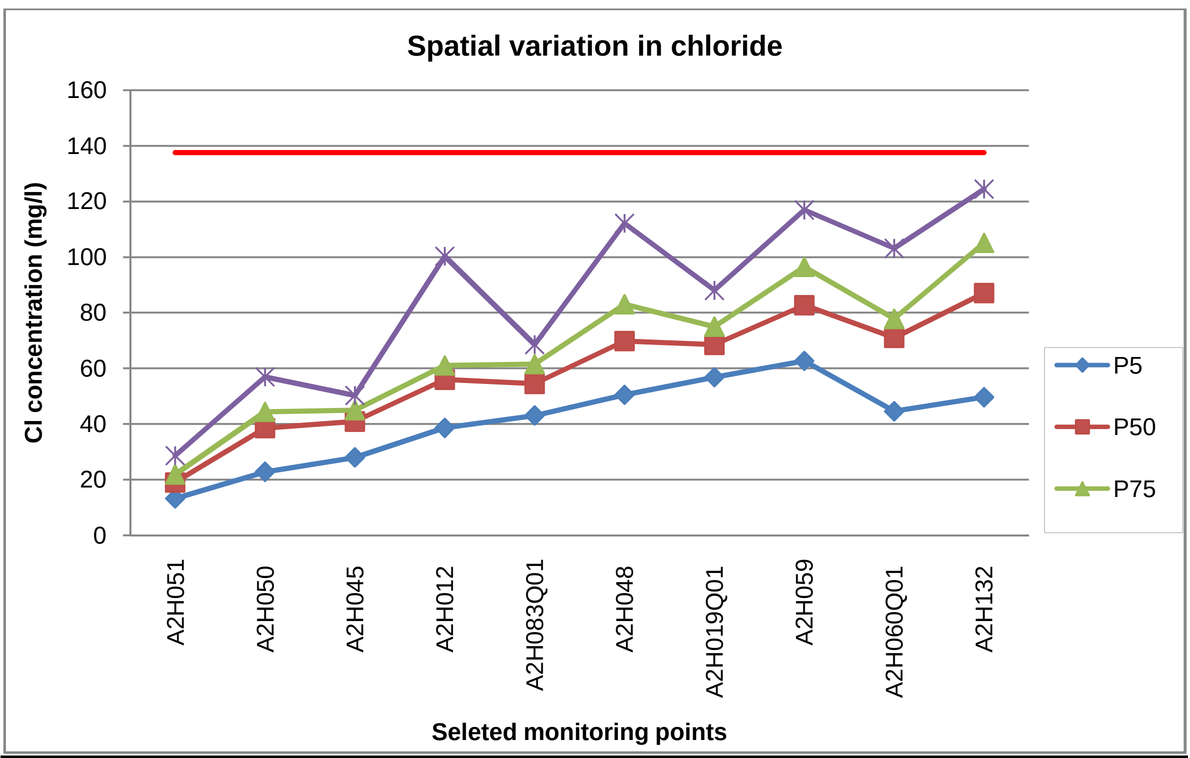
Water										
SO_4-Diss-Water	50.40075	73.8195	110.56505	55.8685	74.604	101.5315	250	**Dom In3**	**200**	
90204: A2H060Q01 CROCODILE RIVER AT NOOITGEDACHT										
Ca-Diss-Water	28.4926	40.189	48.1577	28.7219	40.715	49.377	80	**Dom**	**80**	
Cl-Diss-Water	40.3886	68.27	106.41	44.5771	70.9875	103.10305	137.5	**Dom AIr In3**	**100**	***ideal for domestic and agriculture***
DMS-Tot-Water	329.816	484.38	630.5353	319.01075	469.494	638.8132	800	**AIr**	**800**	
F-Diss-Water	0.3433	0.43	0.5837	0.333	0.42	0.559	1	**Dom**	**0.7**	
K-Diss-Water	5.3521	7.632	11.1987	6.1216	7.877	10.9652	50	**Dom**	**25**	***Ideal for Domestic use***
Mg-Diss-Water	15.1733	25.181	35.6602	15.52	23.383	35.0392	100	**Dom**	**70**	***Ideal for domestic use***
Na-Diss-Water	34.7527	56.806	91.7229	38.27125	57.2335	89.9092	92.5	**AIr**	**70**	***Ideal for Agriculture Irrigation***
NH_3(25)-Union-Diss-W	0.001	0.004	0.0147	0.00015	0.003	0.017	0.044	**EWQG**	**0.044**	
NO_3+NO_2-N-Diss-Water	0.02	0.266	1.1444	0.04	0.481	1.50605	10	**Dom**	**10**	
pH (Upper)	7.9981	8.288	8.6007	7.55225	8.1905	8.4953	8.4	**BHN In3**	**8.4**	
pH (Lower)	7.9981	8.288	8.6007	7.55225	8.1905	8.4953	6.5	**BHN AIr In3**	**6.5**	
PO_4-P-Diss-Water	0.0373	0.127	0.3358	0.0838	0.286	0.6494	0.015	**EWQG**	**0.125**	
SO_4-Diss-Water	43.1546	67.363	93.9618	40.33275	59.8895	84.39475	250	**Dom In3**	**200**	
90214: A2H083Q01 HARTBEESPOORT DAM ON CROCODILE RIV: DOWN STREAM WE										
Ca-Diss-Water	24.22015	30.132	39.5446	29.8869	37.681	43.06805	80	**Dom**	**80**	
Cl-Diss-Water	35.87945	47.089	57.29385	43.0643	54.471	68.5467	137.5	**Dom AIr In3**	**100**	***ideal for domestic and agriculture***
DMS-Tot-Water	311.52655	349.2215	380.0309	315.5645	374.293	441.6529	800	**AIr**	**800**	
F-Diss-Water	0.242	0.279	0.34035	0.2305	0.284	0.3745	1	**Dom**	**0.7**	
K-Diss-Water	5.8927	7.9855	9.7936	6.329	7.774	9.6526	50	**Dom**	**25**	***Ideal for Domestic use***

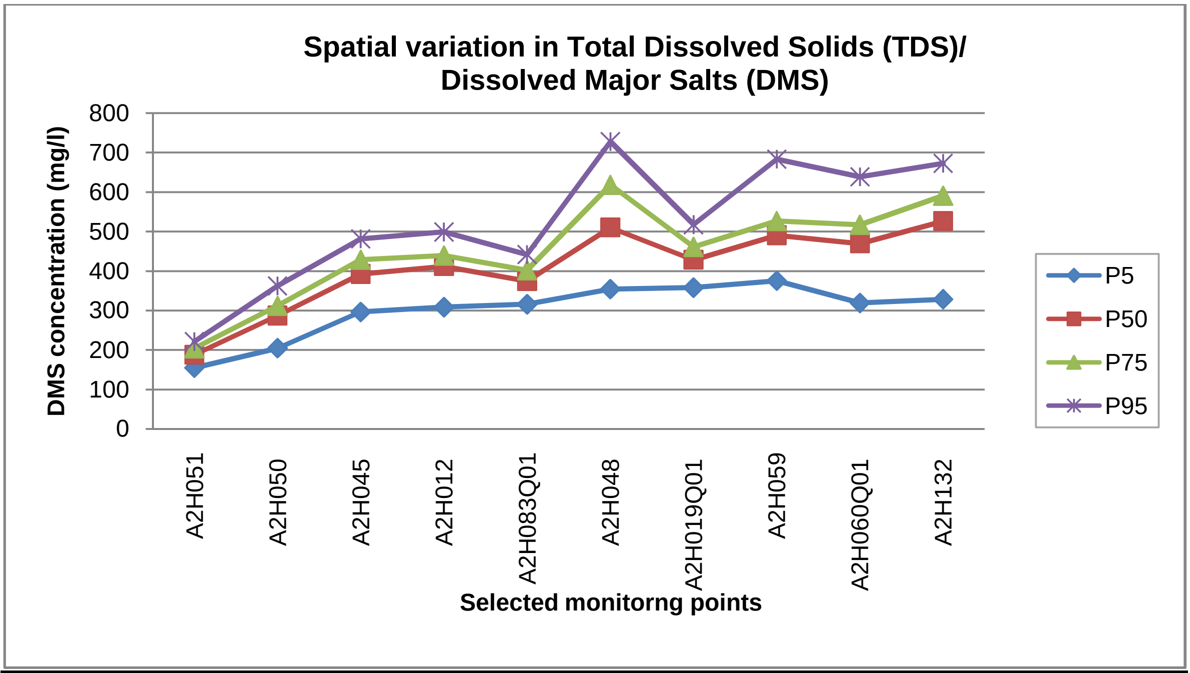
Mg-Diss-Water	13.4618	17.095	20.3588	12.64095	15.109	18.98635	100	**Dom**	**70**	***Ideal for domestic use***
Na-Diss-Water	28.90345	37.9555	49.1511	36.348	44.336	54.996	92.5	**AIr**	**70**	***Ideal for Agriculture Irrigation***
NH_3(25)-Union-Diss-W	0	0.018	0.09445	0.001	0.0255	0.0941	0.044	**EWQG**	**0.044**	
NO_3+NO_2-N-Diss-Water	0.055	1.141	2.44955	0.5572	1.543	3.08	10	**Dom**	**10**	
pH (Upper)	7.57555	8.2835	8.75645	7.6069	8.184	8.8712	8.4	**BHN In3**	**8.4**	
pH (Lower)	7.57555	8.2835	8.75645	7.6069	8.184	8.8712	6.5	**BHN AIr In3**	**6.5**	
PO_4-P-Diss-Water	0.024	0.065	0.237	0.074	0.247	0.508	0.015	**EWQG**	**0.125**	
SO_4-Diss-Water	41.53465	50.1495	57.86575	39.62625	47.374	53.7241	250	**Dom In3**	**200**	
90233: A2H132 HAAKDOORNDRIFT 373 KQ @ PAUL HUGO DAM ON KROKODILRIVI										
Ca-Diss-Water	30.3515	43.3015	54.38775	29.4441	46.154	56.6104	80	**Dom**	**80**	
Cl-Diss-Water	41.38575	76.3465	111.08925	49.639	87.063	124.414	137.5	**Dom AIr In3**	**100**	***ideal for domestic and agriculture***
DMS-Tot-Water	335.71225	514.629	636.34725	328.445	526.407	672.5415	800	**AIr**	**800**	
F-Diss-Water	0.34525	0.4435	0.61025	0.34	0.457	0.5932	1	**Dom**	**0.7**	
K-Diss-Water	5.733	7.179	10.345	6.2228	7.9	10.5155	50	**Dom**	**25**	***Ideal for Domestic use***
Mg-Diss-Water	14.90625	27.5645	34.82025	15.5478	26.82	37.8286	100	**Dom**	**70**	***Ideal for domestic use***
Na-Diss-Water	36.24825	60.7315	90.396	39.06315	66.2705	87.1942	92.5	**AIr**	**70**	***Ideal for Agriculture Irrigation***
NH_3(25)-Union-Diss-W	0.001	0.004	0.0141	0.001	0.003	0.022	0.044	**EWQG**	**0.044**	
NO_3+NO_2-N-Diss-Water	0.02	0.207	1.329	0.04	0.599	1.7181	10	**Dom**	**10**	
pH (Upper)	7.9204	8.333	8.6032	7.6315	8.2185	8.73275	8.4	**BHN In3**	**8.4**	
pH (Lower)	7.9204	8.333	8.6032	7.6315	8.2185	8.73275	6.5	**BHN AIr In3**	**6.5**	
PO_4-P-Diss-Water	0.018	0.064	0.1727	0.07	0.192	0.455	0.015	**EWQG**	**0.125**	
SO_4-Diss-Water	45.2315	70.011	94.6715	45.3874	69.554	104.018	250	**Dom In3**	**200**	

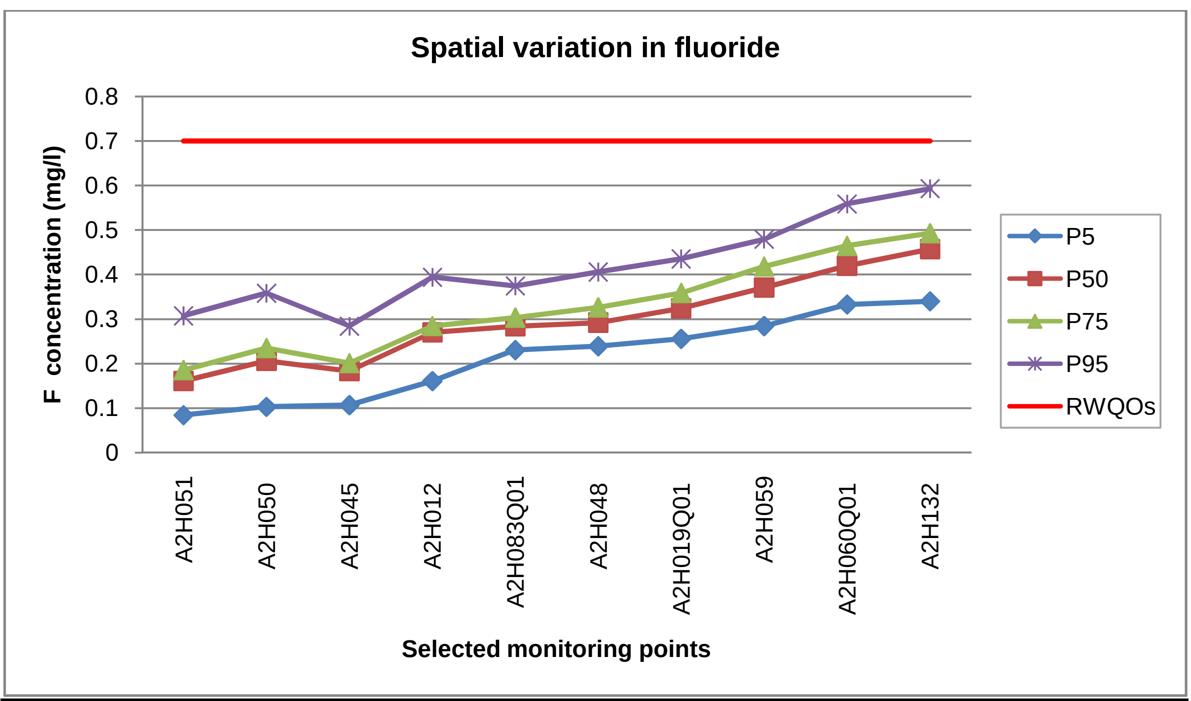
APPENDIX E:

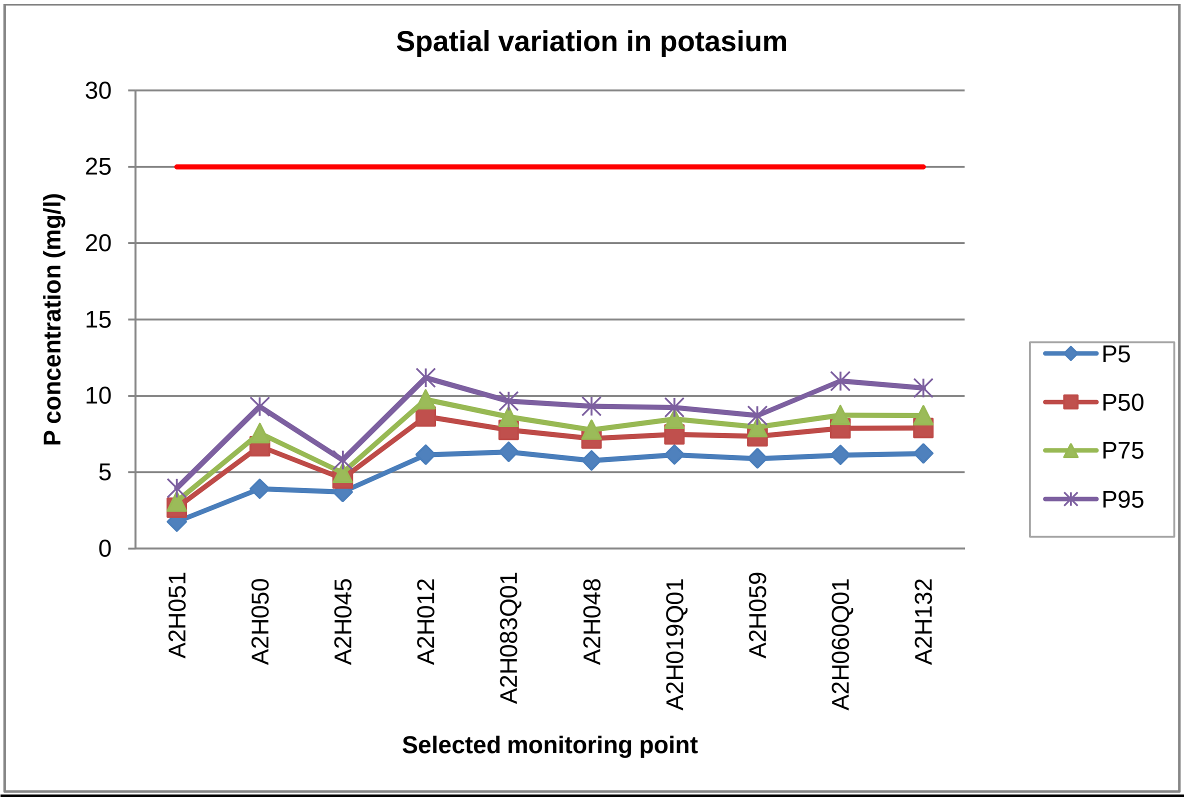
SPATIAL VARIATION OF SELECTED VARIABLES OF CONCERN

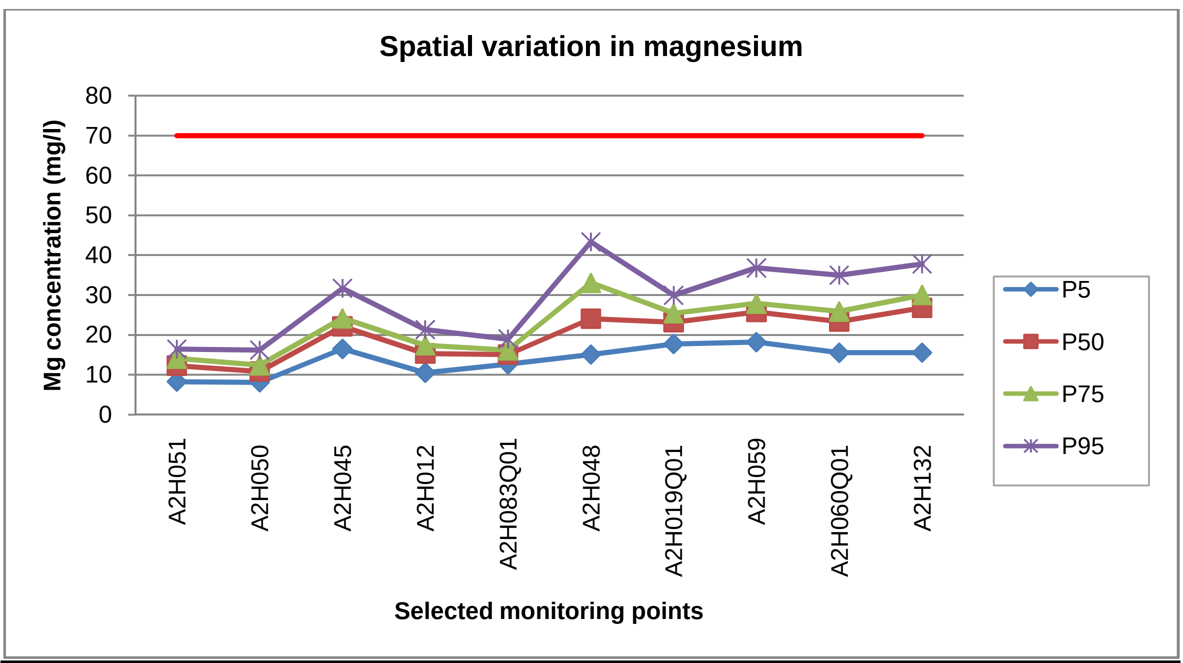

Spatial variation in calsium
Ca concentration (mg/l)
90
80
70
60
50
40
30
20
10
0
90195
90194
90190
90164
90214
90192
90167
90203
90204
90233
Selected monitoring points
P5
P50
P75
P95

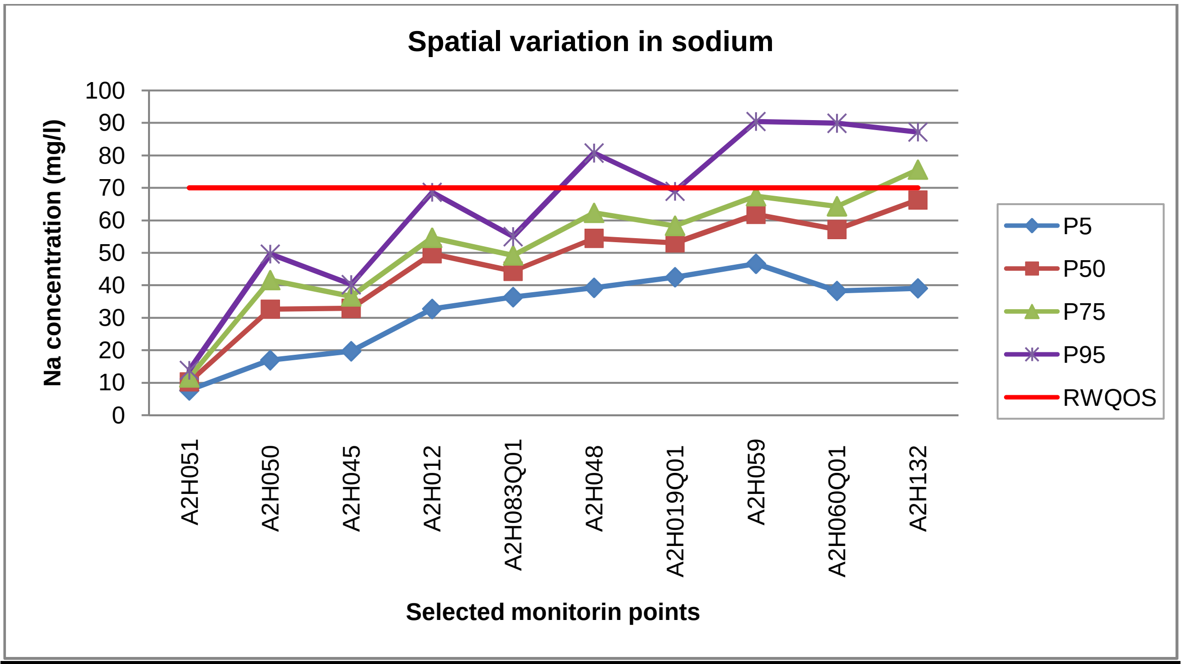

Spatial variation in chloride
Cl concentration (mg/l)
160
140
120
100
80
60
40
20
0
A2H051
A2H050
A2H045
A2H012
A2H083Q01
A2H048
A2H019Q01
A2H059
A2H060Q01
A2H132
Seleted monitoring points
P5
P50
P75

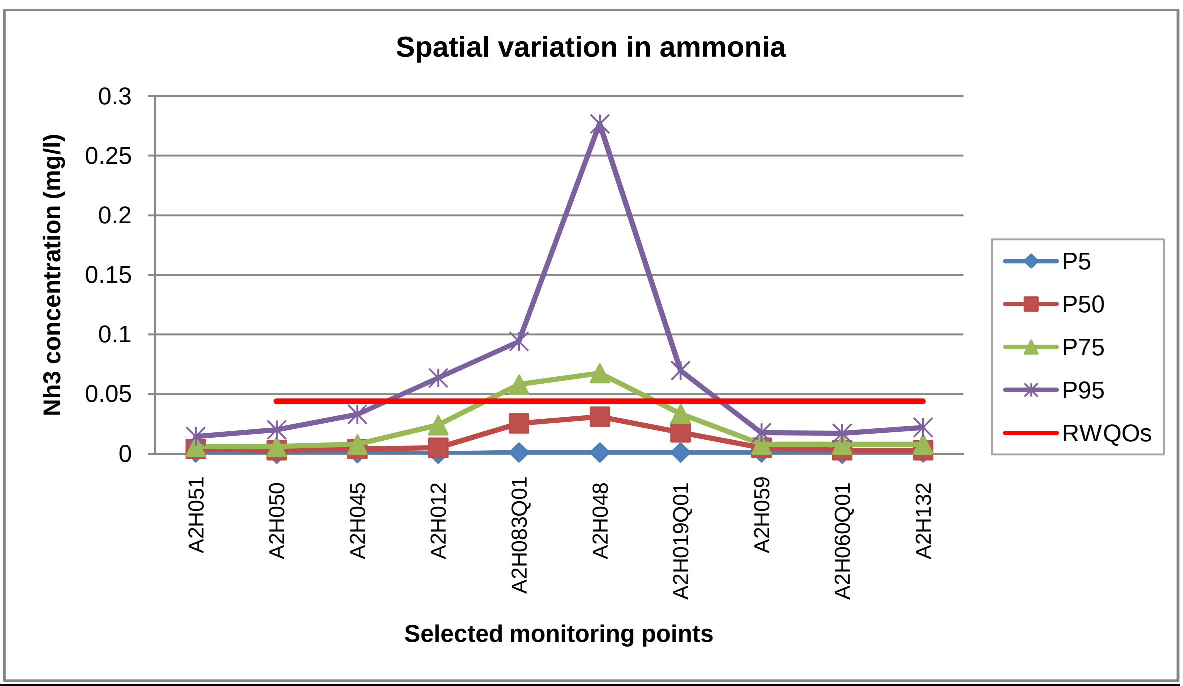

Spatial variation in Total Dissolved Solids (TDS)/ Dissolved Major Salts (DMS)
DMS concentration (mg/l)
800
700
600
500
400
300
200
100
0
A2H051
A2H050
A2H045
A2H012
A2H083Q01
A2H048
A2H019Q01
A2H059
A2H060Q01
A2H132
Selected monitorng points
P5
P50
P75
P95

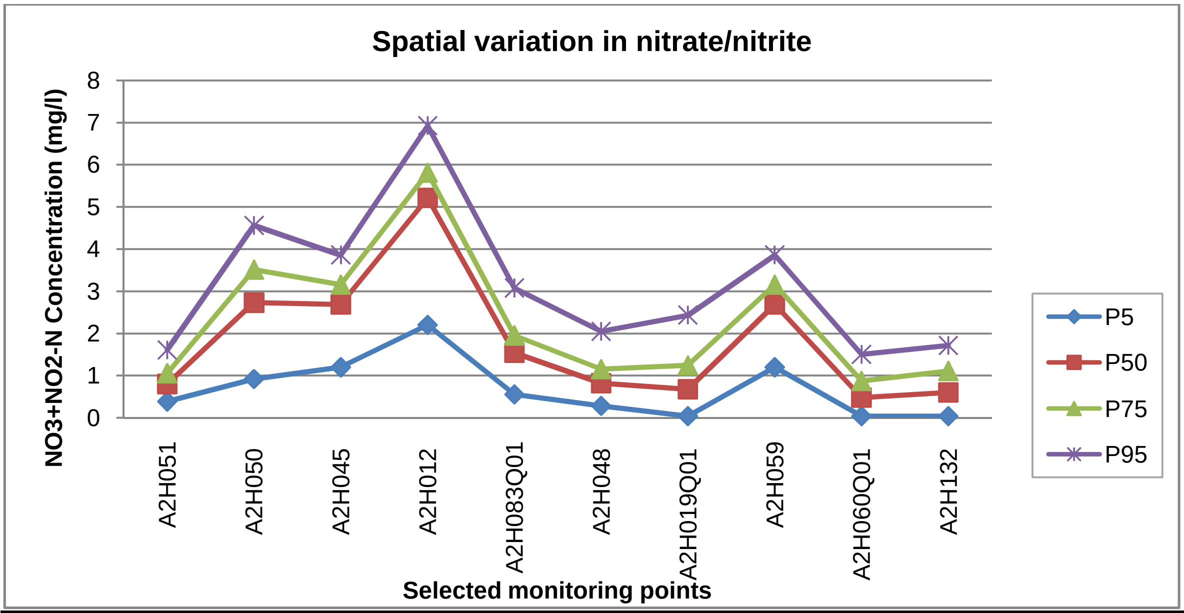

Spatial variation in fluoride
F concentration (mg/l)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
A2H051
A2H050
A2H045
A2H012
A2H083Q01
A2H048
A2H019Q01
A2H059
A2H060Q01
A2H132
Selected monitoring points
P5
P50
P75
P95
RWQOs

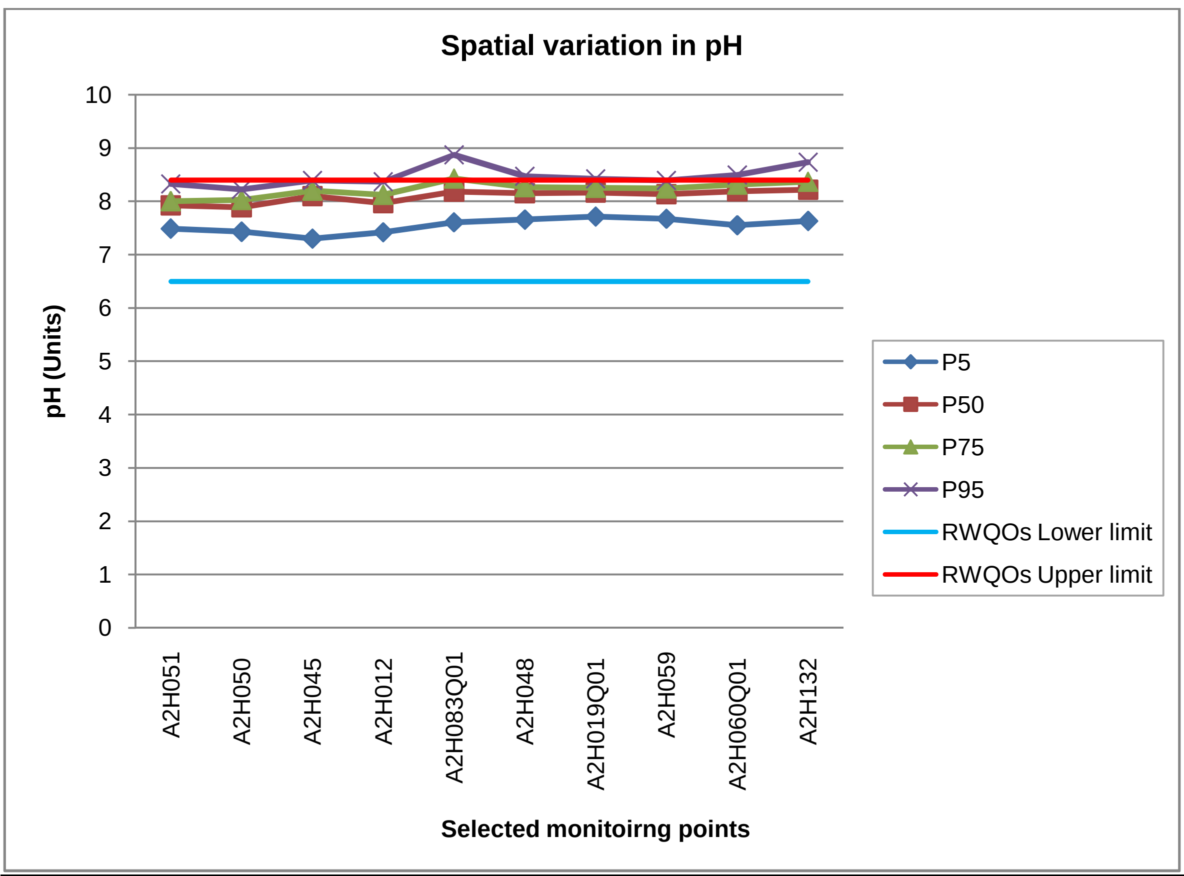

Spatial variation in potasium
P concentration (mg/l)
30
25
20
15
10
5
0
A2H051
A2H050
A2H045
A2H012
A2H083Q01
A2H048
A2H019Q01
A2H059
A2H060Q01
A2H132
Selected monitoring point
P5
P50
P75
P95

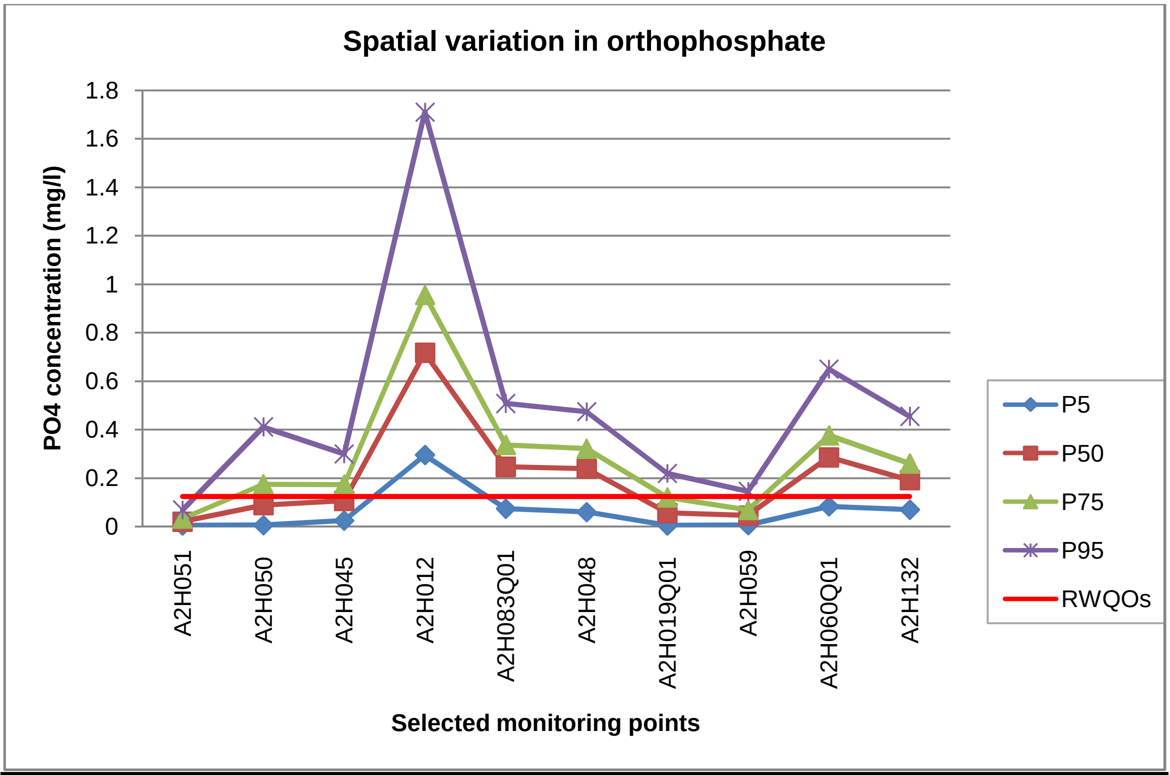

Spatial variation in magnesium
Mg concentration (mg/l)
80
70
60
50
40
30
20
10
0
A2H051
A2H050
A2H045
A2H012
A2H083Q01
A2H048
A2H019Q01
A2H059
A2H060Q01
A2H132
Selected monitoring points
P5
P50
P75
P95

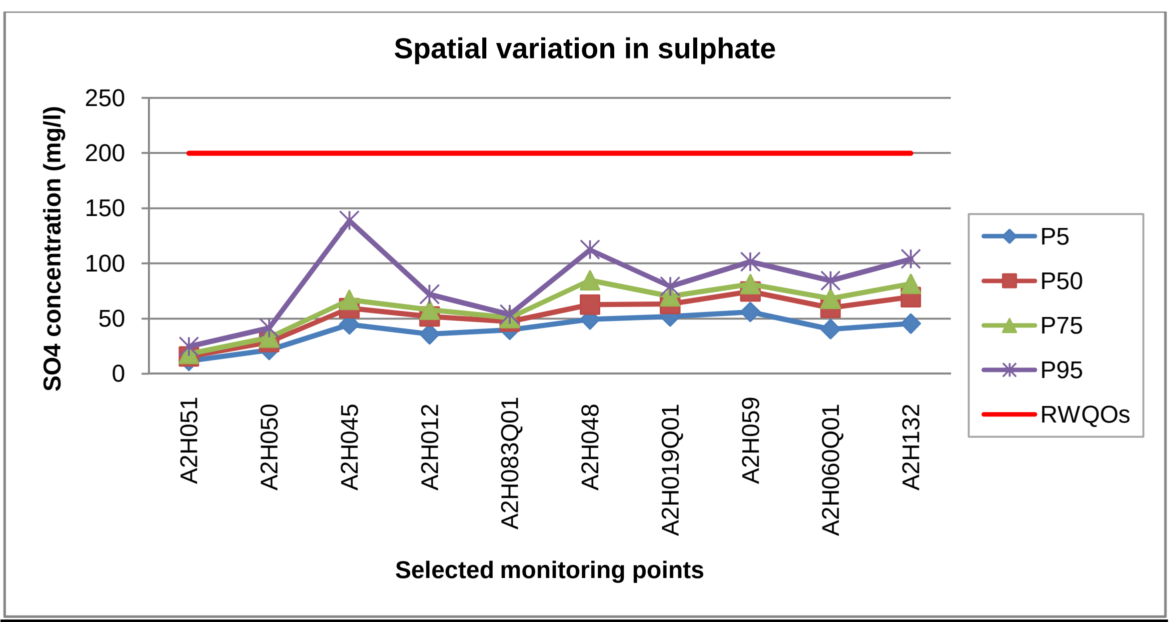

Spatial variation in sodium
Na concentration (mg/l)
100
90
80
70
60
50
40
30
20
10
0
A2H051
A2H050
A2H045
A2H012
A2H083Q01
A2H048
A2H019Q01
A2H059
A2H060Q01
A2H132
Selected monitorin points
P5
P50
P75
P95
RWQOS


Spatial variation in ammonia
Nh3 concentration (mg/l)
0.3
0.25
0.2
0.15
0.1
0.05
0
A2H051
A2H050
A2H045
A2H012
A2H083Q01
A2H048
A2H019Q01
A2H059
A2H060Q01
A2H132
Selected monitoring points
P5
P50
P75
P95
RWQOs


Spatial variation in nitrate/nitrite
NO3+NO2-N Concentration (mg/l)
0
1
2
3
4
5
6
7
8
A2H051
A2H050
A2H045
A2H012
A2H083Q01
A2H048
A2H019Q01
A2H059
A2H060Q01
A2H132
Selected monitoring points
P5
P50
P75
P95


Spatial variation in pH
pH (Units)
0
1
2
3
4
5
6
7
8
9
10
A2H051
A2H050
A2H045
A2H012
A2H083Q01
A2H048
A2H019Q01
A2H059
A2H060Q01
A2H132
Selected monitoirng points
P5
P50
P75
P95
RWQOs Lower limit
RWQOs Upper limit


Spatial variation in orthophosphate
PO4 concentration (mg/l)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
A2H051
A2H050
A2H045
A2H012
A2H083Q01
A2H048
A2H019Q01
A2H059
A2H060Q01
A2H132
Selected monitoring points
P5
P50
P75
P95
RWQOs


Spatial variation in sulphate
SO4 concentration (mg/l)
250
200
150
100
50
0
A2H051
A2H050
A2H045
A2H012
A2H083Q01
A2H048
A2H019Q01
A2H059
A2H060Q01
A2H132
Selected monitoring points
P5
P50
P75
P95
RWQOs

APPENDIX F:

COMPARISON OF WATER QUALITY ASSESSMENT RESULTS FOR FITNESS FOR USE CATEGORISATION AND COMPLIANCE EVALUATION METHODOLOGIES

Comparison of the current water quality status report as per the two approaches			
Monitoring point ID	**Stats of**	**Fitness for use Classification/ Categorization**	**Compliance Evaluation**
90167	Ca-Diss-Water	A	47.2823
90167	Cl-Diss-Water	I	88.0443
90167	DMS-Tot-Water)	T	517.492
90167	F-Diss-Water	I	0.4354
90167	K-Diss-Water	I	9.2462
90167	Mg-Diss-Water	I	29.962
90167	Na-Diss-Water	I	68.9793
90167	NH_3(25)-Union-Diss-Water	A	0.06965
90167	NO_3+NO_2-N-Diss-Water	I	2.4358
90167	pH (Upper)	U	8.423
90167	pH (Lower)	I	7.71335
90167	PO_4-P-Diss-Water	U	0.056
90167	SO_4-Diss-Water	I	79.1898
90190	Ca-Diss-Water	A	57.9374
90190	Cl-Diss-Water	I	50.225
90190	DMS-Tot-Water	T	481.169
90190	F-Diss-Water	I	0.2842
90190	K-Diss-Water	I	5.8081
90190	Mg-Diss-Water	I	31.7224
90190	Na-Diss-Water	I	40.232
90190	NH_3(25)-Union-Diss-Water	I	0.033
90190	NO_3+NO_2-N-Diss-Water	I	3.8626
90190	pH (Upper)	A	8.3932
90190	pH (Lower)	I	7.3
90190	PO_4-P-Diss-Water	U	0.1065
90190	SO_4-Diss-Water	I	138.79

90192	Ca-Diss-Water	A	62.8578
90192	Cl-Diss-Water	A	112.126
90192	DMS-Tot-Water)	T	727.658
90192	F-Diss-Water	I	0.406
90192	K-Diss-Water	I	9.3264
90192	Mg-Diss-Water	I	43.3636
90192	Na-Diss-Water	A	80.7249
90192	NH_3(25)-Union-Diss-Water	U	0.2766
90192	NO_3+NO_2-N-Diss-Water	I	4.20175
90192	pH (Upper)	U	8.46725
90192	pH (Lower)	I	7.6572
90192	PO_4-P-Diss-Water	U	0.2395
90192	SO_4-Diss-Water	I	112.442
90194	Ca-Diss-Water	A	35.2485
90194	Cl-Diss-Water	I	56.9521
90194	DMS-Tot-Water)	A	362.221
90194	F-Diss-Water	I	0.35815
90194	K-Diss-Water	I	9.3035
90194	Mg-Diss-Water	I	16.2225
90194	Na-Diss-Water	I	49.6114
90194	NH_3(25)-Union-Diss-Water	I	0.02
90194	NO_3+NO_2-N-Diss-Water	I	4.5627
90194	pH (Upper)	A	8.2238
90194	pH (Lower)	I	7.4291
90194	PO_4-P-Diss-Water	U	0.089
90194	SO_4-Diss-Water	I	41.4495
90195	Ca-Diss-Water	A	25.5038
90195	Cl-Diss-Water	I	28.6405
90195	DMS-Tot-Water	I	221.335

90195	F-Diss-Water	I	0.30745
90195	K-Diss-Water	I	3.9612
90195	Mg-Diss-Water	I	16.4495
90195	Na-Diss-Water	I	13.857
90195	NH_3(25)-Union-Diss-Water	I	0.0144
90195	NO_3+NO_2-N-Diss-Water	I	1.613
90195	pH (Upper)	A	8.3251
90195	pH (Lower)	I	7.48785
90195	PO_4-P-Diss-Water	T	0.021
90195	SO_4-Diss-Water	I	24.7065
90203	Ca-Diss-Water	A	55.109
90203	Cl-Diss-Water	A	116.892
90203	DMS-Tot-Water	T	683.427
90203	F-Diss-Water	I	0.4797
90203	K-Diss-Water	I	8.7206
90203	Mg-Diss-Water	I	36.8319
90203	Na-Diss-Water	A	90.435
90203	NH_3(25)-Union-Diss-Water	I	0.01765
90203	NO_3+NO_2-N-Diss-Water	I	2.0529
90203	pH (Upper)	A	8.3921
90203	pH (Lower)	I	7.6733
90203	PO_4-P-Diss-Water	U	101.532
90203	SO_4-Diss-Water	I	101.532
90204	Ca-Diss-Water	A	49.377
90204	Cl-Diss-Water	A	103.103
90204	DMS-Tot-Water)	T	638.813
90204	F-Diss-Water	I	0.559
90204	K-Diss-Water	I	10.9652
90204	Mg-Diss-Water	I	35.0392
90204	Na-Diss-Water	A	89.9092

90204	NH_3(25)-Union-Diss-Water	I	0.017
90204	NO3+NO2-N-Diss-Water	I	1.50605
90204	pH (Upper)	U	8.4953
90204	pH (Lower)	I	7.55225
90204	PO_4-P-Diss-Water	U	0.286
90204	SO_4-Diss-Water	I	84.3948
90214	Ca-Diss-Water	A	43.0681
90214	Cl-Diss-Water	I	68.5467
90214	DMS-Tot-Water)	A	441.653
90214	F-Diss-Water	I	0.3745
90214	K-Diss-Water	I	9.6526
90214	Mg-Diss-Water	I	18.9864
90214	Na-Diss-Water	I	54.996
90214	NH_3(25)-Union-Diss-Water	T	0.0941
90214	NO3+NO2-N-Diss-Water	I	3.08
90214	pH (Upper)	U	8.8712
90214	pH (Lower)	I	7.6069
90214	PO_4-P-Diss-Water	U	0.247
90214	SO_4-Diss-Water	I	53.7241
90233	Ca-Diss-Water	A	56.6104
90233	Cl-Diss-Water	A	124.414
90233	DMS-Tot-Water)	T	672.542
90233	F-Diss-Water	I	0.5932
90233	K-Diss-Water	I	10.5155
90233	Mg-Diss-Water	I	37.8286
90233	Na-Diss-Water	A	87.1942
90233	NH_3(25)-Union-Diss-Water	A	0.022
90233	NO_3+NO_2-N-Diss-Water	I	1.7181
90233	pH (Upper)	U	8.73275
90233	pH (Lower)	I	7.6315

90233	PO_4-P-Diss-Water	U	0.192
90233	SO_4-Diss-Water	I	104.018