BOTSWANA-SOUTH AFRICA

Joint Water Quality Project

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DEPARTMENT OF WATER AFFAIRS

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Resilience in the Limpopo Basin Program

JOINT WATER QUALITY BASELINE REPORT

LIMPOPO BASIN BETWEEN THE REPUBLICS OF BOTSWANA AND SOUTH AFRICA

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TABLE OF CONTENTS

List of Tables

List of Figures

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All activities, especially field survey activities, for the water quality baseline assessment were jointly undertaken by officials of the Botswana and South African Departments of Water Affairs *(pictured on the right)*

Some of the joint survey team members from the Botswana and SA Departments of Water Affairs.

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The opinions expressed in this report are those of the authors and do not necessarily reflect the views of the lead government authorities, LIMCOM and their sponsors.

This report resulted from a writeshop held from 23 July to 25 July 2013 in Polokwane, South Africa.

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ACRONYMS

DWA-BOT	Department of Water Affairs, Botswana
DWA-SA	Department of Water Affairs, South Africa
IWRM	Integrated Water Resources Management
JPTC	Joint Permanent Technical Committee
JWQP	Joint Water Quality Project
JWQS	Joint Water Quality Survey
LIMCOM	Limpopo Watercourse Commission
RESILIM	Resilience in Limpopo Basin Programme
SADC	Southern African Development Community
SANS	South African National Standards
USAID	United States Agency for International Development
WHO	World Health Organisation
WMA	Water Management Area
WQ	Water Quality

EXECUTIVE SUMMARY

Limpopo River is a shared water course system that marks the boundary of Botswana, Zimbabwe, South Africa and Mozambique. The Limpopo River emanates where the Marico River and the Crocodile River joins and flows east wards to the Indian Ocean. The Southern African Development Community (SADC) has a protocol on shared watercourse systems, which amongst other things, under general principles, promote that "Member states shall take all measures necessary to prevent the introduction of alien aquatic species into a shared watercourse system which may have detrimental effects on the ecosystem"[1].

The two responsible authorities, the Departments of Water Affairs in Botswana and South Africa, in keeping up with this principle of the protocol have conducted joint field surveys on the section of Limpopo River that forms the boundary of South Africa and Botswana to the existence and extent of water quality contamination. This survey was extended to the South African portion of the transboundary basin between South Africa and Zimbabwe. The current water quality baseline study did not include Mozambique and Zimbabwe because the two countries are yet to be engaged in a multilateral agreement on water quality management.

The SADC protocol on shared watercourse system further promotes that "Member States shall take all measures necessary to prevent the introduction of alien aquatic species into a shared watercourse system which may have detrimental effects on the ecosystem"[2]. In keeping up with this principle, this study sought to assess the state of water quality in the transboundary basin and how this has affected the spread of water hyacinth.

There have been records of a spread of water hyacinth over a large portion of the Botswana-South Africa boundary, and the Botswana Department of Water Affairs has particularly received claims of heavy metal contamination along the Limpopo River main channel. These have led to convening of bilateral meetings between the two countries to address the noted concerns on the state of water quality in the Limpopo River and particularly resolve the spread of water hyacinth.

JOINT FIELD WATER QUALITY SURVEY

The bilateral agreement between South Africa and Botswana on water quality management for a shared watercourse led to the establishment of a Joint Permanent Technical Committee and subsequent commissioning of a joint survey to assess the state of water quality in the Limpopo River and its tributaries including the assessment of hyacinth spread and growth.

The joint water quality field surveys were designed to, amongst others:

- Cover three subsequent seasons as a means of scientifically observing trends and behaviour affected by rain
- Allow for joint collection of data by both Departments, joint on-site assessment of certain parameters and separate laboratory tests of same samples for later comparison and validation
- Include monitoring sites on both the Botswana and South African catchments of Limpopo River

Based on this approach,

- Acceptable criteria for choosing sites were agreed leading to a selection of 23 monitoring sites
- The survey was broken down into three weather periods - first in September-December 2011 (summer), followed by February 2012 (rain) and finally in June/July 2012 (winter).

On-site testing was completed for pH, Electrical Conductivity, Dissolved Oxygen, Total Dissolved Solids and Turbidity. The results from these tests were recorded on-site by officials from the two Departments of Water Affairs. In addition samples were also collected for analysis in laboratories for analysis of Calcium, Dissolved Oxygen, Electric Conductivity, Fluoride, Iron, Lead, Nitrates, Phosphate, pH, Magnesium, Sodium, Potassium, Manganese, Copper, TDS and Turbidity.

[1] *Protocol on Shared watercourse systems in the Southern African Development Community (SADC)*
[2] *Protocol on Shared watercourse systems in the Southern African Development Community (SADC)*

OVERVIEW OF FINDINGS

The South African Water Quality Guideline (Field guide and Aquatic)[3] was used to analyse results against the Targeted Water Quality Range.

The onsite sampling results indicate that turbidity is high for all sampling points although the South African standard is silent on minimum standards. This condition is consistent over all the periods of monitoring. High turbidity can impact on some aquatic species and lead to death or migration when their habitat is affected. Turbidity is often increased by discharges or runoff from irrigation fields along the river. It is therefore essential that quality of discharges complies with legislated standards and that the location of human developments is kept by the required distance of 1:100 year flood line.

According to the SA targeted water quality guideline, Total Dissolved Solids and electric conductivity should be between 0-450mg/l and 0-40 mS/m respectively. The Nwanedi monitoring site was found to be the only site above limit. The resource at this sampling point has been dammed, and this might be regarded as a major cause of high TDS and EC.

Dissolved Oxygen, pH, Electrical Conductivity, Total Dissolved Solids and turbidity were analyzed both on site and in a laboratory. Fluoride, pH, lead, nitrates and phosphate were found to be within the targeted water quality guideline in most the sampling points except points in the Crocodile, Mokolo, Olifants and Notwane Rivers. The concentration of Nitrates in the primary rivers (Crocodile and Marico) and the main channel have led to the development of eutrophic conditions. These eutrophic conditions are conducive for water hyacinth to flourish.

Electrical Conductivity, Total Dissolved Solids, Iron and Dissolved Oxygen were found to be out of range using the SA Targeted Water Quality Guideline in some sampling points, especially in the primary rivers upstream of Limpopo (Crocodile and Marico) and in the main Limpopo River. Dissolved Oxygen was found to be generally lower at Marico-Sikwane, Marico-Olifants, Limpopo-Olifants and Notwane during summer and rainy seasons. Total Phosphates were high in the sites detected and potassium was detected only in the rainy season

SURVEY CHALLENGES

The survey encountered a number of challenges for which purposeful actions will be required to improve future planning, design and execution of similar surveys. The following are some of the key challenges highlighted by the survey team:

a) Lack of appropriate field survey equipment to undertake the survey in an efficient and effective manner. These include boats, on-site laboratory equipment, safety equipment, etc

b) There were no clear and targeted survey targets to inform the key parameters to be prioritised and covered

c) Absence of harmonised methodology, basin water quality objectives and measurement standards between Botswana and South Africa

d) Some monitoring sites were not easily accessible, especially those in South Africa

e) In some parameters, the South African Target Water quality guidelines for aquatic ecosystems standards are high as compared to drinking water quality standard. On the other hand, Botswana does not have standards for aquatic ecological systems.

f) The sampling site selection was not rightly preceded by informed analysis of potential sources of pollution. There was no inventory of these facilities at the time of drafting sampling programme.

g) The South African team members were not able to sample on the Botswana side of the Limpopo basin, and this directly affected the purpose of the joint survey.

[3] *Department of Water Affairs, South Africa, 1996*

CONCLUSION AND RECOMMENDATIONS

The survey has successfully gathered baseline data against which future surveys will be compared, and this information is sufficient to establish an understanding of the status of water quality in the Limpopo River and subsequently trigger necessary courses of action by different authorities to ensure that integrity of water quality in the river is maintained within acceptable standards.

The results confirm that there is reason for concern in relation to the presence, concentration and quantity of different chemical, physical and heavy metal matters in the Limpopo transboundary river catchment between Botswana and South Africa, especially conditions which promote the germination of invasive alien plants such as water hyacinth. Portions of the catchment show signs of pollution but only a few sites and a few parameters are beyond acceptable norms. Part of the study objectives was to determine possible sources of water hyacinth, and although the survey is not conclusive about source points, there is indeed an indication of presence of nutrients in the water body that favour the germination and propagation of water hyacinth. From the information gathered, it is safe to conclude that Hartebeespoort Dam on the Crocodile River is the primary source of pollution and germination of water hyacinth.

Another concern to note is that in a few sites where heavy metals were detected, the concentration exceeded the acceptable limits. The survey concludes that the Limpopo River is polluted; however the extent of pollution differs from river to river. The general trend is that the upstream rivers and the main river channel show presence of pollution than the middle tributary rivers.

The survey team therefore recommends as follows:

a) A more detailed study is required to ascertain the actual sources of pollution. This study, which should include physical inspections of all potential point sources of pollution, such as domestic discharges (sewage effluent) effluent from wastewater treatment plants, farms and mines, must be preceded by detailed identification, description and marking of all potential point sources on both sides of the catchment.

b) The Departments of Water Affairs in both Botswana and South Africa should harmonise their methodologies, targeted water quality parameters, standards and sampling regimes

c) Both departments should utilise appropriate accredited laboratories with clear reports of analytical methods applied and applicable quality management system

d) There should be rapid analysis and communication to stakeholders of results after completion of surveys. Communication must serve as an early warning system to water users, and active involvement must be used to elicit inputs from users themselves on appropriate actions to be taken

e) The authorities in Botswana and South Africa must finalise a joint plan of action on clearing hyacinth and how to engage Working for Water programme in South Africa

f) The surveys must be upscaled to include Zimbabwe and Mozambique in future

g) The participating authorities must agree on target periods and interval of surveys - it is proposed that in the immediate term, surveys should be undertaken at least twice a year, in the summer and winter seasons.

h) Communication between the land owners and the DWA-SA need to be strengthened to facilitate accessibility of sampling points.

i) An integrated water resources management approach must be adopted to incorporate other factors such as hydrology (flows), geology, the water quality parameters (that have been agreed upon), the vegetation as well as the biological monitoring, that is, the use of macro invertebrates to determine the ecological health of the river (South African Scouring System-SASS 5).

j) Control and regulate waste water discharges by ensuring that responsible authorities monitor and comply with the applicable effluent standards.

1 INTRODUCTION

The Limpopo river basin is shared by the four SADC countries which are Botswana, Mozambique, South Africa and Zimbabwe. The riparian states committed to manage their water resources together as far back as 1986 when they jointly formed the Limpopo Basin Permanent Technical Committee. The cooperation was fostered through multilateral agreement to establish the Limpopo Watercourse Commission (LIMCOM) in 2003. The Limpopo River is used not only to supply water to the adjacent settlements within the riparian states, but it also acts as a habitat for different life forms such as fish and macro-invertebrates. Therefore it is essential to monitor the water quality of the river system to guard it against pollution. Monitoring the river water quality by the riparian states also helps them to evaluate the effectiveness of their regulatory frameworks.

Changes in the river water quality can affect the aquatic life. The concept of water resource use is dependent on resource protection. The recognition of water quality should be extended to resource quality and should include quantity and quality of the water, the in-stream biota and the associated riparian biota. The type and class of water quality may vary for every biota such as plants, macro-invertebrates, fish and other aquatic animals. Then the question arises as to how much waste a system can absorb or tolerate before ecosystem damage occurs (Institute of Water Quality Studies (IWQS), 1999). In order to protect water resources the national water laws in South Africa allow for the establishment of a classification system. Since ecosystems are able to function at various levels of integrity, the process makes room for the inclusion of a classification procedure for the recognition of a range of functioning conditions from pristine to modified conditions. However, the national water laws for various countries may differ and they need to be addressed in the context of sustainable use of trans-boundary rivers.

The Botswana and South African Departments of Water Affairs initiated a bilateral process in 2009 to address two areas of concern, first the anticipated spread of water hyacinth along nearly 300 kilometres of the river, with varying levels of concentration; and secondly, claims by irrigation water users that the water was polluted with heavy metals attributed to mining and industrial developments upstream of Limpopo in South Africa. This process culminated in the establishment of a Joint Permanent Technical Committee (JPTC) in November 2010. A Joint Water Quality Project (JWQP) was consequently commissioned to determine and provide the baseline water quality data source for the Limpopo River Basin that is shared water resource between Botswana, Mozambique, South Africa, and Zimbabwe. The water quality data in the upstream and the downstream basin would guide the two countries on suitable remedial and compliance monitoring interventions. In addition, the Joint Water Quality Project was also commissioned with the intention of protecting the quality of the water resources in the shared portion of the Limpopo Basin.

This report documents the first outcomes of the joint water quality monitoring project carried in the Limpopo River to generally assess the water quality condition and identify potential physico-chemical threats to the system. The report covers joint field surveys carried in September-December 2011, February 2012 and June-July 2012.

2 BACKGROUND

2.1 LIMPOPO RIVER BASIN

The Limpopo River basin is shared by four countries: Botswana, South Africa, Zimbabwe and Mozambique (Figure 1). The total catchment area is approximately 408,000 km^2 and the river stretches for approximately 1,770 km starting in South Africa[4], flowing up north were it creates the South Africa-Botswana border, then east as the South Africa–Zimbabwe border and finally south-east through Mozambique to the Indian Ocean.

The main Limpopo river starts with two main tributaries (primary rivers): Crocodile and Marico which establishes the main channel and a number of secondary tributaries - Notwane, Lephalale, Bonwapitse, Matlabas, Mahalapswe, Mokolo, Lotsane, Motloutse, Mogalakwena, Shashe, Sand, Mutshilashokwe,Nzhelele, Mzingwani, Luvuvhu, Shabili, Bubi, Lumane, Mwenezi and Changane.

The Limpopo Water Course Commission (LIMCOM) oversees transboundary relations amongst the four countries.

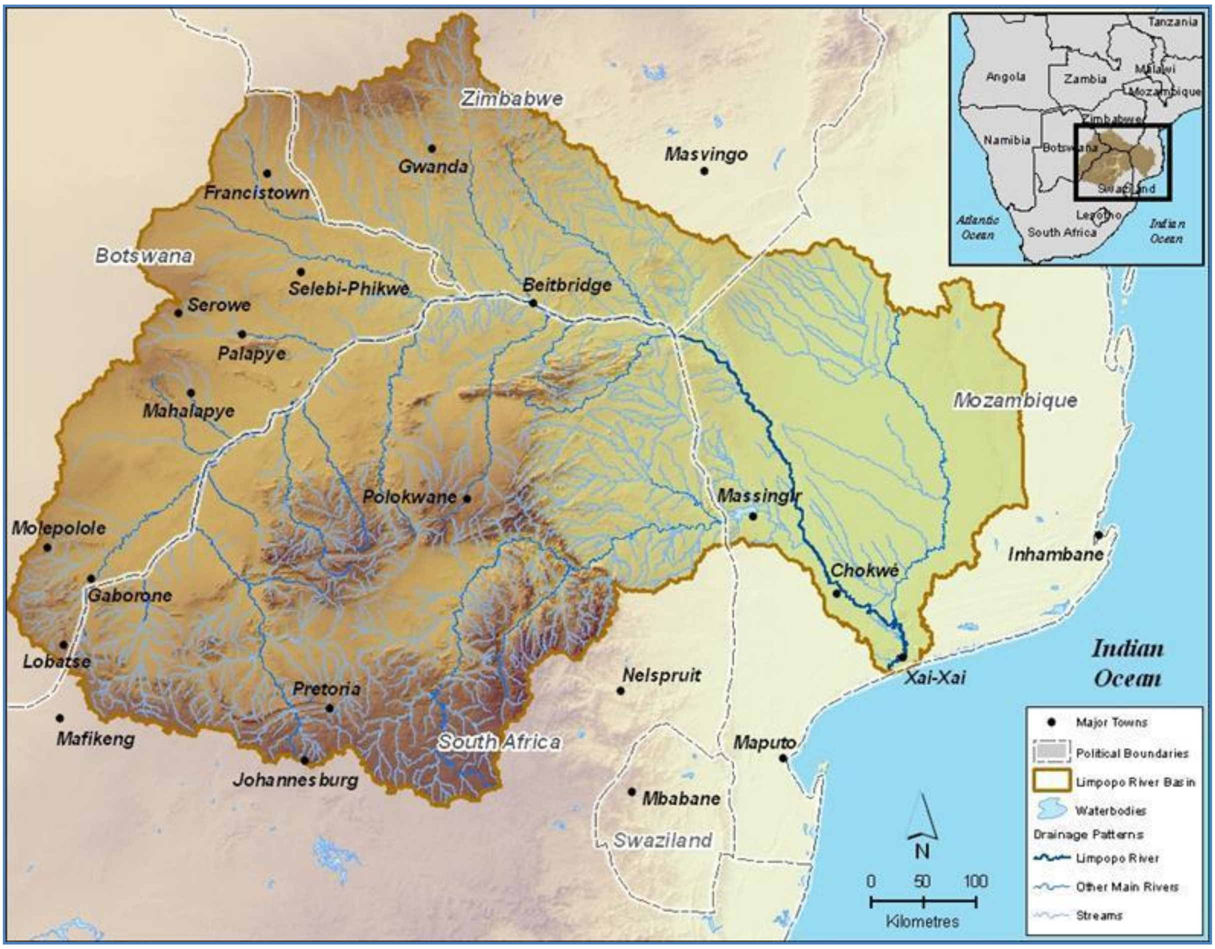


Figure 1: Map of the Limpopo River Basin

2.1.1 DEMOGRAPHICS

The shared basin between Botswana and South Africa carries a population of over 13 million people. Whilst the majority of the population is in South Africa, over 80% of Botswana's population resides on the Limpopo Basin. The shared basin includes large metropolitan areas of Johannesburg and Pretoria, large cities of Rustenburg and Polokwane in South Africa and Gaborone, Lobatse, Palapye ,Mahalapye, Selibe Phikwe and Francistown in Botswana.

[4] Limpopo Water Course Commission www.limcom.org

2.1.2 Status of Water Use

The shared basin supports agriculture, industry, mining and domestic water use in Botswana and South Africa. South Africa's economic activity consumes a lot of water in the basin with commercial agriculture, power generation and mining. Botswana's water use supports mining, small-scale and subsistence farming and power generation.

a) Dams

There are five (5) large dams in Botswana and twenty (20) in South Africa.

b) Power generation

There is one (1) power plant in Botswana along the basin and about three (3) in South Africa.

2.1.3 Potential Sources of Water Pollution

a) Mining

Mining activities - coal, platinum, iron ore, chrome, platinum and diamond - are found in the basin between Botswana and South Africa. Some of the mining activities in the Crocodile River and Limpopo main channel are suspected to be contributing to pollution. Acid Mine Drainage has not been identified in the basin, however some heavy metals have been detected.

b) Agriculture

Commercial agriculture in South Africa uses a lot of chemical components to condition the soil and these are possible pollutants which carry high loads of nutrients.

c) Waste water systems

Botswana has several municipal waste water treatment plants along the basin - Glen Valley, Tonota, Selibe Phikwe, Mambo, and Mahalpye. South Africa has several large human settlements within the basin - from the western and northern parts of Johannesburg to Musina where municipal waste water treatment systems discharge into Limpopo Rivers. Mines and power generation plants in the basin use close circuit systems which do not discharge directly into river systems.

2.2 Water Quality Management

Much of the emphasis in water resource management has revolved around ensuring that users should have not only sufficient quantities of water but desirable water quality too. The issue of water quality can play a dominant role when the available water get scarce and scarce. Water availability is only as good as the quality of that water. Therefore, both quantity and quality need to be considered in detail and they can no longer be managed in isolation of each other.

The consequences of irrigation, the leaching of fertilizers, and more importantly the leaching of salts from deeper soil horizons can render both the lands themselves and the receiving rivers unsuitable for use. Diffuse agricultural 'effluent' may be less visible than direct discharges of sewage or industrial effluent, but is no less pernicious neglected

Surface water quality is affected by many things including sediment and erosion, the diffuse discharges from irrigated farmland (both fertilizers and salinity through leaching), domestic and urban runoff, industrial waste, and sewage discharges. Of these, industrial waste and sewage discharges are the easiest to license and control, but this does not mean that this is problem-free. The Departments often find that the situation with regard to sewage discharges often far exceeds the standards and conditions demanded by licenses. There is a problem of compliance with regard to local authorities and private operators responsible for waste water management systems. The Departments of Water Affairs in both countries are moving towards IWRM to integrate quantity and quality issues. Direct discharges to rivers are licensed and managed on the basis of assimilative capacities of the rivers for various uses through Water Laws enacted by the respective governments.

Where these limits are exceeded, often through the cumulative impact of diffuse discharges, water becomes unavailable to some, or even all users downstream. In South Africa, the Waste Discharge Charge System is available to charge waste water/treated effluent that exceeds the stipulated standards.

2.3 Water Hyacinth

2.3.1 Description

Water hyacinth *Eichhorniacrassipes* (Martius) Solms-Laubach is free-floating perennial aquatic plant native to tropical and subtropical South America[5]. This plant is in the list of aquatic problem plants in both Botswana and South Africa. Their primary impact in water resources is that:

- it reduces light and oxygen in the water;
- it changes the water chemistry (often resulting in fish kill);
- it is known to provide a habitat for disease causing species (snail and mosquito); and
- it affects flora and fauna and also causes significant increase in water loss due to evapo-transpiration.

Water hyacinth is often known to invade bodies of water that have been impacted by human activities. For example, water bodies with elevated levels of nitrate and phosphate from commercial agricultural land or sewage treatment works.[6] The plant may also produce a bacterium called mycrosystis and treatment of highly eutrophicated water is costly and requires different treatment systems to remove where water is used for drinking purposes.

The plant may reproduce vegetatively at an alarming rate by means of side shoots (stolons) which break off and develop into new plants, and its active growing colonies may double their numbers every 11 to 18 days. Their largest concentration is found in water bodies that are enriched by sewage and industrial effluent or by run-off from fertilized agricultural land.

2.3.2 Water Hyacinth Control in the Limpopo Basin

Department of Water Affairs (DWA), Botswana confirmed the floating of water hyacinth to Limpopo River from Crocodile River in 2010 flood (May 2010). The Department engaged DWA in South Africa about the weed's threat to the Limpopo River system. This resulted in organizing a workshop from 8-10 November 2010 on Water hyacinth at Thabazimbi hosted by DWA, RSA. The workshop resolved to prepare Memorandum of Understanding (MoU) to develop a joint strategy between Botswana and RSA for the management of Water hyacinth. Investigations confirmed that the source of infestation into the Limpopo River was from Crocodile River and the Haartbeesport Dam.

Extent of Infestation

A joint helicopter survey was conducted in September 2012. The survey revealed that the weed increased its spread about 25 to 30 km from Martins Drift downstream. It is estimated that, due to the 2012 flooding, water hyacinth has now affected nearly 300 kilometres of the Limpopo River.

Available Options

Appropriate control measures have not been agreed pending a Memorandum of Agreement and further stakeholder consultation. The following are available options:

Physical control: This involves hand removal pulling of plants especially the floating to achieve immediate clearing of the nuisance plants. This can work well with big plants, is labour intensive but effective control. In South Africa, handling, physical removal and disposal of water hyacinth is regulated by the Conservation of Agricultural Resources Act, Act No. 43 of 1983. Physical removal is non-polluting, stops eutrophication and does not harm fish.

[5] http://en.wikipedia.org/wiki/Water_hyacinth
[6] http://www.arc.agric.za/home.asp?PID=1&ToolID=65&ItemID=3023

Where permissible, plants are available for utilization for economically viable use for animal fodder, fertiliser and other uses. The South African laws are strict in this regard, so water hyacinth must be assessed for heavy metal and nutrient load before consideration for agricultural utilisation. Physical control is slow, time consuming, difficult in inaccessible areas, must be repetitive, costly, and disposable systems are required.

Mechanical harvesting: Mechanical harvesters are available commercially both for short-term and long-term control and are very costly.

Chemical control: A number of systematic and contact herbicides are available for use in infested river systems. Chemical control is effective in killing plants in highly infested areas. Application is easy, less expensive and provides extensive demonstration of effective control. It however needs stringent quality control due to possible damage to non-target plants including fish, nutrient enrichment of water from dead plants. Application may be difficult in application to inaccessible areas and there is necessity of repeated application.

Biological control: Biological control involves the introduction of successful insects such as *Neochetinaeichhorniae* and *Neochetinabruchi (Curculionidae)* on to the infestations to into a river system to consume the invasive plant. The biological control of water hyacinth in South Africa currently relies on six established agents. Biological control is effective in static water where the water hyacinth is not highly mobile and works effectively in small infested areas. Biological control is often negatively affected by climatic conditions such as low temperatures and a high incidence of frosting which slows the build-up of natural enemy populations. Complete control may be attained in 2-3 years.

Integrated control: Integration of different control measures may be applied in various ways:

a) Integrating chemical control followed by physical removal especially on the banks.

b) Integrating physical and biological control simultaneously. Physical control should be stopped when the biocontrol weevil is established on the plants

2.3.3 Key Considerations in the Control of Water Hyacinth

a) **Targeted application:** Control measures must be considered on the basis of full understanding of the infestation character. Certain measures work effectively under certain conditions only.
b) **Regulation:** There are restrictions and regulations on various control measures, especially chemical control and in South Africa, physical handling and disposal is regulated.
c) **Coordination:** Effective control requires coordination amongst different parties, and for Limpopo this includes inter-country coordination and protocols.
d) **Consultation**: Stakeholders and users must be consulted before certain measures can be applied.
e) **Costs (and risks)**: Different measures have differing cost implications including environmental costs, and also present different risks

The South African Working for Water Programme has adopted a ten-point plan for 10-point plan for the integrated control of water hyacinth in South Africa. These points are:

1) Identification of the weed;
2) Map the extent of the weed;
3) Identify the cause of the infestation;
4) Consult interested and affected parties;
5) Appointment of a lead agency or champion;
6) Ascertain an acceptable level of control;
7) Consider control options;
8) Implement control options;
9) Monitor control options;
10) Evaluate plan and adjust accordingly.

This plan is implemented on a site specific basis and should be flexible. Each river system is divided into manageable units and suitable measures are applied to suit the circumstances of the specific unit.

3 THE 2011/12 JOINT WATER QUALITY SURVEY

3.1 OBJECTIVES OF THE JOINT SURVEY

a) To determine the state of water quality in the Limpopo Basin

b) To identify the possible sources of pollutants to the Limpopo River from either mine, farm activities or waste water discharge facilities in the Limpopo Catchment in both Botswana and South Africa.

c) To assess the behaviour and trends of contaminants from the catchment rivers to the Trans-boundary Limpopo river

d) To assess the spread of the water hyacinth and initiate appropriate methods of control

e) To develop a cooperative water quality management (WQM) for a shared water course and develop a joint action plan

3.2 SCOPE AND LIMITATIONS OF THE JOINT SURVEY

The scope of the joint survey was based on a bilateral agreement between South Africa and Botswana. In this regard, the study covered the rivers affecting water use along the border of Botswana and South Africa. The rivers in Mozambique and Zimbabwe that drain into the transboundary Limpopo River were not included for monitoring because the Joint Water Quality Survey (JWQS) program does not have joint survey protocols with the two countries. However, the main Limpopo River channel bordering between South Africa and Zimbabwe was monitored. The Sand River, Nzhelele River and Nwanedi River that flow into east in South Africa to join the Limpopo River section between South Africa and Zimbabwe were not part of the Joint Survey.

The current survey limited its scope to investigating the current state of water quality in relation to the aquatic ecosystem. It is the intention of the joint water quality project to use the results of the 2011/12 baseline survey to further investigate possible sources of contamination, especially those linked with anthropogenic activities such as farming, mining and municipal waste water discharges.

3.3 PARAMETERS ANALYSED

3.3.1 ELECTRICAL CONDUCTIVITY (EC)

Electrical Conductivity (EC) is a measure of the capability of water to conduct an electrical current. This capability is as a result of the presence in water of ions such as carbonate, bicarbonate, chloride, sulphate, nitrate, sodium, potassium, calcium and magnesium, all of which carry an electrical charge. The general effluent standard requires that the conductivity ranges between 75 and 250 mS/m. Increase in conductivity has chronic and acute physiological effects on aquatic biota; and has potential to change the ecological structure of ecosystem by eliminating species that are not tolerable to this change.

3.3.2 DISSOLVED OXYGEN (DO)

Dissolved Oxygen analysis measures the amount of gaseous oxygen dissolved in an aqueous solution. Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement), and as a waste product of photosynthesis. The general effluent standard for dissolved oxygen is 75% of saturation and the target water quality value should be between 80 and 120% of saturation. Natural stream purification processes require adequate oxygen levels in order to provide for aerobic life forms. As dissolved oxygen levels in water drop below 3.0 mg/l, aquatic life is put under stress. The lower dissolved oxygen concentration, the greater the stress to organisms. Oxygen levels that remain below 1-2 mg/l for a few hours can result in large fish kills.

3.3.3 PH

The pH value is a measure of the hydrogen ion activity in a water sample. Effects of pH changes consist of change in the ionic and osmotic balance of individual organisms. The pH value must not be less than 5.5 or greater than 9.5 as required by the Target Water Quality Range and the general effluent standards.

3.3.4 Turbidity

Turbidity is the rate of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through a water sample. Turbidity has a considerable effect on the ecology of water bodies by reduced light penetration caused by even intermediate levels of suspended material which reduces photosynthetic activity and primary production by micro and macrophytes. Turbidity must be equal or less than 1 NTU as set out in the Target Water Quality Range, and for the general standards it is not specified.

3.3.5 Total Dissolved Solids

Total dissolved solids (TDS) is a measure of the quantity of all compounds dissolved in water, while total suspended solids (TSS) concentration is a measure of the amount of material suspended in water. The Targeted Water Quality Range for the total dissolved solids is between 0 and 450 mg/l. High TSS lead to reduced penetration of light which in turn reduces photosynthesis. The ultimate impact is that the food production of the ecosystem is reduced due to impact on the food chain.

3.3.6 Nitrates

Nitrates are generally not toxic, but stimulate growth of weeds and can cause eutrophication if present in excess concentrations in water resources. The Targeted Water Quality Range for Nitrate and Nitrite is between 0 and 6 mg N/l (mg/l as Nitrogen (N)).

3.3.7 Phosphate

Agricultural fertilizers use large quantities of phosphate which will stimulate growth in agricultural crops. Phosphates levels must be less than 1 mg/l, as set out in the effluent standards. Targeted Water Quality Range requires soluble ortho-phosphate to be 0.005-0.025 mg/l as P. The impact of elevated phosphate in water resources is that it causes rapid unnatural growth of plants species in the water resources.

3.3.8 Potassium

Potassium (as K^+) is found in low concentrations in natural waters since rocks which contain potassium are relatively resistant to weathering. However, potassium salts are widely used in industry and in fertilisers for agriculture and enter freshwaters with industrial discharges and run-off from agricultural land. Potassium is usually found in the ionic form and the salts are highly soluble. It is readily incorporated into mineral structures and accumulated by aquatic biota as it is an essential nutritional element.

3.3.9 Calcium

Calcium is an alkaline earth metal and exists as the doubly positively-charged ion. Calcium occurs naturally in varying concentrations in most waters and is, together with magnesium, one of the main components of water hardness.

3.3.10 Magnesium

Magnesium is a basic, essential element for plants (the central metallic ion in chlorophyll) and most other living organisms, since it is a component of important enzyme co-factors. The Targeted Water Quality Range for magnesium is 0-30 mg/ l. Excess magnesium intake upsets calcium and potassium metabolism.

3.3.11 Sodium

All natural waters contain some sodium since sodium salts are highly water soluble and it is one of the most abundant elements on earth. It is found in the ionic form (Na^+), and in plant and animal matter (it is an essential element for living organisms). Increased concentrations in surface waters may arise from sewage and industrial effluents. In coastal areas, sea water intrusion can also result in higher concentrations. Concentrations of sodium in natural surface waters vary considerably depending on local geological conditions, wastewater discharges and seasonal use of road salt.

3.3.12 IRON

Iron may be present in natural waters in varying quantities depending on the geology of the area and other chemical properties of the water body. The two common states of iron in water are the reduced (ferrous, Fe) and the oxidised (ferric, Fe) states. Most iron in oxygenated waters occurs 2+ 3+ as ferric hydroxide in particulate and colloidal form and as complexes with organic, especially humic, compounds. The toxicity of iron depends on whether it is in the ferrous or ferric state, and in suspension or solution. Although iron has toxic properties at high concentrations, inhibiting various enzymes, it is not easily absorbed through the gastro-intestinal tract of vertebrates. On the basis of iron's limited toxicity and bio-availability, it is classified as a non-critical element. Iron is also released into the environment by human activities, mainly from the burning of coke and coal, acid mine drainage, mineral processing, sewage, landfill leachates and the corrosion of iron and steel.

3.3.13 MANGANESE

Manganese is an essential micronutrient for plants and animals. It is a functional component of nitrate assimilation and an essential catalyst of numerous enzyme systems in animals, plants and bacteria. When manganese is not present in sufficient quantities, photosynthetic productivity may be limited and plants may exhibit chlorosis (a yellowing of the leaves) or failure of leaves to develop properly. A deficiency in manganese in vertebrates leads to skeletal deformities and reduced reproductive capabilities. High concentrations of manganese are toxic, and may lead to disturbances in various metabolic pathways, in particular disturbances of the central nervous system caused by the inhibition of the formation of dopamine (a neurotransmitter). In aquatic ecosystems, manganese does not occur naturally as a metal but is found in various salts and minerals, frequently in association with iron compounds. Soils, sediments and metamorphic and sedimentary rocks are significant natural sources of manganese. Industrial discharges also account for elevated concentrations of manganese in receiving waters. Various industries use manganese, its alloys and manganese compounds in their processes, or in their products.

3.3.14 COPPER

Copper is a common metallic element in the rocks and minerals of the earth's crust and occurs naturally in most waters, but is regarded as potentially hazardous. The occurrence of natural sources of copper in the aquatic environment is due to weathering processes or from the dissolution of copper minerals and native copper. Metallic copper is insoluble in water, but many copper salts are highly soluble as cupric or cuprous ions. Anthropogenic sources account for 33 - 60 % of the total annual global input of copper to the aquatic environment. The main anthropogenic sources of copper in the aquatic environment are: corrosion of brass and copper pipes by acidic waters; sewage treatment plant effluents; copper compounds used as aquatic algicides; runoff and ground water contamination from the use of copper as fungicides and pesticides in the treatment of soils; and liquid effluents and atmospheric fallout from industrial sources such as mining, smelting and refining industries, coal-burning, and iron- and steel-producing industries.

3.3.15 LEAD

Lead is principally released into the aquatic environment through the weathering of sulphide ores, especially galena. Lead interacts with iron and therefore interferes with haemoglobin synthesis in organisms. Its Targeted Water Quality Range is 0-0.01 mg/l. Acute lead toxicity in fish causes renal disorders that result in interference with sugar metabolism. Lead disrupts haemoglobin synthesis and also interferes with the uptake of calcium and potassium through the gills. Long-term exposure of fish to low levels of lead causes toxic changes in the immune system of fishes, making them more susceptible to infectious diseases.

3.4 Methodology

3.4.1 Sampling Period

The Joint Water Quality Survey (JWQS) monitoring in Botswana was undertaken in three seasons. The three water sampling schedules undertaken in Botswana Limpopo catchment are given below.

- Summer season sampling: 29 November to 2 December 2011
- Rain season sampling: 20-23 February 2012
- Winter season sampling: 13-16 July 2012

The schedule in South Africa was:

- Summer season sampling: 17-24 September 2011
- Rain season sampling: 02-06 February 2012
- Winter season sampling: 25 June to 01 July 2012

The objective was to determine the trends of nutrients as influenced by the seasonality and the changes in vegetation, which determine the health of the aquatic systems. The method also shows the influence of the nutrient load being generated as the result of rain runoff and other anthropogenic activities, which likely plays a part on the health of the rivers.

3.4.2 Methods Used for Collection and Analysis of Samples

At each sample site the area was surveyed and aquatic vegetation identified in the water body. Physical parameters namely electrical conductivity-EC, the potential of hydrogen ions-pH, dissolved oxygen-DO and turbidity were analyzed in-situ (in the field) using a multi parameter meter (SONDE). The water sample was collected in the centre of the river where there was a steady flow /current. Most samples were sampled using bail method, whereby a sample is collected up from the bridge. The water quality samples were collected in a set of one (1) litre plastic sampling bottles. One bottle contains 2ml of nitric acid for sample preservation. The acidified sample was used for determination of cations (Sodium-Na, Potassium-K, and Calcium-Ca, Magnesium-Mg, Iron-Fe, Copper-Cu and Lead-Pb). The other bottle with no acid (non-acidified) was used to collect the water sample to determine anions (Chlorides-Cl, sulphates-SO_4, Nitrates-NO_3 and phosphates-PO_4. Still at the same sampling site a sample was collected in a 500ml sterilized glass bottle for analysis of feacal coliforms and intestinal enterococci. After sampling, samples were put in a cooler box containing ice packs to preserve the sample matrix during transportation to the laboratory. The methods that were used are referenced below.

Methods used for analyzing the above parameters:

i. Intestinal enterococci – Membrane filtration- ISO 7899-2:2000
ii. Faecal coliform- Membrane Filtration- ISO 9308-1:2000 (E)
iii. Anions (Cl,SO_4,NO_3,PO_4) – Ion chromatography- ISO 1034-2:1995
iv. Total Dissolved Solids- Evaporation & drying method
v. Electrical Conductivity, Ph, Dissolved Oxygen, Total Dissolved Solids - Field meter
vi. Na/K- Atomic Absorption Spectrometer- ISO 9964-3:1993
vii. Ca/Mg- Atomic Absorption Spectrometer- ISO 7980:1986
viii. Fe- Atomic Absorption Spectrometer- SABS 207:1990
ix. Mn- Atomic Absorption Spectrometer- SABS 209:1990
x. Cu/Pb-Atomic Absorption Spectrometer- ISO 11885: 1996 (E)

The physical parameters and microbiology were done in the field. The other parameters were determined in a water quality laboratory, Department of Water Affairs, Gaborone.

The laboratory is implementing a laboratory quality management system in accordance with BOS ISO 17025:2005, outlining the general requirements for testing and calibrating laboratories. The Laboratory also participates in a proficiency testing scheme with Botswana Bureau of Standards, BOBS and South African Bureau of Standards, BOBS for all the tested parameters. Cu and Pb were analyzed at Geological Survey Laboratory in Lobatse, Botswana.

3.4.3 STANDARDS

The South African Target Water Quality Standards were used for comparative analysis of the parameters for aquatic use. Detailed standards used in South Africa for different water uses are appended for reference purposes (Annexure 3). The following Table summarises standards used for analysis.

Parameters	BOS 32:2009 Drinking Water Standard (Maximum allowable limits)	BOS 463:2011 Water quality for Irrigation	RSA-Aquatic ecosystem	Joint survey results
DO (mg/L)	n/a	n/a	03-08	1.2 - 7.8
pH (Units)	5.5-9.5	6.5-8.4	6.5-8.5	6.09 - 8.53
EC (µs/cm)	3100	3000	400	19 - 1300
Turbidity (NTU)	5	n/a	n/a	5.01 - 17.9
TDS (mg/L)	2000	2000	n/a	13 - 833
Ca (mg/L)	200	n/a	n/a	2.78 - 56.4
Mg (mg/L)	100	n/a	n/a	1.55 - 39.05
Na (mg/L)	400	230	n/a	0.7 - 81.75
N03 (mg/L)	50	30	n/a	0.12 - 9.24
PO4 (mg/L)	n/a	n/a	0.025	0.097 - 0.203
K (mg/L)	100	n/a	n/a	0.2 - 45.32
Cl (mg/L)	600	350	200	1.43 - 136.4
SO4 (mg/L)	400	200	n/a	1.36 - 87.92
Fe (mg/L)	2	5	n/a	0 - 2.99
Mn (mg/L)	0.5	0.2	0.18	0 - 0.56
Cu (mg/L)	2	0.2	0.0003	0 - 0.016
Pb (mg/L)	0.01	n/a	0.0002	0 - 0.009
Intestinal Enterococci (cfu/100ml)	Not to detect in 100ml sample	n/a	n/a	0 - 12800
Faecal coliform (cfu/100ml)	Not to detect in 100ml sample	< 1000	n/a	0 - 6400

Table 1: Applicable Standards in Botswana and South Africa

3.4.4 AQUATIC VEGETATION

The aquatic plants at each sampling site were identified in three periods of water sampling and tabled in Annexure 2. The list of plants are clubbed from all the sites and listed in the table as in the Primary Rivers, Secondary Rivers and in the Limpopo River. The dominant plant species in the table is in the order of 1st, 2nd and 3rd.

3.5 Joint Water Quality Monitoring Sites

3.5.1 Criteria Applied

The joint survey team applied the following criteria in choosing suitable water quality monitoring sites:

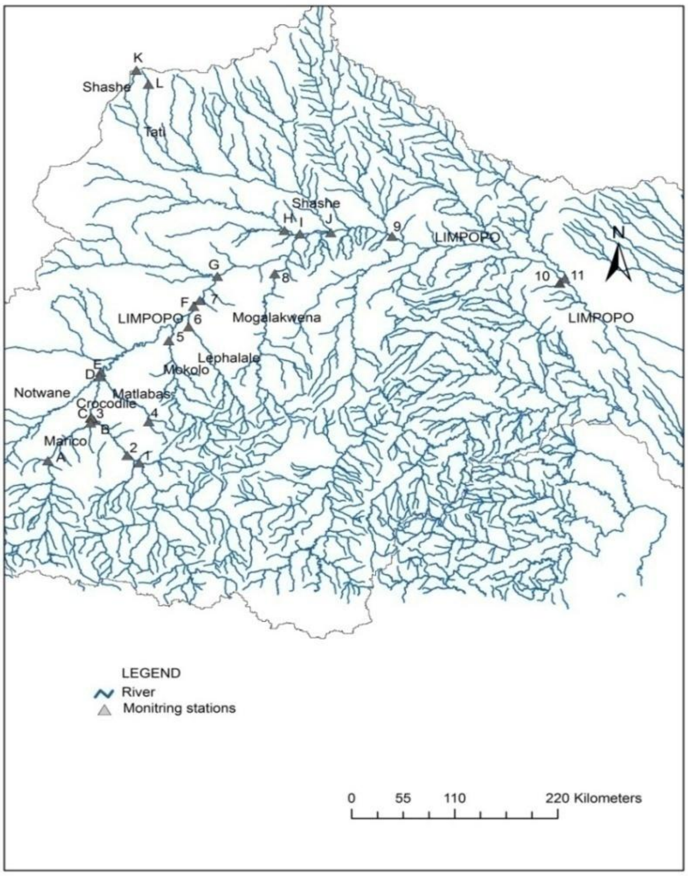
a) **Accessibility**: The sites had to be accessible in all seasons or on all days and the points chosen were not to be disturbed by heavy flows such as the result of rapids and weirs.

b) **Location**: The tributaries or rivers were selected based on their water flows that drain into the Limpopo River from Botswana and South Africa (from Olifants Drift to the Shalimpo, the confluence of Shashe and Limpopo Rivers)

c) **Possible sources of contamination:** In selected cases, sites were identified where water quality contamination was deemed possible, such as from mining activities, irrigation and municipal waste water treatment plants. The criteria may be changed to include points closer to such activities.

d) **Infestation of water hyacinth**: Water hyacinth was observed in May 2010 in Olifants Drift of the Limpopo River. Therefore, some sites were chosen on the basis of this previous observation or anticipation of water hyacinth infestation of the system.

3.5.2 Location and Description of Sites



Botswana sites

A. Marico-Sikwane
B. Marico-Olifants Drift
C. Limpopo-Olifants Drift
D. Notwane River-Limpopo
E. Limpopo-Buffle's Drift
F. Limpopo-Martin's Drift
G. Lotsane River
H. Motloutse River
I. Limpopo River-Lentswe le Moriti
J. Shalimpo
K. Tati River-Masunga
L. Shashe River-Mbalambi

South African sites

1. *Crocodile River Bridge – Upstream Mine*
2. *Crocodile River – Downstream Mine*
3. *Crocodile River – 5 km Olifants Drift Confluence*
4. *Matlabas River Bridge*
5. *Mokolo River Bridge*
6. *Lephalale River Bridge*
7. *Limpopo River - Sterkloop Weir*
8. *Mogalakwena River Bridge*
9. *Limpopo River - Beit Bridge*
10. *Luvuvhu River Bridge– Kruger National Park*
11. *Limpopo River - Crooks Corner*

Figure 2: Location and List of Monitoring Sites in Botswana and South Africa

3.5.2.1 Botswana Sites

- **A. Marico-Sikwane**: Sikwane is a village on the south-east of Botswana where the Border Post is served for the public to cross between Botswana and South Africa and vice versa. The Marico River or Madikwe River as it is also called in Botswana and South Africa originates in South Africa and enters as a trans-boundary river between the two countries at Sikwane. The River bifurcates at about 500 meters in the upstream of the entry point and becomes a single channel up to the Olifants Drift to join the Limpopo River. The river has weirs all along its course at specified locations. The banks are clayey and muddy.
- **B. Marico-Olifants Drift**: This point is about 300 m in the upstream of confluence where the Crocodile River and Marico River join with the Crocodile River together to form the Limpopo River.
- **C. Limpopo-Olifants Drift**: The Limpopo River could be more than 3.5 m deep at this point in the flood season with ca. 200 m across flowing swiftly downstream. Banks are elevated with *P. mauritianus* and marginally infested water hyacinth.
- **D. Notwane River-Limpopo**: The sampling site is about 1 km off the Limpopo River. The flows are high in the flood season while in the dry season, the water might not be present.
- **E. Limpopo-Buffle's Drift**: This point is 6 km in the downstream of the Limpopo River after the confluence of Notwane and Limpopo Rivers. The Water Affairs collects the water flow discharges at this point.
- **F. Limpopo-Martin's Drift**: Martin's Drift is the border post where the Botswana Immigration office is situated and on the other side is the Grobler's Bridge across the Limpopo River where South Africa Immigration and Customs departments are situated. A hub of a cross border activity is significant here all round the year. Water samples have been continuously collected in this site from Botswana side at Martin's Drift at Grobbler's Bridge.
- **G. Lotsane River**: The sampling site was fixed in the Lotsane River at Lotsane Lodge, could be reached from Sherwood. The river is rocky bedded with intermittent sandy areas.
- **H. Motloutse River**: A sampling point was fixed in the Motloutse River about 100 upstream of its confluence with the Limpopo River. The river bed is sandy. The Talana Farm with its extensive irrigation of vegetables and sugarcane is situated along the banks of Motloutse River on the north and the Limpopo River on the east. The Talana Farm also does ostrich farming. Since the Farm is located in the valley and sloping into Motloutse and the Limpopo, it is expected that the pollutants such as fertilizers applied to the farms and the excreta from the Ostrich birds might end up into the rivers in the run offs in the high rainfall season. The Motloutse River is sand-bedded and the banks are vegetated with Acacia sp. and Croton megalobotrys.
- **I. Limpopo River – Lentswe le Moriti**: The sampling point is in the downstream of the confluence of Motloutse and Limpopo Rivers. Limpopo River is sandy here with a width of about 80 m. The village is considered as a model village in Botswana as the liquor and smoking use is prohibited by the village community.
- **J. Shalimpo:** Shalimpo is so named as the Shashe River and Limpopo River join here at the point where Botswana, South Africa and Zimbabwe borders meet here. The Limpopo River flows between South Africa and Zimbabwe and outflows to Mozambique at Crooks Corner.
- **K. Tati River-Masunga**: With its insignificant catchment in Zimbabwe, the Tati River enters at Nlakhawe village in Botswana passes through Zwenshambe and Masunga and other villages to meet Shashe River at Dikathong Dam. Zwenshambe area forms a major catchment for the river in Botswana with the contributions from Ntobe River, Mosejne River, Gungwe River and several streams in the north of Mbalambi area. A sampling point was fixed at Masunga village at the bridge across the river.

L. **Shashe River-Mbalambi** : Shashe River also originates from Zimbabwe, enters Botswana at Mbalambi Village and passes through Kalakamati, Sebina, Marobela to reach the Nthimbale dam, Shashe Dam and finally joins the Dikathong dam. The river flows out from the Dikathong dam as spills being joined by several streams on its way between Zimbabwe and Botswana to enter into the Limpopo River at Shalimpo. The Maenjane, Nyambambisi and Themagana Rvers are the major catchements to the Shashe River after it enters into Botswana. The sampling point is at Mbalambi.

3.5.2.2 South Africa Sites

1. **Crocodile River Bridge – Upstream Mine**: The site is in the upstream of Kumba Iron Ore Mine in Thabazimbi Town about 10 km after the town on the route to Rustenburg. The River originates from the catchment in Gauteng Province, and passes through Limpopo Province to join the Transboundary Limpopo River. The river is perennial and supposedly contains high turbid waters and nutrients. Diatoms in small units of 2 to 3 cm diameter was found floating profusely. It appears that the entire length of the Crocodile River from Thabazimbi is between 20-25 m wide without much of aquatic plants. Both the banks of the river are high steep, sloping very rarely in few areas. The river flowed with its normal levels in January and observed to reduce the water levels by 0.4 m at the second time of sampling and however with large velocity of water as compared to the first sampling.

2. **Crocodile River – Downstream Mine**: The site is in the downstream of the Kumba Iron Ore Mine. A picnic spot for the local communities and others for recreation and fishing is close to the main road on the way to Dwaalboom from Thabazimbi Village. The irrigation farms are common on both the banks. The site has been selected based on its location in the downstream of the iron ore, recreation and farm activities. The water is abstracted from the river for mine activities and it was reported that washings of the mine sometimes contaminate the river. It is also suspected that treated sewage water is likely contaminating the river water at Benalbert in the upstream. Water samples were collected at the bridge of the road proceeding to Dwaalboom

3. **Crocodile River – 5 km Olifants Drift Confluence**: The site is located in just 5 km upstream of the confluence of Crocodile, Marico and Limpopo Rivers at Olifants Drift of Botswana. The banks of the river are sharp and steep without vegetation and water plants were not observed too. The approach for this site is from Lephalale to Sentra via Makopa cross on the way to Derdepoort. The site is also connected to Thabazimbi, Dwaalboom via Makopa.

4. **Matlabas River Bridge**: The Matlabas River is the life river as it has abundant aquatic submergent and rooted floating and emergent plants. The River originates in the central mountain catchment area in Limpopo Province and flows into the Limpopo River. Perennial in nature, the river flows up to April/May every year. Of all the rivers observed in the survey, this is the only river showing abundant aquatic plants. The water samples were collected at the Matlabas River Bridge on the way to Thabazimbi.

5. **Lephalale River Bridge**: 36 km from Lephalale town, Lephalale River is a seasonal river and found dry. No water samples collected. Islands of P. Mauritianus are common in the river. A permanent site for water sampling has been decided to undertake at the bridge. In the second sampling after rains, the river was 0.8 m deep with moderately high velocity. The river was under dry in winter.

6. **Mokolo River Bridge**: On the way to Grobbler's Bridge of the Border Post of South Africa, the Mokolo River is seasonal and found dry and it flows all along 12 km to reach the Limpopo River. However the water sample was collected in the stagnant water of 0.5 m level at the bridge. Mokolo dam on the river is about 100 km from the site in the upstream catchment.

7. **Limpopo River - Sterkloop Weir**: The site is on the main Limpopo River in South Africa side and about 4 km from the Grobbler's Bridge in the upstream. A former water flow discharge site for South Africa has not been functional due to increased height of the weir and hence water flow data collected was found to be not comparable.

Water hyacinth and green algae formed in mats in the margins of the river both in South Africa and Botswana sides. Considerable flow was observed in the rain season and is used as a picnic and fishing site for the safari and land owners nearby.

8. **Mogalakwena River Bridge**: The site is nearby Alldays on the way to Musina. There is a Glen Alpine dam in the upstream of the river. Though seasonal, sometimes water and flows were observed to the Limpopo River in summer months when the farmers along the river request for water from the dam. Limpopo River is ca. 20 km downstream of this point.
9. **Limpopo River - Beit Bridge**: Beit Bridge is across the Limpopo River between South Africa and Zimbabwe. It was reported that some wastes seldom found being discharged into the river from Zimbabwe. Water is reported to present throughout the year at the bridge despite the seasonality of the Limpopo in the entire stretch of the upstream and downstream.
10. **Luvuvhu River Bridge –Kruger National Park**: Luvuvhu River originates from Soutpansberg Mountains around Makhado town, 180 km from Musina. The river passes through Kruger National Park. Two dams are on this river - Albasini and Nandoni dams.
11. **Limpopo River - Crooks Corner:** The site is the point where the Luvuvhu River joins the main Limpopo River that enters into Mozambique after passing between South Africa and Zimbabwe in the upstream. The site is so named as the crocodiles are common in the section of the main river.

Pictures of the sites are appended as **Annexure 4**.

4 FINDINGS AND ANALYSIS OF THE 2011/12 JOINT FIELD SURVEYS

The detailed analytical results are presented in Tables in **Annexure 1** as per the sites listed in the Figure 2. However, the results in graphical presentation are presented on the basis of the flow pattern of the Primary and Secondary Rivers into the trans-boundary Limpopo River in the Limpopo Basin and to appreciate the trends in water nutrients in *summer*, *rain* and *winter* seasons.

Primary Rivers: Crocodile and Marico rivers that flow into the Limpopo River at Olifants Drift (Confluence). The water sampling points in the two major rivers are:

- Crocodile – upstream
- Crocodile –downstream
- Crocodile - 5 km from Olifants
- Marico – Sikwane
- Marico – Olifants

Secondary Rivers: Those Rivers that originate in South Africa from southern region and those rivers that flow in Botswana to the trans-boundary Limpopo River.

Rivers - RSA:

- Matlabas
- Mokolo
- Lephalale (Lephalala)
- Mogalakwena
- Luvuvhu

Rivers – Botswana

- Notwane River (Orginates in RSA & passes through Gaborone dam in Botswana)),
- Lotsane
- Motloutse
- Shashe and Tati Rivers' data is not presented in graphs as they were wet only in rain season. However, the results may be referred in the Annexure Tables.

Trans-boundary Limpopo River: All those water sampling points in the main Limpopo River from Olifants Drift to the Crooks corner (Border of South Africa, Zimbabwe and Mozambique)

- Olifants Drift
- Buffles Drift
- Martins Drift
- Sterkloop weir
- Lentswe Le Moriti
- Shalimpo
- Beit Bridge
- Crooks corner

The data obtained was compared with the South Africa Standards for Aquatic Ecosysem.

4.1 Physico-Chemical Parameters

a) Electrical Conductivity (EC)

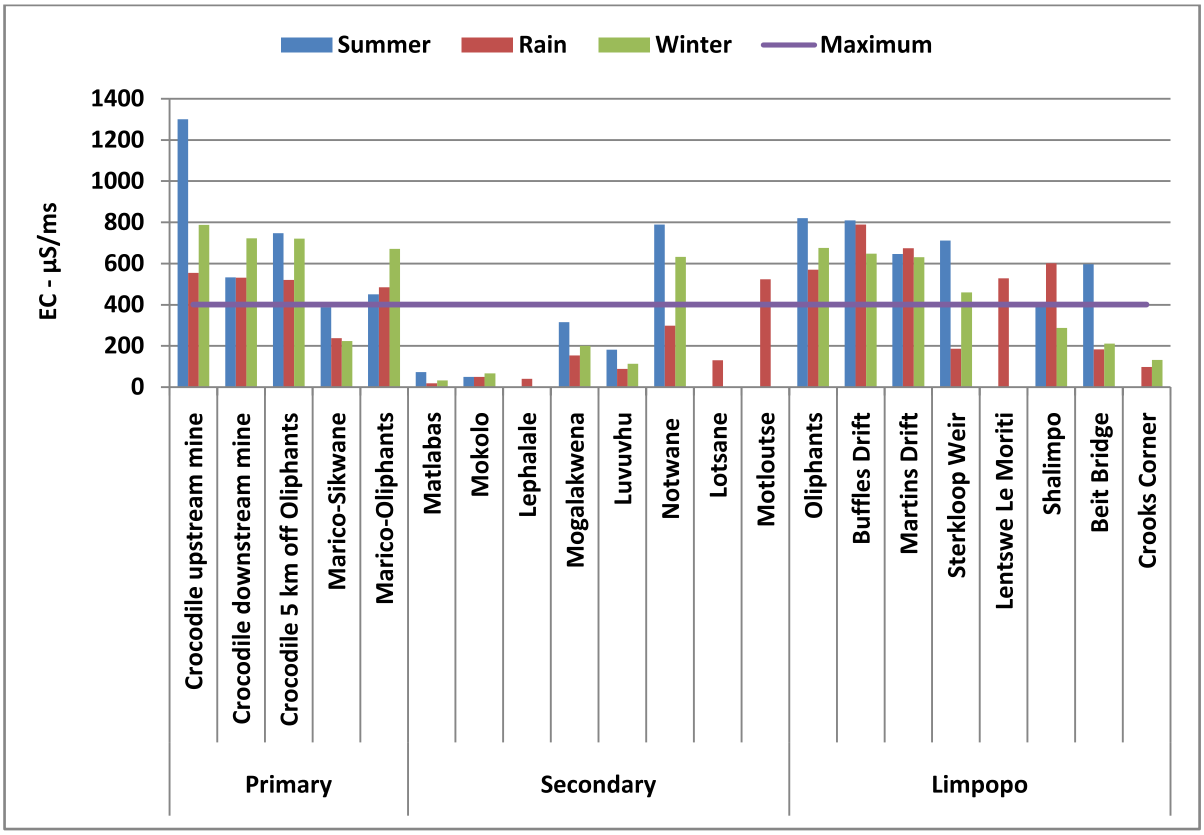


Figure 3: Electrical Conductivity Values of Primary, Secondary and Limpopo Rivers

According to the South Africa Target Water quality guidelines for all users, the EC for aquatic ecosystems should range between 0 and 400 µS/cm.

The EC in all the primary rivers is above the maximum allowable limit except at Marico-Sikwane and the maximum being at Crocodile-upstream (1300µS/cm). Crocodile river originates from above Hartebeespoort Dam where there are some farming activities; then meanders past highly industrialized centers of Gauteng Province and Kumbi Iron Ore mine therefore it is expected that all the above activities will contribute to high electrical conductivity.

In secondary rivers, EC were lesser than 100 µS/cm in Matlabas, Mokolo, Lephalale and Lotsane with respect to Notwane and Motloutse Rivers of Botswana. This was possibly due to discharges from waste water facilities and the farm activities along Notwane and Motloutse rivers respectively.

In the main channel, EC levels are above the maximum limit which is to be expected looking at results from the primary rivers as they drain into the Limpopo River.

b) Potential of Hydrogen (pH)

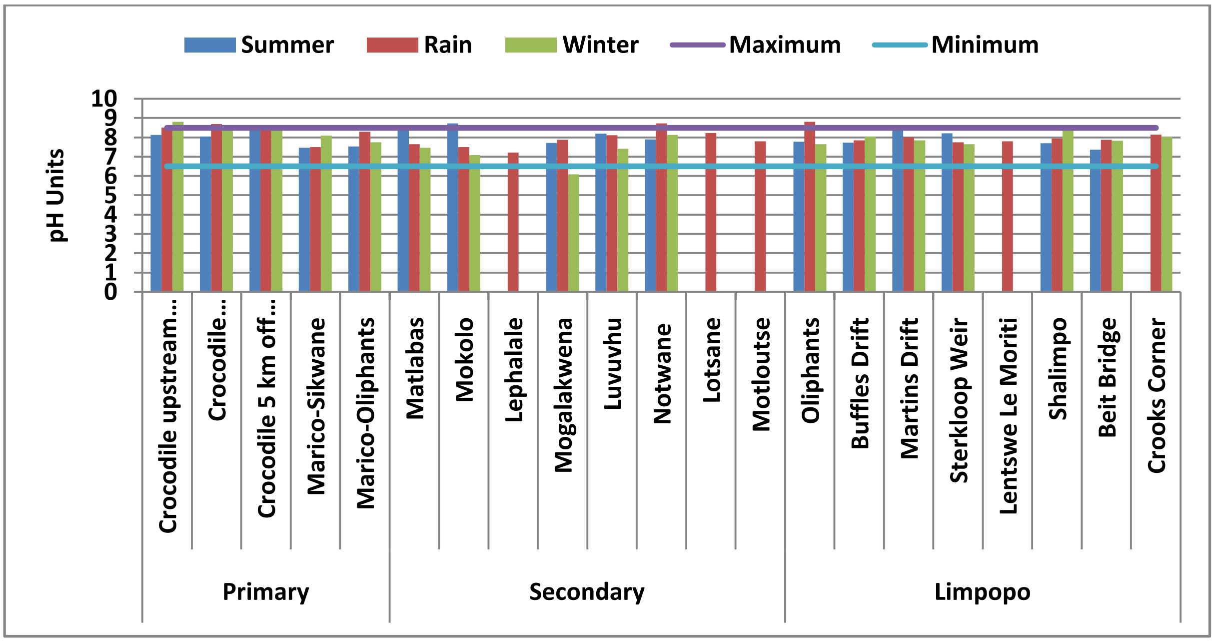


Figure 4: pH Values for Primary, Secondary and Limpopo Rivers

Aquatic ecosystem standard for pH is between 6.5 and 8.5. Crocodile is mostly alkaline and secondary rivers and Limpopo River above neutral to alkaline. Crocodile River, Limpopo River at Olifants and Notwane Rivers were above 8.5. Farming activities where usage of lime for soil conditioning is prevalent may explain the alkalinity observed in the Crocodile River.

c) Dissolved Oxygen(DO)

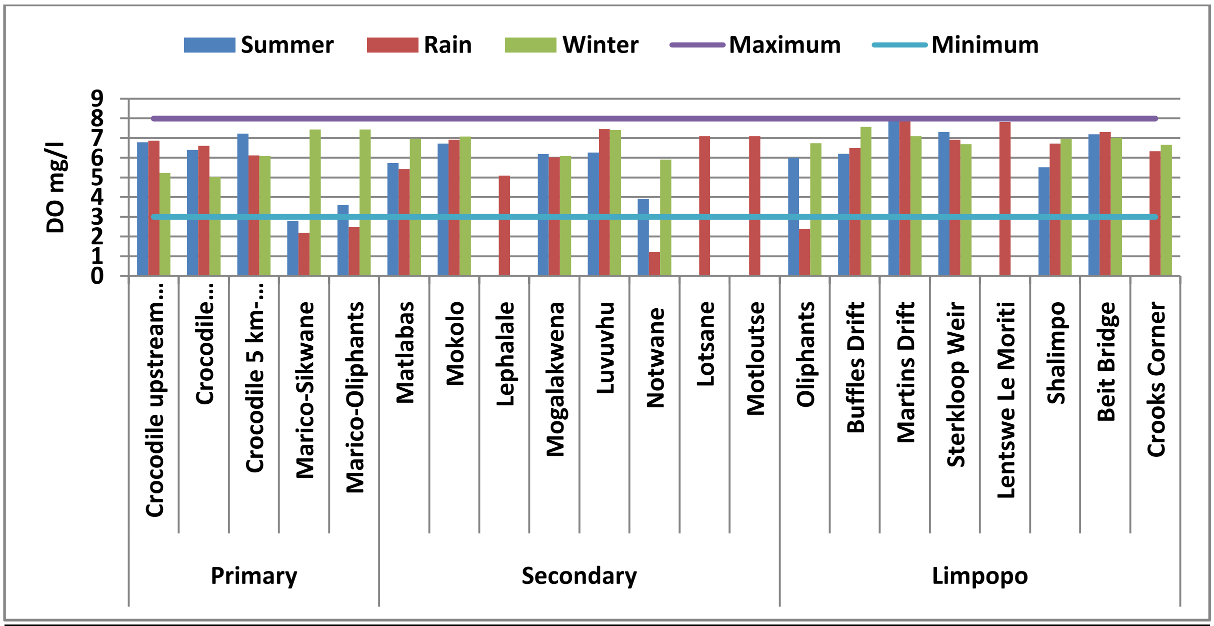


Figure 5: Dissolved Oxygen in Primary, Secondary and Limpopo Rivers

Dissolved Oxygen (DO) normal range is between 3 and 8 mg/L. Looking at above Figure 6, it was observed that DO is generally lower at Marico-Sikwane, Marico-Olifants, Notwane and Limpopo-Olifants mostly in rain season. This could be attributed to influx of sediments as a result of run-off. During the rain, there is runoff from agricultural land, carrying along pesticides, fertilizers, and sediments. Furthermore there are treated effluents from waste water treatment facilities being discharged into Notwane River.

DO at less than 3 mg/L is normally considered low, which reflects decomposed state. If DO is low it translates into a lot of dissolved oxygen being used by microorganisms to break down organic waste (decomposition). Hence lower DO values at the above mentioned sites can be attributed to pollution.

d) Turbidity

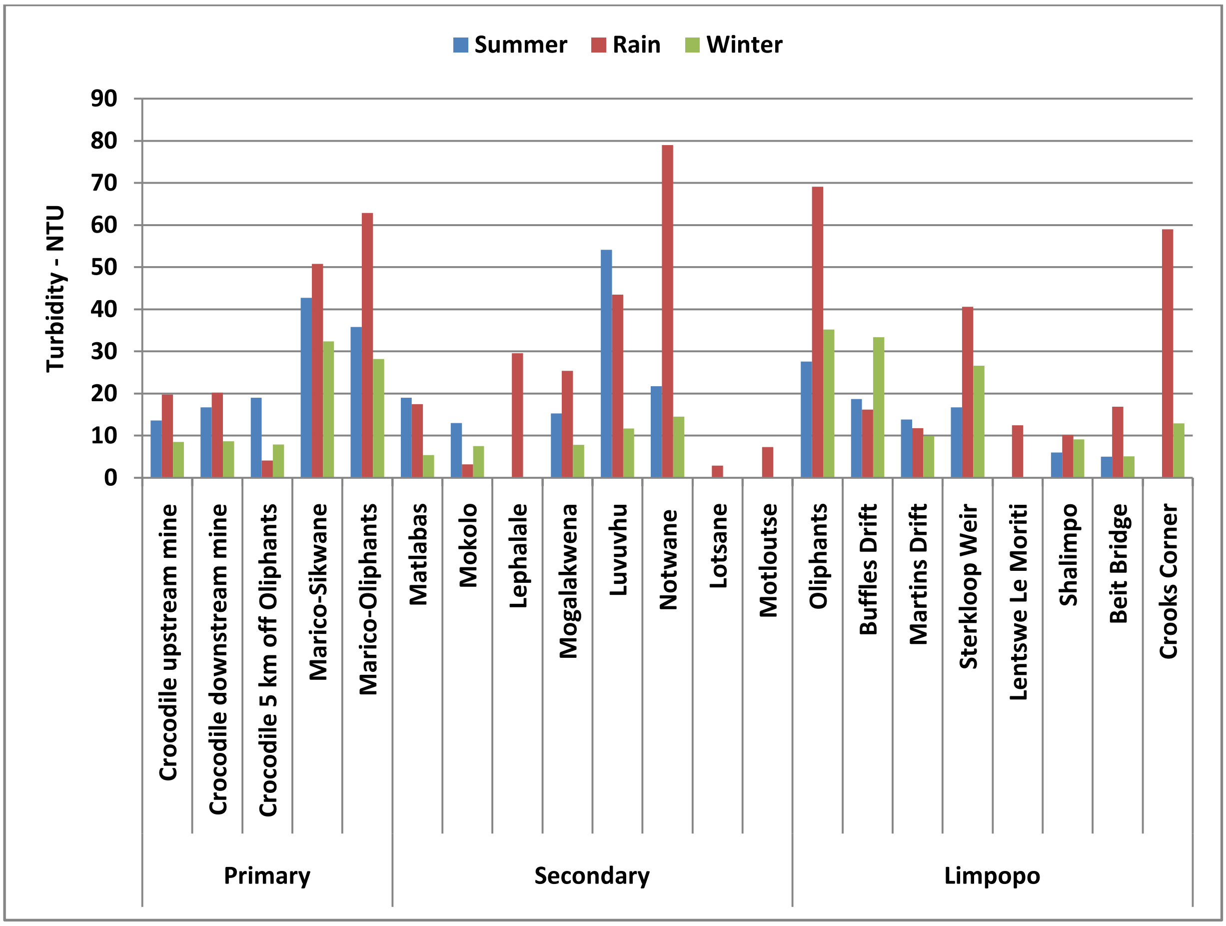


Figure 6: Turbidity in the Primary, Secondary and Limpopo Rivers

In the Aquatic Ecosystem standard the turbidity is not included and therefore not applicable. In the river system when the turbidity is high, there are high suspended solids which create high surface area for microorganisms to attach themselves. In addition, high turbidity in a water body limits light penetration for primary production which has a profound effect on the aquatic life forms such as algae and fish.

Turbidity is high in Marico, Luvuvhu, Notwane, Olifants and Crooks Corner especially during the rainy season. Olifants receives inflows from the Crocodile River which shows some pollution. At Crook's corner, a high number of crocodiles were observed in the river and this clearly disturbs the water leading to high turbidity. The high turbidity can also be attributed to runoff from the land washing out the waste and sediments into the river system.

e) Calcium

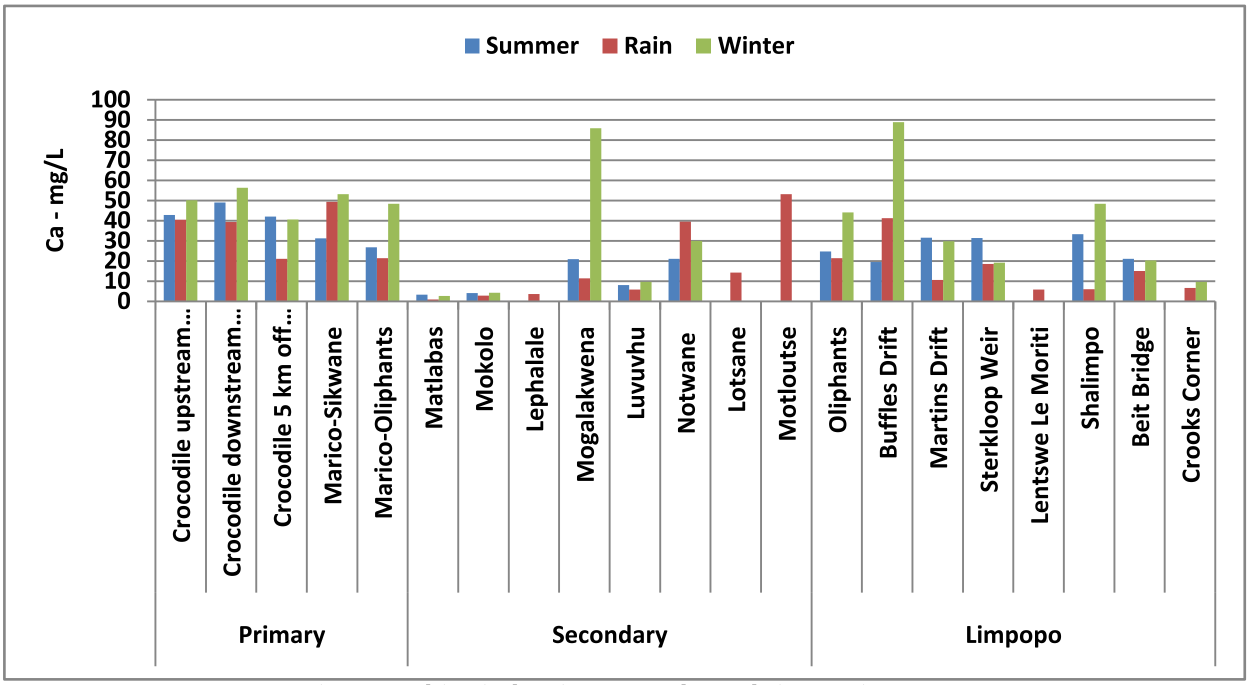


Figure 7: Calcium in the primary, secondary and Limpopo rivers

Calcium is not included in the aquatic ecosystem standard of South Africa. Calcium was particularly high in winter sampling in primary rivers as well as in the upstream of Limpopo River. Furthermore, the highest Calcium was observed in Mogalakwena River (85.9 mg/L) and Buffles Drift (88.9 mg/L) of Limpopo River. The least amount of Calcium was recorded in other secondary rivers such as Matlabas, Mokolo, Lephalale, and Luvuvhu Rivers.

f) Magnesium

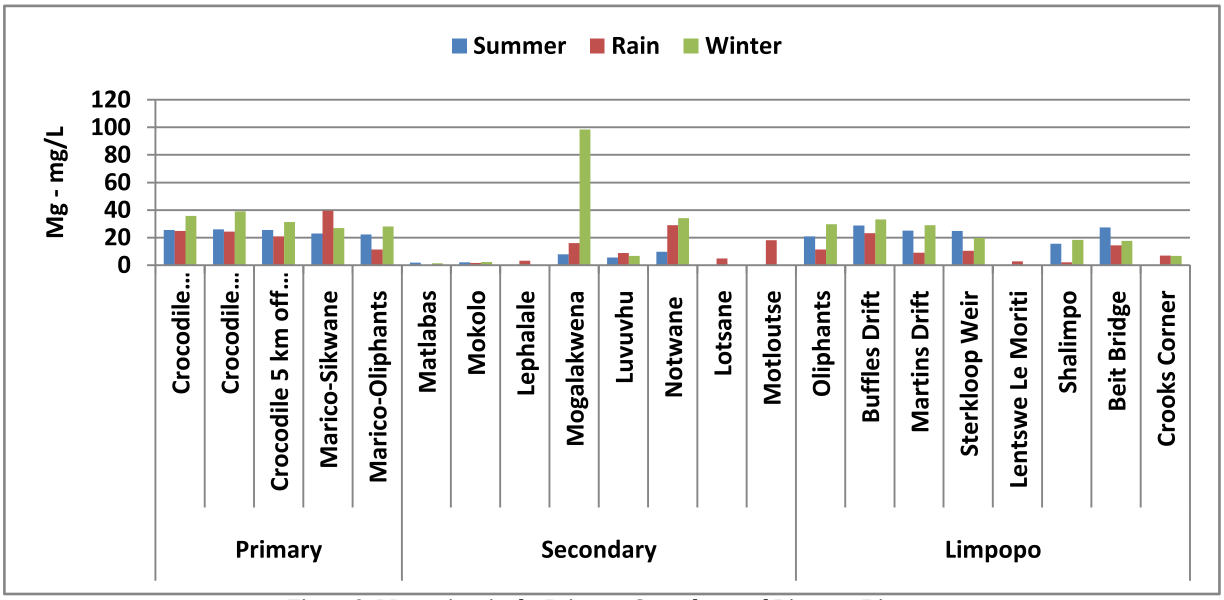


Figure 8: Magnesium in the Primary, Secondary and Limpopo Rivers

Like Calcium, Magnesium is also not included in the aquatic ecosystem standard. Magnesium was mostly between 20 and 40 mg/L in primary and in Limpopo Rivers. The amount of magnesium was less than 10 mg/L in secondary rivers except in Mogalakwena River (98.4 mg/L). Interestingly, its total content was found to be less in rain season in Limpopo River as compared to in the other two sampling periods.

g) Sodium

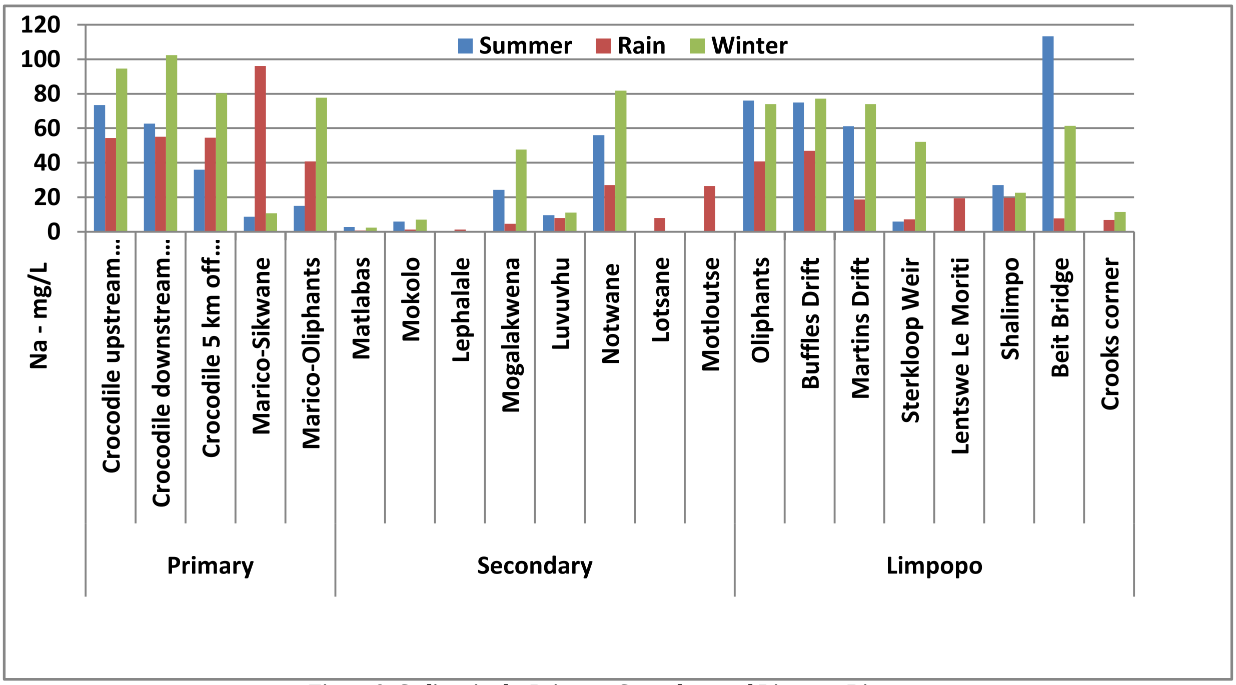


Figure 9: Sodium in the Primary, Secondary and Limpopo Rivers

The maximum allowable limits for sodium are not considered for aquatic ecosystem standard. Sodium was less than 100 mg/L in primary rivers and in Limpopo River showing less in rain sampling period than in summer and winter. However, Beitbridge showed more than 100 mg/L in summer sampling period. The content of sodium was less than 10 mg/L in Matlabas, Mokolo, Lephalale and in Luvuvhu Rivers.

h) Nitrates

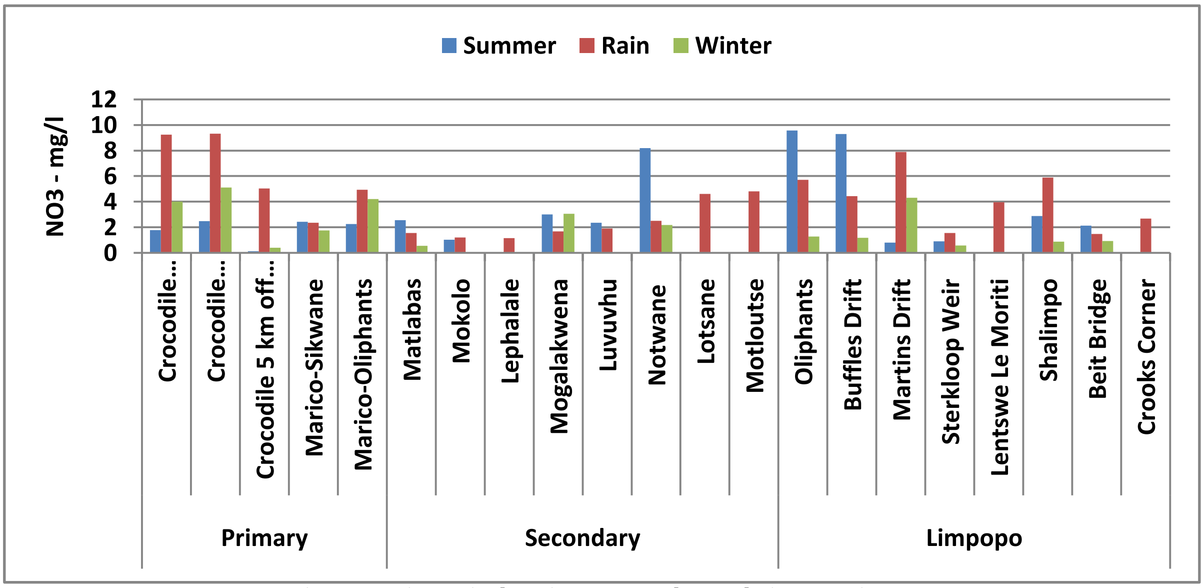


Figure 10: Nitrates in the Primary, Secondary and Limpopo Rivers

The standards for the permissible quantity of nitrates in water are not applicable to aquatic ecosystems. The results show that Nitrates are less in secondary rivers such as Matlabas, Mokolo and Lephalale Rivers. However, Notwane River recorded over 8 mg/L resulted from waste water discharges in Gaborone area as compared to over 4 mg/L in Lotsane and Motloutse rivers in rain period due to some contaminations along the run-off. The quantity was high in Crocodile River upstream in the rain period and upstream of the Limpopo in summer.

The increase in nitrates in the upstream Limpopo in summer was probably resulted from decomposition in the stagnant low levels of water due to evaporation in summer. Excess levels of nitrates in river systems create eutrophic conditions which are evidence of pollution. Algae and other plants use nitrates as a source of food and if there is unlimited source of nitrates; it will lead to uncontrollable growth which can cause algal blooms leading to extreme fluctuations in dissolved oxygen leading to eutrophication and/or anoxia.

i) Phosphates

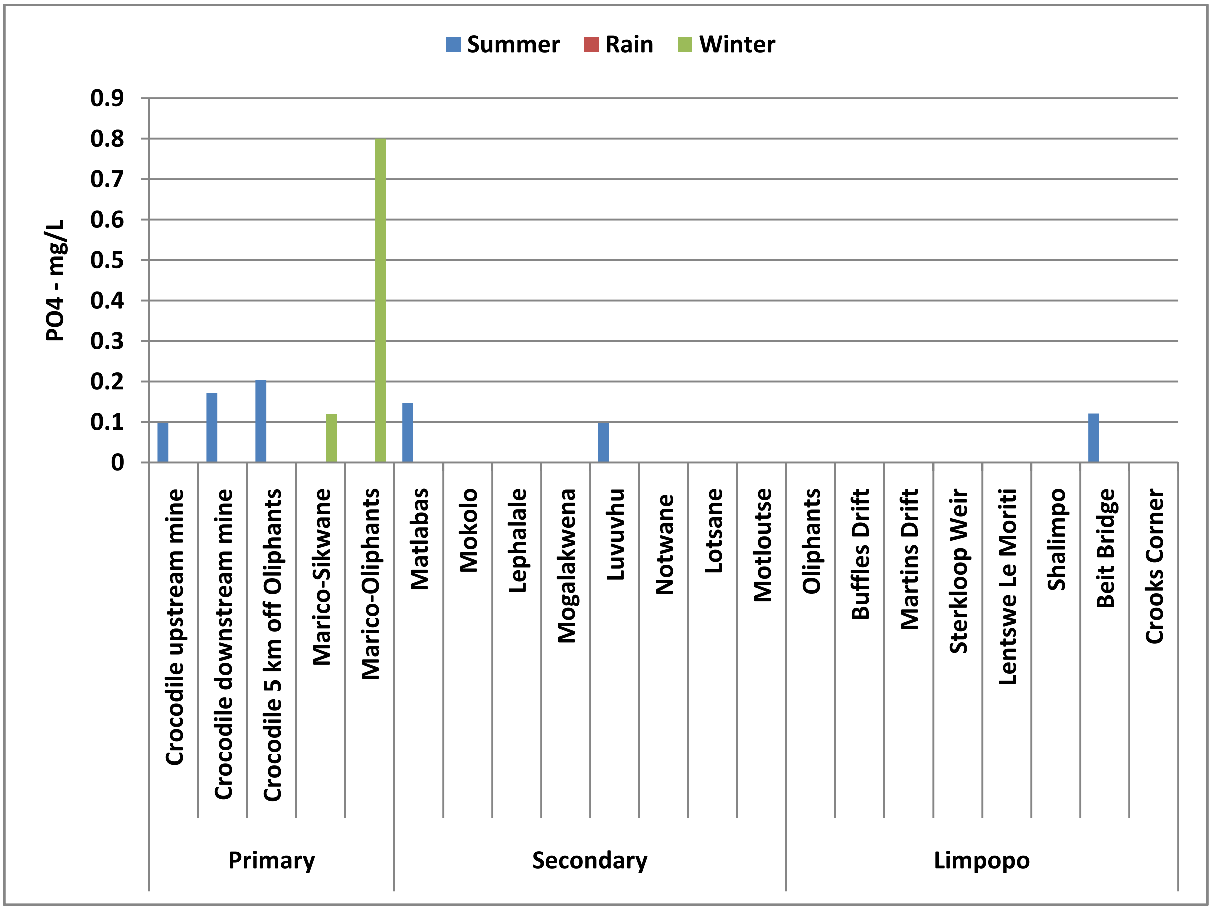


Figure 11: Phosphates in the Primary, Secondary and Limpopo Rivers

Maximum allowable limit for aquatic ecosystems is 0.025 mg/L. Total Phosphates were high in the sites detected. Phosphates can enter aquatic environments in several ways: natural weathering of minerals in the drainage basin; biological decomposition or as run-off from agricultural activities. Elevated levels of phosphates will produce irrepressible algal growth with devastating consequences for aquatic life. From Figure 12 it is evident that Phosphates were extremely high at 0.8 mg/L indicating impacts of the water hyacinth increases in 2012.

j) Potassium

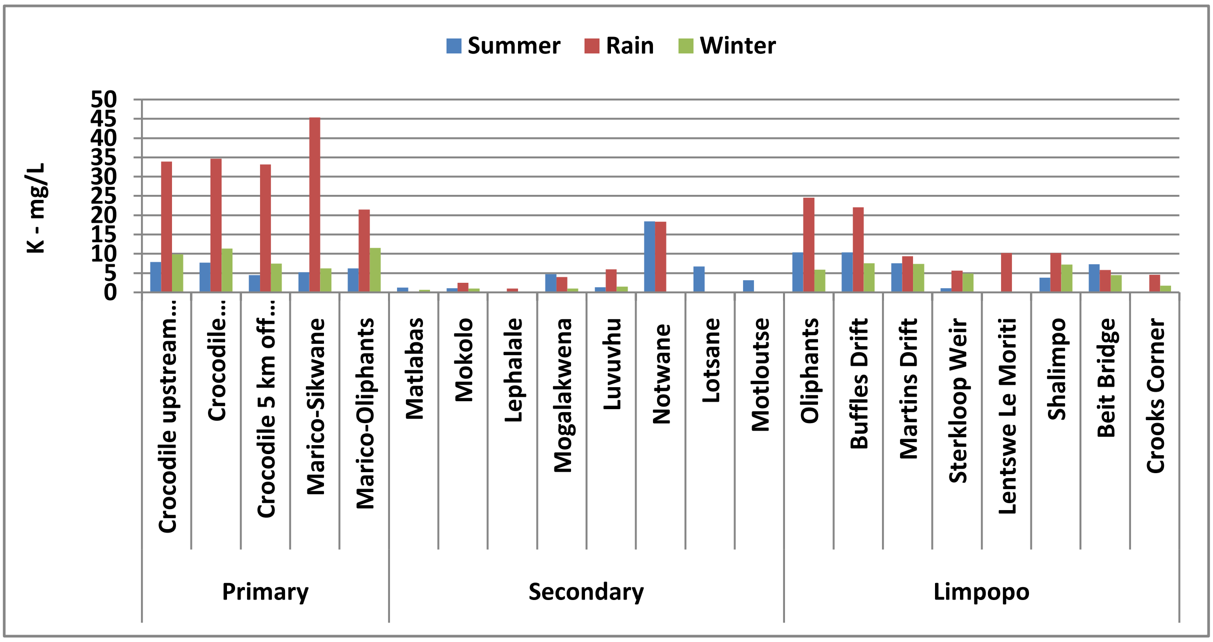


Figure 12: Potassium in the Primary, Secondary and Limpopo Rivers

Potassium parameter is not applicable to aquatic ecosystems. The results explain that potassium levels were high in rainy season in Crocodile, Marico Rivers and in the upstream of the Limpopo River but the quantity declines gradually downstream in the main Limpopo river. Potassium is the constituent of fertilizers, probably contaminated the water systems through fertilizer applications as well as urban waste. Potassium can also form part of nutrients in the river system which contributes to algal growth which is detrimental to aquatic life. Futhermore, the secondary rivers showed very less potassium except in Notwane River as the river is known to have contaminations on its Botswana catchment.

k) Chlorides

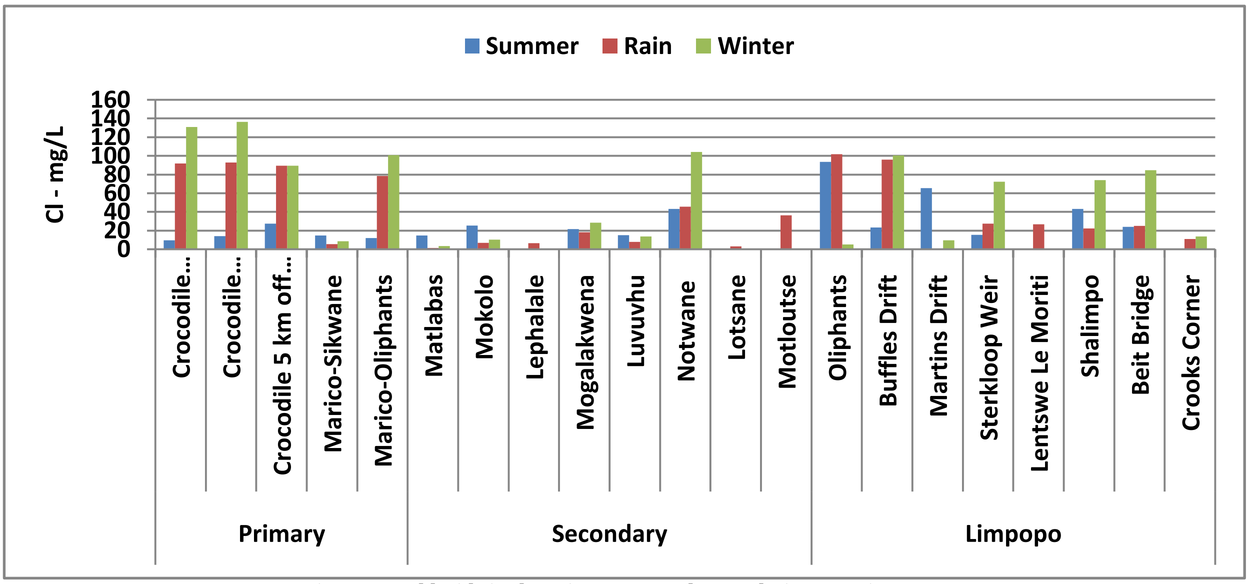


Figure 13: Chloride in the primary, secondary and Limpopo rivers

Total chlorides is not applicable to aquatic ecosystems. Total chlorides showed more or less similar trends in Crocodile River and Marico -Olifants in rain and winter seasons. In the Limpopo River, their content was high in the upstream and remained so over 60 mg/L in winter in the downstream Secondary Rivers recorded mostly less than 20 mg/L except in Notwane River showing more than 100 mg/L.

The varibale amount of Chlorides in the primary, secondary rivers and in the Limpopo River indicates the amount of chlorides load in rain season and their retaining capacity in the system in winter.

l) Sulphates

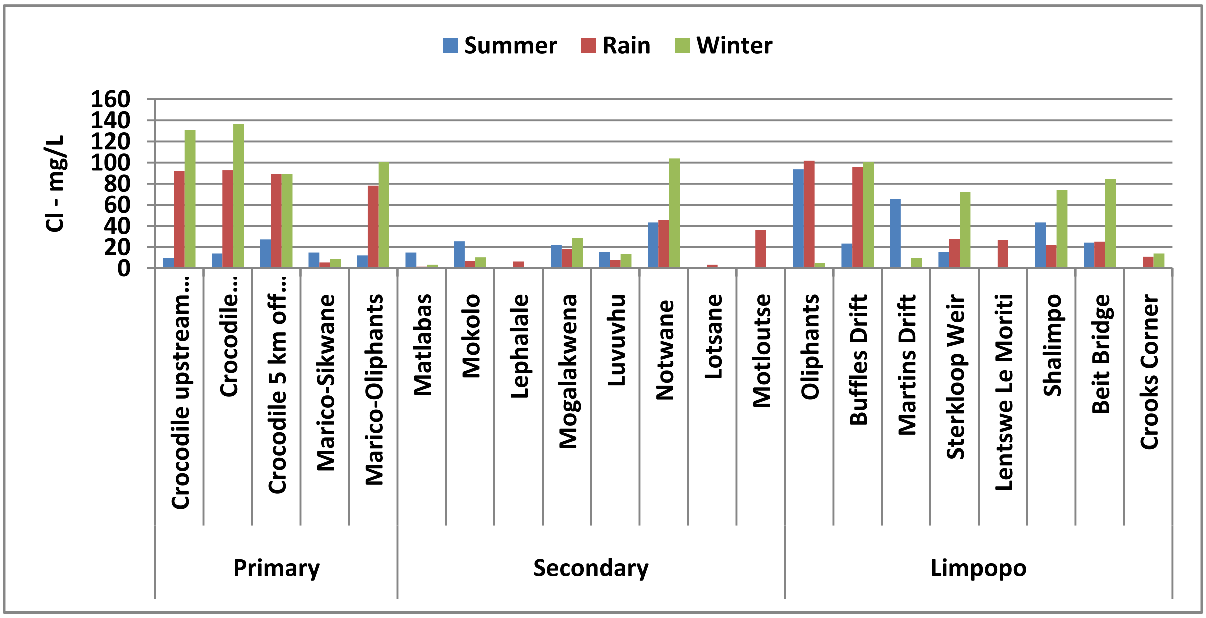


Figure 14: Sulphates in the Primary, Secondary and Limpopo Rivers

The total sulphates show similar trends like total chlorides in primary, secondary and Limpopo Rivers

4.2 HEAVY METALS

m) Iron

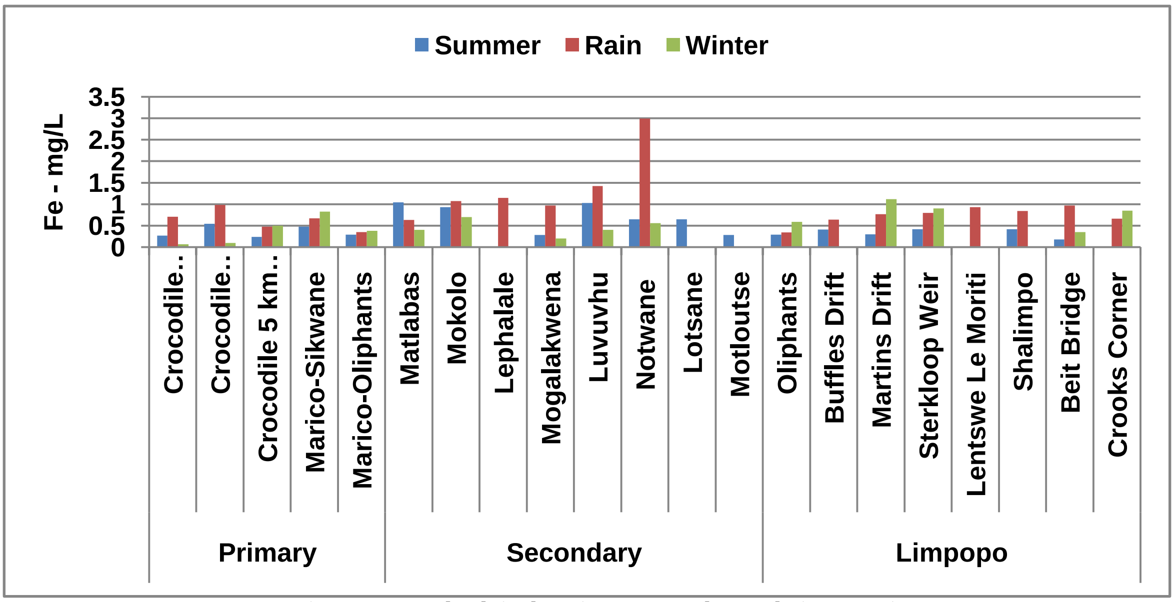


Figure 15: Iron levels in the Primary, Secondary and Limpopo Rivers

Iron does not apply to aquatic ecosystems. The total iron was less than 1 mg/Lin most of the sampling points determined. However, there was high content of iron at Notwane River (2.99 mg/L).The possible source of iron is probably from the waste water discharge into the Notwane River from Gaborone city area in Botswana. The quantity declines in the downstream from Martins Drift except in rain periods.

n) Manganese

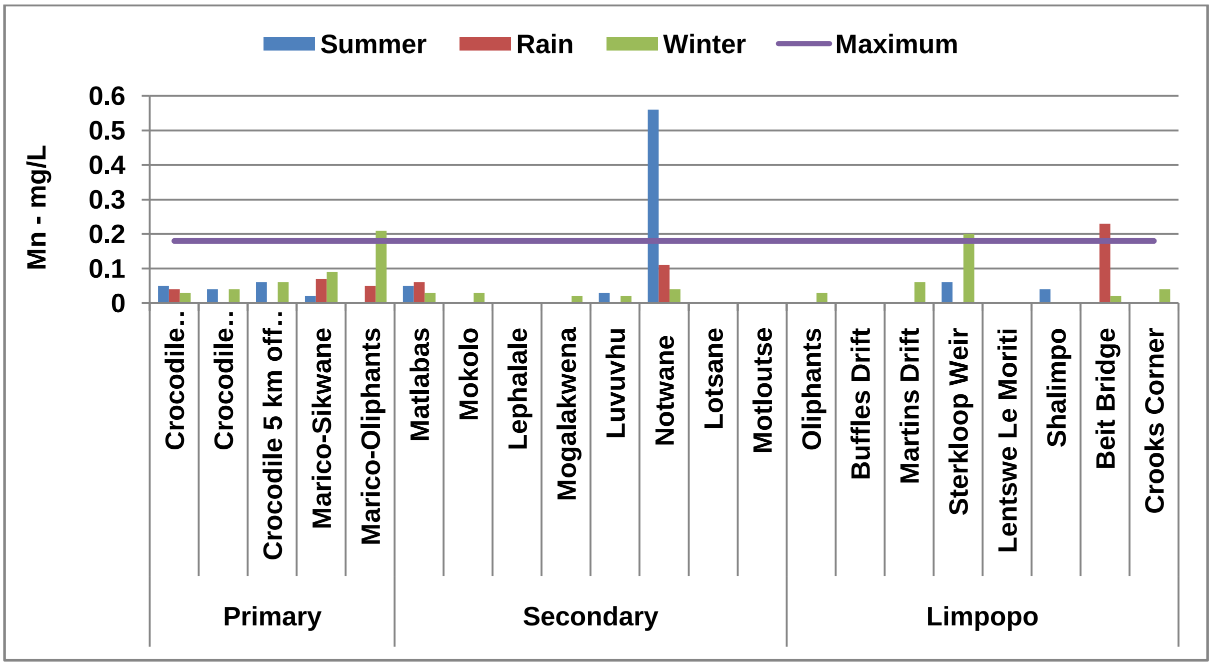


Figure 16: Manganese levels in the Primary, Secondary and Limpopo Rivers

The maximum allowable limit for manganese for the aquatic ecosystem is 0.18 mg/L. The total manganese is found within the limits in most of the sampling sites except in Notwane River in summer season and it was extremely high indicating significant contamination to the river. However, it was marginally high in Marico River at Olifants and at Beit Bridge in Limpopo River. Manganese was not detected in the other sites.

o) Copper

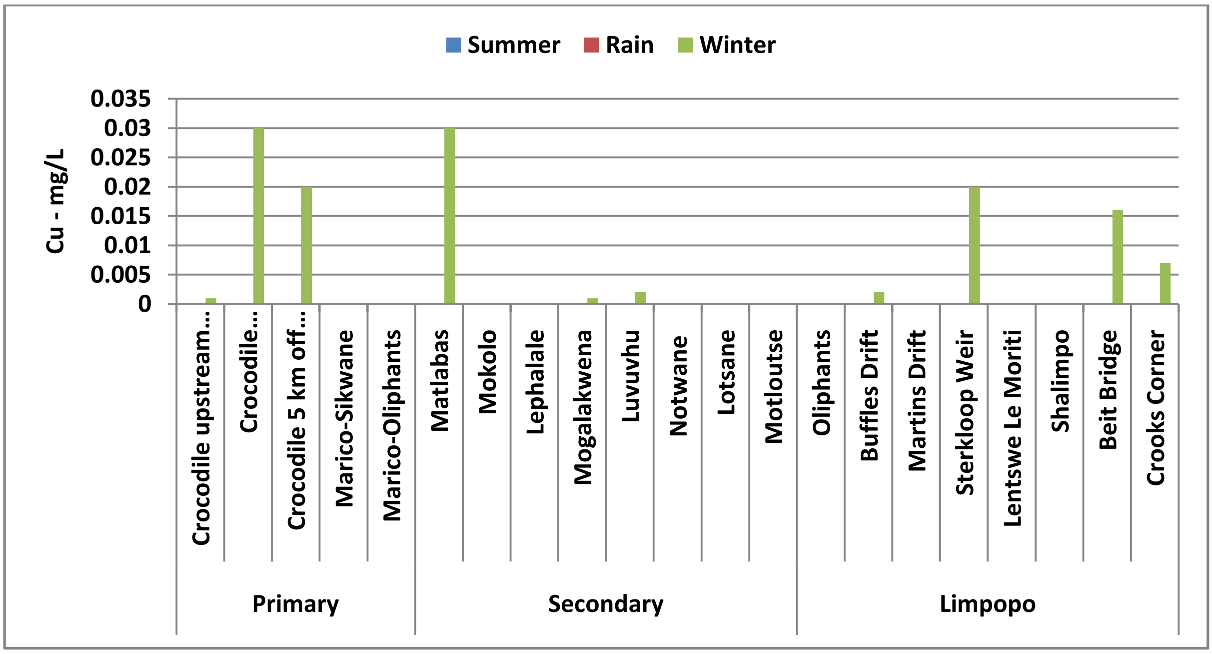


Figure 17: Copper levels in the Primary, Secondary and Limpopo Rivers

The content of copper was higher in all the sites detected as compared to its maximum allowable limit (0.0003 mg/L) in the aquatic ecosystems in winter season in the three categories of water systems. Copper was undetected in several sites as shown in Figure 17.

p) Lead

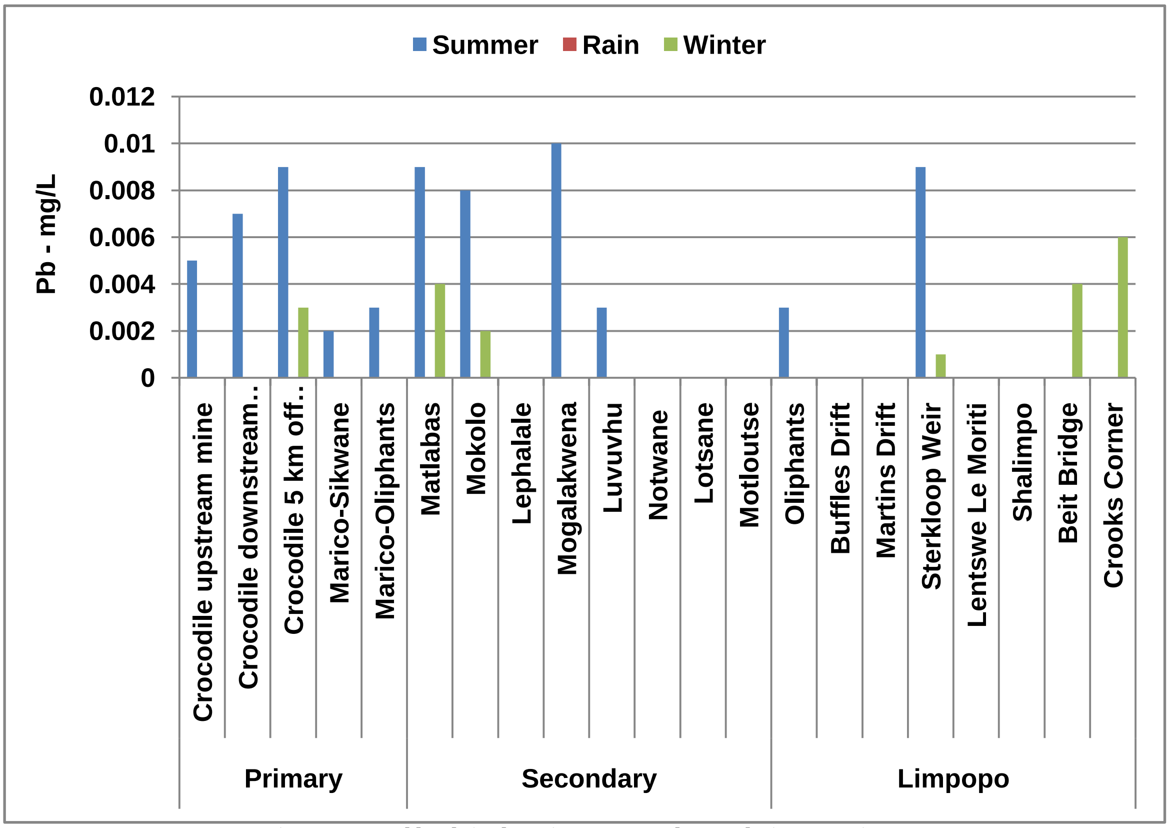


Figure 18: Lead levels in the Primary, Secondary and Limpopo Rivers

The maximum allowable limit for Lead for the aquatic ecosystem is described as 0.0002 mg/L. As per the maximum limit lead was found to be extremely higher in summer in some of the sites than in winter as shown in Figure 18.

5 CONCLUSIONS AND RECOMMENDATIONS

The results presented in this report represent 'snapshots' of the state of water quality throughout the Botswana-SA border of the Limpopo River Basin and the main Limpopo River between the Olifants Drift and the Kruger National Park towards Mozambique during September-November-December 2011 (summer), February 2012 (rain) and June-July 2012 (winter).

Some rivers like Matlabas Mokolo Lephalale are in good condition. Of all the rivers sampled in the survey, Matlabas River is considered as of good water quality which supports high vegetation such as presence of water lilies and other indigenous aquatic vegetation, which is indicative of good water quality.

It is evident from the results that upstream of Limpopo shows a tendency of eutrophication, that is pollution, which can support the growth of water hyacinth. Such tendencies are also showing in Crocodile and Marico Rivers in rain seasons as reflected from high nitrates, high electrical conductivity, high potassium, high phosphates, and heavy metals (copper, manganese and lead)

The results suggest that, although a few parameters were detected in excess of the recognised water quality standards, high nutrient loads (evidenced by growth and rapid spread of water hyacinth) and detectable amounts of heavy metals may be impairing water quality in the Crocodile and main Limpopo River.

These findings highlight the need for more systematic water quality monitoring in the Limpopo River Basin ideally covering Zimbabwe and Mozambique, using comparable methodologies and carried out at similar intervals as may be agreed by the Joint Permanent Technical Committee established between SA and Botswana. Furthermore results should be rapidly fed into the management and decision-making processes in the basin that affect water resources quality and quantity - LIMCOM, Ministries and responsible states agencies. Appropriate remedial and punitive measures must be considered where irresponsible transgression is found.

This will require closer working relationships and communication with water users, municipalities, water user associations, unorganised farming communities and communities residing in the catchment.

Given these observations, the joint survey team proposes the following interventions:

a) The two Departments of Water Affairs in Botswana and South Africa should harmonise their methodologies and sampling regimes.

b) Both departments should utilise appropriate accredited laboratories with clear reports of analytical methods applied and applicable quality management system

c) The survey was conducted between only two countries yet there are four countries in the basin. The survey should be up scaled to all the countries namely Zimbabwe and Mozambique for a more accurate and comprehensive investigation of the Limpopo basin.

d) An inventory of waste water treatment plants, dams and mines from both countries is available. This should enable the development of a strategic sampling programme which will assist to determine directly where the possible sources of contamination are.

e) Communication between the land owners and the DWA-SA needs to be strengthened to facilitate accessibility of sampling points.

f) Develop water quality objectives for the joint water quality monitoring whereby all joint technical committee members agree on sampling sites; frequency of monitoring and what parameters will be tested. Agree on target periods and interval of surveys.

g) Bi-annual (dry and wet periods) joint water quality monitoring surveys must be agreed to with the aim of eventually moving to annual joint water quality monitoring.

h) Active involvement of all relevant stakeholders and giving them feedback on continuous basis (to be decided with all stakeholders at workshop).

i) Adopting an integrated water resources management in our approach whereby other factors such as hydrology (flows), geology, the water quality parameters (that has been agreed upon), the vegetation as well as the biological monitoring, use of macro invertebrates, (South African Scouring System- SASS 5) are taken into consideration which will provide the ecological status of a particular segment of the water body and the vegetation as well. SASS 5 is a method used to assess the biota in the river system to determine the river health. Assessment of flow of contaminants in the Limpopo river basin must be investigated so as to determine exact sources of pollution.

j) Control and regulate waste water discharges by ensuring that responsible authorities monitor and comply with the applicable effluent standards.

k) Comprehensive field investigation needs to be undertaken to determine point and non-point sources of pollution

l) Work closely with water use stakeholders to investigate and propose progressive ways of using grey water for industrial activities

m) Implement a water hyacinth clearance programme in conjunction with Working for Water (SA)

6 PROPOSED ACTION PLAN

6.1 SIX-POINT SHORT-TO-MEDIUM TERM ACTION PLAN

Item #	Issue Description		Action(s)	Responsibilities	By when	Support required
1)	The 2011-12 joint water quality survey could not establish actual polluters. There is a need for detailed information of all users who discharge waste water or conduct activities that are likely to affect the quality of water in the basin	a)	Develop an INVENTORY of all waste water treatment plants, agricultural activities and mining activities	DWA-BOT and DWA-SA (Survey Team)		
		b)	Mark GPS COORDINATES of all the potential pollution points on the catchment map	DWA-BOT and DWA-SA (Survey Team)		
		c)	Carry PHYSICAL INSPECTIONS of all waste water plants, irrigation farms and mining activities	DWA-BOT and DWA-SA (Survey Team)		
		d)	Review permanent MONITORING POINTS to align with "hotspots" where pollution is deemed highly possible	DWA-BOT and DWA-SA (Survey Team)		
2)	Water users, especially those using water for irrigation in the Botswana catchment, need to be frequently updated on the status of water quality in the rivers and assured that relevant authorities are taking necessary measures to resolve any human induced pollution	a)	Develop and implement a COMMUNICATION and STAKEHOLDER ENGAGEMENT STRATEGY and PLAN	DWA-BOT and DWA-SA (Survey Team)		
		b)	Involve DEPARTMENTAL COMMUNICATION UNITS in the implementation of a communication plan	DWA-BOT and DWA-SA (Survey Team)		
		c)	REPORT and PUBLISH RESULTS of the surveys through appropriate inter-governmental (bilateral) and SADC platforms	Joint WQ Committee		
3)	The 2011-12 survey was not guided by a clear framework of parameters to be measured and water quality objectives against which the results will be measured.	a)	Develop a FRAMEWORK for joint water quality monitoring by the two countries outlining parameters, standards and regimes to be used in selecting collecting and analysing data	Joint WQ committee		
4)	The joint water quality survey project must continue in the next phase after completion of a detailed inventory of all potential point sources of pollution	a)	The survey must be UNDERTAKEN TWICE A YEAR - one in summer and another in winter	DWA-BOT and DWA-SA (Survey Team)		
5)	The 2011-12 survey project did not have all the necessary equipment to	a)	Negotiate separately with individual departments and jointly with SADC for support to PURCHASE REQUIRED EQUIPMENT to undertake a successful survey	DWA-BOT and DWA-SA (Survey Team)		
6)	The results of the survey confirm the existence of nutrients which support the germination and spread of water hyacinth. The two countries must identify and agree on a joint response to remove the alien plant from the river.	a)	Develop and implement a JOINT WATER HYACINTH CLEARANCE APPROACH and PROGRAMME	DWA-BOT, DWA-SA, DEA-WfW,		
		b)	Involve relevant PARTNER PROGRAMMES such as WORKING FOR WATER (SA)	Joint WQ committee		

6.2 LONG-TERM ACTION PLAN

Item #	Issue Description	Action	Responsibilities	By when	Support required
a)	Expand the joint survey to include Zimbabwe and Mozambique	• Invite Mozambique and Zimbabwe into the joint survey committee and team	Joint committee		
b)	Review and develop suitable aquatic ecosystem standards	• DWA Botswana to investigate possibilities of developing standards for aquatic ecosystems (and irrigation)	DWA-BOT		
		• DWA SA to align standards and remove incoherent standards between ecosystem and drinking water	DWA-SA		
c)	Ensure the accessibility and safety of monitoring points	• DWA-SA to communicate with land owners and pass necessary laws to allow and protect officials who must access monitoring points	DWA-SA		
d)	Effect a progressive and stringent monitoring and enforcement regime to deal with offenders	• Report cases of pollution to appropriate enforcement units within departments	DWA-SA & DWA-BOT		
		• Implement water discharge charges at points where discharges can be measured	DWA-SA & DWA-BOT		
		• Advocate for the re-use of grey water	DWA-SA & DWA-BOT		
		• Promote organic farming practices and less use of chemical nutrients	DWA-SA & DWA-BOT		

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8 ANNEXURES

ANNEXURE 1: DETAILED RIVER WATER QUALITY RESULTS

BOTSWANA - 1st SAMPLING: 29 NOVEMBER 2011 TO 2 DECEMBER 2011 – SUMMER SEASON

Table 2: *Microbiology and physical characteristics of water samples at 12 joint survey sites in Botswana Limpopo catchment*

No	**Sampling sites**	**Faecal Coliform**	**Intestinal enterococci**	**DO mg/L**	**pH Units**	**EC µS/cm**	**TDS mg/L**	**Turbidity NTU**	
A	Marico River – Sikwane	113	96	2.78	7.46	387	206	42.7	
B	Marico River –Olefants Drift	95	248	3.6	7.53	450	187	35.8	
C	Limpopo – Olefants Drift	0	48	6.0	7.77	820	340	27.57	
D	Notwane River – Ramatlabaki	36	76	3.9	7.89	789	327	21.77	
E	Limpopo – Buffles Drift	28	44	6.2	7.73	809	220	18.7	
F	Lotsane River – Tuli Block	Dry							
G	Limpopo River – Martins Drift	*140*	*20*	*7.92*	*8.36*	*646*	*411*	*13.8*	
H	Motloutse River	*Dry*							
I	Limpopo – Lentswe Le Moriti	*DRY*							
J	Shalimpo	*79*	*79*	*5.52*	*7.69*	*393*	*256*	*5.97*	
K	Shashe River – Mbalambi	1520	888	6.92	7.48	42	27	14.5	
L	Tati River – Masunga	*160*	*72*	*6.84*	*7.84*	*174*	*113*	*8.17*	
				Chemical Characteristics (mg/L)					
No	Sampling sites	Ca	Mg	Na	K	Fe	Mn	Cu	Pb
A	Marico River – Sikwane	31.23	22.97	8.78	5.19	0.48	0.02	ND	0.002
B	Marico River –Olefants Drift	26.76	22.2	15.1	6.23	0.29	0	ND	0.003
C	Limpopo – Olefants Drift	24.8	20.9	76.1	10.4	0.36	0	ND	0.003
D	Notwane River – Ramatlabaki	26.08	9.64	56.0	18.4	0.65	0.56	ND	ND
E	Limpopo – Buffles Drift	19.5	28.8	74.9	10.4	0.41	0	ND	ND
F	Lotsane River – Tuli Block	Dry							
G	Limpopo River – Martins Drift	31.56	25.0	61.28	7.54	0.3	0	*ND*	*ND*
H	Motloutse River	Dry							
I	Limpopo – Lentswe Le Moriti	*DRY*							
J	Shalimpo	33.26	15.63	27.1	3.85	0.42	0.04	ND	ND
K	Shashe River – Mbalambi	7.79	2.87	1.64	0.94	1.46	0.14	ND	ND
L	Tati River – Masunga	25.3	4.43	6.29	4.32	0.14	0	ND	ND
				Chemical characteristics (mg/L)					
No	Sampling sites	Cl	SO4	NO3	PO4				
A	Marico River – Sikwane	14.7	25.39	2.44	0				
B	Marico River –Olefants Drift	11.98	14.7	2.25	0				
C	Limpopo – Olefants Drift	93.59	53.32	9.56	0				
D	Notwane River – Ramatlabaki	43.2	17.62	8.2	0				
E	Limpopo – Buffles Drift	23.4	17.9	9.3	0				
F	Lotsane River – Tuli Block	DRY							
G	Limpopo River – Martins Drift	65.56	36.65	0.79	0				
H	Motloutse River	DRY							
I	Limpopo – Lentswe Le Moriti	DRY							
J	Shalimpo	43.34	23.00	2.89	0				
K	Shashe River – Mbalambi	2.49	2.74	10.98	0				
L	Tati River – Masunga	10.17	4.07	10.17	0				

BOTSWANA –2nd SAMPLING: 20-23 FEBRUARY 2012 – RAIN SEASON

Table 3: *Microbiology and physical characteristics of water samples at 12 Joint Survey Sites in Botswana Limpopo Catchment*

No	**Sampling sites**	**Faecal Coliform**	**Intestinal enterococci**	**DO mg/L**	**pH Units**	**EC µS/cm**	**TDS mg/L**	**Turbidity NTU**	
A	Marico River – Sikwane	426	30	2.18	7.5	237	154	50.8	
B	Marico River –Olefants Drift	20	40	2.47	8.29	485	315	62.9	
C	Limpopo – Olefants Drift	180	16	2.38	8.81	570	365	69.1	
D	Notwane River – Ramatlabaki	170	160	1.2	8.73	299	194	79.0	
E	Limpopo – Buffles Drift	110	200	6.5	7.84	790	320	16.2	
F	Lotsane River – Tuli Block	200	78	7.09	8.23	131	85	2.92	
G	Limpopo River – Martins Drift	*100*	*140*	*7.9*	*8.01*	*674*	*421*	*11.8*	
H	Motloutse River	*70*	*35*	*7.1*	*7.80*	*524*	*335*	*7.27*	
I	Limpopo – Lentswe Le Moriti	*1600*	*220*	*7.81*	*7.8*	*528*	*301*	*12.5*	
J	Shalimpo	*230*	*16*	*6.72*	*7.94*	*601*	*399*	*10.2*	
K	Shashe River – Mbalambi	DRY							
L	Tati River – Masunga	*DRY*							
Chemical characteristics (mg/L)									
No	Sampling sites	Ca	Mg	Na	K	Fe	Mn	Cu	Pb
A	Marico River – Sikwane	49.30	39.50	96.00	45.32	0.67	0.07	ND	ND
B	Marico River –Olefants Drift	21.50	11.30	40.89	21.45	0.35	0.05	ND	ND
C	Limpopo – Olefants Drift	19.24	9.73	48.44	24.56	0.34	0.00	ND	ND
D	Notwane River – Ramatlabaki	39.45	29.05	27.16	18.3	2.99	0.11	ND	ND
E	Limpopo – Buffles Drift	41.30	23.25	46.94	22.03	0.64	0.00	ND	ND
F	Lotsane River – Tuli Block	14.34	4.95	8.01	6.73	0.65	0.00	ND	ND
G	Limpopo River – Martins Drift	10.65	9.05	18.73	9.34	0.77	0.00	ND	ND
H	Motloutse River – Talana farms	53.1	18.1	26.6	3.11	0.28	0.08	ND	ND
I	Limpopo – Lentswe Le Moriti	*5.85*	*2.74*	*19.5*	*10.24*	*0.93*	*0.00*	ND	ND
J	Shalimpo	6.00	2.13	19.69	10.19	0.84	0.00	ND	ND
K	Shashe River – Mbalambi	DRY							
L	Tati River – Masunga	DRY							
Chemical characteristics (mg/L)									
No	Sampling sites	Cl	SO4	NO3	PO4				
A	Marico River – Sikwane	5.5	9.63	2.36	0				
B	Marico River –Olefants Drift	78.31	49.08	4.93	0				
C	Limpopo – Olefants Drift	101.74	66.18	5.72	0				
D	Notwane River – Ramatlabaki	45.46	27.81	2.17	0				
E	Limpopo – Buffles Drift	95.94	61.64	4.44	0				
F	Lotsane River – Tuli Block	3.25	3.07	4.60	0				
G	Limpopo River – Martins Drift	*21.34*	*18.98*	*7.9*	*0*				
H	Motloutse River – Talana farms	36.21	21.14	4.8	0				
I	Limpopo – Lentswe Le Moriti	*26.6*	*15.7*	*3.97*	*0*				
J	Shalimpo	*22.12*	*17.19*	*5.89*	*0*				
K	Shashe River – Mbalambi	*DRY*							
L	Tati River – Masunga	DRY							

BOTSWANA – 3rd SAMPLING: 13-16 JULY 2012 – WINTER SEASON

Table 4: *Microbiology and physical characteristics of water samples at 12 Joint Survey Sites in Botswana Limpopo Catchment*

No	**Sampling sites**	**Faecal Coliform**	**Intestinal enterococci**	**DO mg/L**	**pH Units**	**EC µS/cm**	**TDS mg/L**	**Turbidity NTU**	
A	Marico River – Sikwane	12800	6400	7.43	8.09	224	196	32.4	
B	Marico River –Olefants Drift	800	800	7.43	7.74	672	472	28.2	
C	Limpopo – Olefants Drift	100	60	6.74	7.64	676	166	35.2	
D	Notwane River – Ramatlabaki	0	0	5.91	8.12	633	392	14.5	
E	Limpopo – Buffles Drift	240	20	7.56	8.04	648	512	33.4	
F	Lotsane River – Tuli Block	DRY							
G	Limpopo River – Martins Drift	*40.8*	*42*	*7.09*	*7.84*	*631*	*516*	*9.9*	
H	Motloutse River – Talana farms	*DRY*							
I	Limpopo – Lentswe Le Moriti	*DRY*							
J	Tati River – Masunga	*DRY*							
K	Shashe River – Mbalambi	DRY							
L	Shalimpo	*28*	*34*	*6.96*	*8.34*	*287*	*198*	*9.1*	
Chemical characteristics (mg/L)									
No	Sampling sites	Ca	Mg	Na	K	Fe	Mn	Cu	Pb
A	Marico River – Sikwane	53.25	27.02	10.83	6.2	0.83	0.09	ND	ND
B	Marico River –Olefants Drift	48.35	28.15	77.63	11.53	0.38	0.21	ND	ND
C	Limpopo – Olefants Drift	44.07	29.74	74.0	5.9	0.59	0.03	ND	ND
D	Notwane River – Ramatlabaki	30.2	34.05	81.75	6.5	0.56	0.04	ND	ND
E	Limpopo – Buffles Drift	88.9	33.3	77.2	7.55	ND	ND	0.002	ND
F	Lotsane River – Tuli Block	DRY							
G	Limpopo River – Martins Drift	29.8	28.9	73.95	7.4	1.12	0.06	ND	*ND*
H	Motloutse River– TalanaFarms	DRY							
I	Limpopo – Lentswe Le Moriti	*DRY*							
J	Tati River – Masunga	DRY							
K	Shashe River – Mbalambi	DRY							
L	Shalimpo	48.36	18.26	22.7	7.2	0	0	*ND*	ND
Chemical characteristics (mg/L)									
No	Sampling sites	Cl	SO4	NO3	PO4				
A	Marico River – Sikwane	8.73	20.58	1.75	0.12				
B	Marico River –Olefants Drift	10.7	8.59	4.21	0.8				
C	Limpopo – Olefants Drift	5.08	1.1	1.27	ND				
D	Notwane River – Ramatlabaki	104.0	86.82	0.69	ND				
E	Limpopo – Buffles Drift	100.3	65.18	1.17	ND				
F	Lotsane River – Tuli Block	DRY							
G	Limpopo River – Martins Drift	*9.56*	*8.21*	*4.31*	*ND*				
H	Motloutse River – Talana farms	*DRY*							
I	Limpopo – Lentswe Le Moriti	*DRY*							
J	Tati River – Masunga	DRY							
K	Shashe River – Mbalambi	*DRY*							
L	Shalimpo	*74.0*	*45.4*	*0.87*	*ND*				

SOUTH AFRICA - 1ST SAMPLING: 17 to 24 SEPTEMBER 2011 – SUMMER SEASON

Table 5*: Microbiology and physical characteristics of water samples at 11 Joint Survey Sites in South Africa Rivers of Limpopo Catchment*

No	**Sampling sites**	**Faecal Coliform**	**Intestinal enterococci**	**DO mg/L**	**pH Units**	**EC µS/cm**	**TDS mg/L**	**Turbidity NTU**
1	Crocodile – Upstream mine	40	36	6.78	8.12	1300	833	13.6
2	Crocodile River – downstream mine	178	61	6.87	8.05	533	323	16.7
3	Crocodile River – 5 km off Olifants	45	40	5.23	8.58	747	478	19
4	Matlabas River	18	20	5.73	8.72	73	48	13
5	Mokolo River	380	40	6.72	8.14	50	31	11.7
6	Lephalale River	DRY						
7	Limpopo River@Sterkloop's Weir	*60*	*18*	*7.31*	*8.21*	*711*	*455*	*16.7*
8	Mogalakwena River	*1272*	*540*	*6.19*	*7.71*	*316*	*205*	*15.3*
9	Luvuvhu River – Kruger National Park	*480*	*96*	*6.27*	*8.19*	*182*	*118*	*54.1*
10	Limpopo River – Crooks Corner	DRY						
11	Limpopo River @Beit Bridge	*32*	*10*	*7.2*	*7.36*	*596*	*358*	*5.01*

Chemical characteristics (mg/L)

No	Sampling sites	Ca	Mg	Na	K	Fe	Mn	Cu	Pb
1	Crocodile River – upstream mine	42.85	25.5	73.5	7.9	0.27	0.05	ND	0.005
2	Crocodile River – downstream mine	49	25.96	62.72	7.7	0.64	0.04	ND	0.007
3	Crocodile River – 5 km off Olifants	42.13	25.48	35.95	4.5	0.24	0.06	ND	0.009
4	Matlabas River	3.34	1.93	2.85	1.23	1.04	0.05	ND	0.009
5	Mokolo River	4.12	2.04	6.01	1.04	0.93	0	ND	0.008
6	Lephalale River	DRY	DRY	DRY	DRY	DRY	DRY		
7	Limpopo River@Sterkloop's Weir	31.4	24.95	6.01	1.04	0.42	0.06	ND	0.009
8	Mogalakwena River	20.97	7.91	24.21	4.75	0.28	0	ND	0.010
9	Luvuvhu River – Kruger National Park	8.06	5.64	9.58	1.32	1.03	0.03	ND	0.003
10	Limpopo River – Crooks Corner	DRY	DRY	DRY	DRY	DRY	DRY		
11	Limpopo River @Beit Bridge	21.15	27.5	113.35	7.26	0.18	0	ND	ND

Chemical characteristics

No	Sampling sites	Ca	Mg	Na	K	Fe	Mn	Cu	Pb
1	Crocodile River – upstream mine	42.85	25.5	73.5	7.9	0.27	0.05	ND	0.005
2	Crocodile River – downstream mine	49	25.96	62.72	7.7	0.64	0.04	ND	0.007
3	Crocodile River – 5 km off Olifants	42.13	25.48	35.95	4.5	0.24	0.06	ND	0.009
4	Matlabas River	3.34	1.93	2.85	1.23	1.04	0.05	ND	0.009
5	Mokolo River	4.12	2.04	6.01	1.04	0.93	0	ND	0.008
6	Lephalale River	DRY	DRY	DRY	DRY	DRY	DRY		
7	Limpopo River@Sterkloop's Weir	31.4	24.95	6.01	1.04	0.42	0.06	ND	0.009
8	Mogalakwena River	20.97	7.91	24.21	4.75	0.28	0	ND	0.010
9	Luvuvhu River – Kruger National Park	8.06	5.64	9.58	1.32	1.03	0.03	ND	0.003
10	Limpopo River – Crooks Corner	DRY	DRY	DRY	DRY	DRY	DRY		
11	Limpopo River @Beit Bridge	21.15	27.5	113.35	7.26	0.18	0	ND	ND

Chemical characteristics (mg/L)

No	Sampling sites	Cl	SO4	NO3	PO4				
1	Crocodile River – upstream mine	9.74	22.68	1.77	0.097				
2	Crocodile River – downstream mine	14.02	24.79	2.48	0.172				
3	Crocodile River – 5 km off Olefants	27.31	44.75	0.12	0.203				
4	Matlabas River	14.74	22.65	2.56	0.147				
5	Mokolo River	25.36	43.13	1.02	0				
6	Lephalale River	DRY							
7	Limpopo River@Sterkloop's Weir	15.27	37.08	0	0				
8	Mogalakwena River	21.74	36.83	3.01	0.097				
9	Luvuvhu River – Kruger National Park	15.23	25.65	2.35	0.135				
10	Limpopo River – Crooks Corner	DRY							
11	Limpopo River @Beit Bridge	24.13	42.27	2.13	0.121				

SOUTH AFRICA - 2nd SAMPLING:02-06 February 2012 – RAIN SEASON

Table 6: *Microbiology and physical characteristics of water samples at 11 joint survey sites in South Africa Rivers of Limpopo catchment*

No	***Sampling sites***	***Faecal Coliform***	***Intestinal enterococci***	***DO mg/L***	***pH Units***	***EC µS/cm***	***TDS mg/L***	***Turbidity NTU***
1	Crocodile – Upstream mine	100	35	6.4	8.51	554	355	64.6
2	Crocodile River – downstream mine	100	95	6.61	8.69	531	340	50.1
3	Crocodile River – 5 km off Olifants	36	40	5.01	8.53	521	334	4.13
4	Matlabas River	25	34	5.42	7.64	19	13	17.46
5	Mokolo River	45	50	6.91	7.49	49	32	3.16
6	Lephalale River	80	72	5.09	7.22	41	26	29.76
7	Limpopo River @Sterkloop's Weir	*140*	*120*	6.91	7.74	186	121	40.66
8	Mogalakwena River	*600*	*600*	6.02	7.88	154	100	25.4
9	Luvuvhu River – Kruger National Park	*580*	*206*	7.45	8.11	89	58	*43.5*
10	Limpopo River – Crooks Corner	8600	720	6.33	8.15	98	64	58.96
11	Limpopo River @Beit Bridge	*150*	*180*	7.3	7.87	184	120	16.9

Chemical characteristics (mg/L)

No	Sampling sites	Ca	Mg	Na	K	Fe	Mn	Cu	Pb
1	Crocodile River – upstream mine	40.42	24.83	54.3	33.9	0.71	0.04	?	?
2	Crocodile River – downstream mine	39.44	24.31	55.14	34.7	0.98	0	?	?
3	Crocodile River – 5 km off Olifants	21.07	20.99	54.56	33.2	0.48	0	?	?
4	Matlabas River	0.96	0.39	0.7	0.2	0.63	0.06	?	?
5	Mokolo River	2.78	1.55	4.37	2.45	1.07	0	?	?
6	Lephalale River	3.63	3.24	1.39	0.98	1.15	0	?	?
7	Limpopo River@Sterkloop's Weir	18.54	10.41	7.32	5.67	0.8	0	?	?
8	Mogalakwena River	11.4	15.92	4.69	3.98	0.97	0	?	?
9	Luvuvhu River – Kruger National Park	5.95	8.83	7.93	5.94	1.42	0	?	?
10	Limpopo River – Crooks Corner	6.73	7.02	6.77	4.56	0.66	0	?	?
11	Limpopo River @Beit Bridge	15.14	14.49	7.75	5.78	0.97	0.23	?	?

Chemical characteristics (mg/L)

No	Sampling sites	Cl	SO4	NO3	PO4				
1	Crocodilr River – upstream mine	91.69	62.3	9.24	0				
2	Crocodile River – downstream mine	92.71	62.78	9.31	0				
3	Crocodile River – 5 km off Olefants	89.32	61.31	5.04	0				
4	Matlabas River	1.43	1.36	1.55	0				
5	Mokolo River	6.9	2.90	1.21	0				
6	Lephalale River	6.4	2.67	1.16	0				
7	Limpopo River@Sterkloop's Weir	27.43	13.57	1.56	0				
8	Mogalakwena River	18.28	3.07	1.67	0				
9	Luvuvhu River – Kruger National Park	7.99	0.81	1.90	0				
10	Limpopo River – Crooks Corner	11.06	3.52	2.67	0				
11	Limpopo River @Beit Bridge	25.08	11.19	1.47	0				

SOUTH AFRICA –3rd SAMPLING: 25 JUNE to 01 JULY 2012 – WINTER SEASON

***Table 6** Microbiology and physical characteristics of water samples at 11 Joint Survey Sites in South Africa Rivers of Limpopo Catchment*

No	Sampling sites	Faecal Coliform	Intestinal enterococci	DO mg/L	pH Units	EC µS/cm	TDS mg/L	Turbidity NTU
1	Crocodile – Upstream mine	100	62	7.22	8.8	788	639	8.5
2	Crocodile River – downstream mine	38	40	6.12	8.59	722	596	8.7
3	Crocodile River – 5 km off Olefants	30	32	9.08	8.4	721	562	7.9
4	Matlabas River	60	28	9.96	7.46	32	27	5.4
5	Mokolo River	30	14	7.08	7.39	67	51	7.5
6	Lephalale River	DRY						
7	Limpopo River@Sterkloop's Weir	11	15	6.69	7.64	460	360	26.6
8	Mogalakwena River	128	46	6.09	7.65	201	83	7.8
9	Luvuvhu River – Kruger National Park	1620	150	7.41	8.01	113	47	11.7
10	Limpopo River – Crooks Corner	3000	500	6.65	8.02	132	53	12.9
11	Limpopo River @Beit Bridge	188	98	7.01	7.82	211	87	5.06
Chemical characteristics (mg/L)									
No	Sampling sites	Ca	Mg	Na	K	Fe	Mn	Cu	Pb
1	Crocodile River – upstream mine	50.1	35.75	94.5	9.9	0.07	0.03	0.001	ND
2	Crocodile River – downstream mine	56.4	39.05	102.3	11.35	0.1	0.04	0.03	ND
3	Crocodile River – 5 km off Olefants	40.67	31.45	80.4	7.5	0.5	0.06	0.02	0.003
4	Matlabas River	2.67	1.5	2.48	0.67	0.4	0.03	0.03	0.004
5	Mokolo River	4.21	2.28	7.13	1.01	0.7	0.03	ND	0.002
6	Lephalale River	DRY							
7	Limpopo River@Sterkloop's Weir	19.2	19.74	52.12	4.88	0.9	0.2	0.02	0.001
8	Mogalakwena River	85.9	98.4	47.6	1.02	0.2	0.02	0.001	ND
9	Luvuvhu River – Kruger National Park	9.76	6.77	11.21	1.48	0.4	0.02	0.002	ND
10	Limpopo River – Crooks Corner	9.72	6.74	11.51	1.72	0.85	0.036	0.007	0.006
11	Limpopo River @Beit Bridge	20.3	17.53	61.4	4.5	0.35	0.02	0.016	0.004
Chemical characteristics (mg/L)									
No	Sampling sites	Cl	SO4	NO3	PO4				
1	Crocodile River – upstream mine	130.8	79.8	4.0	ND				
2	Crocodile River – downstream mine	136.4	87.92	5.1	ND				
3	Crocodile River – 5 km off Olifants	89.41	70.32	0.41	ND				
4	Matlabas River	3.31	0.53	0.55	ND				
5	Mokolo River	10.33	8.7	0	ND				
6	Lephalale River	DRY							
7	Limpopo River@Sterkloop's Weir	72.19	44.3	0.58	ND				
8	Mogalakwena River	286.0	43.4	3.06	ND				
19	Luvuvhu River – Kruger National Park	13.77	0.88	nd	ND				
10	Limpopo River – Crooks Corner	13.81	0.89	0	ND				
11	Limpopo River @Beit Bridge	84.57	20.79	0.93	ND				

ANNEXURE 2: PRESENCE OF AQUATIC PLANTS

Table 7: Number of aquatic and wetland plant species in the primary rivers, secondary rivers and in the Limpopo River

Primary Rivers		
Crocodile	1	Phragmites mauritianus Kunth
	2	Eichhornia crassipes (Martius) Solms-Laubach
	3	Azolla pinnata R. Br.
	4	Lemna minor L.
	5	Sesbania bispinosa (Jacq.) W.F. Wight
Marico	1	Phragmites australis (Cav.) Steud.
	2	Phragmites mauritianus Kunth
	3	Eichhornia crassipes (Martius) Solms-Laubach
	4	Potamogeton schweinfurthii A. W. Benn
	5	Potamogeton thunbergii Cham. & Schlechtd
	6	Typha capensis (Rohrb.) N. E. Br
	7	Alternanthera sessilis (L.) DC
	8	Persicaria meisneriana Cham. & Schltdl) M. Gomez
	9	Persicaria attenuata (R. Br.) Sojak subsp.africanaK. L. Wilson
	10	Mimulus gracilis R. Br.
	11	Cyperus articulatus L.
	12	Phyla nodiflora (L.) Greene
	13	Ceratophyllum demersum L.
Secondary Rivers		
Matlabas	1	Phragmites mauritianus Kunth
	2	Nymphaea Sp.
	3	Potamogeton octandrus Poir.
	4	Eragrostis curvula (Schrad.) Nees
	5	Cyperus articulatus L.
	6	Diplachne fusca (L.) Beauv. ex Roem. & Schult.
	7	Aeschynomene indica L.
	8	Polygonum limbatum Meisn.
	9	Commelina subulata Roth
	10	Bergia capensis L.
	11	Hemarthria altissima (Poir.) Stapf & C. E. Hubb
	12	Sesbania bispinosa (Jacq.) W.F. Wight
	13	Rotala myriophylloides Welw. ex Hiern
	14	Nymphoides indica (L.) Kuntze
	15	Persicaria senegalensis (Meisn.) Sojak forma senegalensis
Lephalala	1	Phragmites mauritianus Kunth
Mokolo	1	Phragmites mauritianus Kunth
Mogalakwena	1	Phragmites mauritianus Kunth
	2	Ludwiggia stolonifera (Guil & Poir.) Raven
	3	Cyuperus sp.
	4	Azolla pinnata R. Br.
Luvuvhu	1	Phragmites mauritianus Kunth
Limpopo River		
Limpopo	1	Eichhornia crassipes (Martius) Solms-Laubach
	2	Phragmites australis (Cav.) Steud.
	3	Ludwiggia stolonifera (Guil & Poir.) Raven
	4	Ludwiggia palustris (L.) Troch.
	5	Phyla nodiflora (L.) Greene
	6	Alternanthera sessilis (L.) DC
	7	Sesbania bispinosa (Jacq.) W.F. Wight
	8	Cyperus articulatus L.
	9	Cyperus alopecuroides Rottb.
	10	Commelina diffusa Burm. f. subsp. diffusa
	11	Commelina diffusa Burm. f. subsp. scandens
	12	Azolla pinnata R. Br.
	13	Hydrocotyle verticillata L.
	14	Pennisetum macrourum Trin.
	15	Chara sp.
	16	Lemna minor L.
	17	Pistia stratiotes L.

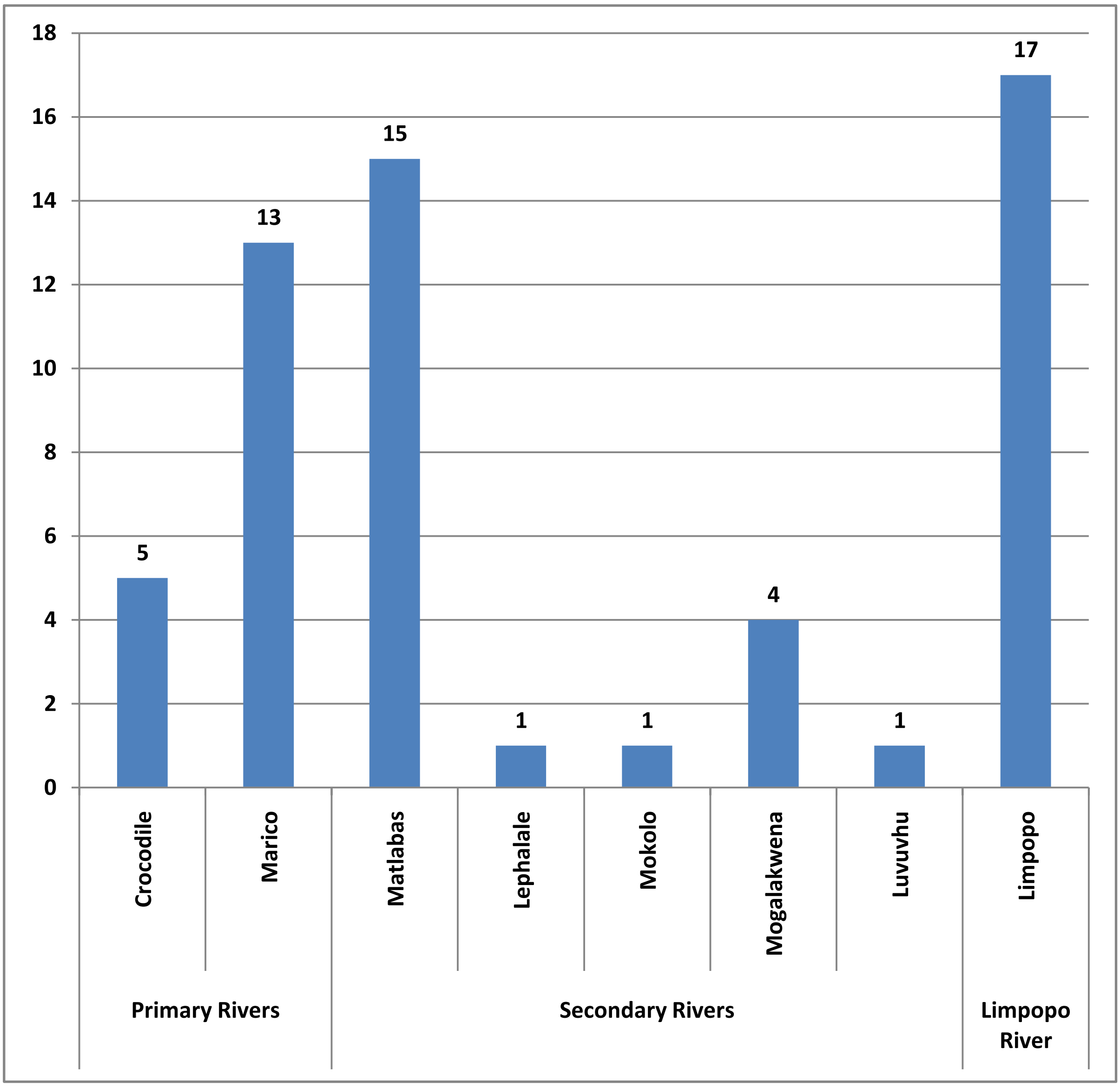


Figure 19: Number of plant species in primary rivers, secondary rivers and in the Limpopo River identified during the joint survey.

A higher number of plant species was recorded in Limpopo River followed by Matlabas and Marico Rivers. Nymphaea sp. and other plant species recorded in Matlabas River indicate similarities with several areas of the Okavango Delta in Botswana. It is not the number of aquatic species that determines the quality of water but it is the type of species. The species such as water hyacinth-*Eichhornia crassipes* (Martius) Solms-Laubach, water lettuce-*Pistia stratiotes* L., redwater fern-*Azolla pinnata* R. Br., and duck weed-*Lemna minor* L., are classified as invasive weeds and are found in the Limpopo River while Crocodile River had three species except the water lettuce. Therefore it is inferred that the invasiveness is reflected in the status of nutrient concentrations in the Limpopo and Crocodile Rivers as compared to the Secondary Rivers.

Pictures of the plants are shown in the next page.

Figure 20: Invasive plants found in Limpopo Rivers - Water Hyacinth-*Eichhornia Crassipes* (Martius) Solms-Laubach, Fern-*Azolla Pinnata* R. Br., And Duck Weed-*Lemna Minor* L, Water Lettuce-*Pistia Stratiotes* L., Redwater

ANNEXURE 3: APPLIED STANDARDS

TARGET WATER QUALITY GUIDELINES FOR ALL USERS (LOWEST, ONLY OR BEST APPLICABLE VALUE) AND STANDARDS

Parameter	Unit	User(s)							Value	Target WQ	SABS:	Uniform Effluent Standards	
		D	R	a	w	I	C	E	used	Guide	Drink water	GENERAL	SPECIAL
PHYSICAL REQUIREMENTS													
Clarity	Secchi disk Depth (m)								R	≥3.0			
Colour	Pt-Co colour units								D	15	20	FREE	NONE
Odour	TON								D	<1	FREE	FREE	NONE
Taste	TTN										FREE	FREE	NONE
Temperature	°C								E	10% or ±2°C		≤ 35	≤ 25
Turbidity	NTU								D	0 - 1	1		
CHEMICAL REQUIREMENTS													
Alkalinity	mg $CaCO_3$/l								I	0 - 50			
Ammonia	mg/l N (pH > 8)								D	0 - 1.0		10	1.0
Calcium	mg/l as Ca								D	0-32			
Chloride	mg/l as Cl								a,I	0-100	250		
Chlorine	mg/l as CP								E	0-0.2		0.1	NIL
Electrical conductivity	mS/m at 25° C(TDS/7)								D,I	0 - 40	70	intake+75;250	intake+15%;250
Fluoride	mg/l as F								D,E	0 - 1.0	1.0	1.0	1.0
Magnesium	mg/l as Mg								D	0-30	70		
Nitrate & Nitrite	mg/l N								D	0 - 6	6		1.5
Nitrogen (Inorganic)	Total N mg/l								a,E	0-0.5			
pH	(at 25° C)								R	6.5 - 8.5	6-9	5.5-9.5	5.5-7.5
Potassium	mg/l as K								D	0-50			
Soap, oil or grease (SOG)	mg/l											2.5	NONE
Soluble ortho-phosphate	mg/l as P								E	0.005-0.025			1.0 #
Sodicity (Na-absorption ratio)	$SAR=\{[Na]/[Ca]+[Mg]\}^{0.5}$ (in mmol/l)								a	0 - 1.5			
Sodium	mg/l as Na								D, a	0 - 70	100	intake + 90	intake + 50
Sulphate	mg/l as SO_4								D	0 - 200	200		
Sulphides	mg/l as H_2S								C	0-0.001		1.0	0.05
Suspended solids	mg/l								a,w	0 - 5		25	10
TDS	mg/l (≈ 7xEC)								D,I	0 - 450			
Total hardness	mg/l $CaCO_3$								I,D	0-50	20		
Aluminium	mg/l as Al								D	0 - 0.15			
Arsenic	mg/l as As								D	0 - 0.01	0.100	0.5	0.1
Asbestos	Fibre count (fibres/l)								D	$0\text{-}10^6$			
Boron	mg/l as B								a	0 - 0.5		1.0	0.5
Cadmium	mg/l as Cd								D	0-0.005	0.010	0.05	0.05 *
Hexavalent Chromium	mg/l as Cr(VI)								D,E	0-0.05		0.05	
Total Chromium	mg/l as Cr											0.5	0.05 *
Cobalt	mg/l as Co								a,w	0-0.05			
Copper	mg/l as Cu								D,a	0 - 0.2	0.5	1.0	0.02
Cyanide	mg/l as Cn								E	0-0.001	0.2	0.5	0.5 *
Iron	mg/l as Fe								D	0 - 0.1	0.1		0.3
Lead	mg/l as Pb								D	0-0.01	0.05	0.1	0.1 *
Lithium	mg/l as Li								a:beet	0-0.075 / 2.5			
Manganese	mg/l as Mn								a,D	0 - 0.02	0.05	0.4	0.1
Mercury	mg/l as Hg								D,w	0- 0.001	0.005	0.02	0.02 *
Nickel	mg/l as Ni								a,w	0-0.20			
Selenium	mg/l as Se								D,a,w	0 - 0.02	0.020	0.05	0.05
Uranium	mg/l as U								D,a	0-0.01			
Vanadium	mg/l as V								D,a	0-0.1			
Zinc	mg/l as Zn								a,D	0 - 1.0	1.0	5.0	0.3
RADIO-ACTIVITY REQUIREMENTS													
Gross α-activity	Bq/l								D	0-0.5			
Uranium-238	Bq/l								D	0-0.89			
Thorium-232	Bq/l								D	0-0.228			
Radium-226	Bq/l								D	0-0.42			
Radon-222	Bq/l								D	0-11			
Gross β-activity	Bq/l								D	0-1.38			
Radium-228	Bq/l								D	0-0.42			
ORGANIC AND GENERAL CHEMICAL REQUIREMENTS													
Chemical oxygen demand	mg O_2/l								I	0 - 10		75	30
Dissolved organic carbon	mg C /l								D	0 - 5			
Dissolved oxygen	% saturation								E	80-120		75	75
Organic Carbon	mg C/l								D	0 - 5			
Oxygen absorbed	mg/l (N/80KMnO4)											10	5
Phenols	mg/l as phenol								D	0-0.001	0.005	0.1	0.01
BIOLOGICAL REQUIREMENTS/INDICATOR ORGANISMS													
Coliphages	counts/100ml								D	0 - 1			
Enteric viruses	$TCID_{50}$/10l								D	0			
Faecal coliforms / *E. coli*	counts/100ml								D	0	0	0	0
Total coliforms	counts/100ml								D	0-5	0		
Heterotrophic bacteria	counts/1ml								D	0-100			
Protozoan Parasites	*Giardia* cyst/10l								D	0			
Standard plate count	counts/100ml										100		

Botswana Drinking Water Standard-BOS 32:2009 2nd edition

Table 1-Microbiolgical safety determinants' requirements

DETERMINANTS	UNITS	ACCEPTABLE LIMIT [a)]
Total coliform	Count/100 ml	Not detected
E.coli [b)]	Count/100 ml	Not detected
Thermotolerant (faecal) coliform bacteria [c)]	Count/100 ml	Not detected
Faecal streptococci	Count/100 ml	Not detected
Clostridium perfringens [d)]	Count/100 ml	Not detected
Cryptosporidium [e)]	Count/volume sampled [f)]	Not detected
Giardia [e)]	Count/volume sampled [f)]	Not detected

a) The allowable annual compliance contribution shall be at least 95% to the limits indicated

b) Definitive,preferred indicator of faecal pollution.

c) Indicator of unacceptable microbial water quality,could be tested instead of E.coli but is not the perferred indicator of faecal pollution. Also provides information on treatment efficiency and after growth in distribution networks.

d) Analyses for Clostridium perfringens should be done biannually. However, during the rainy season or outbreak of water borne diseases, analyses should be carried more often.

e) If Clostridium perfringens is detected, then Cryptosporidium and Giardia should be analysed for.

f) Standard volume usually used is 10 litre or 1000 litre

Table 2-Physical and organoleptic determinants' requirements

DETERMINANTS	RISK CATEGORY	UPPER LIMITS AND RANGES	
		CLASS I(ACCEPTABLE)	CLASS II(MAX.ALLOWABLE)
COLOUR	AESTHETIC	15	50
CONDUCTIVITY AT 25°C	AESTHETIC	1500	3100
DISSOLVED SOLIDS	AESTHETIC	1000	2000
ODOUR	AESTHETIC	NOT OBJETIONABLE	NOT OBJECTIONABLE
pH VALUE AT 25 °C	AESTHETIC/OPERATIONAL	5.5-9.5	5.0-10.0
TASTE	AESTHETIC	NOT OBJETIONABLE	NOT OBJECTIONABLE
TURBIDITY	AESTHETIC/OPERATIONAL	1	5

Table 3-Chemical requirements: inorganic macro-determinants

DETERMINANTS	RISK CATEGORY	UPPER LIMITS AND RANGES	
		CLASS I(ACCEPTABLE)mg/l	CLASS II (Maximum Allowable) mg/l
AMMONIA AS N	AESTHETIC/OPERATIONAL	1	2
CALCIUM AS Ca	AESTHETIC/OPERATIONAL	150	200
CHLORIDE AS Cl	AESTHETIC	200	600
CHLORINE RESIDUAL	AESTHETIC	0.6-1.0	1,0
FLOURIDE AS F	HEALTH	1,0	1,5
MAGNESIUM AS Mg	AESTHETIC/HEALTH	70	100
NITRATES AS NO3	HEALTH	50	50
NITRITES AS NO2	HEALTH	3,0	3,0
POTASSIUM AS K	OPERATIONAL/HEALTH	50	100
SODIUM AS Na	AESTHETIC/HEALTH	200	400
SULFATE AS SO4	HEALTH	250	400
ZINC AS Zn	AESTHETIC/HEALTH	5,0	10,0

Table 4-Chemical requirements:inorgarnic micro-determinants

DETERMINANTS	RISK CATEGORY	UPPER LIMITS AND RANGES	
		CLASS II(ACCEPTABLE)µg/l	CLASS 2(MAX.ALLOWABLE)µg/l
ALUMINIUM AS Al	HEALTH	200	200
ANTIMONY AS Sb	HEALTH	20	50
ARSENIC AS As	HEALTH	10	10
CADMIUM AS Cd	HEALTH	3	3
CHROMIUM AS Cr(total)	HEALTH	50	50
COBALT AS Co	HEALTH	500	1000
COPPER AS Cu	HEALTH	2000	2000
CYANIDE(FREE) AS CN	HEALTH	70	70
CYANIDE(RECOVERABLE) AS CN	HEALTH	70	70
IRON AS Fe	AESTHETIC/OPERATIONAL	300	2000
LEAD AS Pb	HEALTH	10	10
MANGANESE AS Mn	AESTHETIC	100	500,0
MERCURY AS Hg(inorganic)	HEALTH	6	6
NICKEL AS Ni	HEALTH	70	70
SELENIUM AS Se	HEALTH	10	10

Table 5: Chemical requirements:organic determinants

DETERMINANTS	UPPER LIMITS AND RANGES	
	CLASS I(Acceptable)µg/l	CLASS II(MAX.Allowable)µg/l
TOTAL ORANIC CARBON	8000	8000
TOTAL TRIHALOMETHANES	1000	1000
PHENOLS	10	10
CHLOROFORM	300	300
ALDRIN	0	0
DIELDRIN	0,03	0,03
CHLORDANE	0,2	0,2
DDT	2	2
LINDANE	2	2
ENDRIN	0,6	0,6
HEPTACHLOR	0,03	0,03
HEPTACHLOR EPOXIDE	0,03	0,03
METHOXYCHLOR	20	20
PARATHION	50	50
TOLUENE	700	700
XYLENE	500	500
ETHYL BENZENE	300	300

Botswana Waste Water Standard-BOS 93:2004

Table 1- Physical and microbiological requirements

DETERMINANTS	UPPER LIMITS AND RANGES
TEMPERATURE	35 ^{0}C
PH	6.0-9.0
DISSOLVED OXYGEN(MIN)	60 %sat.
BOD5(MAX)	30 mg/l
COD(MAX)	75(filtered) mg/l
COD(MAX)	150(unfiltered) mg/l
COLOUR	50 TCU
TURBIDITY	30 NTU
TOTAL DISSOLVED SOLIDS(TDS)	2000 mg/l
TOTAL SUSPENDED SOLIDS(TSS)	25 mg/l
FAECAL COLIFORM	1000 counts/100ml

Table 2-Chemical requirements-Macro-determinants

DETERMINANTS IN mg/l, unless otherwise stated	UPPER LIMITS AND RANGES
FREE AND SALINE AMMONIA(AS N)	10
ORTHO PHOSPHATE(AS P)OR SOLUBLE PHOSPHATE	1,5
CALCIUM AS Ca	500
CHLORIDE AS Cl	600
CHLORINE RESIDUAL	1,0
FLOURIDE AS F	1,5
NITRATE AS N	22
POTASSIUM AS K	100
SODIUM AS NA	400
SULPHATE AS SO4	400
ZINC AS Zn	5,0

Table 3- Chemical requirements:Micro-determinants

DETERMINANTS IN mg/l,unless otherwise stated	UPPER LIMITS AND RANGES
ARSENIC AS As	0
BORON AS B	0,5
CADMIUM AS Cd	0,02
CHROMIUM VI AS Cr	0,25
CHROMIUM VI AS Cr(TOTAL)	0,5
COBALT AS Co	1
COPPER AS Cu	1
CYANIDE AS CN	0,1
IRON AS Fe	2
LEAD AS Pb	0,05
MANGANESE AS Mn	0,1
MERCURY AS Hg(total)	0,01
NICKEL AS Ni	0,3
SELENIUM AS Se	0,02

ANNEXURE 4: PICTURES OF SAMPLING SITES


A. Marico-Sikwane


B. Marico-Oliphants


C. Limpopo-Oliphants


D. Notwane River


E. Limpopo-Buffles Drift


F. Martins Drift


G. Lotsane River


H. Motloutse River


I. Lentswe Le Moriti


J. Shalimpo


K. Tati River-at the border of Zimbabwe


L. Shashe River-Mbalambi at the border of Zimbabwe

1. Crocodile Upstream

2. Crocodile-Downstream mine

3. Crocodile - 5km off Olifants

4. Matlabas River

5. Mokolo River

6. Lephalale River

7. Limpopo River- Sterkloop weir

8. Mogalakwena River

9. Limpopo-Beit bridge

10. Luvuvhu River

11. Limpopo - Crooks Corner

ANNEXURE 5: PROFILE OF LIMPOPO RIVER BASIN BETWEEN BOTSWANA AND SOUTH AFRICA

BOTSWANA LIMPOPO RIVER BASIN

Botswana occupies an area of 582 000km^2. It is one of the most sparsely populated countries in southern Africa, with just around 2 million people living in the country; many of whom live in the larger urban areas, including Gaborone, Francistown and Molepolole. About 1.6 million people live in the Limpopo basin. Water is a very important resource in Botswana, so much so that the national currency is called the Pula – or rain.

In Botswana catchments are categorized by the nine (9) hydrological zones being Okavango, Kwando, Limpopo, Boteti, Molopo, Makgadikgadi, South East, Central East and North East.In the Limpopo River basin the majority of the area is considered to be rural. There are six administrative districts found within the basin: North East; Central; Kgatleng; South East and parts of Kweneng.

The major river basins include the Ngotwane, Bonwapetsi, Lotsane, Motloutse, and Shashe system[7] (NWMP, 1991). Together they constitute a combined drainage area of some 80 000km^2(MMP, 1987). This constitutes the drainage area in the Limpopo basin on the Botswana side. This basin is situated in the eastern part of the country. The rivers generally drain in the easterly direction, flowing into the left bank of the Limpopo River which forms the international Botswana and South Afrian. The major tributaries of the Limpopo basin are Notwane river, Mahalapye, Shashe,Thune, Lotsane and Motloutse river.The main urban centres within the basin are Serowe, Selebi-Phikwe, Palapye, Mahalapye, Francistown, Mochudi and Gaborone (capital city) (LBPTC 2010).

Topography

The country is flat and surrounded by higher plateaus of Zambia to the north, Zimbabwe to the north east, South Africa to the southeast, and Namibia to the west, giving it a saucer like physiography (NWMP,2006).

Climate and Rainfall

The climate of Botswana is characterized by generally unvarying temperatures around the 30’s in the summer months and the 19’s to 20’s in winter. The mean monthly maximum temperature ranges from 29.2^{0}C to 37^{0}Cin summer and 19.8^{0}C TO 28.9^{0}Cin summer while the mean monthly minimum temperatures range from -6^{0}C to 13.6^{0}C in winter (NWMP, 2006).

Over 90% of the rainfall occurs in summer months. Sometimes the rainfall tends to occur in wet spells lasting several days at a time. These wet spells are interspersed with lengthy dry spells. Storm rainfall intensities are usually high but the duration of the storms short. The average rainfall of 450 mm. Drought is endemic.

Land Use and Vegetation

The southern and eastern regions of Botswana are generally semi-arid. The main economic activities in the basin are traditional rain-fed crop farming and cattle rearing, game farming and eco-tourism. Botswana's agricultural industry in the Limpopo basin is dominated by cattle rearing and subsistence farming. Agriculture is plagued by various factors like poor soil conditions and erratic rainfall.

Crop production is hampered by traditional farming methods, recurrent drought, erosion, and disease. Most of the land under cultivation is in the eastern region of Botswana.

Most of the major urban centres and villages lie in the Limpopo basin, including the capital city.

Water Challenges

The main water challenges in Botswana are water scarcity and pollution of both surface and ground water resources.

[7] National Water Management Plan, 1997

Secondary Catchment	Tributaries	Dams	Yield Mm3/annum	Use	Waste water establishments
Botswana Rivers of Limpopo Basin	Notwane River	Gaborone	141.4	Domestic/ Industrial	Glen Valley waste water treatment plant
	Lotsane River	Lotsane	40	Domestic/Irrigation	
	Shashe River	Shashe Dikgatlhong	85 400	Domestic	Tonota village sewage ponds
	Motloutse River	Letsibogo	100	Domestic	Selibe Phikwe town ponds
	Thune River	Thune	90	Domestic/Irrigation/	-
	Nnywane	Nnywane	2.3	Domestic	-
	Tati	Ntimbale	26.4	Domestic	-Mambo care works
	Mahalapye	-	-	-	Mahalpye village ponds

Table 8: Botswana Tributaries and Water Use

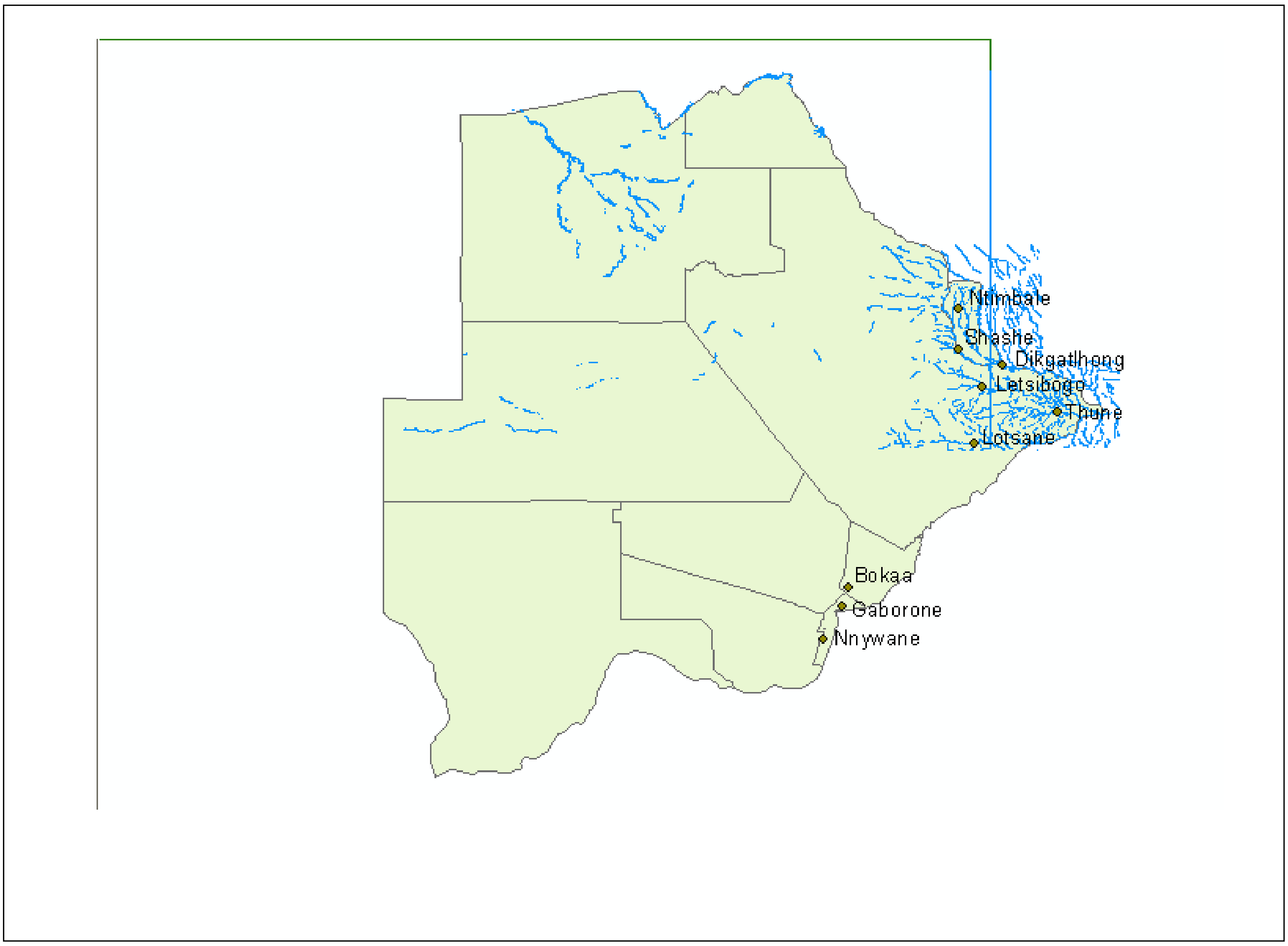
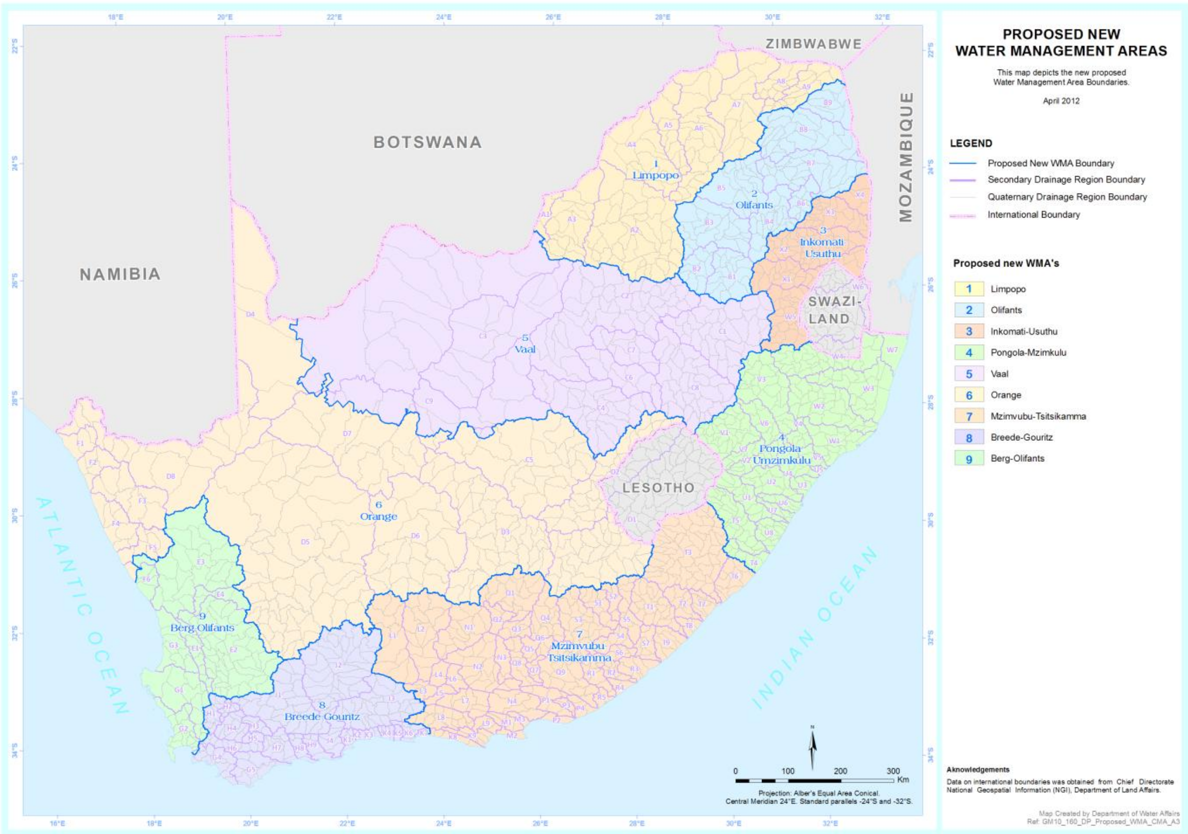


Figure 21: Figure Showing Major Dams on the Limpopo Basin in Botswana

SOUTH AFRICA LIMPOPO RIVER BASIN[8]

Limpopo catchments in South Africa are divided into two Water Management Areas (WMAs), namely Limpopo Water Management Area to the west bordering South Africa, Botswana and Zimbabwe flowing into Mozambique;and Olifants Water Management Area to the east of the main basin flowing into Mozambique before joining the main Limpopo River inside Mozambique. Significant towns include Polokwane, Mokopane, Mookgopong, Modimolle, Louis Trichardt, Musina and Lephalale. The survey falls within the Limpopo Water Management Area.The Limpopo Water Management Area is shown in Figure 2, with other eight WMAs in South Africa.

Figure 22: Proposed New Water Management Areas, South Africa



The region is semi-arid, with economic activity mainly centred on livestock farming and irrigation, together with increasing mining operations. Approximately 760 rural communities are scattered throughout the water management area, with little local economic activity to support these population concentrations.

There are numerous tributaries that contribute to the Limpopo WMA.The Marico and Crocodile Rivers form the headwaters of the Limpopo at their confluence.The Marico, Upper Molopo and Upper Ngotwane River catchments make up the western part of the Water Management Area. The Crocodile (West) River catchment forms a major part of the Limpopo WMA. The Crocodile River is a major tributary of the Limpopo River which discharges into the Indian Ocean in Mozambique while thePienaars, Apies, Moretele, Hennops, Jukskei, Magalies and Elands rivers are themajor tributaries of the Crocodile River, which together make up the tertiaryhydrological catchment with its 39 quaternary catchments.

[8] This information is abstracted from the latest version of the Limpopo CMA establishment Business Case

Topography

While the topography of the Limpopo WMA is mostly flat, the Waterberg mountainrange forms an escarpment along the south-western border with altitudes in excessof 1 800m. From here the WMA slopes gradually down to the Limpopo River, henceall rivers in the Limpopo WMA drain in a northerly direction and flow into theLimpopo River.The Crocodile River and some of its main tributaries rise in the south of the catchment in the Witwatersrand topographical feature at an altitude close to 2000 masl., where the rivers wind their way through the Daspoort Ridge to the Magaliesburg mountain range at the Hartbeespoort Damwhere the altitude is around 1200 masl. On the other end, the topography is generally very flat with undulating hills in the lower reaches of the Marico River. Overall, the Limpopo WMA is geologically diverse.

Climate

The climatic conditions vary within the Limpopo Water Management Area, which ranges from the Waterberg Mountains in the south, northwards to the hot, dry Limpopo River valley on the border with Zimbabwe. The mean annual temperature of the Limpopo WMA ranges from 16° in the south to 22° in the north, with an average of 20° for the WMA as a whole (DWA, 2004). The average maximum monthly temperature is 30° in the month of January, while the average minimum monthly temperature is 4° in the month of July (DWA, 2004). For the Crocodile river, the upper higher lying areas of the catchment experience cold winters (daily average minima and maxima of 10C and 150C respectively) and reasonably hot summers (100 and 300 C).

Rainfall

The Mean Annual Precipitation (MAP) in the WMA ranges widely, with rainfall ranging from as little as 200 mm/annum in the north to over 1 200mm/annum in the Soutpansberg Mountains. In general, rainfall decreases from the south to the north, with the lowest rainfall occurring in the Limpopo valley in the north-east of the WMA. Rainfall occurs mainly in summer, (i.e. October to March). The peak rainfall months are in January and February and rainfall occurs generally as thunderstorms.

During the driest year, the annual rainfall in the Limpopo WMA ranges generally between 100-200 mm in the extreme north with the majority of the catchment ranging between 200-400 mm increasing up to 600 mm in the south. Rainfall in the Soutpansberg watershed ranges between 800-1200 mm per annum. In accordance with the rainfall patterns the relative humidity is higher in summer than in winter. Humidity is generally highest in February (the daily mean ranges from 64% in the west to above 70% in the east).

Population

The Limpopo Water Management Area in South Africa affects approximately 7 015 610 people residing in metropolitan cities, secondary cities, towns and rural settlements.

Economic activity

Approximately 51.5%of the South African Gross Domestic Product (GDP) originates in the Limpopo WMA, which is the largest of all the WMAs in the country (DWA, 2004). Urban areas cover an area of 665 km^2. Activities in these areas make up a significant portion of the economic activity such as service and government sectors, manufacturing, trade and industry (DWA, 2004). Together with mining activities they constitute just more than half of the country's Gross Domestic Product, which makes water supply to this catchment very important.

The economy of the Limpopo WMA is relatively more competitive than the remainder of South Africa with respect to agriculture and mining, which affirms the primary nature and function of the Limpopo WMA as an agricultural and mining region. Government expenditure is also very prominent in the WMA and offers a comparative advantage due to the fact that it is a primary activity that drives economic development. The

Limpopo WMA possesses a comparative advantage in trade and tourism activities, seen within a national context, even though this sector is fairly important to the regional economy (DWA, 2004).

It is significant to note that with the land and water resources available for agriculture already highly developed, economic growth in the WMA will largely be dependent on new mining developments. The greatest potential lies in the mining and beneficiation of platinum group metals, and coal mining for power generation or as a base for possible petro-chemical industries, as well as natural gas near Lephalale which could be economically exploited.

Water Availability and Requirements

The secondary catchments in the Limpopo Water Management Area includesubareas such as Crocodile West and Marico rivers, Limpopo Rivers, Luvuvhu and Mutale Rivers as shown in the Table 8. The water availability estimate for the Limpopo WMA, at a 98% assurance (1:50 Year Yield) of supply is shown in Table 8.

Table 9: Available Water Resource Yield inthe Year 2006 (Million m^3/annum)

Secondary Catchment	Sector/Key Area	Total sub area requirements		Usable Return Flow			Total Local Yield	Transfers in	Grand Total
		Surface water	Ground water	Irrigation	Urban	Mining & bulk			
Crocodile West Rivers	Upper Crocodile	111	31	21	158	15	336	279	615
	Apies/Pienaars	38	36	4	106	2	186	182	368
	Elands	30	29	3	10	14	86	71	157
	Lower Crocodile	7	29	14	1	8	59	112	171
Marico Rivers	Marico	30	23	2	3	1	59	0	59
	Upper Molopo	9	9	0	5	2	25	0	25
	Upper Ngotwane	1	5	0	0	0	6	0	6
Limpopo Rivers	Matlabas						4	0	4
	Mokolo						83	0	83
	Lephalala						24	0	24
	Mogalakwena						112	3	115
	Sand						105	15	120
	Nzhelele-Nwanedi						46	0	46
	Main stem Limpopo						79	0	79
Levuvhu and Mutale Rivers	Luvuvhu								
	Mutale								
Grand Total							**1210**	**662**	**1872**

Source: Adapted and adopted from the Marico; Crocodile; and Limpopo ISPs (DWA-SA, 2004; 2004a)

The current water requirements estimate for the Limpopo WMA, at a 98% assurance (1:50 Year Yield) of supply is shown in Table 9.

Table 10: Water requirements

Secondary Catchment	Sector/Key Area	Total sub area requirements		Usable Return Flow			Total Local Yield	Transfers in	Local Requirements
		Surface water	Ground water	Irrigation	Urban	Mining & bulk			
Crocodile West Rivers	Upper Crocodile	111	31	21	158	15	336	279	556
	Apies/Pienaars	38	36	4	106	2	186	182	280
	Elands	30	29	3	10	14	86	71	113
	Lower Crocodile	7	29	14	1	8	59	112	171
Marico Rivers	Marico	30	23	2	3	1	59	0	58
	Upper Molopo	9	9	0	5	2	25	0	48
	Upper Ngotwane	1	5	0	0	0	6	0	10
Limpopo Rivers	Matlabas						4	0	4
	Mokolo						83	0	83
	Lephalala						24	0	36
	Mogalakwena						112	3	114
	Sand						105	15	222
	Nzhelele/ Nwanedi						46	0	57
	Main stem Limpopo						79	0	79
Levuvhu and Mutale Rivers	Luvuvhu								
	Mutale								
Grand Total							**1210**	**662**	**1831**

Source: Adapted and adopted from the Marico; Crocodile; and Limpopo ISPs (DWA-SA, 2004; 2004a)

The current yield balance within the Limpopo WMA, given the water availability and water requirements estimate in Tables 8 and 9 above, is an estimated 75 million m^3/annum deficit. The deficits in the Limpopo rivers catchment relate to opportunistic irrigation situated in the Sand and Lephalala, which have the highest and third-highest deficit in the Limpopo WMA, and over-allocated irrigation in the Nzhelele-Nwanedi.

The balances in the Apies/Pienaars and Upper Crocodile sub-areas are due to urban return flows in excess of what is currently used in these sub-catchments; where only the Rietvlei Dam catchment and the Sterkstroom River in the Upper Crocodile Sub-area experience significant negative water balances.In the Marico river catchment, the Upper Ngotwane catchment is in deficit of approximately 4 million m^3/a. This is mainly because the level of assurance of supply for the users supplied from the Ngotwane Dam is much lower than the norm. These are the irrigators who may be irrigating annual crops and do not require higher levels of assurance of supply. The Upper Molopo catchment has the second highest deficit in the Limpopo WMA, although the current surface yield is not utilised to its full capacity. The deficit is in the groundwater abstraction, which is more than the available groundwater as currently understood. The yield from groundwater may be much higher than currently understood.

International considerations

The Limpopo River Basin, of which all the rivers in the Limpopo WMA are a part, is shared by South Africa, Botswana, Zimbabwe and Mozambique. There are no water sharing agreements on the Limpopo as a whole, although there is an agreement between South Africa and Mozambique (formerly Portugal) relating to the Massinger Dam situated on the Olifants River, which is a tributary of the Limpopo River. The existing agreement (**TSWASA Agreement**) on the water resources of Molatedi Dam between Botswana and South Africa (including the former homeland of Bophuthatswana) needs to be reviewed to account for the over-allocation from the dam. There is a distinct need for frequent exchange of information between the basin states and to measure the allocations to each state so that adjustments to the TSWASA Agreement can be made. On the Upper Molopo River, there are concerns from Botswana that increasing water use in the upper catchments are impacting on the availability of water from the sand wells on which the local Botswana communities are dependent on. The strategic option is to ensure that the catchments are managed as one unit. The organizational and administrative structures for the TSWASA Agreement has since changed and needs to be restructured in the light that the former area of Bophuthatswana was reincorporated into South Africa (DWA, 2004 - Marico ISP)

The Limpopo Watercourse Commission serves as the forum for the Limpopo basin countries and is responsible for the management of the water resources of the Limpopo River. This Commission, formed on 27 November 2003, replaces the Limpopo Basin Permanent Technical Committee. One of this Commission's first tasks is the commissioning of a Joint Basin Study of the Limpopo River and the development of a water use agreement for the Limpopo Basin. As of 2004, due to the international nature of the WMA, the further development of the resource in the South Africa remains under the authority of its Minister of Water Affairs and will not be delegated to the CMA (DWA, 2004).

Crocodile West and Marico Rivers sub area

The Marico, Upper Molopo and Upper Ngotwane River catchments make up the western part of the Crocodile West and Marico sub area. These catchments border on Botswana to the northwest and, the Crocodile West catchment in the east (Figure 1).

Topography

The topography of the area is generally very flat with undulating hills in the lower reaches of the Marico River. The Marico and Crocodile Rivers form the headwaters of the Limpopo at their confluence. The flow in the Marico River is highly variable and intermittent. There are two major storage reservoirs that regulate the flow in the Marico River, namely the Marico Bosveld Dam in the upper catchment and the Molatedi Dam further down-stream. There are several other dams as shown in the Table. The Ngotwane River (Notwane River as it is called in Botswana) is a tributary of Limpopo River. It flows into Botswana before turning and joining the Limpopo

River. The Molopo River is a tributary of the Orange River, discharging into pans in Botswana before turning south and emerging as surface flow just before it reaches the Orange River.

Climate and Rainfall

The climate of the catchments of Marico, Upper Molopo and Upper Ngotwane is generally semi-arid in the east and dry in the west. Mean Annual Precipitation (MAP) ranging between 600 and 800 mm in the Marico catchment to between 400 and 600 mm in the Upper Molopo catchments (DWAF: 1997). The average potential Mean Annual Evaporation (MAE) as high as 2800 mm, with the highest levels occurring in December (DWAF 2001).

Vegetation

Grassland and sparse bush-veld shrubbery and trees cover most of the terrain. The vegetation type is susceptible to erosion. Forest and woodland is located in the upper catchments of Marico and Upper Ngotwane where the dolomitic aquifers are located.

Land Use

- The land use characteristics of the Marico catchment comprise rural economic activities consisting of subsistence dry land agriculture and cattle grazing with some commercial irrigation in the upper catchment and along the Marico River downstream of the Marico Bosveld Dam and Molatedi Dam. There are no major towns in the catchment but smaller settlements are scattered throughout.

- In the Upper Molopo catchment the land use pattern is mainly grazing and dry land subsistence agriculture, with Mafikeng the major urban and industrial town in the catchment. Commercial irrigated agriculture occurs in the northern and western portions of the catchment. The majority of the population in the catchment lives in the rural areas. There is an internal migration within the catchment from the rural areas into the urban and peri-urban areas of Mafikeng, which is putting pressure on the available resources such as water supply to the town. The other urban area is Itsoseng situated 30 km northwest of Lichtenburg.

- In the Upper Ngotwane catchment, there is cattle grazing and subsistence agriculture. Overgrazing in some portions of the catchment, particularly the Upper Molopo and Upper Ngotwane, results in excessive soil erosion and loss of land cover. This has an impact on groundwater recharge. There is very little urbanisation in the catchments of the Marico, Upper Molopo and Upper Ngotwane. The only significant urban areas in these catchments are:

  - Mafikeng, the capital of the North West Province. This is situated in the Upper Molopo catchment.
  - Zeerust, a mining and agricultural town situated in the Marico catchments

Economically the Marico, Upper Molopo and Upper Ngotwane catchments are the poorest in the Crocodile (West) and Marico WMA. The economy is mainly the primary sectors of agriculture on the dolomites of the Upper Molopo and the Marico catchment as well as mining around Zeerust, with some secondary industries such as cement manufacturing at the Slurry. The tourism sector is growing particularly in the lower Marico in the game reserves of Madikwe.

Water Challenges

It is expected that strong population growth (due to migration to the urban areas in the sub area) will occur, accompanied by a concentration of economic development in the Tshwane- Johannesburg area. Consequently a significant growth in water requirements in the Upper Crocodile and Apies/Pienaars sub-areas may therefore be expected. Additional water requirements will also be expected in the Elands Sub-area as a result of the rapid expansion in mining related activities.

One of the challenges is to marry continued development with the supply of water that is fit for use by all users, including the aquatic ecosystem. This is so in light of water pollution in the Elands sub area attributed to boreholes that dry-up, collapse and/or which have been gradually polluted after 8 to 10 years by poor sanitation practices; as well as large quantities of effluent discharged into the rivers such as the Jukskei River.

Poor cost recovery and a scourge of illegal connections have led to the collapse of these systems (poor maintenance, poor pressure differentials and hence interrupted supply). This is especially pronounced in the semi-urban areas in the triangle between Brits, Tshwane and Temba (on the way to Bela-Bela) which have been serviced with basic levels of water supply in the past.

Rehabilitation of old water supply infrastructure and rejuvenation of old groundwater sources still poses the greatest challenge to planners and implementers alike in this catchment. Lots of people may have infrastructure, but do not always have water in taps and or lack a reliable source of this essential commodity.

Over-exploitation of groundwater is experienced in the vicinity of Mafikeng. Therefore the linkage (interaction) between surface and groundwater needs to be described and addressed in tandem with the issues surrounding the dewatering of mines just north of the Magaliesberg. In doing so, the mines will probably have to prove that they are not impacting on the upstream farming activities and the terrestrial environment around the mines. There are also severe eutrophication problems at dams in the sub area.

Limpopo Rivers sub area

Matlabas River catchment

The Matlabas catchment is a largely undeveloped catchment with limited water resources and limited water use. There are no significant dams in this catchment and a significant portion of the water use is from groundwater due to the low assurance of the run-of-river yields. The surface water flow is very erratic in the river and flow is ephemeral and 2 million m^3/annum is sourced from surface water. There are no reported water quality problems in the Matlabas area, either surface or groundwater. Due to the low levels of development, no water quality problems are anticipated in the river catchment.

Mokolo River catchment

The Mokolo catchment is a well-developed catchment with industries, mines and extensive agricultural activities. The main industrial development relates to Eskom's Matimba Power Station. Associated with this power station is the Grootgeluk Coal Mine which supplies coal to the power station, local users, as well as for export. Both these bulk users are supplied with water from the Mokolo Dam. Further development of the substantial coal reserves and gas fields and other coal based industries and related development are possible. This area, together with the Lephalala area, have approximately 40% of South Africa's remaining coal reserves and the development of new power stations in this area is inevitable as coal reserves on the high veld become depleted. Extensive irrigation occurs in the Mokolo catchment, both upstream and downstream of the Mokolo Dam (Full supply capacity 146 Mm^3/annum). The water resources of the Mokolo are dominated by the Mokolo Dam, situated in the lower reaches of the Mokolo River. Groundwater quality in much of the Mokolo area is generally poor due to the coal and gas fields. This poor quality groundwater could still be used for industrial purposes or irrigation, however, but is unsuitable for domestic use. Coal mining activities are also impacting on the surface water quality of the Mokolo area. Kumba Resources are conducting salinity monitoring in the catchment but the catchment lacks a proper water quality management plan. The coalmining activities could also have a negative impact on the groundwater quality. The rapid and uncontrolled growth of informal settlements is a source of concern with regard to the surface and groundwater quality in this area.

Lephalala River catchment

The Lephalala River originates in the Waterberg mountains where the rainfall is relatively high, and flows north to the Limpopo River. The runoff for this area originates in the upper reaches, and most of the surface water use in the area is found in these upper catchments, where the large number of farm dams supports a significant amount of irrigation. The middle reaches of the Lephalala River consist of a pristine wilderness area, while the dry lower reaches support irrigation from an alluvial aquifer and small weirs which are fed by the Lephalala River. There are no industries or mines in the catchment. There is Vischgat dam on the river

The water quality of the Lephalala River is generally good. However, there are a rapidly growing number of hotels and game lodges in the upper catchment and the effluent from these establishments could become a problem if not treated properly, especially during winter when natural dilution is at a minimum. There is also a risk that the use of fertilizers for irrigation will lead to deterioration in the water quality over time.

Mogalakwena River Catchment

The Mogalakwena River catchment with moderate rainfall in the upper mountainous reaches declines to the north. The main urban centers are Modimolle, Mookgopong and Mokopane. There are only two significant dams in the area are: the Doorndraai Dam (Full water supply capacity 44.2 Mm^3/annum) situated in the upper reaches on Sterk River, which supplies water to Mookgopong and to irrigation downstream of the dam, and the Glen Alpine Dam (Full water supply capacity 20 Mm^3/annum), situated on Mogalakwena River supplies water to irrigation and water supply to the villages.

This area is becoming increasingly important economically as platinum mines are expanding in the area and there is still vast untapped mining potential. It is crucial therefore that the water supply in this Key Area is secured and well managed to support these mining developments. The irrigation sector is currently the largest water user in this Key Area. According to the DWAF WMA report (DWAF, 2003b) invasive alien plants in the upper reaches of the catchment have a significant impact on the available yield in the area.

There are no reported serious water quality problems in the Mogalakwena catchment. However, there is a risk that surface water quality in the catchment could be affected by diffuse pollution from densely populated informal settlements and mines. Groundwater pollution is also a threat due to mine water decant, the high concentration of pit latrines in certain areas, and the naturally occurring fluorides emanating from the underlying granite in many areas. There is a need to determine and verify the extent and sources of both surface and groundwater pollution in the catchment.

Water challenges

Water resources in the Limpopo sub area are nearly fully developed with all available water being highly utilised. Moreover, limited options for further resource development exists - attributable to the arid climate, unfavourable topography, sandy rivers as well as important conservation areas.

Although the resources and requirements approximately are in balance at present, the implementation of the Reserve is expected to result in serious deficits in some of the main river catchments. This is further compounded by planning arrangements already in place for large new mining developments in the Mokapane-Mogoto area for which additional water will be required.

Urban and industrial growth will mainly be concentrated in the Polokwane area, where local water resources already are in short supply and need to be augmented by transfers from other catchment within the WMA or from other WMAs. Already BelaBela and Louis Trichardt are dependent on transfers in for part of their water supplies.

Furthermore, the possibility for new power stations and/or petrochemical industries to be developed around the coalfields in the Lephalale area will also add huge pressure on already over-committed water resources, and compete with other uses and users for the same resources.

Luvuvhu and Mutale Rivers sub area

The Luvuvhu area lie entirely within the Limpopo Province and shares watercourses with Zimbabwe and Mozambique, and the Limpopo River demarcates the northern boundary. The Kruger National Park (KNP) lies along the eastern boundary. Mozambique forms the eastern border of the KNP. The confluence of the Luvuvhu and Limpopo Rivers forms the common point where South Africa borders on both Zimbabwe and Mozambique. The report covers only the Luvuvhu catchment characteristics.

Topography

The topography of the Luvuvhu catchment varies from a zone of high mountains in the west through low mountains and foothills in the central part to a zone consisting of flat lowland plains in the east. The highest peaks have an elevation of more than 2000 m above mean sea level (msl). The plains zone covers most of the sub area and is generally flat with gentle slopes. The main urban area in the Luvuvhu catchment is Thohoyandou.

Climate

The mean annual temperature ranges from about 18 °C in the mountainous areas to more than 28 °C in the northern and eastern parts of the WMA, with an average of about 25.5 °C for the WMA as a whole. Maximum temperatures are experienced in January and minimum temperatures occur on average in July.

Precipitation

Rainfall is seasonal and occurs mainly during the summer months (i.e. October to March). The peak rainfall months are January and February. The mean annual precipitation varies from less than 450 mm in the lowland plain (northern and eastern part of the WMA) to more than 2300 mm in the mountainous areas (south western and north western parts of the WMA).

Land use

Present land use is dominated by the large undeveloped expanse, which demarcates the Kruger National Park. Extensive areas under rain fed cultivation together with a large number of rural villages, occur throughout most of the remaining Low veld area.

Intensive irrigation farming is practiced in the parts of the Letaba River and as well as in the upper Luvuvhu River catchment. Vegetables (including the largest tomato production area in the country), citrus and a variety of fruits such as bananas, mangoes, avocados and nuts are grown. Large areas have been planted with commercial forests in the high rainfall parts like Thohoyandou. Approximately 35% of the land area along the eastern boundary falls within the Kruger National Park, with the rivers flowing through the park of particular importance with regard to maintaining ecosystems. Several private game reserves adjoin the park, whilst a number of other conservation areas are scattered throughout the water management area.

International

The Luvuvhu/Mutale sub-area forms part of the Limpopo River Basin, which is shared by South Africa, Botswana, Zimbabwe and Mozambique. Developments and water resource management in South Africa can impact directly on Mozambique. Co-operation on water matters between South Africa and Mozambique is facilitated through the bilateral Joint Water Commission between the two countries. International co-operation with respect to the use and management of the watercourses in the Limpopo River Basin (Luvuvhu River), is overseen by the Limpopo Watercourse Commission (LWC), with membership by all four basin states. Lake Fundudzi is the natural lake in the area.

Luvuvhu River is of good water quality and not adversely affected by the activities in the catchment. However, there is a tendency towards eutrophication. The catchment is divided into three zones for land use and water quality analysis:

a. Luvuvhu River to the Mutshindudi River Confluence

Land use in the upper reaches of the Luvuvhu catchment, upstream of Albasini Dam, is dominated by forestry and agriculture. There is also extensive development of small holdings for fruit farming in the upper reaches. The Levubu Irrigation scheme is situated directly below the Albasini Dam. Subsistence farming is widely practiced across this area and there are plans to revive small holder irrigation schemes.

There are a number of tea and coffee estates supplied by Vondo Dam, Makumbane Dam, Mambedi Dam and others (Table). Water quality is adequate for agricultural purposes throughout the catchment.

The population of the catchment is concentrated around Thohoyandou. The town is supplied from Vondo Dam. However, nutrients from washing and bathing in rivers can stimulate algal growth. Clay from the river banks is used for brickmaking, resulting in increased erosion of the banks. The riparian zone is also damaged by clearing of vegetation for firewood and by overgrazing. Lack of adequate solid waste disposal facilities also results in increased litter and pollution of surface water resources. There are a number of sewage treatment plants in the catchment: Thohoyandou sewage treatment plant, Malamulele sewage treatment plant, Venda Prison sewage treatment plant and remain potential sources of pollution. The effluent from the Thohoyandou sewage treatment plant (STP) is used in a fish farm.

b. Mutale River

The predominant land uses are rural settlements and subsistence agriculture. There are two sewage treatment plants in the catchment: Donald Fraser sewage treatment plant and William Earl sewage treatment plant. Coal mining takes place in the lower Mutale catchment. The Sambandou Wetland is of ecological importance and threatened by agricultural development.

c. Luvuvhu River from the Mutshindudi River Confluence to the Mozambique Border:

This area lies predominantly in the Kruger National Park. There are no adverse water quality problems in the area, though low levels of eutrophication are evident

Summary of challenges in the WMA

The following water challenges are the most pronounced in the WMA.

- Water resources nearly fully developed with all available water being highly utilised
- Limited options for further resource development exists - attributable to the arid climate, unfavourable topography, sandy rivers as well as important conservation areas
- Resources and requirements approximately in balance at present
- Implementation of the Reserve is expected to result in serious deficits in some of the main river catchments
- Planning has been made for large new mining developments in the Mokapane-Mogoto areafor which additional water will be required
- Urban and industrial growth will mainly be concentrated in the Johannesburg, Tswane and Polokwane areas, where local water resources already are in short supply and need to be augmented by transfers from other WMAs.
- There are severe eutrophication problems at dams in the WMA.
- Possibility for new power stations and/or petrochemical industries to be developed around the coalfields in the Lephalale area

- Water pollution owing to large quantities of effluent discharged into the rivers in urban and industrial areas in the WMA.

In addition to the above challenges, the expanded area of operation of the Limpopo WMA means that integrated information management will be a key driver to facilitate IWRM. Therefore the current monitoring and information management systems will need to be improved.

Table 11: Catchments, Dams and Water Use Profile

Secondary Catchment	Sector/Key Area	Dams	Yield Mm3/a	Use
Crocodile West Rivers	Upper Crocodile	Hartbeesport	?	?
	Apies/Pienaars	-	-	-
	Elands	-	-	-
	Lower Crocodile	-	-	-
	Groot Marico	Marico-Bosveld	9.6	Irrigation
Marico Rivers	Klein Marico	Klein-Maricopoort	1.4	Irrigation
	Klein Marico	Kromellenboog	1.8	Irrigation
	Thulana	Madikwe	1.2	Domestic
	Sandsloot	Sehujwane	0.52	Domestic
	Groot Marico	Molatedi dam	21	Irrigation/Domestic
	Thulane	Pella	0.74	Domestic
Limpopo Rivers	Matlabas	-		
	Mokolo	Mokolo	23	Domestic/Industrial
	Lephalala	Vischgat	?	?
	Mogalakwena	Doorndraai Glen Alpine	8.6 5.6	Domestic/irrigation Irrigation
	Sand	Houltrivier	24.5	Irrigation
	Nzhelele	Nzhelele	0.6	Irrigation
	Nwanedi	Nwanedi Luphephe	? ?	? ?
	Main stem Limpopo	-	-	
Levuvhu and Mutale Rivers	Luvuvhu/Mutale	Vondo Albasini Luvuvhu/Nandoni Mutshedzi	16.9 5.0 55 ?	Domestic/Industrial Irrigation Domestic/Irrigation ?