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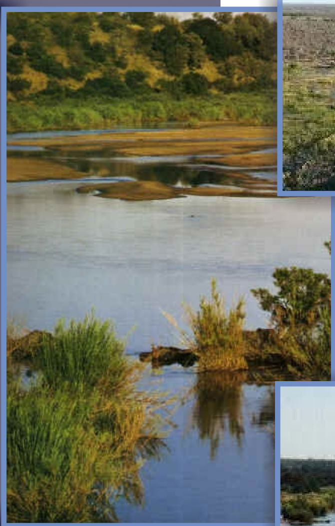
REPUBLIC OF SOUTH AFRICA

DIRECTORATE: NATIONAL WATER RESOURCE PLANNING

Development of a Reconciliation Strategy for the Luvuvhu and Letaba Water Supply System

WATER QUALITY ASSESSMENT REPORT



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DEVELOPMENT OF A RECONCILIATION STRATEGY FOR THE LUVUVHU AND LETABA WATER SUPPLY SYSTEM

WATER QUALITY ASSESSMENT REPORT

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DEVELOPMENT OF A RECONCILIATION STRATEGY FOR THE LUVUVHU AND LETABA WATER SUPPLY SYSTEM

Water Quality Assessment

EXECUTIVE SUMMARY

The Department of Water Affairs (DWA) has identified the need for the Reconciliation Study for the Luvuvhu-Letaba WMA. The WMA is almost fully developed and demands from the Letaba River currently exceed the yield capability of the system. Regulation for the Letaba WMA is mainly provided by Middle Letaba, Ebenezer and Tzaneen Dams. In the Luvuvhu WMA the recently completed Nandoni Dam will be used in combination with Albasini, Vondo and Damani dams to be managed as one system. It is expected that the total yield from this combined system will be fully utilized by around 2020, considering only the current planned projected demands. The yield of the Albasini Dam has reduced over the years and as a consequence the dam is over allocated. The Shingwedzi catchment is situated almost entirely in the Kruger National Park and for all practical purposes no sustainable yield is derived from surface flow in the Shingwedzi catchment.

The main objective of the study is to compile a Reconciliation Strategy that will identify and describe water resource management interventions that can be grouped and phased to jointly form a solution to reconcile the water requirements with the available water for the period up to the year 2040 and to develop water availability assessment methodologies and tools applicable to this area that can be used for decision support as part of compulsory licensing to come. The development of the strategy requires reliable information on the water requirements and return flows (wastewater) as well as the available water resources for the current situation and likely future scenarios for a planning horizon of thirty years.

To achieve the above objectives, the following main aspects will be covered in the study:

- *Update the current and future urban and agricultural water requirements and return flows;*
- *Assess the water resources and existing infrastructure;*
- *Configure the system models (WRSM2005, WRYM, WRPM) in the Study Area at a quaternary catchment scale, or finer where required, in a manner that is suitable for allocable water quantification;*
- *To firm up on the approach and methodology, as well as modelling procedures, for decision support to the on-going licensing processes;*
- *To use system models, in the early part of the study, to support allocable water*

quantifications in the Study Area and, in the latter part of the study, to support ongoing licensing decisions, as well as providing information for the development of the Reconciliation Strategy;

- *Formulate reconciliation interventions, both structural and administrative/regulatory;*
- *Document the reconciliation process including decision processes that are required by the strategy; and*
- *Conduct stakeholder consultation in the development of the strategy.*

The objective of this water quality review task *is to use the available water quality data and water quality reports from previous studies to develop an understanding of the water quality profiles of the major rivers in the study area. The understanding achieved will be used to provide the qualitative input on the impact that the reconciliation options could have on water quality.*

The study area was divided into four resource units, namely: Luvuvhu main and Mutale River catchment areas; the Shingwedzi River catchment area; the Groot Letaba catchment area; and Middle and Klein Letaba catchment areas.

The water quality status of the Luvuvhu River is driven by intensive agriculture of sub-tropical fruits and afforestation in the upper catchment, the urban sprawl of Thohoyandou in the middle catchment and the KNP in the lower end of the catchment. The water quality trends in the middle to lower Luvuvhu River indicate a deterioration of the phosphates, nitrates and ammonia levels. The water quality of the Luvuvhu main catchment has remained very good and on the whole falls within the interim RWQOs. The main concerns are the elevated nutrients and ammonia downstream of urban areas, as well as associated bacteriological contamination that can be expected. There is also limited contamination from the Tshikondeni mining area.

The majority of the catchment of the Shingwedzi River's catchment falls within the KNP. Outside the land use is mainly subsistence agriculture and informal urban settlements. In general the water quality of the Shingwedzi River catchment has remained very good however shows contamination from the domestic wastewater treatment works, as well as general urban pollution from the larger villages.

The water quality of the Groot Letaba catchment has remained very good in the upper reaches of the catchment, moving towards a slight deterioration further downstream due to low flow conditions. Nutrients, particularly phosphates are elevated primarily due to run-off from irrigation scheme areas prior to and within the Hans Merensky Nature Reserve.

The Middle and Klein Letaba rivers are in a moderately modified to modified state due mostly to densely populated settlements and agriculture above the Middle Letaba Dam and upper Klein Letaba River. The current water quality down the Klein Letaba River indicates ideal values of ammonia, sulphates and nitrates, with unacceptable phosphate values are as a result of a number of WWTWs and waste disposal sites leading to eutrophication.

There is a number of densely populated and informal settlements in the study area and this creates *a potential for water use directly from the resources, bacteriological monitoring in the study area is inadequate and needs to be increased at points up and downstream of the urban areas, and specifically wastewater treatment works. Also wastewater treatment works in the study area need to be upgraded to improve the quality of the effluent being discharged as this is impacting on human health and other water users in the area.*

Development of a Reconciliation Strategy for the Luvuvhu and Letaba Water Supply System: Water Quality Review

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Water Quality Review Report

1 INTRODUCTION

1.1 BACKGROUND

The Department of Water Affairs (DWA) has identified the need for the Reconciliation Study for the Luvuvhu-Letaba WMA. The WMA is almost fully developed and demands from the Letaba River currently exceed the yield capability of the system. Regulation for the Letaba is mainly provided by Middle Letaba, Ebenezer and Tzaneen Dams. The recently completed Nandoni Dam located in the Luvuvhu basin will be used in combination with Albasini, Vondo and Damani dams to be managed as one system. It is expected that the total yield from this combined system will be fully utilized by around 2020, considering only the current planned projected demands. The yield of the Albasini Dam has reduced over the years and as a consequence the dam is over allocated. The Shinwedzi catchment is situated almost entirely in the Kruger National Park and for all practical purposes, no sustainable yield is derived from surface flow in the Shingwedzi catchment.

The main urban areas in these catchments are Tzaneen and Nkowakowa in the Groot Letaba River catchment, Giyani in the Klein Letaba River catchment and Thohoyandou and Makhado (Louis Trichardt) in the Luvuvhu catchment. An emergency water supply scheme to transfer water from Nandoni Dam is currently under construction to alleviate the deficits of the stressed Middle Letaba sub-system in the Letaba River basin. Other future developments planned to be supplied from Nandoni Dam will already utilize the full yield available from the Nandoni sub-system by 2021, without supporting Giyani. Supporting Giyani from Nandoni will bring this date forward to approximately 2018

Intensive irrigation farming is practised in the upper parts of the Klein Letaba River catchment (upstream and downstream of the Middle Letaba Dam), the Groot Letaba (downstream of the Tzaneen Dam) and Letsitele rivers, as well as in the upper Luvuvhu River catchment. Vegetables (including the largest tomato production area in the country), citrus and a variety of sub-tropical fruits such as bananas, mangoes, avocados and nuts are grown. Large areas of the upper catchments have been planted with commercial forests in the high rainfall parts of the Drakensberg escarpment and on the Soutpansberg. The area, particularly the Groot Letaba sub-area, is a highly productive agricultural area with mixed farming, including cattle ranching, game farming, dry land crop production and irrigated cropping. Agriculture, with the irrigation sector in particular, is the main base of the economy of the region. Large scale utilization of the groundwater resource occurs mostly downstream of the Albasini Dam in the Luvuvhu catchment, where it is used by irrigators as well as in the vicinity of Thohoyandou where it is used to supply rural communities. The limited mineral resources in the Luvuvhu basin are dominated by deposits of cooking coal in the northeast near Masisi. In addition to irrigation water supply from the dams in the study area, towns, villages and rural settlements are also supplied with potable water.

DWA and other institutions involved in the management of the water resource and supply systems of the Luvuvhu-Letaba catchments, have in the past carried out various studies on intervention measures to improve the water supply situation. The knowledge base that has been created by these studies provides a sound and essential platform from which the Reconciliation Strategy will be developed. In order to harness this information a Literature Review Report (DWA, 2013) was compiled to summarise the available information in one document and also present a synthesis of the information by highlighting the pertinent aspects of Integrated Water Resource Management that will be assessed and incorporated in the Reconciliation Strategy.

1.2 MAIN OBJECTIVES OF THE STUDY

The main objective of the study is to compile a Reconciliation Strategy that will identify and describe water resource management interventions that can be grouped and phased to jointly form a solution to reconcile the water requirements with the available water for the period up to the year 2040 and to develop water availability assessment methodologies and tools applicable to this area that can be used for decision support as part of compulsory licensing to come. The development of the strategy requires reliable information on the water requirements and return flows (wastewater) as well as the available water resources for the current situation and likely future scenarios for a planning horizon of thirty years.

To achieve the above objectives, the following main aspects will be covered in the study:

- Update the current and future urban and agricultural water requirements and return flows;
- Assess the water resources and existing infrastructure;
- Configure the system models (WRSM2005, WRYM, WRPM) in the Study Area at a quaternary catchment scale, or finer where required, in a manner that is suitable for allocable water quantification;
- To firm up on the approach and methodology, as well as modelling procedures, for decision support to the on-going licensing processes;
- To use system models, in the early part of the study, to support allocable water quantifications in the Study Area and, in the latter part of the study, to support ongoing licensing decisions, as well as providing information for the development of the reconciliation strategy;
- Formulate reconciliation interventions, both structural and administrative/regulatory;
- Document the reconciliation process including decision processes that are required by the strategy; and
- Conduct stakeholder consultation in the development of the strategy.

1.3 STUDY AREA

The study area comprises of the water resources of the catchment of the Luvuvhu, Mutale, Letaba and Shingwedzi rivers linked to adjacent systems as indicated by the inter-basin transfers on **Figure 1.1**. This area represents the entire WMA 2 and includes tertiary catchments A91, A92, B81, B82, B83 and B90. Adjacent areas supplying water to this WMA or getting water from this WMA are also part of the study area.

The Luvuvhu-Letaba water management area (WMA) is located in the north-eastern corner of South Africa, where it borders on Zimbabwe in the north and on Mozambique along the eastern side. It falls entirely within the Northern Province, and adjoins the Olifants and Limpopo WMAs to the south and west respectively. The Luvuhu-Letaba WMA forms part of the Limpopo River Basin, an international river shared by South Africa, Botswana, Zimbabwe and Mozambique.

Approximately 35% of the land area of the WMA along the eastern boundary falls within the Kruger National Park. The rivers flowing through the park are of particular importance to the maintenance of ecosystems.

The confluence of the Luvuvhu and Limpopo rivers forms the common point where South Africa borders on both Zimbabwe and Mozambique. The Shingwedzi River first flows into the Rio des Elephantes (Olifants River) in Mozambique, which then joins the Limpopo River.

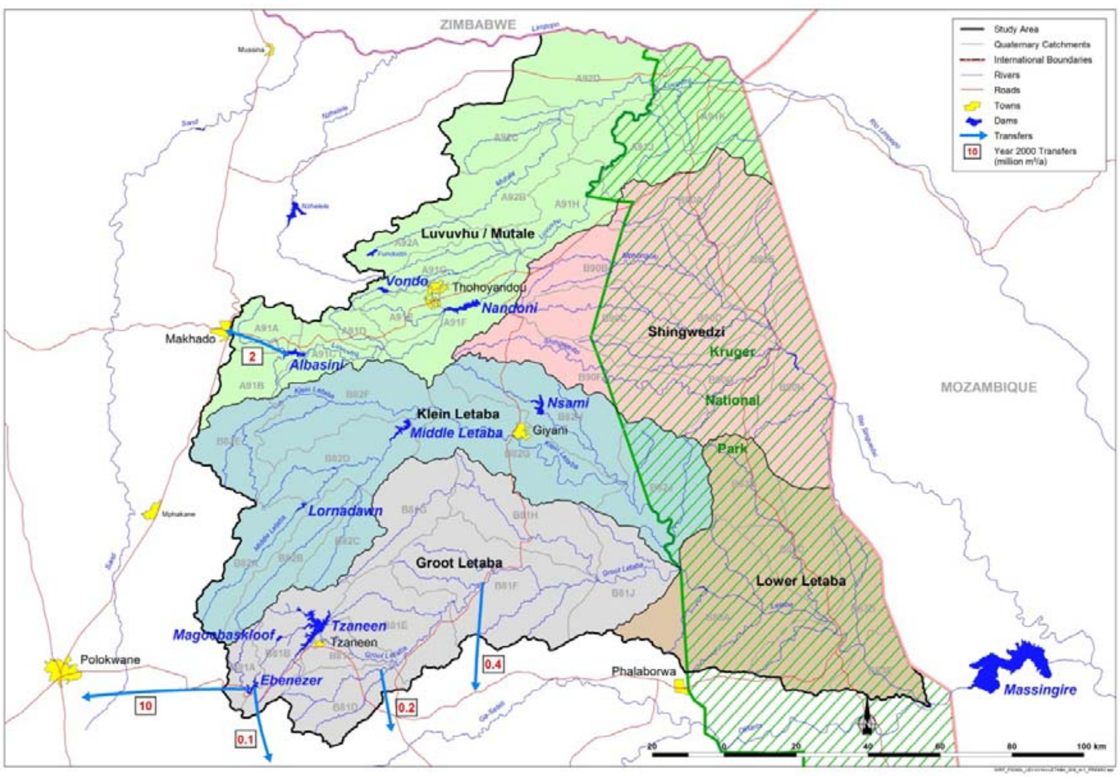

Figure 1.1: Study Area

The two main branches of the Letaba River, the Klein and Groot Letaba, have their confluence on the western boundary of the Kruger National Park. The Letaba River flows into the Olifants River just upstream of the border with Mozambique (**Figure 1.1**).

The topography is marked by the northern extremity of the Drakensberg range and the eastern Soutpansberg, which both extend to the western parts of the water management area, and the characteristic wide expanse of the Lowveld to the east of the escarpment. Climate over the water management area is generally sub-tropical, although mostly semiarid to arid. Rainfall usually occurs in summer and is strongly influenced by the topography.

Along the western escarpment rainfall can be well over 1 000 mm per year, while in the Lowveld region in the eastern parts of the water management area rainfall decreases to less than 300 mm per year and the potential evaporation is well in excess of the rainfall. Grassland and sparse bushveld shrubbery and trees cover most of the terrain, marked by isolated giant Boabab trees.

The geology is varied and complex and consists mainly of sedimentary rocks in the north, and metamorphic and igneous rocks in the south. High quality coal deposits are found near Tsikondeni and in the northern part of the Kruger National Park. The eastern limb of the mineral rich Bushveld Igneous Complex touches on the southern parts of the WMA. With the exception of sandy aquifers in the Limpopo River valley, the formation is of relatively low water bearing capacity. A wide spectrum of soils occurs in the WMA, with sandy soils being most common.

1.4 PURPOSE OF THIS REPORT

The objective of the water quality review task was to identify the water quality variables of concern, the pollution sources and the water users in the catchment. In order to develop a water quality profile of the Letaba/Luvhuvu River System water quality information has been collected and collated in the report to follow.

1.5 WATER QUALITY BACKGROUND

The term *water quality* is used to describe the physical, chemical, biological and aesthetic properties of water, all of which determine its fitness for use and its ability to maintain the health of aquatic organisms (DWAF, 1996). Water quality therefore expresses the suitability of water to sustain various uses or processes. Any particular use will have certain requirements for the physical, chemical or biological characteristics of water. Consequently, water quality can be defined by a range of variables which limit water use. Human health is affected directly by the proximity, availability and quality of water resources.

Rapid urbanisation and therefore increasing water use for basic human needs, development and recreation is one reason for prioritising water resource management in South Africa. In addition, water use inevitably results in the discharge of water containing waste, reducing assimilative capacity in stream flow. As catchments become increasingly developed, the effects of point and diffuse sources of pollution are likely to mask the natural cyclic patterns in aquatic ecosystems to an even greater extent.

The Letaba River catchment is highly regulated, particularly in the upper catchments where most of the runoff is generated. Surface water mainly originates in the mountainous areas and is regulated by several dams in the upper (Magoebaskloof and Ebenezer dams) and middle reaches of the river. The Letaba River is further regulated by a series of irrigation weirs that limit the flows of water into the Kruger National Park. There are further regulatory weirs and dams within the Kruger National Park (KNP).

Intensive irrigation farming is practised in the upper parts of the Klein Letaba River catchment (upstream and downstream of the Middle Letaba Dam), the Groot Letaba (downstream of the Tzaneen Dam) and Letsitele rivers, as well as in the upper Luvuvhu River catchment. Vegetables (including the largest tomato production area in the country), citrus and a variety of sub-tropical fruits such as bananas, mangoes, avocados and nuts are grown. Large areas of the upper catchments have been planted with commercial forests in the high rainfall parts of the Drakensberg escarpment and on the Soutpansberg.

There are a number of dams in the study area from which in addition to irrigation water supply, towns, villages and rural settlements are supplied with potable water. The major dams are: Nandoni Dam, Vondo Dam, Albasini Dam, Ebenezer Dam, Tzaneen Dam, Mogoebaskloof Dam, Altenzur Dam, Lornadawn Dam, Middle Letaba Dam and Nsami (Hudson Ntsanwis) Dam.

There is limited coal mining in the Mutale catchment area. The Tshikondeni Colliery owned by Exxaro Resources Limited is located approximately 140 km east of the town of Musina in Limpopo Province. It is an underground mine that employs approximately 770 people and currently produces 414ktpa of premium hard coking coal.

2 SCOPE OF WORK FOR WATER QUALITY REVIEW

The process of developing the reconciliation strategy will involve the formulation of supply options that may include additional dams, re-use of effluents and desalination.

The purpose of the water quality review is to use the available water quality data and water quality reports from previous studies to develop an understanding of the water quality profiles of the major rivers in the study area. The understanding achieved will be used to provide the qualitative input on the impact that the reconciliation options could have on water quality.

2.1 APPROACH TO WATER QUALITY REVIEW

In summary the activities that were undertaken as part of this task are:

- Collection and analysis of the available water quality data including available data from the DWA database, mines, EIA processes, ecological Reserve and local municipality databases. The data was assessed for trends and general;
- Collection and analysis of the available point source discharge volume and water quality information will be collated and analysed to determine discharge loads;
- Compilation of land use maps for use to identify areas of diffuse pollution such as urban, irrigation and dry land agriculture;
- Identification of water users in the catchment and use of the South African WQGs, ecological reserve requirements coupled with the current water quality status in developing management strategies for the river system;

- Comparison of the water quality against the WQGs to identify the water quality variables of concern;
- Determination of the potential sources of pollution based on the water quality variables of concern;
- Evaluation of future water quality impacts from irrigation;
- Assessment of potential effects of nutrients and urban area wash-off; and
- Identification and assessment of mitigation measures.

3 WATER QUALITY USER REQUIREMENTS

3.1 MAIN WATER USERS

The main urban areas are Tzaneen and Nkowakowa in the Groot Letaba River catchment, Giyani in the Klein Letaba River catchment, and Thohoyandou in the Luvuvhu River catchment. The rural population is scattered throughout the WMA.

The main water users in the WMA are:

- Domestic users ranging from densely populated informal urban settlements and formal urban to scattered rural settlements;
- Aquatic systems;
- Tourism;
- Irrigation:
- Fruit growers in the Magoebaskloof/Tzaneen area (especially tomatoes, mangos, litchis, avocados, kiwis, tomatoes, bananas, citrus, cherries, pecan and macadamia nuts as well as papayas); and
- Tea plantations;
- Commercial forests;
- Dry land crops including:
  - Maize is the staple food in the Province. It is also used as animal feed. On the basis of area and volume of production, it remains the most important dry-land crop;
  - Sorghum;
  - Cotton;

- Ground nuts; and
- Sunflowers.

- Limited underground coal mining in the Mutale catchment.

3.2 WATER QUALITY ISSUES

The Department of Water Affairs document: Planning Level Review of Water Quality in South Africa (DWA, 2011) has indicated the following water quality issues in the Luvuvhu/Letaba WMA (Table 1).

Table 1: Water quality issues in the Luvuvhu/Letaba WMA (DWA, 2011)

Water Quality Issue	Driver	Effect
Eutrophication (nutrient enrichment)	Wastewater treatment works, Intensive agriculture fertilizer use, and dense urban sprawl un-serviced sewage.	Algal growth, smell, toxic algae, taste and odour, irrigation system clogging, aesthetics, recreational water users.
Microbial contamination	Wastewater treatment works and Informal dense settlements.	Recreational users (human health), washing and bathing.
Turbidity	Informal dense settlements Urbanisation, forestry, mining, agriculture,	Dam and weir sedimentation, irrigation clogging.
Salinisation	Wastewater treatment works, agricultural (intensive irrigation) and mines (operational and abandoned).	Increased water treatment costs, soil salinity and irrigation system clogging.
Toxicants	Pesticides (subtropical fruits, nuts) industry and DDT for malaria control.	Fish kills, human health impacts, bioaccumulation of pollutants in fish and crocodiles and crocodile deaths.
Altered flow regime	Dams and weirs, Inter-basin transfers.	Increased turbidity (erosion), algal growth, water temperature increase, dissolved oxygen changes, taste and odour changes, impact on recreational water users, fish kills, and habitat reduction due to changed environmental flows.

Regulation and water shortages

The impact of deteriorating water quality, coupled with water shortages experienced in the Letaba Catchment area have led to intense competition for the available water resources between different sectors.

The most ecologically modified sections in the Groot Letaba River are found primarily at the Tzaneen Dam due to the reduction in flow because of upstream impoundments (Tzaneen and

Ebenezer dams), large weirs as well as direct abstraction for irrigation (DWA, 2011). The water quality problems are primarily associated with intensive irrigated agriculture (fertilizer, salts and pesticide runoff).

Pesticides

The intensive irrigated agriculture in the Letaba and Luvuvhu rivers has resulted in the use of a wide range of pesticides. Most of these pesticides are categorised as Persistent Organic Pesticides (POPs). South Africa is a signature of the Stockholm Convention on POPs.

DDT is an approved chemical for malaria control in the Luvuvhu catchment and there are records of DDT bioaccumulation in the fish and humans in this catchment. There is evidence of human health impacts on this catchment as a result of the use of these pesticides and this is the subject to ongoing studies by the Universities of Pretoria and Cape Town's medical facilities.

Eutrophication

The planning level review of water quality in South Africa project undertaken by DWA (DWA, 2011) indicated that the majority of the large impoundments in the Luvuvhu/Letaba WMA are oligotrophic meaning that the nutrient levels are low enough to limit algal blooms.

Cholera

Cholera is an acute intestinal infection caused by ingestion of food or water contaminated with the bacterium *Vibrio cholera*. It has a short incubation period, from less than one day to five days, and produces an enterotoxin that causes copious, painless, watery diarrhoea that can quickly lead to severe dehydration and death if treatment is not promptly given. Vomiting also occurs in most patients.

In most cases, transmission of cholera occurs through eating food or drinking water that is contaminated with *Vibrio cholera* bacteria. *Vibrio cholera* can get into food or water either naturally or via contaminated faeces. It is very unlikely for cholera to be spread directly from person to person through casual contact.

The endemic and seasonal nature of cholera depends upon the survival of Vibrio cholera in a viable but not necessarily culturable state in ecologic niches in aquatic environments during inter-epidemic periods. In response to environmental stress in aquatic environments, such as low concentrations of nutrients and low temperatures, *V. cholera* adopt a viable state that enables them to carry out metabolic functions and form colonies without being culturable. Once favourable environmental conditions return, *V. cholera* can become culturable again. *V. cholera* in a viable but non-culturable state has produced clinical symptoms of cholera in volunteers, which confirms that it maintains its pathogenicity in aquatic environments despite the inability of the cells to be cultured.

In respect of the Luvuvhu/Letaba area while it is not clear of exact hot spots the environment is conducive to cholera survival. Due to weakened health system in Zimbabwe and failing sanitation systems and access to clean water, Zimbabwe constantly experiences cholera outbreaks. In

October 2008 there was an outbreak which spread to nine of the country's provinces with 6072 suspected cholera cases and 294 deaths as at 18 November 2008.

On 15 November 2008, the South African Department of health received reports of cholera at Beitbridge and on 17 November 2008, Limpopo Provincial Department of Health reported an increase in the number acute diarrhoea with one death that occurred on 16 November 2008. On 19 Nov 2008 the National Institute of Communicable Diseases confirmed Vibrio cholerae isolated in 5 out of 11 stool samples tested. As at 23 November 2008 Beitbridge Hospital reported an admission rate of 200 patients per day with a cumulative number of 1876 patients and 63 deaths.

The extent of the cross border movement of people into Limpopo is a factor that contributes to cholera cases in South Africa. This was evidenced by the number of cases which were reported in Limpopo during November 2008: 187 cases of cholera were treated and three deaths reported in Limpopo.

The migration of people from Zimbabwe to various towns within the Luvuvhu/Letaba area is likely to lead to the presence of cholera in wastewater streams. The poor performance of wastewater treatment works in these towns will also exacerbate the problem, should downstream users need to abstract water for consumption. The endemic and seasonal nature of cholera, because of its' ability to maintain pathogenicity in aquatic environments despite the inability of the cells to be cultured, mean that cholera may be present in these downstream sites.

3.3 WATER QUALITY GUIDELINES

The Department of Water affairs (DWA) Water Quality Guideline Series has been used as a basis of overall comparison for this study (DWAF, 1996). The more stringent of the guidelines set for the main water users in the area (aquatic life, irrigation, and domestic uses) were used. The WQGs for the catchment are set out in Table 2.

Table 2: Water Quality Guidelines (WQGs) for the WMA

Parameter	Unit	WQG	User category
Aluminium	mg/l	<0.01	A
Ammonia	mg/l	1	D/A
Arsenic	mg/l	0.01	A/D
Beryllium	mg/l	<0.1	I
Boron	mg/l	<0.5	I
Cadmium	mg/l	< 0.005 (<0.0005)	I (A)
Calcium	mg/l	32	D
Chloride	mg/l	<100	I
Chromium III	mg/l	<0.012	A
Chromium IV	mg/l	<0.01	A
Cobalt	mg/l	<0.5	I
Copper	mg/l	<0.2 (0.0015)	I (A)
Cyanide	mg/l	<0.001	A

Parameter	Unit	WQG	User category
Dissolved Oxygen	mg/l	80-120	A
Electrical Conductivity	mS/m	40	I
Faecal coliforms	Counts per 100 ml	0	D
Fluoride	mg/l	0.7 (<2)	D (I)
Iron	mg/l	0.1	D
Lithium	mg/l	<2.5	I
Magnesium	mg/l	30	I
Manganese	mg/l	<0.02	I
Mercury	mg/l	0.001 (0.0004)	D (A)
Nickel	mg/l	<0.2	I
Nitrate	mg/l	6	D
Total inorganic nitrogen	mg/l	<0.5 (5)	A (I)
pH	mg/l	6.5-8.4	I
Phenol	mg/l	0.001 (<0.03)	D (A)
Orthophosphate	mg/l	<0.025	A
Potassium	mg/l	<50	D
Selenium	mg/l	0.02 (<0.002)	I (A)
Sodium	mg/l	<70	I
SAR	mg/l	<2	I
Sulphate	mg/l	200	D
Total Dissolved Solids	mg/l	260	I
Zinc	mg/l	<1 (<0.002)	I(A)

Note: "A" = agricultural use; "I" = industrial use; "D" = domestic use; "mg/l" = milligrams per liter.

The National Eutrophication Monitoring Programme (NEMP) describes the eutrophication status of a water body as set out in the table below

Table 3: Eutrophication potential

Statistic	Unit	Trophic status			
Mean annual chlorophyll a	μg/*l*	0<x≤10	10<x≤20	20<x≤30	>30
		Oligotrophic (low)	Mesotrophic (moderate)	Eutrophic (significant)	**Hypertrophic (serious)**
% of time chlorophyll a> 30μg/*l*		Current nuisance value of algal bloom productivity:			
	%	0	0<x≤8	8<x≤50	>50
		negligible	moderate	significant	**serious**
		Potential for algal and plant productivity:			
Mean annual Total phosphorus	mg/*l*	x≤0.015	0.015<x≤0.047	0.047<x≤0.130	>0.130
		negligible	moderate	significant	**serious**

3.3.1 Conductivity

The amount of current conducted through water (EC) is proportional to the concentration of ions in solution and therefore, also proportional to both the concentration and extent of dissociation of the dissolved salts.

The total dissolved salts (TDS) concentration is directly proportional to the electrical conductivity (EC) of water. An approximate conversion of EC to TDS (at 25 °C) in freshwater systems is:

EC (mS/m) x 7 = TDS (mg/ℓ)

3.3.2 Alkalinity

Alkalinity is the acid-neutralising capacity of water and is usually expressed as mg $CaCO_3$/ℓ. Alkalinity is mostly taken as an indication of the concentration of carbonate, bicarbonate and hydroxide but may include contributions from borate, phosphates, silicates and other basic compounds.

Total alkalinity (TAL) is considered as a rather conservative property of natural waters (Kempe, 1990). The total alkalinity concentrations typically found in freshwater system range between 50 and 250 mg/ℓ.

3.3.3 pH

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

3.3.4 Metals

Trace metals are important in aquatic ecosystems and occur in all natural waters, sometimes in minute quantities, because they are products of geological weathering. Water quality guidelines provide an objective means for judging the quality needed to maintain a particular environmental value (DWAF, 1996).

Metals are taken up by both fauna and flora. If the excretion phase is slow the uptake may provoke an increase in the concentration of the metal in the organism which can lead to the bioaccumulation phenomenon. Therefore, even in waters that appear to be pristine, certain metals are reaching surprisingly high levels in fish and other aquatic organisms.

Metals may be taken up in the inorganic or organic form. For some elements, such as arsenic and copper, the inorganic form is the most toxic. For others, such as mercury, tin and lead, the organic forms are the most toxic. At low concentrations many metals, including mercury, cadmium, lead, arsenic and copper, inhibit photosynthesis and phytoplankton growth.

3.3.5 Turbidity

Turbidity influences both the quantity and the quality of light penetrating water. More turbid water prevents the penetration of sunlight, thereby reducing the growth and activity of phytoplankton. The concentration of suspended solids increases with the discharge of sediment washed into rivers or dams due to soil erosion and re-suspension of deposited sediment in the river beds.

3.3.6 Nutrients

Inorganic nutrients provide the chemical constituents on which the entire food web is based. Nutrient cycling implies by definition that nutrients pass among different components of a cell, community or ecosystem and can be cycled and reutilised by some of these components. Nutrient cycling occurs at many spatial and temporal scales.

Nitrogen is always present in aquatic ecosystems; most abundantly as an inert nitrogen gas (N_2) that is unavailable to most of the algae. Nitrate, ammonia, nitrite, urea, and dissolved organic compounds are less abundant, but usually of more biological interest. In both oxic and anoxic conditions, nitrogen cycles between all these compounds and in different phases, i.e. gaseous, soluble, and particulate forms.

Processes such as denitrification (reduction of nitrates or nitrites to nitrogen-containing gases), organic matter burial in sediments, sediment sorption, and plant and microbial uptake can remove nitrogen from the river, and thus affect the amount of nitrogen that is transported by rivers to coastal ecosystems (Billen *et al.*, 1991). However, not all nitrogen loaded into rivers is ultimately exported to estuaries or the ocean.

Ammonium (NH_4)

Ammonia occurs naturally in water bodies arising from the breakdown of nitrogenous organic and inorganic matter in soil and water, excretion by biota, reduction of the nitrogen gas by microorganisms and from gaseous exchange within the atmosphere. Ammonia exists in water bodies in two forms: unionised (free) ammonia (NH_3) and as the ionised ammonium ion (NH_4). The unionised form is toxic to aquatic organisms while the ionised form is non-toxic. The extent to which the two forms exist in a water body is driven by pH and temperature. The target water quality range for unionised ammonia is 0.007 mg/ℓ.

Ammonium (NH_4^+) is most easily assimilated by photosynthetic organisms. Assimilation of ammonia requires the least energy, followed by nitrate, then fixation of molecular nitrogen. Ammonia is a common pollutant and is one of the nutrients that contribute to eutrophication. The principle form of inorganic nitrogen in sewage is ammonia.

Nitrate (NO_3^{2-})

Nitrate is normally the most common form of combined inorganic nitrogen in lakes and streams. Natural concentrations, which seldom exceed 0.1 mg/ℓ NO_3-N, may be enhanced by municipal and industrial wastewaters, including leachates from disposal sites and sanitary landfills (Chapman, 1996).

Phosphate (PO_4)

Phosphorus is rarely found in high concentrations in freshwaters as plants and algae actively take it up. As a result there can be considerable seasonal fluctuations in concentrations in surface waters. In most natural surface waters, phosphorus ranges from 5 to 20 µg/ℓ PO_4-P (Chapman, 1996). Phosphorus from domestic wastewater returns can contribute significantly to eutrophication.

3.3.7 Bacteriological

Faecal coli are used to evaluate the quality of wastewater effluents, river water, raw water and treated drinking water. *Escherichia coli*, a direct indicator of faecal contamination of the water, is often used as an indicator of the potential presence of all microbial pathogens, including viruses and parasites, as well as bacteria which cause external infections and respiratory illness.

3.3.8 Toxicants

A list of potential toxicants and typical sources is set out in Table 4.

Table 4: Examples of potential sources of various toxicants in natural waters

Toxicant	Typical sources
Heavy metals	Mining industry, chemical industry, tanning
Inorganics	Mining industry
Pesticides	Pesticide manufacture and formulation; Agriculture
Petroleum products	Petroleum industry
Petrochemicals	Petrochemical industry
Surfactants	Household aqueous waste, industrial laundering and other cleansing operations
Pharmaceuticals	Pharmaceutical industry, agriculture, hospitals

Exposure to toxic chemicals can occur in a number of ways such as via contaminated food and water, skin absorption, inhalation, or transmission from mother to child across the placenta, and in breast milk. It is quite evident that the impacts of toxicants on people and animals warrant concern and attention. Monitoring the degree to which toxicity and individual toxicants exist in water resources is one important component of establishing the extent to which these substances are a problem in South Africa.

Inorganic toxicants (such as metals) and organic toxicants (such as pesticides, petroleum products and pharmaceuticals) can enter water resources and have devastating impacts on ecosystem integrity. The following summarises the critical ecological issues:

- Besides occasional immediate and highly visible impacts of accidental spills such as fish kills, many toxicants have more subtle, though no less serious, long-term impacts on aquatic biota;
- Impacts such as endocrine disruption, manifest at extremely low concentrations of toxicants;
- The nature of many long-term impacts makes them difficult to detect and quantify;
- Some toxicants are highly resistant to degradation in the environment and may persist for decades;
- Some organic toxicants degrade rapidly in the environment, or are metabolised, to other chemicals that may also be toxic;
- Many organic toxicants and some metals (for example mercury) have an affinity for animal tissue (*e.g.* in fish) and sediments in water resources. The chemical therefore gradually accumulates in these media to levels many thousands of times of the original background levels;
- Contaminated animals can be eaten by other animals up the food chain (including humans);
- Contaminated sediments can be scoured during floods, mobilising trapped toxicants and increasing the risks of exposure downstream; and
- Certain toxicants, like the persistent organic pollutants (POPs) addressed in the Stockholm Convention (2001), are highly volatile. They can be transported vast distances through the atmosphere away from their original sources. POPs have even been found in the Arctic, Antarctic and remote Pacific islands [UNEP, 2002].

4 RESOURCE UNITS

The water quality in the following main catchments is described in the sections to follow:

- Luvuvhu main and Mutale River catchment areas;
- Shingwedzi River catchment area;
- Groot Letaba catchment area; and
- Middle and Klein Letaba catchment area.

4.1 INTRODUCTION

The DWA monitoring points in the WMA are illustrated in Figure 1. A list of the sampling points in the WMA is included as Appendix A and the results for the points along the main rivers are attached as Appendix B.

There are a number of drainage lines evident within the catchments that pass through the urbanised areas, many of which do not have corresponding station identification names (ID's) and hence not statistically analysed. Thus, these have not been included in the results in Appendix B.

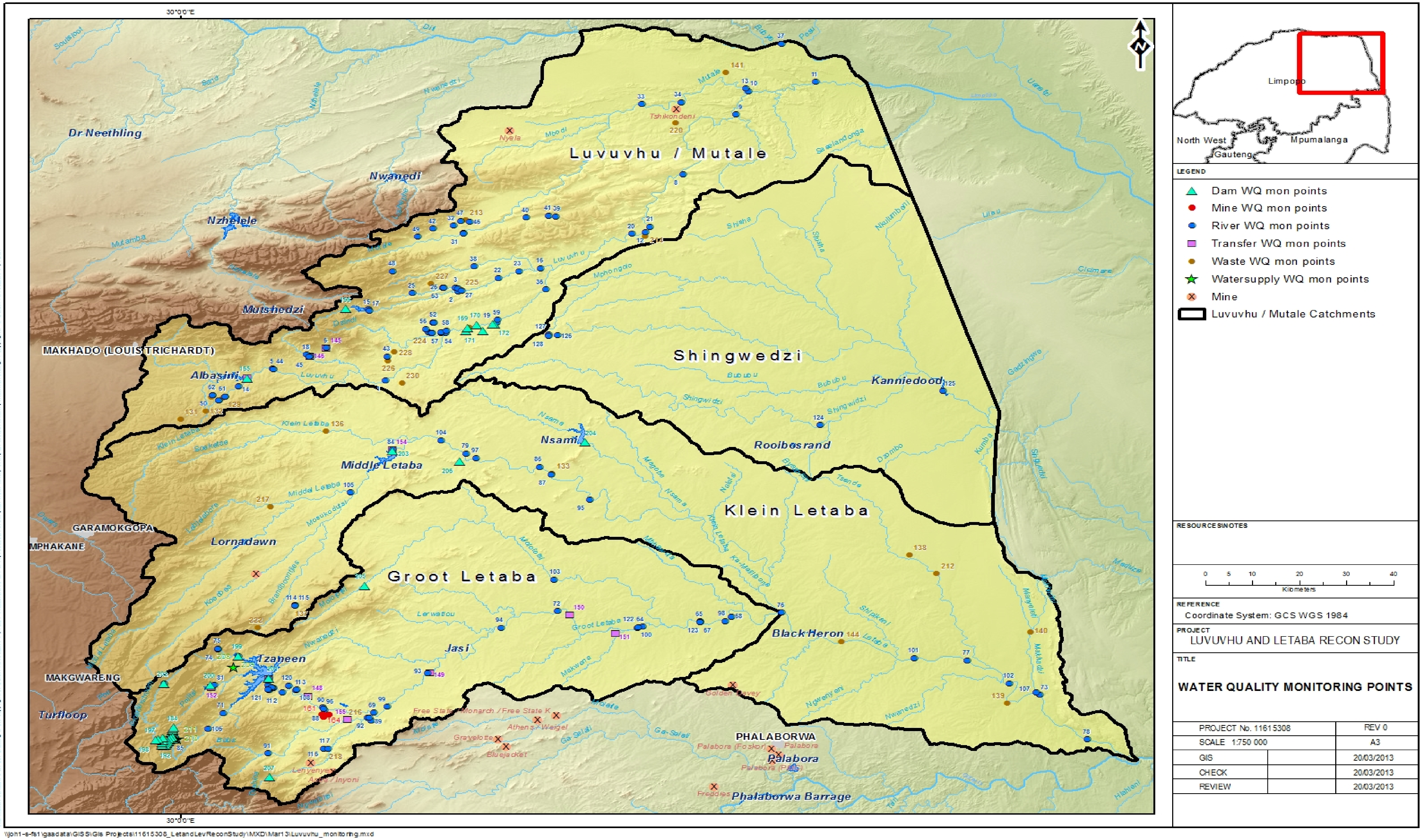

Figure 1 : Luvuvhu/Letaba Water Management Area showing water quality monitoring points

4.2 LUVUVHU MAIN AND MUTALE CATCHMENT AREA

4.2.1 Tributaries

The main rivers in the Luvuvhu main catchment area are the Luvuvhu and Mutale with the main tributaries being Matsaringwe; Mutshindudi (with Vondo Dam); Dzindi; Latoyanda and Doringspruit (Figure 2).

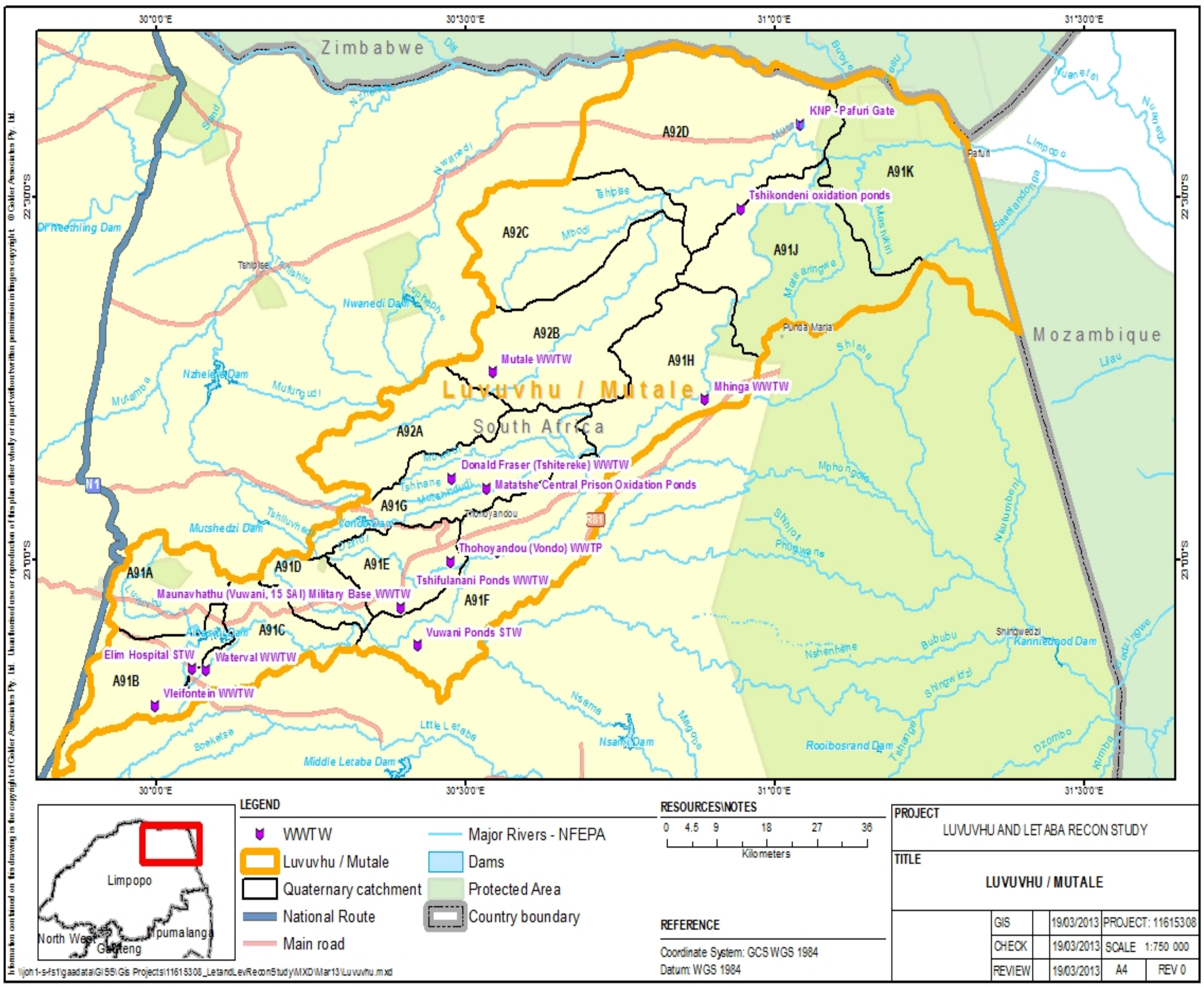

Figure 2 : Luvuvhu Main catchment area

4.2.2 Physical and chemical water quality

The Luvuvhu catchment starts in quaternary catchment A91A just downstream of the town of Makhado flowing through agricultural land to the Albasini Dam. A tributary originating just upstream of the Mpheni Village enters the main tributary (Doringspruit) just upstream of the dam. There appears to be overflow from the oxidation ditch type wastewater treatment works and maturation ponds in the village of Mpheni to the tributary. The main impacts on the dam are therefore related to urban pollution and agricultural run-off. There are no sampling points upstream of the dam; however, water quality in the Albasini Dam shows visual eutrophication with nutrient values of phosphate (0.05mg/l) and nitrate (0.3mg/l). The phosphate level exceeds the WQGs (Table 1).

The Mudzwiriti (Styldrift) tributary starts in quaternary A91B in the Mpheni village, upstream of the Albasini Dam; however, it confluences downstream of the dam. It includes run-off from Waterval B village as well as any discharge from the wastewater treatment works (10ML/d).

Downstream of the Albasini Dam, Latonanda tributary flows through extensive agricultural lands and some forestry, with irrigation canals. Water quality is excellent and well within the WQGs.

Sampling point A9H1 on the Luvuvhu River is just upstream of the villages of Tshivhazwaulu and Tshino shows good water quality within the potable water limits and WQGs.

The town of Thohoyandou is located north west of the Nandoni Dam. There are a number of drainage lines evident that pass through the urbanised areas to a tributary, many of which have number based identifications (ID’s) and not shown based on the map (i.e. 188179 etc.). The analysis of the point (188179) upstream of the wastewater treatment works in the town indicates diffuse pollution impacts from the town (nitrate: 1.8mg/l; phosphate: 1.6mg/l and ammonia: 6.3 mg/l). The point just downstream of the Thohoyandou domestic wastewater treatment works (188180) indicates that the works is discharging poor quality effluent with water quality in the river at that point: nitrate: 9.9mg/l; phosphate: 3.1mg/l and ammonia: 8.6 mg/l). Sampling points 190223 and 190217 also in Thohoyandou on tributary Luk, indicate some diffuse pollution (elevated ammonia of 2.2 mg/l). This flows into Mphaphuli tributary upstream of the wastewater treatment works and then into the Nandoni Dam.

Further stormwater conduits through the various settlements of Thohoyandou all enter the dam so that diffuse pollution loads are likely to be high.

There are no results for samples taken in the dam, however, sampling point 190136 at the Nandoni Dam outlet on the Luvuvhu River shows good water quality, although slightly elevated phosphate (0.2 mg/l) when compared to the WQGs.

Vondo Dam is situated on the Mutshindudi tributary. Sampling point A9R2 just upstream of Vondo Dam shows excellent water quality within the limits of the WQGs entering the dam. Tea plantations and forestry surround the dam. Two sampling points downstream of the dam indicates excellent water quality, within the limits of the WQGs, leaves the dam.

The Mutshindudi tributary confluences with the Luvuvhu downstream of Nandoni Dam. At point A9H3 upstream of the Vondwe oxidation ponds and cultivated agricultural land adjacent to several villages, limited results indicate good water quality and limited impacts from the adjacent land uses with the 95th percentile TDS of 97 mg/l. Vondwe oxidation ponds in the area receiving sewage from the villages are situated adjacent to the water quality site 188125 which is just downstream of some agricultural lands. Results from this site (188125) show some nutrient pollution: phosphate 1.4 mg/l, ammonia 3 mg/l and nitrate of 1.2 mg/l indicating potential impacts from agricultural run-off and diffuse pollution from the oxidation ponds.

Mvuwe is an irrigation dam on the Mutshindudi tributary.

A9H12 sampling point is just downstream of the villages: Mahagala, Mhinga, Botsoleni and Mhingaville. Water quality at this site is very good, well within potable water limits and the WQGs. Results at point A9H8 on the Luvuvhu River upstream of the confluence with the Mutale River and downstream of the confluence with an unnamed tributary on which the villages of Hamakuya, Khavhambe, Mutshikilini and Domboni, Dothi are located show no human settlements impacts. There are however no sampling points on the unnamed tributary itself.

Mutale catchment

There is limited sampling along the Mutale River. There is some underground coal mining in this catchment. The Tshikondeni Colliery owned by Exxaro Resources Limited is located approximately 140 km east of the town of Musina in Limpopo Province. It is an underground mine that employs approximately 770 people and currently produces 414ktpa of premium hard coking coal. Conventional board and pillar extraction methods are used and coal is beneficiated using cyclones, spirals and froth flotation. The beneficiated product is trucked to Musina and railed to the Arcelor Mittal works in Vanderbijlpark. The mine has coal reserves of 6Mt and a resource of 36Mt.

Results from point 118517 indicate that a drainage line from the mine to the Mutale River (just upstream) indicates pollution emanating from the mining areas (increased sulphate and high pH 9 and phosphate of 7.8 mg/l). Point A9H013 upstream of the confluence with the Luvuvhu indicates an increase in dilution with low EC (<25 mg/l) and overall excellent water quality.

Just upstream prior to the confluence with the Limpopo River the water quality in the Mutale River is excellent for all parameters assessed, falling well within the water quality requirements for all users.

The water quality parameters of pH, total dissolved solids, chloride, phosphates, nitrates and ammonia were assessed to be the variables of concern. These are therefore plotted in the following graphs which represent box and whisker plots for the complete dataset profiling the ***Luvuvhu River main stem***, dating on average up to the year 2010. The red line in each plot is the water quality guideline value proposed in the absence of the Resource Quality Objectives (RQOs). The table of statistics is available in Appendix B for detail regarding the plots.

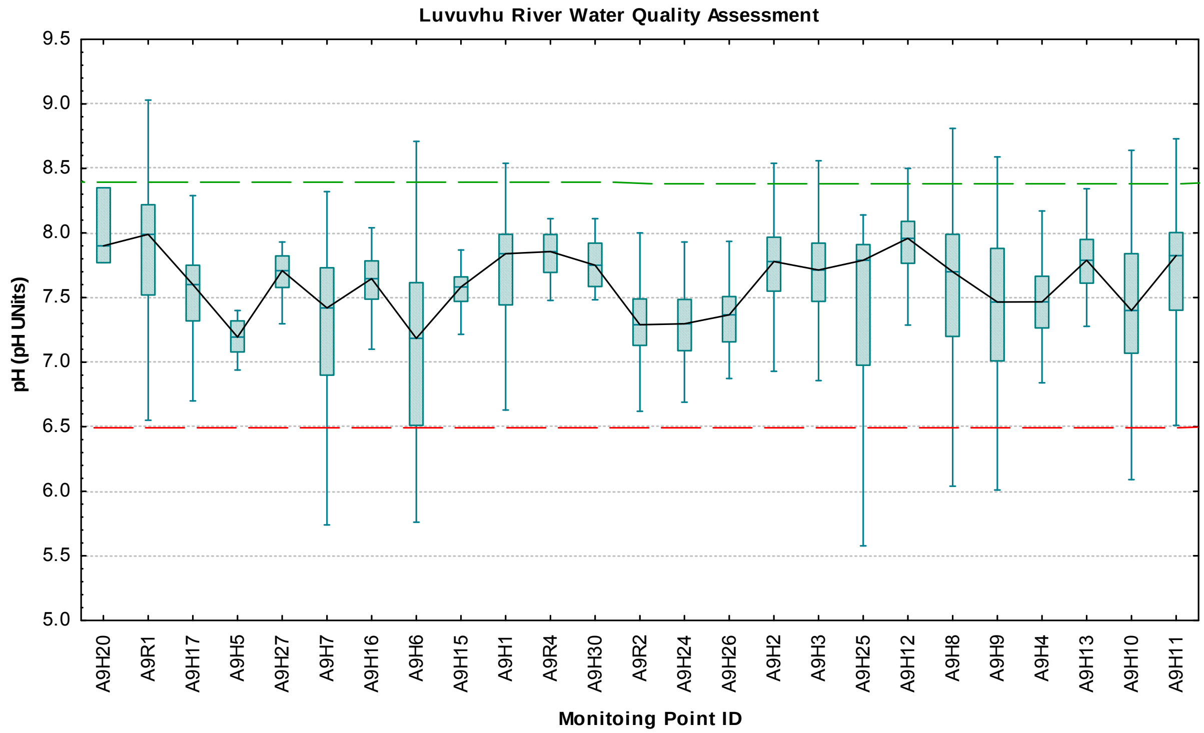

Figure 3: River profiles of mean pH values in Luvuvhu Main catchment area

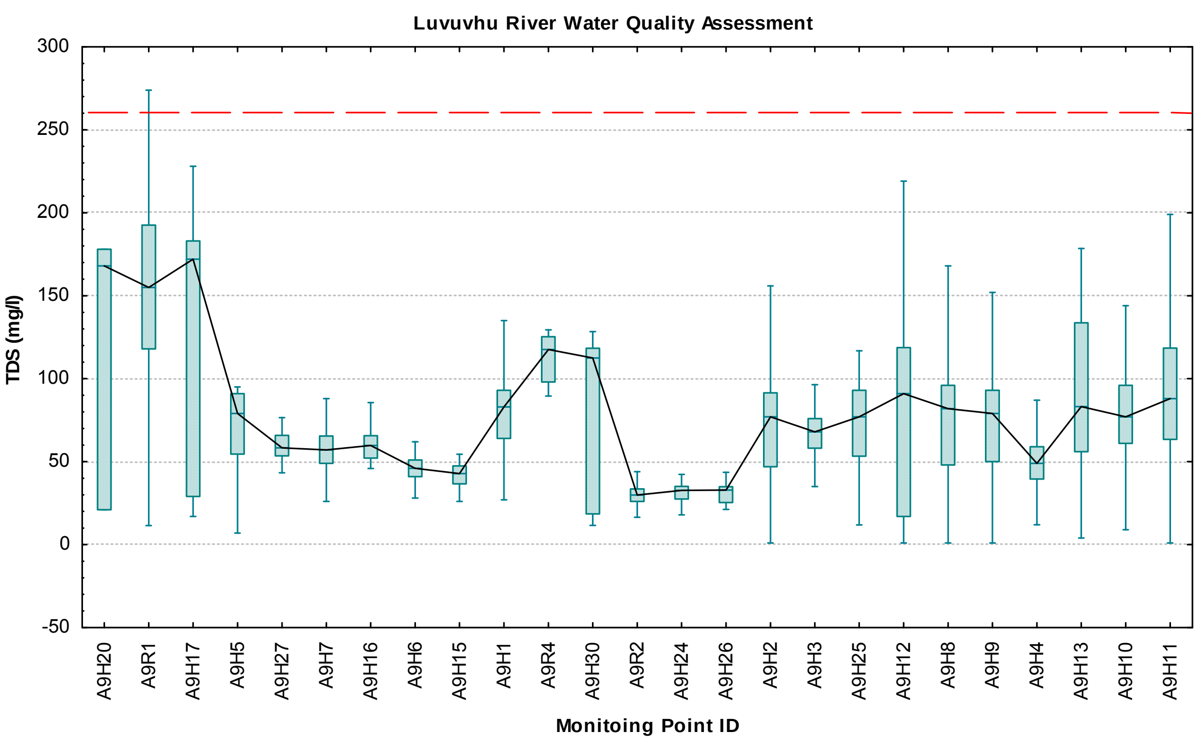

Figure 4: River profiles of mean TDS values in Luvuvhu Main catchment area

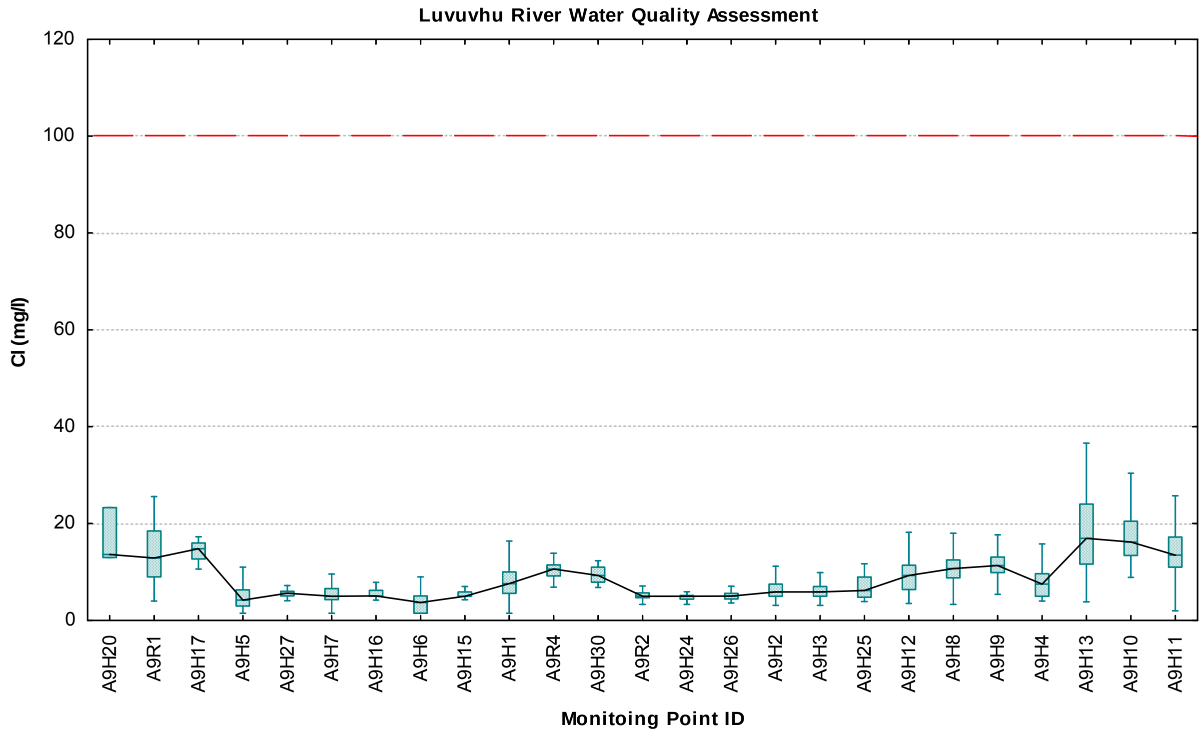

Figure 5: River profiles of mean chloride values in Luvuvhu Main catchment area

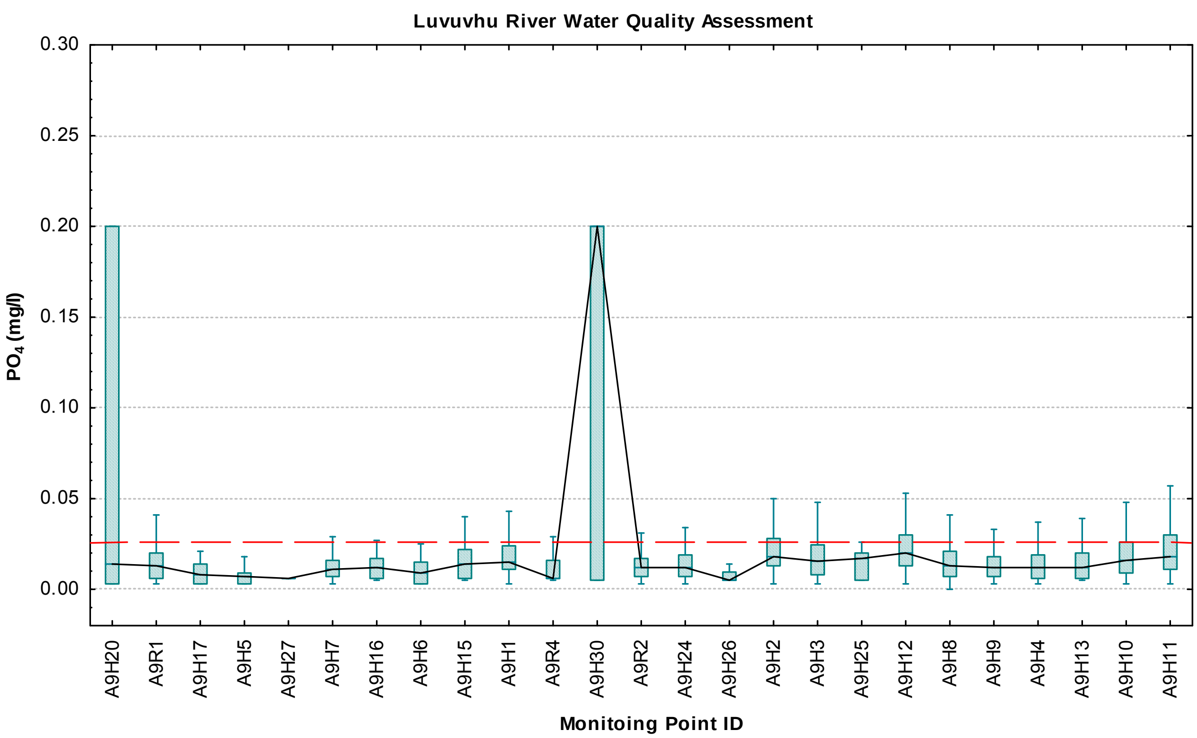

Figure 6: River profiles of mean phosphate values in Luvuvhu Main catchment area

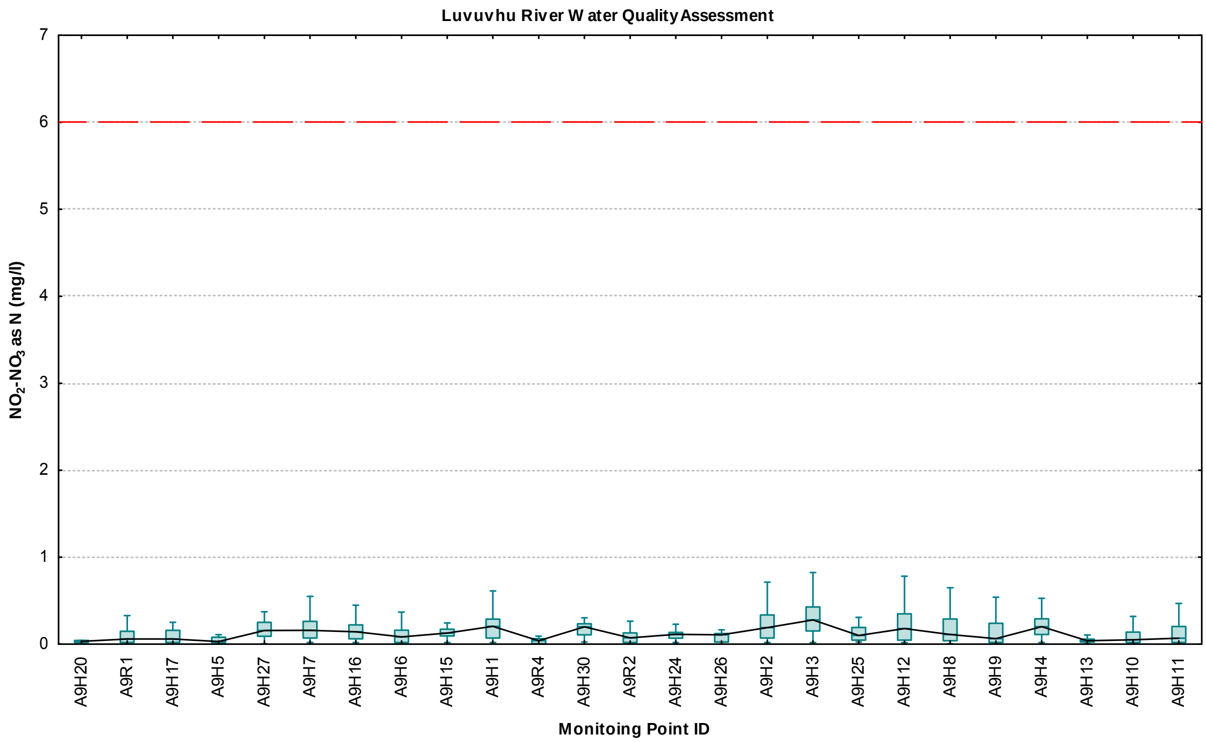

Figure 7: River profiles of mean nitrate values in Luvuvhu Main catchment area

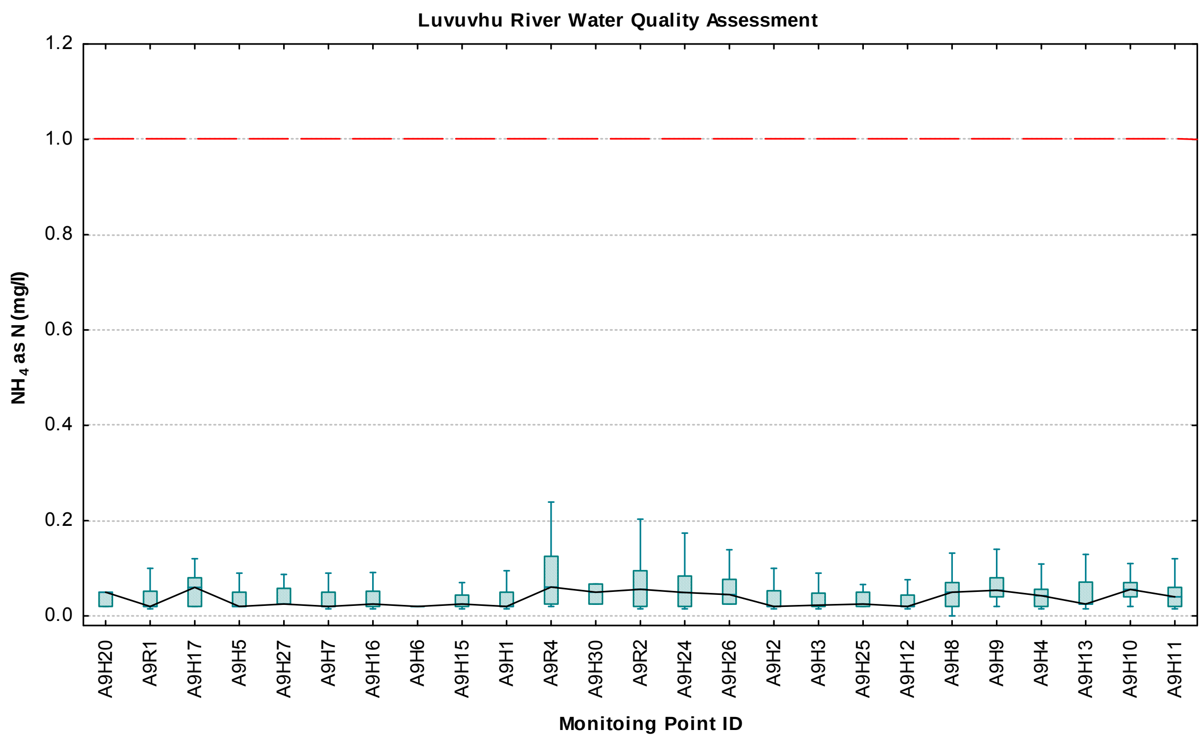

Figure 8: River profiles of mean ammonia values in Luvuvhu Main catchment area

4.2.3 Bacteriological

There is limited microbiological river data, however the results of effluents from the wastewater treatment works indicate that bacteriological contamination is high at all wastewater treatment works. It is therefore likely that in the rivers, downstream of wastewater treatment works the bacteriological count will be high.

4.2.4 Conclusions

The water quality of the Luvuvhu main catchment has remained very good and on the whole falls within the interim RWQOs. The main concerns are the elevated nutrients and ammonia downstream of urban areas, as well as associated bacteriological contamination that can be expected. There is also limited contamination from the Tshikondeni mining area.

The water quality status of the Luvuvhu River is driven by intensive agriculture of sub-tropical fruits and afforestation in the upper catchment, the urban sprawl of Thohoyandou in the middle catchment and the KNP in the lower end of the catchment. The unacceptable phosphate values that occur all the way into the KNP are as a result of the use of fertilizers for the intensive agriculture and domestic waste water treatment plant effluent from Thohoyandou and lack of formal treatment for the dense urban sprawl outside the KNP.

The water quality trends in the middle to lower Luvuvhu River indicate a deterioration of the phosphates, nitrates and ammonia levels. This deterioration in water quality is a result of the intense agriculture and domestic wastes associates with Thohoyandou and the un-serviced intense dense settlements upstream of the KNP. The Luvuvhu River is subject to ongoing research into the human health and fish impacts associated to the use of DDT for malaria control in the catchment ((Burger et al, 2008).

4.3 SHINGWEDZI RIVER CATCHMENT

4.3.1 Tributaries

The majority of the catchment falls within the Kruger National Park (KNP). There are very few monitoring points in the catchment. The main tributaries of the catchment include:

- Kumba;
- Dzombo;
- Bububu; and
- Mpongolo which includes:
    - Nkulumbeni;
    - Phungwane;
    - Shisha; and
    - Several unnamed tributaries.

The Mpongolo Dam is located in this catchment.

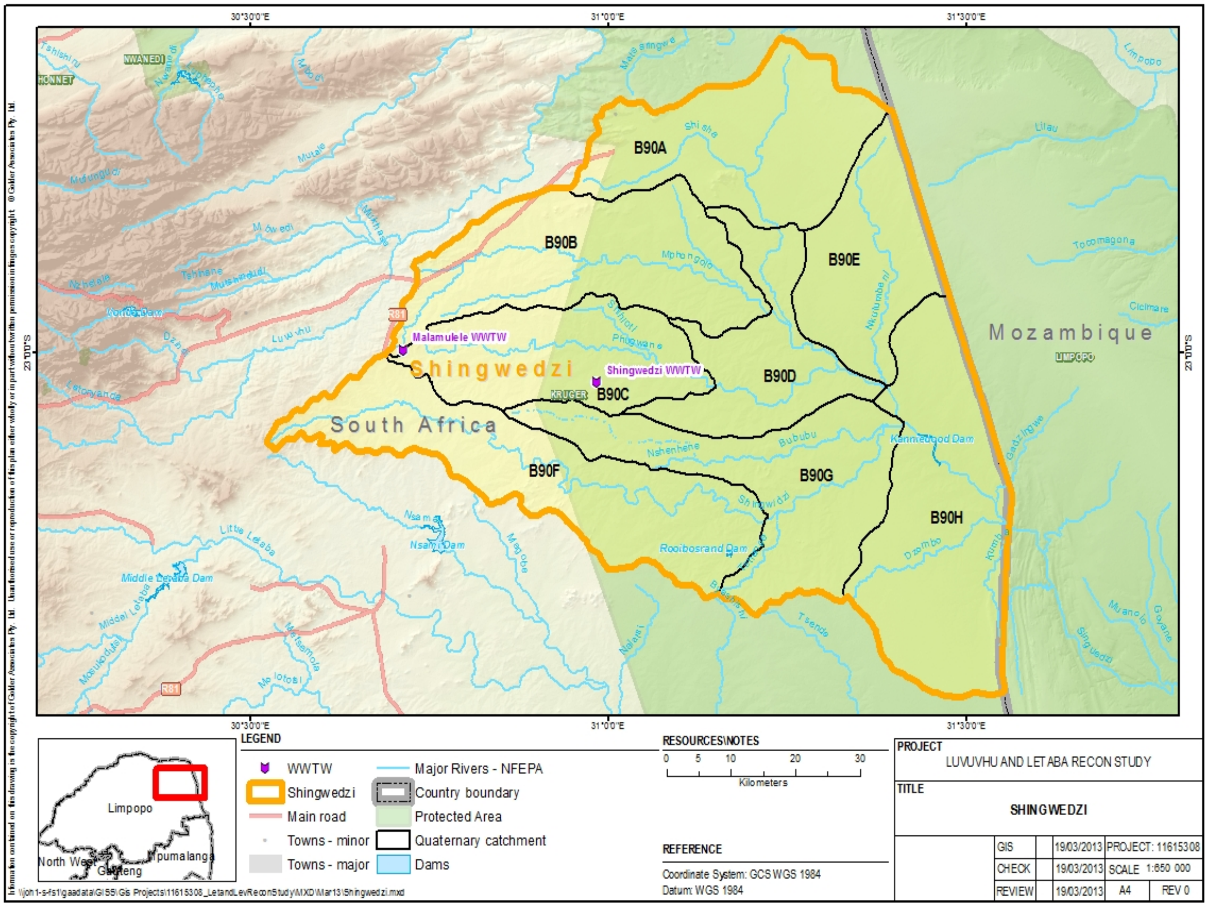

Figure 9 : Shingwedzi catchment

4.3.2 Physical and chemical water quality

The Shingwedzi River originates south of Nandoni dam flowing in an easterly direction and it joins the Mpongolo River about 140 kms downstream of the origin and just upstream of the Kanniedood Reservoir.

The town of Malumelele is located on the Shingwedzi River. The water quality point downstream of the town and the domestic wastewater treatment works of Malamulele show elevated levels of electrical conductivity (92 mS/m); TDS (644 mg/l); pH 8.4; phosphate (6.2 mg/l); nitrate (7.9 mg/l) and ammonia (13 mg/l) clearly indicating poor management of the domestic wastewater treatment works (biofilter) which enters a small irrigation dam. This joins the Phungwane River. Points within the village indicate diffuse pollution from the town. The Phungwane River enters the Mpongolo River.

The dam on the Mpongolo is surrounded by some villages including Makuleke village, as well as pivot systems further west suggesting that this is an irrigation dam.

B9H2 is located on the Shingwedzi River just before the confluence with an unnamed tributary approximately 120 kms downstream of the origin at a small impoundment in the Kruger National Park. Water quality is poor, indicating possible mobilisation of contaminants due to animal activity during low flow or it can be a natural occurrence. Similar results are indicated on the river just before it leaves the KNP into Mozambique.

The following graphs represent box and whisker plots for the complete dataset for the ***Shingwedzi main stem***, dating on average up to the year 2010. The red line in each plot is the water quality guideline value proposed in the absence of the Resource Quality Objectives (RQOs). The table of statistics is available in Appendix B for more detail regarding these plots.

4.3.3 Bacteriological

As for the Luvuvhu main catchment the river samples taken do not include bacteriological samples. Based on the poor operation of the domestic wastewater treatment works it can however be expected that the bacteriological quality will be poor downstream of these points.

4.3.4 Conclusions

The majority of the catchment of the Shingwedzi River's catchment falls within the KNP. Outside the land use is mainly subsistence agriculture and informal urban settlements. In general the water quality of the Shingwedzi River catchment has remained very good however shows contamination from the domestic wastewater treatment works, as well as general urban pollution from the larger villages.

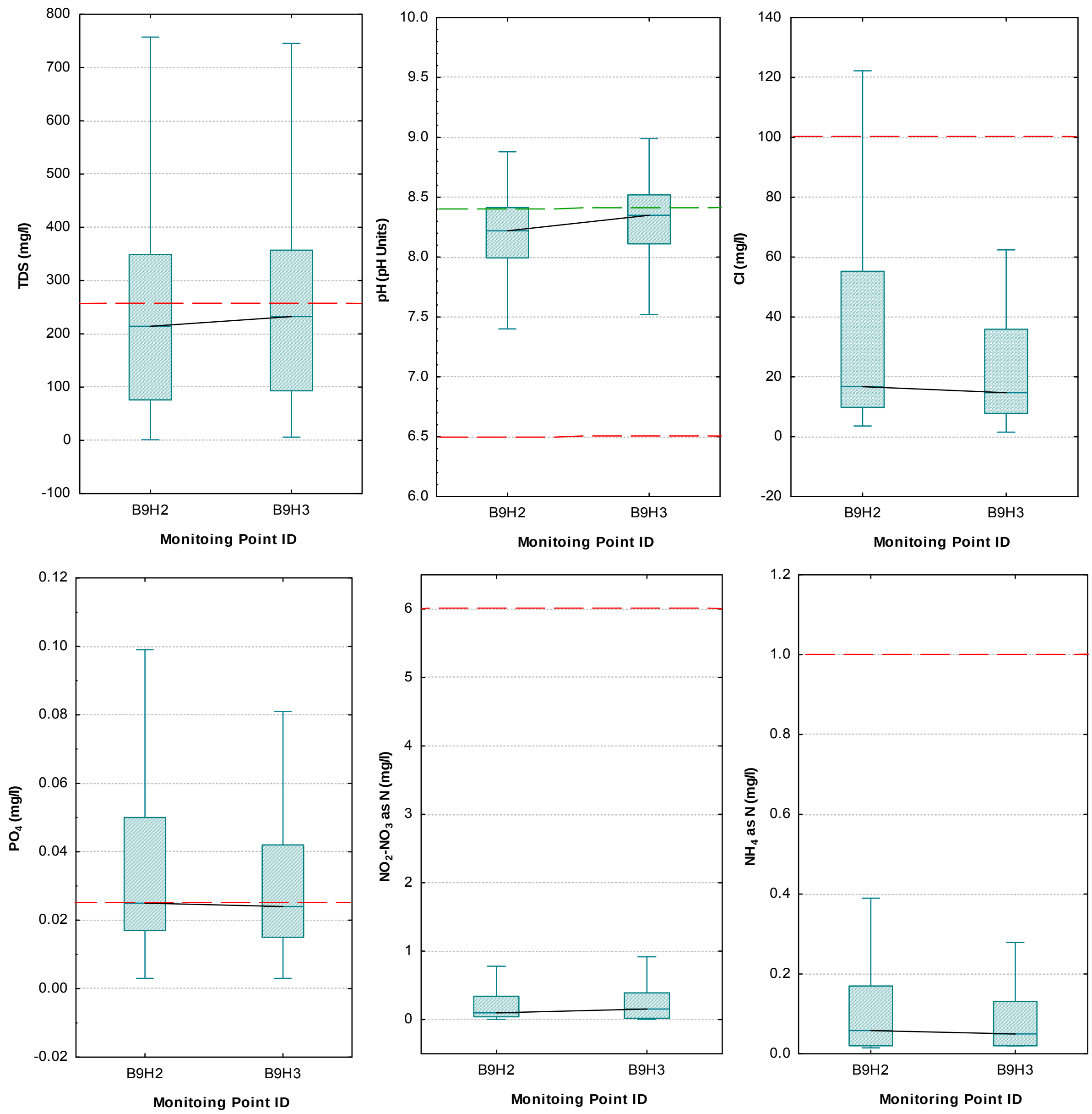

Figure 10: Mean concentrations of variables of concern along the Shingwedzi River catchment

4.4 GROOT LETABA CATCHMENT AREA

The main dams in the Groot Letaba catchment are the Molototsi Dam, Tzaneen Dam, Magoebasklood Dam and Ebenrezer Dam.

The Klein and Groot Letaba Rivers confluence at a water quality point situated on the border of the KNP (B8H28).

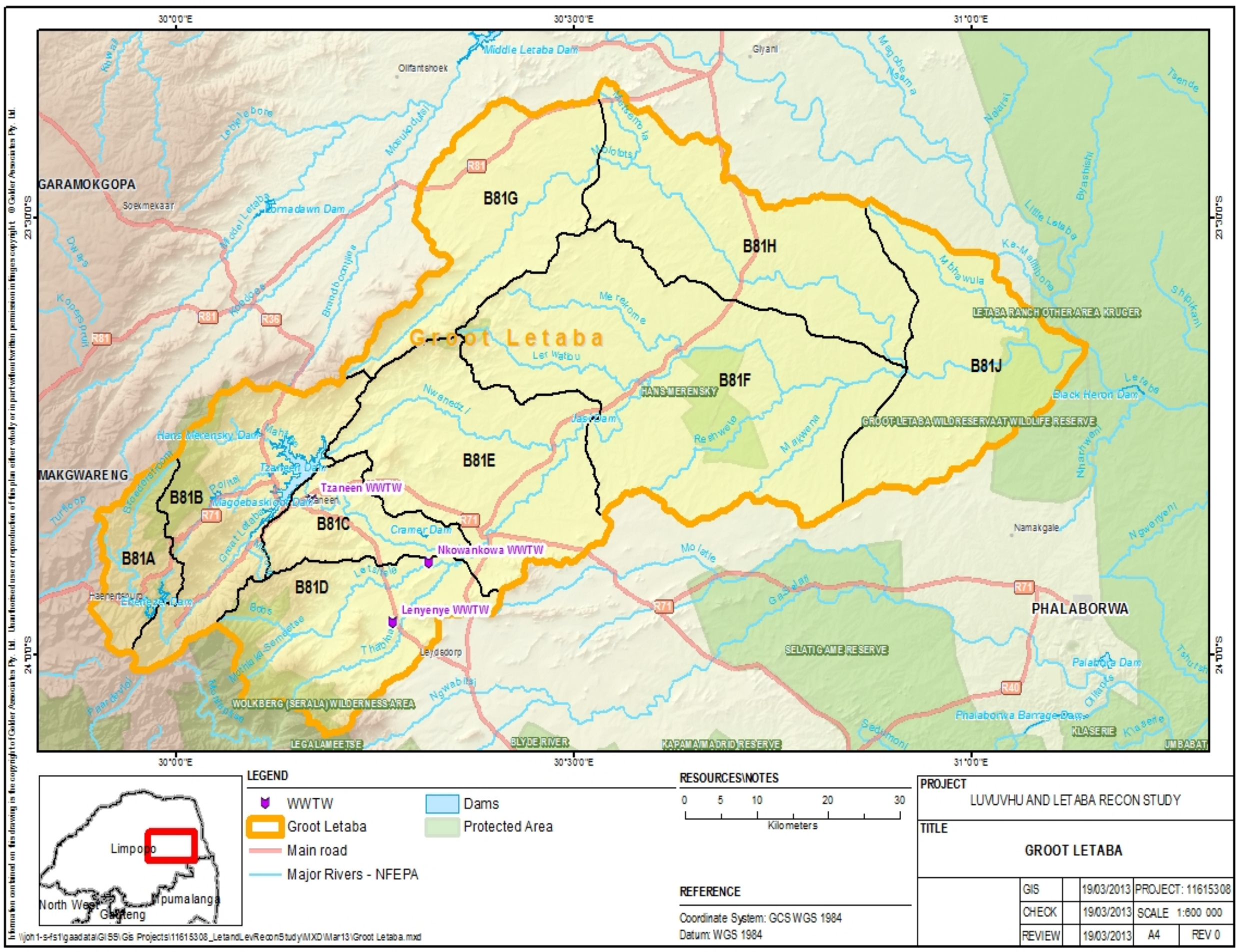

Figure 11 : Groot Letaba catchment

4.4.1 Physical and chemical water quality

The Groot Letaba starts just upstream of Dap Naude Dam in the Magoebaskloof area where the river is known as the Broederstroom. Water quality in the dam is well within the WQGs. The river flows south to the Ebenezer Dam through plantations. Water quality of the Ebenezer Dam is well within the WQGs, however is surrounded by recreational facilities and plantations, so ongoing monitoring of the dam is important for early detection of any potential nonpoint pollution sources. Downstream of the Ebenezer

Dam the river becomes Groot Letaba flowing northeast. At the point upstream of the Tzaneen Dam water quality is still of excellent quality well within the WQGs.

The tributaries entering the Tzaneen Dam are:

- Politsi River starting in the Magoebaskloof on which the Magoebasklood Dam is loacted; and
- Mahitse River starting in the Magoebaskloof.

Sampling point 188764 just downstream of the dam indicates excellent water quality in the river, well within the WQGs. The dam is surrounded by residential and irrigation so ongoing monitoring of the dam is important for early detection of any potential nonpoint pollution sources which already indicated as nutrient levels are slightly elevated showing some impact from activities around the dam. Water quality points downstream of the Tzaneen domestic wastewater treatment works indicate impacts with increased nutrient levels: phosphate (1 mg/l); nitrate (4.5 mg/l) and ammonia (1.2 mg/l). Some eutrophication is visible in the river. Impacts from irrigated plantations (possibly citrus along the river) also show further impacts from the irrigated areas. There are also several irrigation dams which overflow to the Groot Letaba.

At point B8H9 just before the confluence with the Lesitele tributary nutrients are still elevated. The Lesitele flows through densely populated areas. In addition, water quality results show the impacts from the Nkowankowa domestic wastewater treatment works, ponds which appear to be in the flood plain. The discharge quality is poor with phosphate (7mg/l), ammonia (13 mg/l) and nitrates of (15.6 mg/l). The Thabina tributary joins the Letsitele River just before it's confluence with the Groot Letaba. The Thabina flows through the Leyeenyee settlement and water quality shows impacts from the oxidation ponds and urban run-off.

Sampling point 187692 at the Gravelotte/Tzaneen Road about 5 kilometres downstream of the confluence, shows improved water quality. The Great Letaba Irrigation Scheme covers an extensive area along the river to the border of the Hans Merensky Game Park. Further downstream along the river at point B8H008 the water quality deteriorates (electrical conductivity (101.5 mS/m), TDS (710 mg/l), sodium (138.5 mg/l) and chloride of 192.7 mg/l. Nutrients are low with phosphate (0.08 mg/l), nitrate (0.35 mg/l) and ammonia (0.11 mg/l). This is at the confluence of the Klein Letaba and the border of the KNP. This deterioration accumulates further downstream as evidenced by the global increasing TDS trend in Figure 13

The following graphs represent box and whisker plots for the complete dataset for the profile of the ***Groot Letaba main stem***, dating on average up to the year 2010. The red line in each plot is the water quality guideline value proposed in the absence of the Resource Quality Objectives (RQOs). The table of statistics is available in Appendix B for more detail regarding the plots.

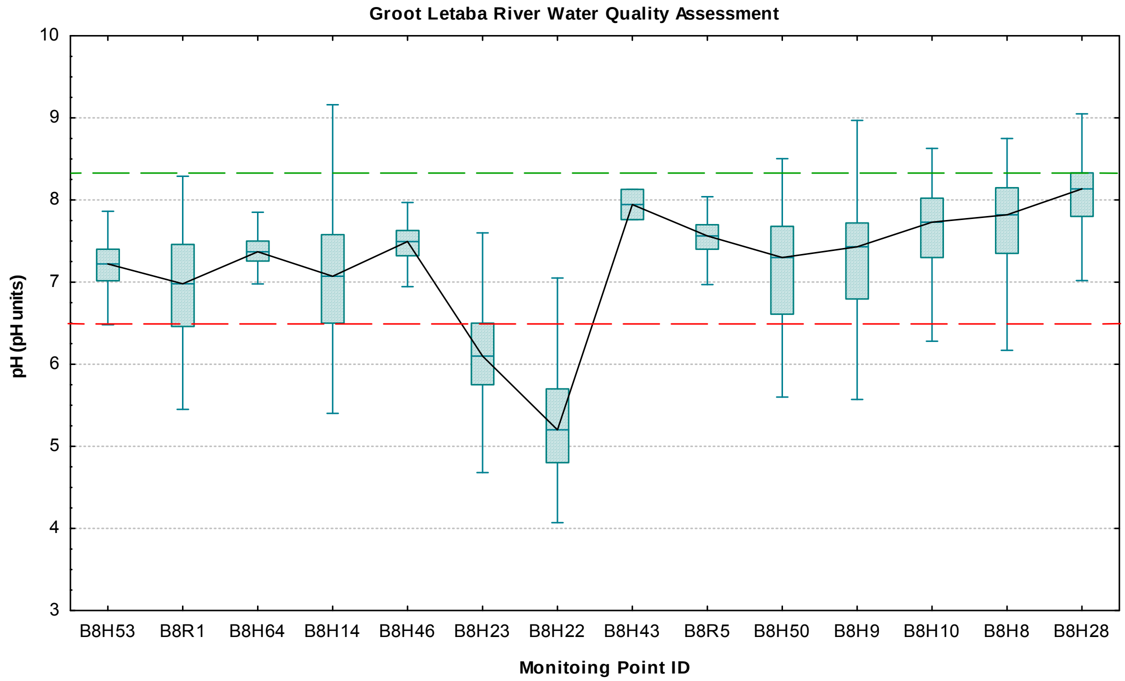

Figure 12: Mean pH values along the Groot Letaba River

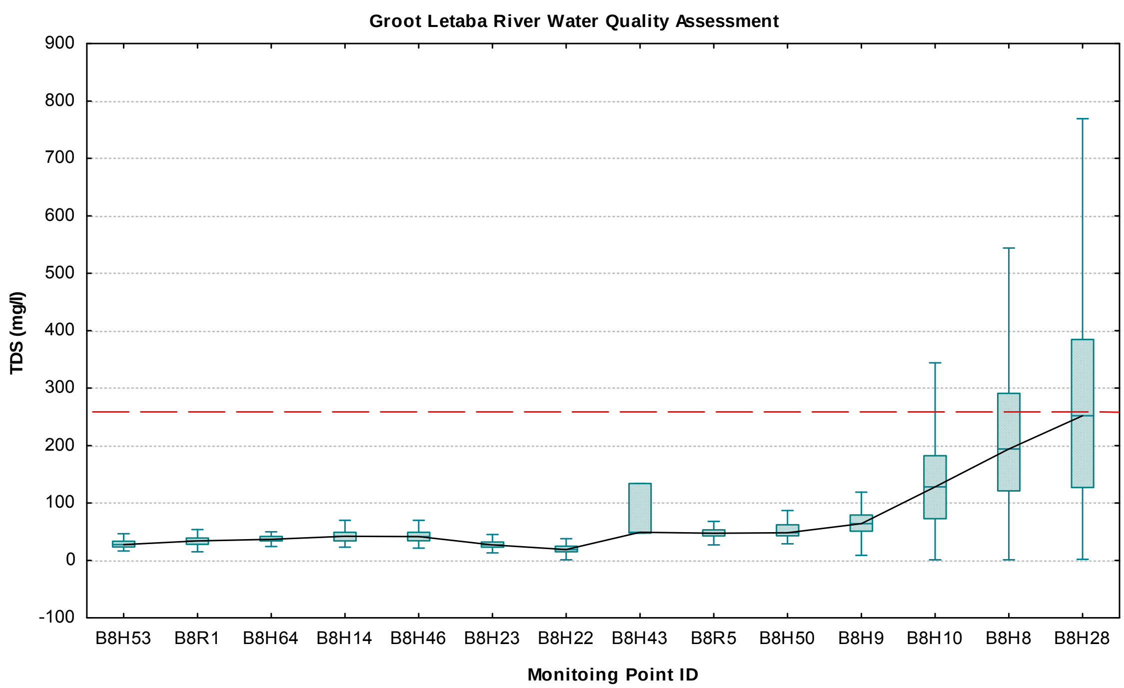

Figure 13: Mean TDS concentrations along the Groot Letaba River

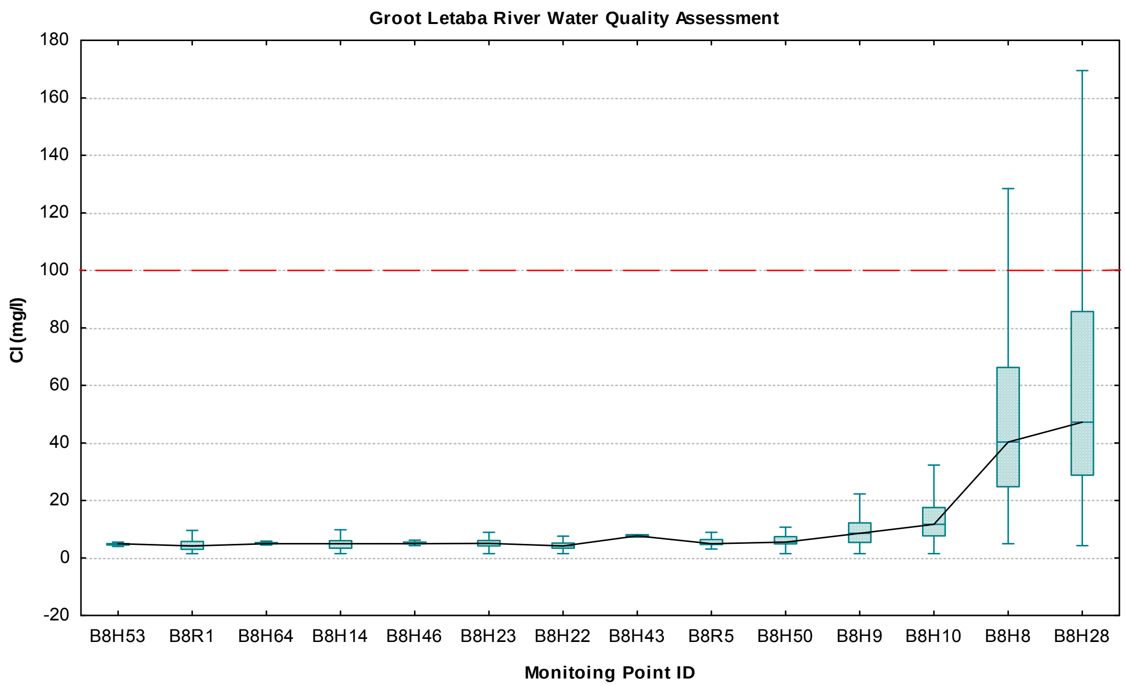

Figure 14: Mean chloride concentrations along the Groot Letaba River

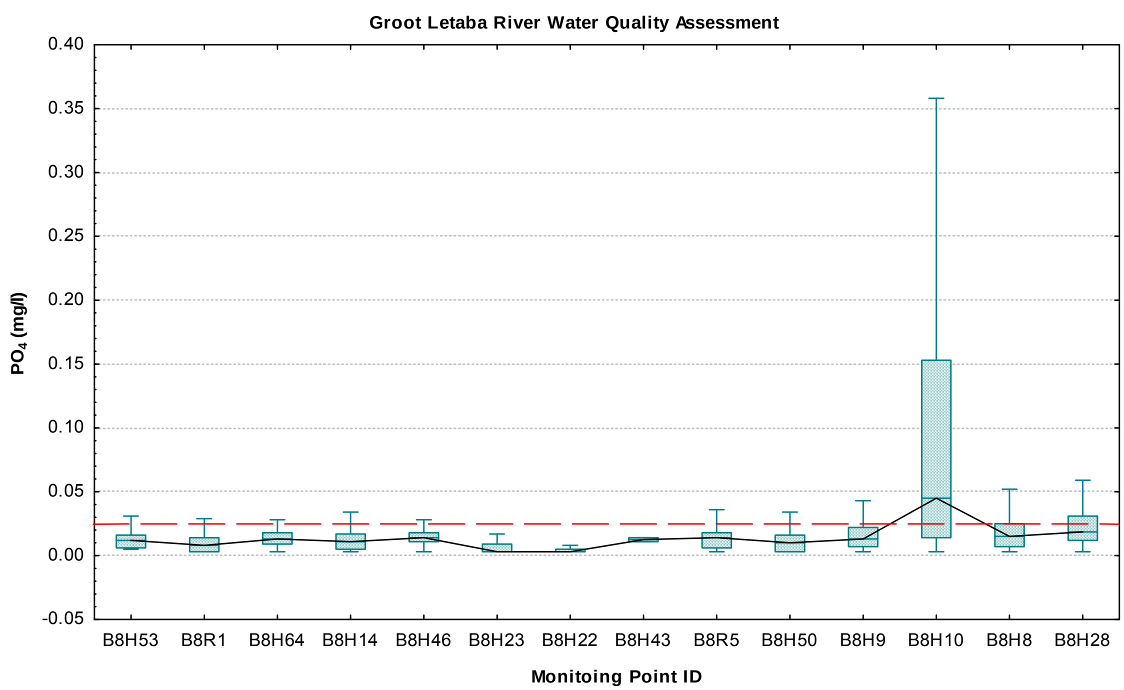

Figure 15: Mean phosphate concentrations along the Groot Letaba River

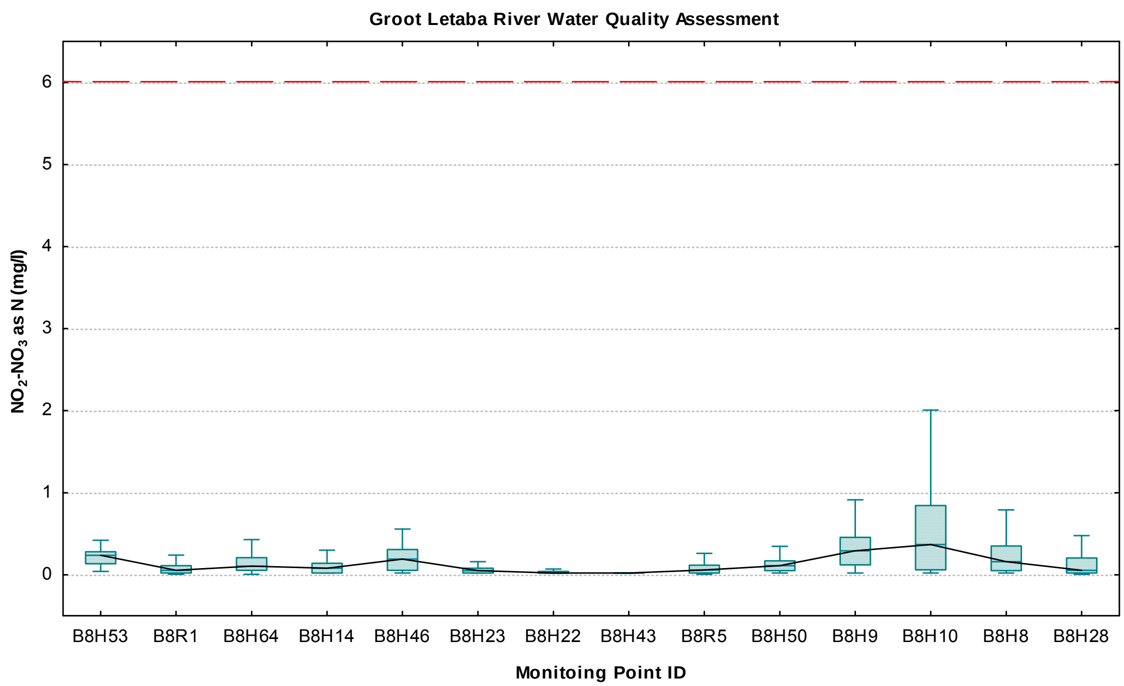

Figure 16: Mean nitrate concentrations along the Groot Letaba River

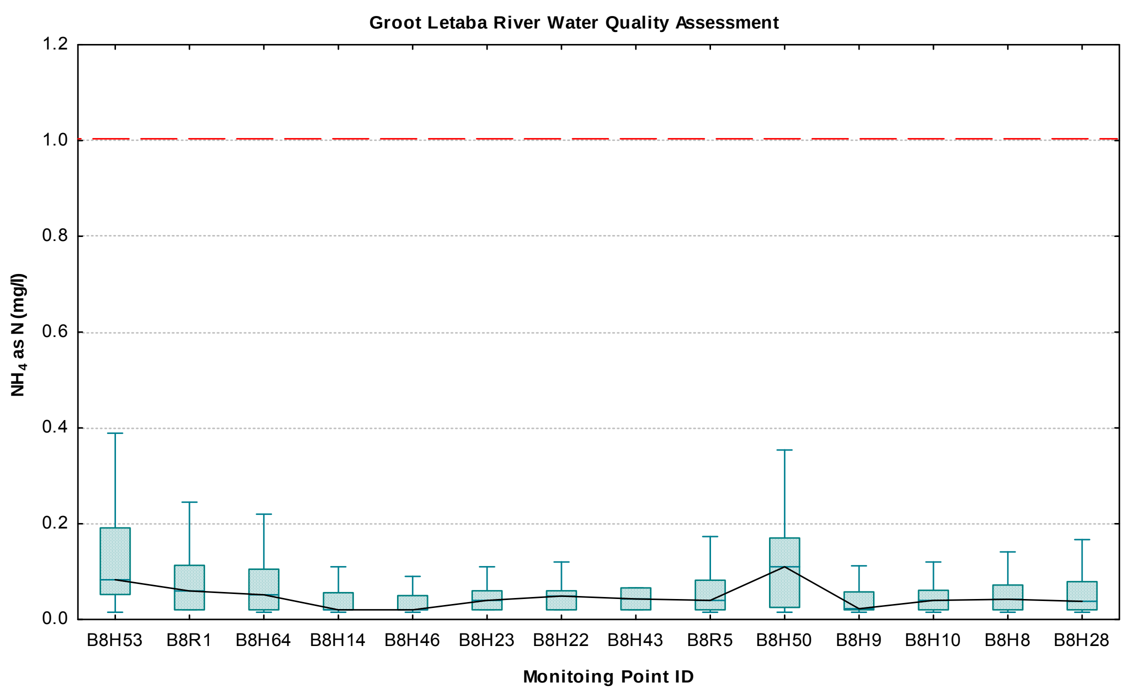

Figure 17: Mean ammonia concentrations along the Groot Letaba River

4.4.2 Bacteriological

As for the previous catchments the river samples taken do not include bacteriological samples. Based on the poor operation of the domestic wastewater treatment works it can however be expected that the bacteriological quality will be poor downstream of these points.

4.4.3 Conclusions

In general the water quality of the Groot Letaba catchment has remained very good in the upper reaches of the catchment, moving towards a slight deterioration further downstream due to low flow conditions. Nutrients, particularly phosphates are elevated primarily due to run-off from irrigation scheme areas prior to and within the Hans Merensky Nature Reserve.

The water type appears to be sodium chloride dominated so that as evaporation takes place sodium and chloride concentrations increase. Typically the water quality issues in the Groot Letaba catchment area are driven by diffuse pollution including:

- Afforestation: upper catchment (turbidity, fertilizers);
- Agricultural runoff from intensive cultivated lands – banana and citrus (fertilizers, salts, nutrients, pesticides);
- Villages close to rivers (microbiological, litter, turbidity);
- Animal grazing and watering (microbiological, turbidity); and
- Low surface water flow conditions.

The point sources of pollution in the Letaba River are limited to effluents from wastewater treatment works.

4.5 MIDDLE AND KLEIN LETABA CATCHMENT AREA

There are several small dams (Hudson Ntsanwisi Dam, Middle Letaba Dam and Lornadawn Dam) in this catchment.

The main tributaries of the Middle Letaba are:

- the Mosukoditsi River: the Koedoes and Brandboontjies tributaries; and
- Lebjelebore.

The Altenzur Dam is located on the upper parts of the Koedoes River.

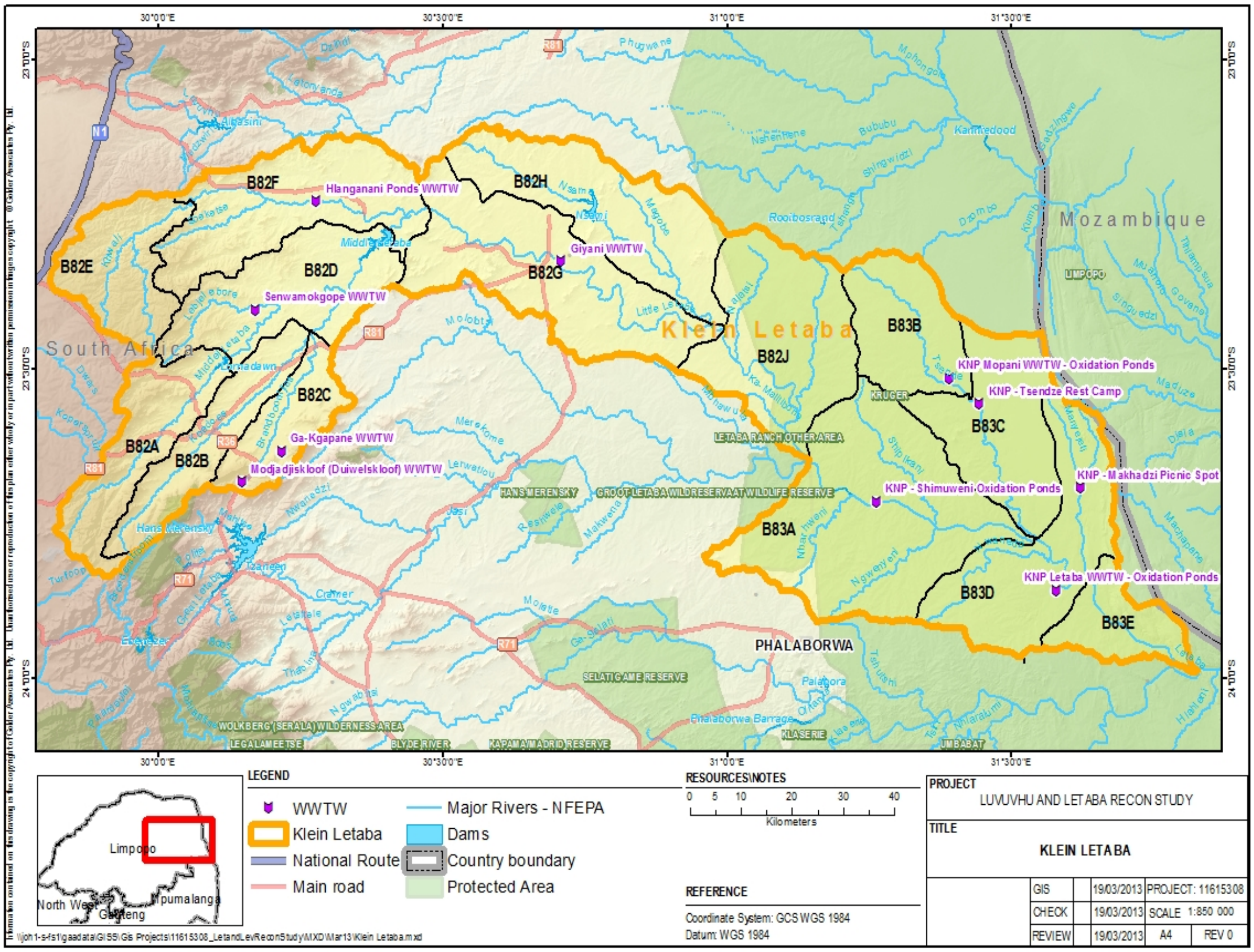

Figure 18 : Middle and Klein Letaba catchment areas

The main impacts on the Soeketse River are limited runoff from small villages and small-scale farming. An unnamed tributary enters the Soeketse just upstream of the Ha-Mashamba village. There are a few well defined tributaries passing through the village. There are no water quality monitoring sites on this stretch of the Klein Letaba.

Drainage to Brandboontjies River is through the densely populated town of Ka-Kgapane and includes discharge from a domestic wastewater treatment works. Sampling point 190140 is on Modubatse tributary downstream of the domestic wastewater treatment works. Water quality at this point is poor with elevated nutrients: nitrates (23.2 mg/l), ammonia (5.3 mg/l), phosphate (7.4 mg/l). Downstream of this in the Brandboontjies tributary the major land use is agriculture.

Just below the start of the Middle Letaba (approximately 22 kilometres downstream) the Ga-Mokolo and Ga-Sekgopo settlements show extensive small-scale farming, up stream of the Lornadawn Dam. Extensive agriculture lines the Middle Letaba. The first monitoring point is at the Middle Letaba Dam. Water quality shows electrical conductivity of 45 mS/m and total dissolved solids of 324 mg/l. Nutrients are low. The Klein Letaba joins the Middle Letaba after the Middle Letaba Dam. The river is now known as the Klein Letaba. An irrigation channel from the Middle Letaba Dam follows the course of the river with several smaller irrigation dams ending at the R582 road. There is very little flow in the river as it passes through the town of Giyani. Water quality in the river just upstream of the town and domestic wastewater treatment works at sampling point 183878 indicates impacts from the town. Electrical conductivity (93.7 mS/m), total dissolved solids (656 mg/l), phosphate (0.5mg/l), nitrates (0.2 mg/l) and ammonia (22 mg/l). Sampling point 183879 downstream of the Giyani domestic wastewater treatment works, shows further impacts from the town and wastewater treatment works, with increased concentrations of phosphate (8.4 mg/l), nitrate (7.5 mg/l) and ammonia (27 mg/l). Downstream of the town of Giyana there is extensive small-scale farming. The Nsami tributary enters the Klein Letaba River about 41 kilometres upstream of the confluence of the Groot and Klein Letaba.

The Hudson Ntsanwisi (Nsami) Dam is located on the middle parts of the Nsami River passing through the town of Makosha. Water quality in the dam is good with electrical conductivity of (33.8 mS/m), total dissolved solids of (241 mg/l), phosphate (0.04 mg/l), nitrates (0.08 mg/l) and ammonia (0.098 mg/l), well within the WQGs. The Magobe tributary enters the Nsami River just before the border of the KNP where the Klein Letaba flows along the border before the confluence with the Groot Letaba. There are several non-perennial tributaries entering the Letaba in the KNP upstream of the Engelhard Dam just before the Moçambique border. Water quality from the Letaba domestic wastewater treatment works is poor with phosphate (9.4 mg/l), nitrate (58 mg/l) and ammonia (37 mg/l). It is likely that this is having an impact on the dam: electrical conductivity (83.5 mS/m), total dissolved solids (719 mg/l), phosphate (0.044 mg/l), nitrate (0.6 mg/l), ammonia (0.88 mg/l). in addition the inflow from Makhadzi River to the dam is a poor quality with electrical conductivity (126 mS/m), total dissolved solids (962 mg/l), nitrate (1.86 mg/l), ammonia (0.4 mg/l) and phosphate (0.19 mg/l).

The following graphs represent box and whisker plots for the complete dataset for the ***Klein Letaba main stem***, dating on average up to the year 2010. The red line in each plot is the water quality guideline value proposed in the absence of the Resource Quality Objectives (RQOs). The table of statistics is available for more detail regarding these plots.

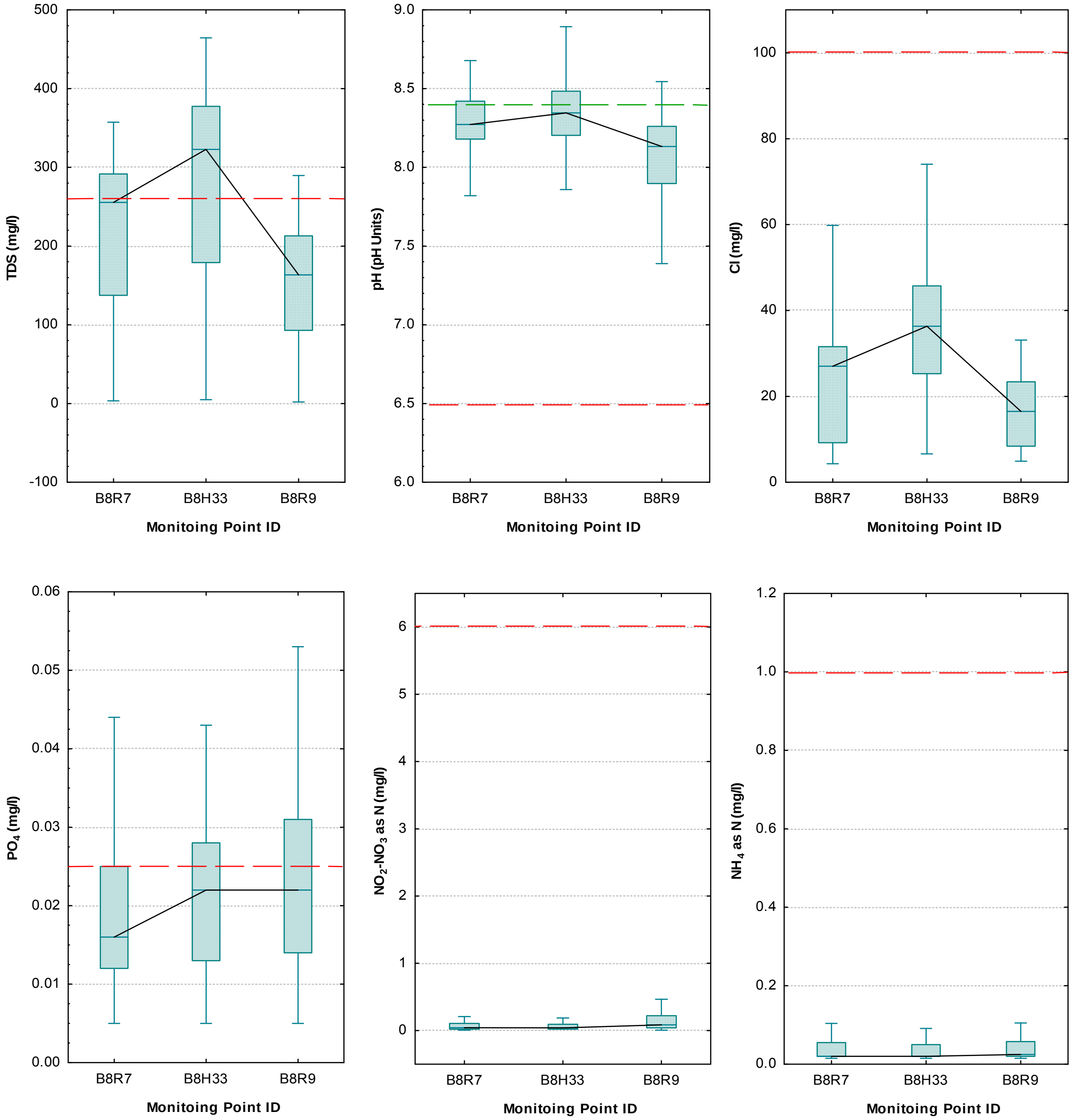

Figure 19: Mean concentrations of variables in the Klein Letaba catchment

The following graphs represent box and whisker plots for the complete dataset for the ***Letaba River main stem***, dating on average up to the year 2010. The table of statistics is available for more detail regarding these plots.

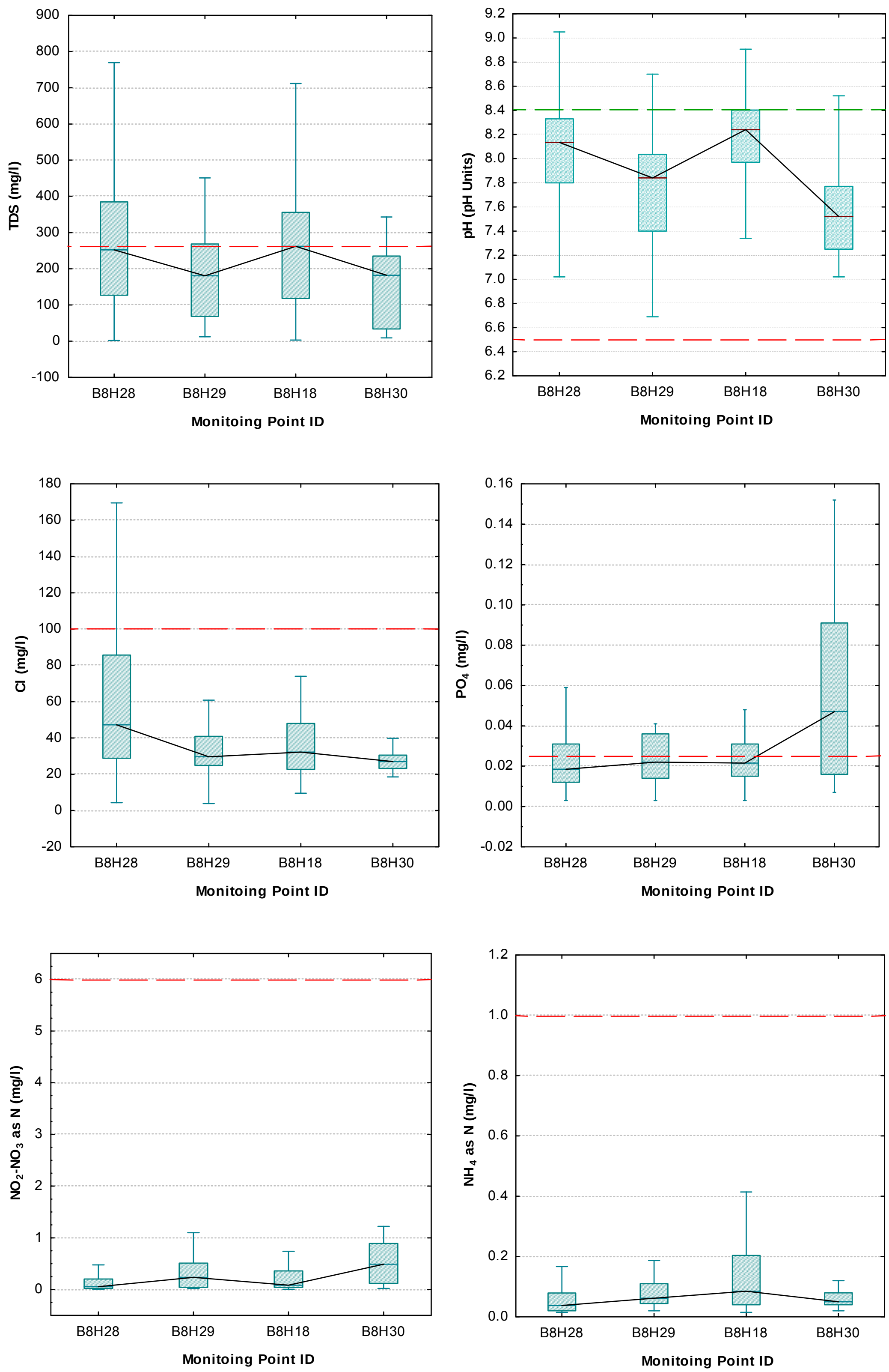
TDS (mg/l)
pH (pH Units)
Cl (mg/l)
PO4 (mg/l)
NO2-NO3 as N (mg/l)
NH4 as N (mg/l)
B8H28
B8H29
B8H18
B8H30
Monitoing Point ID

Figure 20: Mean concentrations for variables in Middle Letaba catchment

4.5.1 Bacteriological

As for the previous catchments the river samples taken do not include bacteriological samples. Based on the poor operation of the domestic wastewater treatment works it can however be expected that the bacteriological quality will be poor downstream of these points, as well as in the KNP due to animal activity.

4.5.2 Conclusions

The Middle and Klein Letaba rivers are in a moderately modified to modified state due mostly to densely populated settlements and agriculture above the Middle Letaba Dam and upper Klein Letaba River. The primary land-use is dense rural/urban settlements (limited subsistence agriculture, with livestock), with a very dry landscape. Water quality impacts may relate to sewage effluent leading to eutrophication. The current water quality down the Klein Letaba River indicates ideal values of ammonia, sulphates and nitrates. There are tolerable salt values (electrical conductivity and TDS) which are as a result of afforestation and runoff from the intensive agriculture. The unacceptable phosphate values are as a result of a number of WWTWs and waste disposal sites leading to eutrophication.

The Molototsi River's main land-use is rural informal settlements with limited subsistence and cultivated agriculture, with livestock. The landscape is dry and when the river flows it carries a high sediment load due to the informal settlements and cultivated agriculture that takes place into the flood plain of the river.

The water quality trends in the Letaba River indicate that the TDS values are increasing due to land use practices such as increased subsistence agriculture and afforestation. This results in a continuous sediment movement down the length of the river into the KNP.

4.6 EUTROPHICATION STATUS IN DAMS

The National Eutrophication Monitoring Programme measures chlorophyll-*a* at five sites in the Luvuvhu/Letaba WMA (Albasini Dam, Magoebaskloof Dam, Tzaneen Dam, Middle Letaba Dam and Nsami Dam). Table 4 shows the eutrophication potential for the summer 2011- 2012 period based on one sample only indicates that the dams are oligotrophic. Considering the median total phosphorous values taken from WMS for the dams, the eutrophication potential ranges from moderate to moderate/significant in the Nsami Dam indicating that eutrophication is becoming a concern in the study area.

Table 5: Trophic status and eutrophication potential

Dam	Median chlorophyll-*a* (µg/l)	Median TP	Trophic status	Eutrophication potential
Albasini	1.2	0.024	Oligotrophic	Moderate
Magoebaskloof	1.2	0.025	Oligotrophic	Moderate
Tzaneen	1.2	0.023	Oligotrophic	Moderate
Middle Letaba	1.2	0.026	Oligotrophic	Moderate
Nsami	1.2	0.046	Oligotrophic	Moderate/significant
Vondo Dam	-	0.017	-	Moderate
Dap Naude	-	0.015	-	Negligible/moderate

5 CONCLUSIONS

Throughout the study area the main concerns are the elevated nutrients and ammonia downstream of urban areas, as well as associated bacteriological contamination that can be expected. This is also indicated by the potential for eutrophication in the major dams in the study area. In respect of cholera outbreaks in the area, while exact hot spots are not clearly identified, the poor sanitation as well as discharge to resources from poorly operated and maintained wastewater treatment works, the environment is conducive to cholera survival.

The water quality status of the Luvuvhu River is driven by intensive agriculture of sub-tropical fruits and afforestation in the upper catchment, the urban sprawl of Thohoyandou in the middle catchment and the KNP in the lower end of the catchment. The water quality trends in the middle to lower Luvuvhu River indicate a deterioration of the phosphates, nitrates and ammonia levels. The unacceptable phosphate values that occur all the way into the KNP are as a result of the use of fertilizers for the intensive agriculture and domestic waste water treatment plant effluent from Thohoyandou and lack of formal treatment for the dense urban sprawl outside the KNP.

The Luvuvhu River is subject to ongoing research into the human health and fish impacts associated to the use of DDT for malaria control in the catchment.

The majority of the catchment of the Shingwedzi River's catchment falls within the KNP. Outside the land use is mainly subsistence agriculture and informal urban settlements. In general the water quality of the Shingwedzi River catchment has remained very good however shows contamination from the domestic wastewater treatment works, as well as general urban pollution from the larger villages.

In general the water quality of the Groot Letaba catchment has remained very good. The water type appears to be sodium chloride dominated so that as evaporation takes place sodium and chloride concentrations increase. Typically the water quality issues in the Groot Letaba catchment area are driven by diffuse pollution including:

- Afforestation: upper catchment (turbidity, fertilizers);
- Agricultural runoff from intensive cultivated lands – banana and citrus (fertilizers, salts, nutrients, pesticides);
- Villages close to rivers (microbiological, litter, turbidity); and
- Animal grazing and watering (microbiological, turbidity).
- The point sources of pollution in the Letaba River are limited to effluents from wastewater treatment works.

The Middle and Klein Letaba rivers are in a moderately modified to modified state due mostly to densely populated settlements and agriculture above the Middle Letaba Dam and upper Klein Letaba River. The primary land-use is dense rural/urban settlements (limited subsistence agriculture, with livestock), with a very dry landscape. Water quality impacts may relate to sewage effluent leading to eutrophication. The current water quality down the Klein Letaba River indicates ideal values of ammonia, sulphates and nitrates. There are tolerable salt values (electrical conductivity and TDS) which are as a result of afforestation and runoff from the intensive agriculture. The unacceptable phosphate values are as a result of a number of WWTWs and waste disposal sites leading to eutrophication.

The Molototsi River's main land-use is rural informal settlements with limited subsistence and cultivated agriculture, with livestock. The landscape is dry and when the river flows it carries a high sediment load due to the informal settlements and cultivated agriculture that takes place into the flood plain of the river.

The water quality trends in the Letaba River indicate that the TDS values are increasing due to land use practices such as increased subsistence agriculture and afforestation. This results in a continuous sediment movement down the length of the river into the KNP.

6 RECOMMENDATIONS

Considering the number of densely populated and informal settlements in the study area and the potential for water use directly from the resources, bacteriological monitoring in the study area is inadequate and needs to be increased at points up and downstream of the urban areas, and specifically wastewater treatment works. This will also give a better understanding of the potential for cholera outbreaks.

The wastewater treatment works in the study area need to be upgraded to improve the quality of the effluent being discharged as this is impacting on human health and increased eutrophication potential in the study area which will in turn impact on other water users such as irrigation farmers and water treatment plants.

7 GLOSSARY

Term	Definition
Algal bloom	The rapid excessive growth of algae or phytoplankton, which can form a dense surface scum; generally caused by high nutrient levels, favourable light and temperature conditions.
Alkalinity	Capacity of water to neutralize acids by its content of bicarbonates, carbonates, and/or hydroxides – The buffer capacity of a water body.
Assimilative Capacity	Natural ability of a waterbody to neutralize or decompose potential pollutants without harmful effects to the environment.
Bioaccumulation	Build-up of a pollutant in the body of an aquatic organism by uptake food of and directly from the surrounding water.
Biota	The sum of the living organisms of any designated area.
Chemical Oxygen Demand (COD)	Measurement of the amount of oxygen used in the chemical break-down of organic matter in water. Is a good indicator of the total amount of organic waste.
Denitrification	The biological reduction of NO_3^- or NO_2^- to N_2 or gaseous nitrogen oxides.
DO	Dissolved oxygen concentration in water (mg/ℓ or % saturation) and readily available to fish and other aquatic organisms.
Eutrophication	The process of enrichment of waters with plant nutrients, primarily phosphorus, causing abundant aquatic plant and algal growth.
Heavy metals	Metallic elements with high atomic weights e.g., copper, mercury, chromium, cadmium, arsenic or lead. Heavy metals can damage living things at low concentrations and tend to accumulate in the food chain.
Nitrification	The biological oxidation of ammonium to nitrate ($NH_4^+ \rightarrow NO_3^-$) with nitrite ($NO_2^-$) as an intermediate in the reaction sequence.
Nutrients	Elements essential for plant or animal growth. Major nutrients include nitrogen, phosphorus, carbon, oxygen, sulphur, and potassium.
Pathogen	Disease-causing biological agent such as a bacterium, virus, or fungus.

Phytoplankton	Small (often microscopic) aquatic plants suspended in water.
Plankton	Plants (phytoplankton) and animals (zooplankton), usually microscopic, floating in aquatic systems.
Pollution	An undesirable change in the physical, chemical, or biological characteristics of air, water, soil, or food that can adversely affect the health, activities, or survival of humans or other living organisms.
Salinisation	Is the process by which the concentration of dissolved solids in inland waters is increased.
TDS	Total dissolved solids – a measure the inorganic salts (and organic compounds) dissolved in water.
Toxicant	A chemical capable of producing an adverse response (effect) in a biological system at concentrations that might be encountered in the environment, seriously injuring structure or function or producing death. Examples include pesticides, heavy metals and biotoxins.
TSS (SS)	Total suspended solids concentration is a measure of the amount of material suspended in water, which includes a wide range of sizes of material, from colloids (0.1 μm) through to large organic and inorganic particulates.
Turbidity	measure of water cloudiness due to suspended solids. Turbidity is a murkiness of water, reflecting the amount of sediment in the water, measured in Nephelometric turbidity units (NTU).
Water quality	Describes the physical, chemical, biological and aesthetic properties of water which determines its fitness for use and its ability to maintain the health of farmed aquatic organisms.
Zooplankton	The animal portion of the plankton.

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Appendix A

Water quality sampling points assessed

No. on Fig 1	Water quality site	Latitude	Longitude	Description	Type	n	First date	Last date
1	**A91 90388**	-23.11167	30.38972	Luvuvhu River at Weltevreden/Schuyns hoog	Rivers	227	31/01/1990	12/06/2008
3	**A91 90390**	-22.89722	30.52389	Tshinane River at Chibase/Sibasa	Rivers	152	31/01/1990	23/02/2011
7	**A91 90394**	-23.055	30.245	Latonanda River at Levubu Settlement	Rivers	122	01/02/1990	06/11/2008
8	**A91 90395**	-22.63556	30.95861	Luvuvhu River at Shidzivane/Kruger National Park	Rivers	398	07/01/1990	31/05/2011
11	**A91 90398**	-22.42167	31.21111	Luvuvhu River at Pafuri/Kruger National Park	Rivers	324	02/01/1990	23/05/2011
12	**A91 90399**	-22.76972	30.88694	at Mhingas on Luvuvhu River	Rivers	396	31/01/1990	08/06/2011
15	**A91 90403**	-22.94806	30.35639	Mutshindudi River at Chibase/Sibasa	Rivers	115	30/06/1997	14/09/2007
17	**A91 188154**	-22.95139	30.35806	Tshivhasa Duthuni near R523 Road on Mutshindudi River	Rivers	27	19/06/2007	23/02/2011
18	**A91 188155**	-23.0525	30.23944	at Levubu Settlements on Latonanda	Rivers	27	19/06/2007	24/11/2010
19	**A91 190136**	-22.97852	30.60104	Nandoni Dam Downstream of Dam Weir on Luvuvhu River	Rivers	13	20/01/2009	01/04/2011
27	**A91 188125**	-22.90497	30.53532	Tshinane River Upstream of Matatshe Prison Ponds	Rivers	30	10/11/2004	16/03/2010
29	**A91 188179**	-23.00007	30.4709	Mphaphuli Upstream of Thohoyandou Sewage Treatment Works	Rivers	74	10/11/2004	24/02/2010
30	**A91 188180**	-23.0017	30.47725	Mphaphuli Downstream of Thohoyandou Sewage Treatment Works	Rivers	75	10/11/2004	24/02/2010
13	**A92 85326**	-22.43772	31.07806	at Mutale Bend Kruger National Park on Mutale	Rivers	125	16/08/2003	20/05/2011
31	**A92 188507**	-22.77214	30.53856	Tshandama Tengwe S 255 MT Bridge 2 Km to Tshandama Tribal of	Rivers	34	10/02/2005	24/02/2010

No. on Fig 1	Water quality site	Latitude	Longitude	Description	Type	n	First date	Last date
32	**A92 188509**	-22.75439	30.52019	Tshandama Tengwe S 255 MT Bridge near Tshandama Tribal Offic	Rivers	22	17/03/2005	10/02/2009
33	**A92 188516**	-22.47292	30.87958	Sanari Village Mutale Bridge Upstream of Tshikondeni Mine Ne	Rivers	34	10/02/2005	16/03/2010
34	**A92 188517**	-22.46942	30.95514	Bileni Tshikondeni 88 MT Downstream of Tshikondeni Mine near	Rivers	24	17/03/2005	16/03/2010
37	**A91 189421**	-22.33339	31.14636	Kruger National Park at Hulukulu on Limpopo	Rivers	36	12/12/2006	23/05/2011
39	**A92 190114**	-22.73256	30.71503	Sambandou Village Next to Community Residents on Sambandou R	Rivers	21	31/08/2006	16/03/2010
40	**A92 190115**	-22.73583	30.65925	Tshitavha Village Bridge on Sambandou River	Rivers	35	10/02/2005	16/03/2010
41	**A92 190116**	-22.73147	30.70122	Sambandou Village Sambandou Well Next to Nnyawedzeni Primary	Rivers	20	31/08/2006	16/03/2010
42	**A92 190118**	-22.76153	30.48086	Tshandama Pile Village Community Residence on Tshiombedi Riv	Rivers	30	28/06/2005	24/02/2010
45	**A91 190138**	-23.05661	30.24306	Klein Australie 13 LT. Weir on Lotanyanda River Before Tshak	Rivers	42	30/01/2007	23/06/2009
46	**A92 190148**	-22.74586	30.55044	Tengwe 255 MT Bashasha Village Downstream of Tshilamba Oxida	Rivers	15	29/01/2008	09/12/2009
50	**A91 190213**	-23.14619	30.05825	Doornspruit 41 LT. - Mpheni Village-at Culvert D/S Elim Hosp	Rivers	17	26/08/2005	16/01/2008
51	**A91 190217**	-22.97879	30.48058	Manini Village Thohoyandou Bridge Downstream of Manini Pump	Rivers	75	25/07/2005	24/02/2010
52	**A91 190223**	-22.97807	30.48235	Manini Village Thohoyandou Upstream of A Pump Station on Luk	Rivers	36	25/07/2005	09/12/2009

No. on Fig 1	Water quality site	Latitude	Longitude	Description	Type	n	First date	Last date
60	**A91 1000005468**	-23.15758	30.07111	Styldrift 46 LT. - Duplicate of Point 188152	Rivers	28	28/09/2004	12/05/2009
62	**A91 1000005471**	-23.14625	30.05822	Tributary of Muhohode Downstream of Elim S/W	Rivers	34	28/09/2004	21/01/2009
68	**B81 90524**	-23.65806	31.05	at Letaba Ranch on Groot Letaba	Rivers	958	21/09/1977	02/03/2011
69	**B81 90525**	-23.88028	30.36694	the Junction on Groot-Letaba	Rivers	736	20/11/1969	26/03/2010
70	**B81 90526**	-23.89222	30.35583	Letsitele River at Mohlaba S Reserve 567	Rivers	754	20/11/1969	08/04/2010
71	**B81 90527**	-23.88056	30.07972	at Grysappel on Groot Letaba	Rivers	510	21/11/1969	01/03/2011
73	**B83 90529**	-23.83861	31.64083	Great Letaba River at Engelhardt Dam/Kruger Nat P	Rivers	165	02/01/1990	06/09/2010
76	**B83 90536**	-23.64861	31.14722	Great Letaba River at Mahlangene/Kruger Nat Park	Rivers	726	09/11/1983	31/05/2011
79	**B82 90539**	-23.281	30.54306	Tabaan State Land on Klein-Letaba	Rivers	103	23/01/1996	05/04/2011
81	**B81 90542**	-23.81667	30.0625	Magoebaskloof Dam at Down Stream Weir on Politsi	Rivers	161	02/06/1983	04/08/2009
83	**B81 90546**	-23.8125	29.96667	Dap Naude Dam on Broederstroom Riv: Down Stream W	Rivers	85	30/04/1993	04/08/2009
85	**B81 90549**	-23.94583	29.98389	at Onverwacht Ebenezer Dam on Groot Letaba	Rivers	136	16/07/1998	07/04/2010
86	**B82 183878**	-23.312	30.68342	Giyani Upstream of STW near R81 Adolf Mhinga Bridge on Klein	Rivers	341	06/11/2001	01/03/2011
87	**B82 183879**	-23.3299	30.7064	Downstream of Giyani Sewage Works at Irrigation Abstraction	Rivers	838	06/11/2001	16/03/2010
88	**B81 187157**	-23.87478	30.27303	Letaba Downstream of Bridge on Groot Letaba	Rivers	384	13/08/2003	18/01/2010
89	**B81 187159**	-23.8992	30.3622	Berlyn Letsitele Tank on Ritshidele Stream	Rivers	393	13/08/2003	18/01/2010

No. on Fig 1	Water quality site	Latitude	Longitude	Description	Type	n	First date	Last date
90	**B81 187161**	-23.86781	30.26919	Letabasdrift on Marive Stream	Rivers	352	14/04/2004	18/01/2010
96	**B81 187689**	-23.8715	30.27068	Letaba Hospital near Valencia Estate at the Bridge on Great	Rivers	45	02/12/2003	16/03/2010
99	**B81 187692**	-23.86667	30.39222	the Junction 521 LT. South of the Gravelotte Tzaneen Road on	Rivers	48	03/12/2003	25/11/2008
107	**B83 188133**	-23.83419	31.63342	Makhadzi at Inflow to Engelhard Dam in Knp	Rivers	32	07/09/2004	10/04/2008
108	**B81 188196**	-23.82806	30.21861	Yamorna Weir Tzaneen on Groot-Letaba	Rivers	23	27/09/2004	26/01/2007
109	**B81 188764**	-23.80632	30.16473	Site 1 Downstream of Tzaneen Dam on Groot Letaba	Rivers	20	06/12/2005	12/10/2006
110	**B81 188765**	-23.8286	30.16713	Site 2 Manorvlei on Groot Letaba	Rivers	20	06/12/2005	12/10/2006
111	**B81 188766**	-23.8223	30.17442	Site 3 Manorvlei on Groot Letaba	Rivers	20	06/12/2005	12/10/2006
112	**B81 188767**	-23.8335	30.19203	Site 4 Lushof on Groot Letaba	Rivers	20	06/12/2005	12/10/2006
113	**B81 188768**	-23.8267	30.21913	Yamorna at Site 5 on Groot-Letaba	Rivers	20	06/12/2005	12/10/2006
114	**B82 190140**	-23.6314	30.21577	Ga-Kgapane Downstream of Sewage Treatment Works on Modubatse	Rivers	56	07/12/2004	16/03/2010
115	**B82 190141**	-23.63237	30.21691	Ga-Kgapane Upstream of Waste Water Treatment Works on Moduba	Rivers	50	07/12/2004	16/03/2010
116	**B81 190449**	-23.96281	30.27154	Lenyenye Location near R36 Road Upstream of Lenyenye Oxidat	Rivers	41	07/12/2004	16/03/2010
117	**B81 190450**	-23.96282	30.27922	Lenyenye Location near R36 Lydenburg Road Bridge Downstream	Rivers	46	12/07/2005	16/03/2010
118	**B81 191499**	-23.82287	30.17367	Tzaneen Pusela 555 LT. -Downstream of Tzaneen WWTW on	Rivers	40	15/01/2007	16/03/2010

No. on Fig 1	Water quality site	Latitude	Longitude	Description	Type	n	First date	Last date
				Groot				
119	**B81 191500**	-23.82202	30.1724	Tzaneen Pusela 555 LT. -Upstream of Tzaneen WWTW on Groot le	Rivers	40	15/01/2007	16/03/2010
120	**B81 191501**	-23.81717	30.20358	Tzaneen Lushof 540 LT. -near R71 on Groot Letaba	Rivers	30	12/10/2006	16/03/2010
121	**B81 191502**	-23.82587	30.16482	Tsaneen Pusela 555 LT. -at Taxi Rank near Tzaneen Mall on Gr	Rivers	50	12/10/2006	16/03/2010
124	**B90 90582**	-23.21528	31.22	at Silvervis Dam/Kruger Nat Park on Shingwedzi	Rivers	220	15/10/1991	21/04/2010
125	**B90 90583**	-23.13611	31.45472	at Kanniedood Dam Kruger Nat Park on Shingwedzi	Rivers	240	13/01/1990	04/04/2010
126	**B90 188499**	-23.00812	30.71813	Boltman 211 LT. -Malamulele Downstream of Malamulele STW Nea	Rivers	17	20/01/2009	23/02/2010
127	**B90 190155**	-23.00564	30.70083	Malamulele Upstream of Malamulele STW near Dept. of Agricult	Rivers	30	26/06/2007	23/02/2010
128	**B90 190183**	-23.00839	30.70203	Boltman 211 LT. -Malamulele Downstream Malamulele STW Bridge	Rivers	20	26/06/2007	07/07/2009
165	**A91 90405**	-23.10686	30.12506	Albasini Dam on Luvuvhu River: near Dam Wall Q01	Dam / Barrage	338	23/02/1966	03/08/2011
166	**A91 90406**	-22.94639	30.31444	Vondo Dam on Mutshindudi River: near Dam Wall Q01	Dam / Barrage	135	31/01/1990	20/01/2009
167	**A91 190095**	-22.98219	30.59897	Molenje S 204 LT. Nandoni Dam near Dam Wall on Luvuvhu Q01	Dam / Barrage	74	02/11/2007	26/07/2011
173	**B81 90550**	-23.9408	29.9851	Ebenezer Dam-Ebenezer Dam on Groot-Letaba: near Q01	Dam / Barrage	405	02/05/1968	22/06/2011
199	**B81 90576**	-23.7492	30.1076	Doornfontein 196 LT. -	Dam /	21	21/06/197	08/09/2

No. on Fig 1	Water quality site	Latitude	Longitude	Description	Type	n	First date	Last date
				Hans Merensky Dam on Ramadie Q01	Barrag e	6	3	009
200	**B81 90577**	-23.8162	30.0554	Turksvygbult 550 LT. - Magoebaskloof Dam on Politsi Q01	Dam / Barrag e	63 9	19/11/197 5	04/08/2 011
201	**B81 90578**	-23.8	30.16667	Doornhoek 535 LT. - Tzaneen Dam on Groot Letaba: Ne Q01	Dam / Barrag e	58 2	11/05/197 7	05/08/2 011
202	**B81 90579**	-23.8125	29.96667	Woodbush Reserve-Dap Naude Dam on Broederstroom: Q01	Dam / Barrag e	16 6	14/11/197 5	07/09/2 009
203	**B82 90580**	-23.274	30.4037	Sterkrivier 97 LT. - Middle Letaba Dam on Middel le Q01	Dam / Barrag e	17 5	06/02/199 6	10/07/2 011
204	**B82 90581**	-23.2545	30.77072	Nsami at Nsami Dam near Dam Wall Q01	Dam / Barrag e	11 6	16/01/199 6	10/07/2 011
206	**B82 185112**	-23.2995	30.532	Pallakop Irrigation Dam Extraction Point	Dam / Barrag e	31 8	06/11/200 1	22/12/2 009
145	**A91 177703**	-23.03694	30.27694	Livhungwa River: Barotta Canal	Canal	65	16/05/200 0	28/10/2 010
146	**A91 90400**	-23.055	30.245	Canal from Latonanda River at Levubu Settlement	Canal	52	30/05/198 6	28/04/2 010
152	**B81 90541**	-23.82222	30.05694	Turksvygbult on Left Canal from Magoebaskloof Dam	Canal	13 1	27/01/199 8	23/02/2 010
153	**B81 90544**	-23.8	30.16667	Tzaneen Dam on Great Letaba River: Left Canal	Canal	15 6	30/01/198 5	22/01/2 007
154	**B82 90547**	-23.27167	30.40306	Middle Letaba Dam on Mid. Letaba River: Right Can	Canal	20 8	29/12/198 6	25/02/2 010

Appendix B

Water quality data for main points

Station ID	TDS (mg/l)							EC (mS/m)							pH						
	Means	*N*	Std.Dev	Min	Max	5th	95th	Means	*N*	Std.Dev.	Min	Max	5th	95th	Means	*N*	Std.Dev.	Min	Max	5th	95th
A9H1	76.26	299.00	48.60	1.00	619.18	11.12	124.39	13.29	299.00	5.59	6.16	92.90	9.20	17.10	7.66	292.00	0.49	5.52	8.54	6.60	8.16
A9H2	69.49	212.00	32.35	1.00	175.00	9.00	114.10	11.17	212.00	3.29	3.90	22.50	5.70	15.70	7.70	202.00	0.42	5.90	8.54	6.80	8.17
A9H3	66.96	192.00	35.58	4.00	372.00	6.99	91.59	10.02	191.00	3.66	5.00	44.70	6.60	12.40	7.64	182.00	0.41	6.30	8.56	6.71	8.16
A9H4	47.81	150.00	20.70	3.40	116.00	5.00	78.40	8.31	150.00	2.10	4.20	17.60	5.60	11.80	7.41	140.00	0.45	5.82	8.55	6.37	8.00
A9H5	65.75	26.00	32.08	7.00	95.00	11.00	95.00	11.72	26.00	1.88	6.90	15.60	7.80	14.60	7.17	26.00	0.25	6.58	7.89	6.62	7.40
A9H6	41.95	61.00	15.51	3.00	67.00	5.00	56.00	6.67	61.00	1.54	4.90	16.90	5.30	7.50	7.00	60.00	0.78	4.02	8.71	5.86	7.89
A9H7	54.68	227.00	20.98	3.80	149.00	6.00	75.88	8.33	227.00	1.71	4.40	18.50	6.11	10.84	7.27	222.00	0.61	4.90	8.32	6.16	7.97
A9H8	74.38	662.00	45.84	1.00	513.00	8.00	138.17	14.10	661.00	4.62	5.60	74.30	8.90	20.60	7.57	663.00	0.61	1.00	8.81	6.52	8.29
A9H9	71.78	216.00	40.06	1.00	182.00	8.00	145.00	13.76	216.00	4.11	1.40	33.80	8.60	22.30	7.42	216.00	0.59	5.13	8.59	6.57	8.24
A9H10	79.37	223.00	51.52	1.00	371.00	9.00	162.00	15.35	223.00	6.18	6.10	54.70	9.50	26.60	7.39	223.00	0.56	5.81	8.64	6.46	8.27
A9H11	97.14	464.00	85.08	1.00	657.00	11.00	222.00	17.55	464.00	10.51	7.60	97.50	10.20	32.40	7.69	464.00	0.49	5.90	9.09	6.68	8.27
A9H12	78.80	411.00	48.13	1.00	219.00	11.00	142.45	14.81	411.00	3.33	6.90	32.70	9.70	20.00	7.89	411.00	0.32	5.60	8.50	7.28	8.23
A9H13	95.18	64.00	64.04	3.98	321.50	11.18	174.53	16.96	64.00	8.04	6.84	46.10	7.87	28.40	7.77	64.00	0.23	7.28	8.34	7.39	8.12
A9H15	39.45	65.00	15.84	4.24	79.64	4.73	64.26	6.71	65.00	1.56	5.53	16.10	5.69	9.18	7.56	65.00	0.22	6.69	8.17	7.24	7.87
A9H16	53.74	60.00	23.26	1.78	97.14	5.62	80.95	8.80	60.00	1.17	5.10	13.50	7.17	10.39	7.61	60.00	0.27	6.38	8.04	7.15	7.92
A9H17	136.26	41.00	73.06	17.00	228.00	17.00	211.00	25.12	41.00	2.60	20.30	30.70	20.40	29.40	7.50	41.00	0.36	6.70	8.29	6.80	7.90
A9H20	122.33	3.00	87.90	21.00	178.00	21.00	178.00	27.87	3.00	5.61	24.00	34.30	24.00	34.30	8.01	3.00	0.30	7.77	8.35	7.77	8.35
A9H24	30.57	115.00	9.85	3.00	76.78	3.64	41.46	4.77	115.00	0.96	3.16	10.43	3.55	6.08	7.26	115.00	0.36	5.15	7.93	6.70	7.77
A9H25	74.69	15.00	27.35	11.82	116.87	11.82	116.87	10.58	15.00	2.64	6.86	15.50	6.86	15.50	7.23	15.00	1.12	4.82	8.14	4.82	8.14
A9H26	33.84	26.00	19.74	2.31	93.80	2.94	91.70	5.66	26.00	2.40	3.50	13.40	3.58	13.10	7.16	26.00	0.75	4.34	7.94	5.49	7.88
A9H27	53.55	29.00	21.36	3.38	76.58	4.31	75.71	8.67	29.00	1.39	4.34	11.50	6.19	11.00	7.65	29.00	0.26	6.78	7.93	7.14	7.89
A9H30	96.10	13.00	80.44	11.60	313.60	11.60	313.60	17.83	13.00	8.31	11.46	44.80	11.46	44.80	7.73	12.00	0.29	7.07	8.11	7.07	8.11
A9R1	145.16	266.00	68.82	1.00	273.96	15.00	236.84	23.70	266.00	6.86	5.50	54.40	13.90	34.00	7.85	267.00	0.49	5.00	9.03	7.01	8.44
A9R2	30.39	150.00	17.31	2.14	159.00	3.00	51.63	5.21	150.00	3.22	3.00	35.80	3.55	8.50	7.27	150.00	0.46	5.51	8.33	6.33	7.94
A9R4	101.06	25.00	40.85	1.37	129.51	14.46	129.34	16.41	25.00	1.67	12.80	18.40	13.12	18.40	7.84	25.00	0.18	7.48	8.11	7.52	8.08
B8H2	37.48	4.00	22.19	5.00	54.60	5.00	54.60	6.95	4.00	0.70	6.10	7.80	6.10	7.80	7.07	4.00	0.45	6.48	7.50	6.48	7.50
B8H7	568.82	1.00	0.00	568.82	568.82	568.82	568.82	84.70	1.00	0.00	84.70	84.70	84.70	84.70	8.29	1.00	0.00	8.29	8.29	8.29	8.29
B8H8	220.75	811.00	161.86	1.00	998.00	17.00	527.91	40.02	811.00	23.00	5.90	153.40	14.70	84.80	7.72	780.00	0.54	5.03	8.75	6.75	8.42
B8H9	69.88	703.00	52.12	1.00	583.00	7.00	157.14	12.17	703.00	7.53	5.00	82.00	6.80	25.60	7.26	604.00	0.60	5.57	8.97	6.20	8.06
B8H10	132.51	694.00	85.63	1.00	426.00	13.00	289.00	22.64	694.00	9.88	4.60	60.80	10.00	41.50	7.63	513.00	0.52	5.21	8.63	6.73	8.28
B8H14	40.30	466.00	18.63	2.00	179.00	4.00	64.27	6.32	466.00	1.89	3.70	24.40	4.20	9.55	7.02	438.00	0.67	5.40	9.16	5.90	7.89
B8H17	130.82	132.0	72.72	12.00	278.00	14.00	239.00	23.75	132.00	7.10	9.00	39.90	12.70	35.40	7.19	124.00	0.62	4.92	8.42	6.32	8.24

Station ID	TDS (mg/l)							EC (mS/m)							pH						
		0																			
B8H18	295.86	173.00	232.66	3.00	911.91	22.00	758.52	47.73	173.00	24.21	13.60	130.00	20.90	106.40	8.14	173.00	0.45	6.08	8.91	7.00	8.65
B8H22	19.50	321.00	9.73	1.00	78.00	2.00	33.00	3.28	321.00	1.07	1.60	12.30	2.20	4.80	5.40	321.00	0.89	4.07	9.19	4.37	7.10
B8H23	26.52	321.00	13.96	2.00	193.00	3.00	42.00	4.55	321.00	4.80	2.40	85.10	2.90	6.20	6.13	321.00	0.71	4.33	8.77	4.98	7.31
B8H24	60.51	89.00	35.86	3.00	176.00	7.00	146.00	9.73	89.00	4.88	4.50	24.80	6.00	22.30	6.36	89.00	0.45	5.51	7.98	5.77	7.14
B8H25	78.28	89.00	61.26	5.00	452.00	7.00	155.00	12.68	89.00	9.04	6.00	64.00	6.80	24.80	6.46	89.00	0.46	5.65	7.89	5.74	7.17
B8H26	110.55	91.00	88.04	5.00	458.00	8.00	262.00	20.02	91.00	11.81	5.90	64.00	6.50	37.80	6.58	90.00	0.58	3.65	7.43	5.61	7.31
B8H27	126.03	87.00	81.86	2.00	447.00	16.00	251.00	20.51	87.00	12.00	6.30	64.00	7.00	37.90	6.73	87.00	0.48	5.52	7.91	5.88	7.40
B8H28	275.16	485.00	201.16	2.00	######	22.21	626.98	48.48	485.00	28.46	7.80	249.00	15.70	94.70	8.03	486.00	0.42	6.35	9.05	7.22	8.55
B8H29	179.25	36.00	118.81	12.00	451.00	12.00	385.00	31.75	36.00	11.88	9.10	59.50	13.50	58.60	7.71	36.00	0.48	6.69	8.70	6.70	8.32
B8H30	153.44	27.00	102.37	9.00	343.00	21.00	319.00	31.57	27.00	9.15	9.40	46.30	15.60	46.00	7.53	27.00	0.49	5.99	8.52	7.02	8.40
B8H31		0.00							0.00						7.40	1.00	0.00	7.40	7.40	7.40	7.40
B8H33	270.04	110.00	140.14	4.97	464.56	31.00	427.12	46.05	110.00	10.71	10.76	64.50	25.20	60.40	8.33	110.00	0.26	7.51	8.93	7.86	8.76
B8H43	76.87	3.00	49.48	47.60	134.00	47.60	134.00	11.83	3.00	7.62	6.80	20.60	6.80	20.60	7.95	2.00	0.26	7.76	8.13	7.76	8.13
B8H45	36.59	131.00	16.01	3.21	73.52	4.19	54.92	6.18	131.00	1.03	4.40	13.00	4.90	7.89	7.39	131.00	0.46	4.54	8.31	6.94	7.81
B8H46	41.43	161.00	22.25	3.00	237.96	4.26	64.68	6.51	161.00	2.69	3.80	35.60	4.80	8.65	7.44	154.00	0.37	5.48	8.47	6.70	7.87
B8H50	49.10	174.00	19.89	4.00	161.00	5.00	75.00	7.74	174.00	1.90	5.00	21.80	5.90	11.00	7.17	171.00	0.66	5.60	8.51	6.01	8.10
B8H51	50.99	156.00	16.60	4.00	93.00	6.45	71.86	7.71	156.00	1.33	5.74	14.40	6.20	10.20	7.56	155.00	0.23	6.57	8.55	7.21	7.88
B8H53	27.67	85.00	9.54	2.34	48.80	3.64	43.24	4.07	85.00	0.98	2.60	8.34	2.77	5.56	7.24	84.00	0.44	5.44	8.49	6.60	7.98
B8H54	176.17	218.00	93.35	3.16	375.00	21.14	331.68	28.43	218.00	11.06	7.20	50.50	13.70	45.70	8.01	217.00	0.39	6.50	8.64	7.05	8.44
B8H64	37.07	141.00	12.94	3.00	131.40	4.97	47.39	5.59	141.00	1.37	4.30	18.72	4.56	6.77	7.34	141.00	0.41	5.06	8.52	6.53	7.79
B8R1	32.92	232.00	12.60	2.00	83.00	3.70	51.00	5.13	232.00	1.24	3.30	13.30	3.70	7.20	6.95	228.00	0.64	4.68	9.08	5.90	7.90
B8R2	34.96	216.00	13.80	3.00	115.50	4.18	52.50	5.72	216.00	1.19	3.50	16.50	4.10	7.24	7.04	199.00	0.70	4.41	8.76	5.60	7.94
B8R3	35.92	240.00	12.92	3.00	76.27	4.00	52.86	5.51	240.00	1.04	3.80	12.50	4.10	7.00	7.05	212.00	0.64	5.09	8.46	5.66	7.80
B8R5	47.80	179.00	17.40	4.00	141.86	5.59	76.00	7.06	179.00	1.34	1.00	14.00	5.84	9.40	7.48	179.00	0.39	5.85	8.38	6.70	7.89
B8R6	20.83	164.00	8.61	2.00	56.00	2.00	32.00	3.11	164.00	0.89	1.00	7.60	2.10	4.60	6.54	144.00	0.86	3.26	10.04	5.29	7.74
B8R7	209.00	114.00	106.36	3.39	357.39	17.00	331.88	33.11	114.00	11.27	5.30	49.40	13.70	47.20	8.25	114.00	0.27	6.79	8.68	7.78	8.54
B8R9	145.88	118.00	80.64	2.00	289.73	13.21	249.79	25.56	118.00	6.69	10.90	43.00	12.60	36.10	8.07	118.00	0.29	7.14	8.55	7.46	8.42
B8R11	153.09	8.00	15.14	123.72	176.85	123.72	176.85	21.03	7.00	1.68	17.38	22.20	17.38	22.20	7.94	8.00	0.19	7.58	8.19	7.58	8.19
B9H2	289.13	237.00	293.19	1.00	######	13.00	952.64	47.80	237.00	40.47	7.40	205.00	10.30	141.00	8.11	237.00	0.48	6.29	8.88	6.97	8.64
B9H03	296.15	246.00	359.03	6.00	######	18.44	847.57	56.59	246.00	139.99	9.00	######	14.50	137.00	8.26	246.00	0.60	1.00	9.14	7.60	8.75

Station ID	Ca (mg/l)							Mg (mg/l)							Cl (mg/l)						
	Means	***N***	**Std.Dev.**	**Min**	**Max**	**5th**	**95th**	**Means**	***N***	**Std.Dev.**	**Min**	**Max**	**5th**	**95th**	**Means**	***N***	**Std.Dev.**	**Min**	**Max**	**5th**	**95th**
A9H1	8.05	279.00	2.37	3.80	28.85	5.00	11.60	5.38	279.00	1.91	1.80	31.28	3.70	7.30	8.54	281.00	9.60	1.50	160.57	4.30	12.39
A9H2	7.84	189.00	2.70	0.50	17.70	3.30	11.41	4.63	189.00	1.47	0.50	9.40	2.30	6.80	6.31	189.00	2.03	3.10	16.40	3.80	9.70
A9H3	6.82	180.00	3.09	1.70	33.70	3.65	9.42	4.27	180.00	1.77	1.80	20.00	2.27	5.89	6.13	179.00	1.91	2.00	18.10	3.70	9.60
A9H4	4.28	140.00	1.55	0.50	10.90	2.30	6.70	3.13	140.00	0.97	0.50	7.70	1.85	4.70	7.72	140.00	2.57	4.00	15.80	4.95	12.00
A9H5	7.12	26.00	1.81	4.20	11.70	4.60	10.30	5.45	26.00	1.14	2.00	6.80	3.00	6.80	4.72	26.00	2.64	1.50	11.00	1.50	9.60
A9H6	4.20	60.00	1.13	2.20	9.90	2.65	5.70	2.85	60.00	0.72	1.60	5.00	1.85	4.30	4.08	60.00	3.17	1.50	22.00	1.50	7.65
A9H7	5.31	221.00	2.16	2.00	18.60	2.80	8.22	3.38	221.00	0.93	1.00	10.00	2.14	4.70	5.40	221.00	2.03	1.50	14.60	1.50	9.00
A9H8	8.18	649.00	2.25	1.50	21.60	4.80	12.20	5.73	649.00	2.14	0.50	30.60	3.00	9.00	11.19	649.00	5.21	1.50	102.70	6.00	17.40
A9H9	8.47	206.00	3.07	0.50	21.80	5.30	14.20	5.46	206.00	1.68	0.50	14.30	3.30	8.30	11.98	206.00	3.63	1.50	33.60	8.00	18.00
A9H10	8.11	218.00	3.59	3.50	25.80	4.60	15.40	5.63	218.00	2.71	2.40	24.70	3.10	10.90	18.26	218.00	8.41	8.90	71.00	10.50	34.40
A9H11	9.59	457.00	4.38	4.30	31.01	5.50	19.10	6.80	457.00	4.30	2.20	40.43	3.70	14.10	16.28	458.00	13.24	2.00	147.56	8.40	28.09
A9H12	9.79	396.00	2.30	3.20	16.31	6.20	13.59	6.17	396.00	1.54	2.00	10.70	3.70	8.67	9.05	398.00	2.99	3.50	22.10	4.90	13.22
A9H13	8.41	64.00	4.55	1.68	25.15	3.12	15.53	5.60	64.00	2.93	1.72	16.46	1.93	9.77	19.05	64.00	10.02	3.84	55.10	8.72	34.97
A9H15	4.64	64.00	1.69	2.73	13.68	3.08	7.02	2.22	65.00	0.88	0.75	5.80	0.75	3.42	5.42	65.00	1.09	2.00	10.76	4.39	7.02
A9H16	5.89	60.00	1.14	3.05	8.50	4.13	7.76	3.29	60.00	0.80	0.75	5.13	1.91	4.46	5.52	59.00	1.45	2.00	11.44	2.00	8.33
A9H17	16.92	39.00	2.29	13.30	21.90	13.70	21.40	12.46	39.00	1.74	10.10	15.80	10.10	15.80	14.61	39.00	2.65	10.60	26.10	10.70	17.30
A9H20	19.25	2.00	1.34	18.30	20.20	18.30	20.20	12.05	2.00	4.45	8.90	15.20	8.90	15.20	16.63	3.00	5.78	13.00	23.30	13.00	23.30
A9H24	3.02	102.00	1.06	1.24	7.89	1.90	4.47	1.54	102.00	0.48	0.50	4.40	0.50	2.03	4.83	102.00	1.01	2.50	8.47	2.50	6.56
A9H25	7.13	15.00	2.07	3.49	10.94	3.49	10.94	4.43	15.00	1.27	2.46	6.83	2.46	6.83	6.76	15.00	2.25	3.90	11.71	3.90	11.71
A9H26	2.66	24.00	0.82	0.50	4.01	1.47	3.85	1.10	24.00	0.59	0.75	2.99	0.75	1.91	5.29	24.00	1.96	2.00	13.03	3.62	7.08

Station ID	Ca (mg/l)							Mg (mg/l)							Cl (mg/l)						
A9H27	5.62	28.00	1.45	2.72	8.55	2.98	8.31	2.98	28.00	1.04	0.75	4.79	0.75	4.77	5.57	28.00	1.24	2.00	8.94	4.06	7.21
A9H30	10.40	8.00	2.69	6.62	13.74	6.62	13.74	6.20	6.00	0.63	5.21	6.95	5.21	6.95	9.44	14.00	1.72	6.80	12.35	6.80	12.35
A9R1	16.34	258.00	5.30	3.70	40.00	8.60	25.15	11.45	258.00	3.80	2.66	22.33	6.00	17.30	13.94	261.00	6.36	4.00	57.00	6.00	23.20
A9R2	2.75	138.00	2.48	1.22	26.43	1.58	5.03	1.96	138.00	1.69	0.50	18.38	1.00	3.20	5.57	138.00	2.34	1.50	21.71	3.60	8.60
A9R4	11.34	21.00	1.99	7.86	14.55	8.05	14.49	6.40	22.00	1.21	3.98	8.95	4.13	8.20	10.32	24.00	1.71	6.87	13.90	7.61	12.86
B8H2	3.58	4.00	0.72	2.50	4.00	2.50	4.00	1.73	3.00	0.38	1.30	2.00	1.30	2.00	6.17	3.00	4.31	1.50	10.00	1.50	10.00
B8H7	36.80	1.00	0.00	36.80	36.80	36.80	36.80	27.14	1.00	0.00	27.14	27.14	27.14	27.14	159.53	1.00	0.00	159.53	159.53	159.53	159.53
B8H8	18.60	750.00	7.80	2.90	46.60	8.60	33.79	12.30	750.00	7.20	1.00	45.90	4.08	27.30	52.84	752.00	43.07	5.00	274.50	12.50	140.19
B8H9	7.45	602.00	4.72	1.30	46.60	3.70	15.56	3.99	602.00	3.02	0.50	33.40	1.90	8.40	11.31	602.00	10.64	1.50	106.70	3.20	31.60
B8H10	14.72	490.00	6.59	2.70	45.90	6.00	26.50	8.57	490.00	4.11	0.50	33.60	3.80	16.40	14.16	488.00	10.05	1.50	69.80	3.90	33.60
B8H14	3.48	434.00	1.92	0.50	24.30	1.70	5.94	1.91	434.00	0.85	0.50	11.60	0.75	3.00	4.81	436.00	2.34	1.50	18.00	1.50	8.30
B8H17	14.42	123.00	4.47	4.80	25.10	7.70	22.00	8.78	123.00	2.94	2.40	15.40	4.20	13.20	25.45	123.00	8.22	8.30	51.20	12.70	39.70
B8H18	26.60	171.00	11.95	8.00	63.10	11.50	56.80	20.28	171.00	15.07	3.70	60.10	6.40	56.10	44.97	172.00	38.60	9.54	188.25	14.10	153.17
B8H22	1.03	317.00	1.11	0.50	8.60	0.50	2.70	0.56	317.00	0.24	0.50	3.00	0.50	1.00	4.21	317.00	1.79	1.50	17.70	1.50	6.80
B8H23	1.48	315.00	1.51	0.50	20.20	0.50	2.70	0.77	315.00	1.47	0.50	24.50	0.50	1.30	5.57	315.00	7.77	1.50	137.00	1.50	7.90
B8H24	5.98	89.00	3.04	1.10	17.40	3.10	13.10	3.00	89.00	1.90	0.50	8.90	1.40	8.20	7.84	89.00	5.66	1.50	28.00	3.00	21.30
B8H25	7.51	89.00	4.87	3.00	37.00	3.50	14.20	3.89	89.00	2.85	1.00	19.10	1.80	8.60	11.73	89.00	13.08	3.60	95.30	4.10	24.90
B8H26	11.46	90.00	6.65	1.90	37.40	3.50	22.10	7.03	90.00	4.43	1.00	19.20	1.70	14.70	19.51	90.00	15.28	3.00	97.70	4.00	38.40
B8H27	11.97	87.00	6.83	3.00	35.00	3.50	21.70	7.32	87.00	4.54	1.00	19.10	1.70	14.60	20.10	87.00	15.32	3.30	94.90	3.90	38.20
B8H28	22.58	483.00	10.10	4.30	93.08	8.70	36.90	16.29	482.00	9.58	1.40	71.95	4.40	32.97	65.68	486.00	53.96	4.30	299.70	13.20	168.58
B8H29	18.02	35.00	5.95	4.70	28.70	8.00	27.40	10.72	35.00	4.38	2.50	21.10	4.10	18.30	34.18	35.00	18.01	3.90	84.20	13.00	82.20
B8H30	19.95	27.00	6.64	6.30	32.50	9.40	30.30	10.76	27.00	3.78	2.40	17.60	3.90	16.80	28.11	27.00	7.06	18.50	46.20	19.20	41.60
B8H31		0.00							0.00							0.00					
B8H33	26.16	101.00	6.04	6.11	40.44	13.39	33.81	24.36	101.00	7.22	2.93	40.28	12.37	33.93	36.38	101.00	14.53	6.60	74.05	15.50	60.23
B8H43	8.95	2.00	7.00	4.00	13.90	4.00	13.90	5.05	2.00	3.89	2.30	7.80	2.30	7.80	7.70	2.00	0.57	7.30	8.10	7.30	8.10
B8H45	3.67	127.00	0.93	1.38	6.51	2.27	5.10	1.65	128.00	0.57	0.50	3.85	0.75	2.34	5.10	130.00	1.21	2.00	12.21	2.50	6.63
B8H46	4.15	154.00	1.99	1.79	21.35	2.35	6.94	2.04	154.00	1.14	0.75	14.15	1.29	3.16	5.43	154.00	2.35	1.50	26.14	2.50	8.36
B8H50	4.67	170.00	1.99	1.90	20.30	3.10	7.40	2.33	170.00	1.02	0.50	12.20	1.30	3.60	6.20	170.00	2.48	1.50	14.20	1.50	10.70
B8H51	4.59	155.00	1.17	1.98	8.67	2.76	7.40	2.30	155.00	0.55	1.00	5.94	1.67	3.20	5.64	155.00	1.22	2.00	10.48	4.40	8.20
B8H53	2.66	85.00	1.30	0.50	7.82	0.50	4.49	0.95	85.00	0.57	0.50	4.09	0.50	1.89	4.63	85.00	1.27	2.00	8.20	2.50	6.65
B8H54	19.01	202.00	7.06	3.70	36.67	8.70	30.16	10.93	203.00	4.51	2.40	22.24	5.00	18.04	17.60	203.00	10.41	3.60	38.21	5.70	34.37
B8H64	3.28	140.00	1.07	0.50	8.22	2.07	5.21	1.60	141.00	0.76	0.50	8.62	0.75	2.12	5.16	139.00	0.91	2.50	8.78	3.92	6.86
B8R1	2.80	226.00	2.12	0.50	21.40	1.00	4.60	1.54	226.00	0.63	0.50	4.00	0.50	2.50	4.40	226.00	2.22	1.50	12.60	1.50	8.60
B8R2	2.85	199.00	1.15	0.50	11.20	1.30	4.47	1.30	199.00	0.60	0.50	5.80	0.50	2.00	6.09	199.00	1.83	1.50	11.20	3.60	9.20
B8R3	2.95	211.00	0.97	0.50	9.30	1.60	4.40	1.59	211.00	0.53	0.50	5.09	0.75	2.30	4.92	211.00	2.13	1.50	11.80	1.50	9.10
B8R5	4.18	179.00	1.28	0.50	10.65	2.80	6.82	2.14	179.00	0.66	0.75	6.18	1.30	3.45	5.65	179.00	2.31	1.50	28.20	3.40	8.60
B8R6	1.33	143.00	0.88	0.50	6.60	0.50	2.50	0.74	143.00	0.40	0.50	2.00	0.50	1.60	3.28	143.00	1.81	1.50	11.51	1.50	6.00
B8R7	22.18	108.00	7.17	4.20	34.57	8.60	30.96	12.75	108.00	4.86	1.40	20.47	4.60	18.92	22.84	110.00	11.49	4.30	59.81	6.10	35.27
B8R9	16.39	112.00	4.16	7.10	27.28	8.50	23.31	8.60	112.00	2.83	3.20	16.83	3.94	13.72	16.79	113.00	7.62	4.90	33.12	5.90	28.71
B8R11	13.27	7.00	1.09	11.34	14.90	11.34	14.90	5.93	7.00	0.70	4.96	6.94	4.96	6.94	16.81	7.00	0.98	15.22	17.98	15.22	17.98
B9H2	24.71	237.00	13.69	4.05	92.51	5.90	46.27	18.61	237.00	16.61	0.75	91.31	3.80	52.18	48.53	237.00	72.05	3.60	579.90	5.80	210.56
B9H03	26.86	244.00	10.18	5.70	73.50	9.70	43.00	17.19	244.00	13.34	2.70	90.94	4.30	45.27	45.02	244.00	73.31	1.50	587.50	5.10	205.86

Station ID	PO4 (mg/l)							NO2-NO3 as N (mg/l)							NH4 as N (mg/l)						
	Means	***N***	**Std.Dev.**	**Min**	**Max**	**5th**	**95th**	**Means**	***N***	**Std.Dev.**	**Min**	**Max**	**5th**	**95th**	**Means**	***N***	**Std.Dev.**	**Min**	**Max**	**5th**	**95th**
A9H1	0.02	289.00	0.02	0.00	0.18	0.00	0.05	0.23	292.00	0.41	0.02	6.74	0.02	0.46	0.04	288.00	0.05	0.02	0.71	0.02	0.09
A9H2	0.04	201.00	0.09	0.00	1.01	0.01	0.09	0.22	201.00	0.17	0.02	0.74	0.02	0.55	0.04	201.00	0.03	0.02	0.21	0.02	0.09
A9H3	0.02	176.00	0.02	0.00	0.20	0.01	0.05	0.31	172.00	0.22	0.02	1.42	0.02	0.69	0.04	178.00	0.02	0.02	0.11	0.02	0.08
A9H4	0.02	138.00	0.03	0.00	0.29	0.00	0.04	0.22	138.00	0.15	0.02	0.82	0.02	0.53	0.04	138.00	0.02	0.02	0.11	0.02	0.09
A9H5	0.01	24.00	0.01	0.00	0.02	0.00	0.02	0.08	26.00	0.11	0.02	0.48	0.02	0.31	0.04	23.00	0.03	0.02	0.16	0.02	0.09
A9H6	0.01	59.00	0.01	0.00	0.11	0.00	0.03	0.10	60.00	0.09	0.02	0.44	0.02	0.29	0.03	59.00	0.02	0.02	0.16	0.02	0.06
A9H7	0.02	218.00	0.02	0.00	0.27	0.00	0.04	0.20	220.00	0.18	0.02	1.24	0.02	0.56	0.05	218.00	0.12	0.02	1.72	0.02	0.12
A9H8	0.02	647.00	0.04	0.00	0.51	0.00	0.06	0.21	647.00	0.26	0.01	2.35	0.02	0.73	0.06	647.00	0.06	0.00	1.32	0.02	0.12
A9H9	0.02	206.00	0.03	0.00	0.22	0.00	0.07	0.17	206.00	0.22	0.02	1.30	0.02	0.67	0.06	206.00	0.05	0.02	0.39	0.02	0.14
A9H10	0.03	218.00	0.10	0.00	1.03	0.00	0.07	0.15	218.00	0.25	0.02	1.59	0.02	0.69	0.06	218.00	0.03	0.02	0.23	0.02	0.12
A9H11	0.04	458.00	0.34	0.00	7.27	0.01	0.08	0.17	452.00	0.25	0.01	1.83	0.02	0.61	0.05	458.00	0.08	0.02	1.40	0.02	0.12
A9H12	0.03	398.00	0.13	0.00	2.53	0.01	0.06	0.22	397.00	0.22	0.02	2.28	0.02	0.59	0.04	410.00	0.05	0.02	0.78	0.02	0.08
A9H13	0.02	63.00	0.06	0.01	0.45	0.01	0.04	0.07	63.00	0.08	0.01	0.39	0.01	0.22	0.06	63.00	0.07	0.02	0.54	0.02	0.12
A9H15	0.02	64.00	0.02	0.01	0.14	0.01	0.07	0.16	64.00	0.15	0.02	0.93	0.03	0.34	0.05	65.00	0.13	0.02	1.02	0.02	0.12
A9H16	0.01	57.00	0.01	0.01	0.09	0.01	0.04	0.15	48.00	0.11	0.02	0.50	0.03	0.30	0.04	58.00	0.03	0.02	0.20	0.02	0.11
A9H17	0.01	39.00	0.01	0.00	0.03	0.00	0.02	0.10	41.00	0.10	0.02	0.44	0.02	0.25	0.06	39.00	0.05	0.02	0.27	0.02	0.18
A9H20	0.07	3.00	0.11	0.00	0.20	0.00	0.20	0.03	2.00	0.02	0.02	0.04	0.02	0.04	0.07	5.00	0.09	0.02	0.23	0.02	0.23
A9H24	0.02	115.00	0.02	0.00	0.10	0.00	0.04	0.12	115.00	0.06	0.02	0.43	0.02	0.25	0.08	115.00	0.12	0.02	0.84	0.02	0.22
A9H25	0.01	15.00	0.01	0.01	0.03	0.01	0.03	0.12	15.00	0.09	0.03	0.31	0.03	0.31	0.03	15.00	0.02	0.02	0.07	0.02	0.07
A9H26	0.01	24.00	0.01	0.01	0.04	0.01	0.03	0.10	23.00	0.10	0.03	0.41	0.03	0.33	0.05	27.00	0.03	0.03	0.14	0.03	0.10

Station ID	PO4 (mg/l)							NO2-NO3 as N (mg/l)							NH4 as N (mg/l)						
A9H27	0.01	26.00	0.01	0.01	0.02	0.01	0.02	0.18	27.00	0.14	0.01	0.65	0.01	0.37	0.05	27.00	0.07	0.03	0.37	0.03	0.13
A9H30	0.12	15.00	0.10	0.01	0.20	0.01	0.20	0.17	12.00	0.09	0.03	0.30	0.03	0.30	0.07	11.00	0.07	0.03	0.21	0.03	0.21
A9R1	0.02	242.00	0.03	0.00	0.20	0.00	0.05	0.10	259.00	0.10	0.01	0.65	0.02	0.28	0.04	235.00	0.04	0.02	0.24	0.02	0.13
A9R2	0.03	150.00	0.14	0.00	1.70	0.00	0.03	0.09	150.00	0.08	0.02	0.39	0.02	0.26	0.07	150.00	0.06	0.02	0.35	0.02	0.18
A9R4	0.01	24.00	0.01	0.01	0.03	0.01	0.03	0.07	24.00	0.12	0.01	0.47	0.01	0.38	0.10	24.00	0.14	0.02	0.68	0.03	0.24
B8H2	0.01	2.00	0.01	0.01	0.01	0.01	0.01	0.03	4.00	0.03	0.02	0.07	0.02	0.07	0.04	1.00	0.00	0.04	0.04	0.04	0.04
B8H7	0.02	1.00	0.00	0.02	0.02	0.02	0.02	1.58	1.00	0.00	1.58	1.58	1.58	1.58	0.02	1.00	0.00	0.02	0.02	0.02	0.02
B8H8	0.02	752.00	0.04	0.00	0.47	0.00	0.07	0.26	752.00	0.33	0.02	3.96	0.02	0.85	0.06	752.00	0.07	0.02	0.78	0.02	0.16
B8H9	0.09	599.00	1.74	0.00	42.51	0.00	0.05	0.36	595.00	0.43	0.02	5.85	0.02	0.88	0.05	588.00	0.06	0.02	0.70	0.02	0.11
B8H10	0.15	506.00	0.30	0.00	2.48	0.00	0.77	0.75	498.00	1.32	0.02	12.04	0.02	2.95	0.06	496.00	0.10	0.02	0.92	0.02	0.16
B8H14	0.02	435.00	0.03	0.00	0.34	0.00	0.03	0.10	434.00	0.09	0.02	0.91	0.02	0.23	0.06	435.00	0.35	0.02	7.07	0.02	0.13
B8H17	0.01	123.00	0.02	0.00	0.19	0.00	0.05	0.23	122.00	0.15	0.02	0.60	0.02	0.54	0.06	123.00	0.08	0.02	0.63	0.02	0.20
B8H18	0.03	172.00	0.04	0.00	0.45	0.01	0.07	0.29	172.00	0.64	0.01	7.05	0.01	1.15	0.57	172.00	1.43	0.02	6.53	0.02	5.24
B8H22	0.01	317.00	0.02	0.00	0.38	0.00	0.02	0.03	321.00	0.05	0.02	0.44	0.02	0.07	0.05	317.00	0.04	0.02	0.46	0.02	0.11
B8H23	0.01	315.00	0.02	0.00	0.29	0.00	0.02	0.07	321.00	0.14	0.02	2.03	0.02	0.18	0.05	315.00	0.03	0.02	0.36	0.02	0.09
B8H24	0.01	89.00	0.01	0.00	0.04	0.00	0.01	0.15	89.00	0.15	0.02	0.65	0.02	0.48	0.04	89.00	0.02	0.02	0.08	0.02	0.07
B8H25	0.01	89.00	0.01	0.00	0.07	0.00	0.03	0.16	89.00	0.17	0.02	0.88	0.02	0.48	0.04	89.00	0.02	0.02	0.09	0.02	0.08
B8H26	0.01	90.00	0.01	0.00	0.04	0.00	0.02	0.15	90.00	0.14	0.02	0.88	0.02	0.42	0.04	90.00	0.04	0.02	0.32	0.02	0.09
B8H27	0.01	87.00	0.02	0.00	0.11	0.00	0.03	0.19	87.00	0.35	0.02	2.80	0.02	0.56	0.04	87.00	0.02	0.02	0.11	0.02	0.10
B8H28	0.03	486.00	0.03	0.00	0.35	0.01	0.07	0.16	482.00	0.26	0.01	2.74	0.02	0.63	0.08	486.00	0.21	0.02	3.41	0.02	0.25
B8H29	0.04	35.00	0.06	0.00	0.35	0.00	0.15	0.33	35.00	0.35	0.02	1.27	0.02	1.10	0.08	35.00	0.04	0.02	0.19	0.02	0.18
B8H30	0.05	27.00	0.04	0.01	0.15	0.01	0.11	0.51	27.00	0.38	0.02	1.22	0.02	1.05	0.07	27.00	0.07	0.02	0.41	0.02	0.12
B8H31	2.70	1.00	0.00	2.70	2.70	2.70	2.70		0.00						18.90	1.00	0.00	18.90	18.90	18.90	18.90
B8H33	0.03	109.00	0.02	0.01	0.19	0.01	0.06	0.10	106.00	0.17	0.02	1.06	0.02	0.40	0.04	109.00	0.03	0.02	0.19	0.02	0.10
B8H43	0.01	2.00	0.00	0.01	0.01	0.01	0.01	0.02	2.00	0.00	0.02	0.02	0.02	0.02	0.04	2.00	0.03	0.02	0.07	0.02	0.07
B8H45	0.02	131.00	0.01	0.00	0.08	0.01	0.03	0.16	128.00	0.15	0.02	0.56	0.02	0.49	0.25	131.00	0.20	0.02	1.21	0.02	0.65
B8H46	0.01	154.00	0.01	0.00	0.06	0.01	0.03	0.19	153.00	0.14	0.02	0.56	0.02	0.44	0.04	153.00	0.06	0.02	0.71	0.02	0.08
B8H50	0.01	170.00	0.01	0.00	0.04	0.00	0.03	0.13	171.00	0.10	0.02	0.78	0.02	0.29	0.12	170.00	0.11	0.02	0.56	0.02	0.35
B8H51	0.02	155.00	0.04	0.00	0.38	0.01	0.04	0.15	155.00	0.15	0.02	1.30	0.02	0.39	0.16	155.00	0.16	0.02	0.72	0.02	0.50
B8H53	0.02	85.00	0.04	0.01	0.37	0.01	0.03	0.21	83.00	0.10	0.04	0.42	0.04	0.36	0.15	85.00	0.17	0.02	0.90	0.02	0.57
B8H54	0.02	214.00	0.04	0.00	0.40	0.00	0.06	0.16	209.00	0.32	0.02	4.22	0.02	0.52	0.06	215.00	0.07	0.02	0.63	0.02	0.19
B8H64	0.02	137.00	0.02	0.00	0.22	0.01	0.03	0.15	138.00	0.17	0.01	1.23	0.02	0.45	0.07	138.00	0.06	0.02	0.31	0.02	0.20
B8R1	0.01	212.00	0.01	0.00	0.07	0.00	0.03	0.08	227.00	0.11	0.01	1.26	0.02	0.23	0.08	202.00	0.08	0.02	0.49	0.02	0.25
B8R2	0.02	196.00	0.02	0.00	0.13	0.00	0.05	0.14	196.00	0.15	0.01	0.77	0.02	0.47	0.05	195.00	0.04	0.02	0.21	0.02	0.13
B8R3	0.01	211.00	0.01	0.00	0.06	0.00	0.03	0.17	210.00	0.14	0.01	0.65	0.02	0.40	0.05	207.00	0.07	0.02	0.90	0.02	0.11
B8R5	0.01	179.00	0.01	0.00	0.17	0.00	0.03	0.09	177.00	0.10	0.01	0.53	0.02	0.29	0.06	179.00	0.07	0.02	0.35	0.02	0.20
B8R6	0.02	143.00	0.04	0.00	0.49	0.00	0.04	0.23	142.00	0.14	0.02	0.94	0.02	0.42	0.04	138.00	0.03	0.02	0.22	0.02	0.10
B8R7	0.02	113.00	0.03	0.01	0.25	0.01	0.05	0.10	113.00	0.15	0.01	0.90	0.02	0.45	0.04	113.00	0.03	0.02	0.16	0.02	0.11
B8R9	0.03	115.00	0.07	0.01	0.72	0.01	0.06	0.14	116.00	0.13	0.01	0.53	0.02	0.40	0.05	116.00	0.05	0.02	0.50	0.02	0.12
B8R11	0.01	7.00	0.00	0.01	0.02	0.01	0.02	0.06	7.00	0.09	0.01	0.25	0.01	0.25	0.03	7.00	0.03	0.03	0.09	0.03	0.09
B9H2	0.05	237.00	0.06	0.00	0.50	0.01	0.20	0.38	237.00	0.92	0.01	8.04	0.02	1.30	0.32	237.00	1.62	0.02	19.85	0.02	0.69
B9H03	0.05	244.00	0.12	0.00	1.67	0.01	0.15	3.29	244.00	45.83	0.01	716.10	0.02	1.17	0.21	244.00	1.14	0.02	17.42	0.02	0.52