water affairs

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Water Requirements and Availability Reconciliation Strategy for the Mbombela Municipal Area

WATER QUALITY REPORT

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FINAL

APPROVAL

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Executive Summary

The water use within the Mbombela Local Municipality (MLM) has increased rapidly over the last few years and the available water resources will soon be insufficient to supply the users within the municipal area at an acceptable level of assurance. IWR Water Resources has been appointed to develop a Water Reconciliation Strategy.

Poor water quality has a direct impact on water quantity in a number of ways, and therefore water quality requirements are key to the development of a reconciliation strategy. Polluted water that cannot be used for drinking, bathing, industry or agriculture effectively reduces the amount of useable water within a given area. The current water quality status of the Crocodile River deteriorates downstream, with unacceptably high levels of salts (EC), turbidity, pH and phosphates occurring from below the Kaap River confluence. The major drivers of water quality deterioration due to high phosphate levels are a combination of waste water effluent (Nelspruit, Kanyamazane, Matsulu, Hectorspruit, Malelane and Komatipoort), and runoff from fertilisers used for the intensively irrigated sugar cane and subtropical fruits. The increased salt levels result from diffuse returns from intensive agriculture and gold mining activities in the Kaap River Catchment The increased pH values are due to algal growth, and the uptake of carbon dioxide for photosynthesis. At night the photosynthesis stops, and algae and bacteria release carbon dioxide, forming carbonic acid and causing a drop in pH again, due to nutrients. Sampling, however, typically takes place during day time which then may indicate a higher pH values. Increased levels of arsenic and manganese occur in the Crocodile catchment as a result of mining activities in the Kaap River. The origin of the arsenic is from both operational and closed mining activities. In the Elands River there is a recorded increasing trend in salts and chloride associated with the pulp and paper mill in the catchment. Chloride concentrations in the Crocodile River at Rivulets are, however, stabilising. (SAPPI Ngodwana, 2012)

The water quality trend in the Crocodile catchment indicates an increasing trend of turbidity and nutrients (phosphates and nitrogen) upstream of the Kaap River confluence due to increased urbanisation (treated and untreated waste water returns to the river).

The water quality trend below the Kaap River confluence indicates increased turbidity and sulfate (UIPAC spelling) values. The increased turbidity is due to runoff from dense settlements in Matsulu, as well as agricultural runoff, and mining. The increased sulfates values are due to the mining activities in the Kaap and Queens rivers.

In terms of organic pollutants, the Crocodile River (near the premises of a paper mill in Mpumalanga) had the largest amount of Polycyclic Aromatic Hydrocarbons-congeners exceeding the Interim Sediment Quality Guidelines, Probable Effect Levels and Lowest Effect Levels. The concentration of dioxin-like compounds at this site was above the levels stipulated in the Interim Sediment Quality Guidelines. The sites situated down-stream of this site in the Crocodile River closer to the borders of neighbouring countries had less significant concentrations of organic pollutants. It was recommended that attention should also be given to heavy metal levels at these sites as these may pose as significant co-stressors.

Water Quality Management Strategy

The biggest challenge to water quality management lies in the vicinity of Nelspruit, where multiple "impactors" need to be managed. These impactor activities include the disposal of solid wastes that often end up in and/or close to the river, and the quality of effluents that are being discharged.

Elevated levels of manganese and arsenic are allegedly reported across the catchment, however the monitoring results for these parameters were not available from DWA'. Overall, the water quality in the Crocodile River at the intake of the abstraction works of the Nelspruit domestic/industrial water supply network is good, and has no effect on the water availability for Nelspruit (i.e. no special treatment or dilution

water is required). Poor discharge qualities from waste water treatment works, mines and industries do however have impacts on downstream abstraction points and the treatment processes at these abstraction points are not designed to treat these effluents.

An improvement in water quality through better pollution control is required to achieve a good ecological state for in-stream biota at and downstream from Nelspruit; improved management of the riparian zone is also required. Control of alien plants, especially in riparian zones, is needed in all catchments.

A strategic assessment and management of the trout industry in the Crocodile catchment is required.

Control of agricultural activities that involve clearing of ground cover (especially near to the riparian zone) in the Sabie Catchment is imperative for the improvement of the water quality in the Sabie River.

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List of Acronyms and Abbreviations

AMD	Acid Mine Drainage
As	Arsenic
Ba	Barium
Be	Beryllium
Bi	Bismuth
CMS	Catchment Management Strategy
CMA	Catchment Management Agency
Cd	Cadmium
Cr	Chromium
Co	Cobalt
Cu	Copper
COD	Chemical Oxygen Demand
DDT	Dichlorodiphenyltrichloroethane
DIN	Dissolved Inorganic Nitrogen
DEA	Department of Environmental Affairs
DLC	Dioxin like Compounds
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EA	Environmental Agency
EDCs	Endocrine Disrupting Compounds
EIS	Ecological Importance and Sensitivity
Fe	Iron
Hg	Mercury
IDP	Integrated Development Plan
ISP	Internal Strategic Perspective
ISQS	Interim sediment quality guidelines
IUPAC	International Union of Pure and Applied Chemistry
IWWMPs	Integrated Water and Waste Management Plans
KNP	Kruger National Park
LEL	Lowest Effect Level
MLM	Mbombela Local Municipality
Mn	Manganese
Mo	Molybdenum
NEMP	National Eutrophication Monitoring Programme
Ni	Nickel
NGOs	Non-governmental Organisations
NMAR	Normal Mean Annual Runoff
NMMP	National Microbiological Monitoring Programme
NTMP	National Toxicity Monitoring Programme
NWA	National Water Act
OCP	Organo Chlorine Pesticides
PAH	Polycyclic Aromatic Hydrocarbons
Pb	Lead
PCB	Polychlorinated Biphenyls
PCDD	Poly Chlorinated Dibenzo-p-Dioxins (dioxins in short)
PCDF	Poly Chlorinated Dibenzo Furans (dibenzofurans in short)
PEC	Present Ecological State
PEL	Probable effect level
POPs	Persistent Organic Pollutants
QC	Quaternary Catchment

RDMs	Resource Directed Measures
RHP	River Health Programme
RQOs	Resource Quality Objectives
RQS	Resource Quality Services
RWQOs	Resource Water Quality Objectives
RU	Resource Unit
SAWQGs	South African Water Quality Guidelines
Sr	Strontium
TDS	Total Dissolved Salts
TIN	Total Inorganic Nitrogen
TWQR	Target Water Quality Range
UNEP	United Nations Environmental Programme
V	Vanadium
WDCS	Waste Discharge Charge System
WMA	Water Management Area
WMS	Water Management System
WQM	Water Quality Management
WQP	Water Quality Planning
WRC	Water Research Commission
WRCS	Water Resource Classification System
WSA	Water Services Authority
WSDP	Water Services Development Plan
WWTWs	Wastewater Treatment Works
Zn	Zinc

1 GENERAL COMMENTS

1.1 WASTE WATER TREATMENT

In South Africa, there is a general lack of knowledge and understanding amongst owners of waste water treatment plants in South Africa regarding the following operations and maintenance issues: it is assumed that the works in the study area do not differ from the general norm in South Africa:

- Plant design (especially volumetric capacity);
- Treatment processes and technologies;
- Water quality and its impacts on the receiving environment (including the inter-relationship between surface and Groundwater sources);
- Statutory compliance issues, including Environmental Authorisations in terms of the National Environmental Management Act(Act 107 of 1998); licences/general authorisations in terms of the National Water Act (Act 36 of 1998); and the special effluent standards in force in the Crocodile River catchment;
- Need for qualified process controllers readily present on site;
- Standards of general housekeeping (including neatness of the terrain, security fences; access control; etc.)
- Kabokweni Oxidation ponds is a new treatment system, however the inability of the technology to achieve the reserve requirements should place the upgrading of this technology as a high priority.

1.2 RECONCILIATION STRATEGY

Most of the water quality problems in the Crocodile River catchment area are pollution problems which need to be addressed at source: if the water is not treated then the water will become unfit for use. In most cases if the water is fit for human consumption, then it is fit for industry, except for a few cases in which the water must be pre-treated.

Industries should be encouraged to ensure that water containing waste is not released if it fails to comply with the required determined standards. Discharging substandard effluent to the sewer because the treatment process cannot treat the specific variables is no solution. In the event of the failure of wastewater treatment systems emergency measures need to be put into place to contain rather than release, the effluent.

Arsenic occurs naturally in the catchment but that its release into the river water is as a result of mining activity. The increased arsenic concentrations in the Kaap River is therefore t due to mining activities and should be addressed at source through better regulation. DWA and the Department of Minerals Resources should agree on a strategy to manage the historically closed and abandoned gold mines. Illegal alluvial gold mining in the catchment should be controlled.

The second proposed control strategy focuses on setting strict maximum limits for water abstraction during periods of low flow, and on ensuring that there is always a minimum river flow available to maintain the target water quality during the dry season. Restricting low flow is applicable when rivers do not normally experience frequent extremely low flows. When rivers do normally experience frequent low flows, for example in arid and semi-arid regions, low-flow augmentation from an upstream reservoir can be proposed as the second control strategy, in which case, the relationships between reservoir operation and the resultant river water quality in downstream reaches should be well understood.

Regulating the flow pattern of water released from an upstream reservoir has the potential to achieve a remarkable reduction in the TDS and ammonia nitrogen concentrations in the lower reaches of the Crocodile River. Ideally, the augmented flow pattern should follow or mimic the seasonal pattern of unregulated river flows. Based on flow data from 1987 to 1990, the minimum flow at the upper point of the Crocodile River study site should be at least 5 $m^3 \cdot s^{-1}$ so that the salinity (TDS) and ammonia concentrations in downstream reaches can be improved. Importantly, one should also note that the proposed management options are not a stand-alone solution to guarantee the defined water quality objectives. Thus, in addition to the proposed management option, effluent quality standards and diffuse pollution regulation should always be considered. (Deksissa, Ashton, & Vanrolleghem, 2003).

The preliminary water quality reserve for the study area is a C which means a moderately altered environment. The ecological importance and sensitivity of the area is however the driver to improve the category to a B and this needs to be taken cognisance of when the water reconciliation strategy is formulated.

2 INTRODUCTION AND SCOPE OF REPORT

The water use within the Mbombela Local Municipality (MLM) has increased rapidly over the last few years and the Inkomati Catchment Management Agency has therefore appointed IWR to develop a Water Reconciliation Strategy to ensure that sufficient water of an acceptable quality is available for the future of the municipality.

Poor water quality has a direct impact on water quantity in a number of ways and therefore water quality requirements are key to the development of a reconciliation strategy. Polluted water that cannot be used for drinking, bathing, industry or agriculture effectively reduces the amount of useable water within a given area Typically water quality is determined by comparing the physical and chemical characteristics of a water sample with water quality guidelines or standards. The South African Water Quality Guidelines (DWAF, 1996) have been used as the guiding documents in determining water user requirements if the Water Quality Reserve is not available.

SRK Consulting has been appointed to produce a water quality report to be incorporated into the Reconciliation Strategy.

3 BACKGROUND TO THE RECONCILIATION STRATEGY STUDY

In the process of compiling the Internal Strategic Perspectives (ISPs) for all the Water Management Areas (WMAs), in the country, the Department of Water Affairs and Forestry (DWAF) identified the need to develop strategies that will ensure adequate future reconciliation of water requirements and water availability in the main metropolitan areas as well as smaller municipal areas and towns.

In 2004 DWAF embarked on a series of reconciliation strategies for the metropolitan areas and larger cities in the country.

This was followed by four studies aimed at developing similar reconciliation strategies for all other towns in the North, East, Central and South planning regions.

The purpose of the studies was to gather information about the bulk water balance situation of all the towns in the country, to select those towns most in need of comprehensive strategies for reconciliation of water availability with future water requirements; and to identify the most appropriate series of intervention that will form part of such strategies.

Following a prioritisation exercise, MLM emerged as one of the municipalities that are most in need of a comprehensive strategy for reconciliation of water availability against future water requirements. Mbombela Local Municipality is obliged to include water resource planning information in the Water Services Development Plans (WSDPs) and Integrated Development Plans (IDPs) which must also be aligned with the Inkomati Catchments Management Strategy (CMSs) /ISPs.

The MLM’s area of jurisdiction comprises:

- Nelspruit and White River (including the industrial area of Rocky Drift)
- Hazyview
- Nsikazi North -towns and rural settlements
- Nsikazi South - towns and settlements
- Matsulu - mostly rural settlements.

4 PURPOSE OF THE STUDY

The main objective of the overall study is to provide a comprehensive water requirements and availability reconciliation strategy for the MLM up to 2035. Water quality needs to be considered alongside water quantity in water resource management. Therefore, the purpose of this component was to identify the key water quality issues or potential water quality problems in the study area.

5 THIS REPORT

This report is the output of Task 7 as described in the Inception Report (IWR, 2012) and covers the water quality component. It describes the water quality requirements for the domestic, agricultural, industrial, environmental and recreational water use sectors. Existing available information to characterise the current water quality situation of the MLM was reviewed, and an analysis of historical trends was undertaken.

5.1 WATER QUALITY SITUATION ASSESSMENT

No water quality monitoring was included in in the study but could be done on a follow up study. The water quality situation assessment was based on readily available information and no further sampling was undertaken.

5.2 CHARACTERISE THE CURRENT SITUATION AND HISTORICAL TRENDS

Different user sectors have different water quality requirements, and/or differing concerns about the same water quality constituents. Broadly, characterising the current situation and historical trends involved:

- Identifying and characterising the main water uses;
- Determining the typical water quality issues or problems experienced by the main water users;
- Identifying the water quality constituents associated with each problem or issue;
- Specifying a target water quality range for each of the key constituents, and
- Formulating and recording water-related issues, concerns and problems.

5.3 PROJECT THE IMPACTS OF FUTURE WATER-RELATED DEVELOPMENT SCENARIOS ON WATER RESOURCES

The aim of this task was to ensure that the proposed management options were informed by an understanding of potential water quality outcomes. By being thus informed, the strategies developed during the course of this study would be oriented to influence development processes in the planning stages to the advantage of the water quality of the MLM and downstream users.

5.4 FORMULATE AND PRIORITISE CATCHMENT MANAGEMENT OPTIONS

The purpose of this component was to provide a pragmatic but relevant spatial structure, and inform decisions at appropriate spatial and temporal resolutions for the water quality management options. Further, it provided a monitoring plan to enable the auditing of the implementation of catchment management options.

Methods were developed to monitor the progress of the implementation of management options in order to maintain the present status, rehabilitate water resources or implement the defined management options to meet Resource Water Quality Objectives (RWQOs).

6 PROJECT AREA

The MLM is the designated Water Services Authority (WSA) responsible for the policy setting, planning, management and oversight or water service provision in its area of jurisdiction.

Nelspruit is the capital of Mpumalanga province, and like the other major town in the area, White River, it is situated in the in the N4 Maputo development corridor. Both towns are situated in large and highly productive Irrigation farming and forestry areas and have seen significant growth in recent years because of commercial and industrial development linked to the Maputo Corridor and the tourism potential of the surrounding area such as the Mpumalanga Escarpment and Lowveld and the Kruger National Park (KNP).

Associated with the industrial growth is the population growth which has been significant due to rural migration to the towns, as well as immigrants from the neighbouring countries of Mozambique and Swaziland.

Growth in the areas of Hazyview, Nsikazi and Matsulu is linked to that of Nelspruit and White River.

7 POTENTIAL CONTAMINATION SOURCES

7.1 DENSE SETTLEMENTS

Poor water quality in dense settlements has a wide range of significant impacts on human health, social development, and environment and down-stream use values. Poor water quality usually occurs as a result of low standards of water supply and poor sanitation, which are often a feature of many developing areas. The diseases that arise as a result of inadequate water services are the cause of a large proportion of infant and child deaths as well as many of the diseases in adults.

As urban areas become denser and heavily populated, the pollutant loads they produce are likely to increase, thereby increasing the risk of disease. The provisions for the removal of waste water need to be comprehensive and more complex. More importantly, these services must be operated effectively in order to ensure that they do not fail.

Although most waterborne diseases are transmitted by the faecal-oral route, there are secondary, longer-term waterborne diseases that can result from water polluted by dense settlements further upstream: a wide variety of pathogenic viruses, protozoa, and bacteria may be transmitted by water.
Ironically, most pollution from dense settlements occurs where the demand for the resource is greatest. With this one observes opportunity costs, or the cost of not being able to undertake a certain economic activity in the future due to the environmental degradation. The typical types of environmental impact arising from dense settlement pollution are sedimentation, faecal pollution and eutrophication, which may have dramatic impacts on the economic activities of downstream users. Irrigated agriculture for example is frequently confronted with lower plant yields because the pollution in the water settles on leaves and reduces photosynthesis. The presence of nutrients such as nitrogen and phosphorus can also stimulate unwanted plant growth, for example during a fruit development period.

Pollution from dense settlements also causes blockages in irrigation equipment that not only affects production but can be costly to remove and to control. Irrigation with contaminated water reduces the market value of a number of irrigated crops, such as vegetables and fruits that are not cooked before they are consumed (DWAF, 2001).

The economic impact of pollution from dense settlements on aquatic environments will be felt most through the reduction in amenity value and the value of the resource as a tourist destination. As South Africa's tourism and leisure industry is set to grow and is proffered as a vehicle for future economic growth, these impacts will be increasingly severe.

Livestock farmers also suffer economic costs when pollution from dense settlements is inadvertently ingested by their stock. Apart from the palatability effects, there are a number of diseases that can be spread through contaminated water, with associated impacts on stock production, which can greatly reduce the market value of livestock (DWAF, 2001).

Human consumption of contaminated water is extremely costly in terms of disease costs, lost productivity costs and mortality costs. Water service providers therefore are particularly vigilant about treating water to acceptable potable standards. The cost of treatment increases dramatically with the presence of pollution from dense settlements (DWAF, October 2001).

7.2 WASTE DISPOSAL

Urban development results in an increased production of waste, creating a need for additional and improved waste-management facilities. All urban areas have waste disposal sites, which may also be poorly managed. There are no groundwater monitoring boreholes at many of the solid waste facilities, and although most waste disposal site experience some runoff during high rainfall periods, leachate collection systems are often poor or non-existent and sites may be located in flood plains, or associated with important groundwater resources.

Although techniques for containing waste are available, and are being applied to new facilities, older waste repositories had no structured lining systems, and they have often been found to have released contaminated leachate into adjacent water resources.

7.3 WASTE WATER TREATMENT WORKS

Waste water treatment works (WWTWs) form an important part of water resources management (WRM). Effluent treatment prevents pollution of water resources and allows the integration of treated effluent into the water supply system.

Many municipalities have limited budgets and resources, and are not managing WWTWs optimally. They may therefore have a serious impact on the quality of receiving surface water resources.

Industries may also discharge their waste to the local municipal WWTW with very little pre-treatment, and as a result may be responsible for a large percentage of the volume of effluent and waste load which is discharged by the WWTW. Ineffective municipal by-laws and the fact that such industries are a major source of employment and income to the area makes it very difficult for the local authorities to take action, resulting in poor water quality effluents being discharged from the sewage works.

7.4 AGRICULTURE

The impact of drainage from agricultural activities on water quality may be significant. This includes irrigation return flows and seepage, which may contain salts, nutrients (fertilisers), other agro-chemicals (including herbicides and pesticides) and runoff or effluent from animal husbandry locations such as feedlots, piggeries, dairies, or chicken farms, which also contribute to contamination (DEAT, 2007).

7.5 INDUSTRY AND MINING

Sand winning is taking place along the Crocodile River. It is uncertain what percentage of these operations are authorised and which are illegal. Sand winning has a detrimental effect on the water quality of the river, as the extraction of alluvial material from within or near a streambed has a direct impact on the stream’s physical habitat characteristics. These characteristics include channel geometry, bed elevation, substrate composition and stability, in-stream roughness elements (large woody debris, boulders, etc.) depth, velocity, turbidity, sediment transport, stream discharge and temperature. Altering these habitat characteristics can have negative impacts on both in-stream biota and the associated riparian habitat. The detrimental effects to biota resulting from bed material mining such as sand winning are caused by three main processes:

(1) Alteration of the flow patterns resulting from modification of the river bed,
(2) An excess of suspended sediment and
(3) Damage to riparian vegetation and in-stream habitat.

The disturbance activities can also disrupt the ecological continuum in many ways. Local channel changes can propagate impacts upstream or downstream and can trigger lateral changes. Alterations of the riparian zone can result in changes in channel conditions that can impact aquatic ecosystems in a similar way as some in-channel activities. (Hill & Kleynhans, 1999).

Below the confluence of the Crocodile River with the Kaap River, total dissolved solids (TDS) concentrations have been observed to increase markedly, as the Kaap River drains an extensive area of active and abandoned gold mines (Deksissa, Ashton, & Vanrolleghem, 2003). Worryingly, electrical conductivity (EC) values measured in the Kaap River continue to increase steadily with time.

Mine water is generally high in dissolved solids with sulphate the dominant or indicator anion and calcium and magnesium the captions. Some of the waters contain high sodium.

Mining can result in change of pH (acidity of the water), increased salinity, increased metal content, and increased sediment load. Industrial contributions are more varied, depending on the industrial process, but can include poisonous and hazardous chemicals, nutrients, elevated salinity and increased sediment (DEAT, 2007).

There are manufacturing and metallurgic industries in the Mbombela and White River areas, as well as a paper mill in the Ngodwana area. Ecotourism is also an important industry in the area, with a number of private game parks and conservancies and the KNP located in the Lower Sabie sub-area. The Sappi Ngodwana Paper Mill is situated at the confluence of the Elands and Ngodwana rivers. The mill does not discharge effluent directly into the river: it is, irrigated onto the 514 hectares of farmlands adjacent to the mill. The irrigated effluent has contaminated the groundwater in this area with the primary influence of this groundwater contamination being the deterioration of the surface water quality, as well as negatively impacting the quantity of water in the Elands River.

The groundwater enters the Elands River through three springs near Ngodwana, namely Fraser’s eye, Northern eye and Eye X. The groundwater from both Fraser’s eye and Eye X has been contaminated with calcium, potassium, magnesium, sulfates, and most importantly, chlorides. All these substances contribute to the increase in conductivity in the Elands River, which in turn may have a possible impact on the ecological integrity of the system.

Waste disposal from industry and mining also results in an increased production of waste, creating a need for additional and improved waste-management facilities. (DEAT, 2007)

8 WATER QUALITY MONITORING

8.1 DEPARTMENT OF WATER AFFAIRS

DWA has been operating a salinity monitoring programme, now known as the National Chemical Monitoring Programme (NCMP), on South African rivers for more than 30 years.

When the programme began, the focus areas were the suitability of water for irrigation and the nutrient concentrations at hydrometric flow gauging stations and reservoirs. It has however been realised that the monitoring of major salts alone is insufficient for detection of long term change in water quality, leading to the design and implementation of additional national monitoring programmes for eutrophication, microbiology, ecosystem health, toxicity and radioactivity.

Each of these programmes will, in future, also be able to provide long term data for trend detection. Although prediction of water quality problems is difficult, the associated research and development programme should enable the programmes to keep up with changing demands. (van Niekerk, Silberbauer, & Hohls, 2009) All DWA's long-term monitoring sites include monitoring of the major ions (Mg^+, Na^+, Ca^+,SO_4, Cl^-), pH, and nutrients (PO_4-P, NO_2, NO_3 & NH_3).

9 WATER USERS

Authorised water users are directed (through water use licences) to monitor their discharges, and also upstream and downstream water quality in the river to determine the impact of their discharge on the water resource.

9.1 SEMBCORP

9.1.1 Surface Water Sampling

Sembcorp (Silulumanzi) is the water service provider responsible for bulk water supply in Nelspruit, which includes Mataffin, and also Matsulu.

Sembcorp is currently sampling 112 monitoring points which include reservoir, river, and borehole abstraction points for drinking water treatment, as well as waste water treatment and discharge points. Monitoring points and trend analyses of their data can be seen in **Appendix A**. In addition to these points they also take monthly samples at Delta Manganese Industrial, Coca Cola Industrial and Manganese Metals Company Industrial discharges. As well as analysing the normal parameters which include nitrates and phosphates, analysis is also done for the variables shown in**Table 9-1**.

Table 9-1: Variables analysed in water samples taken by Sembcorp

VARIABLES
Manganese as Mn
Iron as Fe
Total Chrome as Cr
Copper as Cu
Cobalt as Co
Magnesium as Mg
Sodium as Na
Potassium as K
Zinc as Zn
Total Viable Organisms
Arsenic as As
Free Cyanide as CN
Aluminium as Al
Dissolved Mercury as Hg
Lead as Pb

9.1.2 Groundwater sampling

Sembcorp also takes groundwater samples at Nelspruit Airport, Lupisi, and at Mpakeni 1, and 2. These points are indicated in **Figure 9-1.** The results are evaluated against drinking water guidelines since these points are all located within communities and are used for drinking water. The graphs showing the trends in EC are shown in **Figure 10-1.** Sampling has been taking place at least weekly (and in some instances more regularly) since 2008.

- **Airport**
  Although the EC is still within the parameters described in the Drinking Water Health Guidelines (WRC, 1998) and lies in the “no effect” range, there is an increasing trend.

- **Lupisi**
  The EC is currently within the domestic water health range which is classified as “slight possibility of salt overload in sensitive groups”. The trend here is however declining.

- **Mpakeni 1**
  Although the conductivity is still within the parameters described in the Drinking Water Health Guidelines (WRC, 1998) and lies in the “no effect” range, there is an increasing trend.

- **Mpakeni 2**
  Although the conductivity is still within the parameters described in the Drinking Water Health Guidelines (WRC, 1998) and lies in the “no effect” range, there is an increasing trend.

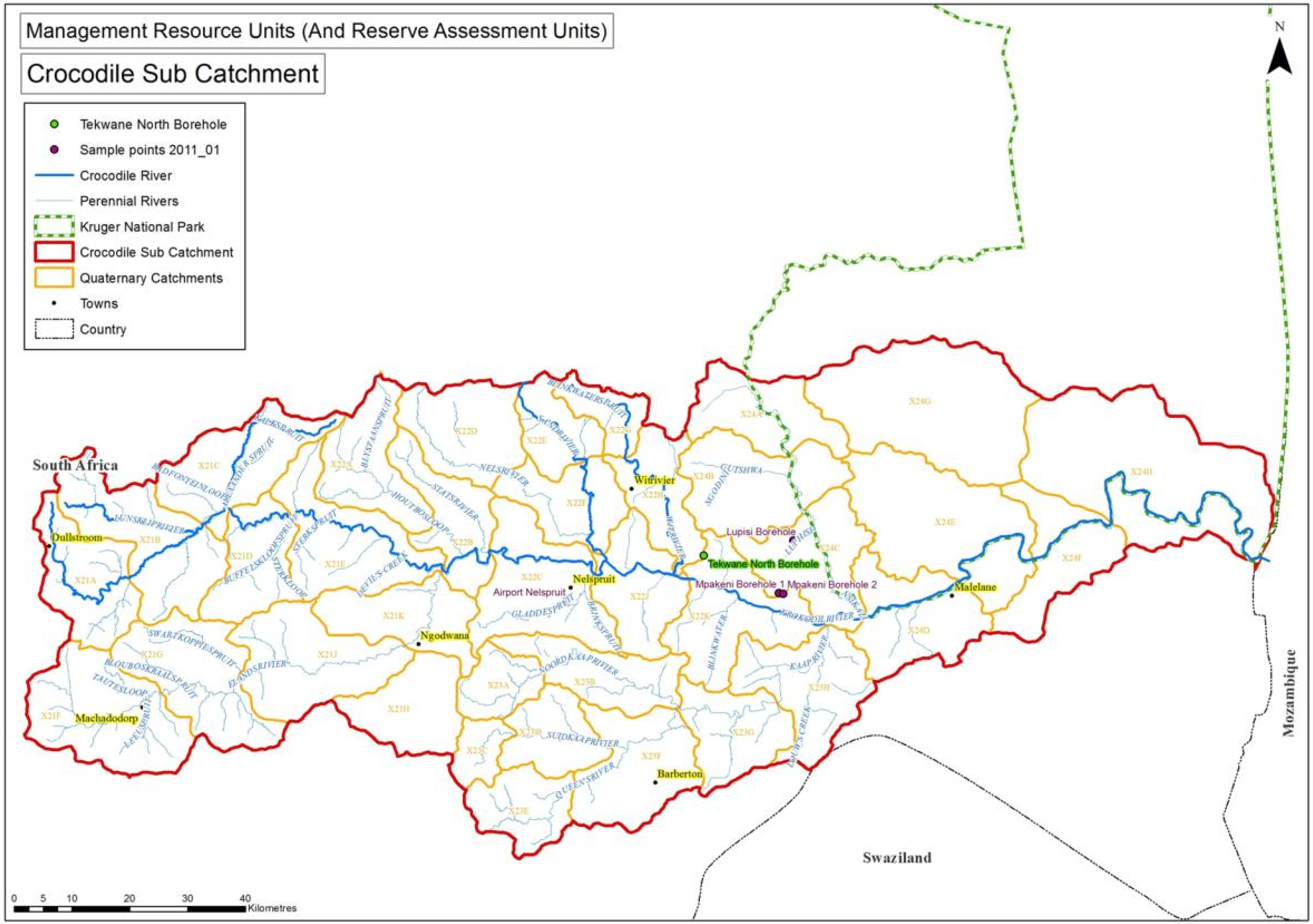

Figure 9-1: Groundwater points sampled by Sembcorp

9.1.3 Sappi Ngodwana

The Sappi Ngodwana paper mill lies upstream from the study area and has the potential to impact on the downstream water quality. Sappi is obliged to conduct a comprehensive monitoring programme in terms of their Water Use Licence (WUL) conditions. The results are then reported at the Environmental Liaison Committee which includes DWA and the Inkomati Water Management Agency (ICMA). Sappi takes river water quality sampling in both the Elands River at Lindenau, and the Crocodile River at Rivulets. The results contained in **Appendix I** were presented at the Environmental Liaison Committee (SAPPI Ngodwana, 2012) meeting held on 21 November 2012 and were supplied to the project team by the ICMA.

9.1.4 Water quality trends

The quality of the effluent being discharged from the mill is measured in terms of oxygen demand, either biological oxygen demand (BOD) or chemical oxygen demand (COD) and total suspended solids (TSS). Only river monitoring data relating to COD, chlorides, sulfates and sodium were received for the Elands River and only chlorides for the Crocodile River.

- **Lindenau**
  - Chloride concentration in the river is consistently below the target level of 120 mg/ℓ. with slight a downward trend
  - Sulfate concentration is also well below the target of 165 mg/ℓ with increased concentrations during low flow conditions. The trend has however been increasing since 2000.
  - Sodium concentrations are also below the target level of 95 mg/ℓ in the river, however higher concentrations are observed in low flow conditions. The sodium trend tends to be increasing since 2007.
  - COD has been fairly constant below 60 mg/ℓ. Spikes occurred during both high and low flow periods which may indicate that spillages occurred.

- **Rivulets**
  - Chloride concentration target level is set to 25 mg/ℓ or 25 T/d. Spikes above the target levels occur during low flow conditions. Golder (Water for Africa, 2009) has modelled that the trend should be increasing; however Sappi reports an even trend.

10 PREVIOUS WATER QUALITY STUDIES

10.1 REPORT TITLE: WATER RESOURCE PLANNING SYSTEM SERIES: WATER QUALITY PLANNING SUB SERIES NO. WQP 2.0 RESOURCE DIRECTED

A number of water quality issues have been identified in previous studies conducted in the Inkomati river catchment area. One of the studies was undertaken by DWA as part of the Water Resources Planning Systems Series. (Water Resource Planning Systems, Water Quality Planning, 2011) The study focused on the water quality status and trends in streams and rivers. The nineteen water management areas (WMAs), including the Inkomati WMA, which forms the major river basins of South Africa, provided the geographical basis for the water quality perspective assessment.

10.1.1 Objectives

The primary objectives were to characterise the state of surface-water quality; determine temporal trends at those sites that had been consistently monitored for a decade (January 1999 to February 2008); and build an understanding of how natural features and human activities have affected the water quality of our water resources.

10.1.2 Approach

The methodology involved comparing the in-stream water quality to a generic set of Resource Water Quality Objectives (RWQOs) for all users throughout all WMAs. RWQOs are a mechanism through which the balance between sustainable and optimal water use and protection of the water resource can be achieved. RWQOs are the water quality components of the Resource Quality Objectives (RQOs) which are defined by the National Water Act (NWA) as “clear goals relating to the quality of the relevant water resources”.

This report focussed on the chemical quality of the nation’s water resources. It did not deal with the biological or microbiological status of the surface water resources as this information was not readily available on a national scale. A snapshot of some areas was however given in the context of a WMA. Groundwater quality was also not addressed in this report.

Six parameters were selected to provide an indication of the fitness for use of water resources by the designated user groups. These included:

- EC (mS/m) to provide an indication of salinisation of water resources ;
- Orthophosphate (PO_4-P) (mg/ℓ) as an indicator of the nutrient levels in water resources (eutrophication is becoming a threat).
- Nitrate (NO_3 + NO_2 - N) (mg/ℓ) was assessed but showed a 97% compliance to ideal RWQOs due to the fact that the upper limit is set at 6 mg/ℓ based on the most sensitive user.
- Sulfate (SO_4^{2-}) (mg/ℓ): as an indicator of mining impacts. Sulfate is a major issue in many catchment areas;
- Chloride (Cl^-) (mg/ℓ): as an indicator of agricultural impacts, sewage effluent discharges and industrial impacts;
- Ammonia (NH_3-N) (mg/ℓ): as an indicator of toxicity, and
- pH (pH units): as an indicator for mining impacts as well as natural variability nationally.

In-stream water quality of surface water resources was assessed using chemical monitoring data at a range of monitoring sites throughout the country (in each of the 19 WMAs) which was compared to a generic set of conservative level RWQOs to determine compliance for the selected water quality variables. The 95th percentile values were used to assess EC, sulfate, chloride, ammonia and pH compliance to the RWQOs, while the 50th percentile values were used to assess phosphate compliance.

A generic set of RWQOs for the country's surface water resources was used to assess compliance and determine current water quality status. While it is known that water resources vary considerably and different management RWQOs are in place in many catchment areas, it was necessary to provide a generic set of assessment RWQOs which would provide a consistent indication of fitness for use of water resources anywhere in the country. The RWQOs used for the compliance assessment were derived using the RWQOs Model (Version 4.0) which uses as its basis the South African Water Quality Guidelines (DWAF, 1996 (5)) Quality of Domestic Water Supplies: Assessment Guide, Volume 1 (WRC, 1998) and Methods for determining the Water Quality Component of the Reserve (Department of Water Affairs and Forestry, 2002) and are based on the strictest water user criteria and thus represent fairly conservative limits.

10.1.3 Findings

10.1.3.1 Inkomati water quality status

The water quality data covering the period 2006 to 2008 was analysed statistically and compared to RWQOs to determine the water quality variables of concern in the different parts of the catchment. Trends were also analysed for the period 1999 to 2008. The analysis results highlight the following: -

- **Sabie**

  The water quality analysis in the Sabie River indicates unacceptable levels of phosphates throughout the catchment. This is due to return flows from WWTWs, the large surface area dense settlements in Bushbuckridge that are mainly un-serviced, and runoff from the intensive fertilised cultivation of subtropical fruits.

  The water quality trends in the Sabie River indicate increasing nutrient and turbidity levels. The turbidity trend is due to over-grazing, and the removal of vegetation for firewood from the slopes of the river in the Bushbuckridge area. The increasing nutrient levels are due to the use of fertilisers for the growth of sub-tropical fruits and from sewage waste (both formal and un-serviced).

- **Crocodile**

  The current water quality status of the Crocodile River deteriorates downstream with unacceptable values of salts (EC), turbidity, pH and phosphates occurring from below the Kaap River confluence. The major drivers of the phosphate deterioration are a combination of waste water effluent (Nelspruit, Kanyamazane, Matsulu, Hectorspruit, Malelane and Komatipoort) and runoff from fertilisers used for the intensively irrigated sugar cane and subtropical fruits. The increased salt values are from diffuse returns from the intensive agriculture and the gold mining activities in the Kaap and Queens rivers. The increased pH values are due to algal growth, due to nutrients, causing pH values to become more basic.

  In the Elands River there is a recorded increasing trend in salts and chloride associated with the pulp and paper mill in the catchment. There are some recorded industrial pollution incidents around Nelspruit which have resulted in high manganese levels in the river, sediments and bioaccumulation into fish. There are also recorded cyanide and arsenic pollution incidents in the Kaap and Queens rivers associated with the gold mining operations.

  The water quality trend in the Crocodile catchment indicates an increasing trend upstream of the Kaap River confluence of turbidity and nutrients (phosphates and nitrogen) due to increased urbanisation (treated and untreated waste water returns to the river).

The water quality trend below the Kaap River confluence indicates increased turbidity and sulfate values. The increased turbidity is due to runoff from dense settlements in Matsulu, agricultural runoff and mining. The increased sulfate values are due to the mining activities in the Kaap and Queens rivers. **Table 10-1** summarises general water quality issues and effects whilst **Figure 10-1** shows inorganic water quality trends in the Inkomati WMA.

Table 10-1: Water quality Issues and effects

WATER QUALITY INDICATOR	ISSUES	DRIVER EFFECT
Eutrophication	Waste water treatment works, intensive agriculture fertiliser use and dense urban sprawl un-serviced sewage	Algal growth, smell, toxic algae, water treatment extra costs, taste and odour, irrigation clogging, aesthetics, recreational water users
Microbial contamination	Waste water treatment works, informal dense settlements	Recreational users (human health), washing and bathing
Turbidity	Informal dense settlements urbanisation, mining, agriculture, point source discharge	Dam sedimentation, water treatment costs, irrigation clogging
Salinisation	Mines (operational and decommissioned), waste water treatment works, agricultural (intensive irrigation)	Increased water treatment costs, soil salinity, irrigation system clogging
Toxicants	Pesticides (subtropical fruits, nuts) industry	Fish kills, bio-accumulation, KNP mammals
Altered flow regime	Dams and weirs	Turbidity (erosion), Algal growth, water temperature increase, dissolved oxygen changes, taste and odour changes, impact on recreational water users, Fish kills, changes in environmental flows
Acid mine drainage	Mines (operational and decommissioned), controlled releases	Mobilisation of metals, fish and crocodile kills, bio-accumulation, KNP mammals
Metal contamination	Mines (operational and abandoned)	Mobilisation of metals, fish and crocodile kills, bio-accumulation, KNP mammals

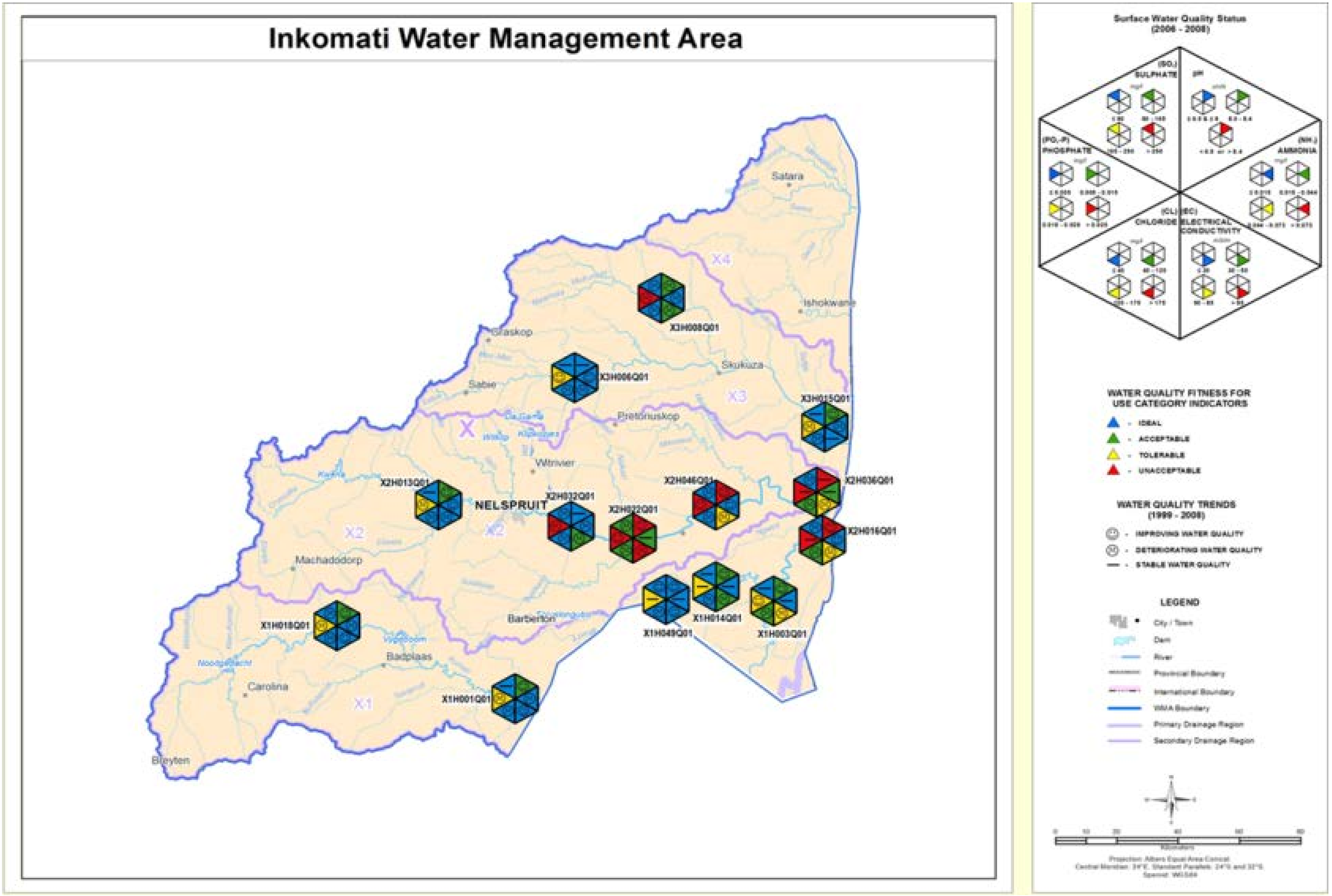

Figure 10-1 : Inkomati WMA inorganic water quality trends (Water Resource Planning Systems, Water Quality Planning, 2011)

11 PERSISTENT ORGANIC POLLUTANTS

11.1 REPORT TITLE: PERSISTENT ORGANIC POLLUTANTS IN THE ENVIRONMENT, WRC REPORT NO. 1561/1/11

A previous WRC-funded study, "Survey of Certain Persistent Organic Pollutants In Major South African Waters" (Vosloo. R., 2005) focusing on the levels of dioxin-like compounds (DLCs) in South African sediments, indicated that Poly Chlorinated Dibenzo-p-Dioxins (PCDD/Fs) and Poly Chlorinated Bi-phenyls (PCBs) were present in selected aquatic environments throughout the country (Vosloo. R., 2005). Of the 22 aquatic sites included in the study, the highest levels of DLCs were measured in the Vaal Triangle region, Gauteng. Therefore, this project, WRC POPs II, Phase I focussed on determining the levels of DLCs in selected water bodies of this area.

It was important to determine the extent of dioxin-like pollution in the Vaal Triangle area, since the rivers of this region drain into the Vaal Dam (27°00’ S, 28°19’ E), which provides potable water for the region. This means that a large number of people may be exposed to dioxin-contaminated water, and some to contaminated fish.

The aim of the next study was to do a more comprehensive investigation of dioxin-like persistent organic pollution in the Vaal Triangle area.

The objectives of Phase I were:

- To gain a better understanding of dioxin-like pollution in the aquatic environment of the Vaal Triangle region by determining the presence of these pollutants in sediment and fish tissue.
- To quantify the amount of PCDD/Fs and PCBs in sediment and fish tissue by calculating TCDD-equivalents using the H4IIE-luc reporter gene bio-assay.
- To determine bio-accumulation of PCDD/Fs and PCBs in biota by comparing the quantities of DLCs in sediment and fish tissue to one another.
- To compare TCDD-equivalent values, obtained with the H4IIE-luc bio-assay, with results obtained from chemical analysis, as an additional measure to confirm the levels of Dioxin like Compounds (DLC)s measured with bio-analysis.

11.1.1 Objective

The aims and objectives of Phase II (Roos. C., 2011) were:

- o To assess the scale and significance of the occurrence of persistent organic pollutants (POPs) and other Organo Chlorine Pesticides (OCP)s in the water environment in South Africa,
- o To better identify and quantify the fate and effect of selected POPs and other OCPs in the water environment, and
- o To guide and inform the development of appropriate policy and regulatory measures that will support implementation of the requirements of the SCPOPs, and substantially contribute to the protection of water resources and water-linked ecosystem with regard to POPs, by:
  - Identifying and quantifying selected POPs and other OPs in the water environment,
  - Assessing the levels and distribution of these compounds,
  - Determining the possible sources and releases to the environment, and
  - Assessing the effects on human health to identify communities possibly at risk.

11.1.2 Approach

This study focussed on a group of highly persistent, toxic pollutants which is ubiquitous in terrestrial and aquatic environments all over the world. Here, we characterised the scale and significance of certain organic pollutants (OPs), especially POPs in selected water bodies of South Africa, specifically targeting sediments as matrix, which are the main reservoirs of these pollutants in aquatic environments. POPs are highly stable, toxic, hydrophobic and lipophilic compounds, with the ability to accumulate in biological tissues.

A total of 30 sites were selected to represent primarily areas with potentially high POPs concentrations in South Africa. The samples from the Crocodile River were mostly collected near to agricultural lands and sugarcane plantations. Two samples (a sediment and soil composite sample) were also collected close to paper mills near Nelspruit.

The Komati River was mostly sampled in agricultural areas, where there might be quantifiable levels of OCPs, but the levels of DLCs were below the assay's detection limit. The study did not aim to address the issue of the risks of PCDD/PCDF and PCB to humans or wildlife directly. Risk is a factor of both exposure and hazard (toxicity). An assessment of the risks posed by PCDD/PCDF and PCB would need to consider the bio-availability of each congener as well as other factors that would affect potential exposure.

11.1.3 Findings

The Crocodile River below the premises of a paper mill in Mpumalanga) had the largest amount of Polycyclic Aromatic Hydrocarbons (PAH) -congeners exceeding the ISQGs, Probable Effect Level (PEL) and Lowest Effect Levels (LEL). The concentration of DLCs at this site was above the ISQG. The sites situated down-stream of this site in the Crocodile River closer to the borders of neighbouring countries had less significant concentrations of organic pollutants. It was recommended that attention should also be given to heavy metal levels at these sites as these may pose as significant co-stressors.

The concentration of pollutants measured in South African soils and sediments were intermediate when compared to the levels measured in some European, Asian and Scandinavian countries, with the exception of a few sites where exceptionally high levels of compounds were measured.

12 MICROBIOLOGICAL MONITORING

DWA is monitoring 13 points on a bi-monthly basis in the Inkomati WMA and presenting the results in a bi-monthly report. The purpose of the bi-monthly report is to give feedback to stakeholders on the National Microbiological Monitoring Programme (NMMP) monitoring data gathered over a two-month period in the Water Management Area.

Since the NMMP is a national monitoring programme, the data and information that are produced gives only a national perspective of the levels of faecal pollution in identified priority areas in South Africa.

Guideline values are given for the four types of water uses monitored as part of the NMMP. Human users may be exposed to health risks if they use surface water of qualities exceeding the guideline value for:

1. Direct drinking from the resource;
2. Full-body contact recreation;
3. Irrigation of crops that will be consumed raw (uncooked and even unwashed), and
4. Ingestion of water that has undergone only partial treatment i.e. home treatment (sedimentation, filtration and disinfection)

Assurance that water is microbial safe has traditionally been determined by measuring bacterial indicators of water quality, most commonly coliforms and Escherichia coli (E. coli), due to the fact that the number of different types of pathogens (disease causing organisms) that can be present in water as a result of pollution with human or animal faeces is very large and it is not possible to test water samples for each specific pathogen.

The presence of E. coli in water is still considered to represent the presence of faecal pollution and is used to indicate that pathogenic bacteria, viruses and protozoa may also be present. The user of water containing pathogens may be at risk of developing a water-related disease if the pathogen is ingested.

The health risk of ingesting the water without treatment was high at most of the sampling points over the past year, with a medium risk to irrigation of crops at a number of points.

13 THE RESERVE

Various Reserves have been determined at different levels of confidence for stretches of rivers in the Crocodile Catchment. The majority of them have however not focussed on water quality but were more specifically focussed on flow requirements and the basic human needs reserve.

A summary of all the Reserve determinations done can be seen in **Table 13-1**.

Table 13-1: Summary of Reserve determinations in the Crocodile Catchment

Quat	River	Level of Determination	Date of Reserve	Resource Units	EIS	Present Ecological States (Water Quality)	Recommended
X21E	Crocodile	Comprehensive	2011		High	C	B/C
X21F	Elands						
*X21K	Elands	Comprehensive	2007		Moderate to High	B	B
X22C	Crocodile	Comprehensive	Not yet finalised but recommended to use X22K	4		C	B
X22D	Nels	Desk	2007			C	C
X22F	Nels	Desk	2006			C	C
X22H	White River	Intermediate (2002)	Not yet finalised but recommended to use X22K	4		C	C
X22J	Crocodile	Intermediate (2002)	Not yet finalised but recommended to use X22K (2009)	4		C	C
X22K	Crocodile	Intermediate	2009	4	High to Very High	C	C
X23A	Noord Kaap	Desktop	2007			C	C
X23E	Suidkaap	Desktop	2006			C	C
X23G	Kaap	Intermediate	2004	7	Moderate	C	C
X23H	Kaap	Intermediate	2001		Moderate	D	
X24C	Nsikazi	Desktop	2006			B/C	B/C
X24E	Lower Crocodile	Comprehensive	2011	6		C	B
X24G	Lower Crocodile	Comprehensive	2011				
X24H	Lower Crocodile	Comprehensive	2011				
X31A	Sabie	desk				C	B/C
X31B	Sabie	desk				B	A/B

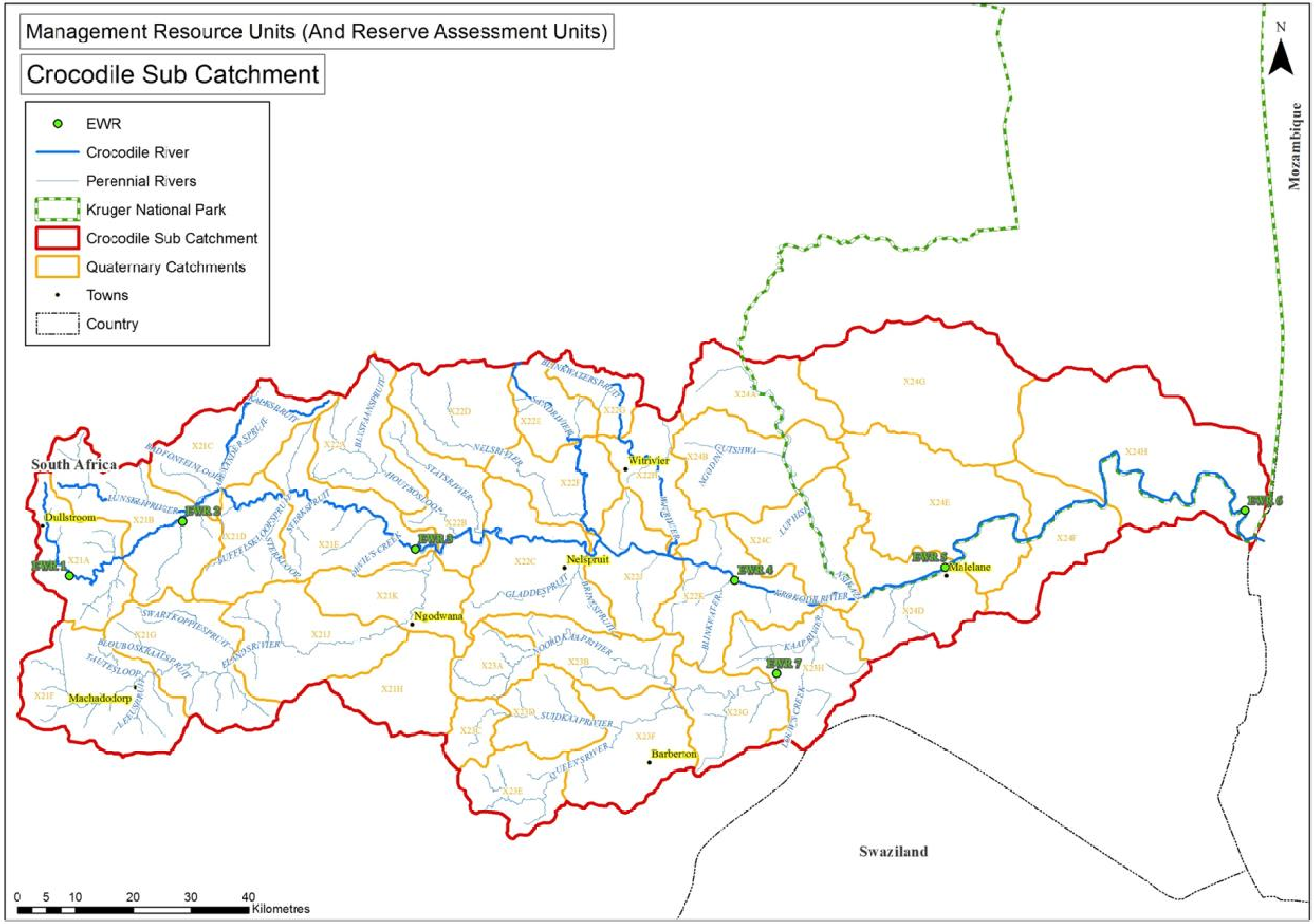

Figure 13-1: The Ecological Water Requirement (EWR) site for this RU is located in the QC X22K (EWR Site 4: KaNyamazane) RUs. The results of the Reserve study conducted at site EWR are summarised in Table 13-3.

During the comprehensive Reserve determination of the Crocodile River in 2010, the river was demarcated into seven surface water Resource Units (RUs). The area of this study falls well within one of these, RU 4, which comprises quaternary catchments (QC) X22A-X22K, as shown in **Figure 13-2**.

Table 13-2: Summary of .the Ecological State for the Crocodile River up to EWR Site 4 in QC X22K

Water Resource	QC	PES	EIS	REC	NMAR (Million m^3)	Reserve % NMAR	Level of Reserve Determination
Crocodile River	X22K	C	High	B	754.1	73.08	Comprehensive (EWR Ste 4)

** Present Ecological State (PES), Ecological Importance and Sensitivity (EIS), Recommended Ecological Category (REC) and the Reserve expressed as a percentage of the cumulative normal Mean Annual Runoff (NMAR)*

13.1 RESOURCE UNIT 4

The high to very high EIS of the Crocodile River in RU 4 is mainly attributable to the ecological importance of this system as a natural corridor for a high diversity of aquatic biota (there are 14 fish species and numerous birds and invertebrates that depend on this system) and the presence of a diversity of habitat types and the occurrence of various sensitive (in terms of flow and water quality) and endangered aquatic species(such as hippo, crocodile, the Orangefin Barb, Southern Barred Minnow and the Shortspine Suckermouth).

In keeping with the objectives of the RDM to improve or at least maintain the present ecological state (PES) of significant water resources, the preliminary Recommended Ecological Category (REC) for the Crocodile River in QC X22K was determined as a C.

According to the Rapid II Reserve study for the White River by Nepid Consultants (Nepid Consultants, 2007) the water quality of White River (a tributary of the Crocodile River) in QC X22H is more degraded than that of the Crocodile River, with the main problem pertaining to elevated nutrient levels. According to the report, the water quality below Longmere Dam, above the proposed discharge point by the White River sewerage works is already slightly eutrophic due to the surrounding agricultural runoff.

Furthermore, there have been significant changes in water quality from natural conditions over the years, especially in terms of temperature. This is attributed to the impacts of Longmere Dam. Winter stream temperatures are warmer than natural, while summer temperatures are lower than natural. The changes in water temperatures might have a significant impact on in-stream species composition and oxygen concentration.

DWA recognises the PES of the Crocodile River at EWR Site 4 as a C Category, which represents a moderately modified state of ecological integrity. (DWA, 2010) This is mainly attributable to pressure from intensive agricultural, industrial and urban land use in the catchment area of RUt 4 .Domestic runoff as well as urban and industrial waste from Nelspruit; together with other impacts on the riparian zone have had a significant impact on the health of the Crocodile River.

In keeping with the objectives of the RDM to improve or at least maintain the PES of significant water resources, the preliminary REC for the Crocodile River in quaternary catchment X22K was determined as a C. However, as the EIS at EWR 4 is high, it was recommended that the Crocodile River at EWR Site 4 be improved to a B Category. This would require improvements to the flow regime, an overall improvement in the water quality, i.e. nutrients alien vegetation removal and erosion control. The PES for the individual biophysical components of the Crocodile River Ecosystem at EWR Site 4 as well as the reasons for the PES are summarised in **Table 13-3**.

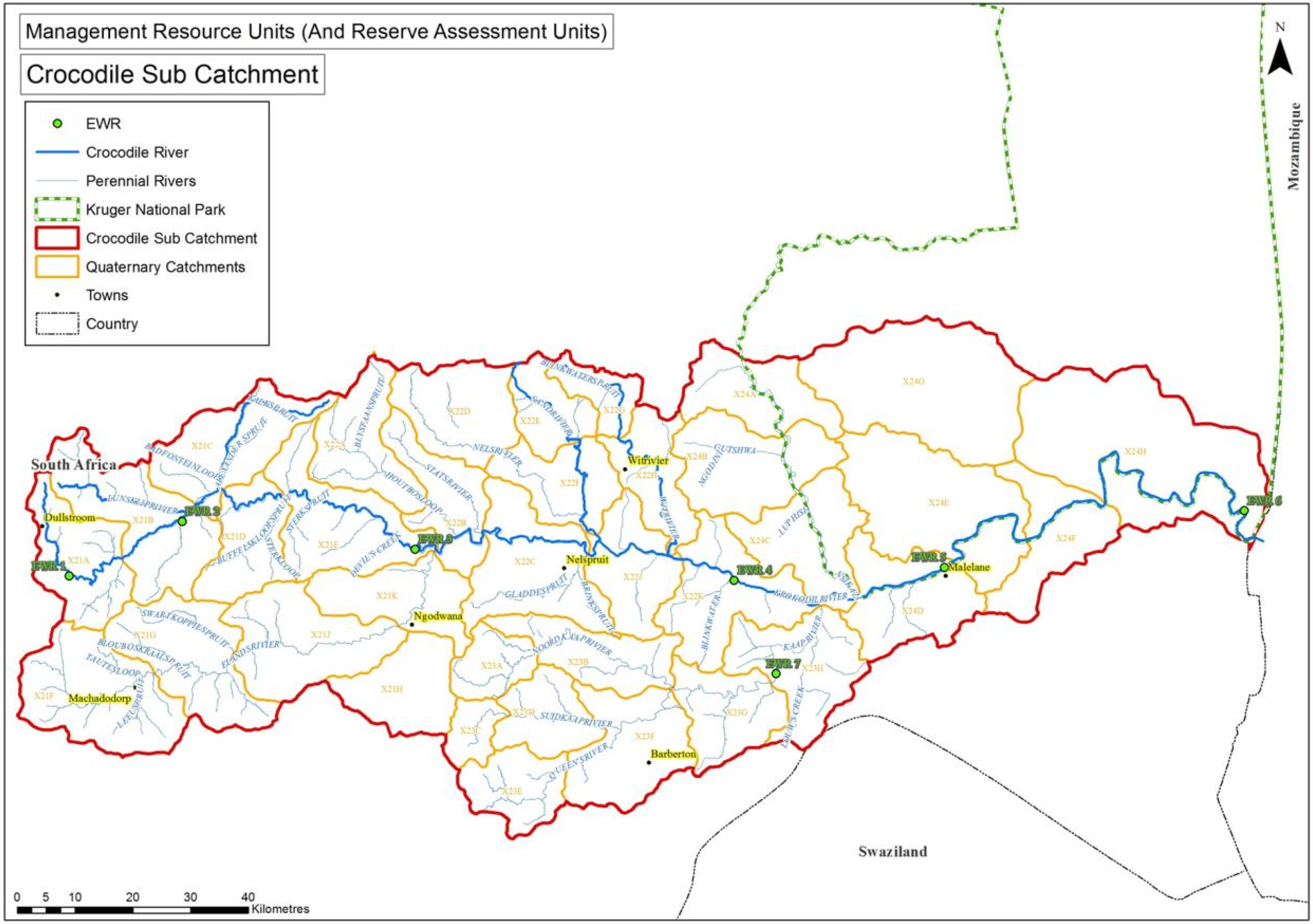

Figure 13-2: Management Resource Units in the Crocodile River

Table 13-3: PES, sources, and causes for the individual biophysical components of the Crocodile River Ecosystem at EWR Site 4

	PES	Confidence	Causes	Source
Hydro	C	3	Altered low flow and flooding	Kwena Dam, Irrigation and Forestry
Physico/ Chemico	C	3	Elevated Nutrients, Toxics, temperature turbidity and oxygen fluctuations	Extensive cultivation, Urban/peri-urban areas. Poor land management and return flows
Geomorphology	B/C	3	Reduced sediment transport capacity	Reduced flood flow and increased abstraction from Nelspruit
			Increased sediment supply	Agriculture and some informal settlement areas
Riparian Vegetation	C	3.6	Increased reed cover	Reduced flows with expansion of marginal zones
			Change in species composition	Exotic species invasion
			Reduced woody cover and abundance and increased cover by grasses and open sand	Vegetation removal, grazing trampling and frequent fires
Fish	B	4	Altered fish assemblage (loss in abundance. breeding and feeding success).	Altered water quality, Nelspruit Municipal, White River Municipal and industrial runoff

14 INKOMATI WATER AVAILABILITY ASSESSMENT: WATER QUALITY SITUATION

This study (Water for Africa, 2009) was initiated in response to the major stresses facing the WMA in terms of high water demands by Eskom, irrigation, afforestation, industry, and rapidly increasing domestic water demands. The water shortages experienced in the area have led to intense competition for the available water resources among user sectors. In addition, a substantial portion of the population in the WMA does not have access to the basic level of services. Furthermore, the large numbers of dams in the study area not only change the flow regime but also impact the water quality.

14.1 OBJECTIVE OF THE STUDY

This water quality assessment aimed to provide a reconnaissance level analysis of the available information pertaining to the current water quality situation in the X1, X2 and X3 catchment areas, and by doing so identify water quality issues or aspects that have an impact on water resource management in the Inkomati WMA.

The study area for the assessment comprised the X drainage area, which included the Komati, Crocodile and Sabie River catchments. Key monitoring points were identified for each river system, based on the availability of reliable data sets. The points selected were located on the main stem of the rivers and on the major tributaries. The assessment was limited to historical water quality data obtained from DWAF. A large number of water quality variables were found to be monitored in these catchments. However, the data used for the analysis had different time scales, different sampling frequencies, different laboratories and used different analytical methods.

The lack of an integrated holistic monitoring programme for the different water resources made the identification of water quality trends difficult. Taking these limitations into account, the data was used to determine the water quality status and to correlate this with activities in the area. Water quality was assessed based on the trends identified and on the basis of compliance to selected water quality guidelines in terms of the South African Water Quality Guidelines (SAWQGs).

14.2 CONCLUSION

The water quality in the Inkomati WMA was reported to be in a good to fair condition. The main water quality issues related to nutrients and in certain catchments to elevated salt levels. These issues were related mainly to land based activities such as urbanisation, industrial activity, and agricultural activity such as intensive irrigation. It was recommended that these sources be controlled to maintain the quality and prevent any further deterioration.

15 ASSUMPTIONS AND LIMITATIONS

The following assumptions are made regarding the water quality sampling and data analysis of all samples by these institutions (DWA and SEMBCORP) was undertaken by accredited laboratories which complied with the quality criteria of these institutions.

- Sampling and sample handling were done according to an approved protocol prescribed by these institutions and that these protocols are acceptable best practice
- The analytical methods and the detection limits used will stand up to critical scrutiny.

The following limitations are noted with regard to this water quality report for the Mbombela Reconciliation Strategy:

- This was a desktop study and no water quality sampling took place during this study for the purpose of this study
- It was not possible to explain the wide variance, of many variables, in monitoring results reported during this investigation since no record of pollution incidents in the catchment at the particular times was available. Should finer analysis of the available data be required it is proposed that a further study be commissioned focussing on these discrepancies only. The trend analysis is however a good indication of the general water quality.
- Water quality reflected from samples taken at WWTWs is measured quality in the rivers, and are not discharge qualities.

16 WATER DEMAND CENTRES

For practical purposes the catchment which is covered in this study has been logically divided into the following water demand centres (WDCs):

- Nelspruit (including Mataffin, the agricultural college and Matumi golf course)
- White River town (including White River country estate and Rocky's Drift
- Hazyview
- Nsikazi South
- Nsikazi North
- Karino Plaston Corridor (including areas in Nsikazi South not getting water from Kanyamazane, e.g. Mamelodi, Tekwane North and Emoyeni)
- Matsulu
- Ngodwana, Kaapsehoop, Elandshoek)

These WDCs are shown in **Figure 16-1**.

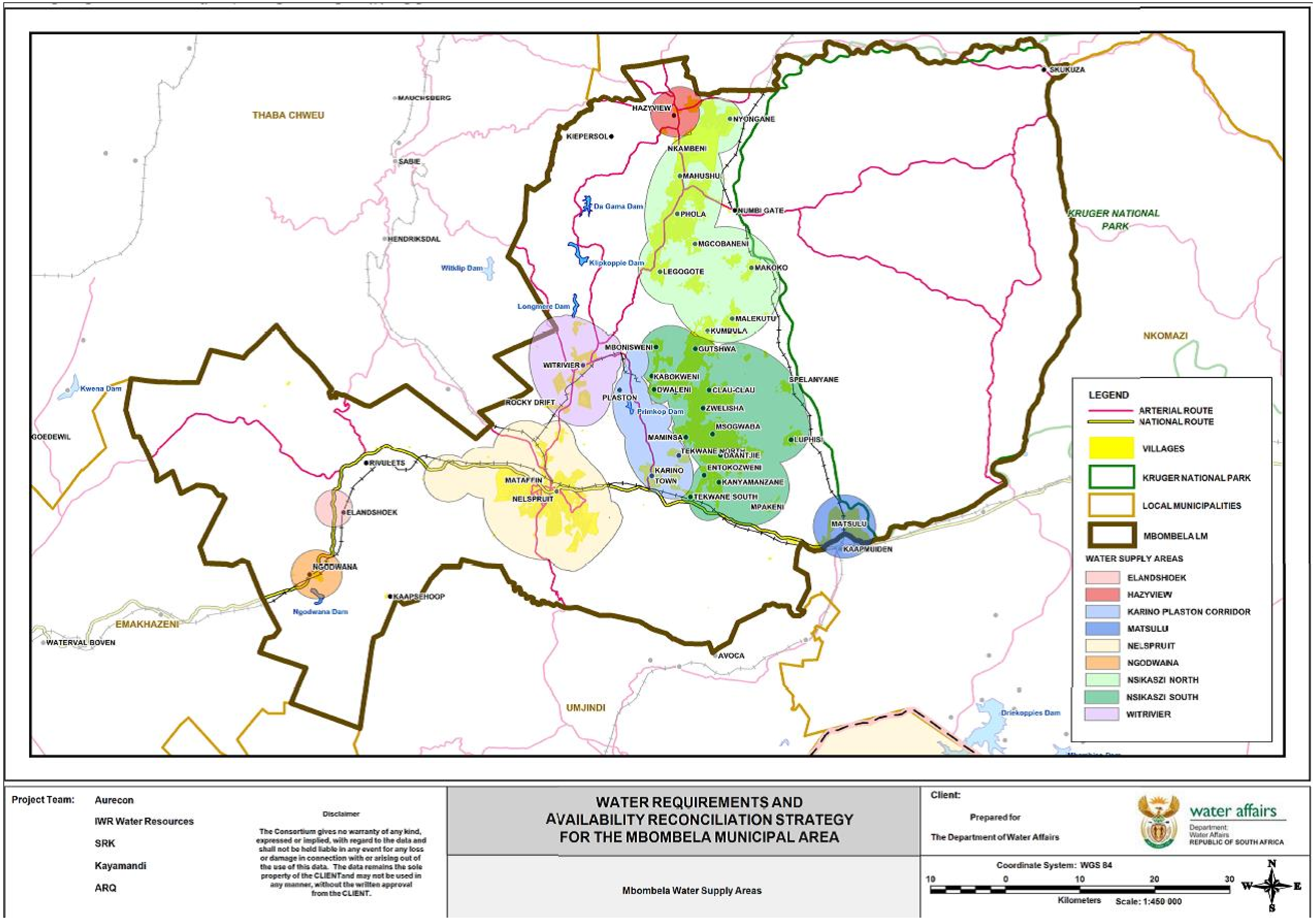

Figure 16-1: Water Demand Centres

17 NELSPRUIT (INCLUDING MATAFFIN, THE AGRICULTURAL COLLEGE AND MATUMI GOLF COURSE)

17.1 SOURCES OF POLLUTION

The in-stream and riparian conditions deteriorate in the Crocodile River in and area around Nelspruit as indicated by riparian habitats and vegetation (poor), fish (fair to poor) and invertebrates (poor to unacceptable). Downstream from Nelspruit the river gradually recovers to a fair state. This section of the Crocodile River is impacted by intensive agricultural, industrial and urban land uses. Large areas are used for irrigated agriculture, ranging from fruit (predominantly citrus) orchards to vegetable cultivation (DEAT, 2007).

Poor water quality in the Nelspruit area is specifically associated with domestic runoff, littering and increased nutrients. Water is abstracted from the Crocodile River for irrigation and to purify for domestic use. In addition to formal agricultural activities, alien plants and aquatic weeds such as water hyacinth have an impact on the riparian and in-stream health respectively. A sampling site near Schagen, which has been used since the 1970s, is now so densely infested with alien vegetation that it is barely accessible. Domestic runoff and urban and industrial waste from Nelspruit have a significant impact on the health of the Crocodile River. (DEAT, 2007)

Major industries in this WDC include the following:

17.1.1 Industry

- Manganese Metal Company
  The Manganese Metal Company (MMC) is the single largest producer of pure electrolytic manganese (Mn) metal in the world. MMC produces electrolytic manganese - the purest form of manganese - from ore mined in South Africa via a hydrometallurgical extraction process. A range of products are manufactured and marketed from the metal, with the majority being exported. All the products are manufactured using a selenium free process, leading to a minimum 99,9% Mn content.

- Delta EMD
  Delta EMD is a leading global supplier of electrolytic manganese dioxide (EMD), which is used primarily for the manufacture of dry cell batteries worldwide.

  MMC and Delta Manganese discharge manganese into the sewer system when they experience failures in their systems and cannot treat their own effluent. This discharge then flows to the Kingstonvale WWTW, with potential consequences for the water quality of the WDCs downstream on the Crocodile River.

- Coca-Cola Fortune (CCF)
  Coca-Cola Fortune (CCF) is one of four licensed Coca-Cola bottlers in South Africa. Coca-Cola Fortune has five manufacturing sites in South Africa, of which one is situated in Nelspruit.

17.1.2 Waste water treatment works

- Kingstonvale Waste Water Treatment Works
  Kingstonvale WWTW is an activated sludge process with nutrient removal and anaerobic sludge digestion. The treatment works has a design capacity of 26 Mℓ/d and

is currently being operated at an average of 50% of its capacity. Kingstonvale WWTW is a major contributor of the high nutrient loads in the river.

17.1.3 Other

Other sources of pollution exist in the Nels River and Gladde Spruit, the two tributaries which flow into the Crocodile River in the vicinity of Nelspruit. Agricultural runoff here is typified by increases in EC, trace elements, and nutrients. Diffuse source releases from Papas Quarry, which is used by MMC for manganese sludge storage at the confluence with the Gladde Spruit, are a source of increased manganese concentrations in the Crocodile River.

17.2 ACTUAL WATER QUALITY VERSUS WATER QUALITY OBJECTIVES

The overall state of this section of the Crocodile River can be described as fair. Upstream from Nelspruit the in-stream biota reflects a good to fair ecological state.

The Reserve RWQOs that have been set for this section were based on the recommendation of DWA to use the comprehensive Reserve determination undertaken for Sappi in the Elands River (X21K).

The actual water quality monitored by DWA through the Chemical Monitoring Programme evaluated against water user requirements are shown in **Table 17-1** below.

DWA's water quality standards and guidelines are met in the Crocodile River and its tributaries in the vicinity of Nelspruit in terms of 90th percentile for pH, conductivity, total dissolved solids, chlorides and sulphates. However, ammonia levels in the discharge stream from Kingstonvale WWTW exceed the DWA standard more than 10 times.

Table 17-1: Water Quality Guidelines and Standards for the Nelspruit area

Variable	Water quality standards and guidelines							Water Quality at (90th Percentile)			X21K
	Stds	Guidelines (DWAF, 1996 (5)) (DWAF, 1996 (7)) (DWAF, 1996 (1)) (DWAF, 1996 (2))						@ Kingstonvale WWTW	@ Papas Quarry in Gladdespruit	Crocodile @ Weltevrede	Preliminary Reserve
mg/ℓ unless otherwise specified	SANS241: 2011 Lifetime consumption	Domestic use (sulfate from WHO Guideline, 2004)	Bathing	Laundry	Livestock watering	Irrigation	Aquatic ecosystems	WMS 1000009827	WMS 1000009826	X22 102975	
pH Value @ 23°C	5,0 - 9,5	5,0 - 9,5	4,5 - 9,5	5,0 - 10	Ns	6,5 - 8,5	6,5 – 9,0	7,72	8,03	8,07	
Conductivity (mS/m @ 22°C)	170	150	520	Ns	40 - 270	Ns	Ns	90	35,3	26,2	
Total Dissolved Solids	1 200	1 000	3 400	1 000 - 5 000	260 - 1 775	260&	<15% change from normal cycle; no change in amplitude/frequency of cycles	549	92,7	182	
Chloride, Cl mg/ℓ	300	200	No effects	2 000 - 3 000	100-700	100&	Ns	58	6,91	21,1	
Sulfate, SO_4 mg/ℓ	500	500	600	1 000	Ns	Ns	Ns	185	15,3	185	
Phosphate mg/ℓ	Ns	NS	NS	NS	NS	NS	NS	10,7	0,7	10,7	<0,058
Ammonia mg/ℓ	1,5			Ns	Ns		0,015 as unionised ammonia	17,7	0,6	0,091	<0,046
Arsenic mg/ℓ		0 - 10			0 - 1	0 - 0,1					
Manganese mg/ℓ		0,05 - 0,10			0 - 10	0 - 0,2					

Crops sensitive to total dissolved solids/electrical conductivity include fruit, almonds, root vegetables (except beet), maize, sunflowers and rice. Tolerant crops include asparagus, sugarbeet, sorghum, oats, wheat and rye
Crops sensitive to chloride include sunflower, wheat, and citrus. Tolerant crops include tobacco, maize, oats where tolerance is based on reduction in vegetative growth &: Based on sensitive crops

17.3 TREND ANALYSES

Sampling has been taking place in the Crocodile River at Weltevreden since 1972, and data is available until June 2011. A total of 1 251 EC measurements are available. The EC varies between 3,8 mS/m and 90,3 mS/m. EC has steadily been increasing since 2000, but appears to be stable now. The increase could possibly be ascribed to rapid urbanisation, since same trend is observed for phosphate and ammonia.

The water quality trend in the Crocodile catchment upstream of the Kaap River confluence indicates an increasing trend in turbidity and nutrients (i.e. phosphates and nitrogen), due to increased urbanisation (e.g. treated and untreated waste water returns to the river). The ammonia level is extremely high, which poses a serious threat to the aquatic environment.

Water samples are also being taken by Sembcorp at various points in the rivers for general analysis, including sampling for metals at both the new and old Nelspruit WTWs.

17.4 WATER QUALITY MANAGEMENT STRATEGY

The operations and maintenance (O&M) activities of many of the WWTWs are poor, and as a result, poor quality effluents are discharged. In many cases, the WWTWs are not able to handle either the hydraulic or the organic loads. As a result, the installed treatment technology is not always working to specification.

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

The medium to long term strategy will be the further management of phosphorus by reducing the load discharged from point sources. A nutrient balance study is therefore proposed which will result in a better understanding of the sources and fate of nutrients (phosphorus and nitrogen) and will provide the rationale for revising the current 1 mg/ℓ phosphorus discharge standard. A perspective is needed on the extent and costs of the measures needed (such as banning phosphorus containing detergents) to reduce the phosphorus loads received at the WWTWs.

17.5 ACTIONS

The following actions are proposed for mitigating the poor water quality situation in the stretch of the Crocodile River near to Nelspruit:

1. The reason for low compliance at the Kingstonvale WWTW relates to non-compliant chemical discharges. It is imperative that the root cause for non-compliance is found, since the WWTW is operating within capacity. If the reason for non-compliance is an operational issue it may more easily be rectified than if the works were operating over capacity.

2. The illegal discharge into the waste water system from MMC and Delta EMD should be addressed. The industries should have emergency measures put in place which will be automatically implemented when their systems fail. MLM would be held responsible when their WWTW effluent does not comply with the conditions set out in their WUL.

3. Programmes to remove alien vegetation along the river should be started if the areas are not yet covered under the Working for Water Programmes.

18 WHITE RIVER TOWN (INCLUDING WHITE RIVER COUNTRY ESTATE AND ROCKY'S DRIFT

18.1 SOURCES OF POLLUTION

The following water pollution threats currently exist in and around the town of White River:

18.1.1 Waste water treatment works

- White River Waste Water Treatment Works
  The White River WWTW is operated well within its design capacity of 6 Mℓ/d. It is an activated sludge treatment works with sludge drying beds. However, the water being discharged does not comply with the licenced standards.

- Rocky's Drift Waste Water Treatment Works
  Rocky's Drift WWTW has is a small activated sludge plant with a daily capacity of 1,5 Mℓ/d, with associated sludge drying beds. No monitoring is currently being undertaken which has resulted in the plant achieving a poor Green Drop assessment.

- Other
  Rocky's Drift is a light industrial area which has the potential for contaminated run-off during storm events.

  Hazyview Rural communities which are poorly serviced have the potential to impact on water quality when wastes are flushed into the water resources during storm events. The more densely the populations become the bigger the potential for pollution. (DWAF, 2001).

  Forestry activities close to or within the riparian zone are the primary threat to the health of the riparian habitats and vegetation. (DEAT, 2007).

  Trout farming is a threat to in-stream ecological health, through diversion of water for dams and weirs, which impact on the water flows in the area. Further, rivers may become enriched with nutrients from fish feed and waste. (DEAT, 2007).

18.2 ACTUAL WATER QUALITY VERSUS WATER QUALITY GUIDELINES

Measurements at Rocky's (Rocky's Drift) show that no parameters measured exceed the target water quality guidelines.

The actual water quality monitored by DWA through the Chemical Monitoring Programme evaluated against water user requirements are shown in **Table 18-1** below.

Table 18-1: Water Quality Guidelines and Standards for the White River area

Variable	Water quality standards and guidelines							Water Quality at(90th Percentile)
	Stds	Guidelines for Domestic, Agriculture and Aquatic Ecosystem (DWAF, 1996)						@ Rocky's at Rocky's Drift
mg/ℓ unless otherwise specified	**SANS241: 2011 Lifetime consumption**	**Domestic use (sulphate from WHO Guideline, 2004)**	**Bathing**	**Laundry**	**Livestock watering**	**Irrigation**	**Aquatic ecosystems**	**WMS 192543**
pH Value @ 23°C	5,0 - 9,5	5,0 - 9,5	4,5 - 9,5	5,0 - 10	Ns	6,5 - 8,5	6,5 – 9,0	8,08
Conductivity (mS/m @ 22°C)	170	150	520	Ns	40 - 270	Ns	Ns	49,1
Total Dissolved Solids	1 200	1 000	3 400	1 000 - 5 000	260 - 1 775	260[&]	<15% change from normal cycle; no change in amplitude/frequency of cycles	327
Chloride, Cl	300	200	No effects	2 000 - 3 000	100 - 700	100[&]	Ns	53,1
Sulfate, SO_4	500	500	600	1 000	Ns	Ns	Ns	0,6
Phosphate	Ns	Ns	Ns	Ns	Ns	Ns	Ns	2,7
Ammonia	1,5			Ns	Ns		0,015 as unionised ammonia	0,48
Arsenic mg/ℓ		0 - 10			0 - 1	0 - 0,1		
Manganese mg/ℓ		0,05 - 0,10			0 - 10	0 - 0,2		

18.3 TREND ANALYSES

Limited monitoring data is available, with a sampling record only since 2009. Seventeen EC measurements have been taken, with values varying between 9,92 mS/m and 49,3 mS/m; with a median of 39,7 mS/m. Seasonal variation in water quality data is observed. The EC remained stable with no upward trend for the period over which data is available.

19 HAZYVIEW

19.1 SOURCES OF POLLUTION

19.1.1 Waste water treatment works

- Hazyview Waste Water Treatment Works
  The Hazyview WWTW is an activated sludge plant with associated drying beds. The design capacity is 0,7 Mℓ/d. The works is currently being operated at 50% above its design capacity resulting in discharge of poor water quality and low compliance. The plant is also non-compliant with the chemical physical compliance (DWA, 2011).

19.1.2 Industry

Sawdust from sawmill and forestry activities close to or within the riparian zone of the Sabie River are the primary threat to the health of the riparian habitats and vegetation, as the dust washes into the river during rainfall events. Cresols and phenols leach out of the sawdust, acidifying the soil and water. The dust physically smothers vegetation and in-stream habitats, lowering vegetation health, and invertebrate diversity and abundance. Finer dust particles clog the gills of fish.

Erosion and sedimentation results from dirt roads and fruit orchards, such as banana plantations, close to the Sabie River. This impairs in-stream water quality and reduces habitat availability. (DEAT, 2007).

19.1.3 Other

The water quality trends in the Sabie River indicate increasing nutrient and turbidity levels. The turbidity trend is due to over-grazing, and the removal of vegetation for firewood from the slopes of the river. The increasing nutrient levels are due to run off from areas associated with the use of fertilisers for the growth of sub-tropical fruits, as well as from sewage waste (both formal and un-serviced). (DEAT, 2007)

19.2 ACTUAL WATER QUALITY VERSUS WATER QUALITY OBJECTIVES

Hazyview sewage effluent conforms to the DWA Standards and guidelines as far as the parameters pH, EC, TDS, chloride, sulphates and phosphates are concerned, but the ammonia levels exceed the standard by more than 10 times.

The actual water quality monitored by DWA through the Chemical Monitoring Programme evaluated against water user requirements are shown in **Table 19-1** below.

Table 19-1: Water Quality Guidelines and Standards for the Sabie River

Variable	Water quality standards and guidelines							Water Quality at 90th Percentile	X21K
	Stds	Guidelines (DWAF, 1996)						@ Hazyview Sewage Effluent	Reserve
mg/ℓ unless otherwise specified	SANS241: 2011 Lifetime consumption	Domestic use (sulphate from WHO Guideline, 2004)	Bathing	Laundry	Livestock watering	Irrigation	Aquatic ecosystems	WMS10000010080	
pH Value @ 23°C	5,0 - 9,5	5,0 - 9,5	4,5 - 9,5	5,0 - 10	Ns	6,5 - 8,5	6,5 – 9,0	8,05	
Conductivity (mS/m @ 22°C)	170	150	520	Ns	40-270	Ns	Ns	86,1	
Total Dissolved Solids	1 200	1 000	3 400	1 000 - 5 000	260 - 1 775	260&	<15% change from normal cycle; no change in amplitude/frequency of cycles	303	
Chloride, Cl	300	200	No effects	2000 - 3 000	100 - 700	100&	Ns	115	
Sufate, SO4	500	500	600	1 000	Ns	Ns	Ns	29	
Phosphate	Ns	Ns	Ns	Ns	Ns	Ns	Ns	8,3	0,058
Ammonia	1,5			Ns	Ns		0,015 as unionised ammonia	19	0,046
Total Inorganic N									1,83
Arsenic mg/ℓ		0-10			0 - 1	0 - 0,1	Arsenic mg/ℓ		0 - 10
Manganese mg/ℓ		0,05 - 0,10			0 - 10	0 - 0,2	Manganese mg/ℓ		0,05 - 0,10

19.3 TREND ANALYSES

Sampling started in mid-2008. However, no sampling or recorded measurements are available for 2009 and 2010. All the parameters except ammonia comply with the water user requirements: The ammonia exceeds the requirement for both the aquatic environment and drinking water standards. EC varies between 4,24 and 100 mS/m with a median of 46,7 mS/m. too few samples have been analysed for phosphates and ammonia to allow logical conclusions to be made regarding the trend of these parameters.

19.4 WATER QUALITY MANAGEMENT STRATEGY

The Hazyview plant must be considered for an upgrade to increase its current design capacity.

20 NSIKAZI SOUTH

20.1 SOURCES OF POLLUTION

20.1.1 Poor development and services

The Nsikazi South area, home to approximately 85% of the population of Mbombela, reflects generally poor development, and weak engineering and infrastructure services. These include:

- Low levels of engineering services including water, sewerage, roads and storm water control, and social facilities;
- Uncontrolled development associated with influx of people and fragmented (dispersed) development, and
- Rural communities which are poorly serviced have the potential to impact on water quality when wastes are flushed into the water resources during storm events.

20.1.2 Waste water treatment works

- Kanyamazane WWTW
  The Crocodile (East) River is associated with domestic runoff, littering and an increase in nutrients from WWTWs. Kanyamazane WWTW is an activated sludge works with associated sludge drying beds, with a design capacity of 12 Mℓ/d. Poor operational compliance results in high nutrient loads being released into the river.

- Kabokweni WWTW
  Kabokweni WWTW is an oxidation pond system with a capacity of 2 Mℓ/d. It is a new works, which was commissioned in 2011. The works discharges to the Ghutshwa River (Van Oudshoorn, 2012).

  Although both these works are operated below their design capacities, they are discharging poor quality effluent.

20.1.3 Other

Irrigated agriculture in the area contributes to high nutrient loads and possibly high levels of pesticides and herbicides.

Quarrying and sand winning occurs along the lower Crocodile River before the confluence with the Kaap River which has the potential to increase turbidity and suspended solids in the river.

20.2 ACTUAL WATER QUALITY VERSUS WATER QUALITY OBJECTIVES

The actual water quality monitored by DWA through the Chemical Monitoring Programme evaluated against water user requirements are shown in **Table 20-1** below.

Table 20-1: Water Quality Guidelines and Standards for Nsikazi South

Variable	Water quality standards and guidelines							Water Quality at(90th Percentile)	
	Stds	Guidelines (DWAF, 1996)						Down Stream Kanyemazane WWTW	Down Stream Kabokweni WWTW
mg/ℓ unless otherwise specified	SANS241: 2011 Lifetime consumption	Domestic use (sulphate from WHO Guideline, 2004)	Bathing	Laundry	Livestock watering	Irrigation	Aquatic ecosystems	X22 9839	
pH Value @ 23°C	5,0 – 9,5	5,0 – 9,5	4,5 – 9,5	5,0 - 10	Ns	6,5 – 8,5	6,5 – 9,0	7,97	7,83
Conductivity (mS/m @ 22°C)	170	150	520	Ns	40 - 270	Ns	Ns	75,3	84,1
Total Dissolved Solids	1 200	1 000	3 400	1 000 - 5 000	260 – 1 775	260[&]	<15% change from normal cycle; no change in amplitude/frequency of cycles	327	601
Chloride, Cl	300	200	No effects	2 000 – 3 000	100 - 700	100[&]	Ns	70,2	65,7
Sulfate, SO_4	500	500	600	1 000	Ns	Ns	Ns	42,6	11,7
Phosphate	Ns	Ns	Ns	Ns	Ns	Ns	Ns	6,2	5,42
Ammonia	1,5			Ns	Ns		0,015 as unionised ammonia	4,6	29,4
Arsenic mg/ℓ		0 - 10			0 - 1	0 - 0,1			
Manganese mg/ℓ		0,05 - 0,10			0 - 10	0 - 0,2			

20.3 WATER QUALITY MANAGEMENT ACTIONS

The non-compliance at the WWTW relates to its chemical discharges. It is imperative that the root cause for non-compliance is found, since the treatment works is operating within capacity. The reason for non-compliance may be an operational issue which might be easily rectified.

Oxidation pond technology does not, however, remove nutrients with the consequence that nitrogen and phosphates are discharged into the river, increasing the potential for eutrophication downstream.

20.4 TREND ANALYSES

Sampling at this point has been taking place since 2009. Exceptionally high levels of ammonia are consistently measured which relates to the type of treatment technology at the WWTW at Kabokweni. It is therefore expected, but unacceptable.

21 NSIKAZI NORTH

21.1 SOURCES OF POLLUTION

Nsikazi North is an area comprising largely poorly serviced rural communities.

Rural communities which are poorly serviced have the potential to impact on water quality when wastes are flushed into the water resources during storm events. The more densely the populations become, the bigger the potential for pollution (DWAF, 2001).

21.2 ACTUAL WATER QUALITY VERSUS WATER QUALITY OBJECTIVES

No water quality sampling is currently being undertaken by DWA in the Nsikazi North area.

22 KARINO PLASTON CORRIDOR (INCLUDING AREAS IN NSIKAZI SOUTH NOT GETTING WATER FROM KANYAMAZANE, E.G. MAMELODI, TEKWANE NORTH AND EMOYENI)

22.1 SOURCES OF POLLUTION

Rural communities which are poorly serviced have the potential to impact on water quality when wastes are flushed into the water resources during storm events. The more densely the populations become the bigger the potential for pollution. (DWAF, 2001)

Agricultural development in this area can potentially be responsible for high phosphates and nitrates in the catchment, a result of fertilizers leaching out of the ground.

22.2 ACTUAL WATER QUALITY VERSUS WATER QUALITY OBJECTIVES

The actual water quality monitored by DWA through the Chemical Monitoring Programme evaluated against water user requirements are shown in **Table 22-1** below.

Table 22-1: Water Quality Guidelines Standards and Objectives at Karino

Variable	Water quality standards and guidelines							Water Quality at 90th Percentile
	Stds	Guidelines (DWAF, 1996)						On Crocodile at Karino
mg/ℓ unless otherwise specified	SANS241: 2011 Lifetime consumption	Domestic use (sulfate) ate from WHO Guideline, 2004)	Bathing	Laundry	Livestock watering	Irrigation	Aquatic ecosystems	X22 2953
pH Value @ 23°C	5,0 – 9,5	5,0 – 9,5	4,5 – 9,5	5,0 - 10	Ns	6,5 – 8,5	6,5 – 9,0	7,54
Conductivity (mS/m @ 22°C)	170	150	520	Ns	40 - 270	Ns	Ns	27,8
Total Dissolved Solids	1 200	1 000	3 400	1 000 – 5 000	260 – 1 775	260&	<15% change from normal cycle; no change in amplitude/frequency of cycles	173
Chloride, Cl	300	200	No effects	2 000 – 3 000	100 - 700	100&	Ns	21,1
Sulfate, SO_4	500	500	600	1 000	Ns	Ns	Ns	26,7
Phosphate								0,084
Ammonia	1,5			Ns	Ns		0,015 as unionised ammonia	0,188

&: Based on sensitive crops
Crops sensitive to total dissolved solids/electrical conductivity include fruit, almonds, root vegetables (except beet), maize, sunflowers and rice. Tolerant crops include asparagus, sugar beet, sorghum, oats, wheat and rye
Crops sensitive to chloride include sunflower, wheat, and citrus. Tolerant crops include tobacco, maize, oats

22.3 TREND ANALYSES

Sampling records from DWA are available from 1972. All the parameters comply with the water user requirements. EC varies between 6 and 86 mS/m with a median of 17 mS/m. There was an initial increasing trend from 1997 to 2003 in EC however if the measurements are now compared on a month to month and year on year basis the levels are now higher but have stabilised. Measurements have not been linked to flow rates in the river.

Sembcorp is also monitoring water quality at various points in the river and at the Karino Water Treatment Works which also include analysis of metals. Increased Arsenic levels are regularly reported and an increasing trend is observed which can be seen in **Table 23-1**.

23 MATSULU

23.1 SOURCES OF POLLUTION

23.1.1 Matsulu WWTW

Matsulu WWTW is a 6 Mℓ/d design capacity activated sludge process with associated drying beds. The plant is currently operating below capacity however chemical compliance is poor (DWA, 2011). Waste water is being discharged to the Crocodile River.

23.1.2 Other

Rural communities which are poorly serviced have the potential to impact on water quality when wastes such as faeces, litter and household rubbish are flushed into the water resources during storm events.

23.2 ACTUAL WATER QUALITY VERSUS WATER QUALITY OBJECTIVES

The actual water quality monitored by DWA through the Chemical Monitoring Programme evaluated against water user requirements are shown in**Table 23-1** below.

Table 23-1: Water Quality Guidelines, Standards and Objectives for Matsulu

Variable	Water quality standards and guidelines								X21K
	Stds	Guidelines (DWAF, 1996)						Matsulu WWTW	Reserve
mg/ℓ unless otherwise specified	SANS241: 2011 Lifetime consumption	Domestic use (sulphate from WHO Guideline, 2004)	Bathing	Laundry	Livestock watering	Irrigation	Aquatic ecosystems	WMS10000010080	
pH Value @ 23°C	5,0 – 9,5	5,0 – 9,5	4,5 – 9,5	5,0 - 10	Ns	6,5 – 8,5	6,5 – 9,0	8,05	
Conductivity (mS/m @ 22°C)	170	150	520	Ns	40-270	Ns	Ns	88,5	
Arsenic	< 0,01							0,024	
Total Dissolved Solids	1 200	1 000	3 400	1 000 – 5 000	260 – 1 775	260[&]	<15% change from normal cycle; no change in amplitude/frequency of cycles	682	
Chloride, Cl	300	200	No effects	2 000 - 3 000	100 - 700	100[&]	Ns	50,1	
Sulfate, SO_4	500	500	600	1000	Ns	Ns	Ns	41	
Phosphate	Ns	Ns	Ns	Ns	Ns	Ns	Ns	0,013	0,058
Ammonia	1,5			Ns	Ns		0.015 as unionised ammonia	0,02	0,046
Total Inorganic N									1,83
Arsenic mg/ℓ		0 - 10			0 - 1	0 - 0,1			
Manganese mg/ℓ		0,05 – 0,10			0 - 10	0 – 0,2			

23.3 TREND ANALYSES

DWA is currently sampling only the inlet at the WWTW and the closest downstream point in the Crocodile River being monitored is in the Crocodile River at Malelane. Sembcorp is monitoring the water treatment inlet works and consistently report elevated levels of arsenic (exceeding the limit of 0.01mg/ℓ) and manganese in the water. An increasing trend in arsenic levels is observed, which can be seen in the figures presented in **Appendix G**: Arsenic Graphs.

24 OTHER WATER DEMAND CENTRES (NGODWANA, KAAPSE HOOP, ELANDSHOEK)

24.1 SOURCES OF POLLUTION

24.1.1 Industry

Sappi Paper Mill located in Ngodwana on the Elands River produces pulp which is used in the production of newsprint, kraft and white top linerboard, with the balance sold as market pulp.

The mill also produces elemental chlorine-free (ECF) bleached softwood pulp, made from a blend of southern pine grown in local plantations and bleached hardwood pulp from *Eucalyptus grandis*. The standard kraft pulping process is used in combination with a series of bleaching stages.

24.1.2 Mining

The Kaap River sub-catchment has been intensively mined for minerals, and the impacts of these mining operations are still reflected in the water quality of streams and rivers in this sub-catchment. (Heath & Melville, 1999). The Kaap River catchment is affected by agricultural activities, (irrigation and forestry).

24.2 ACTUAL WATER QUALITY VERSUS WATER QUALITY OBJECTIVES

Sampling records are available from 2008 for the Elands River. All the parameters comply with water user requirements. EC varies between 12 and 83 mS/m with a median of 41 mS/m, increasing during the dryer seasons and low flow situations, and dropping again in the summer season. Measurements have not been linked to flow rates in river. Phosphates and ammonia both exceed the water quality objectives set in the Reserve.

Both the agricultural and forestry activities taking place in this catchment use significant amounts of water, and change the quality of water returning to the river. In addition to formal agricultural activities, alien plants and aquatic weeds such as water hyacinth have impacted on riparian and in-stream health. However, the ecological state of the catchment is regarded as being “good”. According to the State of the Rivers Report (DEAT, 2007) it is desirable to manage the Kaap River Catchment to maintain a “good” ecological state.

The PES of the Kaap River catchment (RU 7), at the outlet of X23G where the Reserve was determined, is a category C, representing a moderately modified state. Sappi monitors the river as a condition of their WUL, the results of this analysis are presented in **Table 24-1**.

Table 24-1: Actual water quality versus water quality objectives

Variable	Water quality standards and guidelines							Water Quality at 90^{th} Percentile	Reserve X21K
	Stds	Guidelines (DWAF, 1996)						On Elands River DS Ngodwana	
	SANS241: 2011 Lifetime consumption	Domestic use (sulphate from WHO Guideline, 2004)	Bathing	Laundry	Livestock watering	Irrigation	Aquatic ecosystems	X21 192552	
H Value @ 23°C	5,0 – 9,5	5,0 – 9,5	4,5 – 9,5	5,0 - 10	Ns	6,5 – 8,5	6,5 – 9,0	7,4	6,5 – 8,8
Conductivity (mS/m @ 22°C)	170	150	520	Ns	40 - 270	Ns	Ns	73,2	
Total Dissolved Solids	1 200	1 000	3 400	1 000 – 5 000	260 – 1 775	260[&]	<15% change from normal cycle; no change in amplitude/frequency of cycles	333	
Chloride, Cl	300	200	No effects	2 000 - 3 000	100 - 700	100[&]	Ns	61,7	
Sulfate, SO_4	500	500	600	1 000	Ns	Ns	Ns	107	
Phosphate								0,07	0,058
Ammonia	1,5			Ns	Ns		0,015 as unionised ammonia	0,14	0,046
Total inorganic Nitrogen									1,83
Arsenic		0 - 10			0 - 1	0 – 0,1			
Manganese		0,05 – 0,10			0 - 10	0 - 0,2			

&: Based on sensitive crops

Crops sensitive to total dissolved solids/electrical conductivity include fruit, almonds, root vegetables (except beet), maize, sunflowers and rice. Tolerant crops include asparagus, sugarbeet, sorghum, oats, wheat and rye

Crops sensitive to chloride include sunflower, wheat, and citrus. Tolerant crops include tobacco, maize, oats

24.3 TREND ANALYSES

Seasonal water quality variations are observed. Data is available from only 16 water quality samples taken from February 2009 to January 2012, of which chemical analysis have only been done on four samples. Observations are not linked to flow rates in the river. Both ammonia and phosphate levels exceed the water quality objectives set in the Reserve.

From a month on month and year on year comparison for available data from 2009 to 2012, it can be concluded that TDS has stabilised over time.

25 MONITORING OF HEAVY METALS

DWA has been monitoring heavy metals (in addition to the other standard variables) at selected monitoring stations in the Crocodile River only. The monitoring points are shown in **Figure 25-1**. The heavy metal variables are not consistent for all monitoring points and the monitoring frequency and monitoring periods are short and infrequent not allowing for an evaluation of trends. **Table 25-1** summarises the results of the heavy metals analysis in the Crocodile catchment.

Table 25-1: Summary of heavy metal analysis in the Crocodile catchment

Station No.	Monitoring Point	Variables Analysed	Starting Period	End Period
1000009991	Crocodile downstream of Komatipoort Golf Course	Fe, Mn	2007	2012
1000010141	Kaap before confluence with Crocodile	As, Fe ,Mn	2012 (only 2 samples were taken)	2012
1000003124	Karino Bridge in Crocodile River	Fe, Mn	2008	2012
1000009990	Kruger National Park - @ Crocodile Bridge on Crocodile River @ Crocodile Bridge R/C	Fe, Mn	2011	2012
102958	Crocodile River at Montrose	Al, As, B, Ba, Be, Cd, Co, Cr (vi), Cu, Fe, Hg, Mn, Mo, Pb,	1992	1994
102963	Ten Bosch Kruger National Park on Crocodile River	Al, As, Ba, Be, Cd, Cr, Cu,Fe, Hg, Mn, Mo, Ni, Pb, Si,Sr, Ti,V, Zn, Zr	1992 (with the exception of Si being done from 1977 to 2011	1995
102987	Crocodile River at Malelane Bridge/Kruger National Park	Al, As, Ba, Be, Cd, Co, Cr, Cu,Fe, Hg, Mn, Mo, Ni, Pb, Si,Sr, Ti,V, Zn, Zr	1992	1995

(Resource Quality Services, 2013)

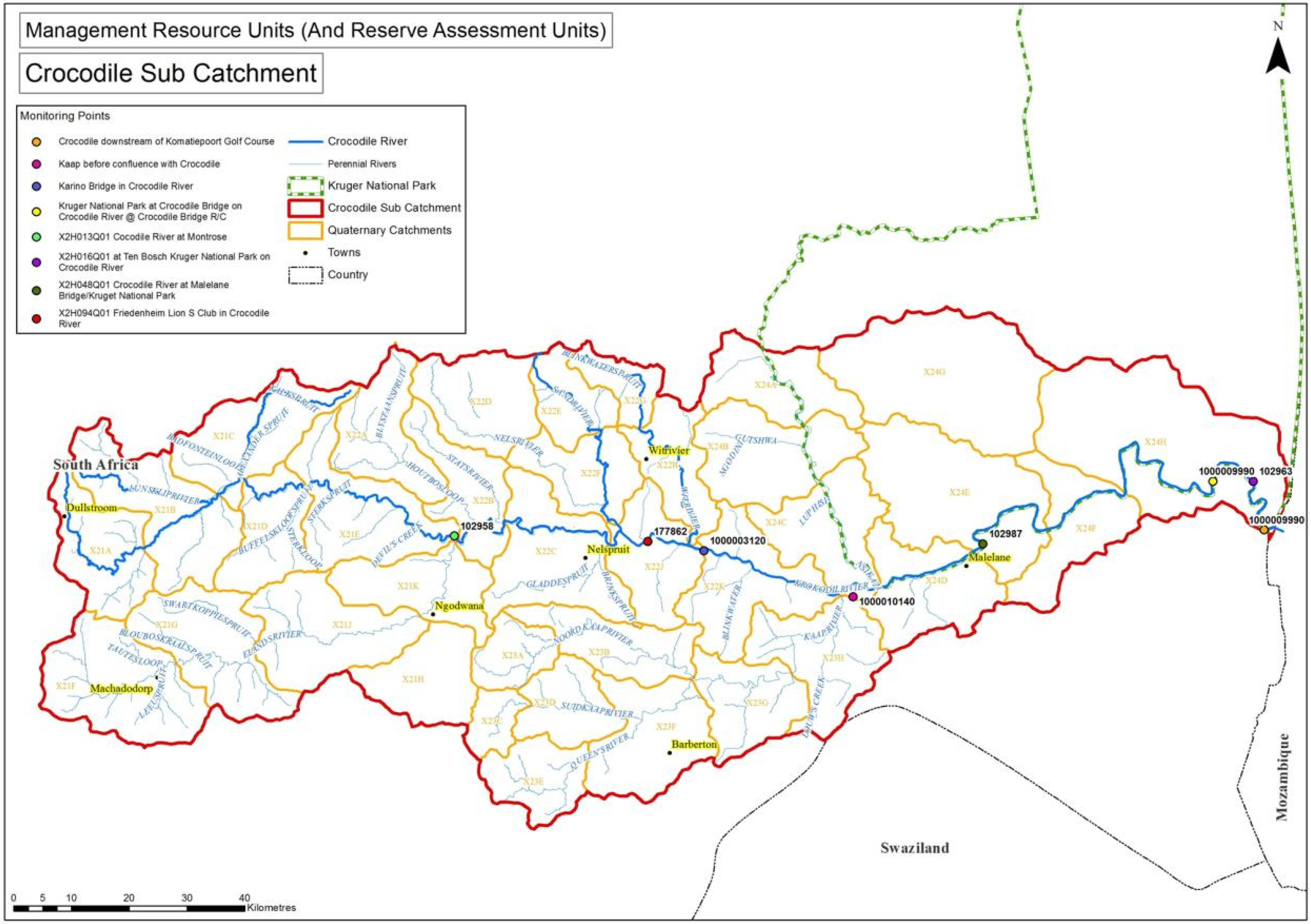

Figure 25-1: DWA monitoring points for heavy metals in the Crocodile River

26 WATER QUALITY MANAGEMENT STRATEGY

The biggest challenge to water quality management in the Crocodile River is in the vicinity of Nelspruit, where multiple "impactors" need to be managed. These activities include the disposal of solid wastes that often end up in and close to the river, and the quality of effluents that are being discharged.

Elevated levels of manganese and arsenic are alleged to occur across the catchment however the results for these parameters were not available from DWA's monitoring programme. Overall, the water quality in the Crocodile River at the intake of the abstraction works of the Nelspruit domestic/industrial water supply network is good and has no effect on the quality of water available for Nelspruit (i.e. no special treatment or dilution water is required). Poor discharge qualities from WWTW and industries do however have impacts on downstream abstraction points, where the treatment processes are not designed to treat these effluents.

An improvement in water quality, through improved pollution control, is required to achieve a good ecological state for in-stream biota at and downstream from Nelspruit. Improved management of the riparian zone is also required. Control of alien plants especially in riparian zones, is required in all catchments.

A strategic assessment and management of the trout industry in the Crocodile catchment needs to be undertaken. Evaluating the socio economic benefit to the region.

Control of agricultural activities, that involve clearing of ground cover (especially near to the riparian zone) in the Sabie Catchment, is required.

27 GENERAL COMMENTS

27.1 WASTE WATER TREATMENT

There is in general lack of knowledge and understanding amongst owners and operators of WWTWs in South Africa regarding the following issues, and it is assumed that the WWTWs in the study area are similar to the general norm in South Africa:

- Plant design (especially volumetric capacity);
- Treatment processes and technologies;
- Water quality and its impacts on the receiving environment (including the inter-relationship between surface and groundwater sources);
- Statutory compliance issues, including Environmental Authorisations in terms of NEMA (1998); licences/general authorisations in terms of NWA (1998); and special effluent standards enforced in the Crocodile River catchment;
- Absence of qualified process controllers readily present on site;
- General housekeeping (including neatness of the terrain, security fences; access control; etc.) (not regarded as a priority);

Kabokweni Oxidation ponds is a new treatment system, however the inability of the technology to achieve the Reserve requirements should place the upgrading of this technology as a high priority.

27.2 RECONCILIATION STRATEGY

Most of the water quality issues in the Crocodile River catchment area relate to pollution problems which must be addressed at source; if the water is not treated then it will become unfit for use. Generally, when water is fit for human consumption, it is fit for industrial use, except for a few cases in which the water must be pre-treated.

Industries should be encouraged to ensure that no water containing waste is released that does not comply with the determined standards. Discharging substandard effluent into the sewer is no solution if the treatment process cannot treat the specific variables. Emergency measures should be put in place to contain rather than release effluent in the event of failure of waste discharge treatment systems.

The increased arsenic concentrations in the Kaap River have a natural origin. The release into the water is however a result of mining activities and should be addressed at source through better regulation. DWA and the Department of Minerals Resources should agree on a strategy for the management of the historically closed and abandoned gold mines. Illegal alluvial gold mining in the catchment should be controlled.

The second proposed control strategy focuses on setting strict maximum limits for water abstractions during periods of low flow, and ensuring that there is always a minimum river flow available to maintain the target water quality during the dry season. This method is applicable to rivers that do not normally experience frequent extremely low flows. When rivers do frequently experience low flows, for example in arid and semi-arid regions, low-flow augmentation by an upstream reservoir can be proposed as the second control strategy. In this second control strategy, the relationships between reservoir operation and the resultant river water quality in downstream reaches should be well understood.

Regulating the flow pattern of water released from the Kwena Dam has the potential to achieve a remarkable reduction in the TDS and ammonia nitrogen concentration in the lower reaches of the Crocodile River. Ideally, the augmented flow pattern should follow or mimic the seasonal pattern of unregulated river flows. Based on flow data for 1987 to 1990, the minimum flow at the upper point of the Crocodile River study site should be at least 5 m^3·s-1 so that the TDS and ammonia concentrations in downstream reaches can be improved.

Importantly, it should also be noted that the proposed management options are not a stand-alone solution to guarantee the defined water quality objectives. Thus, in addition to the proposed management options, effluent quality standards and diffuse pollution regulation should always be considered. (Deksissa, Ashton, & Vanrolleghem, 2003)

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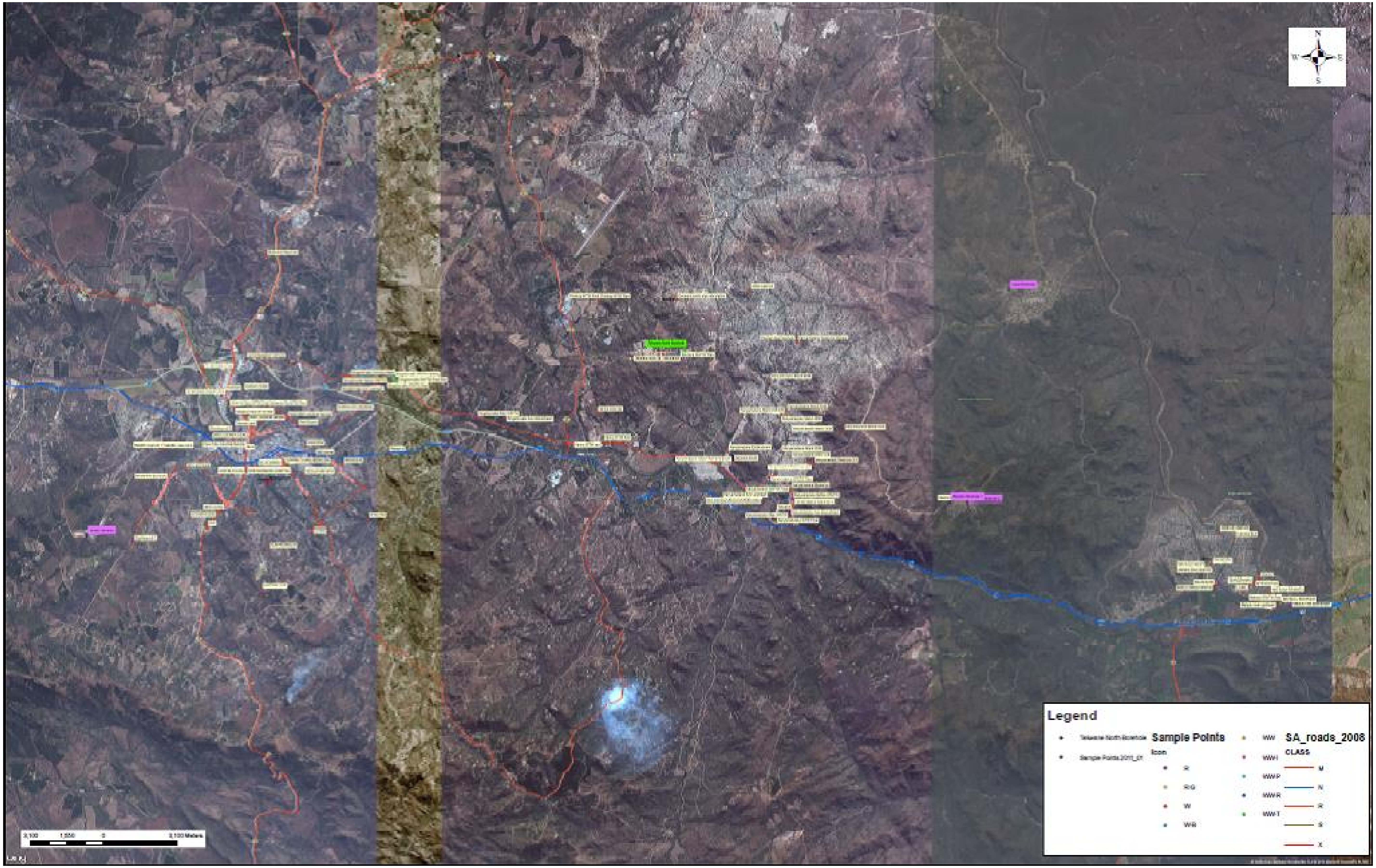
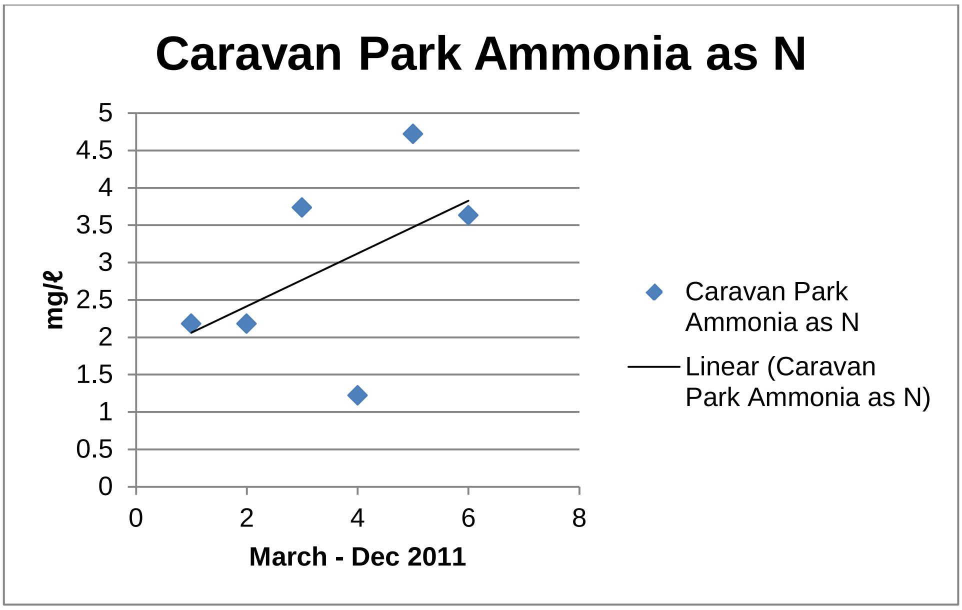
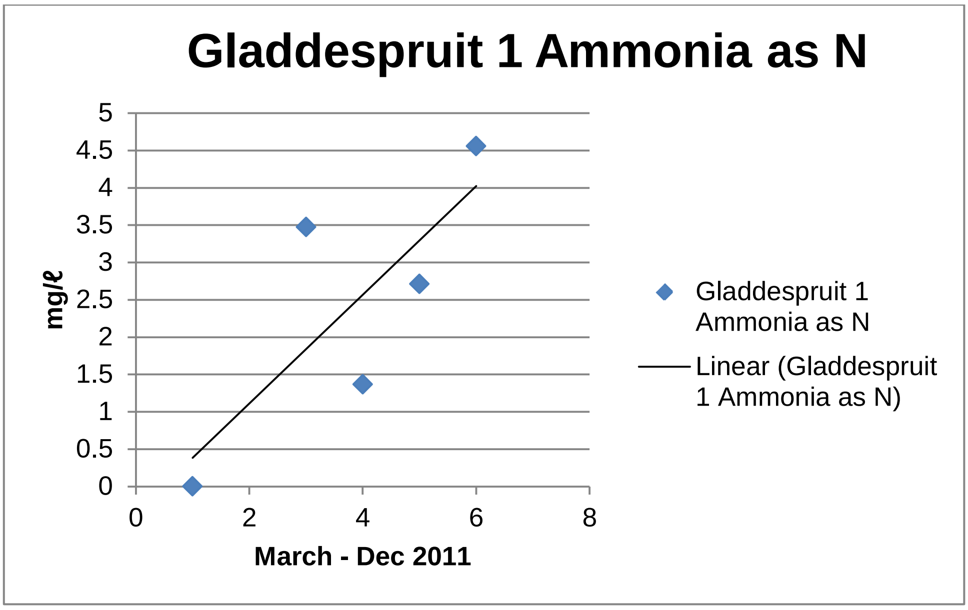
Appendix A: Sembcorp Monitoring Points

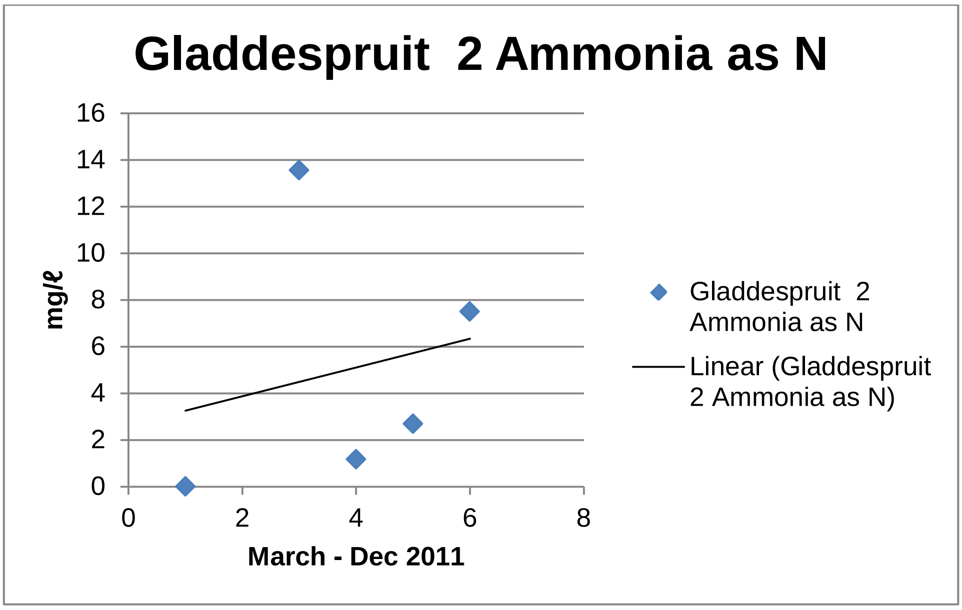


N
W
E
S
Legend
Sample Points
Icon
R
RG
W
WR
WW
WW-I
WW-P
WW-R
WW-T
SA_roads_2006
CLASS
M
N
R
S
X
3,100
1,550
0
3,100 Meters

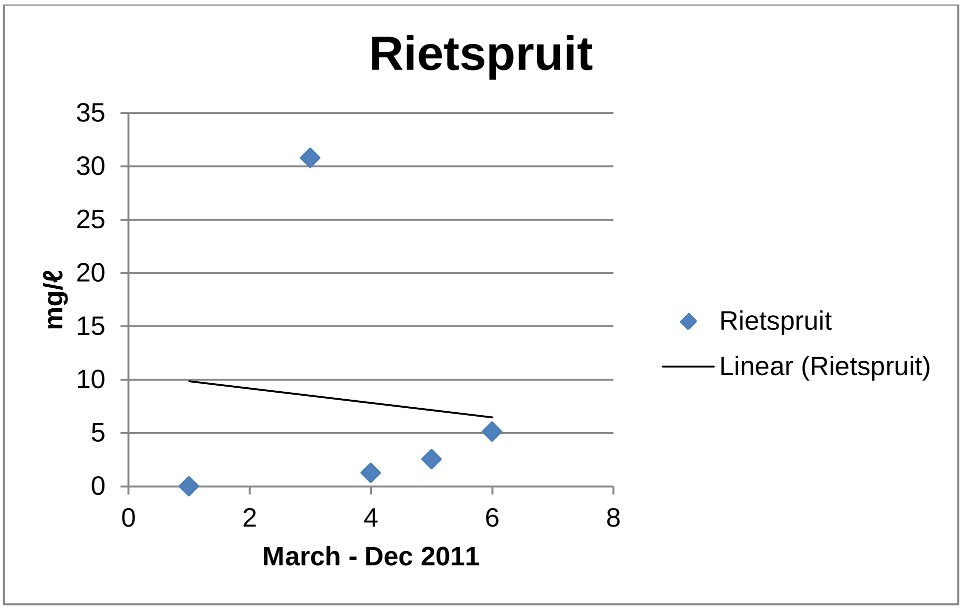
Appendix B: Ammonia Graphs

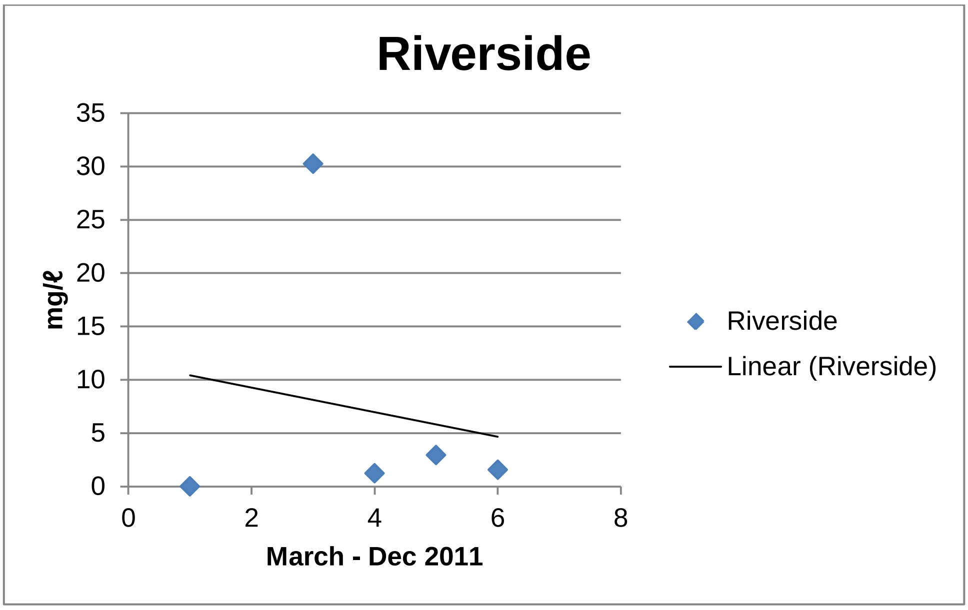

Caravan Park Ammonia as N
mg/ℓ
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
2
4
6
8
March - Dec 2011
Caravan Park Ammonia as N
Linear (Caravan Park Ammonia as N)

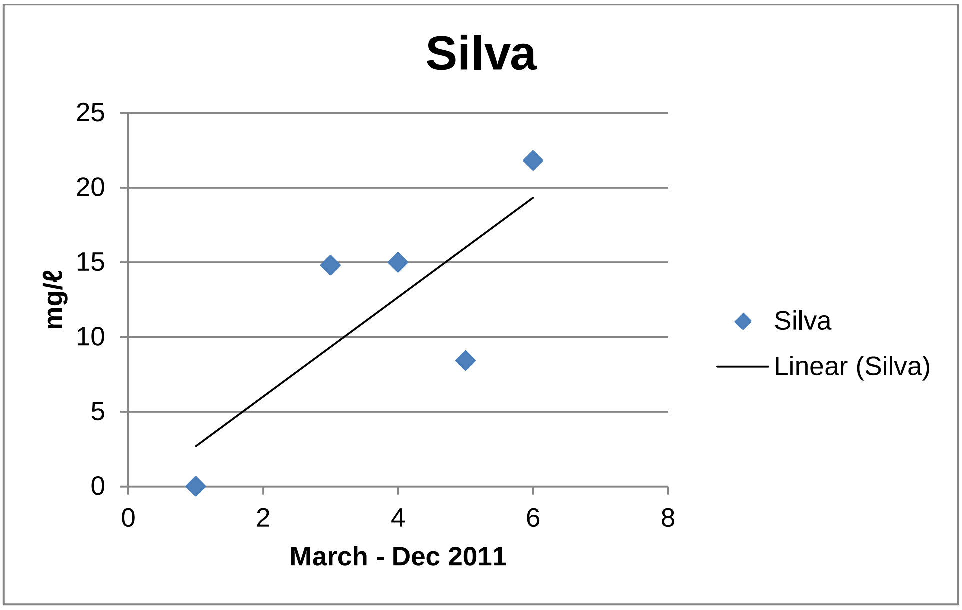

Gladdespruit 1 Ammonia as N
mg/ℓ
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
2
4
6
8
March - Dec 2011
Gladdespruit 1 Ammonia as N
Linear (Gladdespruit 1 Ammonia as N)

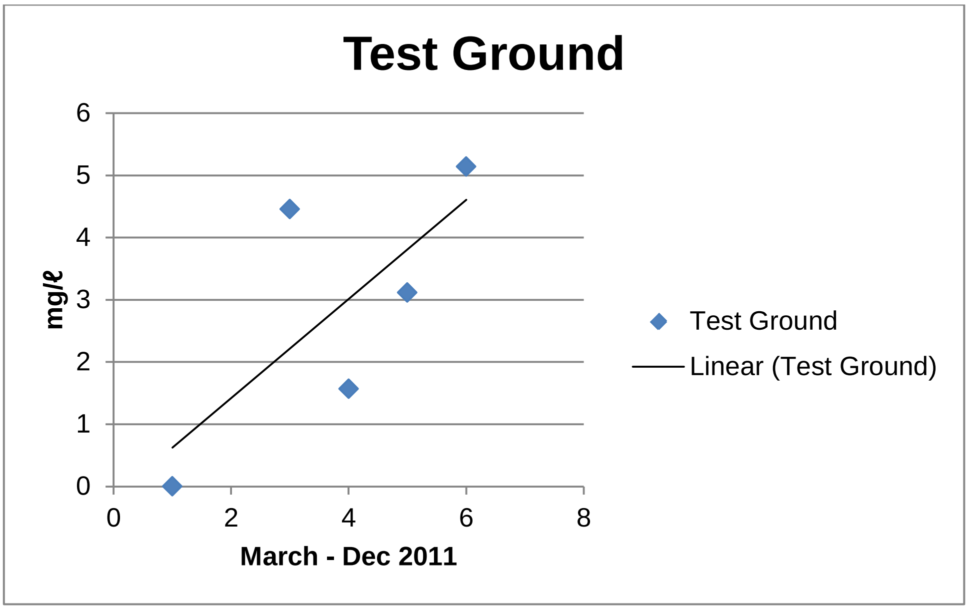

Gladdespruit 2 Ammonia as N
mg/ℓ
0
2
4
6
8
10
12
14
16
0
2
4
6
8
March - Dec 2011
Gladdespruit 2 Ammonia as N
Linear (Gladdespruit 2 Ammonia as N)

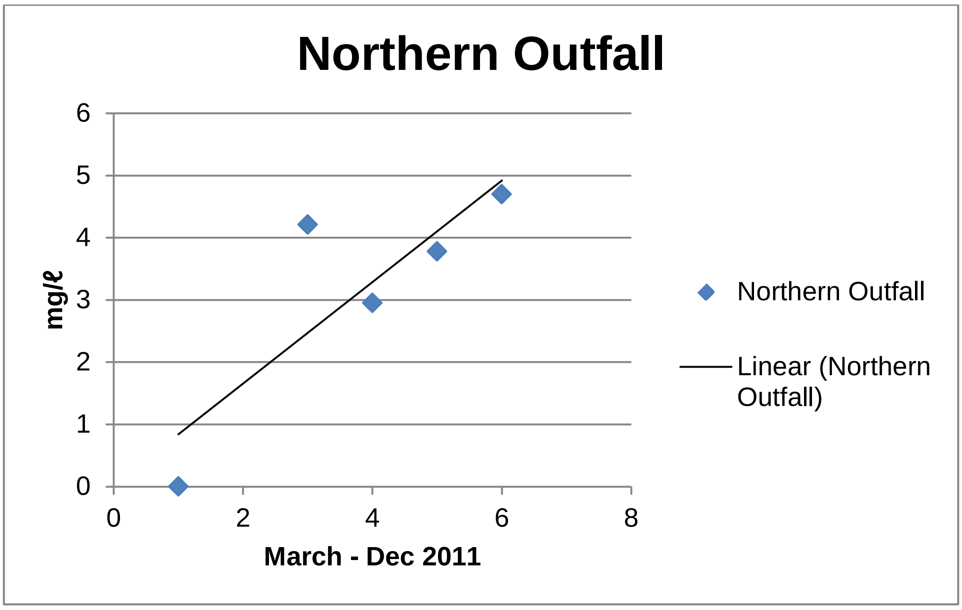

Golf course
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
mg/ℓ
0
2
4
6
8
March - Dec 2011
Golf course
Linear (Golf course)

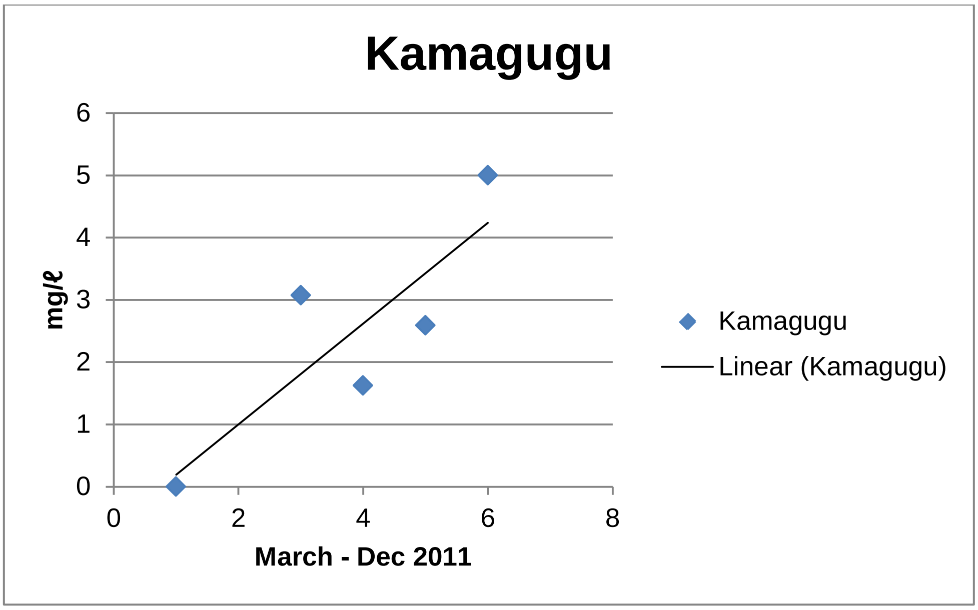

Rietspruit
35
30
25
20
15
10
5
0
mg/ℓ
0
2
4
6
8
March - Dec 2011
Rietspruit
Linear (Rietspruit)

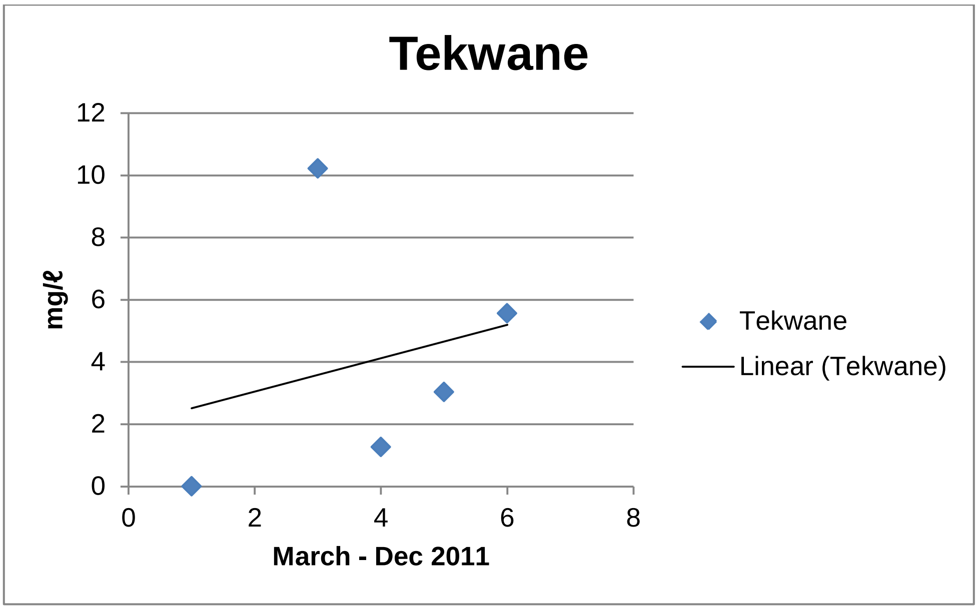

Riverside
35
30
25
20
15
10
5
0
mg/ℓ
0
2
4
6
8
March - Dec 2011
Riverside
Linear (Riverside)


Silva
mg/ℓ
25
20
15
10
5
0
0
2
4
6
8
March - Dec 2011
Silva
Linear (Silva)

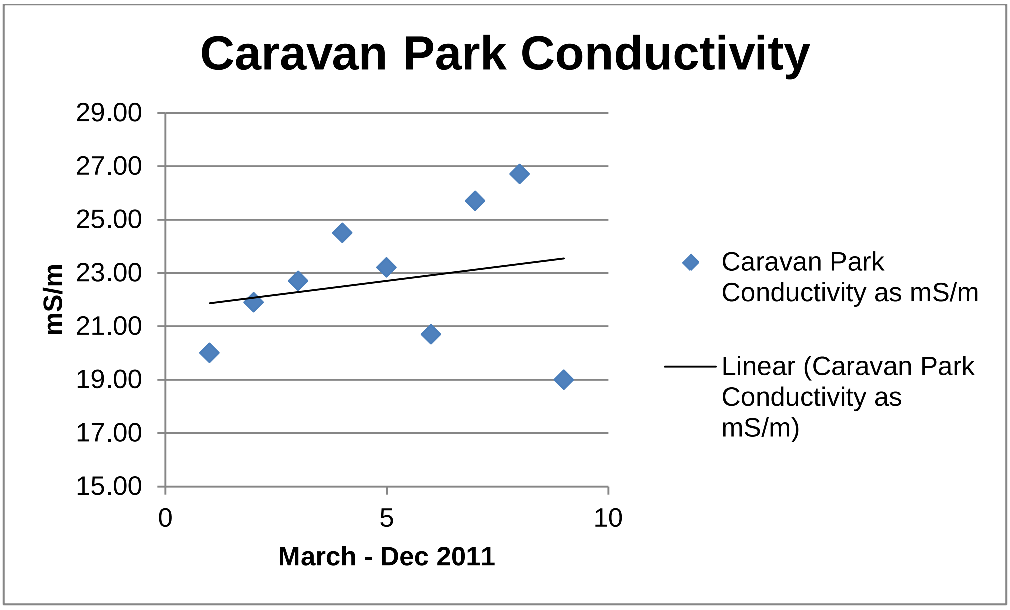

Test Ground
mg/ℓ
6
5
4
3
2
1
0
0
2
4
6
8
March - Dec 2011
Test Ground
Linear (Test Ground)

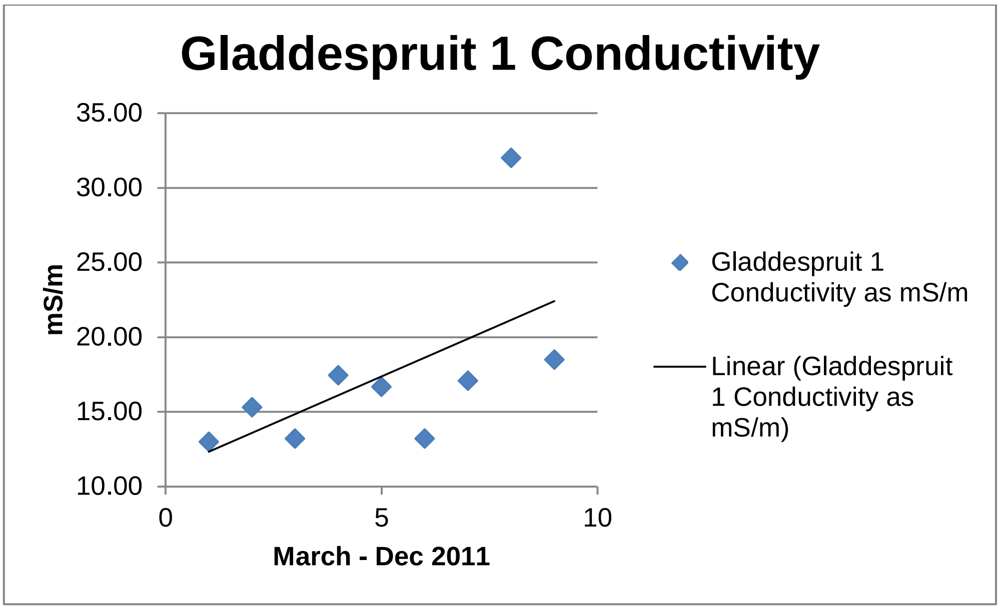

Northern Outfall
mg/ℓ
6
5
4
3
2
1
0
0
2
4
6
8
March - Dec 2011
Northern Outfall
Linear (Northern Outfall)

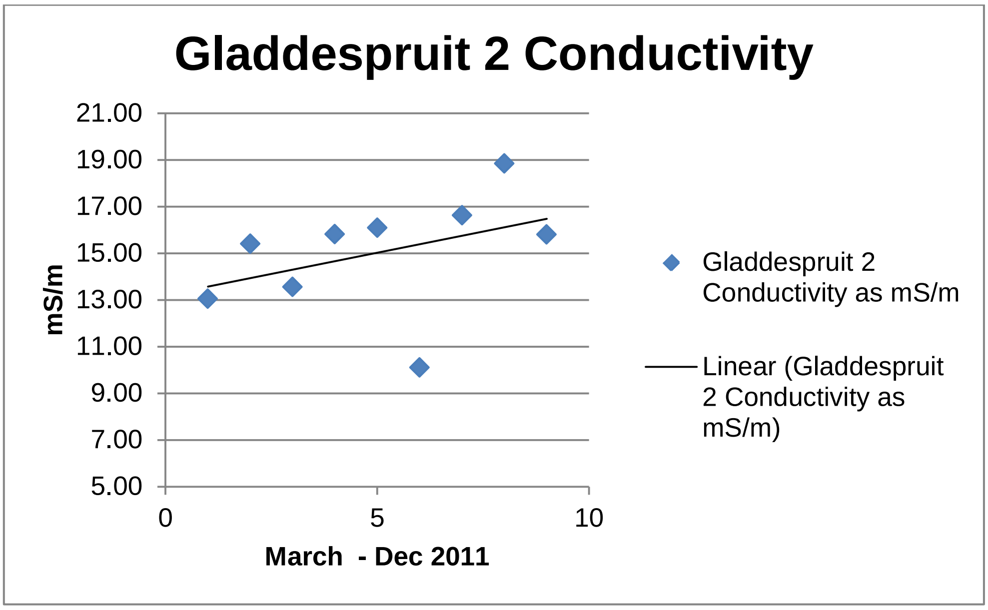

Kamagugu
mg/ℓ
6
5
4
3
2
1
0
0
2
4
6
8
March - Dec 2011
Kamagugu
Linear (Kamagugu)

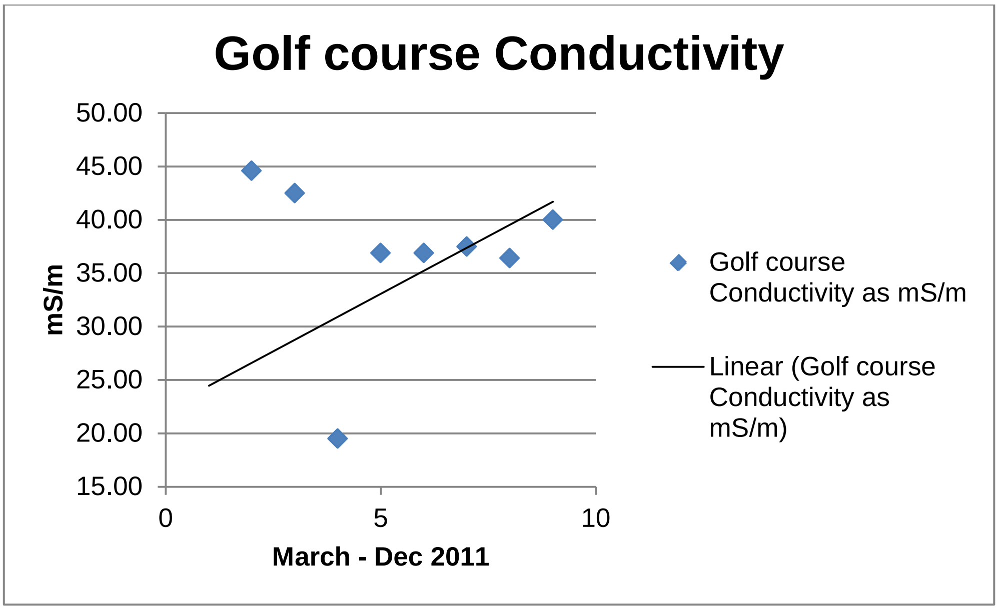

Tekwane
mg/ℓ
12
10
8
6
4
2
0
0
2
4
6
8
March - Dec 2011
Tekwane
Linear (Tekwane)

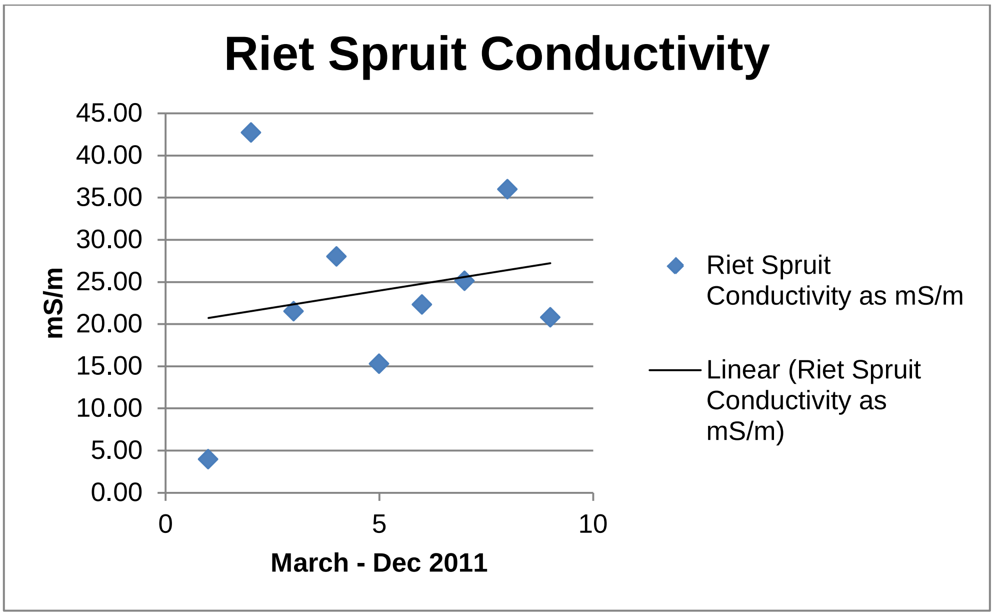
Appendix C: Conductivity Graphs

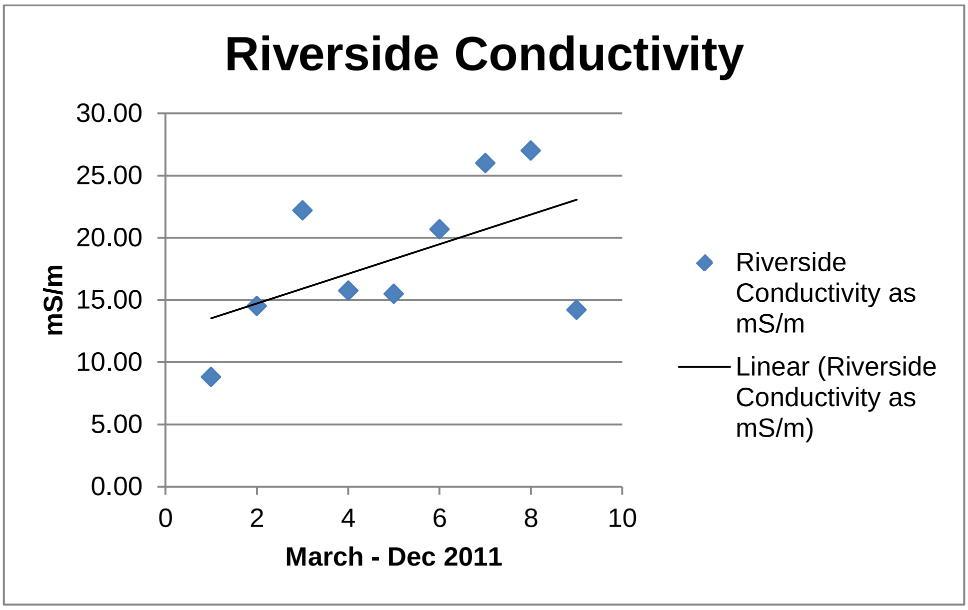

Caravan Park Conductivity
mS/m
29.00
27.00
25.00
23.00
21.00
19.00
17.00
15.00
0
5
10
March - Dec 2011
Caravan Park Conductivity as mS/m
Linear (Caravan Park Conductivity as mS/m)

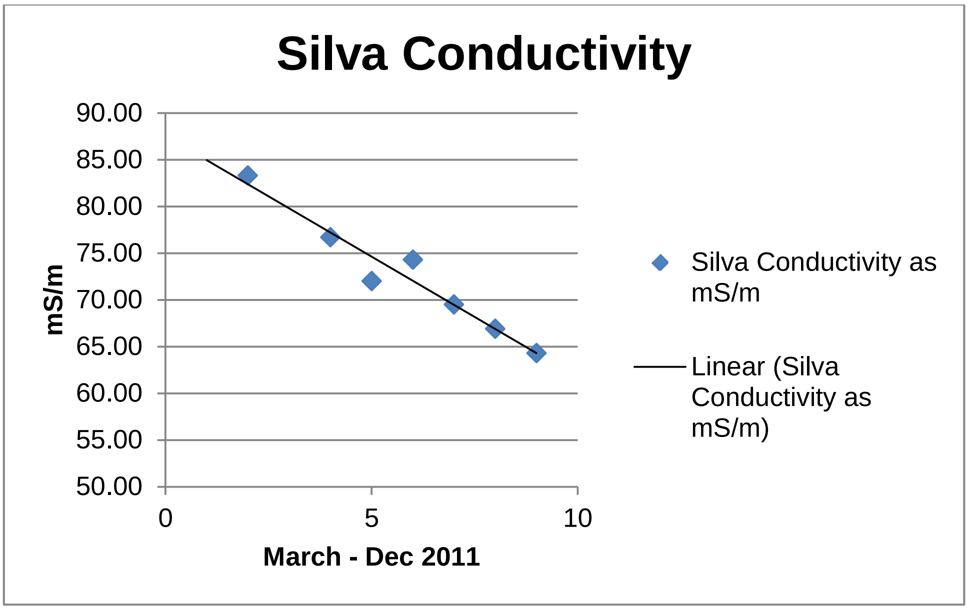

Gladdespruit 1 Conductivity
mS/m
35.00
30.00
25.00
20.00
15.00
10.00
0
5
10
March - Dec 2011
Gladdespruit 1 Conductivity as mS/m
Linear (Gladdespruit 1 Conductivity as mS/m)

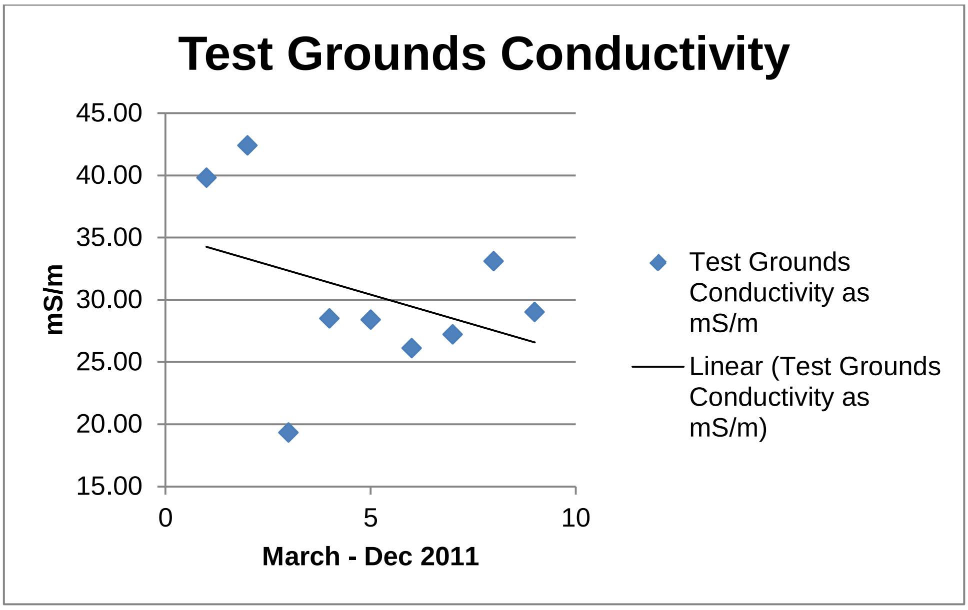

Gladdespruit 2 Conductivity
mS/m
21.00
19.00
17.00
15.00
13.00
11.00
9.00
7.00
5.00
0
5
10
March - Dec 2011
Gladdespruit 2 Conductivity as mS/m
Linear (Gladdespruit 2 Conductivity as mS/m)

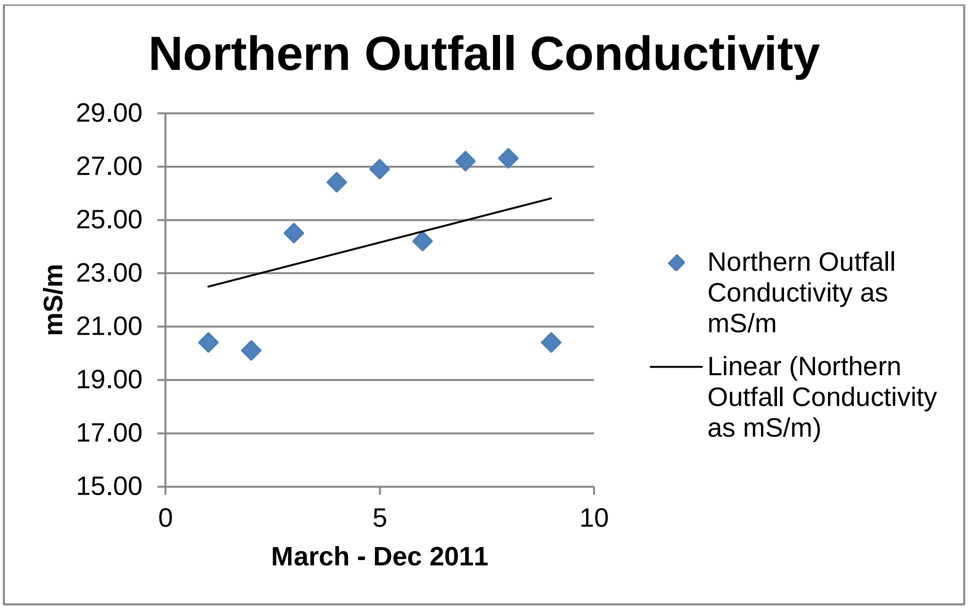

Golf course Conductivity
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
mS/m
0
5
10
March - Dec 2011
Golf course Conductivity as mS/m
Linear (Golf course Conductivity as mS/m)

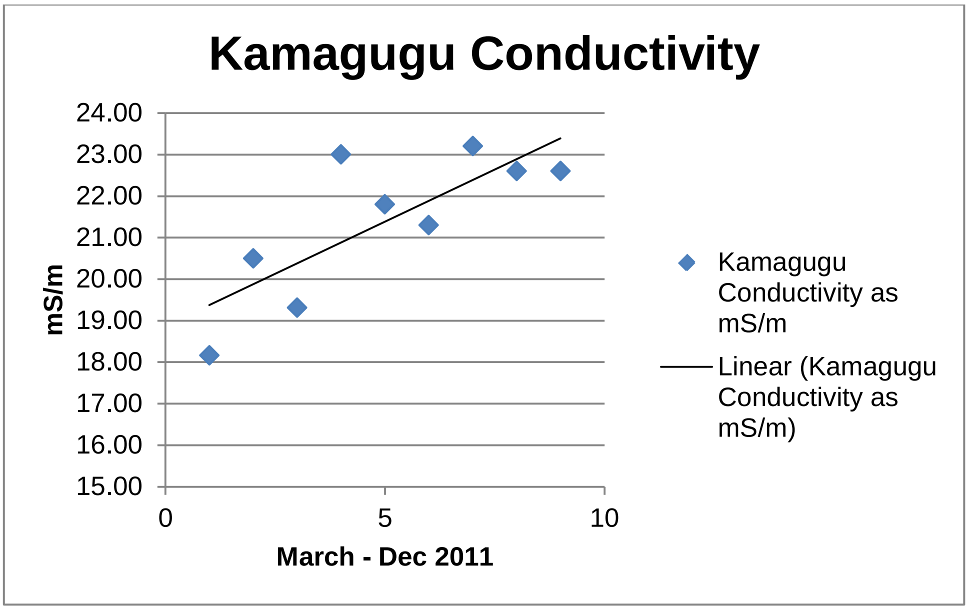

Riet Spruit Conductivity
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
mS/m
0
5
10
March - Dec 2011
Riet Spruit Conductivity as mS/m
Linear (Riet Spruit Conductivity as mS/m)

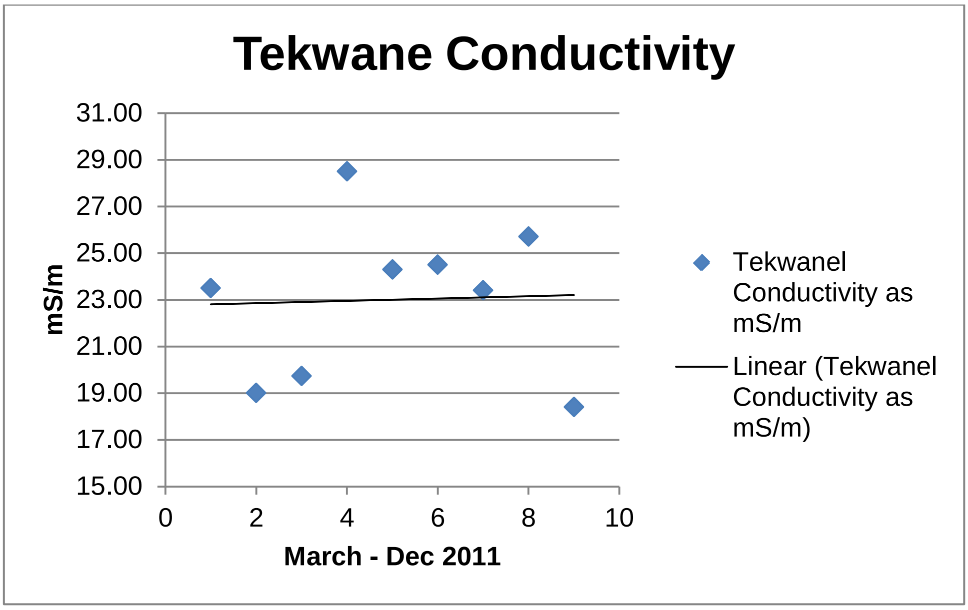

Riverside Conductivity
30.00
25.00
20.00
15.00
10.00
5.00
0.00
mS/m
0
2
4
6
8
10
March - Dec 2011
Riverside Conductivity as mS/m
Linear (Riverside Conductivity as mS/m)


Silva Conductivity
90.00
85.00
80.00
75.00
70.00
65.00
60.00
55.00
50.00
mS/m
0
5
10
March - Dec 2011
Silva Conductivity as mS/m
Linear (Silva Conductivity as mS/m)

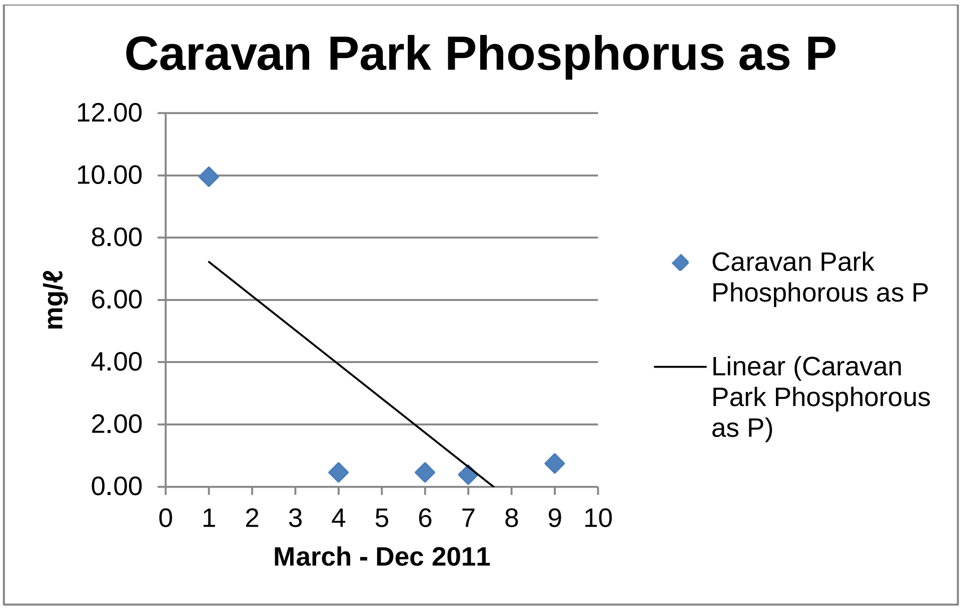

Test Grounds Conductivity
45.00
40.00
35.00
30.00
25.00
20.00
15.00
mS/m
0
5
10
March - Dec 2011
Test Grounds Conductivity as mS/m
Linear (Test Grounds Conductivity as mS/m)

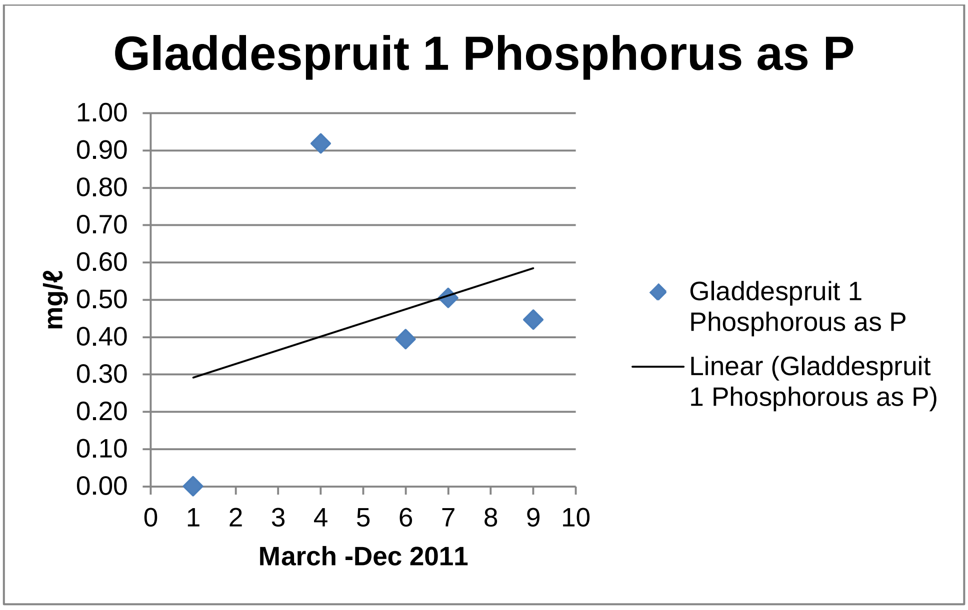

Northern Outfall Conductivity
29.00
27.00
25.00
23.00
21.00
19.00
17.00
15.00
mS/m
0
5
10
March - Dec 2011
Northern Outfall Conductivity as mS/m
Linear (Northern Outfall Conductivity as mS/m)

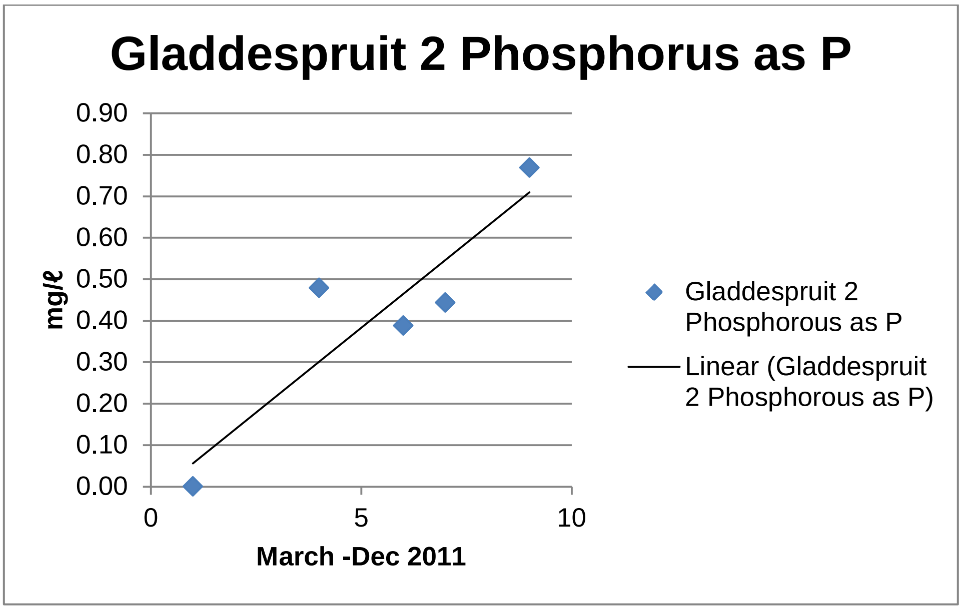

Kamagugu Conductivity
24.00
23.00
22.00
21.00
20.00
19.00
18.00
17.00
16.00
15.00
mS/m
0
5
10
March - Dec 2011
Kamagugu Conductivity as mS/m
Linear (Kamagugu Conductivity as mS/m)

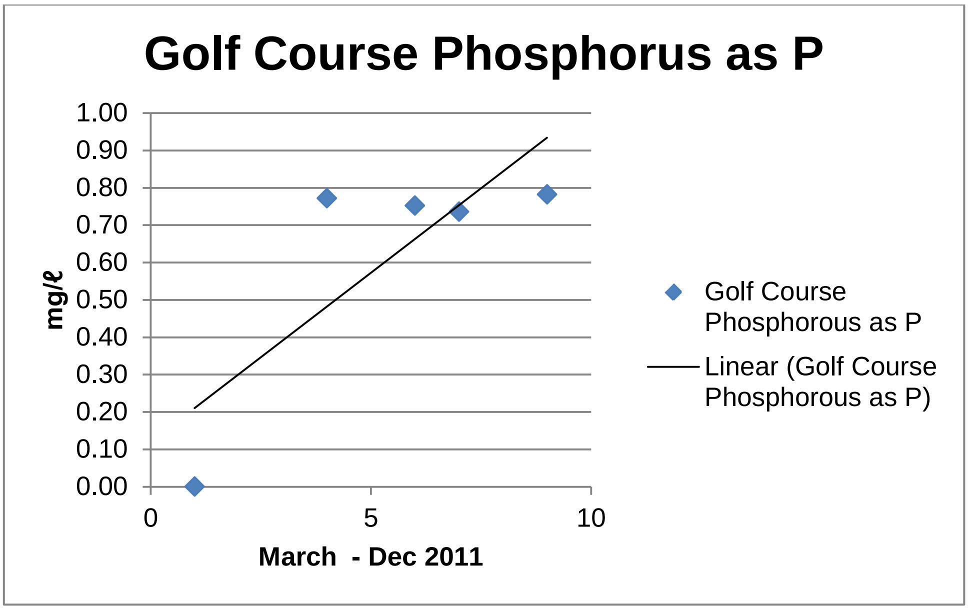

Tekwane Conductivity
31.00
29.00
27.00
25.00
23.00
21.00
19.00
17.00
15.00
mS/m
0
2
4
6
8
10
March - Dec 2011
Tekwanel Conductivity as mS/m
Linear (Tekwanel Conductivity as mS/m)

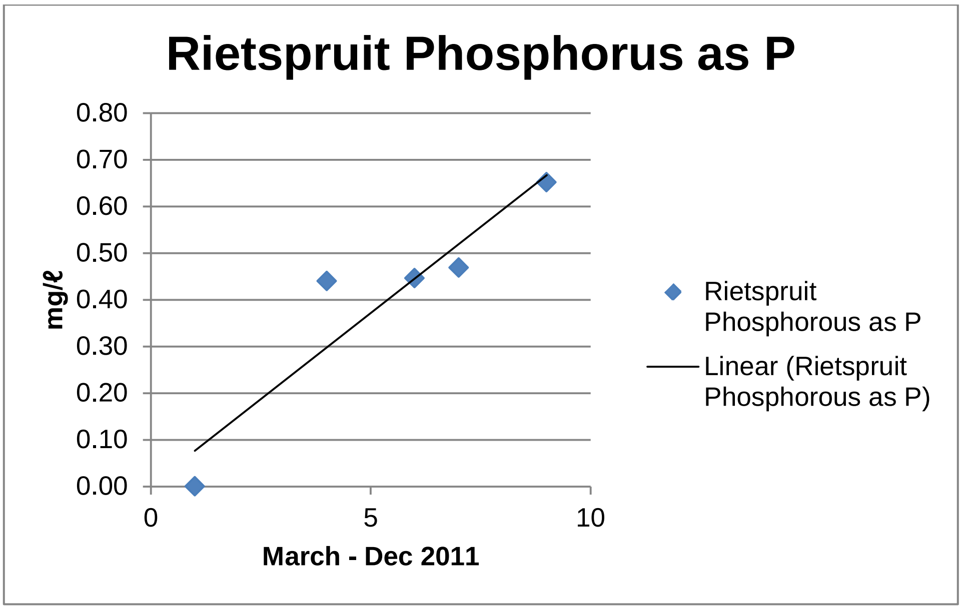
Appendix D: Phosphorus Graphs

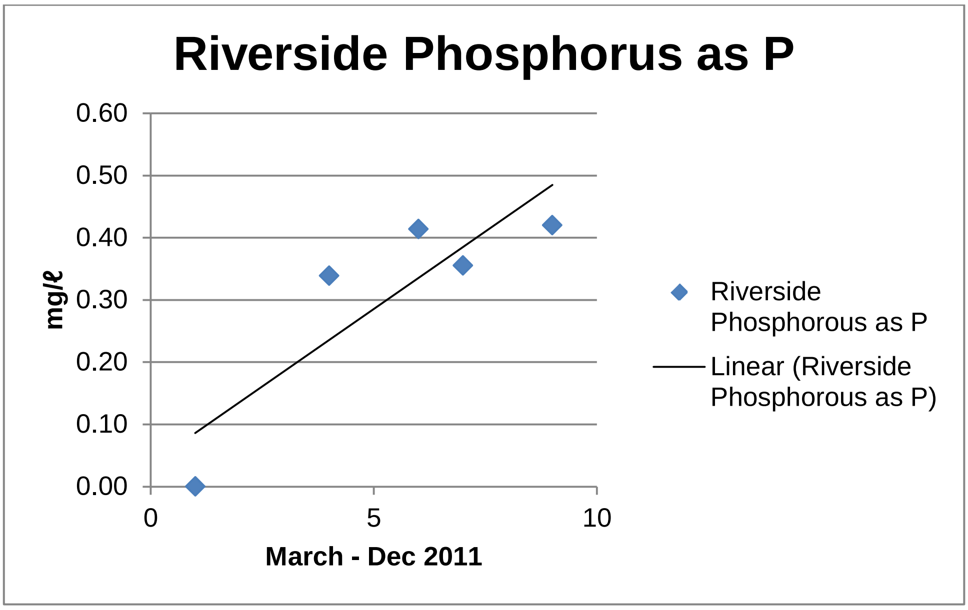

Caravan Park Phosphorus as P
12.00
10.00
8.00
6.00
4.00
2.00
0.00
mg/ℓ
0 1 2 3 4 5 6 7 8 9 10
March - Dec 2011
Caravan Park Phosphorous as P
Linear (Caravan Park Phosphorous as P)

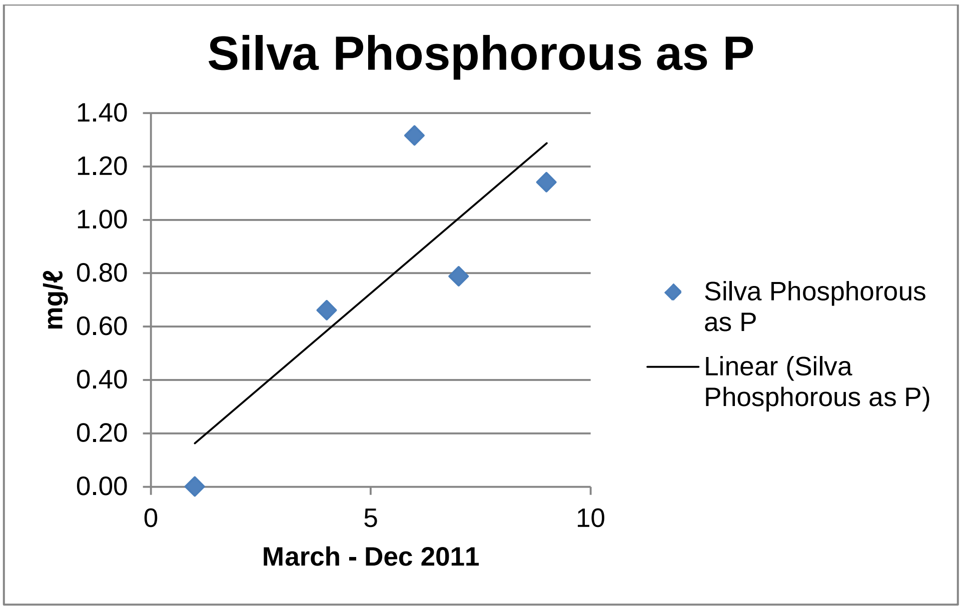

Gladdespruit 1 Phosphorus as P
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
mg/ℓ
0 1 2 3 4 5 6 7 8 9 10
March -Dec 2011
Gladdespruit 1 Phosphorous as P
Linear (Gladdespruit 1 Phosphorous as P)

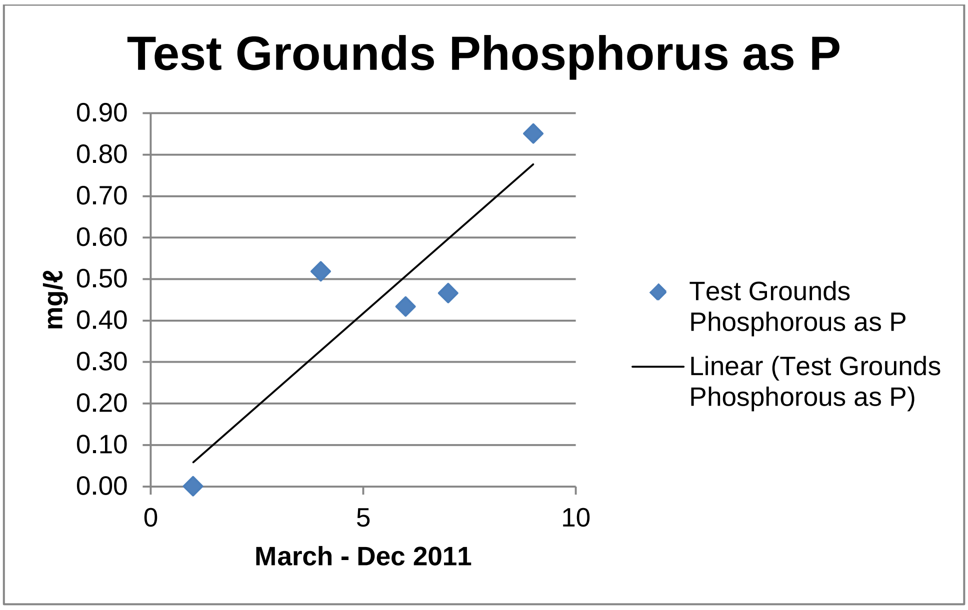

Gladdespruit 2 Phosphorus as P
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
mg/ℓ
0 5 10
March -Dec 2011
Gladdespruit 2 Phosphorous as P
Linear (Gladdespruit 2 Phosphorous as P)

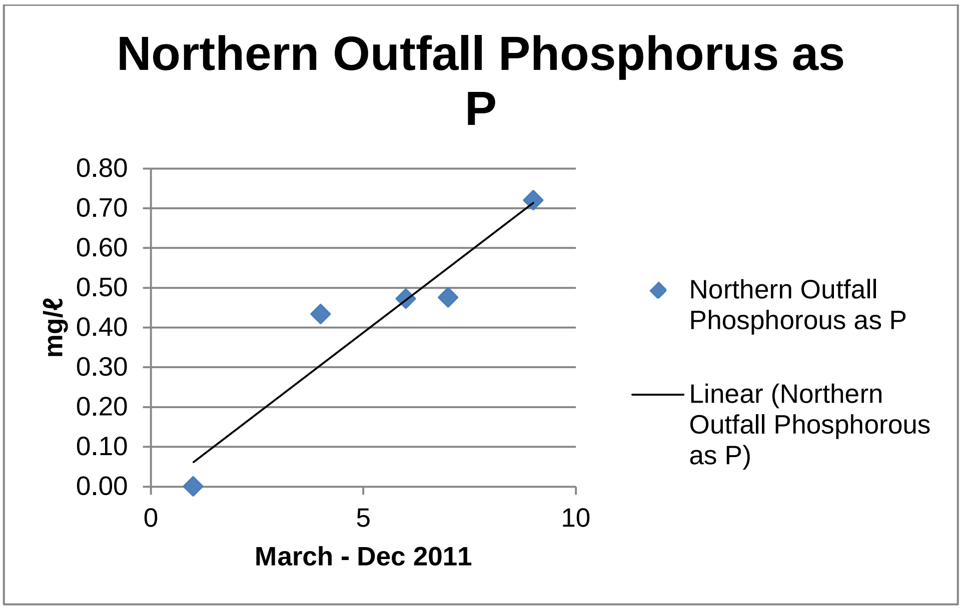

Golf Course Phosphorus as P
mg/ℓ
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
5
10
March - Dec 2011
Golf Course Phosphorous as P
Linear (Golf Course Phosphorous as P)

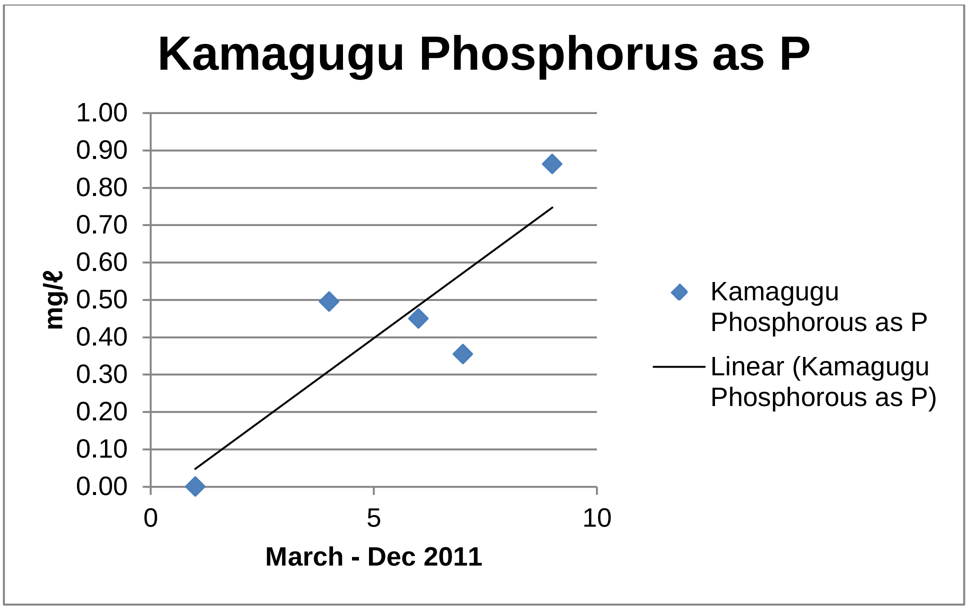

Rietspruit Phosphorus as P
mg/ℓ
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
5
10
March - Dec 2011
Rietspruit Phosphorous as P
Linear (Rietspruit Phosphorous as P)

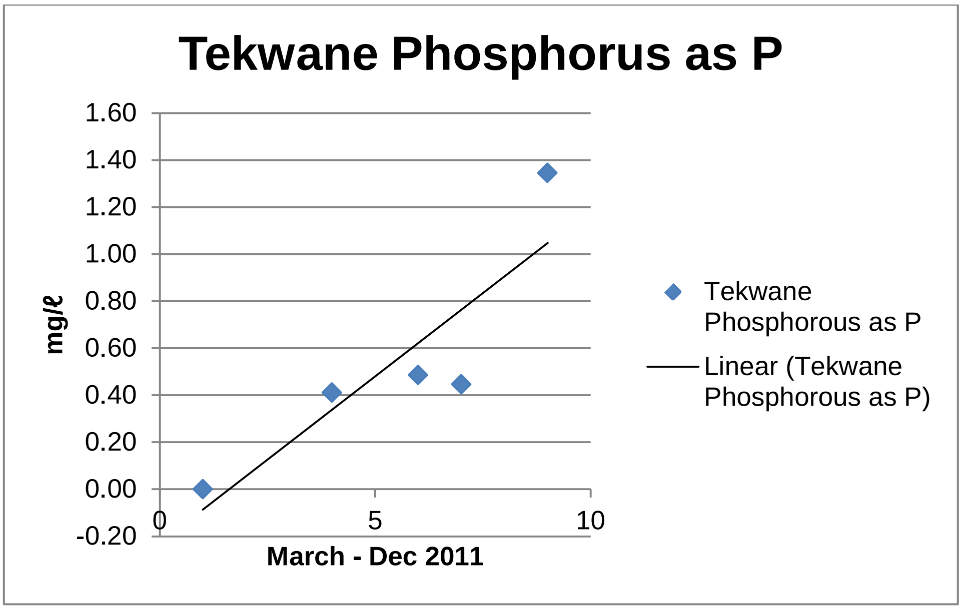

Riverside Phosphorus as P
mg/ℓ
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
5
10
March - Dec 2011
Riverside Phosphorous as P
Linear (Riverside Phosphorous as P)


Silva Phosphorous as P
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
mg/ℓ
0
5
10
March - Dec 2011
Silva Phosphorous as P
Linear (Silva Phosphorous as P)

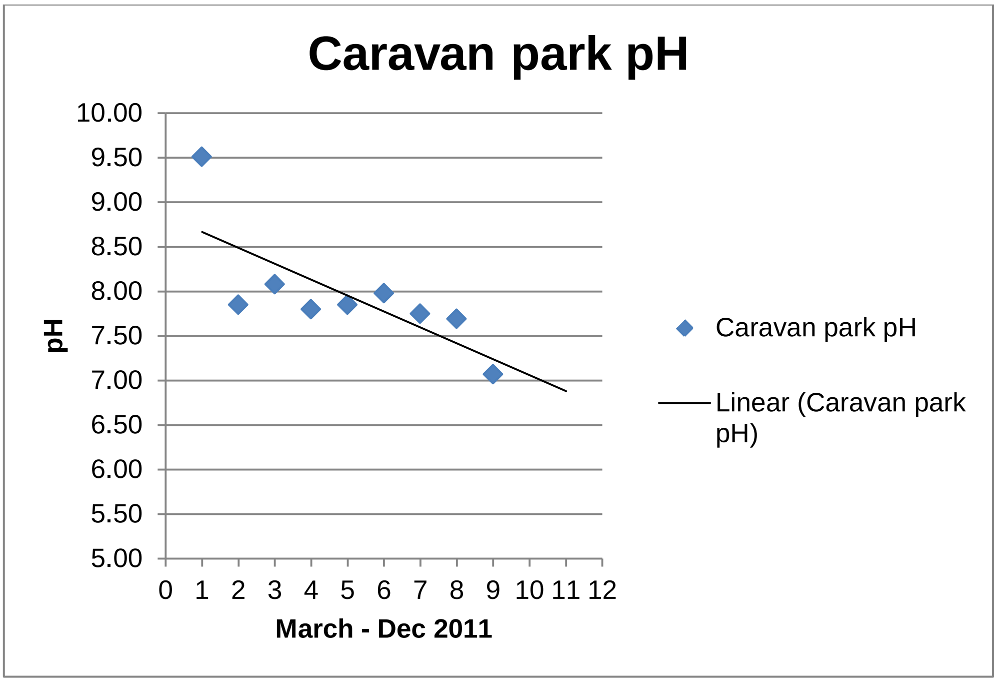

Test Grounds Phosphorus as P
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
mg/ℓ
0
5
10
March - Dec 2011
Test Grounds Phosphorous as P
Linear (Test Grounds Phosphorous as P)


Northern Outfall Phosphorus as P
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
mg/ℓ
0
5
10
March - Dec 2011
Northern Outfall Phosphorous as P
Linear (Northern Outfall Phosphorous as P)

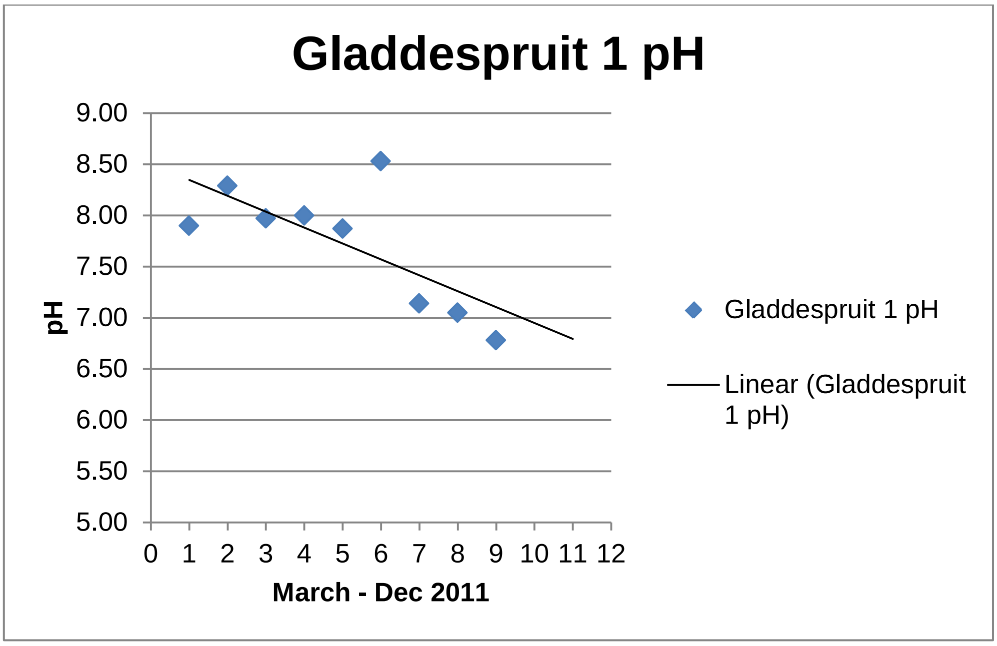

Kamagugu Phosphorus as P
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
mg/ℓ
0
5
10
March - Dec 2011
Kamagugu Phosphorous as P
Linear (Kamagugu Phosphorous as P)


Tekwane Phosphorus as P
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
mg/ℓ
0
5
10
March - Dec 2011
Tekwane Phosphorous as P
Linear (Tekwane Phosphorous as P)

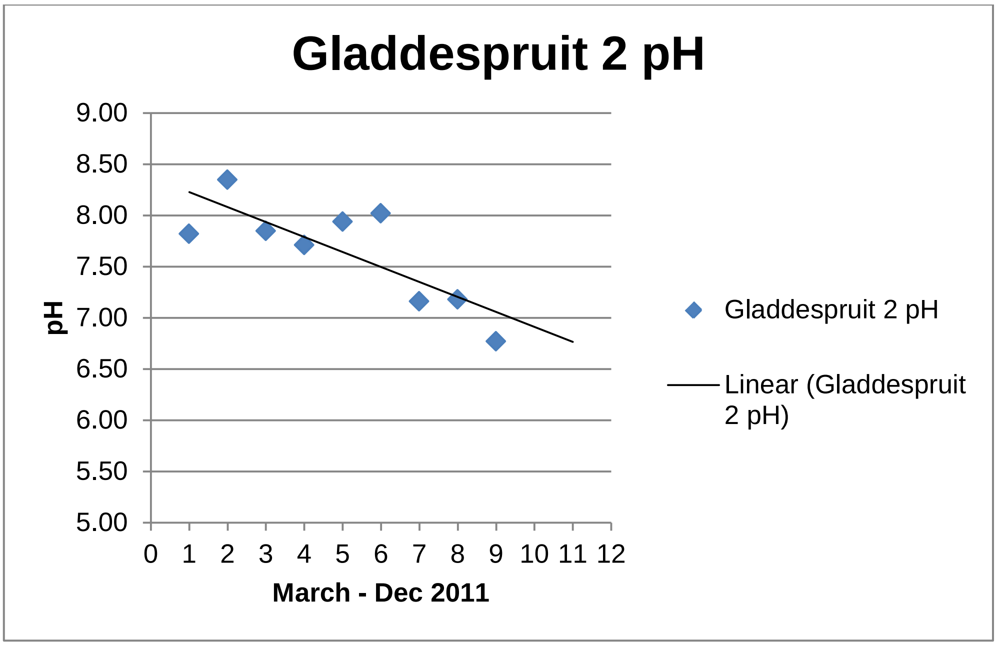
Appendix E: pH Graphs

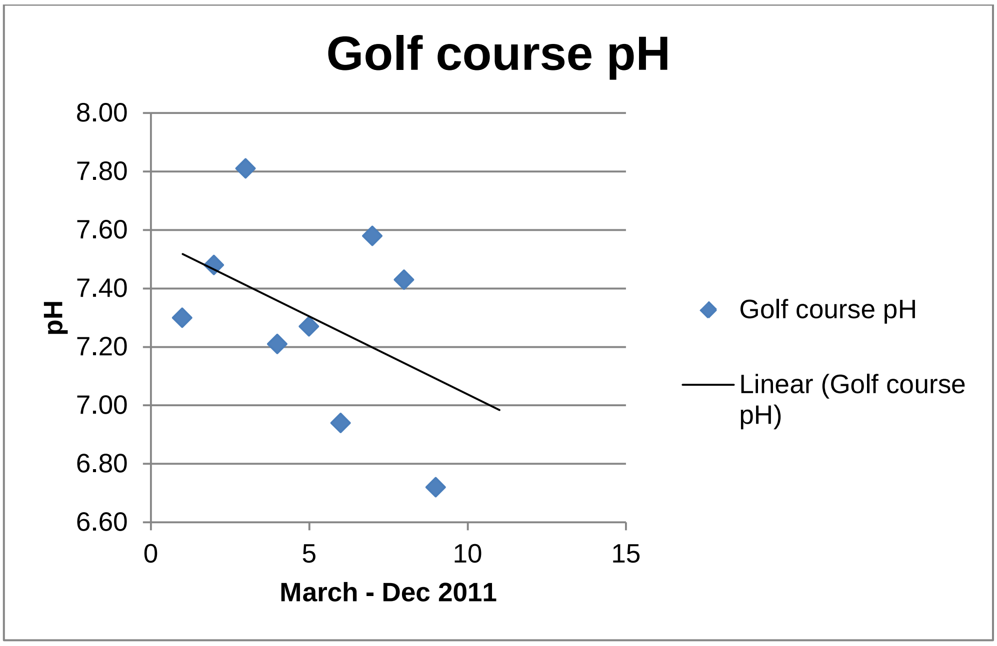


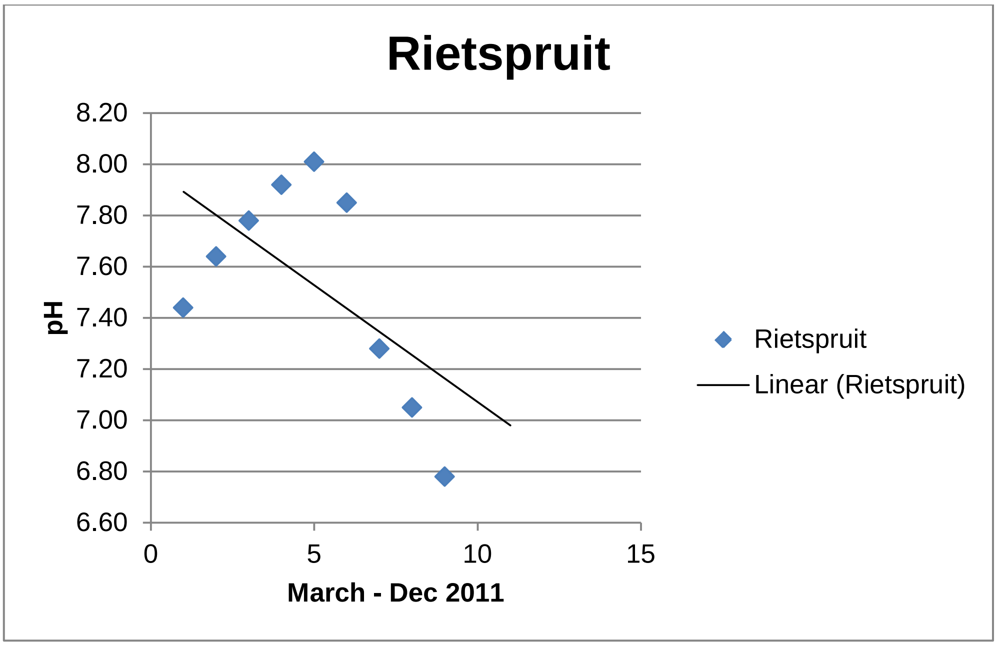
Caravan park pH
10.00
9.50
9.00
8.50
8.00
7.50
7.00
6.50
6.00
5.50
5.00
pH
0 1 2 3 4 5 6 7 8 9 10 11 12
March - Dec 2011
Caravan park pH
Linear (Caravan park pH)

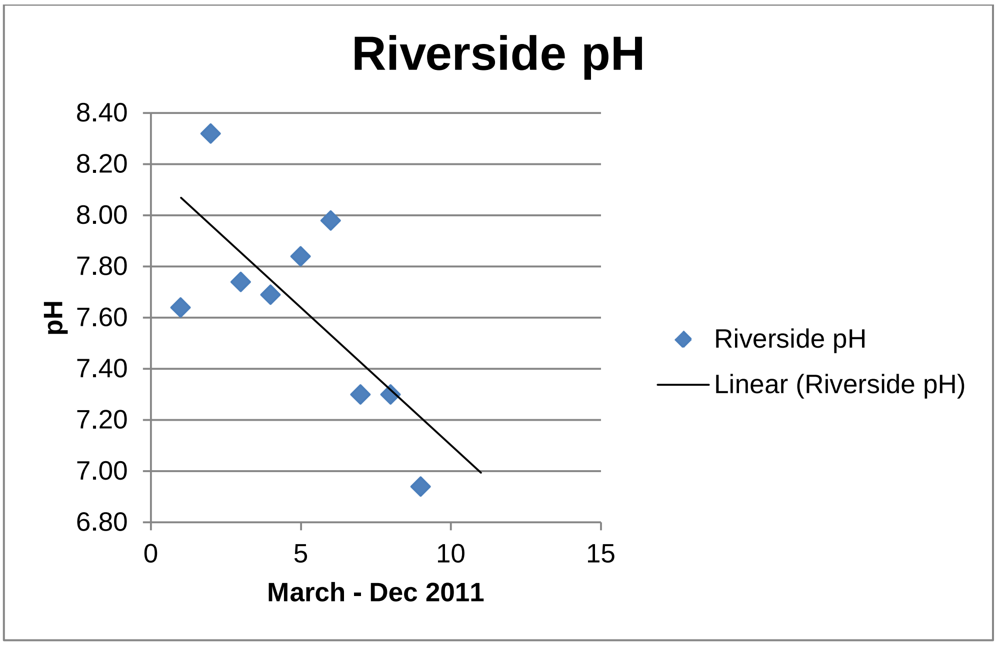


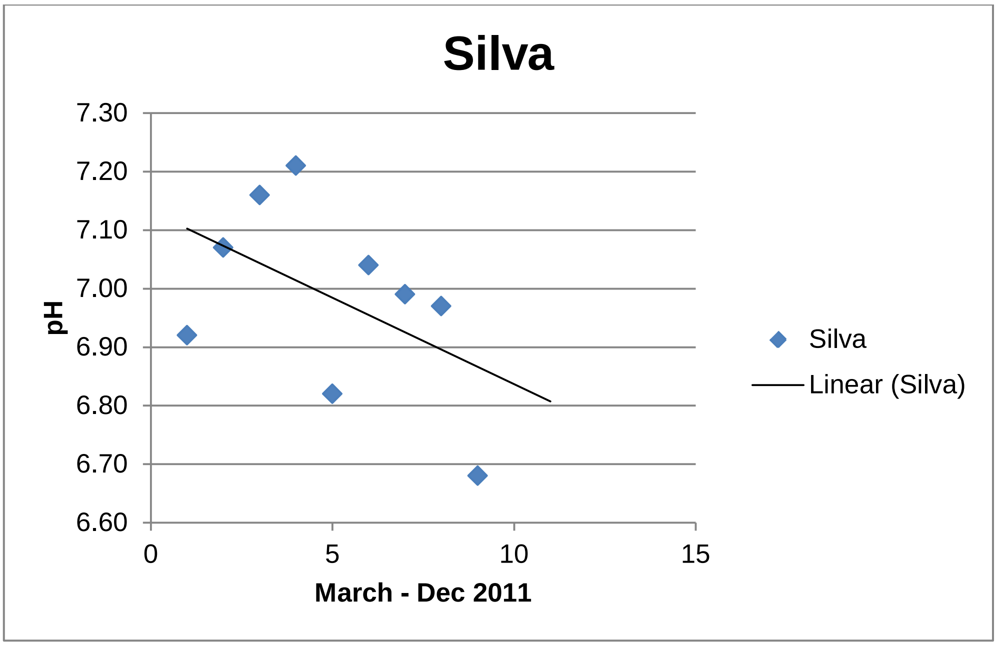
Gladdespruit 1 pH
9.00
8.50
8.00
7.50
7.00
6.50
6.00
5.50
5.00
pH
0 1 2 3 4 5 6 7 8 9 10 11 12
March - Dec 2011
Gladdespruit 1 pH
Linear (Gladdespruit 1 pH)

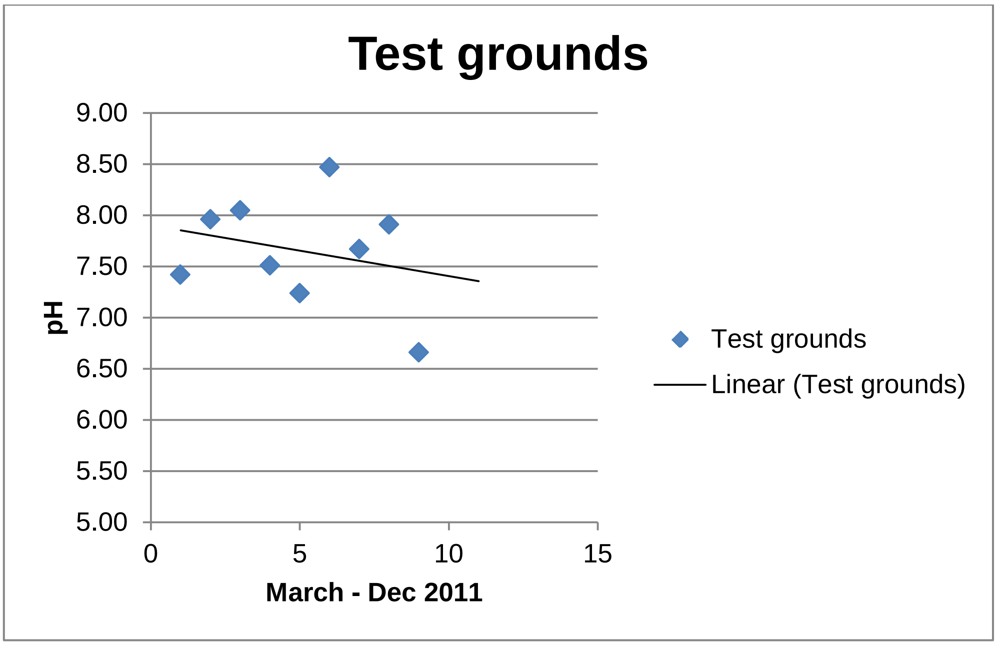

Gladdespruit 2 pH
9.00
8.50
8.00
7.50
7.00
6.50
6.00
5.50
5.00
pH
0 1 2 3 4 5 6 7 8 9 10 11 12
March - Dec 2011
Gladdespruit 2 pH
Linear (Gladdespruit 2 pH)

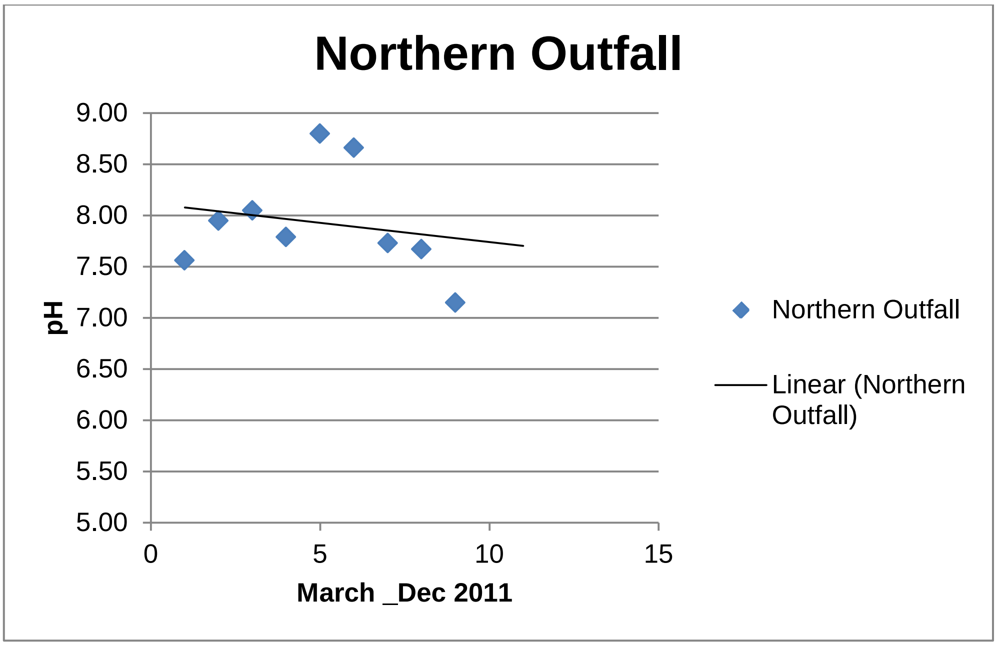

Golf course pH
8.00
7.80
7.60
7.40
7.20
7.00
6.80
6.60
pH
0 5 10 15
March - Dec 2011
Golf course pH
Linear (Golf course pH)

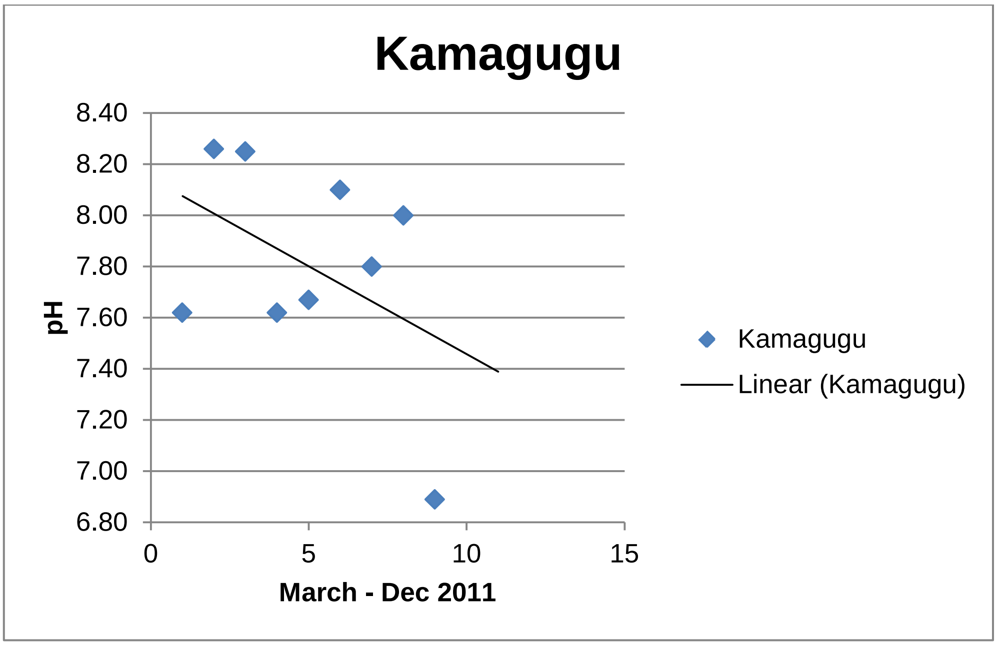

Rietspruit
pH
8.20
8.00
7.80
7.60
7.40
7.20
7.00
6.80
6.60
0
5
10
15
March - Dec 2011
Rietspruit
Linear (Rietspruit)

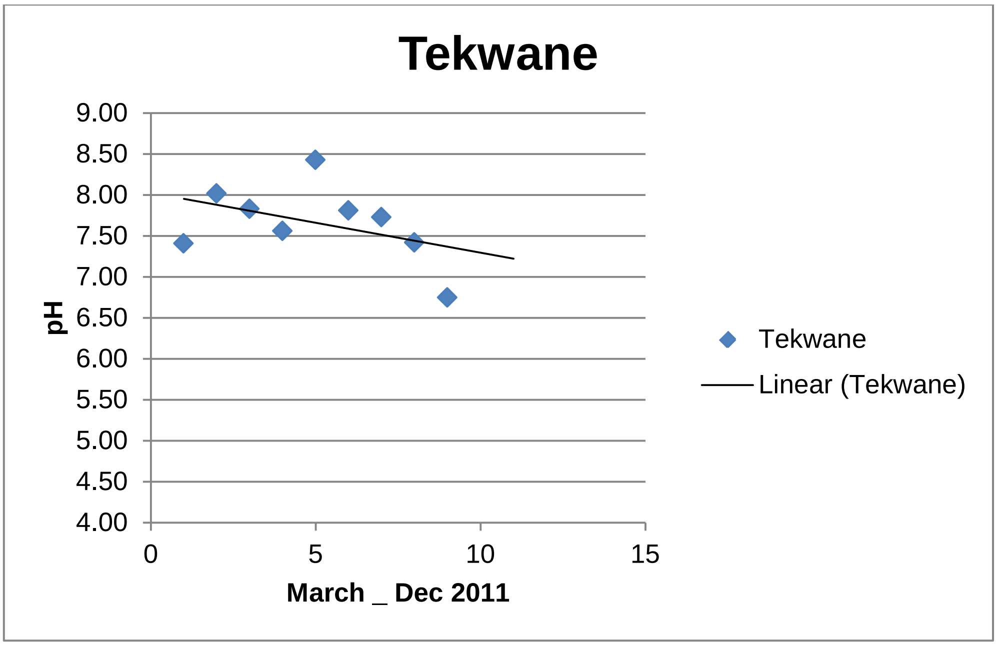

Riverside pH
pH
8.40
8.20
8.00
7.80
7.60
7.40
7.20
7.00
6.80
0
5
10
15
March - Dec 2011
Riverside pH
Linear (Riverside pH)


Silva
7.30
7.20
7.10
7.00
6.90
6.80
6.70
6.60
pH
0
5
10
15
March - Dec 2011
Silva
Linear (Silva)

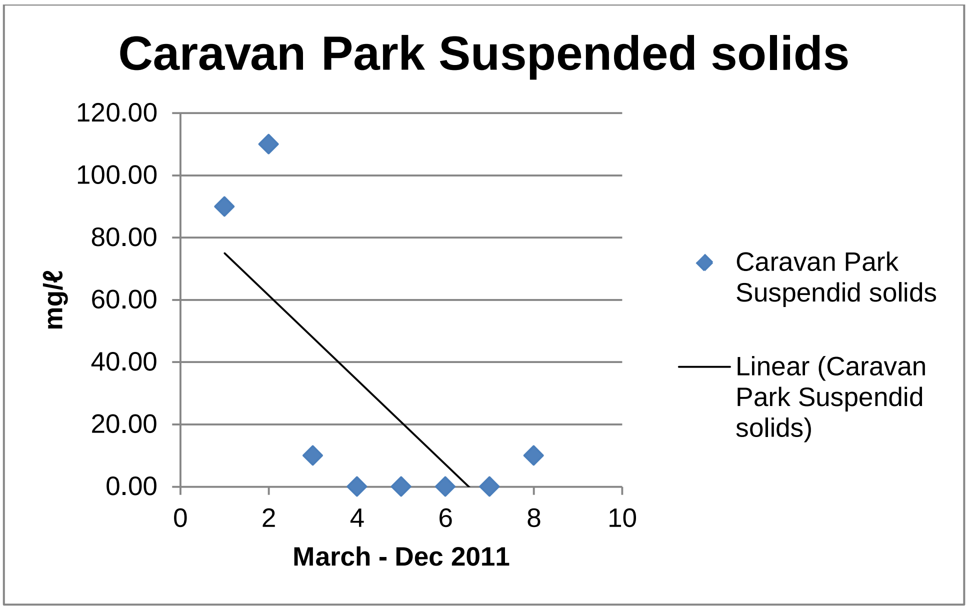

Test grounds
9.00
8.50
8.00
7.50
7.00
6.50
6.00
5.50
5.00
pH
0
5
10
15
March - Dec 2011
Test grounds
Linear (Test grounds)

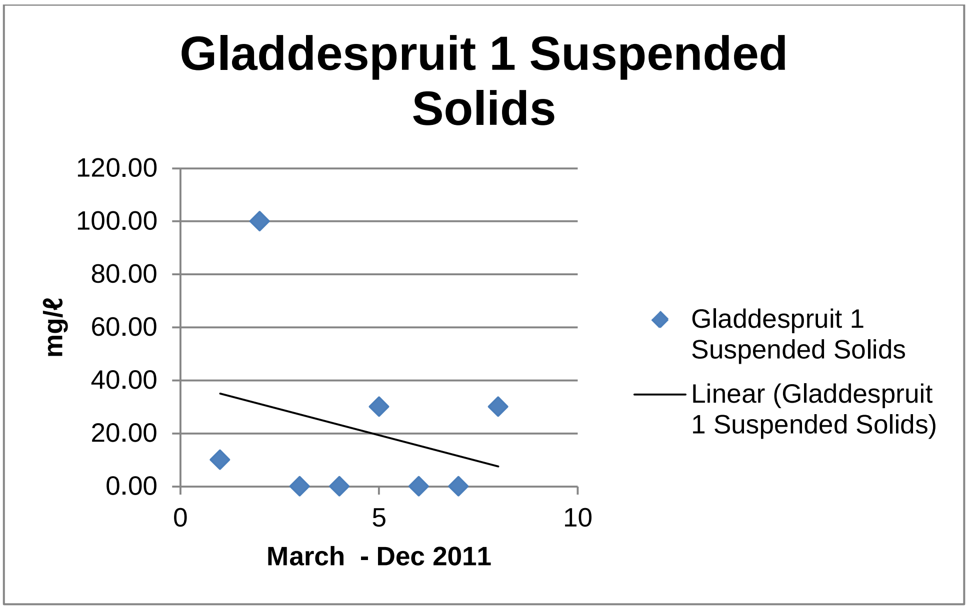

Northern Outfall
9.00
8.50
8.00
7.50
7.00
6.50
6.00
5.50
5.00
pH
0
5
10
15
March _Dec 2011
Northern Outfall
Linear (Northern Outfall)

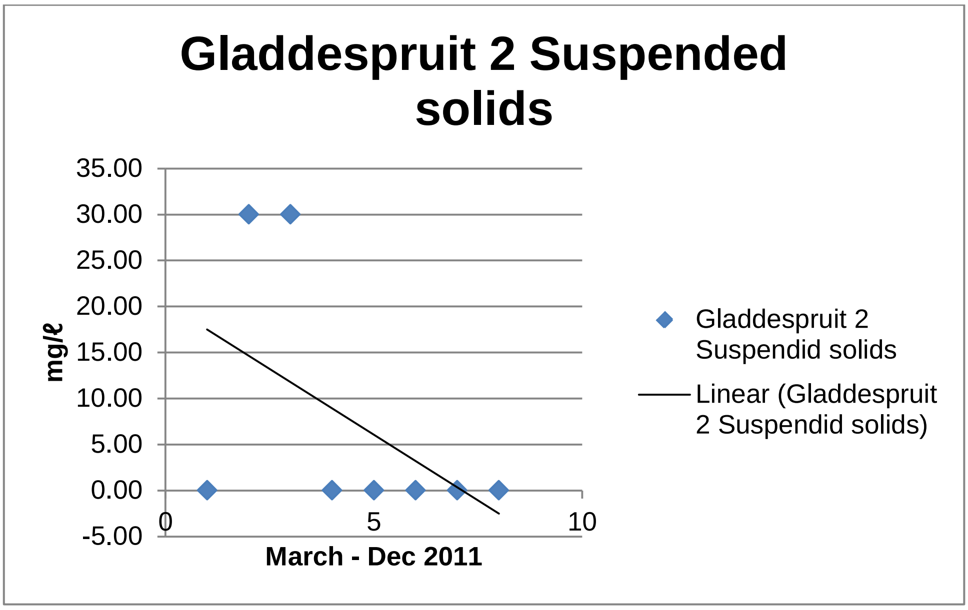

Kamagugu
8.40
8.20
8.00
7.80
7.60
7.40
7.20
7.00
6.80
pH
0
5
10
15
March - Dec 2011
Kamagugu
Linear (Kamagugu)


Tekwane
9.00
8.50
8.00
7.50
7.00
6.50
6.00
5.50
5.00
4.50
4.00
pH
0
5
10
15
March _ Dec 2011
Tekwane
Linear (Tekwane)

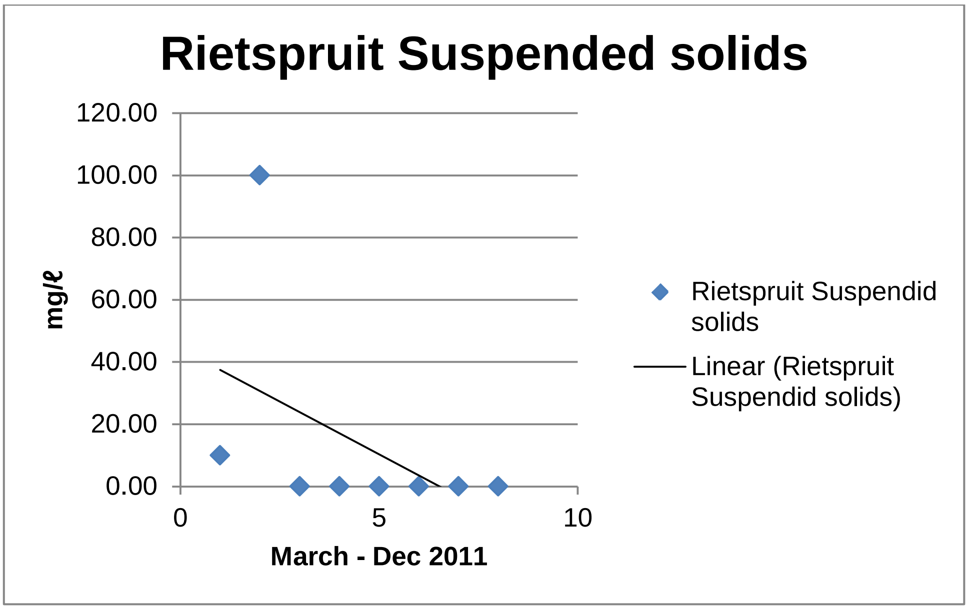
Appendix F: Suspended Solids

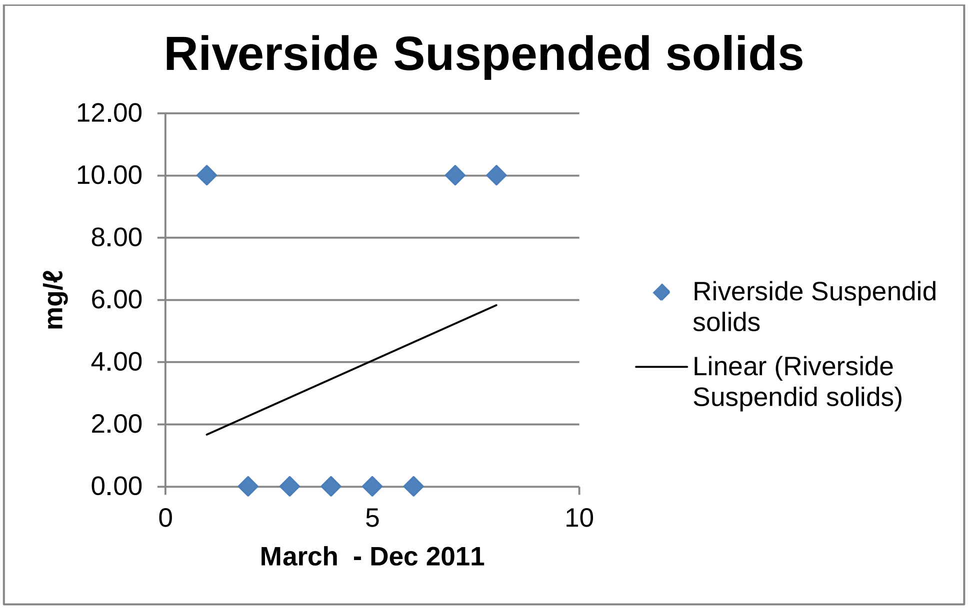

Caravan Park Suspended solids
mg/ℓ
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0
2
4
6
8
10
March - Dec 2011
Caravan Park Suspendid solids
Linear (Caravan Park Suspendid solids)

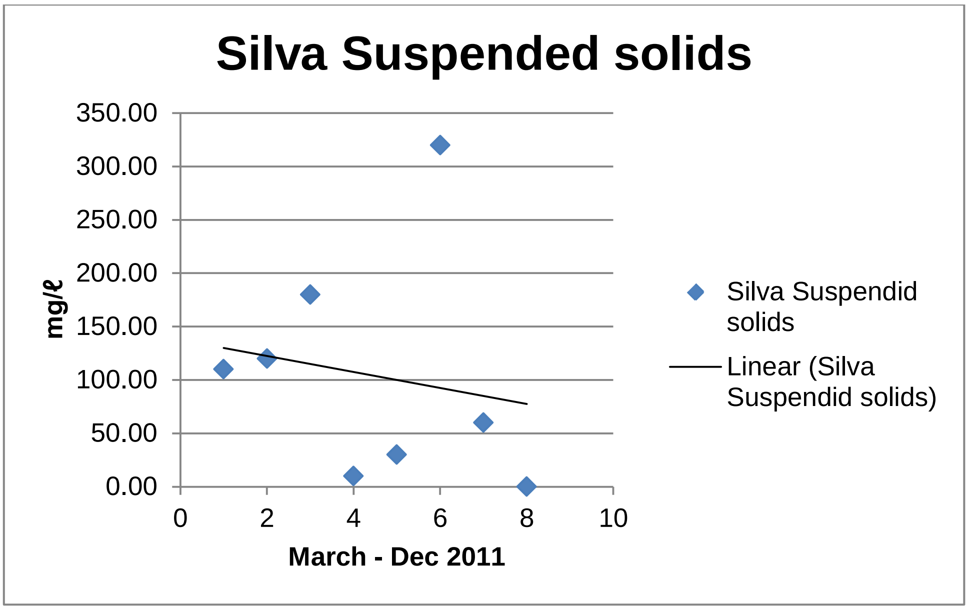

Gladdespruit 1 Suspended Solids
mg/ℓ
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0
5
10
March - Dec 2011
Gladdespruit 1 Suspended Solids
Linear (Gladdespruit 1 Suspended Solids)

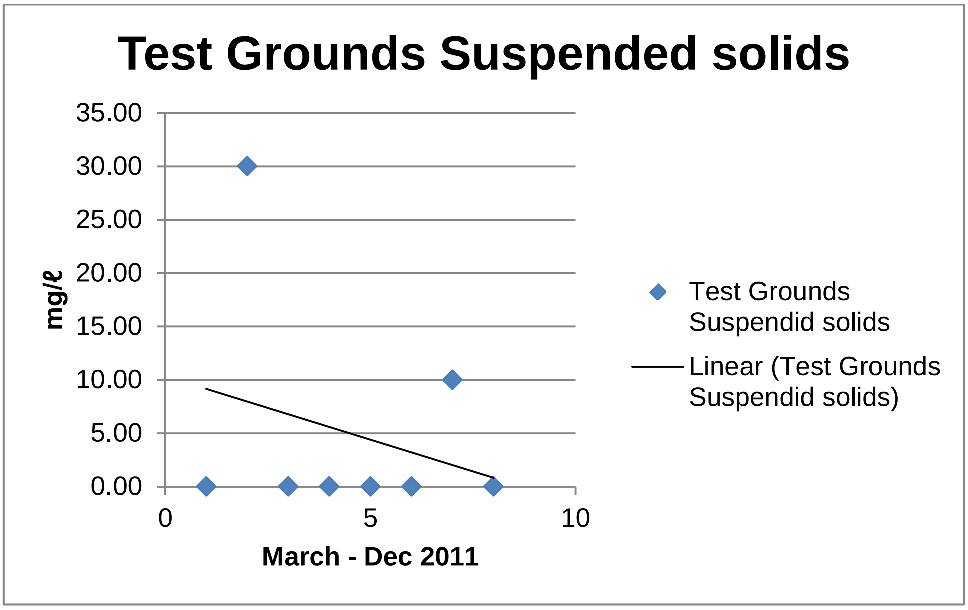

Gladdespruit 2 Suspended solids
mg/ℓ
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
0
5
10
March - Dec 2011
Gladdespruit 2 Suspendid solids
Linear (Gladdespruit 2 Suspendid solids)

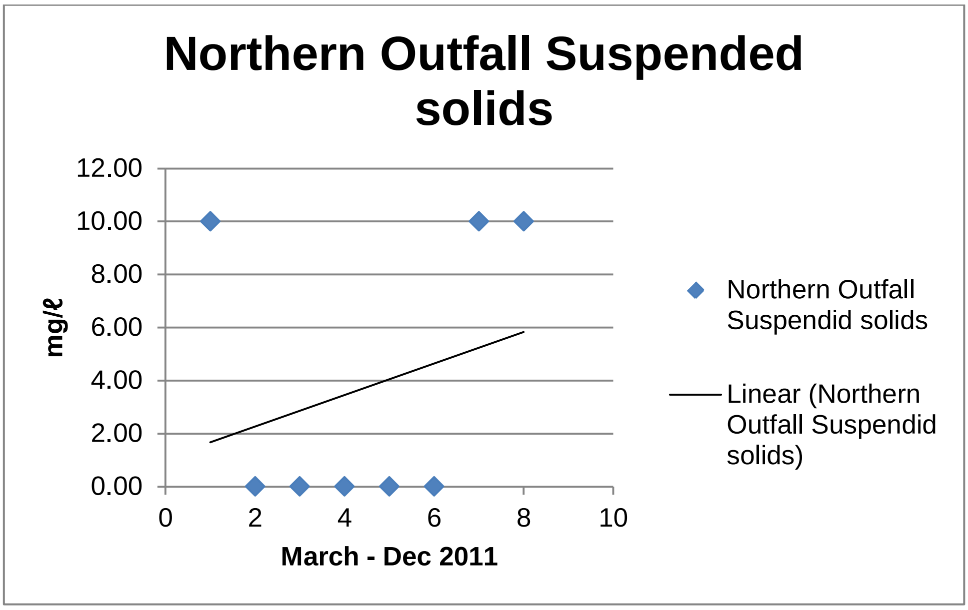

Golf Course Suspended solids
mg/ℓ
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0
5
10
March - Dec 2011
Golf Course Suspendid solids
Linear (Golf Course Suspendid solids)

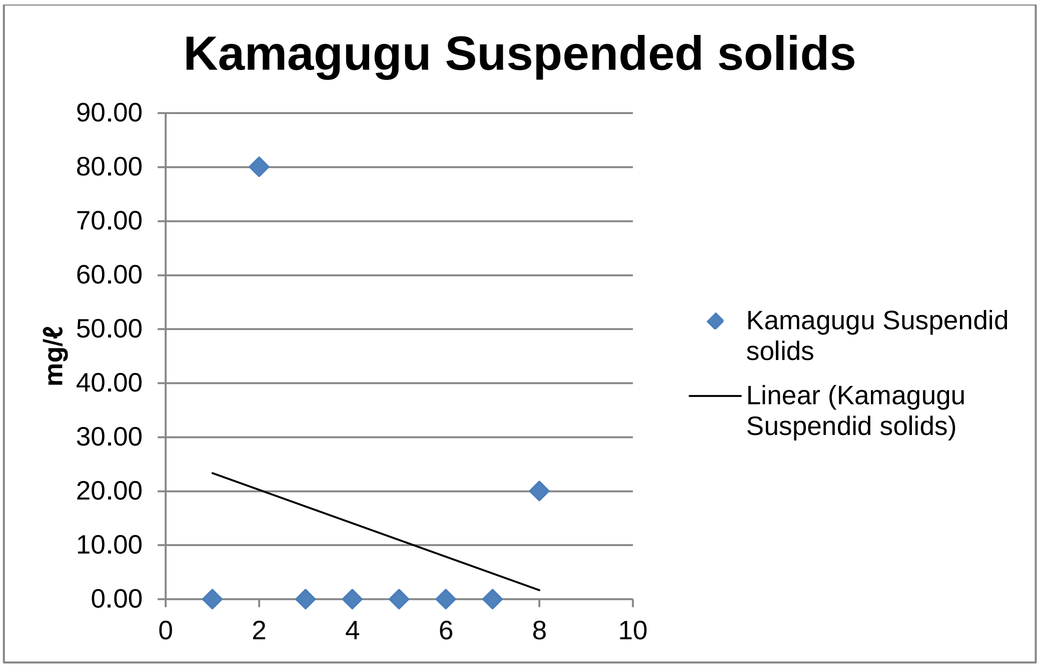

Rietspruit Suspended solids
mg/ℓ
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0
5
10
March - Dec 2011
Rietspruit Suspendid solids
Linear (Rietspruit Suspendid solids)

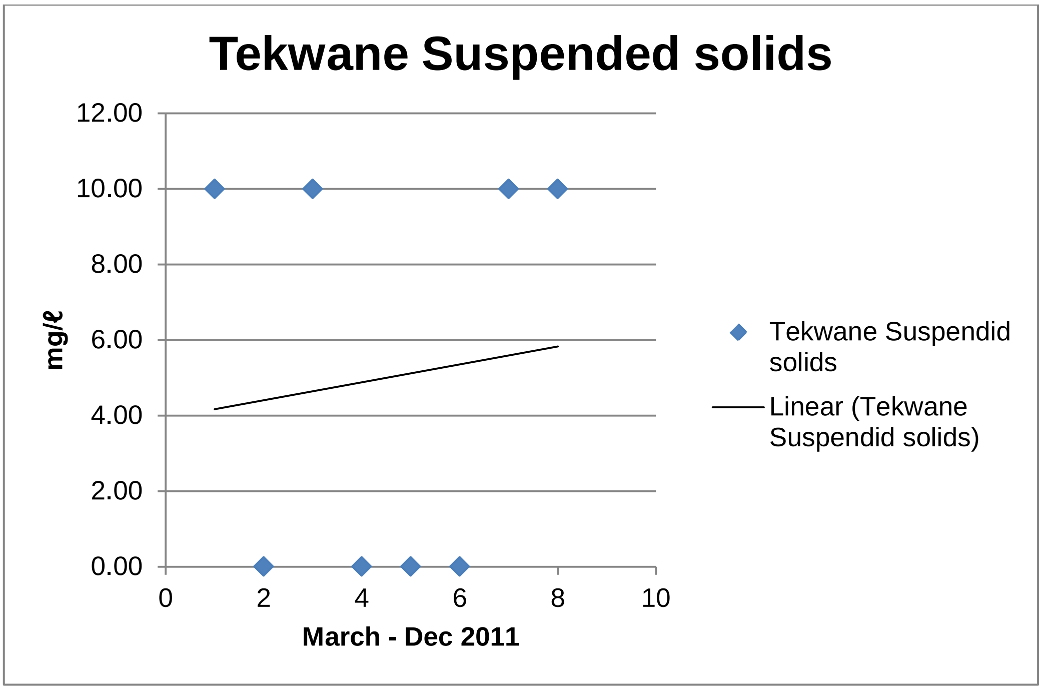

Riverside Suspended solids
mg/ℓ
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
5
10
March - Dec 2011
Riverside Suspendid solids
Linear (Riverside Suspendid solids)


Silva Suspended solids
mg/ℓ
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0
2
4
6
8
10
March - Dec 2011
Silva Suspendid solids
Linear (Silva Suspendid solids)

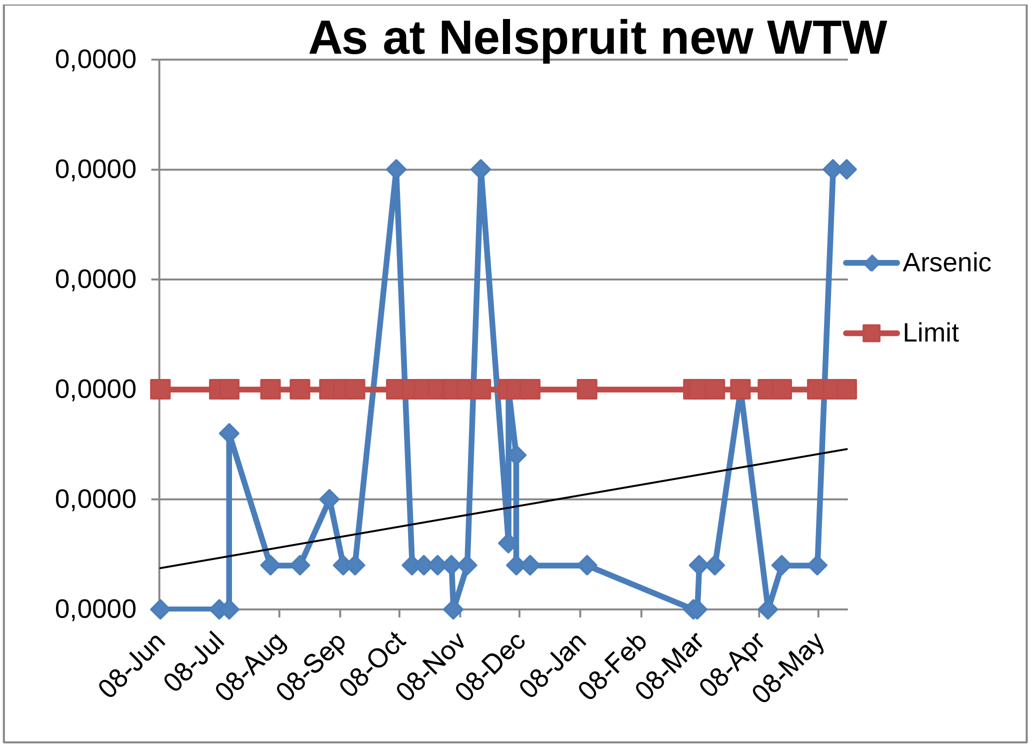

Test Grounds Suspended solids
mg/ℓ
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
5
10
March - Dec 2011
Test Grounds Suspendid solids
Linear (Test Grounds Suspendid solids)

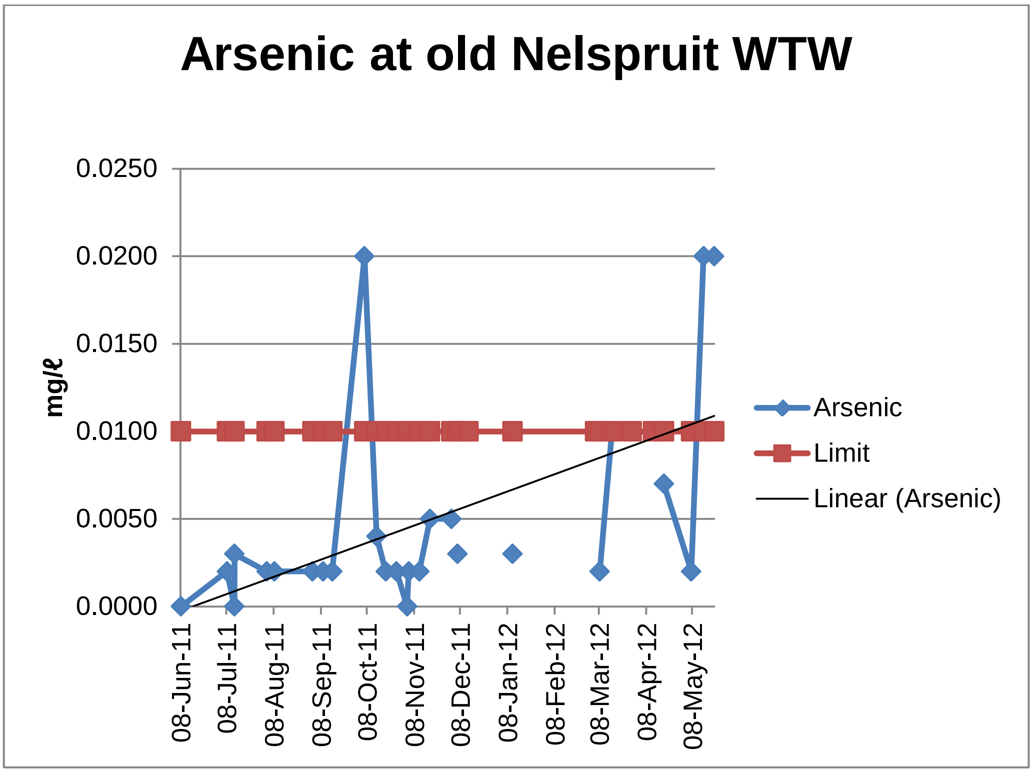

Northern Outfall Suspended solids
mg/ℓ
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
2
4
6
8
10
March - Dec 2011
Northern Outfall Suspendid solids
Linear (Northern Outfall Suspendid solids)

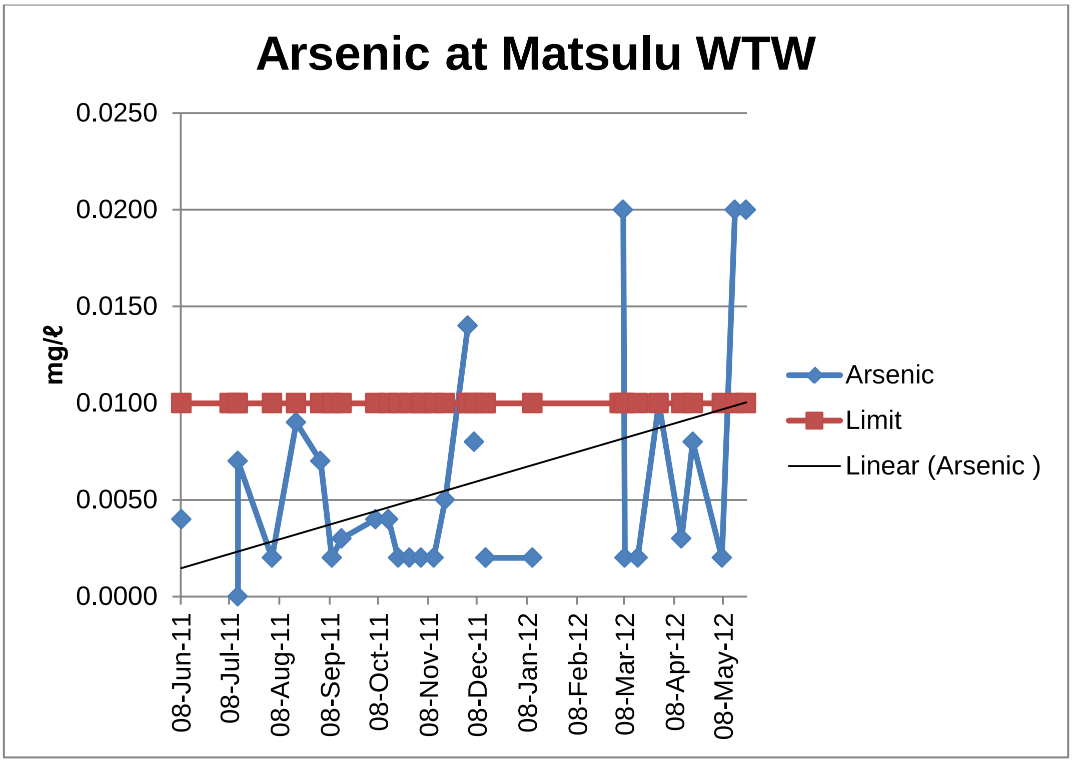

Kamagugu Suspended solids
mg/ℓ
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
2
4
6
8
10
Kamagugu Suspendid solids
Linear (Kamagugu Suspendid solids)

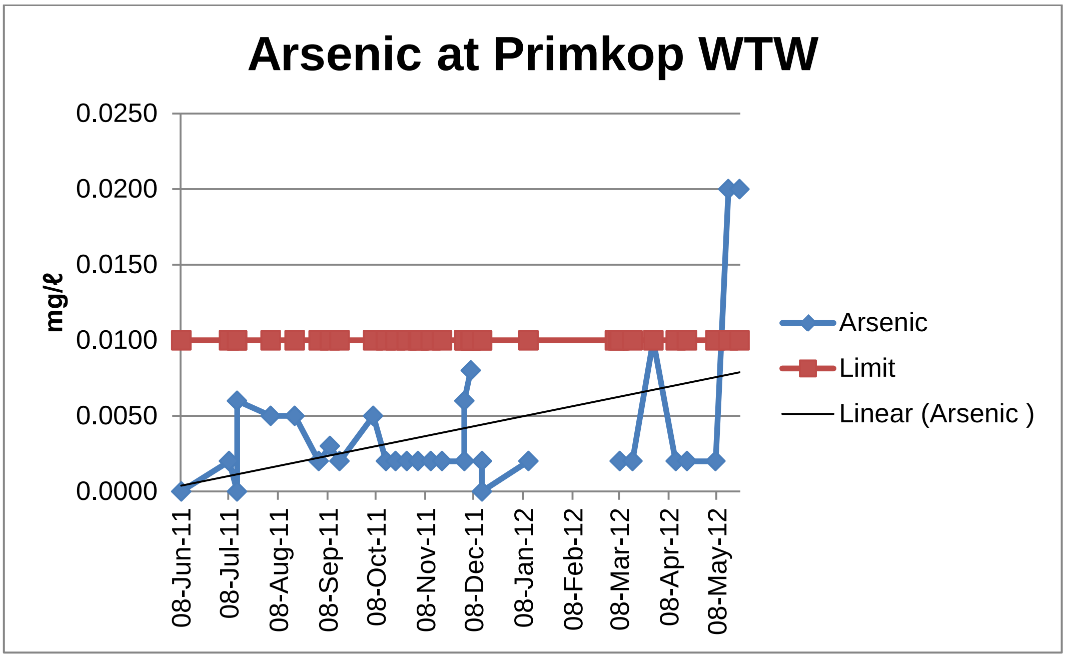

Tekwane Suspended solids
mg/ℓ
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
2
4
6
8
10
March - Dec 2011
Tekwane Suspendid solids
Linear (Tekwane Suspendid solids)

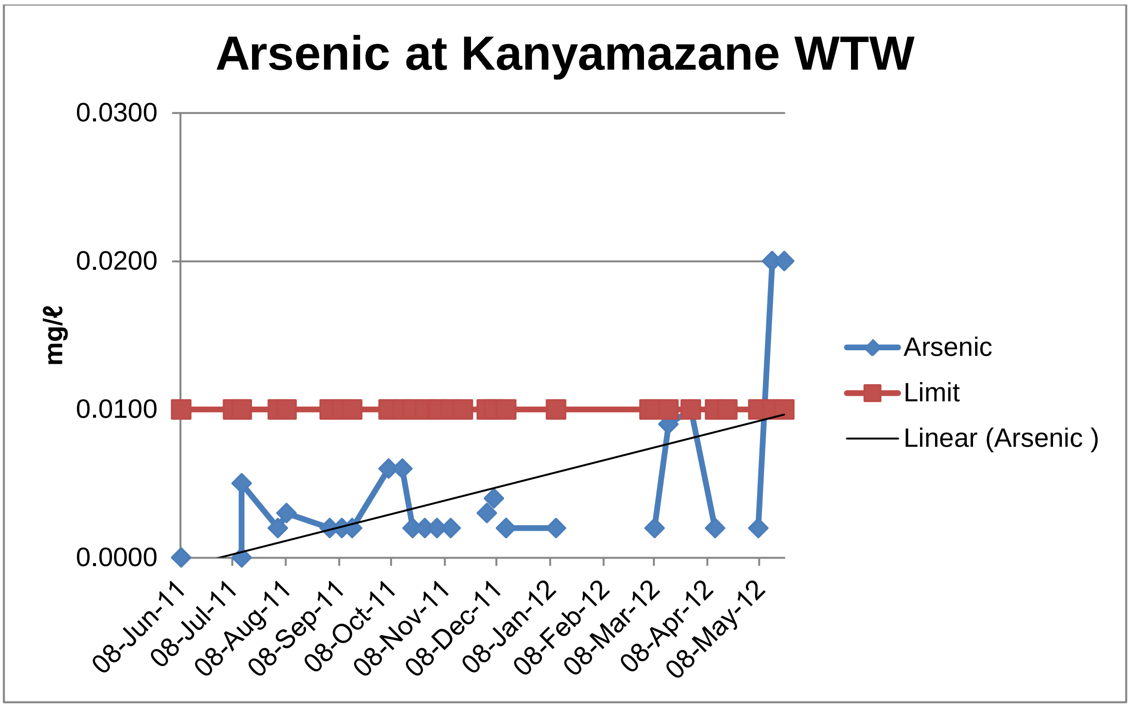
Appendix G: Arsenic Graphs

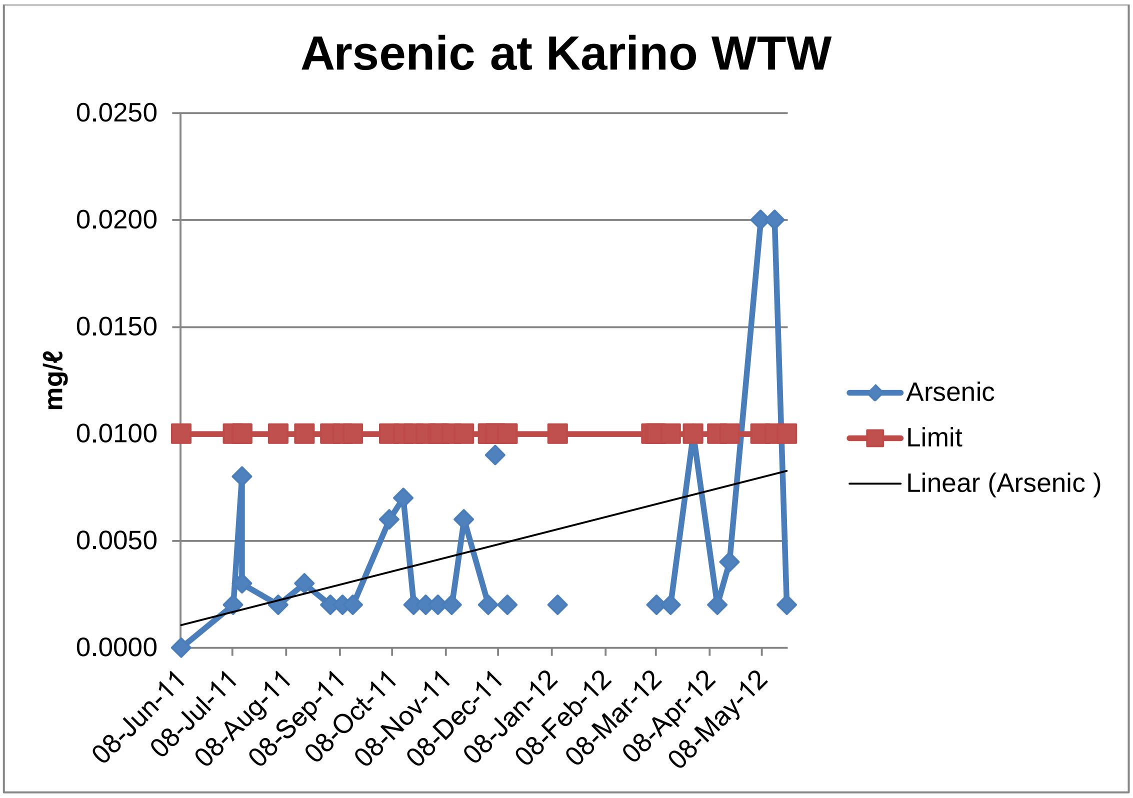

As at Nelspruit new WTW
0,0000
0,0000
0,0000
0,0000
0,0000
0,0000
Arsenic
Limit
08-Jun
08-Jul
08-Aug
08-Sep
08-Oct
08-Nov
08-Dec
08-Jan
08-Feb
08-Mar
08-Apr
08-May


Arsenic at old Nelspruit WTW
mg/ℓ
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
Arsenic
Limit
Linear (Arsenic)
08-Jun-11
08-Jul-11
08-Aug-11
08-Sep-11
08-Oct-11
08-Nov-11
08-Dec-11
08-Jan-12
08-Feb-12
08-Mar-12
08-Apr-12
08-May-12

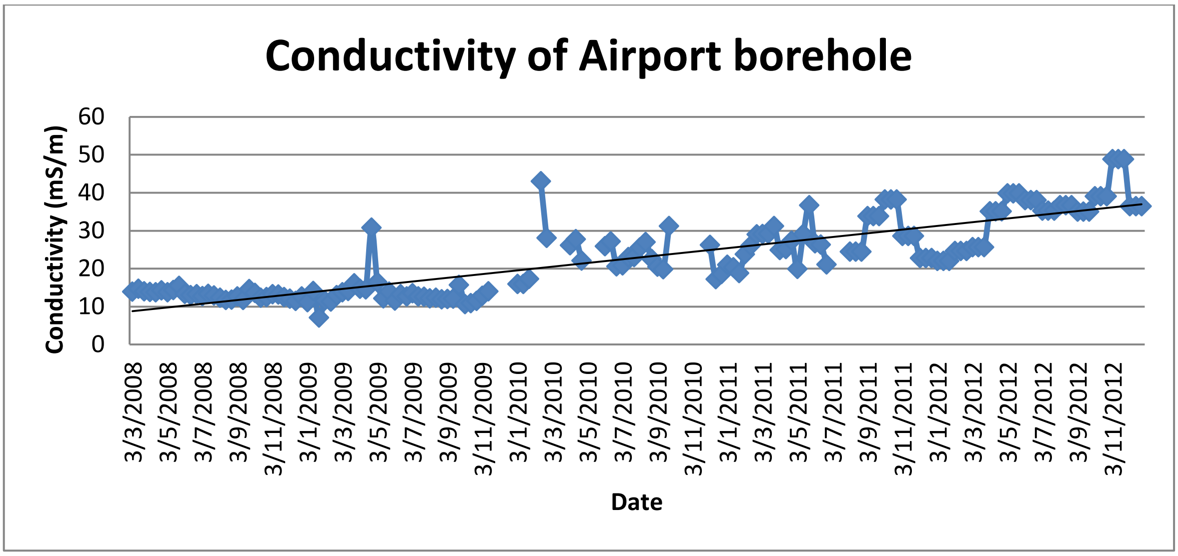

Arsenic at Matsulu WTW
mg/ℓ
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
08-Jun-11
08-Jul-11
08-Aug-11
08-Sep-11
08-Oct-11
08-Nov-11
08-Dec-11
08-Jan-12
08-Feb-12
08-Mar-12
08-Apr-12
08-May-12
Arsenic
Limit
Linear (Arsenic)

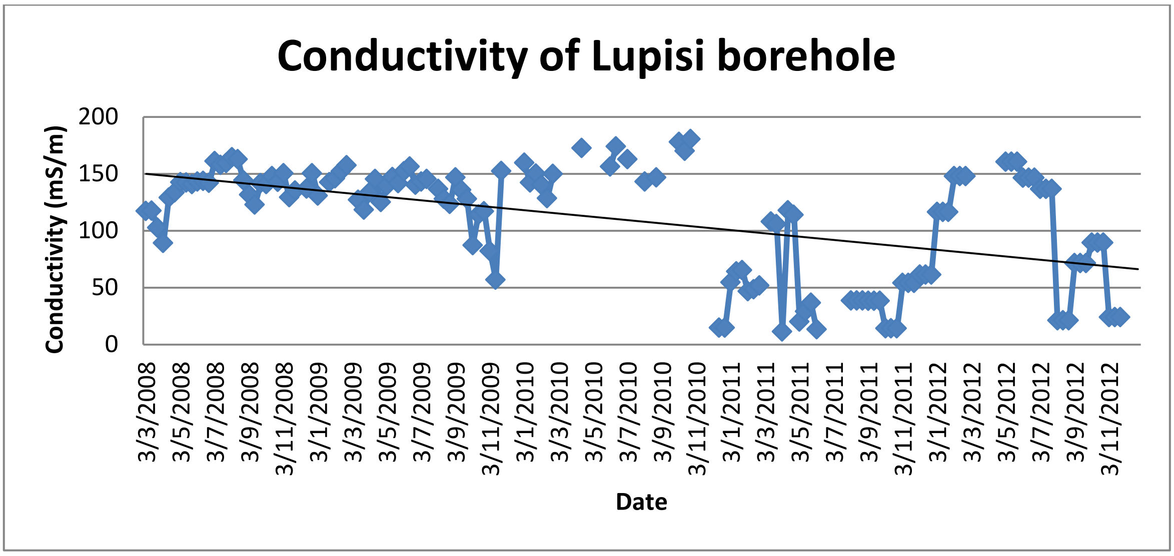

Arsenic at Primkop WTW
mg/ℓ
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
08-Jun-11
08-Jul-11
08-Aug-11
08-Sep-11
08-Oct-11
08-Nov-11
08-Dec-11
08-Jan-12
08-Feb-12
08-Mar-12
08-Apr-12
08-May-12
Arsenic
Limit
Linear (Arsenic)

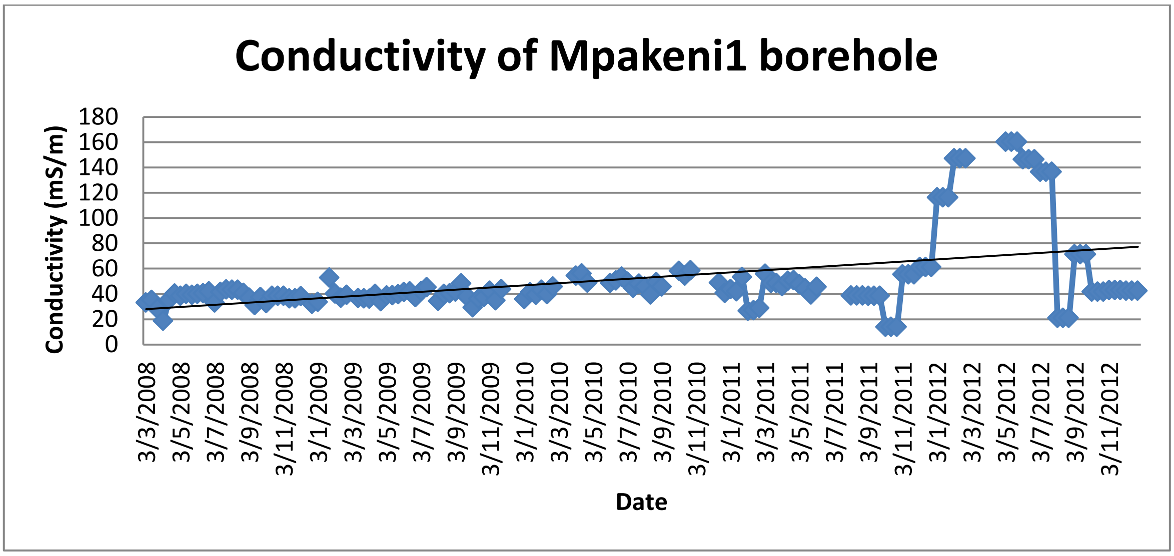

Arsenic at Kanyamazane WTW
0.0300
0.0200
0.0100
0.0000
mg/ℓ
08-Jun-11
08-Jul-11
08-Aug-11
08-Sep-11
08-Oct-11
08-Nov-11
08-Dec-11
08-Jan-12
08-Feb-12
08-Mar-12
08-Apr-12
08-May-12
Arsenic
Limit
Linear (Arsenic)

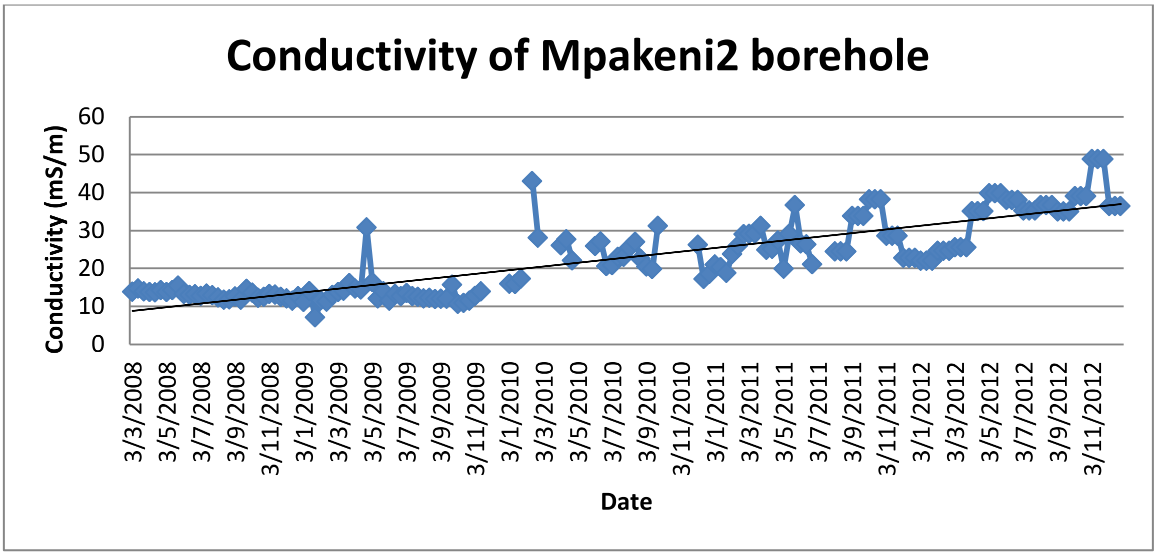

Arsenic at Karino WTW
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
mg/ℓ
08-Jun-11
08-Jul-11
08-Aug-11
08-Sep-11
08-Oct-11
08-Nov-11
08-Dec-11
08-Jan-12
08-Feb-12
08-Mar-12
08-Apr-12
08-May-12
Arsenic
Limit
Linear (Arsenic)

Appendix H: Sembcorp Borehole Monitoring Results

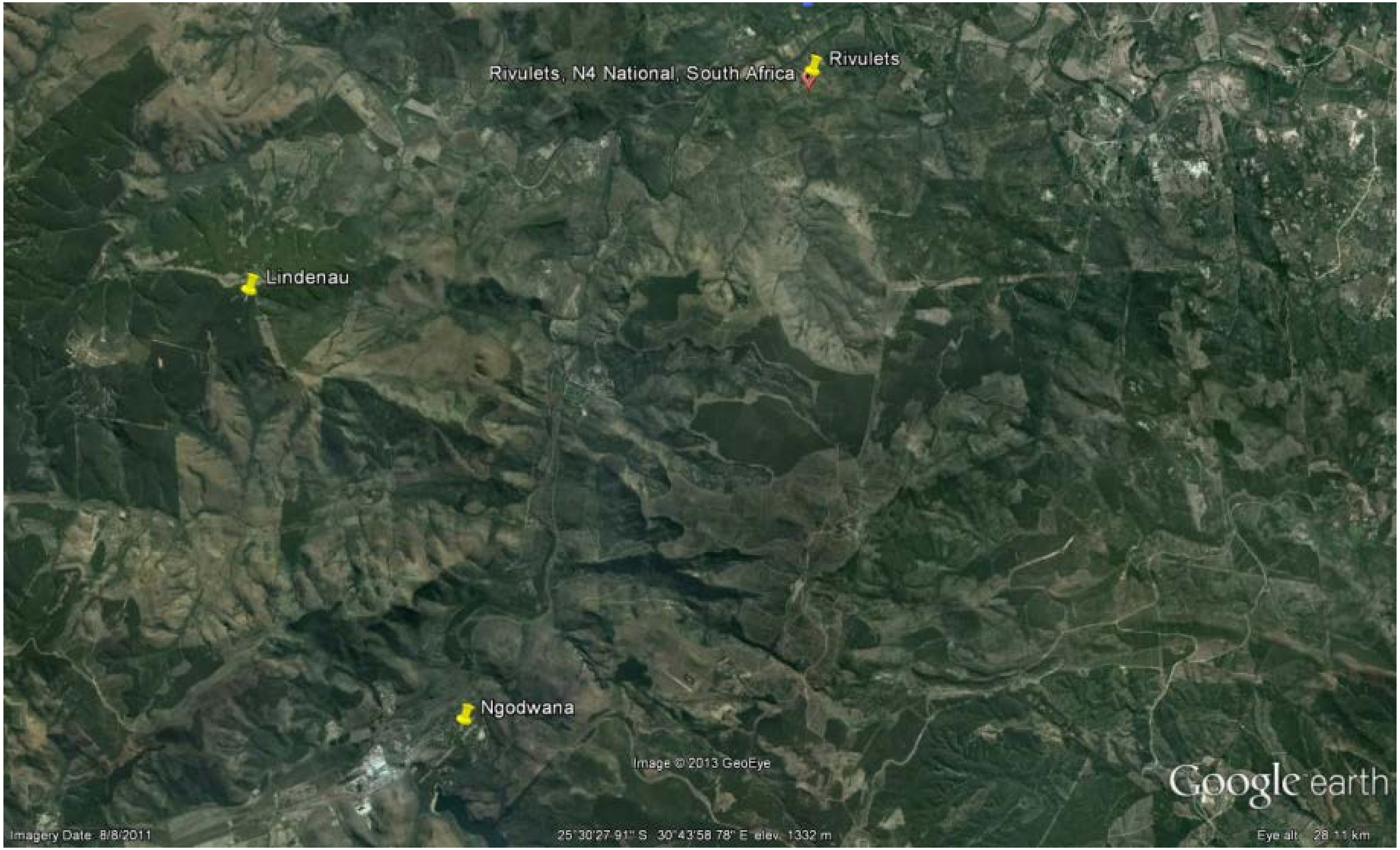

Conductivity of Airport borehole
Conductivity (mS/m)
60
50
40
30
20
10
0
3/3/2008
3/5/2008
3/7/2008
3/9/2008
3/11/2008
3/1/2009
3/3/2009
3/5/2009
3/7/2009
3/9/2009
3/11/2009
3/1/2010
3/3/2010
3/5/2010
3/7/2010
3/9/2010
3/11/2010
3/1/2011
3/3/2011
3/5/2011
3/7/2011
3/9/2011
3/11/2011
3/1/2012
3/3/2012
3/5/2012
3/7/2012
3/9/2012
3/11/2012
Date


Conductivity of Lupisi borehole
Conductivity (mS/m)
200
150
100
50
0
3/3/2008
3/5/2008
3/7/2008
3/9/2008
3/11/2008
3/1/2009
3/3/2009
3/5/2009
3/7/2009
3/9/2009
3/11/2009
3/1/2010
3/3/2010
3/5/2010
3/7/2010
3/9/2010
3/11/2010
3/1/2011
3/3/2011
3/5/2011
3/7/2011
3/9/2011
3/11/2011
3/1/2012
3/3/2012
3/5/2012
3/7/2012
3/9/2012
3/11/2012
Date

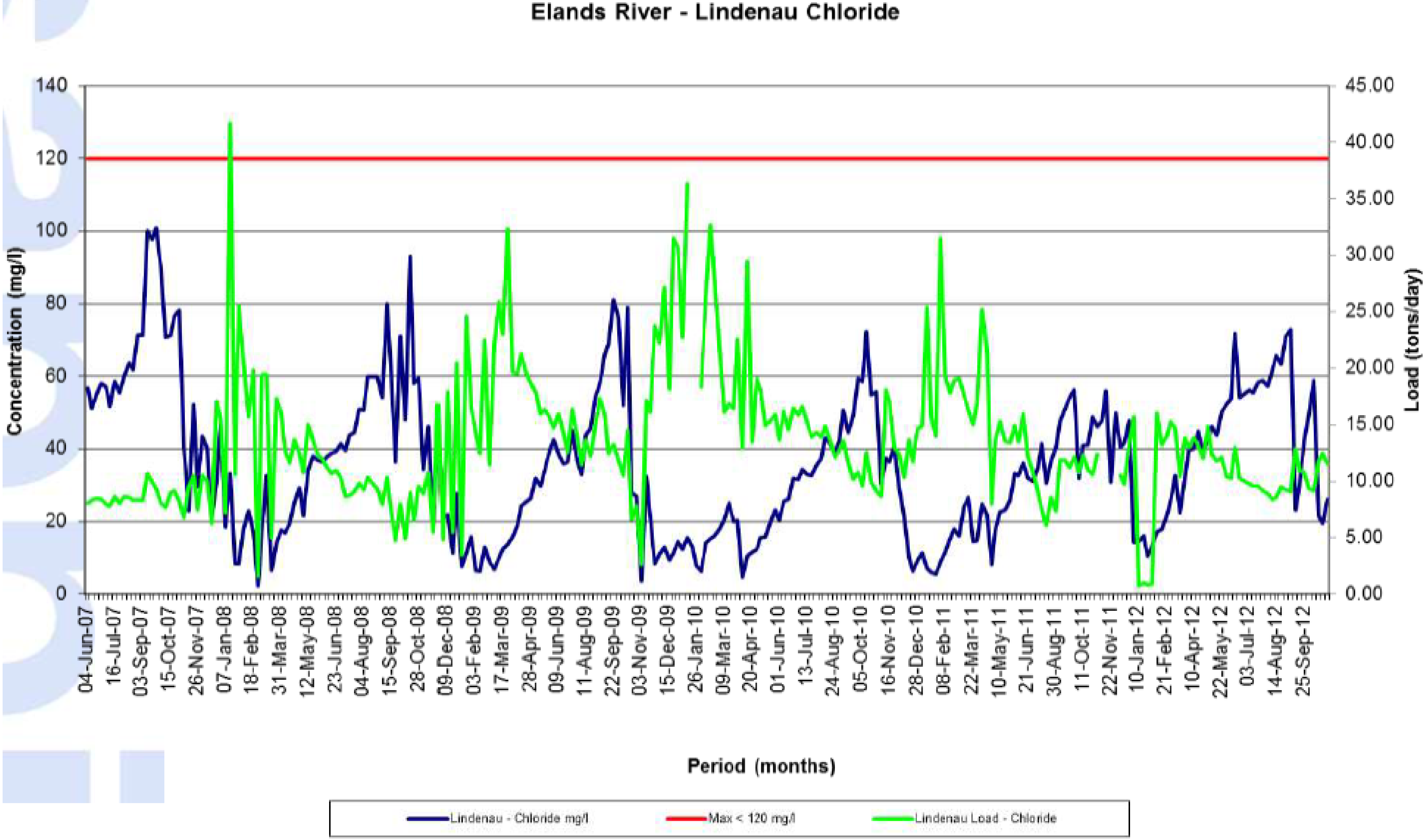

Conductivity of Mpakeni1 borehole
Conductivity (mS/m)
180
160
140
120
100
80
60
40
20
0
3/3/2008
3/5/2008
3/7/2008
3/9/2008
3/11/2008
3/1/2009
3/3/2009
3/5/2009
3/7/2009
3/9/2009
3/11/2009
3/1/2010
3/3/2010
3/5/2010
3/7/2010
3/9/2010
3/11/2010
3/1/2011
3/3/2011
3/5/2011
3/7/2011
3/9/2011
3/11/2011
3/1/2012
3/3/2012
3/5/2012
3/7/2012
3/9/2012
3/11/2012
Date

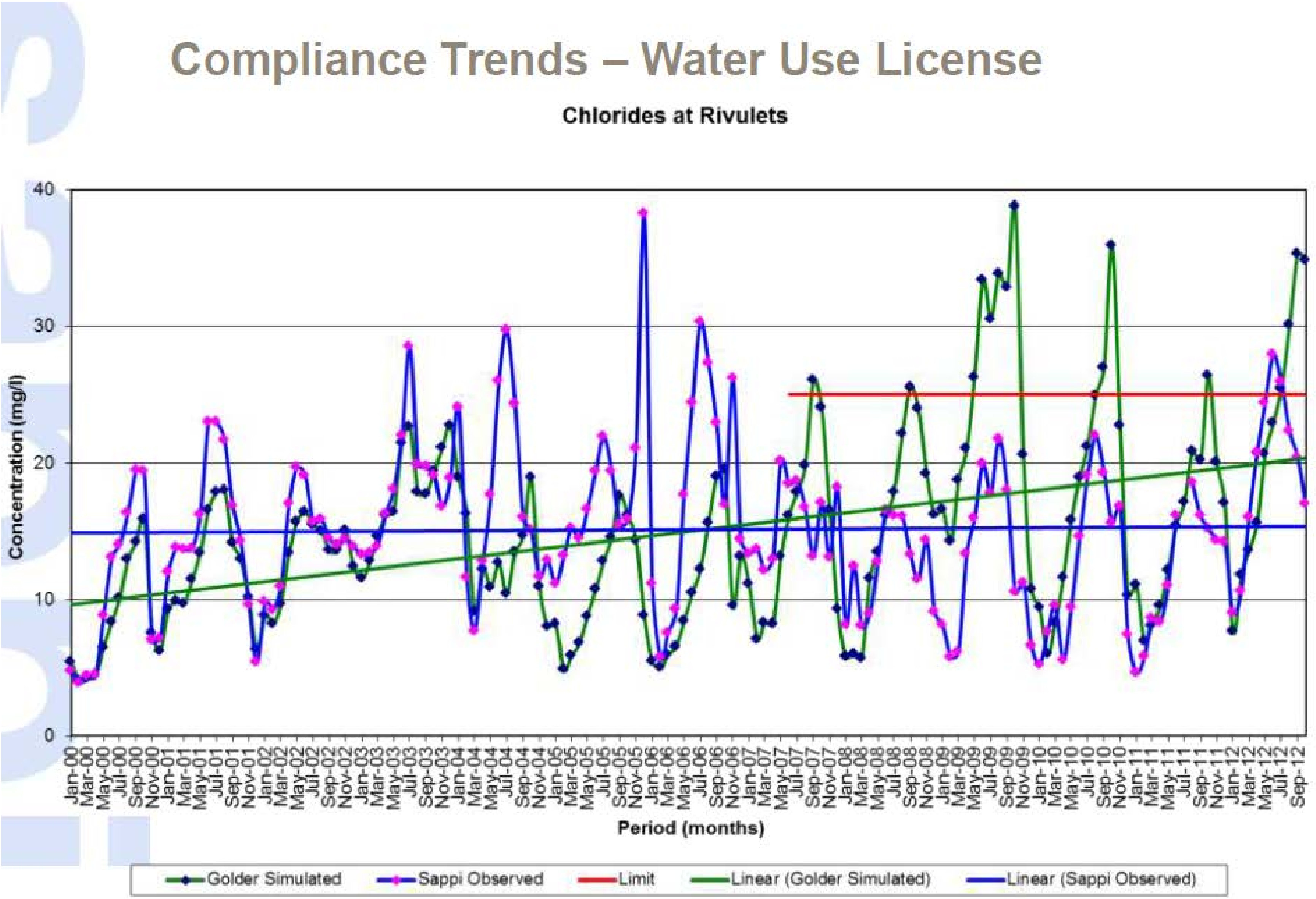

Conductivity of Mpakeni2 borehole
Conductivity (mS/m)
0
10
20
30
40
50
60
3/3/2008
3/5/2008
3/7/2008
3/9/2008
3/11/2008
3/1/2009
3/3/2009
3/5/2009
3/7/2009
3/9/2009
3/11/2009
3/1/2010
3/3/2010
3/5/2010
3/7/2010
3/9/2010
3/11/2010
3/1/2011
3/3/2011
3/5/2011
3/7/2011
3/9/2011
3/11/2011
3/1/2012
3/3/2012
3/5/2012
3/7/2012
3/9/2012
3/11/2012
Date

Appendix I: Sappi Ngodwana Monitoring Graphs

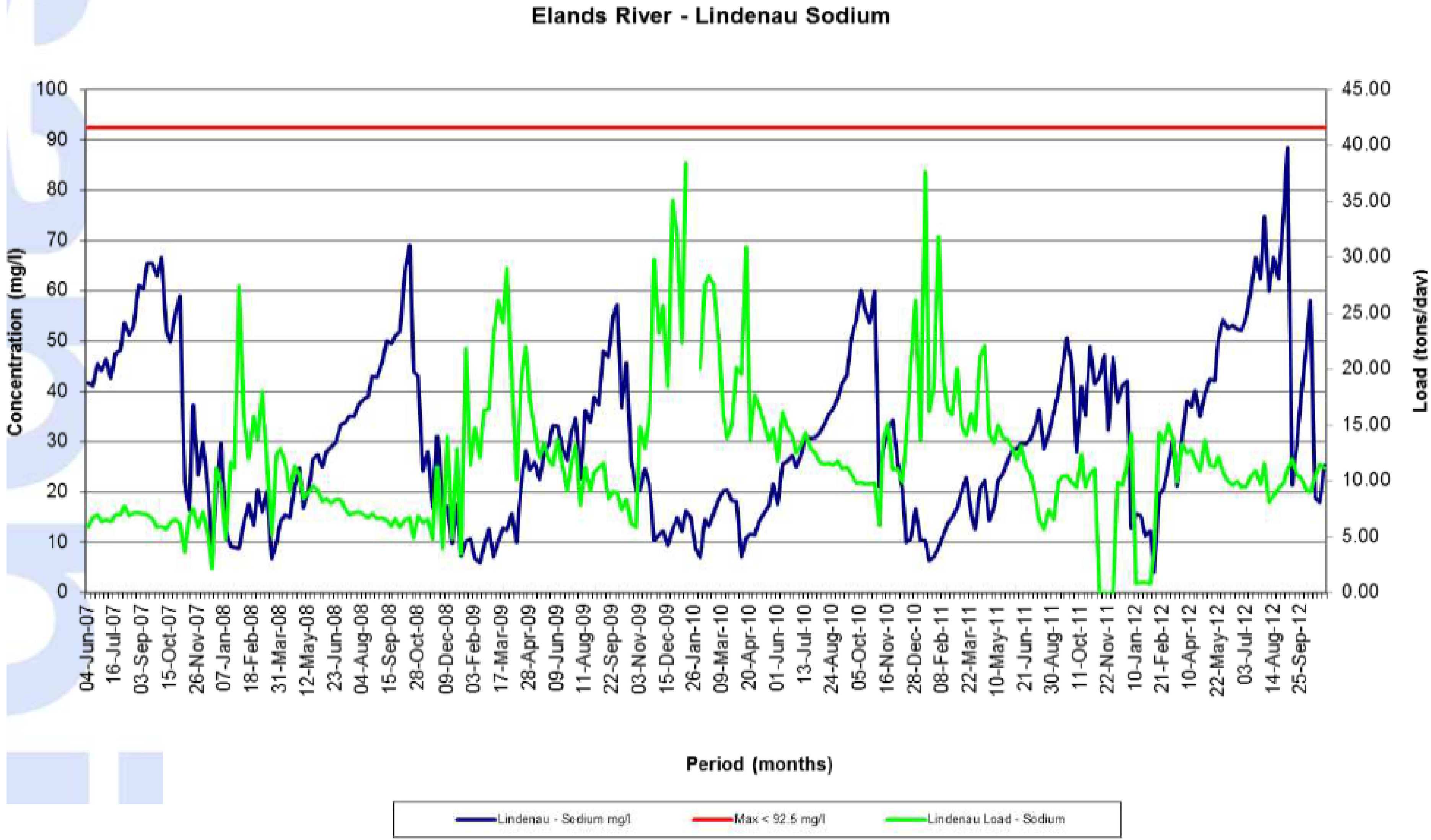

Rivulets
Rivulets, N4 National, South Africa
Lindenau
Ngodwana
Image © 2013 GeoEye
Google earth
Imagery Date: 8/8/2011
25°30'27.91" S 30°43'58.78" E elev. 1332 m
Eye alt 28.11 km

Compliance Trends – Water Use License

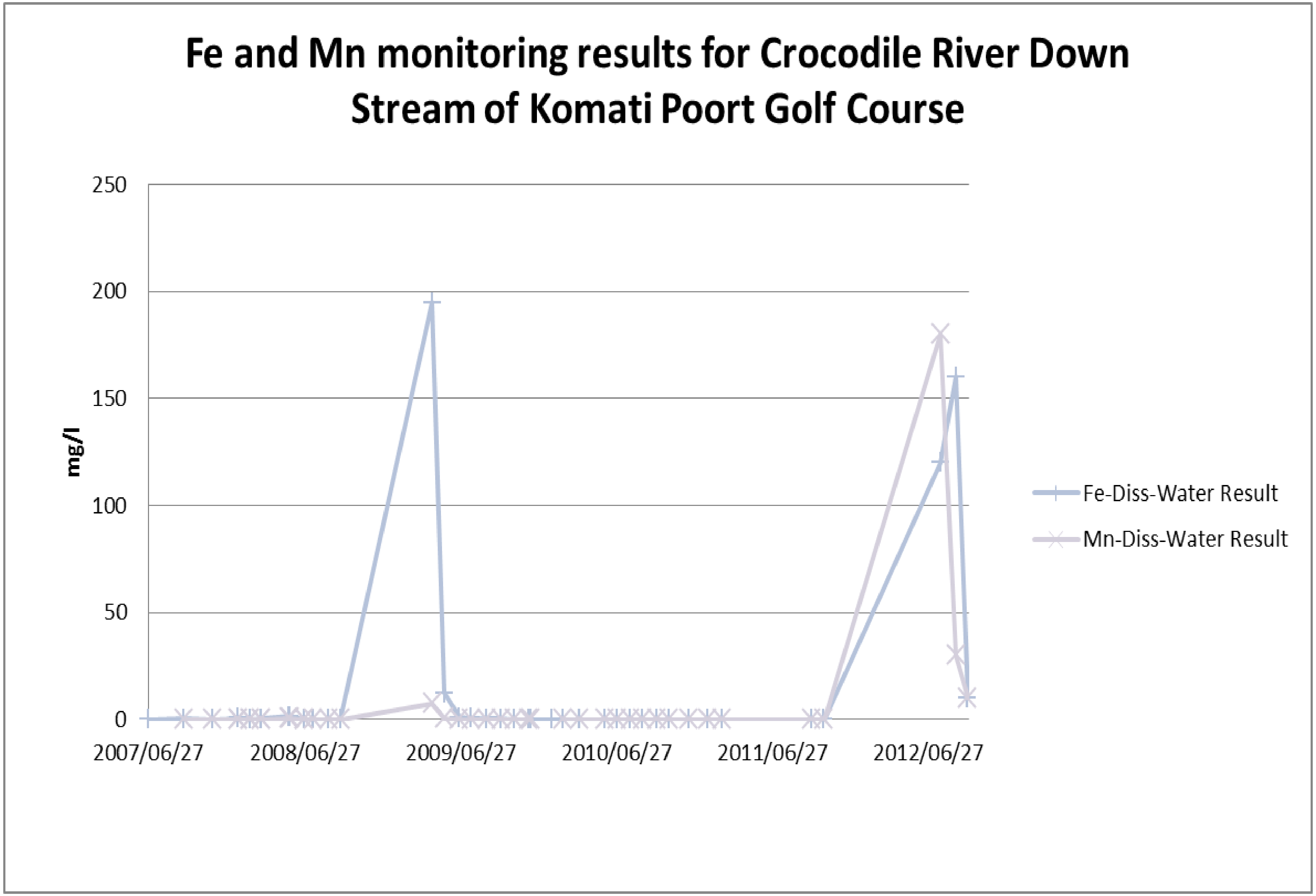



Compliance Trends – Water Use License
Chlorides at Rivulets
40
30
20
10
0
Concentration (mg/l)
Jan-00 Mar-00 May-00 Jul-00 Sep-00 Nov-00 Jan-01 Mar-01 May-01 Jul-01 Sep-01 Nov-01 Jan-02 Mar-02 May-02 Jul-02 Sep-02 Nov-02 Jan-03 Mar-03 May-03 Jul-03 Sep-03 Nov-03 Jan-04 Mar-04 May-04 Jul-04 Sep-04 Nov-04 Jan-05 Mar-05 May-05 Jul-05 Sep-05 Nov-05 Jan-06 Mar-06 May-06 Jul-06 Sep-06 Nov-06 Jan-07 Mar-07 May-07 Jul-07 Sep-07 Nov-07 Jan-08 Mar-08 May-08 Jul-08 Sep-08 Nov-08 Jan-09 Mar-09 May-09 Jul-09 Sep-09 Nov-09 Jan-10 Mar-10 May-10 Jul-10 Sep-10 Nov-10 Jan-11 Mar-11 May-11 Jul-11 Sep-11 Nov-11 Jan-12 Mar-12 May-12 Jul-12 Sep-12
Period (months)
Golder Simulated
Sappi Observed
Limit
Linear (Golder Simulated)
Linear (Sappi Observed)

Compliance Trends – Water Use License



Appendix J: Manganese and Iron Monitoring Results at Bottom of Crocodile Catchment


Fe and Mn monitoring results for Crocodile River Down Stream of Komati Poort Golf Course
mg/l
250
200
150
100
50
0
2007/06/27
2008/06/27
2009/06/27
2010/06/27
2011/06/27
2012/06/27
Fe-Diss-Water Result
Mn-Diss-Water Result