Situation Analysis of the Health-Related Water Quality Problems of the Umtata River

The report of a project funded by the Water Research Commission (Water Quality Monitoring to Fulfill the Needs of Integrated Catchment Management in a Densely Populated Rural Catchment)

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EXECUTIVE SUMMARY

1 Introduction

The National Water Act (NWA), 1998 (Act 36 of 1998) provided for the establishment of catchment agencies with the following functions:

a) To investigate and advise on the protection, use, development, conservation, management and control of water resources in its water management areas.

b) To develop a catchment management strategy

c) To coordinate the related activities of the water management institutions within management areas.

The new Integrated Catchment Management (ICM) plan in the NWA is a bold plan of government to bring water management to participatory level. The Umtata River is one of the designated catchment management areas in South Africa (it falls into the Mzimvubu to Keiskamma Water Management Area).

The Umtata River provides water and a conduit for effluent disposal in a densely populated area of Eastern Cape. The catchment supports a rapidly growing population in which Umtata is the main town. Other towns in the study area are Mqanduli, Ngqeleni, Libode and Elliotdale. Other large informal settlements located in the catchments are Tabase, Tipini, Pollar Park and Kambi, all situated along the riverbanks. Population numbers and rate of change in the catchment are at present in a state of uncertainty.

The Umtata River rises in the plateau region of the Eastern Cape, approximately midway between the Drakensberg escarpment and the sea (Fig. 1). Its catchment is some 100 km long and up to 50 km in breadth. The main tributary of the Umtata River is the Ngqungdu River that enters the main river on the right-bank about 27 km from the coast. State owned dams in the catchment are the Mabeleni Dam in the headwaters supplying Mhlahlane Rural Water Scheme, Corana Dam supplying a large population north east of Umtata, Mlanga Dam, supplying the Libode Rural Water Supply Scheme and the very large Umtata Dam which supplies the Umtata Municipality Water Supply Scheme and Eskom's First and Second Fall hydro-power stations.

The catchment is generally undulating, hilly and broken towards the coast with a steep escarpment at the headwaters. In the vicinity of Umtata the river flows through a wide plain with a flat gradient; further downstream the river is incised in a deep gorge. The geology of the catchment is constituted by mudstones of the Beaufort Group from the headwaters to about 30 km from the coast and hence by shales, mudstones and sandstones of the Ecca Group, with extensive exposures of dolerite intrusions mostly in the higher lying areas. There are scattered deposits of alluvium in some of the valleys.

Soils in the catchment are moderate to deep and vary between sandy loam in the upper half to clayey loam in the downstream half.

There are extensive pine plantations in the headwaters, with a total area of 5 100 ha. Natural vegetation is temperate with transitional forest and scrub in the upper half of the catchment, coastal tropical forest in the downstream part and tropical bush and savanna in the deeper river valleys.

Sediment yield of the catchment is in the moderate range, decreasing in the downstream direction from about 300 to 1150 t/a/ha. However, it has been noted that donga erosion in the vicinity of Umtata both upstream and downstream of Umtata Dam is severe, due possibly to the nature of the soil and the increased run-off from settlements.

The management of the Umtata River and its water resources has been giving cause for concern for many years. Data has been very scanty about water quality in the river. However, the deterioration in water quality in the middle and lower reaches of the river has given rise to worries that water supplied from the river will be unfit for domestic use or that water treatment will have to become more sophisticated and more expensive. Of particular concern is the health of the communities along the banks of the river that depend on it primarily for their domestic water supply.

2 Aims

The initial aim of the project was to carry out a water quality-monitoring programme to fulfill the needs of integrated catchment management for the Umtata River. Other subsidiary aims of the project were to identify the primary and secondary users and uses of water in the catchment, to identify the major sources of pollution and to identify facilities and options for ensuring that the water is safe for use.

However, due to lack of human resources, the initial objective could not be met, instead a situation analysis of health-related water quality problems in the river was carried out using the assessment and interpretation of water quality guidelines (DWAF, 1996b-h; Quality of Domestic Water Supplies, 1998). The information from this study would form the basis for a programme of catchment management for the river.

3. Methodology

A questionnaire approach was used to identify the uses and users of water from the river. The sampling sites (ten) for water tests were chosen to reflect the different activities along the river course, upstream to downstream. Samples for chemical and microbiological analyses were collected according to the standard procedures described in the sampling guides (Quality of Domestic Water Supplies, 1999; DWAF, 1992). The pH, conductivity, total dissolved solids (TDS), and turbidity were performed using the pH, conductivity and turbidity meters, respectively. Nitrate, phosphate and sulphate were determined using the Nova 60 Water Analyzer while chloride was determined by standard argentometric method. Total hardness of water samples were determined by EDTA titration and heavy metals by standard spectro-photometric methods (Basset et al., 1978; Van Loon, 1982; Fries and Getrost, 1977; DWAF, 1992). Faecal and total coliform counts were performed using the membrane filtration method (DWAF, 1992).

4. Objectives reached

The following objectives have been reached:

- The uses and users of water from the river were identified
- The current water quality in the river were assessed
- Major sources of pollution to the river were identified
- Facilities and options were identified that would ensure that the water is safe for use
- Recommendations were made for the design of a water quality monitoring programme for the integrated catchment management in the River Catchment

5. Results

5.1 Users and uses of water in the Catchment

Water supplies in the catchment are mainly derived from four dams, but the Umtata River meets the main supply to Umtata. The questionnaire method was used to identify the users and uses of water in the catchment. A household structured questionnaire was designed and translated into local Xhosa language and was administered house to house by trained interviewers.

The major primary user of water from the Umtata River is the Umtata Municipality. The municipality supplies all other secondary users in the catchment with treated water abstracted from the river. There are other primary users, among the local people at informal settlements situated along the riverbanks - Tabase, Kambi, Pollar Park and

Mhlanhlane locations and at Norwood in central Umtata. They use raw water directly from Umtata River for domestic and recreational purposes.

The main uses of water from the river are for domestic (cooking, drinking and washing), agricultural, that is, livestock watering (irrigation is rarely practiced in the catchment) and recreational purposes (swimming). Other uses include aquaculture (agricultural) and industrial (cooling of engines in the wood industry) although, these are less significant. Almost all the respondents to the questionnaire use water from the Umtata River as domestic water supply.

5.2 Incidence of water related diseases

The incidence of diarrhoea seemed very prevalent in the catchment. From the results of the questionnaire, 100 % of respondents from Pollar Park, 99 % from Tabase, 49 % from Tipini, 47 % from Norwood, 39 % from Mhlanhlane and 31 % from Kanbi locations have suffered from diarrhoea. However, the incidence of diarrhoea was not correlated to the age of sufferer which is a limitation.

5.3 Diffuse and point sources into the River

The major point sources of pollution into the river are:

i) Effluent discharge from the Umtata Sewage Treatment Works

ii) Effluent discharge from the old sewage ponds near the Umtata prison

iii) Raw sewage discharge from Langeni Forest Industry

Waste disposal sites situated on or near the riverbanks are suspected of producing polluted seepage during local rainfall events. Diffuse sources are storm water runoffs from agricultural lands and from numerous settlements located near the riverbanks. These informal settlements have little or no sanitation.

5.4. The Water Quality Situation in the Umtata River

The major problems with the river are the total and faecal coliforms, turbidity, nutrient and cadmium levels. The problems are particularly severe in the middle and lower reaches of the river. The faecal coliform counts varied between 0 – 21 000/100 ml while the total coliforms counts varied between 0 – 69 000/100 ml. Turbidity ranged from 0.28 – 1899 NTU while the cadmium levels varied between 0.018 - 0.26 mg/l. Nutrient levels are equally high as nitrate varied between 0.01 mg /ml and 28 mg/l as N while phosphate levels ranged from 0.02 - 3.81 mg P/ml.

5.5 Effects of Rural and Peri-urban Settlements on Water Quality

Several rural and peri-urban settlements are located upstream, midstream and down stream the river, which are likely to have impact on water quality. Upstream, there are three plantation stations around which have developed squatter camps with no proper sanitation. In addition, upstream, there is Tabase location, midstream, Kambi and Mhlahlane locations and down stream, Pollar Park and Tipini locations which are peri-urban settlements near Umtata town. Domestic wastes and run-off from these settlements discharge into the river.

6 Discussion

6.1 Limitations of the questionnaire approach

The followings are the recognized limitations with the use of questionnaire in this study:

(i) The samples size is small and the statistical basis may not be valid which arose because of lack of interest of stakeholders to facilitate better access to the community. Therefore questionnaires were administered house to house and during daytime when some members of the household were at work.

(ii) There was no gender representativity. Most respondents were women. This is because in the study area, most men are migrant workers and women usually head the household.

(iii) In the questionnaire, true/false was determined by perception.

(iv) The incidence of diarrhoea was not correlated to the age of the sufferer

6.2 Major users

The results of the questionnaire have identified the major use of water from the river as domestic (cooking, drinking and washing) and the Umtata Municipality as the primary user of water from the river supplying other secondary users in the catchment with treated water. However, most of the people in the rural settlements along the riverbank are primary users who use water directly from the river for a variety of purposes including domestic (cooking, drinking and washing), agricultural (livestock-watering) and recreational (swimming, especially children).

6.3 Water quality trends

The results of the water quality studies have shown that the main quality problems with the river are turbidity, coliform counts, nutrient and cadmium levels that are abnormally high in almost all sites sampled. Some expected trends were observed such as concentrations of most parameters surveyed are higher downstream than upstream or midstream of the river. Also, some seasonal variations are indicated with summer months' values for most parameters being higher than winter months' values.

6.4 Water quality parameters of concern

The high coliform counts in the river, which could be due to poor sanitation in the catchment exposes the rural population who use water directly from the river for domestic purposes to high incidence of water-related diseases. The high turbidity could cause problems with water purification, especially flocculation and filtration process of water from Umtata Dam. Excessive turbidities also could make it difficult to disinfect the water properly. The high nutrient levels in the river are probably due to diffuse sources from settlements and agricultural run-offs and to point discharge from the Umtata Sewage Works. This causes eutrophication and possible presence of toxic algae in the river, which could be detrimental to fishes and livestock when the river water is used for livestock watering. The presence of algal bloom due to eutrophication could negatively affects the use of the river for recreation. The high nutrient levels could also increase the treatment cost of water from the river to potable standard. High nitrate in potable or raw water from the river could expose the domestic users (especially babies and pregnant women) to the incidence of methaemoglobinemia. High cadmium levels in the river water could also have chronic health effects on the rural population who use water from the river directly for domestic purposes and to livestock that drink from the river.

Generally, based on the DWAF guidelines for domestic water supply (Quality of Domestic Water Supplies, 1998), the overall class of water quality in the river is 5 - "purple" (that is unacceptable) indicating that the river is not fit for domestic use without treatment.

7. Conclusions

Water quality problems in the Umtata River are ultimately a consequence of poor sanitation, sewage works and waste management and erosion problems in the catchment. There could also be pollution from non-point sources although this was not quantified. The potential for managing water quality in the river has to be viewed within the context of these problems.

8. Recommendations

8.1 Recommendations for Water Quality Monitoring Systems

The main requirements for water quality monitoring in the Umtata River, to ensure that the water is safe for use, is to monitor the parameters of concern at key points in the river showing different land and water uses.

To obtain this, suitable monitoring points should be:

- At the source (ideally should be a reference point)

- Upstream after Tabase location
- At Kambi location (before the Dam)
- At Umtata Dam
- Downstream after Pollar Park location
- Downstream after Umtata Prison
- Downstream after Norwood Bridge
- Downstream after Umtata Sewage Works
- Downstream after Tipini Location
- At First and Second Falls.

At each point, turbidity, nitrates, phosphates, total coliform, faecal coliform should be measured preferably biweekly (Quality of Domestic Water Supplies, 1998), if viable. Heavy metals (particularly cadmium) should be measured at least six monthly intervals at all sites also depending on viability. This would be a routine monitoring system, designed to give early warning of adverse conditions in the river.

Discharges (both point- and diffuse sources) should be monitored since they are a major determinant of water quality. A monitoring programme should be implemented quarterly (3 months) for all point source discharges, especially if they do not comply.

The main areas not monitored in this project were: compliance monitoring of effluent discharge from Umtata Sewage Treatment Works; discharge from old sewage pond near the Umtata Prison, sewage discharge from Langeni Forest Industry and seepage from waste disposal sites at Norwood and Tipini.

8.2. Recommended Options for Ensuring that Water from the Umtata River is Safe for Use

There are water quality problems in all the reaches of the river. In the upper reaches there are rural settlements with no sanitation, thus the problem with faecal contamination. Because of the hilly slope at this reach, donga erosion and the run-off from the nearby settlements accounts for the problem of turbidity even at this reach, though these are felt much more at the middle and lower reaches. The middle reach is an area of agriculture and also of rural settlements. Water quality is also not acceptable at this reach, with high turbidity, coliforms and nutrients. The lower reach is predominantly an area of peri-urban settlements. Run-off from the settlements plus discharge of partially treated or untreated waste effluents from the Sewage Treatment Works and from the sewage ponds into the river plus leachates from waste disposal sites located near the river are the main contributory factors to bad water quality in the reach. Water quality is worst at this reach of the river.

The following strategies are available as options for improving water quality in the river:

- Using the DWAF's National Strategy, a Problem Tree Analyses could be done to decide on how to improve sanitation systems at the rural and peri-urban settlements located around the catchment. Several of these settlements are located near the riverbanks, without adequate water supplies or sanitation. Effluents from these settlements cause unquantified local pollution. The priority here should be to provide amenities.

- A policy could be implemented that will manage land use and prevent erosion in the upper and middle reaches of the river.
- Agricultural practices could be managed in such a way as to control the use of pesticides and fertilizers. This could influence nutrient levels in the river.
- A valid permit to be obtained by the Umtata Sewage Works to comply with the DWAF effluent regulations according to the National Water Act, 1998.
- Discharge of untreated or partially treated domestic sewage by the Langeni Forest Industry must be prevented. The sewage pond near the Umtata Prison must also apply for a valid permit according to the National water Act, 1998.
- Monitoring and removal of waste sites close to the riverbanks at Norwood Bridge and Tipini location and planning of more appropriate sites by the municipality and a Catchment Management Authority (CMA) for all waste disposal sites in the catchment.
- Routine education programmes to the rural community on the need for clean and hygienic environment must be developed and implemented to prevent pollution of the river.

9. Suggestions for Future Research

The followings are recommendations for future research:

- An investigation into cadmium pollution in the river and its possible health-related effects on the rural community in the catchment
- A bio-monitoring programme for the river.

- Development of a catchment management programme for the Umtata River Catchment
- Impact assessment of the use of pesticides in the river catchment**.**

10. Capacity building

Through report back to the community, awareness was raised on the need for clean and hygienic environment to prevent pollution of the river. In particular, they were made aware of the strong interrelationship between water quality and the incidence of water related diseases and the role that poor sanitation and/or bad hygiene behaviour could play in affecting water quality and in promoting incidence of water related diseases.
Capacity was built among residents in the catchment who are primary users of water from Umtata River on alternative ways to treat the raw water from the river to make it safe for domestic use, e.g. by boiling, sedimentation, sand filtration, sunlight pasteurization and use of bleach powder. Those that have no sanitation facilities were advised to bury their faeces in the soil rather than exposing them to be washed into the river.

As part of the capacity building, this project was used to produce 1 MSc. and 2 BSc. Honours. Three students from Border Technikon, Department of Analytical Chemistry also did their internships on this project.

11. Technology Transfer

There was technology transfer to the rural population on alternative water treatment procedures, for example boiling, use of bleach powder, sedimentation, sand filtration and sunlight pasteurization.

A Workshop with the stakeholders was held in Umtata, during which the outcomes of the project were communicated. This led to the prevention of further cadmium pollution into the catchment.

12. Presentation of Paper

A paper entitled "*Quality Assessment for Fluorides, Nitrates and Phosphates in Drinking Water and Waste Water Effluents of Major Cities in the Easter Cape, South Africa*" was presented at the Eastern Analytical Conference in Somerset, NJ USA, 14-19 November 1999.

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LIST OF DEFINITIONS

DWAF : Department of Water Affairs and Forestry

Eutrophication: The process of nutrient enrichment which frequently leads to the growth of algal scums.

Nutrients : Chemicals that are essential foods for plants, and particularly for planktonic algae when dissolved in water. Common examples are phosphates, nitrates, nitrites and ammonium.

ICM : Integrated Catchment Management

GIS : Geographical Information System

TERMS OF REFERENCE

The primary initial aim of the project was to carry out a water quality-monitoring programme to fulfill the needs of integrated catchment management in the Umtata River. Other subsidiary aims of the project are:

1. To identify the primary and secondary users and uses of water in the catchment.
2. To identify the major sources of pollution to the river
3. To suggest options for ensuring that the water is safe for use

However, due to lack of human resources, the initial primary objective could not be met, instead, a situation analysis of health-related water quality problems of the Umtata River was carried out using the assessment and interpretation of water quality guidelines. This information would form the basis for a programme of catchment management for the river.

1. INTRODUCTION

1.1 The Problem and Its Setting

A large population of Transkei, most of which is rural, uses water from Umtata River for various purposes and it is one of the new designated catchment management areas. Is the water from this river fit for use for the various purposes it is currently being used? What is the perception of users of water from this river on its quality? If the water is not fit for use for some or all the purposes, what cheap remedial action can be suggested to make the water suitable for use?

When a river is classified in accordance with intended uses, specific water quality criteria are established to ensure that the most beneficial use will not be deterred by pollution. The common water use classifications are domestic, agricultural, industrial, recreational and aquatic environmental (in-stream ecosystem) (Hammer, 1975, Viessman, Jr., and Hammer 1998). Both natural and human factors influence the quality of a water source. The degree of impact of operative factors varies depending on the type and characteristics of the source involved. Surface water for example, is generally, vulnerable to human contamination (AWWA, 1990). South Africa’s water resources have been under increasing threat of pollution in recent years due to rapid demographic changes, which has coincided, with the establishment of human settlements lacking appropriate sanitary infrastructure. This especially applies to peri-urban areas, which surround the larger metropolitan towns in the country, where many such settlements have developed with no proper water supply and sanitation services. People living in these areas, as well as downstream users, often utilize the contaminated surface water for drinking, recreation and irrigation, which creates a situation that, poses a serious health risk to the people (Verma and Srivastava, 1990).

1.2 Integrated Catchment Management

Water resource management in South Africa is going through a period of major change. This is reflected in two new acts, the Water Services Act of 1997 (Act No. 108 of 1997) and the National Water Act (Act No 36 of 1998). The acts are founded on the principles of efficient service delivery and sustainable use of water resources. Resource quality monitoring, assessment and national information system in support of decision-making are primary requirements of both acts.

The National Water Act of 1998 provided for the establishment of catchment management agencies with the following functions:

a) To investigate and advise on the protection, use, development, conservation, management and control of water resources in its water management areas.

b) To develop a catchment management strategy.

c) To coordinate the related activities of the water management institutions within management areas

The new Integrated Catchment Management (ICM) plan in the National Water Act, 1998, is a bold plan of government to bring water management to participatory level. The Umtata River catchment is one of the designated catchment management areas in South

Africa. An important aspect of the management of this river is its quality monitoring to know its "state" and to plan strategy for pollution control in the river.

1.3 Description of the Umtata River Catchment

1.3.1 The River Catchment

The Umtata River rises in the plateau region of the Eastern Cape, approximately midway between the Drakensberg escarpment and the sea (Fig. 1). The catchment of the river itself is some 100-km long and up to 50 km in breadth. The main tributary of the Umtata River is the Ngqungqu River that enters the main river on the right banks about 27 km from the coast. The catchment is generally undulating, hilly and broken towards the coast and with a steep escarpment at the headwaters. In the vicinity of Umtata, the river flows through a wide plain with a flat gradient. Further downstream, the river is incised in a deep gorge (DWAF, 1998).

1.3.2 Geology

The geology of the catchment area of any river is important when discussing the chemical composition of its water resources. The geology of the Umtata River Catchment is constituted by mudstones and sandstones of the Beaufort group from headwaters to about 30 km from the coast, and thence, by shales, mudstones and sandstones of the Ecca group, with exposures of dolerite intrusions mostly in the higher lying areas. There are scattered deposits of alluvium in some valleys (DWAF 1998, Du Preez and Jonas, 1983).

The various geological formations erode under the influence of the current weather conditions to form a great variety of soils. Soils in the catchment are moderate to deep and vary between sandy loams in the upper half to clayey loam in the downstream half.

The major types of soil found in the Transkei are (a) Solonetzic or alkaline soils (b) Podsolic soils (c) Laterite Yellow Earths and (d) Lithological and related soils (van der Merwe, 1962).

The parent rock for the solonetzic soils is sandstone and shale with dolerite intrusions (du Preez and Jonas, 1983). This soil is poor in nitrogen but rich in lime, magnesium and potassium with a comparatively low availability of phosphate (du Preez and Jonas, 1983).

The podsolic soils group is divided into three separate regions. The first region is the highveld prairie, which consists chiefly of sedimentary rocks in which dolerite intrusions sometimes occur. The typical soil is well developed and deep. It consists of a crumbly sandy loam and the substratum is greatly clay with foundations of more compact clay. (du Prezz and Jonas, 1983). The second region is the semi-coastal region. The surface soil consists of a sandy loam with a layer of ferrugineos (derived from granite) concretions but not cemented (du Preez and Jonas, 1983). The substratum is dense, impervious thin clay, which gradually merges into the unweathered rock. In spite of its well-developed layers, this soil type is remarkably shallow. The third is the coastal region. The geological formation is sedimentary rock with dolerite intrusions and granite (du Preez and Jonas, 1983). The surface is usually well developed but because of the steep topography there is no accumulation of material in the subsoil. The well-developed soil consists of a brubbly, sandy loam resting on a layer of small round densely packed ferruginous concretions, underlain by a compact impervious clayey material (du Preez and Jonas, 1983). The sandy soils vary from fairly acid to extremely acid. They are low in lime, magnesium, available phosphate and nitrogen but fairly high in potassium (du Preez and Jonas, 1983). The red soils derived from dolerite contain an appreciable amount of nitrogen and potassium but are poor in lime and available phosphate.

The lateritic yellow earths consist of basic igneous and sedimentary rocks. The well-developed yellow earth consists of a dark brown, crumbly clay surface soil with a yellowish-brown crumbly clay subsoil (du Preez and Jonas, 1983). The yellow earth is very acid and contains little lime and available phosphate while potassium and nitrogen are fairly high (du Preez and Jonas, 1983).

The lithological type soils consist of basalt and quartzite (du Preez, 1983). The reaction of the soil varies from slightly to very acid. The soil is poor in the various plant nutrients. The soils of the mountain region are generally poorly developed and are in general, shallow. Deep soil is found in the valleys only or on the gentle slopes.

1.3.3 Plantations

There are extensive plantations in the headwaters, with a total area of 5100 ha. Natural vegetation is temperate and transitional forest and scrub in the upper half of the catchment, and coastal tropical forest in the downstream part, with tropical bush and savanna in the deeper river valleys. Sediment yield in the catchment is of the "moderate range", decreasing in the downstream direction from about 300 to 150 t/a/ha. However, it is has been noted that donga erosion in the vicinity of Umtata both upstream and downstream of Umtata Dam is severe, due possibly to the nature of the soil and the increased run-off from settlements (DWAF, 1998).

1.3.4 Dams

State owned dams in the catchment are the Mabeleni Dam in the headwaters with a capacity of 2,0 X $10^6 m^3$ supplying the Mhlahlane Rural water Supply Scheme, Corana Dam with a capacity of 0,71 X $10^6 m^3$ supplying a large population north east of Umtata, Mlanga Dam with a capacity of 1,53 X $10^6 m^3$ supplying Libode Rural Water Supply Scheme which is partly in the Mzimvubu catchment and the very large Umtata Dam with a capacity of 254 X $10^6 m^3$ which supplies the Umtata Municipality Water Supply Scheme and the Eskom's First and Second Falls. The dams are owned and operated by the DWAF. At First and Second Falls there are dams of capacity 0.96 X $10^6 m^3$ and 1,3 X $10^6 m^3$ respectively that store water for peak period electricity generation, increase the available head of the turbines and provide the means of diverting water to the hydro-power stations situated immediately below the falls (DWAF, 1998).

1.3.5 Settlement

Umtata is the only large town in the catchment. There are several well-known holiday resorts along the coast including Hole In The Wall, Coffee Bay and Umtata Mouth. Several rural settlements are located close to the riverbank.

1.3.6 Population, Social Organization and Economy of the Catchment

Population numbers and rate of change in the catchment are at present in a state of uncertainty. However, the catchment is about the most densely populated area in the former Transkei. It is believed that, particularly in the rural areas, many of the men are employed as migrant workers elsewhere in the country and that in consequence many households are in effect headed by women (DWAF, 1998).

No detailed information is available regarding the economy of the catchment itself. However, in common with the rest of the former Transkei, it is believed that the average per capita domestic product is extremely low, thus most of the people belong to the poor socio-economic group. In Umtata, and to a much lesser extent in the other towns, there are relatively affluent people employed by government, by educational institutions or in commerce (DWAF, 1998).

In the catchment there are large areas devoted to the dry land cultivation of maize, although in the rugged terrain towards the coast this is generally limited to the small flatter hilltops. Some houses also have small vegetable patches. There is no large-scale irrigation scheme in the catchment. This is an important area where water from Umtata River could have been put into good use. The number of cattle in the catchment appears to be small and water from the river is commonly used for livestock watering. It seems unlikely that the catchment is self sufficient in agriculture (DWAF, 1998).

1.4 Background to the Study

1.4.1 Uses

The major uses of water are domestic water supply, agriculture, industrial, recreation and aquatic life. Many uses are restricted within narrow ranges of water quality (Harmer, 1975). The water from the Umtata River is used for most of these purposes, especially for the domestic (that is cooking, drinking and washing), agricultural (livestock watering) and recreational (swimming) uses. Compared to other areas of the Eastern Cape, the catchment is densely populated and both developed and informal settlements exist. Many of the informal settlements are without proper water supply and sanitation. Thus this river receives diffuse source discharges as well as point source discharge from one Sewage Treatment Works and from other sewage ponds in the catchment.

1.4.2 Pollution

Pollutants and their related environmental impacts have remained largely unmeasured and ignored in the poor communities. For most developing communities, there is very little treatment of municipal or industrial wastewater. Where there is sufficient water to adequately dilute the pollution, the rivers may carry out natural remediation. Often this is not enough and also, the danger is that in a situation where water pollution may be steadily increasing, unless an effort is made to build up records and understanding of the processes and trends, the change over from tolerable conditions may become as a sudden event. Unless controlling authorities understand local water quality process and are monitoring how pollution trends are developing the associated problems may arrive too suddenly for remedial action to be taken. If pollution is allowed to grow unchecked, the result may be sudden loss of aquatic ecosystem and profound effect on downstream users some of who may be primary users of the water (DFID, 1998).

1.4.3 Management

The management of the Umtata River and its water resources has given a cause for concern. Data has always been scanty about water quality in the river. However, the deterioration in water quality in the middle and lower reaches of the river has given rise to concerns that water supplied from the river will be unfit for domestic use and other uses such as recreational or that water treatment will have to become more sophisticated and more expensive. Of particular concern is the health of the communities along the banks of the river that depend on it primarily for their domestic water supply. This study investigates health-related water quality problems in the Umtata River and identifies the major sources of pollution.

1.5 Aims of the project

The initial aim of the project was to do a water quality-monitoring programme to fulfill the needs of integrated catchment management for Umtata River.

Other subsidiary aims of the project are:

- To identify the primary and secondary users of water from the river and the various uses of water in the catchment, including domestic, agricultural, industrial, recreational and aquatic environmental uses.
- To identify the major sources of pollution in the catchment
- To identify facilities and options for ensuring that water consumed is safe.

Due to lack of human resources, the initial primary aim could not be achieved, instead a situation analysis of health-related water quality problems of the Umtata River was carried out using the assessment and interpretation of the water quality guidelines. This would form the basis for a programme for catchment management of the river. The other subsidiary objectives were also achieved.

1.6 Effect of Water Quality on Water Use

The major uses of water are domestic (cooking, drinking and washing), agricultural (irrigation, live-stock watering and aquaculture), industrial (processes and cooling), recreational (swimming, skiing, yachting, fishing) and for aquatic ecosystem use. These uses are restricted within narrow ranges of water quality (Hammer, 1975,Viessman, Jr. and Hammer, 1998, AWWA, 1998).

1.6.1 Effects of poor water quality on health

Water related disease is one, which is in some way related to water in the environment or to impurities within water. Water-related diseases may be divided into those, which are caused by biological agents (pathogens), or those that are caused by some chemical substance in water. There are four categories of water related diseases, and these include water-borne, water-washed, water-based and water-vectored diseases (DWAF, 1996a).

The transmission of disease by polluted water has a long history. It is estimated that there are more than 800 million cases of diarrhoea every year in the world, causing up to 4.5 m. deaths (Esrey et al., 1990). South Africa is no exception. Inadequate water supply and sanitation are largely responsible for this and the most defenseless and economically marginal segments of society, especially children are usually the most susceptible and therefore suffer the greatest. Contaminated water not only holds the potential to cause human suffering, but also results in economic loss (Pegram, et. al., 1998).

1.6.2 Domestic uses

This is probably the most important use of water. According to the Reconstruction and Development Programme (RDP) (ANC, 1994), water is a natural resource and should be made available in a sustainable manner to all South Africans. In this country, access to clean potable water is considered a basic human right. In 1994, it was estimated that out of a population of 43 million, an estimated 12 million South Africans do not have sufficient access to clean potable water and 21 million people do not have adequate sanitation (DWAF, 1996a). Some of these 12 million make do with polluted surface water, some queue day and night at hand pumps, others walk for kilometers to wells, dams, springs, and rivers, and some purchase water from vendors at a cost they can barely afford (R10 – R50 p/kl). Most of these people are daily using water that is hazardous to their health (DAWF, 1999a).

1.6.2.1 Parameter of water quality for domestic uses

Physico-chemical water quality properties such as temperature, pH, conductivity, total dissolved solids (TDS), turbidity, anions (chlorides, nitrates, phosphates and sulphates), hardness, metals and microbiological factors affect the use of water for different purposes including domestic. Drinking water standards dictate the quality of water that should be achieved without reference to desirable raw water quality. Although it is possible to renovate highly polluted surface waters to these standards, the process required would be both complex and expensive. Even then, some pollutants such as chloride and nitrate would not be removed. Raw water quality criteria have been developed to aid in selection of water sources such that surface supply chosen can be treated to drinking standards by commonly applied treatment processes that have been proved by demonstration, and that are within reasonable economic costs. However, a special situation is observed in the Umtata River in that people in the informal settlements often utilize the surface water directly for domestic purpose including drinking. Therefore, the South African Water Quality Guidelines - Domestic Use (DWAF, 1996b, Quality of Domestic Water Supplies 1998) would be used for classifying the river water for domestic use. Various physico-chemical and microbiological parameters affect river water quality and its suitability for domestic use.

1.6.2.1.1 Temperature and pH

Temperatures at which a water sample is collected and at which physico-chemical measurements are made are important for data correlation and interpretation purposes. For domestic use high temperature may increase the toxicity of many substances such as heavy metals in waters. Temperature and pH are two important factors in addition to microbial activities within an aquatic medium, which govern the methylation of elements such as lead and mercury (Van Loon, 1982, Dojlido and Best, 1993). Extreme pH values have pronounced effects on the taste of the water, with low pH values resulting in sour taste, and high pH values resulting in soapy taste. Direct health effects are the consequence of irritation or burning of the mucous membranes by extreme of pH. The indirect health effects are consequences of the health effects of corrosion products formed during cooking or from distribution pipes, most commonly occurring at acidic pH values. The permissible pH ranges for domestic water supply in South Africa are 6 – 9 (DWAF, 1996b, Quality of Domestic Water Supplies, 1998).

1.6.2.1.2 Electrical conductivity and total dissolved solids

Electrical conductivity (EC) is a useful indicator of the mineralization in water sample. It correlates with the total dissolved solids (TDS) of that sample. Health effect of EC occurs only at levels above 370 mS/m. The effects of high EC may include disturbances of salt and water balance, adverse effects on certain heart patient and individuals with high blood pressure, adverse effects on individuals with renal disease and laxative effects where there are elevated concentrations of sulphate present. Total dissolved solids give a reasonably good indication of the suitability of a water type for a particular use. Water high in TDS is less palatable than one with moderate mineral content and may induce unfavourable physiological reaction when consumed. The South African criterion for TDS in domestic water supply is 450 mg/l (Quality of Domestic Water Supplies, 1998).

1.6.2.1.3 Turbidity

Turbidity, defined scientifically as the light-scattering ability of water, is a measure of the cloudiness or muddiness of water. Turbidity is caused by the presence of suspended solid matter. Excessive turbidity in water can cause problems with water purification processes such as flocculation and filtration. There is also a tendency to an increase in trihalomethane (THM) precursors, where highly turbid waters are chlorinated. Elevated turbidities are often associated with the possibility of microbiological contamination, as high turbidity makes it difficult to disinfect water properly (Van Loon, 1982, Quality of Domestic Water Supplies, 1998). The South African criteria for turbidity in domestic water is < 0.1 NTU (Quality of Domestic Water Supplies, 1998).

1.6.2.1.4 Nitrate

The potential health risk of nitrate in water has lead to increased stringency in nitrate monitoring in waters because it can be reduced to nitrite, which has been linked to the conditions known as methaemoglobinemia in infants and pregnant women (Bush and Mayer, 1982; Canter, 1987). Owing to toxicity, the nitrate content of drinking water is regulated by European Union Directive 80/778/EEC, which states a maximum admissible concentration (MAC) of 50-mg NO_3^-/l. The EPA, based on the WHO guideline, adopted a MAC of 45 mg NO_3^-/l. The WHO also states a guideline of 10-mg NO_3^- as N/l in drinking water as a safe limit for babies (Council Directive 80/778/EC, 1980; WHO, 1984), which is the same as the South African criteria for nitrate in domestic water (DWAF, 1996b, Quality of Domestic Water Supply, 1998). Phosphates normally do not pose a health threat in domestic water.

1.6.2.1.5 Heavy metals

The accumulation of heavy metals in aquatic environment have a direct health consequences to man. Interest in metals like Fe, Mn, Zn and Cu, which are required for metabolic activity in organisms, lie in the narrow window between their essentiality and toxicity (Skidmore, 1964; Spear, 1981). Others like Pb, Cd and Hg exhibit extreme toxicity even at trace levels and have bioaccumulation effects, thus necessitating regular monitoring. The concentration of Cd in unpolluted water is usually less than 1 μg/l. Chronic health effects of Cd include kidney damage and pain in the bones (itai-itai disease) (Stoeppler, 1991). The South African guideline for Cd is 5 μg/l (DWAF, 1996b, Quality of Domestic water Supplies, 1998). Natural concentration of lead in natural waters is usually less than 0.010 mg/l. The South African target water quality range for domestic water is 0 – 10 μg/l (DWAF, 1996b). Levels > 100 μg/l could give a neurological damage in foetuses and young children (DWAF, 1996b).

1.6.2.1.6 Microbiological quality

Faecal coliforms(FC) are the most commonly used bacterial indicator of faecal pollution. They are found in water wherever the water is contaminated with faecal wastes of human and animal origin. Total coliforms (TC) comprise of bacterial species of faecal origin as well as other bacterial group (e.g., bacteria commonly occurring in soil). The coliforms are indicative of the general hygienic quality of the water and potential risk of infectious diseases from water. The South African guideline for faecal coliform is 0- 1 counts/100 ml and the guideline for total coliform, is 0 – 10 counts/100 ml (Quality of Domestic

Water Supplies, 1998). High FC and TC counts in water are usually characterized by diarrhoea and sometimes by fever and other secondary complications.

1.6.3 Agricultural uses

Water is critical to agriculture. In arid and semi-arid regions, water constitutes the difference between unproductive wastelands and highly productive food-generating units. In humid areas, rainfall is usually adequate to produce good crops, but even there, supplemental irrigation is being relied on more and more to prevent crop failures and to improve the quality of the products produced. Water requirements for irrigation are mostly seasonal, varying with climate and type of crop and irrigation water use often conflicts with many other uses (Viessman, Jr. and Hammer, 1998). Other important uses of water in agriculture are livestock watering and aquaculture.

1.6.3.1 Water quality for agricultural uses

The use of water for these purposes is regulated by the water quality. Sufficient water resources of adequate quality are essential for sustainable agricultural development. Increasingly, in many parts of the world, as municipal and industrial demands for freshwater increase and discharges go unchecked, the quality of the water remaining available for irrigated agriculture is deteriorating. As a consequence crop yields are being affected and, in some cases, human health is being threatened (e.g. by contamination of crops with pathogenic organisms and or toxic substances) (DFID, 1999).

Excess quantities of major ions (sodium, magnesium, calcium, chloride and sulphate) are responsible for salinization of soils. Sodium is particularly dangerous when used to irrigate heavy clay soils since it reduces the stability of the soil particles and causes physical degradation (sodicity). Calcium and magnesium counteract sodicity. Trace elements can be selectively toxic to animal and plant life if there is an excess (or shortfall) of them compared to normal background concentrations. Heavy metals (copper, lead, cadmium, chromium and mercury) accumulate in the food chain and cause hazard at all levels of the ecosystem (Chapman, 1996) and could also cause chronic metal poisoning in livestock during watering. The South African Water Quality Target Range for cadmium in water for livestock watering is 0- 0.02 mg/l (DWAF, 1996f). Cyanobacteria and blue-green algae (produced during eutrophication) release toxins that during population explosion (hypertrophic status) could reach dangerous levels. Cyanotoxins could cause the deaths of livestock if they drink the contaminated water (van Ginkel, 2001, Murray et. al., 2001). The South African target water quality range for some variables related to eutrophication as it affects agricultural uses are: irrigation – nitrate/nitrite, 0 – 0.5 mg/l as N, pH, 6.5 – 8.4, livestock watering – nitrate, 0 – 100 mg/l, NO_3^- and 0 – 10 mg/l NO_2^- and aquaculture – ammonia, 0 - 0.05 mg/l, phosphorous < 0.1 mg/l and pH, 6.5 – 9.0 mg/l (DWAF, 1996e - g).

1.6.4 Industrial uses

Industrial uses of water vary with product produced, but they generally include both process waters and cooling waters. Most of the industrial use of water is for nonconsumptive industrial uses; more than 90 % is cooling water returned to the source.

Automobile manufacturing, which requires roughly 25 000 gal to make one automobile, derives approximately 60 % of process water from municipal supplies (Hammer 1975, Viessman, Jr. and Hammer, 1998).

1.7.4.1 Water quality for industrial uses

One of the important water criteria for industrial use of water is pH. The South African target water quality range for pH is 5 – 10 depending on the industrial use (DWAF, 1996d).

1.7.5 Recreational uses

About a fourth of a developed nation's outdoor activity depends on water and the use of water for recreation is regulated by its quality. Swimming, fishing, boating, water skiing and ice-skating are such activities. Water requirements for recreation are normally greatest in summer. The sportsman and vacationer desire substantial stream flows and unvarying reservoir levels during this period. Such conditions are optimal for water-based recreation activities but conflict with many withdrawal uses (Viessman, Jr. and Hammer, 1998).

The existence of large areas of macrophytes during eutrophication inhibits or prevents access to waterways using boats. Thus the use of the water for water sports such as skiing, yachting, fishing, etc. is decreased. The presence of unsightly and smelling scums makes the recreational use of the water body for any purpose unpleasant (Murray et al., 2001). The use of water with gross microbiological pollution for swimming and other water activities will predispose users (especially children who have a greater tendency to swallow the water during swimming) to incidence of water–related health problems.

1.7.5.1 Water quality for recreational uses

The South African target guideline range for faceal coliforms for water for full contact recreation is 0 – 130/ 100 ml. The target pH range is 6.5 - 8.5 and the guideline for turbidity is 1.84 NTU (DWAF, 1996c).

1.7.6 Aquatic ecosystem uses

Providing water for the preservation and benefit of fish and wildlife, protection of mashes and estuary areas, and for other environmentally oriented purposes is now considered a necessity. But such water uses are often in conflict with traditional uses and resolving this conflicts is destined to become an increasingly common tasks. The use of water in the aquatic environment also needs to satisfy certain quality criteria.

1.7.6.1 Water quality for aquatic ecosystem uses

The EU has set the following water quality ranges for the protection of fish and other aquatic life: pH, 6 –9, dissolved oxygen, 5.0 9.0 mg/l, ammoniacal nitrogen, 0.005 – 0.025 mg/l, nitrite, 0.01 – 0.03 mg/l, copper, 0.005 – 0.112 mg/l, iron, 0.3 mg/l and zinc, 0.03 – 2.0 mg/l (Chapman, 1996). The South African target water quality range for ammonia is, 0.007 mg/l, dissolved oxygen, and pH, ±5 (DWAF, 1996h).

2 METHODOLOGY

2.1 Short introduction on the methodology

To identify the users and uses of water in the catchment, a questionnaire approach was used. To determine the present quality of water from the river, chemical and microbiological analyses were performed on water samples from the river.

2.1.1 Designing and distribution of the questionnaire

A household structured questionnaire was designed and translated into the local Xhosa language (Appendix D). The questionnaire was administered house to house by trained interviewers.

2.1.2 Study sites for the questionnaire

Six study sites were chosen for administering the questionnaires. Five of the sites were informal settlements along the riverbanks (Tabase, Kanbi, Pollar Park, Mhlahlane and Tipini Locations) and the remaining site was at Norwood in Umtata town. Only Tabase was located upstream the river. The others were sites located either midstream or downstream the river.

2.1.3 Interview schedule

The questionnaire was designed to obtain information on:

i) Background details (age, gender, education, occupation, physical address and type of house).

ii) Water supply and use

iii) Perceived quality of water supply

iv) Incidence of water related diseases

The perceived quality of the water source for the people was determined in terms of taste, colour and smell. The occurrence of diarrhoea among the respondents was used to determine the incidence of water related disease.

2.1.4 Procedure

Trained interviewers who were residents of the area were employed to assist with administering the questionnaire. The interviewers were given maps of the area with the selected sites marked on them. The questionnaires were administered house to house in those selected sites.

2.2 Chemical and microbiological analyses of water Samples

To determine the quality status of the Umtata River for the present uses chemical and microbiological analyses were performed on water samples taken from ten different sites on the river. The sites were chosen to reflect the different activities in the river catchment. Treated water samples from Umtata were also analyzed to determine the efficiency of the treatment processes.

2.2.1 Sampling and sampling sites

The geographical location of the ten chosen sites along the Umtata River as entered into the GIS are given below and are indicated in Fig 2.

Sampling site	Site	Latitude	Longitude
S_1	Near the source	31^o 29’ 35”	28^o 28’ 36”
S_2	After Tabase Location	31^o 29’ 18”	28^o 32’ 39”
S_3	At Kambi Location (Before the Dam)	31^o 27’ 47’	28^o 39’24”
S_4	Mhlamhlane (At the Dam)	31^o 32’ 56”	28^o 44’ 08”
S_5	After the Dam	31^o 33’ 09”	28^o 44’ 45”
S_6	After Pollar Park Location	31^o 34’ 35”	28^o 46’ 35”
S_7	Norwood Bridge	31^o 34’ 59”	28^o 47’ 17”
S_8	After Sewage Works, Umtata	31^o 34’ 59”	28^o 47’ 56”
S_9	At Tipini Location	31^o 35’47”	28^o 48’ 10”
S_{10}	First Fall (Hydro-Electricity Generation after Tipini Location)	31^o 36’ 29”	28^o 49’ 12

Sites 1 and 2 are upstream and close to the source (the source was not accessible). They were chosen because they were supposed to be pristine and could serve as reference points. However, there are three plantation stations located before Site 1 and Tabase location is located before Site 2. These informal settlements will have impact on the river at these two sites. Sites 3 – 5 are midstream the river. Site 3 is before the dam and the river has an impact from the Kanbi informal settlement located near the bank. Sites 4 and 5 are at the Umtata Dam and after the Dam, respectively. Water from Umtata Dam is treated and supplied to most of Umtata. These sites were chosen so as to know the quality of the water from the Dam (Site 4) and after the Dam (Site 5). Sites 6 – 10 are downstream the river. Site 6 is after Pollar Park location located near the riverbank and was chosen to get an indication of the impact of the peri-urban settlement on the river. Site 7 is at Norwood Bridge located at the centre of Umtata. There is a waste disposal \site before the sampling site and the seepage from it during local rainfall events could have an impact on the river. Site 8 is after the main Umtata Sewage Works effluent discharge point while Site 9 is at Tipini location, which is another peri-urban settlement, located at the riverbank. The runoff from this settlement could also have an impact on the river. It is worthy of mentioning, that most of these settlements are located on steeply slopes close to the river, a situation that could greatly increase their impact on the river. Site 10 is at the First Fall (after Tipini location) further down the river. There is another settlement near this sampling site. Samples were taken from the river almost biweekly between May 1999 and April 2000 to cover the four seasons of the year.

Tap water samples from three locations in Umtata (Holiday Inn, Southern Ridge and Shell Ultra City) were also sampled according to the procedures described above.

Before sampling for chemical analysis, sample bottles were cleaned by soaking in detergent for 24 hr., followed by rinsing several times with tap water until free of detergent, rinsed with 5% nitric acid and then thoroughly with distilled-deionized water

(DWAF, 1992; Quality of Domestic Water Supplies, 1999). Samples bottles were cleaned and sterilized according to the standard procedures for microbiological analysis (DWAF, 1992). Samples for chemical and microbiological analyses were collected according to the standard procedures described in the sampling guide (DWAF, 1992; Quality of Domestic Water Supplies, 1999). Samples for trace metal analysis were preserved with 5-ml conc. HNO_3. The samples after collection were placed in cooler boxes with ice chests while being transported to the laboratory and kept at about 4^oC until analyzed. Most samples including all microbiological analyses were analyzed within 24 hours. All chemical analyses were done at least in duplicates. The quality assurance studies were done in triplicates for each parameter.

2.2.2 Physico-chemical analyses

Temperature and pH were determined on-site with pH 330 meter supplied by Merck NT Laboratory Pty Ltd. Conductivity and TDS were also determined on-site with the LF 330 conductivity meter also supplied by Merck NT Pty Ltd. Turbidity was determined using the HI 93703 microprocessor turbidity meter (Hanna Instruments). Nitrate, phosphates and sulphates were determined with the Nova 60 Water Analyzer supplied by Merck NT Pty Ltd. Chloride was determined using the standard argentometric method. Total hardness was determined by standard EDTA titration (Basset et. al., 1978; Van Loon, 1982). Metals were determined by standard spectrometric methods (Fries and Getrost, 1977; DWAF, 1992). Distilled de-ionized water was substituted for test solution when running blanks for the chemical parameters measured.

For quality control, water samples were spiked with known amounts of KNO_3, NaH_2PO_4, $ZnSO4.7H_2O$, $PbNO_3$, $Cd(NO_3)_2$, respectively and the recoveries of nitrate, phosphates, Zn, Cd, and Pb were measured using the standard procedures described above for the parameters (Fries and Getrost, 1977; DWAF, 1992).

2.2.3 Microbiological analyses

Faecal and total coliform counts were performed using the standard membrane filtration method. The mFC and m-Endo agars were used for the faecal coliform and total coliform counts respectively. Both media were purchased from Merck NT Laboratry supplies. The 100 ml water sample was filtered using 0.45 μm pore size, 47 mm diameter filter membrane. M-Endo plates were incubated at 35^{o}C for 24 h while mFC plates were incubated at 44.5^{o}C for 24h (DWAF, 1992).

3 RESULTS

The major primary user of water from the Umtata River is the Umtata municipality, which abstracts water from the Umtata Dam to supply other secondary users in the catchment with treated water. However, there are other primary users in the catchment among the rural population that live in the settlements located along the riverbank as shown in the questionnaire results.

3.1 Results of the Questionnaire

3.1.1 Uses and users of water

The results of the questionnaire are shown in Appendix A. The results indicated that almost all the respondents used water from the river either as primary or secondary users. Most of respondents from Tabase Location (100 %), from Kambi Location (64 %) and from Pollar Park Location (72 %) were primary users of raw water from the Umtata River. Also, 44 % of respondents from Mhlanhlane and 29 % from Norwood in central Umtata were primary users of raw water from the river (Appendix A). The majority of the uses of water from the source are as domestic water supply. Other identified uses of water from the river include, agricultural (livestock watering and aquaculture), recreational (swimming), industrial (for cooling in wood industry).

3.1.2 Perceived water quality

A large percentage of the respondents felt satisfied with the perceived quality of their water source – 94 % of respondents from Kambi, 94 % from Mhlahlane, 75 % from

Pollar Park and 92 % from Tipini locations felt that the taste of their water source is good. However, 55 % from Tabase and 40 % from Norwood felt that the taste is bad. Again 94 % of respondents from Kambi, 94 % from Mhlahlane and 91 % from Tipini felt that the colour of their water source is good while 72 % from Tabase, 81 % from Pollar Park and 40 % from Norwwod felt that the colour is bad. 97 % of respondents from Kambi, 89 % from Mhlahlane and 94 % from Tipini are satisfied with the smell. 23% from Tabase, 56 % from Pollar Park and 40 % from Norwood felt that the smell of their water source is bad (Appendix A).

3.1.3 Incidence of diarrhoea

Generally, people from Tabase and from Pollar Park locations are not satisfied with the quality of their water source. This coincided with the incidence of diorrhroea among the respondents from these settlements. 99% of respondents from Tabase and 100 % from Pollar Park have suffered from diorrhoea. Respondents from other settlements also suffer from diorrhoea – 31 % from Kanbi, 39 % from Mhlahlane, 48 % from Norwood and 49 % from Tipini (Appendix A).

Though a large number of the respondents from most of the settlement felt satisfied with the quality of the water source, the high incidence of diarrhea among the respondents showed that their perception of their water source quality is wrong. Their wrong perception is not unexpected as this might be due to their ignorance of water quality and the fact they have never had any alternative to compare with. Most of the respondents belong to the poor socio-economic group and large number of them is unemployed.

3.2 Results of physico-chemical and microbiological Analyses

3.2.1 Quality assurance studies

The percentage recoveries obtained from the representative anions and cations are, NO_3^-, 90±6 %, PO_4^{3-}, 85±6 %, Cd, 74±5 %, Pb, 85±6 %, Zn, 77±7 % and Mn, 93±3% which validated the chemical procedures used for the analyses of the anions and the cations in the water samples.

3.2.2 Water quality data in the river

The results of water quality studies are presented in Appendix B for all the parameters measured and are also indicated in Figures 3-8 for the parameters of concern. The results indicated high turbidity, high nutrient, high cadmium and gross microbiological pollution.

Turbidity values ranged from 0.28 NTU – 1899 NTU highlighting the known problem of donga erosion in the catchment. The pH, TDS and conductivity values were normal in all the sites as they fell within acceptable limits for domestic supply (Quality of Domestic Water Supplies, 1998).

Faecal and total coliforms counts were abnormally high. Faecal coliform counts varied between 0 – 21 000 counts/100 ml while the total coliform counts ranged from 0 – 69 000 counts/100 ml for all the sites sampled.

Nitrate values ranged from 0.01 mg/l to 28.0 mg/l as N while the phosphate values varied between 0.02 mg/l and 3.81 mg/l as P. Values of chloride, sulphate and total hardness were normal in all the sites as they also fell within acceptable.

Metal concentrations are varied in water samples along the sites. The values of calcium and magnesium are normal in the river for all the sites sampled. The levels of heavy metals - iron, manganese and copper, though, a bit high are less significant. The levels of cadmium varied between 0.01 mg/l to 1.0 mg/l and are higher than acceptable limits for domestic supply (DWAF, 1996b, Quality of Domestic Water Supplies, 1998). There were indications of high levels of lead with average concentrations for each site ranging from 0.07 mg/l (Site 1) in summer to 1.3 mg/l (Site 9) also in summer. The target water quality range for lead in domestic water supply is 0 – 0.01 mg/l (DWAF, 1996b). The levels of zinc in the river for all the sites were within acceptable limits (DWAF, 1996b, Quality of Domestic Water Supplies, 1998).

3.2.3 Water quality data in Umtata treated water samples

The results of quality parameters in the Umtata tap water are also shown in Appendix B. The results indicated that the turbidity values and the coliform counts exceed the acceptable limits for domestic water supply (DWAF, 1996b, Quality of Domestic Water Supplies, 1998). All other parameters determined are within acceptable ranges for domestic water supply.

4 DISCUSSION

4.1 Limitations with the questionnaire approach

The followings are the recognized problems with the use of questionnaire in this study:

i) The sample size is small and the statistical basis may not be valid. This problem arose because of lack of interest of the stakeholders, like the environmental health officers and local staff of the DWAF to help in getting the rural people together. Therefore, the questionnaires were administered house to house. Other problem was that the questionnaires were administered in daytime when some members of the household were at work.

ii) There was no gender representativity. Most of the respondents were women. This is because in the Transkei, most the men are migrant workers and women usually head the household.

iii) In the questionnaire, true/false was determined by perception.

iv) The incidence of diarrhoea was not correlated with the age of sufferer

4.2 Questionnaire report

The results of the questionnaire have identified the major use of water from the Umtata River as domestic and that most of the people in rural settlements along the riverbanks are primary users. Other primary user is the Umtata Municipality who abstracts water from the Umtata Dam to supply other secondary users in Umtata. Also other uses of water from the river include agricultural, (particularly livestock watering), industrial (for the cooling of engines during wood processing), recreational (swimming, particularly among children). It is important to note that irrigation is rarely practiced in the catchment although this could have been important an area to put the water from the river into use.

Although a large percentage of the respondents perceived their water quality to be good, the high incidents of diarrhoea among them support the view that their perception may be wrong as the poorer the quality of water supply, the higher the risk of diarrhoea. However, other factors may play some roles, which would need to be investigated in further studies. These are sanitation practices and the level of hygiene. The fact that in Tipini, where the majority of the respondents are secondary users of water from Umtata River, there is a high incidence of diarrhoea supports the above view. Statistics South Africa has classified the Eastern Cape as the poorest province in South Africa, lacking basic amenities such as sanitation and water supply. This situation applies to the area under study. Most people in the catchment belong to the poor-social economic group and sanitation is poor.

Several workers have concluded in their studies that providing treated water is not enough, it must be matched with good sanitation. (WRC, 1996a). Studies have also shown that generally poor hygienic conditions have potential for increasing the risk of diarrhoea (Tempongko, 1991; Bentley et, al., 1991). Storage of domestic water in the home where water may become contaminated which is common in rural and peri-urban developing communities may be a significant factor in the incidence of diarrhoea. Several studies have shown that water quality deteriorated significantly after handling and storage with increased levels of all indicator organisms, with the exception of phages. The potentially lower cost of interventions designed to improve hygiene behaviour compared to interventions aimed at improving water sanitation facilities have resulted in several studies aimed at identifying hygiene behaviours which, when changed or improved, could assist in reducing water and sanitation related diseases (WRC, 1996b; Verweij et. al., 1991). Such studies would be recommended as future work in the catchment.

4.3 Introduction to water quality in the river

The suitability of water from the Umtata River for the different uses will be determined by its quality. The major uses of water from the river include domestic (cooking, drinking and washing), agricultural (particularly livestock watering) and recreational (swimming, especially by children).

4.3.1 Water quality situation in Umtata River

As the results have shown, the main quality problems with the river as far as domestic, agricultural and recreational uses are concerned are coliform counts, turbidity, nutrient and cadmium levels (Figures 3 - 8). The values of these parameters are abnormally high in almost all the sites sampled in the river showing that they probably have diffuse sources with also probable contribution from point sources. Generally, the results did show some expected trends in water quality of the river from upstream the river to downstream along the ten sampling sites. The concentrations of most of the parameters downstream are higher than at midstream and upstream. Also the nutrient concentrations (phosphate) in the river are expectedly highest at site 8, downstream (after the Umtata Sewage Works discharge point). Eutrophication is most pronounced in the river at this site, which suggests the Sewage Works as a point source for the nutrients. Some seasonal variations are indicated. For instance, water summer months' temperatures are expectedly higher than winter months' and the concentrations of most parameters (e.g. conductivity, TDS, turbidity, chloride and nitrates) are higher in the summer months than in the winter months, showing increased contributions from runoff from the settlements during the summer rains (Appendix B). Using the guidelines of the DWAF for domestic supply (Quality of Domestic Water Supplies, 1998), the overall class of water quality in the river in the ten sampling sites is 5 – purple (that is completely unacceptable for domestic use without treatment).

4.3.1.1 Microbiological

Based on the guideline value of 0/100 ml faecal coliforms (DWAF, 1996b, Quality of Domestic Water Supplies, 1998), the water from the river is not suitable for direct domestic use and may pose a serious health risk to the communities along the bank of the river. For the longest stretch of the river, the faecal coliform levels also did not fall within the guideline of 0 – 130/100 ml set for full-contact creation (DWAF, 1996c). The average levels of FC was >1000/100ml in the middle reaches of the river and >3000/100 ml in the lower reaches of the river. At this level there is a risk of contracting gastrointestinal illness as a result of full-contact recreation or direct consumption of untreated water (DWAF, 1996b&c).

The values of faecal coliform in the river at most sites are also higher than the South African limit of 200 counts/100ml for water that will be used for livestock watering and its use to feed livestock in the catchment could pose a significant health risk to the animals (DAWF, 1996f).

The high microbiological pollution of the river might be due to poor sanitation in the catchment. As already indicated, several informal settlements are located upstream, midstream and downstream the river. The majority of the people in the catchment belong to the poor socio-economic class and they lack proper sanitation. Public defaecation is a common practice, especially around Tipini location (see photos 1 & 2). Upstream the river, there are three plantation stations around which have developed several squatter camps with no sanitation. Contamination of the river by domestic animals is an added factor as it is common to see animals drinking from the river at the same source that the people use for their domestic supplies (see photos 3 & 4).

4.3.1.2 Physical

Turbidity values ranged from 0.28 – 1899 NTU. The acceptable limit for water for domestic use is 0.1 NTU (Quality of Domestic Water Supplies, 1998). This disqualifies the river water for direct domestic use and would make water treatment cost expensive. The high turbidity also makes the sight of the river water unpleasant and it may not be suitable for full-contact recreation.

The high turbidity observed for water samples from almost all the sites is due to known high donga erosion in the catchment possibly due to the nature of the soil and the increased runoff from the settlements.

4.3.1.3 Chemical

4.3.1.3.1 Nitrate and phosphate

Nutrient values in the river varied between 0.01 mg/l and 28.0 mg/l as N for nitrate and 0.02 – 5.0 mg/l as P for phosphate. The South African and WHO safe limit for nitrate in domestic water is 10 mg/l (DWAF, 1996b, Quality of Domestic Water Supplies, 1998, WHO, 1984). This level for nitrate is exceeded at some sites in the river and would make the water unsuitable for direct domestic use as this may expose infants and pregnant women to the risk of methaemoglobinemia (Bush and Mayer, 1982, Canter, 1987).

High nitrate levels also stimulate algal growth (Fried, 1991). Workers have reported that eutrophication-related problems in temperate zone aquatic systems begin to increase at ambient total P concentrations exceeding 0.035 mg P/l. The value is higher for warm water systems – of the order of 0.070 mg P/l (Rast and Thornton, 1996). The associated N concentration would be of the order of 0.34 – 0.70 mg N/l respectively. It is accepted that these represent nutrient threshold levels beyond which there will be a corresponding increase in the risk and intensity of plant-related water quality problems (OECD, 1982). These threshold values for nutrients (Rast and Thronton, 1996) are exceeded in the Umtata River (Appendix B) and eutrophication is well pronounced in the river (see photos 5).

The incidence of eutrophication could adversely affect the use of the river for recreational purposes as the covering of large areas by macrophytes could prevent access to waterways and could cause unsightly and smelling scums, which could make recreation unpleasant.

Though irrigation (whether large scale or small scale) is rarely practiced in the catchment, water from Umtata River is used for livestock watering. The high nutrient values in the river could lead to the growth of blue-green algae, which could release toxic substances (cyanotoxins) into the water. Cyanotxins are recognized to have caused the death of farm livestock (Holdsworth, 1991).

The use of the river for the protection of its aquatic environment needs to be considered especially when one considers what effect the quality of the river could have on its ecology and on that of the estuaries downstream (Umtata mouth). Of critical concern is the impact of the high nutrient and the associated eutrophication on biodiversity. Macrophyte invasions impede or prevent the growth other aquatic plants. Similarly, algal and cyanobacterial blooms consist of species that have out-completed other species for the available nutrients and light (Murray et. al., 2001). Their impact on animal biodiversity is also of concern. By generally lowering the integrity of an ecosystem, only the more tolerant animal species can survive. Mycrocystins – one of the cyanotoxins produced by blue-green algae during eutrophication bioaccumulate in fish, mussels and zooplankton. Cyanotoxins are known to have caused the death of fish and birds in many countries (Holdsworth, 1991).

The high nutrient levels may be due to diffuse sources from urban and agricultural run-off and to point discharge from Umtata Sewage Works. The high phosphate levels at site 8 was most probably due to point discharge from the Umtata Sewage Works and could be a reflection of the poor efficiency of the city major treatment plants. This has been identified as a major point source of pollution into the river and needs to be attended to.

4.3.1.3.2 Cadmium

The only heavy metal of concern in the river is cadmium. The levels of dissolved cadmium in our studies ranged from 0.01 mg/l - 1.0 mg/l in the samples while the acceptable limit in water for domestic use is 0.005 mg/l (DWAF, 1996b, Quality of Domestic Water Supplies, 1998). Two other independent laboratories – Pollution Control Technology, Johannesburg, and CSIR, Pretoria, further confirmed the high levels of cadmium in the river. Though their results vary, all of them further confirm the high concentration of cadmium in the river. For example, while analyses by Pollution Control Technology revealed the values of 5.2 mg/l Cd at Site 5 and 5.3 mg/l Cd at Site 6, respectively, in the samples taken on 29 October 1999, CSIR obtained a value of 0.01 mg/l Cd at Site 9 in samples taken on 3 March 2001. These values are unacceptably high and indicate that the water from the river may not suitable for domestic use as this could expose the primary users of raw water to chronic cadmium poisoning. The main critical organ in man during chronic cadmium poisoning is the kidney where it causes renal failure (Stoeppler, 1991). Other carcinogenic, mutagenic and teratogenic effects of cadmium poisoning in man have been indicated (Stoeppler, 1991). The target water quality range for cadmium in waters that will be sued for livestock watering is 0 – 0.01 mg/l (DWAF, 1996f). These values are exceeded in samples from many sites in the river and this could also be harmful to livestock if the water is used to for livestock watering.

The possible sources of cadmium could be from urban runoff and from disused nickel-cadmium based batteries from the rural communities that have been disposed of in the waste disposal sites. Rains could wash the leachates from these waste disposal sites into the river) (Hutton, et. al, 1987, Stoeppler, 1991). Other possible source is the runoff from agricultural soils that use phosphate fertilizer (cadmium is a common impurity in phosphate fertilizers) (Stoeppler, 1991).

4.3.1.3.3 Other heavy metals

Lead levels are a bit high although this is usually not a problem in domestic water supplies. The source of lead could be from leachates from waste disposal sites, from motor traffic (direct deposition from air) and from urban runoff (Jaworski, et. al., 1987).

The concentrations of the other metals like calcium, magnesium, iron, manganese copper and zinc do not give cause for concern in the river. As the catchment is not industrialized, the source of metals in the river could include contribution from natural sources due to the geology of the river catchment. The calcium and magnesium could be from the geology of the river catchment as the catchment is rich in solonetzic or alkaline soils of which the parent rock is sandstone and shale with dolerite intrusions (du Preez and Jonas, 1983). Such soils are rich with calcium and magnesium. Other sources of the metals in the river could be from urban runoff, runoff from settlements and leachates from waste disposal sites in the settlements (see photo 6).

4.4 Water quality situation in tap water from Umtata

Using the South African guidelines for domestic water supply (Quality of Domestic Water Supplies, 1998), the overall class of the tap water supply in Umtata is 3 (that is, marginally good) (Appendix B). The turbidity, total and faecal coliform counts exceeded the acceptable limits for domestic water supply in some of the samples (DWAF, 1996b, Quality of Domestic Water Supplies, 1998). Given that these parameters were the major problems in the river, this showed that these problems were not totally removed from the water samples by the present treatment procedures and this needs to be looked into.

There is significant microbiological contamination of the tap water, which also exposes the users to incidence of water related diseases. This was further confirmed by the relatively high incidence of diarrhoea among the respondents to the questionnaires from Tipini location and Norwood (Appendix A) who are secondary users of water from the river, although, hygiene may be a contributory factor. The microbiological quality of domestic water source is of great importance and should not be compromised.

4.5 Pollution sources in the catchment

The pollution sources in the catchment are:

- Runoff from settlements and from agricultural lands around the river catchment
- Effluent discharge from the Umtata Sewage Works
- Sewage discharge from the sewage ponds near the Umtata Prison
- Domestic sewage discharge from the Langeni Forest Industry
- Seepage from waste disposal sites situated near the river banks
-

5 Options for ensuring that water is safe for use

There are water quality problems in all the reaches of the river. In the upper reaches there are three plantation stations around which have developed several squatter camps. These settlements have no sanitation. Because of the hilly slope at this reach, donga erosion and runoff from the nearby settlements accounts for the problem of turbidity and coliform counts at this reach though these problems are worse at the middle and lower reaches of the river. The middle reach is an agricultural area and also with several settlements. Runoff from these settlements and donga erosion from the agricultural land is very pronounced at this reach. The lower reach is predominantly an area of peri-urban settlements. Runoff from these settlements plus discharges from partially treated or untreated waste effluents from sewage treatment works and from sewage ponds and seepage from waste sites located near the riverbanks are the main contributory factor to bad water quality in the reach.

The following strategies are available as options for improving water quality in the river:

- Using the DWAF's National Strategy, a Problem Tree Analyses could be done to decide on how to improve sanitation systems at the rural and peri-urban settlements located around the catchment. Several of these are located near the banks of the river, without adequate water supplies or sanitation. Effluents from these settlements cause unquatified local pollution. The priority here should be to provide amenities.
- A policy could be implemented that will manage land use in such a way that will prevent erosion in the upper and middle reaches of the river.
- Agricultural practices could be managed in such a way that will control the use of pesticides and fertilizers. This could reduce nutrient levels in the river.
- A valid permit to be obtained by the Umtata Sewage Treatment Works to comply with the DWAF effluent regulations according to the National Water Act, 1998 (Act 36 of 1998).
- Discharge of untreated domestic sewage from Langeni Forest Industry must be prevented. The sewage ponds near the Umtata Prison must also apply for a valid permit according to the National Water Act, 1998.
- Monitoring and removal of waste sites close to the riverbanks at Norwood Bridge and at Tipini location and planning of more appropriate sites by the municipality and a Catchment Management Authority (CMA) for all waste disposal sites in the catchment.
- Routine education programmes to the rural community on the need for a clean and hygienic environment must be developed and implemented to prevent pollution of the river and contamination of domestic water supply.

6 Recommendation for the design of water quality monitoring programme for integrated catchment management in the Umtata River Catchment

6.1 Management

Good information is the cornerstone for effective management. It is therefore important that in the design and implementation of a water quality monitoring system, the information gathering process is appropriate to the management needs. The monitoring process must ensure that the right kinds of information are collected, processed, analyzed and presented in a way that allows the success or failure of a particular action or decision to be evaluated objectively. If required, timely decisions can then be taken on the choice of any corrective action that might be needed (WRC, 1996b).

6.2 Programmes

A monitoring system for the Umtata River Catchment should address the following:

- The overall water quality needs in the Umtata River, to determine whether or not its fitness for use has been maintained over time according to the uses.
- Indicate the degree to which the different effluent dischargers comply with the DWAF effluent discharge regulations.
- Indicate any trends of change in the concentration of each water quality parameter of concern.

6.3 Sampling points

An extremely important requirement of any monitoring system is the choice of the sampling sites. A water sample collected at a particular sampling site should provide a reliable estimate of the water quality at that site for the time period in question. It is therefore important, for example, that a compliance point located downstream an effluent discharge should not be affected by incomplete mixing of the effluent stream with the receiving water. Typically, such a compliance point should be located beyond the minimum distance for complete mixing to take place. Sampling points in the Umtata River Catchment should be located in those areas, which are vulnerable to the inflow of undesirable effluents. These sites should also be coupled to reference sites upstream of sources of pollution, against which the level of deterioration can be judged. Sampling sites located in dams or reservoirs cannot be easily compared with those located on rivers and effluent outfalls. Nevertheless, both types of sampling sites are required to obtain sufficient water quality information for effective management of the Umtata River system (WRC, 1996b).

Suitable sampling points in the river would be:

- At the source or near the source (ideally should be a reference point)
- Upstream after Tabase Location
- Midstream after Kanbi Location
- Midstream at Umtata Dam
- Downstream after Pollar Park Location

- Downstream after Umtata Prison
- Downstream at Norwood Bridge in central Umtata
- Downstream after Umtata Sewage Treatment Works
- Downstream at Tipini Location
- At First and Second Falls (after Tipini Location)

6.4 Sampling frequency

Another important consideration of any monitoring programme is the need for appropriate sampling frequency that will optimize the expenditure of time and money for the information required. Therefore, it is important to specify at an early stage the precise information requirements that the monitoring programme is designed to satisfy. In the case of effluent compliance monitoring programme, it is important to understand the variability in quality of the effluent stream, as well as the degree to which the effluent meets allowable discharge limits, and the scale and duration of any effects on the receiving aquatic systems. The choice of an appropriate frequency for sample collection therefore becomes a critical issue in the design of an effective monitoring programme. Important parameters to monitor are coliforms, nutrients, turbidity and cadmium levels.

At each point, turbidity, nitrates, phosphates, total coliforms, faecal coliforms levels should be measured preferable biweekly if viable. Other parameters like pH, conductivity, TDS, chlorides, sulphates, water hardness and heavy metals like Cd, Fe, Mn, Cu, Pb and Zn should be measured at six monthly intervals also depending on viability. This would be a routine monitoring system, designed to give early warning of adverse conditions in the river.

6.5 Point sources

A monitoring programme should be implemented quarterly (that is, every 3 months) for all point source discharges, especially if they do not comply. The main areas not at present monitored in this study are:

- Compliance of effluent discharge from Umtata Sewage Treatment Works
- Effluent quality from the old sewage pond near the Umtata Prison
- Quality of domestic sewage discharge from Langeni Forest Industry
- Seepage from waste disposal sites at Norwood Bridge and Tipini Locations.

All these should be included in the monitoring programme for the Umtata River.

Where very little information is available on the variability of an effluent stream, an initial (or pilot) monitoring programme should be designed to obtain as much information as possible on the variability of the effluent quality and its impact on the receiving water system. Statistical analysis of the data will allow evaluation of the most suitable sampling frequency to obtain the information required to monitor the degree of compliance of the effluent with discharge limits set by the Department of Water Affairs & Forestry (WRC, 1996b).

7 CONCLUSION

The Umtata River has been characterized in terms of its physico-chemical and microbiological quality properties. The results have indicated gross pollution of the river, especially as regards turbidity, microbes, nutrient and cadmium metal. This poses a health risk to several rural communities along the riverbanks who rely on it primarily for their domestic source. This explains the relatively high incidence of diarrhoea among the respondents to the questionnaires from these settlements, which probably is due to the high coliform counts in the river. The water quality problems in the catchment are ultimately a consequence of poor sanitation and erosion problems. The gross pollution of the river is affecting the water purification systems in Umtata, which could increase the cost of treating the water to potable standards. The potential for managing water quality in the river has to be viewed within the context of these problems.

8 RECOMMENDATIONS

- Do a Problem Tree Analyses to determine how to upgrade water supplies and sanitary systems in the rural and informal settlements in the catchment to reduce the direct dependence of the local people on the raw river water and to reduce their contribution to the local pollution of the river.
- Manage land use and agricultural practices in the upper and middle reaches of the river in such a way as to reduce erosion and control the use of pesticides and fertilizers.
- The local authority should ensure that the Umtata Sewage Treatment Works apply for and obtain a valid permit and that it complies strictly with the DWAF effluent regulations according to the National Water Act, 1998.
- Prevent untreated or partially treated sewage from the Langeni Forest Industry and from the sewage pond near the Umtata Prison from entering the Umtata River or its tributary by ensuring that valid permits are obtained for such discharges.

- Mend any breakage in the sewer systems at Umtata, which may be resulting in untreated sewage flowing down the Umtata River and its tributaries via urban runoff.
- Monitor the waste disposal sites near the river at Norwwod Bridge and at Tipini Location, so as to measure the effects of leachates from these dumps on water quality during local rainfall events, and remove or seal them if they prove to significantly contribute to water quality deterioration. Also ensure that valid permit is obtained by the municipality for any waste disposal site in the catchment.
- Embark on environmental/hygiene awareness programme specially targeting pupils in the catchment informing them of the implications of unclean environment and unhygienic behaviour on water quality and health.
- Develop the interest of the local stakeholders in the catchment (e.g., DWAF staff at Umtata, local Environmental Health Officers and municipal staff) and encourage their participation in any monitoring and/or catchmnent management programmes to ensure their successful implementations.

9 SUGGESTIONS FOR FUTURE RESEARCH

The followings are recommendations for future research:

- Investigation into cadmium pollution and its possible health-related effects on the rural community in the river catchment.
- Bio-monitoring of Umtata River to determine its ‘health’
- Development of a catchment management programme for the river.
- Impact assessment of the use of pesticides and herbicides on the river.

10 TECHNOLOGY TRANSFER

There was technology transfer to the rural population on alternative water treatment procedures, for example, boiling, use of bleach powder, sedimentation, sand filtration and sunlight pasteurization (Appendix D).

A workshop with stakeholders was held in Umtata, during which the outcomes of the project were communicated. This led to the prevention of further cadmium pollution into the catchment.

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FIGURES

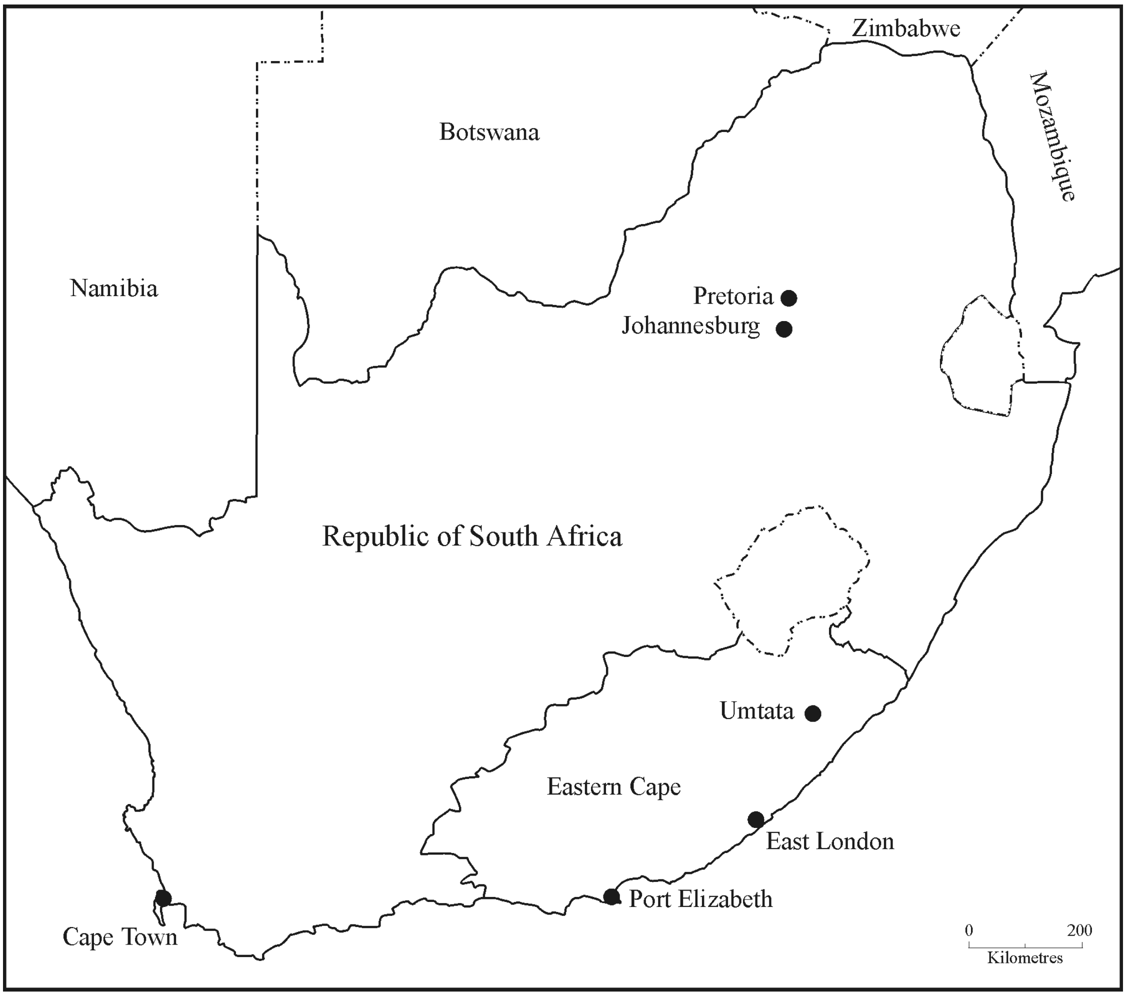


Figure 1: Map of South Africa showing the study area

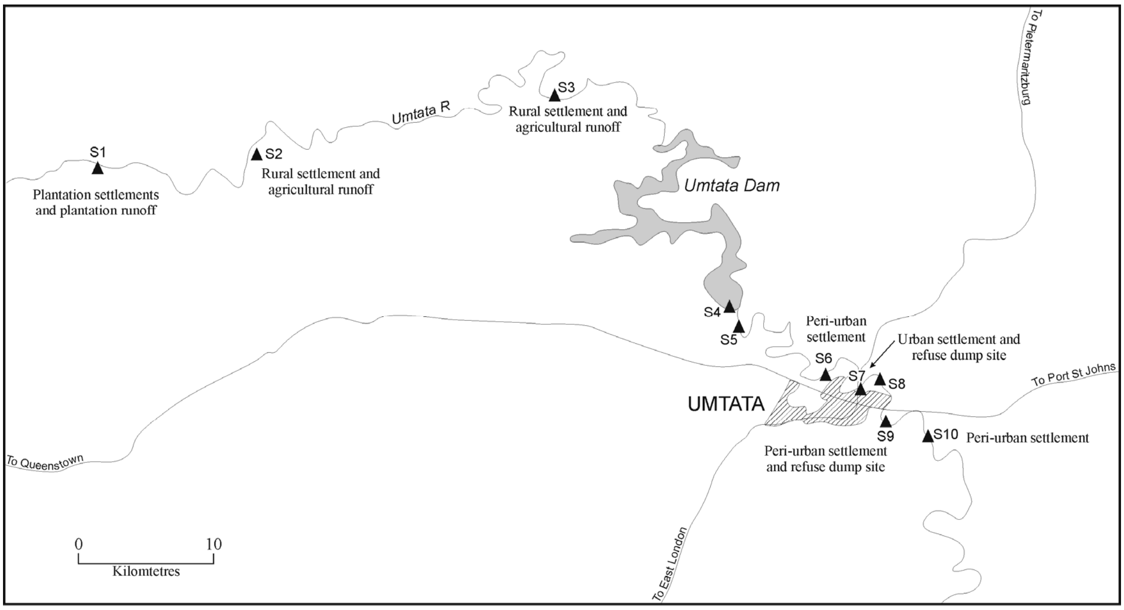


Figure 2: Map of the sampling sites

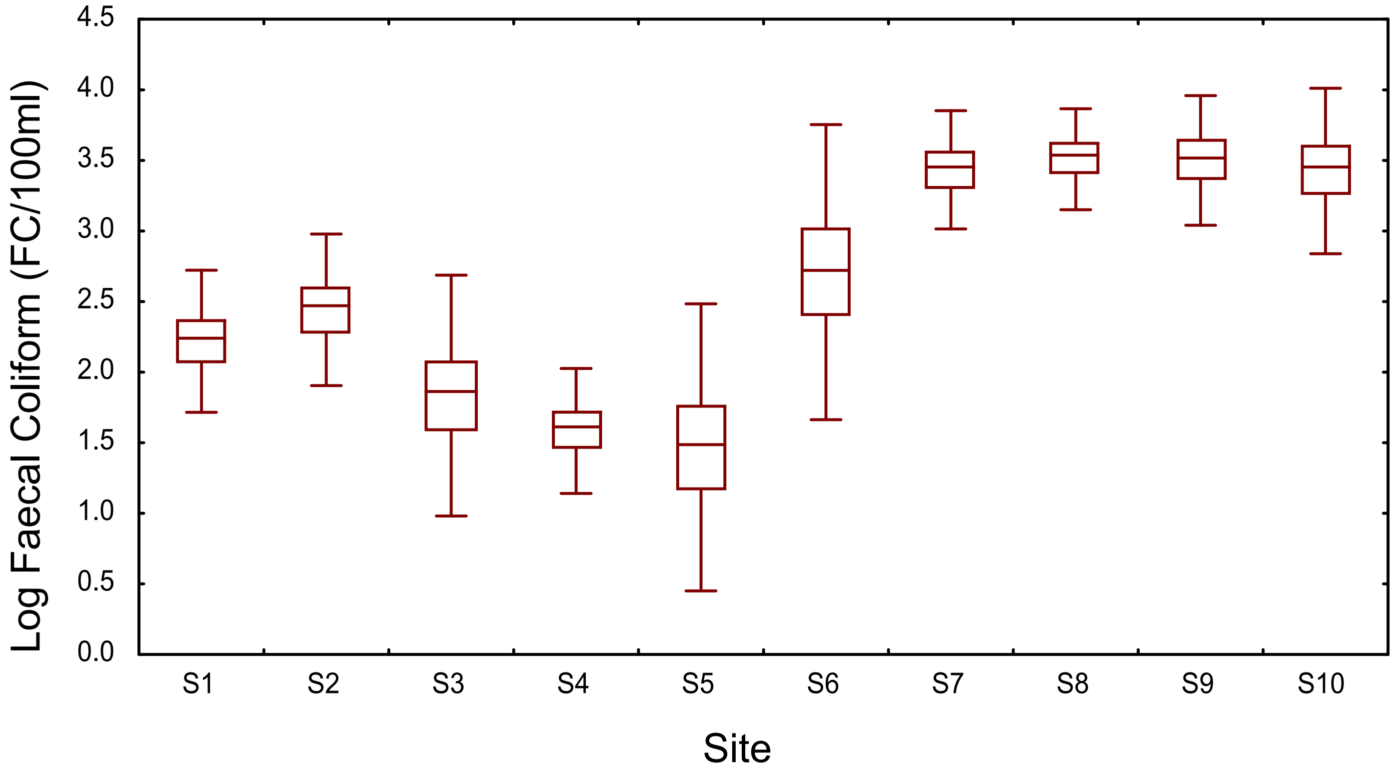


Figure 3: Plot of Faecal Coliform vs Site in Umtata River

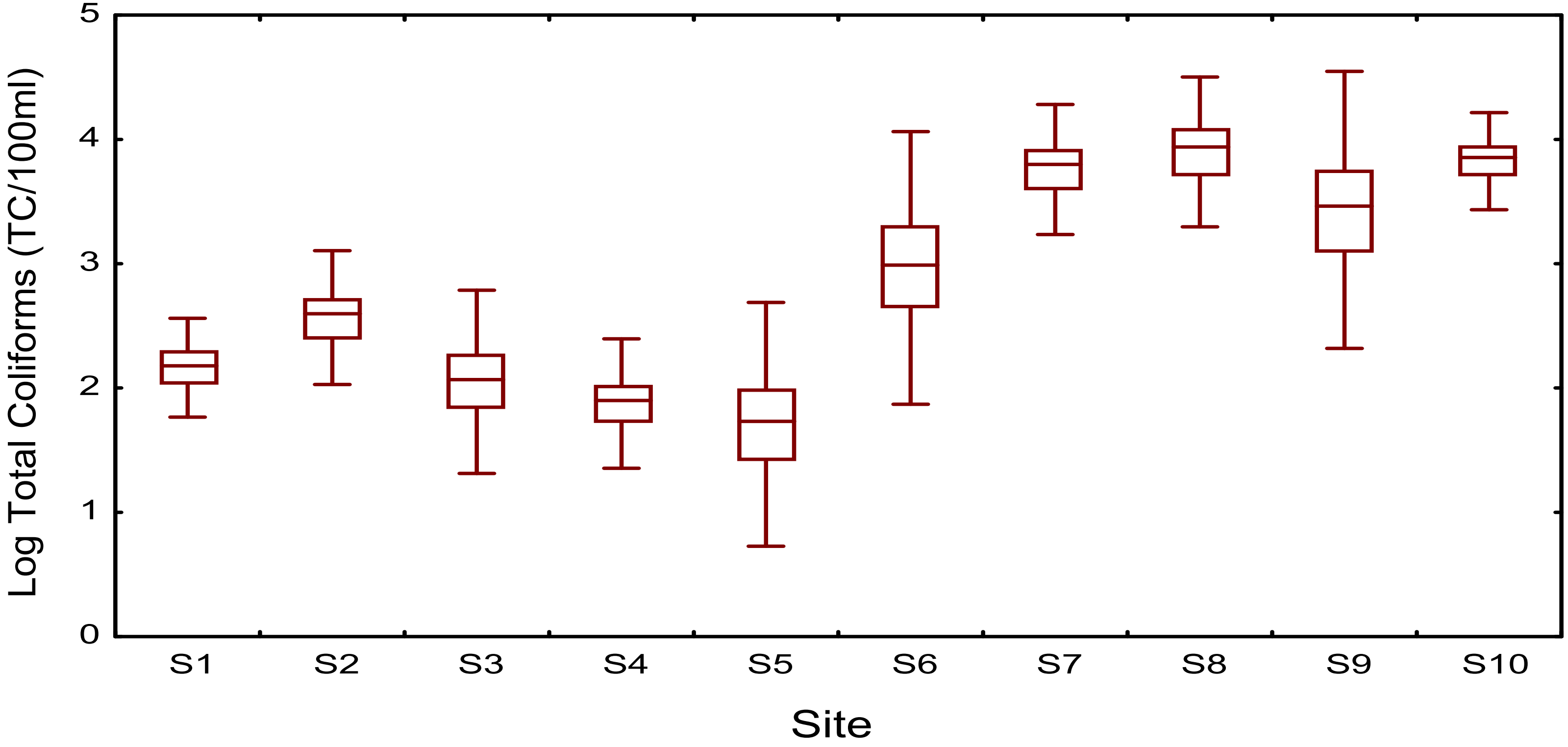


Figure 4 : Box and Whisker Plot of Total Coliforms vs Site in Umtata River

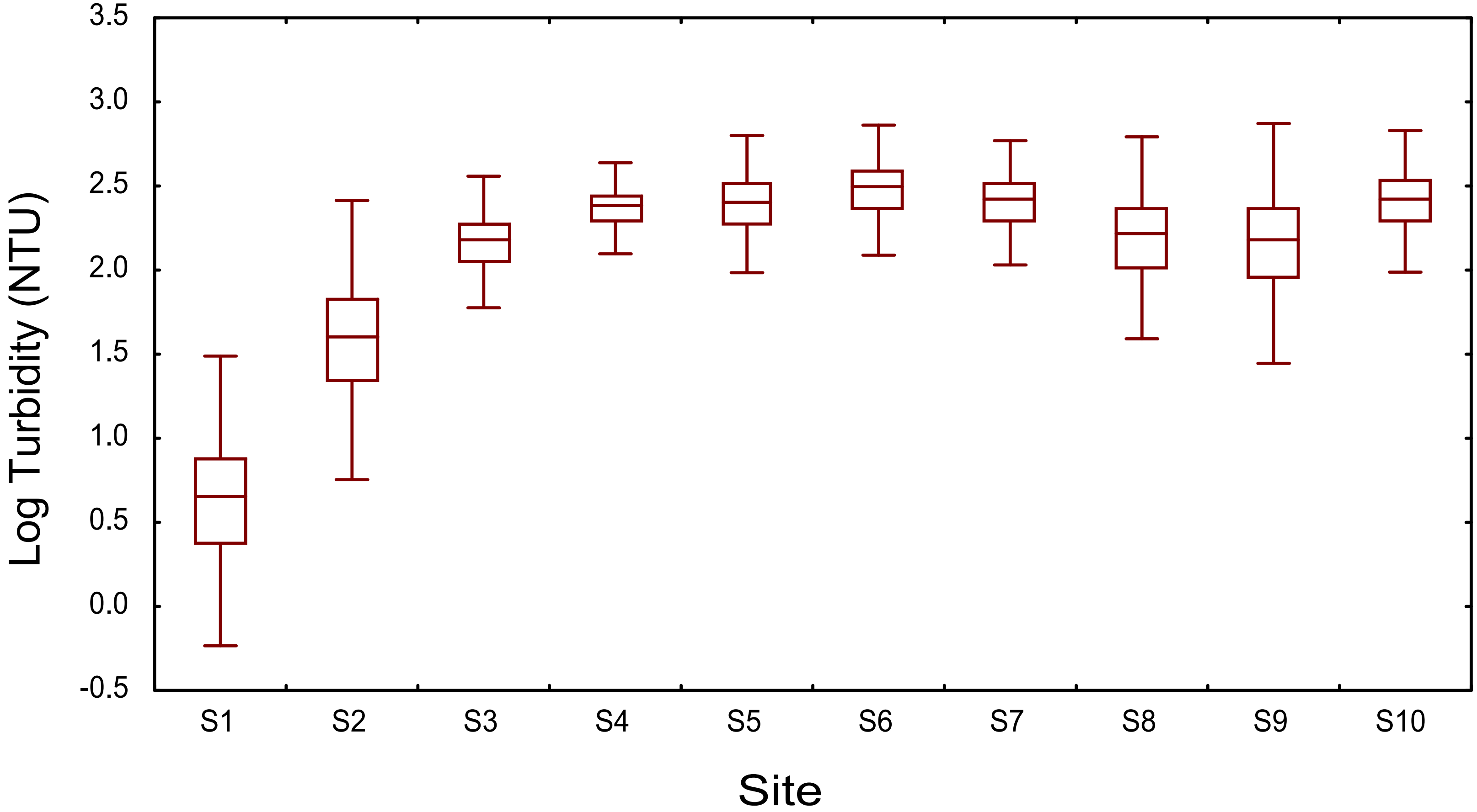


Figure 5: Box and Whisker Plot of Turbidity vs Site in Umtata River

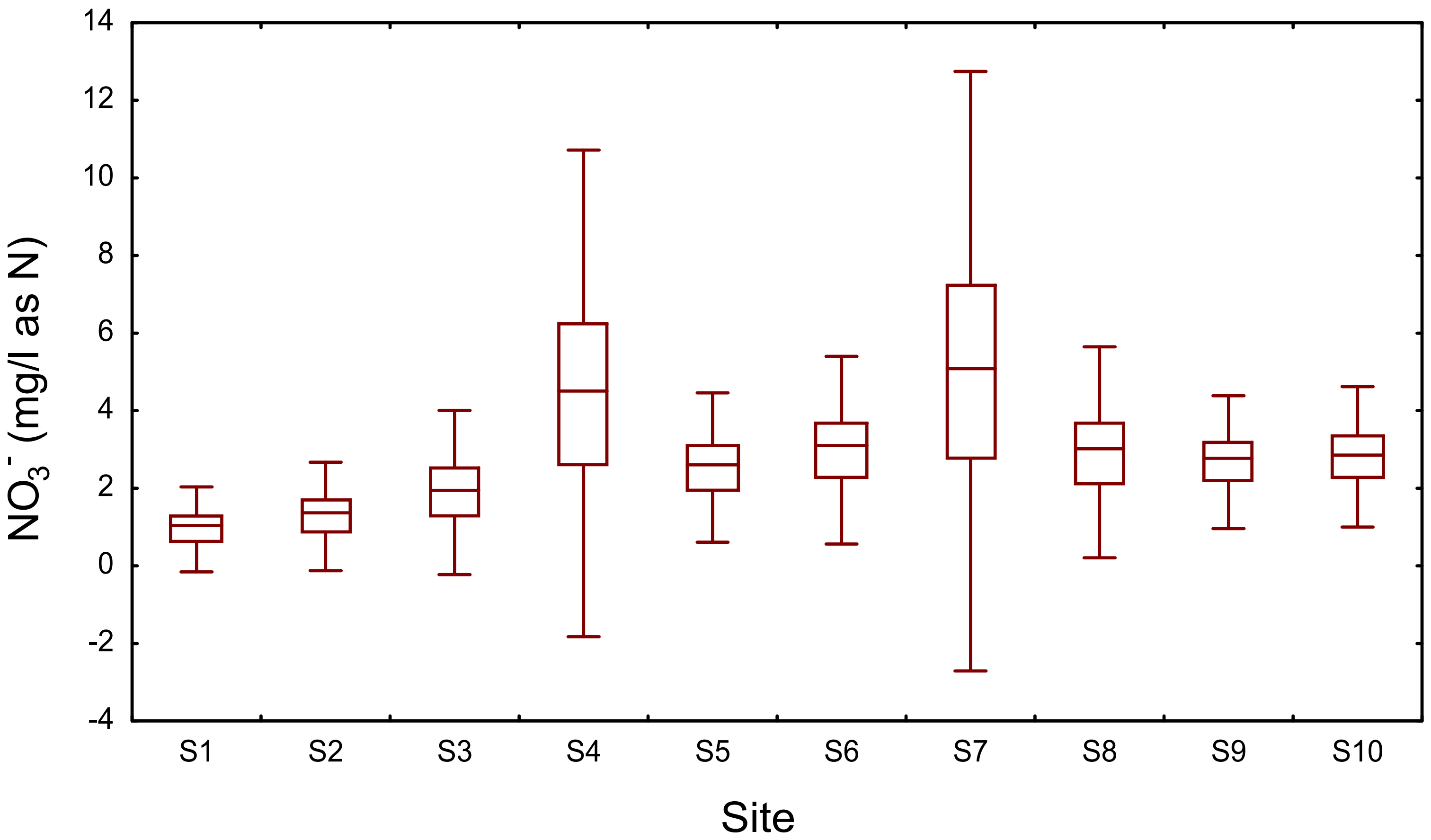


Figure 6: Box and Whisker Plot of Nitrate vs Site in Umtata River

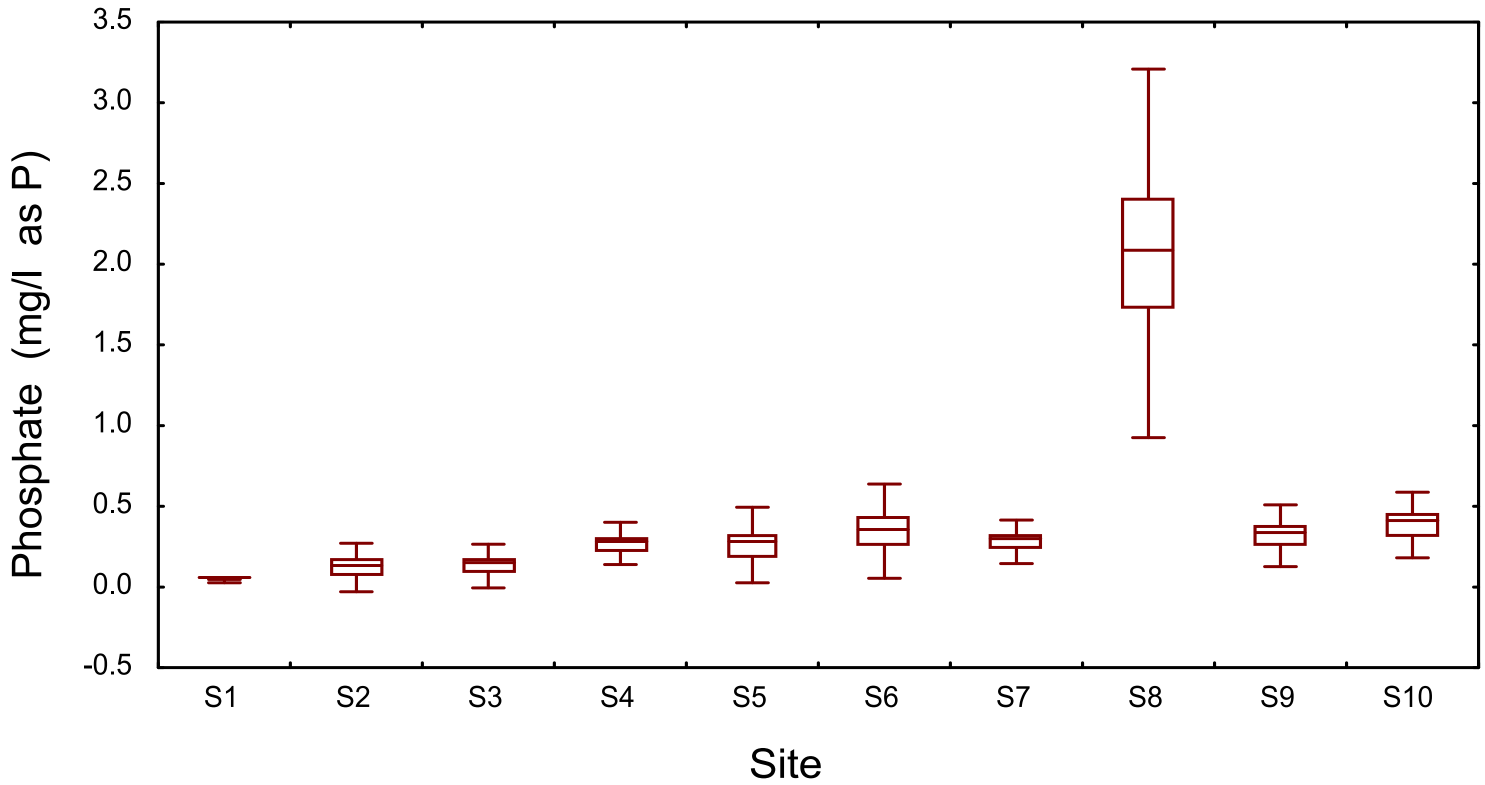


Figure 7: Plot of Phosphate vs Site in Umtata River

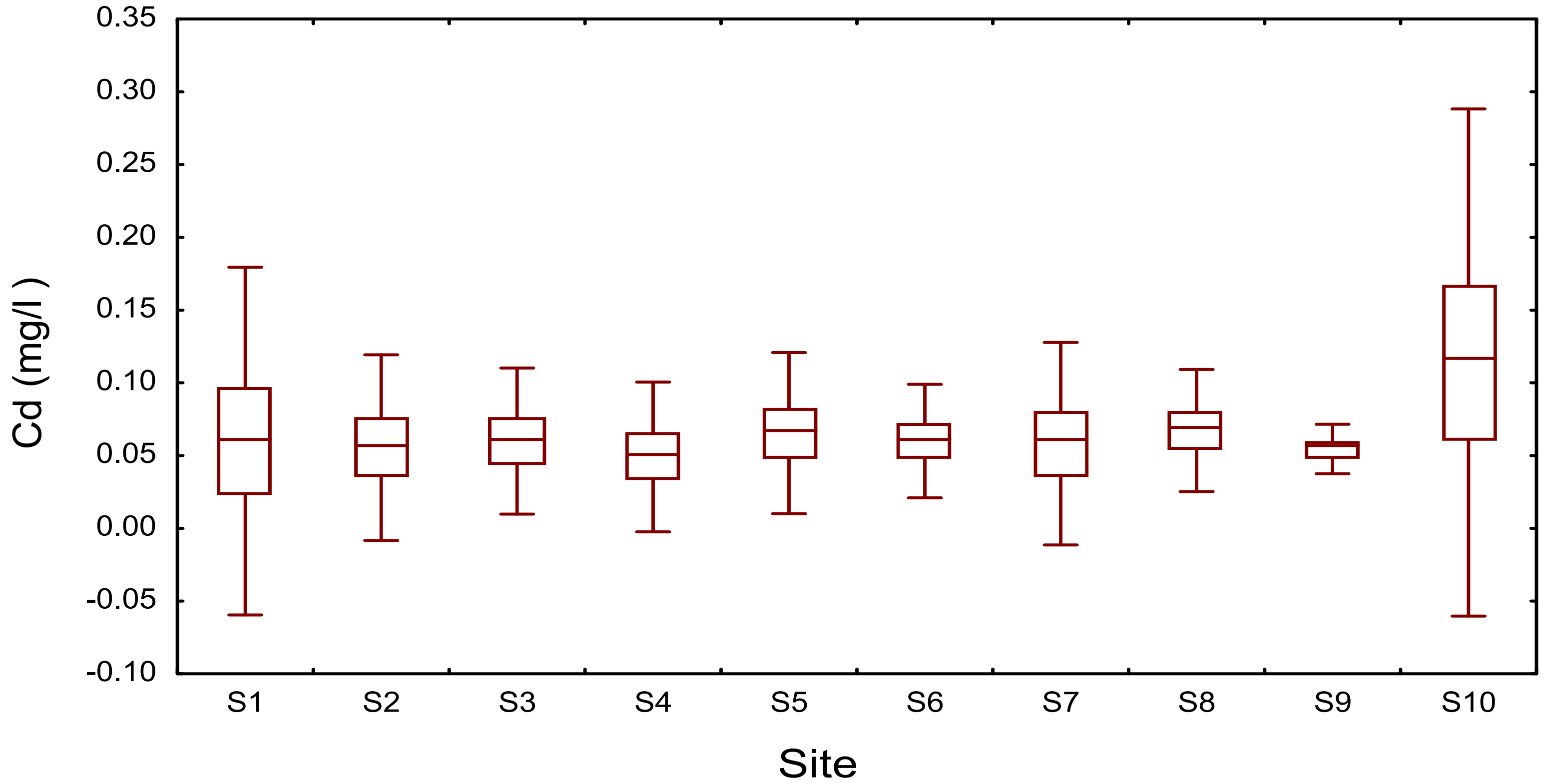
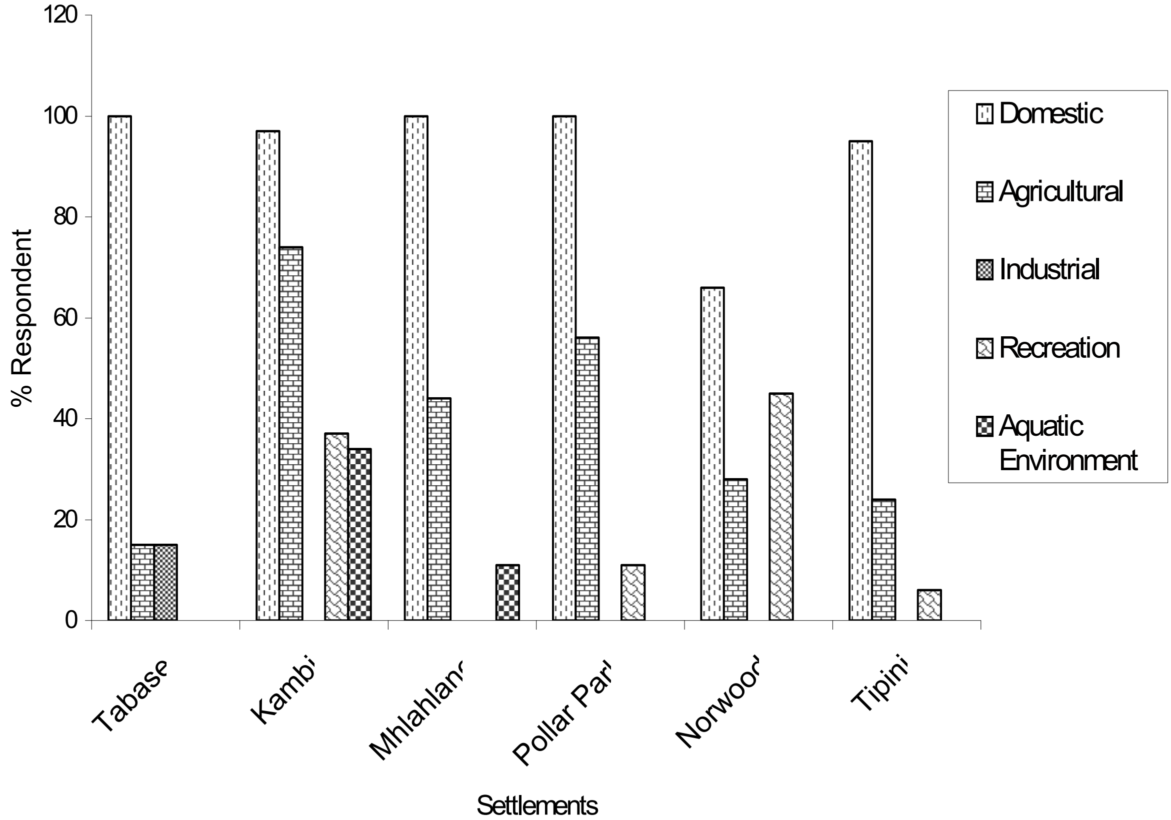


Figure 8: Box and Whisker Plot of Cadmium vs Site in Umtata River

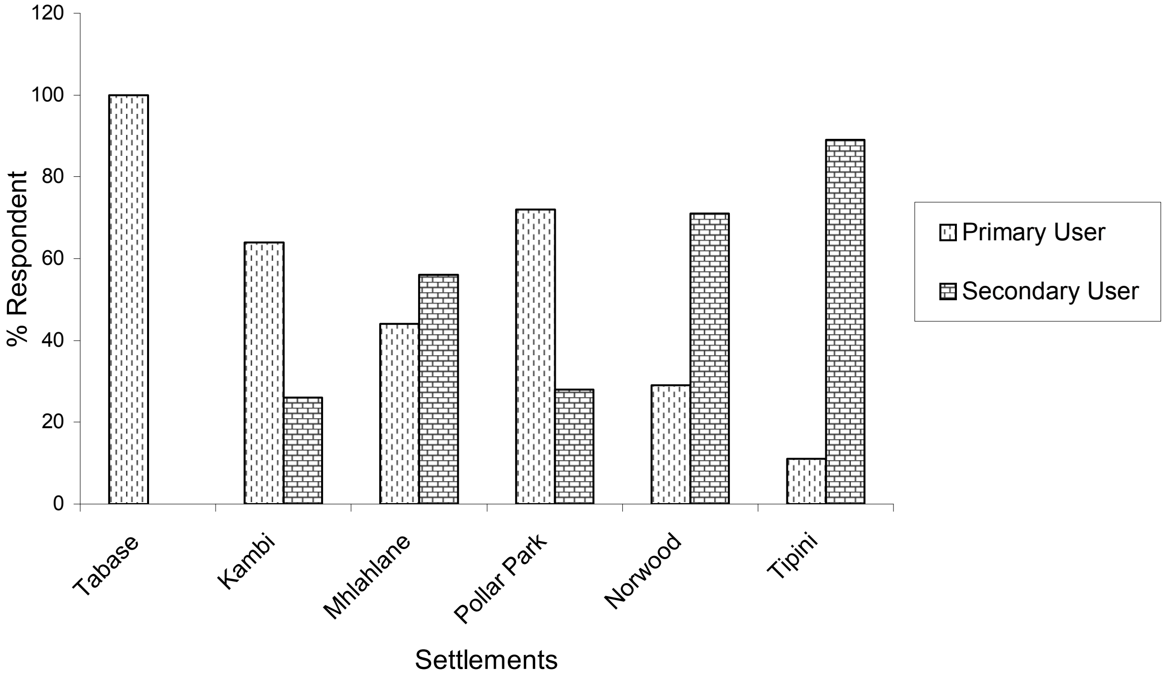
APPENDIX A

Appendix A: Questionnaire Report

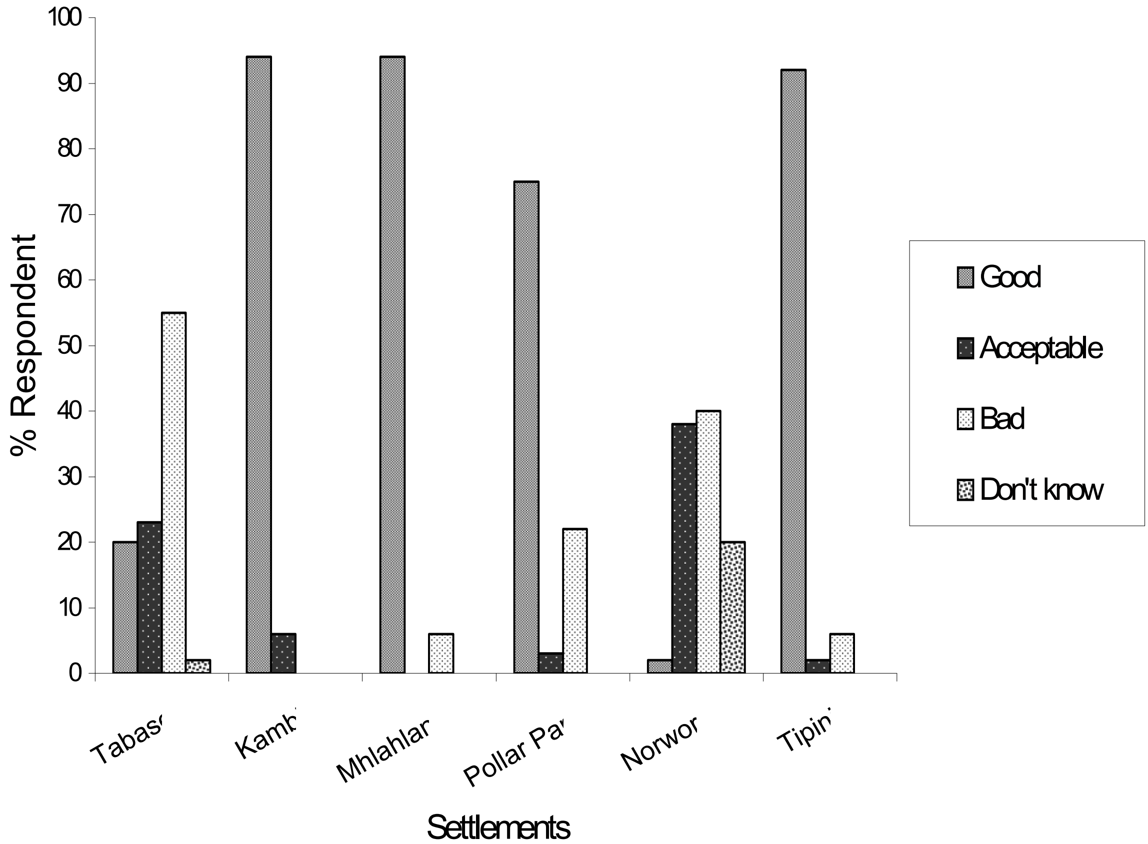
	Tabase Location	**Kanbi Location**	**Mhlahlane Location**	**Pollar Park Location**	**Norwood Location**	**Tipini Location**
AGE RANGE: (Years)	18-52	8-74	20-48	13-64	11-81	6-97
GENDER: Male	20(64%)	11(31%)	13(72%)	21(38%)	44(45%)	45(41%)
Female	11(36%)	24(69%)	5(28%)	34(62%)	54(55%)	65(59%)
EDUCATION: No Education	10(32%)	13(38%)	6(33%)	7(13%)	29(30%)	42(38%)
Std 6-10	14(45%)	18(57%)	10(56%)	23(42%)	65(66%)	68(62%)
Tertiary Education	7(23%)	4(11%)	2(11%)	25(45%)	4(4%)	-
OCCUPATION: Employed	25(81%)	4(12%)	16(89%)	10(18%)	58(59%)	7(6%)
Unemployed	6(19%)	7(20%)	0(0%)	39(71%)	40(41%)	93(94%)
Students	-	24(68%)	2(11%)	6(11%)	-	-
HOUSING: Brickstile	1(3%)	14	4(22%)	28(51%)	44(41%)	7(6%)
Shacks	30(97%)	0(0%)	14(78%)	27(49%)	28(289%)	104(94%)
Other	-	-	-	-	16(16%)	-
WATER USER: Primary Users	31(100%)	22(64%)	8(44%)	40(72%)	28(29%)	12(11%)
Secondary Users	-	9(26%)	10(56%)	11(28%)	70(71%)	98(89%)
WATER USES: Domestic	31(100%)	34(97%)	18(100%)	55(100%)	85(66%)	105(95%)
Aquaculture	-	12(34%)	2(11%)	-	12(12%)	8(7%)
Industrial	5(15%)	-	-	-	-	-
Conservation	-	-	-	-	-	-
Agriculture	5(15%)	26(74%)	8(44%)	34(65%)	27(28%)	27(24%)
Recreation	-	31(37%)	-	6(11%)	44(45%)	7(6%)
WATER SOURCE ACCEPTABILITY: Yes	6(19%)	15(43%)	11(61%)	09(17%)	61(62%)	101(92%)
No	24(81%)	20(57%)	7(39%)	46(83%)	38(38%)	9(8%)
PERCEPTION OF QUALITY OF WATER SOURCE IN TERM OF TASTE: Good	6(20%)	33(94%)	17(94%)	41(75%)	2(2%)	101(92%)
Acceptable	7(23%)	2(6%)	-	2(3%)	37(38%)	2(2%)
Bad	17(55%)	-	1(6%)	12(22%)	39(40%)	7(6%)
Don't Know	1(2%)	-	-	-	20(2%)	-
COLOUR: Good	1(4%)	33(94%)	17(94%)	9(19%)	2(2%)	100(91%)
Acceptable	4(13%)	2(6%)	-	-	37(38%)	4(3%)
Bad	22(72%)	-	1(6%)	46(81%)	39(40%)	7(6%)
Don't Know	4(11%)	-	-	-	20(20%)	-
SMELL: Good	8(25%)	34(97%)	16(89%)	18(33%)	2(2%)	103(94%)
Acceptable	9(29%)	1(33%)	-	6(11%)	37(38%)	4(3%)
Bad	7(23%)	-	2(11%)	31(56%)	39(40%)	4(3%)
Don't Know	7(23%)	-	-	-	20(20%)	-
INCIDENCE OF WATER RELATED DISEASE: Diorrhoea	30(99%)	11(31%)	7(39%)	55(100%)	47(48%)	54(49%)



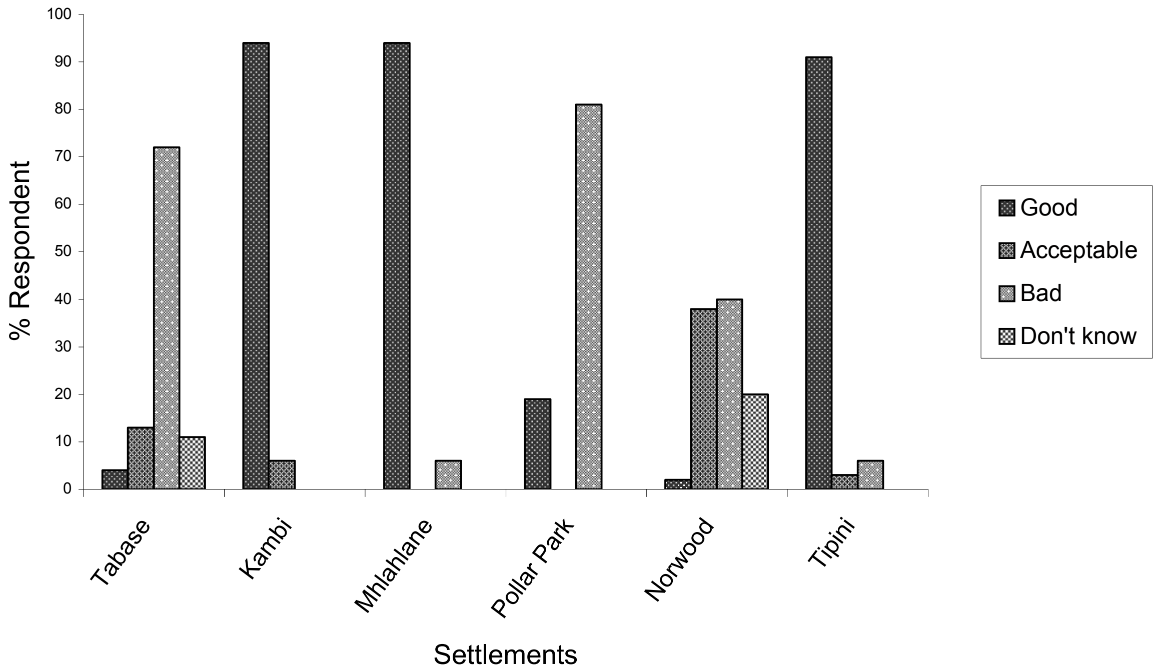
Water Users in the Catchment



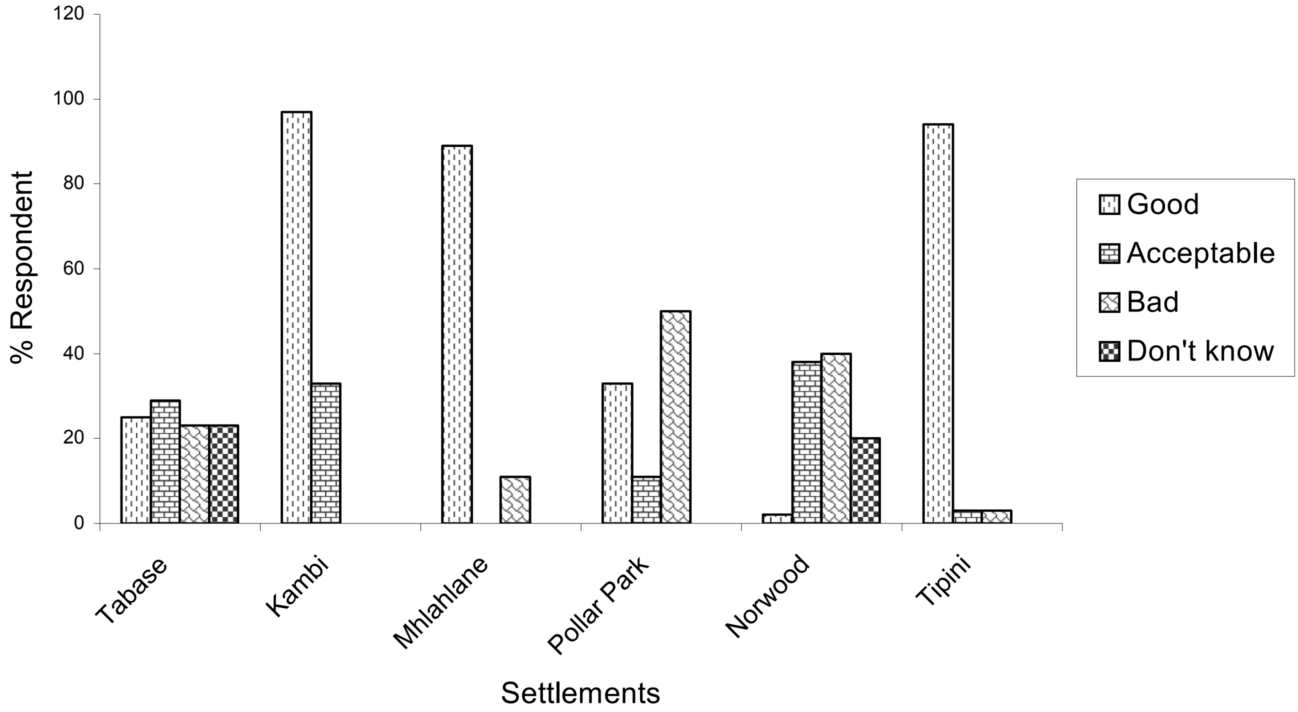
Water Uses in the Catchment



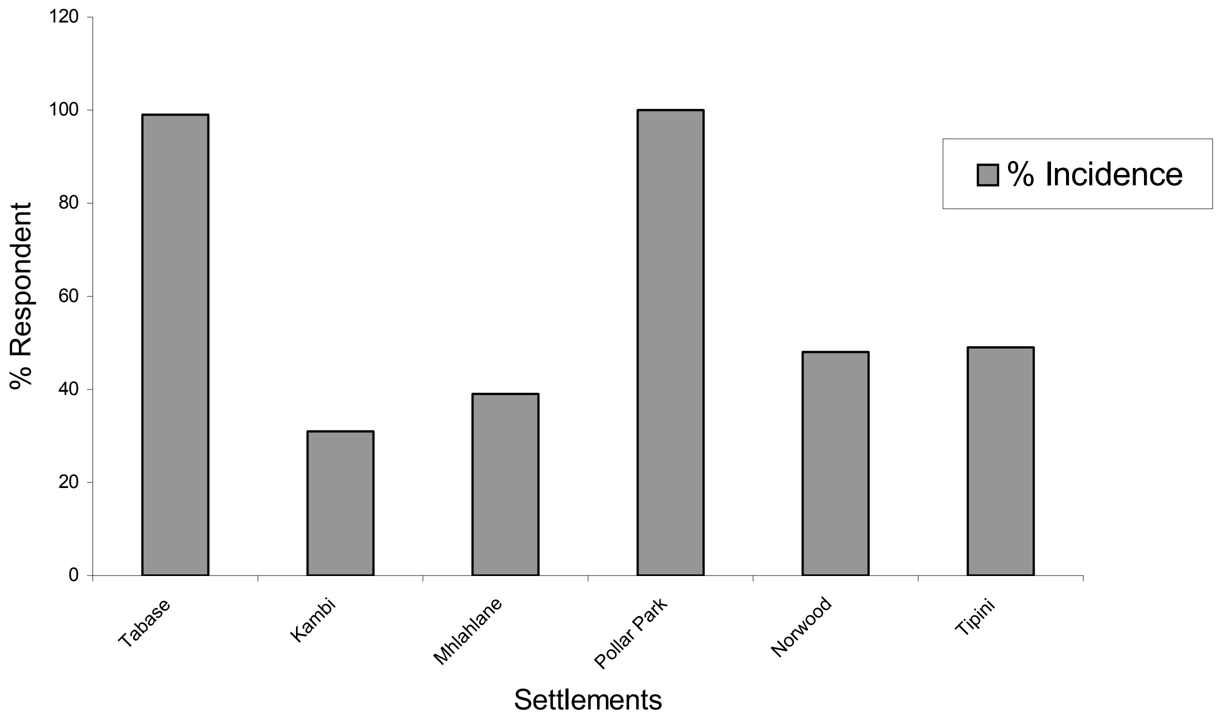
Perception of Water Quality in the Catchment (Taste)



Perception of Water Quality in the Catchment (Colour)



Perception of Water Quality in the Catchment (Smell)



Incidence of Diarrhoea

APPENDIX B

A Sample Data for Umtata River at Site 1 – Near the source

Date: May 1999 – Oct. 1999

Parameter	18/5	04/6	18/6	02/7	15/7	29/7	12/8	26/8	09/9	23/9	15/10	29/10	Max. Value	Avg. Value	Subst Class	S.D
Time	09:24	09:50	10:13	09:55	09:40	09:55	09:45	09:30	08:49	10:04	10:00	09:48				
Temperature, ^{0}C	13.5	11.3	8.3	8.8	9.0	10.3	9.8	10.1	15.3	15.2	19.0	14.3	19	12.1	-----	3.3
pH	6.9	7.5	8.0	8.0	8.5	8.8	8.3	7.1	7.1	7.8	7.5	6.6	8.8	7.7	1	0.7
Conductivity, µS/cm	45.5	47.7	49.1	50.5	51.7	53.0	53.0	66.6	71.8	59.2	57.0	28.4	71.8	52.8	1	10.9
TDS, mg/l	41.0	43.0	44.0	45.0	47.0	48.0	48.0	51.0	64.0	53.0	51.0	25.0	54.0	45.8	1	7.7
Turbidity, NTU	3.3	2.5	0.6	0.0	1.0	9.3	0	0.5	0.3	0.5	1.3	7.7	9.3	2.3	3	3.1
Total coliform, Counts/100ml	70	50	40	230	50	190	200	110	140	210	110	120	230	126.6	4	67.6
Faecal Coliform, Counts/100ml	140	0	2320	2030	130	20	170	70	90	130	50	70	2320	435	5	816.6
Cl^-, mg/l	11.3	2.6	3.0	3.0	3.1	2.5	5.0	4.0	4.0	4.0	4.0	4.0	11.3	4.2	1	2.3
NO_3^- as N, mg/l	0.9	0.4	0.2	0.3	0.5	0.4	0.04	0.7	1.1	0.8	0.9	4.2	4.2	0.9	1	1.1
PO_4^{3-} as P, mg/l	0.05	0.03	0.03	0.04	0.03	0.04	0.06	0.03	0.03	0.03	0.03	0.03	0.06	0.04	----	0.01
SO_4^{2-}, mg/l	28.0	32.0	3.0	25.0	32.0	17.0	17.0	15.0	15.0	30.0	10.0	40.0	40.0	22.0	1	10.8
Ca, mg/l	5.3	3.8	7.0	1.0	1.5	4.5	2.4	2.2	2.4	2.1	N.D	N.D	7.0	3.2	1	1.9
Mg, mg/l	3.4	3.0	2.0	9.0	1.1	2.7	1.1	7.6	8.4	2.8	N.D	N.D	9.0	4.1	1	3.0
Fe, mg/l	0.09	0.20	0.07	0.06	0.06	0.09	0.09	0.03	0.07	0.05	0.09	0.2	0.20	0.09	2	0.05
Mn, mg/l	0.3	0.5	0.2	0.07	0.2	0.2	0.2	0.3	0.3	0.2	0.1	0.3	0.5	0.02	3	0.1
Cd, mg/l	0.02	0.007	0.02	0.05	0.03	0.02	0.01	0.03	0.05	0.01	0.02	0.02	0.05	0.02	3	0.01
Zn, mg/l	0.2	0.09	0.02	0.05	0.04	0.01	0.007	0.02	0.06	0.01	0.02	0.02	0.2	0.05	1	0.05
Pb, mg/l	0.6	0.2	0.3	0.04	0.2	0.02	0.1	0.2	0.6	1.7	0.2	1.0	1.7	0.4	----	0.5
Total Hardness, ($CaCO_3$ mg/l)	17.3	0	17.2	N.D	18.6	N.D	9.3	N.D	0.0	0.0	20.1	N.D	20.1	10.3	1	9.1

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOMESTIC WATER SUPPLIES, 1998)

A Sample Data for Umtata River at Site 1 – Near the source

Date: Nov. 1999 – April 2000

Parameter	10/11/99	8/12/99	20/01/00	10/02/00	01/03/00	17/03/00	13/04/00	Max. Value	Average Value	Subst. Class	S.D
Time	09.17	09.08	09.20	08.50	09.03	N.D	N.D				
Temperature, ^0C	17.9	17.1	17.2	18.8	18.8	N.D	N.D	18.8	18.0	-----	0.8
pH	7.3	6.6	6.6	7.4	6.7	N.D	N.D	7.4	7.0	1	0.4
Conductivity, µS/cm	50.1	33.6	32.9	46.1	37	N.D	N.D	50.1	39.4	1	7.7
TDS, mg/l	44.0	30.0	29.0	41.0	33.0	N.D	N.D	44.0	35.4	1	6.7
Turbidity, NTU	0.4	7.4	74.0	68.0	81.2	N.D	N.D	81.2	46.2	5	39.0
Total coliform, Counts/100ml	100	160	1180	270	150	N.D	N.D	1180	372	5	455.9
Faecal Coliform, Counts/100ml	74	90	850	100	80	N.D	N.D	850	239	5	341.8
Cl^-, mg/l	4.0	1.5	5.2	10.0	8.0	N.D	N.D	10	5.7	1	3.3
NO_3^- as N, mg/l	0.5	3.3	0.1	N.D	0.01	N.D	N.D	3.3	1.0	1	1.6
PO_4^{3-} as P, mg/l	0.04	0.03	0.03	0.05	0.02	N.D	N.D	0.05	0.03	-----	0.01
Ca, mg/l	N.D	17.0	12.0	16.9	102.3	N.D	N.D	120.3	37.1	3	43.5
Mg, mg/l	N.D	9.6	1.1	1.4	1.0	N.D	N.D	9.6	3.3	1	42.1
Fe, mg/l	N.D	0.3	0.2	0.05	0.06	N.D	N.D	0.3	0.1	3	0.1
Mn, mg/l	N.D	0.2	0.2	0.7	0.1	N.D	N.D	0.7	0.3	3	0.3
Cd, mg/l	N.D	0.02	0.02	0.01	0.04	N.D	N.D	0.04	0.02	4	0.01
Zn, mg/l	N.D	0.2	0.02	0.07	0.01	N.D	N.D	0.2	0.08	1	0.9
Pb, mg/l	N.D	0.2	0.02	0.05	0.04	N.D	N.D	0.2	0.07	-----	0.07
Cu, mg/l	N.D	0.1	0.2	0.1	0.07	N.D	N.D	0.2	0.1	1	0.06
Total Hardness, ($CaCO_3$ mg/l)	N.D	20.8	19.4	21.5	10.8	N.D	N.D	21.5	18.1	1	5.0

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOMESTIC WATER SUPPLIES, 1998)

A Sample Data for Umtata River at Site 2 – After Tabase Location
Date: May 1999 – Oct 1999

Parameter	18/5	04/6	18/6	02/7	15/7	29/7	12/8	26/8	09/9	23/9	15/10	29/10	Max Value	Avg. Value	Subst Class	S.D
Time	10:20	10:50	10:42	10:17	10:10	10:24	10:16	10:00	10:10	10:39	10:25	10:25				
Temperature, ^{0}C	16.4	14.0	9.4	9.4	10.3	12.2	11.9	13.2	18.7	18.5	23.2	18.6	23.2	14.7	----	4.4
pH	6.9	7.5	8.0	8.1	8.5	7.9	8.1	7.5	7.5	7.6	7.8	6.6	8.5	7.7	1	0.5
Conductivity, µS/cm	57.2	70.6	69.2	73.0	77.1	89.3	85.5	90.6	116.8	101.6	83.6	33.8	116.8	79.0	1	21.2
TDS, mg/l	51.0	54.0	62.0	66.0	69.0	80.0	77.0	82.0	103.0	91.0	74.0	30.0	103.0	69.9	1	19.3
Turbidity, NTU	16.8	7.0	5.1	3.9	6.1	66.0	9.0	0.8	7.0	1.0	10.9	36.5	66.0	14.1	5	18.9
Total coliform, Counts/100ml	200	200	260	140	220	1260	230	80	130	30	2230	300	2230	440	5	648.1
Faecal Coliform, Counts/100ml	370	165	460	470	150	260	90	10	80	30	1760	100	1760	328.7	1	478.0
Cl^-, mg/l	10.0	2.8	3.1	3.4	3.2	3.5	4.0	5.0	5.0	5.0	5.0	6.0	10.0	4.7	1	2.0
NO_3^- as N, mg/l	0.5	0.4	0.3	0.3	1.0	0.5	0.05	0.6	1.3	0.9	1.0	4.1	4.1	0.9	1	1.1
PO_4^{3-} as P, mg/l	0.03	0.05	0.05	0.05	0.05	0.08	0.08	0.05	0.03	0.05	0.05	0.05	0.08	0.05	----	0.1
SO_4^{2-}, mg/l	25.0	40	5.0	25.0	12.0	21.0	19.0	18.0	20.0	32.0	12.0	43.0	43.0	22.7	1	11.3
Ca, mg/l	4.8	7.9	4.9	1.3	2.1	2.6	2.5	2.4	2.0	2.33	N.D	N.D	7.9	3.3	1	2.0
Mg, mg/l	3.9	3.2	2.0	1.3	1.3	2.7	9.8	9.4	8.0	3.3	N.D	N.D	9.8	4.5	1	3.3
Fe, mg/l	0.07	0.39	0.20	0.06	0.07	0.38	0.22	0.04	0.06	0.08	0.07	0.29	0.39	0.16	3	0.13
Mn, mg/l	0.35	0.50	0.36	0.12	0.37	0.28	0.39	0.25	0.17	0.24	0.01	0.56	0.56	0.29	3	0.15
Cd, mg/l	0.06	0.01	0.05	0.03	0.17	0.02	0.01	0.02	0.07	0.03	0.02	0.01	0.1	0.043	5	0.04
Zn, mg/l	0.66	0.18	0.01	0.07	0.05	0.01	0.02	0.03	0.07	0.03	0.03	0.02	0.66	0.10	1	0.18
Pb, mg/l	0.78	0.19	0.15	0.03	0.25	0.10	0.18	0.20	0.76	1.69	1.07	1.28	1.69	0.56	----	0.55
Cu, mg/l	0.10	0.23	0.16	0.24	0.16	0.15	0.21	0.09	0.19	0.29	0.38	N.D	0.38	0.2	1	0.09
Total Hardness, ($CaCO_3$ mg/l)	19.5	21.7	27.2	15.5	21.5	22.2	27.2	25.1	0.0	21.5	20.7	N.D	27.2	20.2	2	7.5

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOEMSTIC WATER SUPPLIES, 1998)

A Sample Data for Umtata River at Site 2 – After Tabase Location
Date: Nov. 1999 – April 2000

Parameter	10/11/99	8/12/99	20/01/00	10/02/00	01/03/00	17/03/00	13/04/00	Max. Value	Avg. Value	Subst. Class	S.D
Time	09.45	09.32	09.45	10.40	09.37	10.50	09.50				
Temperature, ^{0}C	22.6	20.5	19.0	27.7	22.1	21.3	17.8	27.7	21.5	-----	4.0
pH	7.0	6.7	6.8	7.4	6.9	6.7	6.9	7.4	6.9	1	0.2
Conductivity, μS/cm	70.4	42.8	38.7	62.2	44.8	32	47.5	70.4	48.3	1	13.4
TDS, mg/l	62.0	38.0	34.0	50.0	40.0	29.0	42.0	62.0	42.1	1	10.9
Turbidity, NTU	10.3	32.8	228.0	339.0	43.1	820.0	706.0	820.0	311.3	5	332.3
Total coliform, Counts/100ml	50	200	430	730	350	3000	3000	3000	1108.5	5	1309.0
Faecal Coliform, Counts/100ml	40	200	165	290	120	3000	1840	3000	807.5	5	1153.5
Cl^-, mg/l	12.0	6.0	6.6	12.0	8.0	12.0	0.6	12.0	8.1	1	4.3
NO_3^- as N, mg/l	0.5	3.7	0.1	N.D	0.01	4.4	3.3	4.4	2.0	1	2.0
PO_4^{3-} as P, mg/l	0.04	0.05	0.04	0.1	0.03	0.7	0.5	0.7	0.2	-----	0.3
SO_4^{2-}, mg/l	30.5	11.5	13.0	N.D	33.0	27.0	18.0	33.0	22.1	1	9.2
Ca, mg/l	N.D	27.0	18.0	22.5	95.3	26.8	15.0	95.3	34.1	3	30.4
Mg, mg/l	N.D	9.3	1.3	1.4	1.0	1.2	1.0	9.3	2.5	1	3.3
Fe, mg/l	N.D	0.2	0.4	0.04	0.07	2.1	0.3	2.1	0.5	3	0.8
Mn, mg/l	N.D	0.2	0.2	0.5	0.1	0.4	0.05	0.5	0.3	3	0.1
Cd, mg/l	N.D	0.03	0.02	0.05	0.01	0.02	0.24	0.24	0.06	5	0.09
Zn, mg/l	N.D	0.02	0.03	0.07	0.07	0.10	0.01	0.10	0.05	1	0.03
Pb, mg/l	N.D	0.46	0.03	0.04	0.03	0.07	0.45	0.46	0.18	-----	0.21
Cu, mg/l	N.D	0.29	0.06	0.09	0.09	0.21	0.06	0.29	0.13	1	0.09
Total Hardness, ($CaCO_3$ mg/l)	N.D	21.5	21.5	22.9	10.7	23.6	19.3	23.6	19.9	1	4.7

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOMESTIC WATER SUPPLIES, 1998)

A Sample Data for Umtata River at Site 3 – Before the Dam
Date: May 1999 – Oct.1999

Parameter	18/5	04/6	18/6	02/7	15/7	29/7	12/8	26/8	09/9	23/9	15/10	29/10	Max. Value	Avg. Value	Subst. Class	S.D
Time	11:30	12:06	11:35	11:37	11:06	11:17	11:15	10:57	11:00	11:38	11:40	11:47				
Temperature, ^{0}C	20.7	16.2	14.2	14.1	13.6	14.5	15.8	16.7	17.8	24.4	20.0	26.4	26.4	17.9	-----	4.2
pH	6.7	7.5	8.0	8.2	8.3	7.1	8.0	7.1	7.2	7.9	7.9	6.7	8.3	7.5	1	0.5
Conductivity, µS/cm	6.1	61.7	66.5	66.7	70.1	78.0	83.6	91.1	124.5	104.7	110.0	42.2	124.5	75.4	1	31.7
TDS, mg/l	55.0	56.0	59.0	61.0	63.0	70.0	75.0	82.0	110.0	95.0	98.0	37.0	110.0	71.7	1	21.1
Turbidity, NTU	59.0	69.0	57.0	72.0	126.0	63.0	74.0	63.0	148.0	53.0	170.0	226.0	226.0	98.3	5	56.1
Total coliform, Counts/100ml	10	130	170	0	300	10	20	0	20	10	10	520	520	100	4	161.6
Faecal Coliform, Counts/100ml	10	320	40	110	10	10	0	0	20	0	0	200	320	60	5	101.6
Cl^-, mg/l	116.0	3.6	3.7	7.1	3.6	3.0	7.0	7.0	7.0	N.D	9.0	6	116.0	15.7	2	33.3
PO_4^{3-} as P, mg/l	0.05	0.02	0.05	0.04	0.06	0.09	0.08	0.05	0.09	N.D	0.1	0.1	0.1	0.07	----	0.03
SO_4^{2-}, mg/l	73.0	36.0	5.0	25.0	12.0	12.0	14.0	13.0	22.0	N.D	14.0	31.0	73.0	23.3	1	18.9
Ca, mg/l	6.0	7.6	4.6	1.0	2.8	4.4	2.0	2.7	1.7	2.2	N.D	N.D	7.6	3.5	1	2.1
Mg, mg/l	4.0	2.9	3.1	1.0	1.1	2.7	1.1	1.1	8.5	2.8	N.D	N.D	8.5	2.8	1	2.3
Fe, mg/l	0.4	0.5	0.2	0.1	0.1	0.3	0.5	0.3	0.1	1.0	0.1	0.9	0.9	0.3	3	0.2
Cd, mg/l	0.03	0.01	0.05	0.03	1.0	0.04	0.03	0.03	0.05	0.03	0.02	0.02	0.19	0.05	5	0.05
Zn, mg/l	0.8	0.02	0.02	0.03	0.04	0.04	0.01	0.03	0.04	0.01	0.03	0.07	0.83	0.10	1	0.23
Pb, mg/l	0.95	0.23	0.34	0.04	0.17	0.07	0.32	0.31	0.73	1.56	1.40	1.49	1.56	0.62	----	0.57
Cu, mg/l	0.2	0.3	0.3	0.2	0.2	0.1	0.1	0.2	0.2	0.3	0.4	N.D	0.4	0.2	1	0.09
Total Hardness, ($CaCO_3$ mg/l)	17.3	17.3	18.6	23.9	19.4	22.2	743.7	18.6	11.5	28.8	25.8	N.D	743.7	86.1	5	218.1

N.D. = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOMESTIC WATER SUPPLIES, 1998)

A Sample Data for Umtata River at Site 3 – Before the Dam
Date: Nov. 1999 – April 2000

Parameter	10/11/99	8/12/99	20/01/00	10/02/00	01/03/00	17/03/00	13/04/00	Max. Value	Avg. Value	Subst. Class	S.D
Time	11:47	10:29	10:21	10:40	10:43	10:50	11:30				
Temperature, ^{0}C	27.8	25.3	28.9	27.7	24.6	21.5	24.4	28.9	25.7	------	2.5
pH	7.0	6.9	6.8	7.3	7.4	6.7	7.2	7.4	7.1	1	0.3
Conductivity, µS/cm	75.8	47.8	38.9	62.2	52.0	61.2	58.4	75.8	56.6	1	11.8
TDS, mg/l	55.0	43.0	34.0	50.0	46.0	55.0	52.0	55.0	47.9	1	7.5
Turbidity, NTU	121.0	475.0	1000.0	78.5	64.0	670.0	145.0	1000.0	364.8	5	362.6
Total coliform, Counts/100ml	20	220	800	450	140	1000	570	1000	457	5	358.9
Faecal Coliform, Counts/100ml	10	180	575	150	60	940	290	940	315	5	332.3
Cl^-, mg/l	7.0	3.5	7.7	10.0	8.0	14.0	0.6	14.0	7.3	1	4.3
NO_3^- as N, mg/l	0.6	4.0	0.3	N.D	0.01	5.3	0.9	5.3	1.9	1	2.2
PO_4^{3-} as P, mg/l	0.08	0.28	0.08	0.08	0.15	0.86	0.11	0.86	0.23	------	0.29
SO_4^{2-}, mg/l	28.0	13.5	11.0	N.D	24.0	39.0	28.0	39.0	23.9	1	10.3
Ca, mg/l	N.D	17.0	10.0	21.3	107.3	33.0	14.0	107.3	33.7	3	36.9
Mg, mg/l	N.D	7.6	1.1	1.5	1.3	1.2	1.0	7.6	2.3	1	2.6
Fe, mg/l	N.D	0.90	0.41	0.13	0.05	1.25	0.09	1.25	0.48	3	0.51
Mn, mg/l	N.D	0.38	0.09	0.56	0.45	0.23	0.19	0.56	6.32	3	0.18
Cd, mg/l	N.D	0.03	0.09	0.02	0.04	0.09	0.19	0.19	0.07	5	0.63
Zn, mg/l	N.D	0.03	0.06	0.14	0.08	0.11	0.06	0.14	0.08	1	0.04
Pb, mg/l	N.D	0.96	0.03	0.08		0.07	0.45	0.96	0.32	-----	0.40
Cu, mg/l	N.D	0.19	0.07	0.19	0.03	0.15	0.12	0.19	0.13	1	0.06
Total Hardness, ($CaCO_3$ mg/l)	N.D	19.4	18.6	18.6	23.7	34.4	19.3	34.4	22.3	2	6.2

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOMESTIC WATER SUPPLIES, 1998)

A Sample Data for Umtata River at Site 4 – At the Dam.
Date: May 1999 – Oct. 1999

Parameter	18/5	04/6	18/6	02/7	15/7	29/7	12/8	26/8	09/9	23/9	15/10	29/10	Max. Value	Avg. Value	Subst. Class	S.D
Time	12:23	13:05	12:27	12:32	13:03	12:05	12:07	11:45	11:50	12:30	13:05	12:25				
Temperature, ^{0}C	23.6	17.4	17.1	15.2	15.0	16.6	19.7	18.2	17.8	16.3	20.9	21.5	23.6	18.3	-----	2.6
pH	4.8	7.7	7.6	8.1	8.7	7.7	7.6	6.9	7.5	8.2	8.2	7.0	8.7	7.5	1	1.0
Conductivity, µS/cm	94.9	61.8	69.1	69.2	67.9	69.2	72.0	70.1	96.5	72.0	73.0	76.4	96.5	74.3	1	10.5
TDS, mg/l	8.05	61.0	62.0	62.0	61.0	62.0	63.0	62.0	85.0	65.0	55.0	67.0	85.0	65.8	1	9.3
Turbidity, NTU	199.0	210.0	196.0	155.0	352.0	202.0	196.0	181.0	320.0	171.0	189.0	238.0	352.0	217.4	5	59.3
Total coliform, Counts/100ml	20	150	0	10	20	0	10	60	110	290	60	40	290	64	4	84.7
Faecal Coliform, Counts/100ml	10	265	10	80	20	10	10	20	90	0	30	10	265	46	5	74.6
Cl^-, mg/l	20.3	12.8	4.1	10.0	8.2	4.0	8.0	6.0	6.0	N.D	8.0	9.0	20.3	8.7	1	4.6
NO_3^- as N, mg/l	23.0	2.3	0.3	0.5	1.9	1.5	1.5	1.7	2.8	N.D	1.2	5.8	23.0	3.9	1	6.5
PO_4^{3-} as P, mg/l	0.34	0.21	0.06	0.05	0.08	0.06	0.31	0.16	0.32	N.D	0.18	0.16	0.34	0.18	-----	0.10
SO_4^{2-}, mg/l	30.0	44.0	12.0	25.0	25.0	20.0	22.0	20.0	29.0	N.D	16.0	29.0	44.0	24.7	1	8.5
Ca, mg/l	5.1	5.0	1.0	1.4	0.1	7.6	1.7	2.2	2.6	2.3	N.D	N.D	7.6	2.9	1	2.3
Mg, mg/l	4.2	3.0	1.2	1.0	1.1	2.7	1.4	9.1	7.4	3.3	N.D	N.D	9.1	3.4	1	2.7
Fe, mg/l	0.20	0.82	0.13	0.12	0.14	0.64	0.42	0.57	0.06	0.08	0.13	0.86	0.86	0.35	3	0.30
Mn, mg/l	0.50	1.59	0.39	0.75	0.39	0.52	1.88	1.37	0.76	0.84	0.54	1.19	1.88	0.89	4	0.49
Cd, mg/l	0.043	0.004	0.050	0.045	0.043	0.067	0.036	0.025	0.057	0.059	0.020	0.024	0.067	0.039	5	0.01
Zn, mg/l	0.31	0.084	0.056	0.016	0.035	0.057	0.051	0.018	0.058	0.048	0.058	0.055	0.31	0.017	1	0.07
Pb, mg/l	1.08	0.25	0.34	0.019	0.34	0.04	1.68	0.40	0.69	2.24	0.37	1.75	2.24	0.77	-----	0.74
Cu, mg/l	0.81	0.34	0.12	0.22	0.270	0.136	0.156	0.412	0.258	0.266	0.456	N.D	0.81	0.31	2	0.19
Total Hardness, ($CaCO_3$ mg/l)	21.7	21.7	21.5	28.7	19.1	23.7	21.5	21.5	12.9	20.7	19.3	N.D	28.7	21.13	2	3.7

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOMESTIC WATER SUPPLIES, 1998)

A Sample Data for Umtata River at Site 4 – At the Dam.
Date: Nov. 1999 – April 2000

Parameter	10/11/99	8/12/99	20/01/00	10/02/00	01/03/00	17/03/00	13/04/00	Max. Value	Avg. Value	Subst. Class	S.D
Time	11:35	11:19	12:30	11:30	11:37	12:05	12:35				
Temperature, ^{0}C	23.0	31.3	23.6	32.2	23.0	21.9	28.3	32.2	26.1	------	4.3
pH	7.2	7.4	7.1	7.3	7.7	6.9	7.1	7.7	7.2	1	0.3
Conductivity, µS/cm	95.4	74.7	75.9	94.0	70.4	66.4	59.3	95.4	76.5	1	13.5
TDS, mg/l	84.0	66.0	68.0	81.0	63.0	59.0	52.0	84.0	67.5	1	11.5
Turbidity, NTU	285.0	235.0	1000.0	59.9	39.3	270.0	343.0	1000.0	318.9	5	321.5
Total coliform, Counts/100ml	30	50	660	50	60	1000	170	1000	289	4	385.3
Faecal Coliform, Counts/100ml	10	30	350	30	20	140	40	350	88.57	5	123.2
Cl^-, mg/l	12.5	12.0	18.2	11.0	12.0	10.0	0.4	18.2	10.9	1	5.3
NO_3^- as N, mg/l	0.9	4.2	2.2	N.D	2.8	3.9	4.1	4.2	3.0	1	1.3
SO_4^{2-}, mg/l	30.5	15.5	9.0	N.B	16.0	16.0	14.0	30.5	16.8	1	7.2
Ca, mg/l	N.D	22.0	26.0	25.0	104.1	29.0	12.0	104.1	36.3	3	33.7
Mg, mg/l	N.D	10.3	1.1	1.7	1.	1.2	1.1	10.3	2.7	1	3.7
Fe, mg/l	N.D	0.18	0.41	0.11	0.08	0.56	0.10	0.56	0.24	3	0.20
Mn, mg/l	N.D	0.28	0.15	1.73	0.22	0.41	0.12	1.73	0.49	4	0.62
Cd, mg/l	N.D	0.03	0.019	0.030	0.01	0.05	0.20	0.20	0.069	5	0.071
Zn, mg/l	N.D	0.03	0.09	0.150	0.16	0.15	0.12	0.16	0.11	1	0.05
Pb, mg/l	N.D	1.3	0.02	0.10	0.03	0.08	0.44	1.26	0.32	-----	0.49
Cu, mg/l	N.D	0.19	0.11	0.20	0.14	0.43	0.16	0.434	0.21	1	0.12
Total Hardness, ($CaCO_3$ mg/l)	N.D	43.0	23.7	25.8	21.5	23.7	8.6	43.0	24.3	2	11.0

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOMESTIC WATER SUPPLIES, 1998)

A Sample Data for Umtata River at Site 5 – After the Dam.
Date: May 1999 – Oct.1999

Parameter	18/5	04/6	18/6	02/7	15/7	29/7	12/8	26/8	09/9	23/9	15/10	29/10	Max. Value	Avg. Value	Subst. Class	S.D
Time	12:45	14:00	12:40	13:45	12:16	12:15	12:20	11:55	12:05	12:49	13:25	13:03				
Temperature, ^{0}C	19.1	16.9	14.9	14.0	13.8	12.9	12.9	13.1	15.3	14.8	16.7	16.5	19.1	15.1	-----	1.9
pH	3.4	7.7	7.9	8.3	8.4	7.8	7.7	6.3	8.7	7.4	8.1	7.1	8.7	7.4	1	1.4
Conductivity, µS/cm	286.0	69.9	68.4	68.6	68.7	67.2	69.3	69.7	88.9	71.0	71.7	72.4	286.0	89.2	1	62.2
TDS, mg/l	258.0	61.0	62.0	62.0	62.0	61.0	61.0	63.0	78.0	63.0	64.0	64.0	258.0	80	1	56.3
Faecal Coliform, Counts/100ml	10	95	10	20	10	10	10	0	20	0	20	10	95	18	4	25.1
Cl^-, mg/l	9.1	13.6	8.2	12.0	7.9	1.5	9.0	8.0	8.0	N.D	6.0	10	13.6	8.5	1	3.1
NO_3^- as N, mg/l	0.3	2.8	0.04	0.5	2.8	1.6	1.7	1.0	2.1	N.D	1.5	5.3	5.3	1.7	1	1.5
PO_4^{3-} as P, mg/l	0.04	0.06	0.12	0.12	0.06	0.28	0.28	0.23	0.22	N.D	0.19	0.14	0.28	0.16	-----	0.09
SO_4^{2-}, mg/l	25.0	25.0	16.0	26.8	28.0	26.0	27.0	26.0	26.0	N.D	24.0	32.0	32.0	25.6	1	3.8
Ca, mg/l	7.0	5.8	1.7	0.01	1.0	0.8	2.4	2.4	1.9	2.3	N.D	N.D	7.0	2.5	1	2.2
Mg, mg/l	4.9	8.2	1.7	1.1	1.2	2.7	2.0	9.4	6.2	1.5	N.D	N.D	9.4	3.9	1	3.1
Fe, mg/l	0.20	0.81	0.30	0.08	0.08	0.59	0.48	0.58	0.07	0.07	0.28	0.94	0.94	0.37	3	0.30
Mn, mg/l	0.56	1.99	0.74	0.60	0.61	0.61	1.28	1.50	0.58	0.77	0.12	0.07	1.99	0.79	4	0.55
Cd, mg/l	0.02	0.09	0.06	0.03	0.045	0.13	0.03	0.03	0.07	0.09	0.03	0.02	0.13	0.05	5	0.03
Zn, mg/l	0.51	0.32	0.02	0.07	0.02	0.07	0.18	0.04	0.07	0.07	0.07	0.07	0.51	0.124	1	0.15
Pb, mg/l	1.54	0.31	0.60	0.58	0.38	0.08	0.50	0.49	0.75	1.48	2.8	1.36	2.8	0.91	----	0.76
Cu, mg/l	0.5	0.32	0.17	0.28	0.27	0.25	0.17	0.01	0.19	N.D	N.D	N.D	0.50	0.24	1	0.13
Total Hardness, ($CaCO_3$ mg/l)	19.5	19.5	21.5	21.5	15.7	24.3	20.7	22.2	17.9	N.D	N.D	N.D	24.3	20.3	1	2.5

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOMESTIC WATER SUPPLIES, 1998)

A Sample Data for Umtata River at Site 5 – After the Dam.

Date: Nov. 1999 – April 2000

Parameter	10/11/99	8/12/99	20/01/00	10/02/00	01/03/00	17/03/00	13/04/00	Max. Value	Avg. Value	Subst. Class	S.D
Time	11:47	11:32	12:47	11:42	11:49	12:25	12:50				
Temperature, ^{0}C	17.6	30.6	29.5	32.5	22.1	20.5	23.2	32.5	25.1	-----	5.7
pH	7.2	7.7	8.3	7.6	7.4	7.3	7.2	8.3	7.5	1	0.3
Conductivity, µS/cm	93.2	120.0	127.2	179.3	68.6	68.5	111.7	179.3	109.8	1	38.5
TDS, mg/l	82.0	107.0	113.0	165.0	61.0	61.0	99.0	165.0	98.3	1	36.0
Turbidity, NTU	289.0	158.0	1000.0	34.9	66.2	1080.0	996.0	1080.0	517.7		482.3
Total coliform, Counts/100ml	20	200	3000	80	80	3000	0	3000	911	5	1428.1
Faecal Coliform, Counts/100ml	10	190	3000	10	20	3000	0	3000	890	5	1442.9
Cl^-, mg/l	4.0	12.5	17.5	16.0	14.0	12.0	0.9	17.5	10.9	1	6.2
NO_3^- as N, mg/l	0.8	4.3	1.3	N.D	3.0	5.3	6.8	6.8	3.5	2	2.3
PO_4^{3-} as P, mg/l	0.2	0.1	0.1	0.3	0.4	0.7	0.8	0.8	0.3	-----	0.3
SO_4^{2-}, mg/l	26.5	15.5	13.0	N.D	15.0	17.0	21.0	26.5	18.0	1	4.9
Ca, mg/l	N.D	29.0	31.0	33.7	98.1	75.6	23.0	98.1	48.3	3	30.8
Mg, mg/l	N.D	11.8	1.2	1.9	1.1	0.6	1.0	11.8	2.9	1	4.3
Fe, mg/l	N.D	0.20	0.51	0.09	0.08	2.34	0.15	2.34	0.56	4	0.89
Mn, mg/l	N.D	0.36	0.16	0.76	0.34	0.47	0.08	0.76	0.36	3	0.24
Cd, mg/l	N.D	0.05	0.02	0.03	0.04	0.16	0.21	0.21	0.09	5	0.08
Zn, mg/l	N.D	0.04	0.05	0.14	0.05	0.22	0.22	0.22	0.12	1	0.08
Pb, mg/l	N.D	1.36	0.04	0.02	0.02	0.06	0.5	1.4	0.33	----	0.54
Cu, mg/l	N.D	0.08	0.15	0.08	0.09	0.16	0.08	0.16	0.11	1	0.04
Total Hardness, ($CaCO_3$ mg/l)	N.D	48.0	42.3	39.2	43.0	64.5	32.3	64.5	44.9	2	10.9

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOMESTIC WATER SUPPLIES, 1998)

A Sample Data for Umtata River at Site 6 – After Pollar Park Locaton
Date: May 1999 – Oct. 1999

Parameter	18/5	04/6	18/6	02/7	15/7	29/7	12/8	26/8	09/9	23/9	15/10	29/10	Max. Value	Avg. Value	Subst. Class	S.D
Time	13:12	17:05	13:10	13:28	12:45	12:55	12:50	12:50	12:40	13:30	14:15	13:45				
Temperature, ^0C	18.6	18.8	17.9	15.9	17.8	15.6	16.0	17.1	19.9	21.6	23.3	19.8	23.3	18.5	-----	2.3
pH	6.4	7.5	7.7	8.5	8.3	8.2	7.9	7.1	8.7	7.7	7.9	7.3	8.7	7.7	1	0.6
Conductivity, µS/cm	286.0	81.7	226.0	206.0	81.4	83.1	79.2	77.9	97.9	81.0	73.6	78.6	286.0	121.0	1	73.7
TDS, mg/l	258.0	74.0	222.0	188.0	72.0	75.0	74.0	70.0	85.0	72.0	68.0	70.0	258.0	110.7	1	69.3
Turbidity, NTU	225.0	213.0	203.0	161.0	216.0	208.0	211.0	190.0	156.0	152.0	175.0	210.0	225.0	193.3	5	25.7
Total coliform, Counts/100ml	150	10000	10	550	760	1740	2520	2030	2860	230	200	280	10000	1777	5	2777.1
Faecal Coliform, Counts/100ml	29	380	3000	3000	550	1020	2140	1780	2390	100	70	110	3000	1214	5	1178.9
Cl^-, mg/l	19.0	21.1	11.0	16.0	11.7	5.5	9.0	9.0	9.0	8.0	8.0	12.0	21.1	11.6	1	4.7
NO_3^- as N, mg/l	2.5	2.3	0.05	0.5	0.9	1.9	1.9	1.3	1.7	1.2	1.3	5.7	5.7	1.7	1	1.4
PO_4^{3-} as P, mg/l	0.28	0.31	0.13	0.13	0.25	0.27	0.25	0.19	0.22	0.2	0.19	0.17	0.31	0.22	-----	0.05
SO_4^{2-}, mg/l	25.0	25.0	16.0	28.0	19.0	26.0	29.0	28.0	32.0	60.0	24.0	35.0	60.0	28.9	1	11.1
Ca, mg/l	5.0	5.6	3.8	0.01	0.8	0.9	2.4	2.3	1.4	2.17	N.D	N.D	5.6	2.4	1	1.8
Mg, mg/l	4.1	2.9	2.0	0.9	1.1	2.8	1.2	7.1	9.3	1.7	N.D	N.D	9.3	3.3	1	2.8
Fe, mg/l	0.30	0.76	0.10	0.09	0.09	0.57	0.28	0.59	0.10	0.11	0.25	0.25	0.76	0.29	3	0.23
Mn, mg/l	0.60	1.73	0.30	0.45	0.29	0.30	1.86	1.74	0.94	1.04	0.70	0.75	1.86	0.89	4	0.57
Cd, mg/l	0.06	0.05	0.05	0.06	0.05	0.03	0.02	0.04	0.07	0.05	0.07	0.07	0.075	0.05	5	0.02
Zn, mg/l	0.23	0.09	0.02	0.05	0.05	0.10	0.09	0.04	0.07	0.04	0.09	0.06	0.23	0.08	1	0.05
Pb, mg/l	2.04	0.70	0.75	0.058	0.08	0.11	0.96	0.43	0.14	1.88	2.70	2.12	2.70	1.00	-----	0.94
Cu, mg/l	0.86	0.22	0.14	0.25	0.27	0.23	0.23	0.005	0.65	N.D	N.D	N.D	0.86	0.32	2	0.27
Total Hardness, ($CaCO_3$ mg/l)	23.9	21.7	25.1	23.9	17.9	27.2	7.9	20.8	19.3	N.D	N.D	N.D	27.2	20.9	2	5.7

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOMESTIC WATER SUPPLIES, 1998)

A Sample Data for Umtata River at Site 6 – After Pollar Park Location
Date: Nov. 1999 – April 2000

Parameter	10/11/99	8/12/99	20/01/00	10/02/00	01/03/00	17/03/00	13/04/00	Max. Value	Average Value.	Substance Class	S.D
Time	12:34	12:10	13:40	12:28	12:15	12:50	13:32				
Temperature, ^0C	20.8	25.3	27.2	26.2	22.5	20.5	21.5	27.2	23.4	------	2.7
pH	7.3	7.5	7.7	7.9	7.8	6.1	7.3	7.9	7.3	1	0.5
Conductivity, µS/cm	103.0	104.3	245.0	475.0	82.0	70.7	151.4	475.0	175.9	1	144.4
TDS, mg/l	90.0	93.0	218.0	413.0	73.0	63.0	133.0	413.0	154.7	1	125.3
Turbidity, NTU	305.0	176.0	1000.0	81.6	23.0	3040.0	1000.0	3040.0	803.7	5	1068.6
Total coliform, Counts/100ml	910	3000	3000	24200	1420	3000	0	24200	5075	5	8516.1
Faecal Coliform, Counts/100ml	650	3000	3000	1500	200	3000	0	3000	1621	5	1372.9
Cl^-, mg/l	18.0	13.5	36.5	52.0	16.0	12.0	1.1	52.0	21.3	1	17.1
NO_3^- as N, mg/l	0.7	4.2	1.3	N.D	2.5	14.0	6.2	14.0	4.8	3	4.9
PO_4^{3-} as P, mg/l	0.20	0.19	0.28	0.22	0.42	1.93	0.78	1.93	0.57	------	0.6
SO_4^{2-}, mg/l	27.5	24.5	15.0	N.D	15.0	24.0	20.0	27.5	21.0	1	5.2
Mg, mg/l	N.D	9.8	1.1	1.5	1.0	1.1	1.1	9.8	2.6	1	3.5
Fe, mg/l	N.D	0.56	0.18	0.07	0.09	3.44	0.54	3.44	0.81	4	1.31
Mn, mg/l	N.D	1.03	0.15	0.46	0.19	0.91	0.25	1.03	0.50	4	0.38
Cd, mg/l	N.D	0.03	0.03	0.05	0.05	0.08	0.17	0.17	0.07	5	0.05
Zn, mg/l	N.D	0.05	0.02	0.03	0.15	0.10	0.05	0.15	0.07	1	0.05
Pb, mg/l	N.D	1.73	0.03	0.05	0.01	0.07	0.41	1.73	0.39	------	0.67
Cu, mg/l	N.D	0.18	0.13	0.16	0.17	0.21	0.12	0.21	0.17	1	0.03
Total Hardness, ($CaCO_3$ mg/l)	N.D	42.3	55.9	105.3	45.1	70.9	64.5	105.3	64.0	2	23.0

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOMESTIC WATER SUPPLIES, 1998)

A Sample Data for Umtata River at Site 7 – Norwood Bridge
Date: May 1999 – Oct 1999

Parameter	18/5	04/6	18/6	02/7	15/7	29/7	12/8	26/8	09/9	23/9	15/10	29/10	Max. Value	Avg. Value	Subs. Class	S.D
Time	13:57	15:00	13:45	13:48	13:15	13:30	13:30	13:00	13:05	13:55	14:45	14:10				
Temperature, ^0C	20.0	20.6	18.3	15.7	17.6	15.7	15.5	16.7	20.7	19.3	32.5	19.0	32.5	19.3	-----	4.5
pH	6.7	7.5	7.7	8.1	8.5	7.9	8.4	7.0	7.8	8.4	8.4	7.3	8.5	7.8	1	0.5
Conductivity, µS/cm	102.4	80.4	86.0	250.0	146.6	85.3	83.2	81.5	104.3	80.5	78.6	82.5	250.0	105.1	1	49.5
TDS, mg/l	91.0	72.0	78.0	226.0	139.0	77.0	78.0	73.0	91.0	71.0	69.0	73.0	226.0	94.8	1	45.5
Turbidity, NTU	220.0	211.0	206.0	214.0	213.0	211.0	215.0	175.0	177.0	98.0	176.0	238.0	238.0	196.1	5	36.5
Total coliform, Counts/100ml	1000	60	1460	3000	300	3000	3000	125500	N.D	6700	13500	10200	125500	15247	5	36816.3
Faecal Coliform, Counts/100ml	3000	70	3000	30000	3000	30000	3000	9500	N.D	3400	700	1500	30000	7925	5	11179.3
Cl^-, mg/l	19.0	12.0	21.0	17.0	14.5	8.5	11.0	8.0	9.0	9.0	7.0	14.0	21.0	12.5	1	4.6
NO_3^- as N, mg/l	28.0	2.5	0.5	0.6	3.3	2.2	2.1	2.5	2.5	0.9	1.6	5.4	28.0	4.3	4	7.5
PO_4^{3-} as P, mg/l	0.35	0.38	0.08	0.11	0.21	0.26	3.14	0.21	0.20	0.6	0.17	0.15	3.14	0.49	-----	0.85
SO_4^{2-}, mg/l	27.0	26.0	9.0	24.5	32.0	29.0	27.0	27.0	28.0	42.0	28.0	34.0	42.0	27.7	1	7.5
Ca, mg/l	0.1	6.8	3.5	0.1	0.6	1.2	2.5	2.4	3.8	2.3	N.D	N.D	6.8	2.3	1	2.0
Mg, mg/l	5.1	2.7	2.0	1.8	1.2	2.4	0.9	6.0	7.2	5.38	N.D	N.D	7.2	3.5	1	2.2
Fe, mg/l	0.20	0.66	0.11	0.05	0.10	0.46	0.60	0.61	0.05	0.06	0.14	0.11	0.66	0.26	3	0.25
Mn, mg/l	0.67	1.52	0.50	0.36	0.51	0.54	0.97	1.50	0.89	0.84	0.63	0.93	1.52	5.28	3	15.35
Cd, mg/l	0.03	0.01	0.14	0.02	0.01	0.04	0.04	0.03	0.07	0.03	0.04	0.04	0.14	0.04	5	0.04
Zn, mg/l	0.200	0.37	0.005	0.046	0.083	0.067	0.073	0.045	0.098	0.065	0.085	0.050	0.386	0.100	1	0.101
Pb, mg/l	1.67	1.60	0.12	0.08	0.12	0.29	1.03	0.39	0.63	1.49	2.6	1.24	2.6	0.94	-----	0.80
Cu, mg/l	0.95	0.21	0.17	0.25	0.17	0.17	0.26	0.26	0.39	N.D	N.D	N.D	0.95	0.31	2	0.25
Total Hardness, ($CaCO_3$ mg/l)	23.9	23.9	22.9	25.1	19.3	22.9	N.D	22.2	25.1	N.D	N.D	N.D	25.1	23.16	1	1.84

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOMESTC WATER SUPPLIES, 1998)

A Sample Data for Umtata River at Site 7 – Norwood Bridge

Date: Nov. 1999 – April 2000

Parameter	10/11/99	8/12/99	20/01/00	10/02/00	01/03/00	17/03/00	13/04/00	Max. Value	Average Value	Substance Class	S.D
Time	12:55	12:33	14:10	12:45	12:50	13:07	14:00				
Temperature, ^{0}C	22.4	27.6	26.2	27.4	22.4	20.7	22.5	27.6	24.1	-------	2.8
pH	7.3	7.8	7.5	7.9	7.5	6.5	7.2	7.9	7.4	1	0.5
Conductivity, µS/cm	106.7	290	240.0	411.0	82.4	71.1	171.7	411.0	196.1	1	125.2
TDS, mg/l	94.0	257.0	211.0	353.0	73.0	63.0	153.0	353.0	172.0	1	107.7
Turbidity, NTU	306.0	128.0	1000.0	82.7	87.7	3120.0	375.3	3120.0	728.5	5	1101.9
Total coliform, Counts/100ml	5800	7200	15000	8700	2100	19900	3600	19900	8900	5	6391.1
Faecal Coliform, Counts/100ml	600	4700	7000	2000	100	6700	1400	7000	3214	5	2886.4
Cl^-, mg/l	12.0	33.0	53.5	44.0	14.0	12.0	1.2	53.5	24.2	1	19.40
NO_3^- as N, mg/l	0.6	4.3	2.0	N.D	3.1	6.7	3.1	6.7	3.3	2	2.1
PO_4^{3-} as P, mg/l	0.23	0.17	0.33	0.14	0.43	0.85	0.42	0.85	0.37	-------	0.24
SO_4^{2-}, mg/l	26.0	26.5	32.0	N.D	14.0	23.0	16.0	32.0	22.9	1	6.8
Ca, mg/l	N.D	31.0	46.0	65.9	102.1	72.9	23.0	102.1	56.8	3	29.3
Mg, mg/l	N.D	15.2	1.3	2.7	1.0	1.1	1.0	15.2	3.7	1	5.7
Fe, mg/l	N.D	0.43	0.30	0.20	0.08	3.42	0.15	3.42	0.76	4	1.31
Mn, mg/l	N.D	0.29	0.08	0.52	0.44	0.63	0.05	0.63	0.34	3	0.23
Cd, mg/l	N.D	0.02	0.03	0.03	0.03	0.08	0.26	0.26	0.08	5	0.09
Zn, mg/l	N.D	0.07	0.03	0.08	0.02	0.21	0.25	0.25	0.11	1	0.10
Pb, mg/l	N.D	0.15	0.13	0.18	0.19	0.32	0.10	0.32	0.18	------	0.08
Cu, mg/l	N.D	1.22	0.03	0.07	0.03	0.07	0.41	1.22	0.31	3	0.47
Total Hardness, ($CaCO_3$ mg/l)	N.D	49.5	87.4	104.6	32.3	64.5	51.6	104.6	65.0	2	26.7

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOMESTIC WATER SUPPLIES, 1998)

A Sample Data for Umtata River at Site 8 – After Sewage works
Date: May 1999 – Oct.1999

Parameter	18/5	04/6	18/6	02/7	15/7	29/7	12/8	26/8	09/9	23/9	15/10	29/10	Max. Value	Avg. Value	Subs Class	S.D
Time	14:20	15:20	14:00	14:40	13:42	13:55	13:50	13:25	13:28	14:26	15:07	14:39				
Temperature, ^0C	19.4	18.4	14.4	15.6	19.3	17.1	17.4	17.1	17.9	21.3	22.3	21.1	22.3	18.4	-----	2.3
pH	7.2	7.4	7.4	6.9	8.4	7.8	8.9	6.85	7.9	8.6	8.2	7.3	8.9	7.7	1	0.6
Conductivity, µS/cm	472.0	370.0	394.0	587.0	388.0	346.0	323.0	251.0	307.0	150.0	184.4	144.2	587.0	326.38	1	131.5
TDS, mg/l	429.0	334.0	358.0	528.0	333.0	300.0	289.0	225.0	272.0	133.0	163.0	128.0	528.0	291.0	1	119.1
Turbidity, NTU	24.9	15.0	52.0	808.0	93.0	88.0	141.0	121.0	194.0	128.0	121.0	313.0	808.0	174.9	5	214.7
Total coliform, Counts/100ml	3000	3000	3000	3000	3000	3000	3000	93000	4400	4900	127000	9700	127000	21667	5	41936.2
Faecal Coliform, Counts/100ml	3000	3000	3000	3000	840	3000	3000	9100	2900	3900	3900	3100	9100	3478	5	1925.1
Cl^-, mg/l	25.0	20.2	16.0	57.0	24.4	28.5	23.0	23.0	22.0	23.0	16.0	19.0	57.0	24.7	1	10.7
NO_3^- as N, mg/l	2.2	2.1	0.4	0.7	1.3	2.0	1.9	2.9	2.6	1.5	1.9	10.5	10.5	2.5	1	2.6
PO_4^{3-} as P, mg/l	3.8	3.3	3.3	5.0	2.9	2.9	3.1	2.4	2.1	2.0	1.6	1.0	5.0	2.7	-----	1.1
SO_4^{2-}, mg/l	25.0	28.0	7.0	23.9	25.0	25.0	27.0	28.0	30.0	53.0	29.0	28.0	53.0	27.4	1	10.1
Ca, mg/l	17.0	7.0	1.4	8.0	1.4	2.6	2.5	2.4	1.8	1.7	N.D	N.D	17.0	4.5	1	4.9
Mg, mg/l	5.0	3.1	3.0	1.8	0.9	6.0	0.69	6.1	4.1	2.84	N.D	N.D	6.1	3.35	1	1.94
Fe, mg/l	0.23	0.28	0.17	0.08	0.09	0.23	1.38	0.39	0.19	0.15	0.15	0.15	1.38	0.29	3	0.35
Mn, mg/l	0.70	1.25	0.35	1.16	0.34	0.34	0.58	0.73	2.04	1.48	0.75	1.15	2.04	0.91	4	0.52
Cd, mg/l	0.05	0.08	0.03	0.03	0.04	0.08	0.12	0.04	0.07	0.05	0.03	0.03	0.12	0.05	5	0.03
Zn, mg/l	0.22	0.32	0.04	0.24	0.04	0.06	0.07	0.04	0.05	0.08	0.06	0.04	0.32	0.10	1	0.10
Pb, mg/l	1.98	2.04	1.57	0.09	1.17	0.30	2.05	0.51	0.59	1.39	5.90	5.87	5.9	1.96	-----	1.96
Cu, mg/l	0.90	0.61	0.32	2.10	0.69	0.68	0.69	0.15	0.18	0.50	1.87	N.D	2.10	0.79	4	0.64
Total Hardness, ($CaCO_3$ mg/l)	36.9	45.5	60.9	N.D	54.5	68.1	20.1	43.0	41.5	43.0	50.9	N.D	68.1	46.5	2	13.3

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOMESTIC WATER SUPPLIES, 1998)

A Sample Data for Umtata River at Site 8 – After Sewage works
Date: Nov. 1999 – April 2000

Parameter	10/11/99	8/12/99	20/01/00	10/02/00	01/03/00	17/03/00	13/04/00	Max. Value.	Average Value.	Substance Class	S.D
Time	13:10	12:45	14:37	13:05	13:15	13:27	14:25				
Temperature, ^0C	22.4	26.2	27.9	27.6	24.2	20.8	23.0	27.9	24.6	------	2.7
pH	7.7	7.7	7.3	7.9	7.3	6.8	7.2	7.9	7.5	1	0.4
Conductivity, µS/cm	277.0	328.0	311.0	424.0	268.0	73.0	202.0	424.0	269.0	1	109.7
TDS, mg/l	244.0	293.0	276.0	367.0	238.0	65.0	182.0	367.0	237.9	1	95.1
Turbidity, NTU	235.0	22.7	1000.0	62.6	99.1	3700.0	241.0	3700.0	765.7	5	1336.2
Total coliform, Counts/100ml	1100	8000	10000	69000	3100	24300	2400	69000	16843	5	24311.5
Faecal Coliform, Counts/100ml	700	2800	8000	13700	1200	8000	900	13700	5042.9	5	4970.9
Cl^-, mg/l	19.5	38.5	33.6	40.0	28.0	12.0	1.1	40.0	24.7	1	14.5
NO_3^- as N, mg/l	0.9	4.7	0.4	N.D	0.3	18.3	1.5	18.3	4.3	3	7.0
PO_4^{3-} as P, mg/l	1.60	0.23	0.75	1.41	2.57	2.63	1.27	2.63	1.49	------	0.88
SO_4^{2-}, mg/l	26.5	28.0	16.0	N.D	21.0	26.0	24.0	28.0	23.6	1	4.4
Ca, mg/l	N.D	19.0	75.0	62.7	123.7	71.7	24.0	123.7	62.7	4	38.3
Mg, mg/l	N.D	9.7	1.9	2.3	0.7	1.3	1.1	9.7	2.8	1	3.4
Fe, mg/l	N.D	0.74	2.87	2.22	0.13	3.75	0.25	3.75	1.65	4	1.50
Mn, mg/l	N.D	0.48	0.78	0.57	0.29	0.67	0.09	0.78	0.48	3	0.26
Cd, mg/l	N.D	0.07	0.03	0.08	0.07	0.07	0.18	0.18	0.08	5	0.05
Zn, mg/l	N.D	0.04	0.04	0.10	0.09	0.40	0.07	0.40	0.13	1	0.14
Pb, mg/l	N.D	0.92	0.04	0.06	0.03	0.11	0.42	0.92	0.26	------	0.35
Cu, mg/l	N.D	0.34	0.19	0.20	0.53	0.29	0.08	0.53	0.27	2	0.15
Total Hardness, ($CaCO_3$ mg/l)	N.D	58.1	124.7	135.5	73.1	73.1	53.7	135.5	86.3	2	34.9

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOMESTIC WATER SUPPLIES, 1998)

A Sample Data for Umtata River at Site 9 – Tipini Location

Date: May 1999 – Oct. 1999

Parameter	18/5	04/6	18/6	02/7	15/7	29/7	12/8	26/8	09/9	23/9	15/10	29/10	Max. Value	Avg. Value	Subst Class	S.D
Time	14:43	15:45	14:30	14:40	14:00	14:12	14:16	13:45	13:50	14:52	13:34	15:00				
Temperature, ^{0}C	19.1	18.9	14.9	14.3	13.7	13.6	14.3	14.5	15.7	18.6	18.1	18.4	19.1	16.1	-----	2.2
pH	6.7	7.1	7.6	8.5	8.4	8.1	7.9	6.4	8.0	8.0	8.3	7.3	8.5	7.7	1	0.7
Conductivity, μS/cm	93.8	88.0	96.0	89.5	88.0	93.0	89.6	86.6	112.8	91.0	86.2	89.9	112.8	92.03	1	7.1
TDS, mg/l	84.0	79.0	86.0	80.0	79.0	83.0	87.6	77.0	101.0	81.0	77.0	80.0	101.0	82.9	1	6.6
Turbidity, NTU	24.9	215.0	206.0	216.0	256.0	206.0	209.0	189.0	261.0	38.5	243.0	258.0	261.0	193.5	5	79.2
Total coliform, Counts/100ml	3000	3000	3000	3000	3000	3000	3000	123500	5400	13500	1920	8600	123500	14493	5	34487.9
Faecal Coliform, Counts/100ml	3000	3000	3000	3000	3000	3000	3000	10200	26900	3900	3400	3700	26900	5758	5	6962.3
Cl^-, mg/l	23.0	18.4	10.2	19.0	16.5	6.0	9.0	8.0	8.0	9.0	8.0	16.0	23.0	12.5	1	5.6
NO_3^- as N, mg/l	2.6	1.9	0.1	0.5	0.7	1.9	1.7	1.8	1.4	1.2	1.1	7.2	7.2	1.8	1	1.8
PO_4^{3-} as P, mg/l	0.35	0.04	0.11	0.08	0.25	0.28	0.24	0.26	0.31	0.08	0.21	0.25	0.35	0.21	-----	0.10
SO_4^{2-}, mg/l	47.0	24.0	6.0	25.0	14.0	15.0	16.0	14.0	24.0	31.0	17.0	28.0	47.0	21.7	1	10.7
Ca, mg/l	1.6	4.9	1.3	2.1	1.0	2.0	2.4	4.9	2.2	N.D	N.D	N.D	4.9	2.5	1	1.4
Mg, mg/l	5.0	2.7	4.0	1.8	1.0	2.6	1.0	8.5	6.7	4.6	N.D	N.D	8.5	3.8	1	2.5
Fe, mg/l	0.20	0.25	0.12	0.05	0.04	0.63	0.45	0.59	0.09	0.06	0.14	0.58	0.63	0.27	3	0.23
Mn, mg/l	0.57	1.60	0.34	0.34	0.33	0.34	0.94	1.34	0.76	1.14	0.68	0.97	1.6	0.78	4	0.41
Cd, mg/l	0.03	0.06	0.01	0.04	0.10	0.056	0.03	0.04	0.09	0.05	0.05	0.05	0.104	0.05	5	0.03
Zn, mg/l	0.22	0.34	0.02	0.02	0.03	0.07	0.07	0.07	0.03	0.09	0.07	0.06	0.34	0.09	1	0.09
Pb, mg/l	1.61	1.60	0.52	0.03	0.52	0.12	0.92	0.32	0.59	2.97	3.20	3.24	3.24	1.30	-----	1.21
Cu, mg/l	0.87	0.31	0.44	0.36	0.45	0.07	0.25	0.17	0.49	0.19	0.15	N.D	0.87	0.34	2	0.22
Total Hardness, ($CaCO_3$ mg/l)	23.9	30.3	22.2	26.3	20.7	30.8	130.5	159.9	27.2	35.5	22.9	N.D	159.9	48.2	3	48.5

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOMESTIC WATER SUPPLIES, 1998)

A Sample Data for Umtata River at Site 9 – Tipini Location
Date: Nov. 1999 – April 2000

Parameter	10/11/99	8/12/99	20/01/00	10/02/00	01/03/00	17/03/00	13/04/00	Max. Value.	Average Value.	Subst. Class	S.D
Time	13:45	13:07	13:05	13:55	13:46	13:50	14:48				
Temperature, ^0C	21.5	29.8	26.8	30.1	22.4	20.8	20.9	30.1	24.6	------	4.1
pH	7.5	7.5	7.3	7.7	7.7	7.0	7.3	7.7	7.5	1	0.3
Conductivity, µS/cm	118.0	152.4	251.0	405.0	90.0	76.1	95.3	405.0	169.7	1	119.4
TDS, mg/l	104.0	136.0	224.0	348.0	80.0	68.0	85.0	348.0	149.3	1	102.3
Turbidity, NTU	321.0	281.0	1000.0	96.7	45.3	2930.0	388.0	2930.0	723.1	5	1022.1
Total coliform, Counts/100ml	9100	3700	15000	1400	8300	26300	2200	26300	9429	5	8818.5
Faecal Coliform, Counts/100ml	300	2900	13000	1000	2300	7000	1500	13000	4000	5	4528.4
Cl^-, mg/l	10.5	19.0	36.2	40.0	18.0	14.0	0.7	40.0	19.7	1	13.9
NO_3^- as N, mg/l	0.9	5.5	1.8	N.D	2.1	8.0	4.2	8.0	3.7	1	2.7
PO_4^{3-} as P, mg/l	0.20	0.39	0.30	0.43	0.52	1.06	0.53	1.06	0.49	------	0.28
SO_4^{2-}, mg/l	24.0	17.5	11.0	N.D	26.0	19.0	21.0	26.0	19.7	1	5.3
Ca, mg/l	N.D	19.0	59.0	57.4	103.8	66.7	20.0	103.8	54.3	3	31.8
Mg, mg/l	N.D	10.7	1.3	1.7	0.9	1.1	1.1	10.7	2.7	1	3.9
Fe, mg/l	N.D	1.22	1.52	0.01	0.13	4.47	0.25	4.47	1.26	4	1.67
Mn, mg/l	N.D	0.33	0.52	0.42	0.15	1.28	0.07	1.28	0.46	4	0.43
Cd, mg/l	N.D	0.053	0.04	0.08	0.02	0.09	0.08	0.09	0.06	5	0.03
Zn, mg/l	N.D	0.065	0.03	0.04	0.03	0.19	0.19	0.19	0.09	1	0.08
Pb, mg/l	N.D	1.19	0.07	0.08	0.02	0.19	0.38	1.19	0.32	-------	0.45
Cu, mg/l	N.D	0.35	0.21	0.13	0.16	0.28	0.09	0.35	0.20	1	0.10
Total Hardness, ($CaCO_3$ mg/l)	N.D	40.9	52.3	88.1	32.2	75.2	35.1	88.1	54.0	2	22.9

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOMESTIC WATER SUPPLIES, 1998)

A Sample Data for Umtata River at Site 10 – First Fall (After Tipini)
Date: May 1999 – Oct.1999

Parameter	18/5	04/6	18/6	02/7	15/7	29/7	12/8	26/8	09/9	23/9	15/10	29/10	Max. Value	Avg. Value	Subst Class	S.D
Time	15:00	16:20	14:49	15:00	14:23	14:36	14:40	13:58	14:10	15:07	15:58	15:26				
Temperature, ^{0}C	20.1	18.9	14.7	13.2	14.7	13.9	14.3	15.0	17.4	17.0	19.1	19.8	20.1	16.5	-----	2.5
PH	6.5	7.3	7.9	8.2	8.7	8.4	7.7	7.1	8.2	8.1	8.1	7.4	8.7	7.8	1	0.6
Conductivity, µS/cm	103.4	93.6	101.6	89.1	91.7	19.7	89.5	87.5	111.8	88.4	84.9	101.0	111.8	88.5	1	23.1
TDS, mg/l	93.0	84.0	91.0	80.0	82.0	18.0	81.0	79.0	99.0	79.0	76.0	91.0	99.0	79.4	1	20.5
Turbidity, NTU	229.0	202.0	186.0	202.0	259.0	202.0	198.0	179.0	166.0	16.6	168.0	248.0	259.0	187.9	5	61.3
Total coliform, Counts/100ml	3000	3000	3000	3000	3000	3000	3000	28000	36000	23000	13000	3700	36000	10391	5	11904.3
Faecal Coliform, Counts/100ml	3000	3000	3000	3000	3000	3000	3000	10200	23300	3500	2400	800	23300	5100	5	6153.1
Cl^{-}, mg/l	20.7	15.0	9.7	19.0	14.6	8.0	10.0	8.0	7.0	8	4.0	13.0	20.7	11.4	1	5.1
NO_3^{-} as N, mg/l	2.5	2.1	0.1	0.6	2.3	1.6	1.5	1.6	1.1	0.8	1.0	4.9	4.9	1.7	1	1.2
PO_4^{3-} as P, mg/l	0.30	0.50	0.12	0.12	0.29	0.28	0.26	0.29	0.30	0.06	0.24	0.31	0.50	0.26	-----	0.11
SO_4^{2-}, mg/l	45.0	23.0	8.0	25.0	9.0	12.0	13.0	12.0	22.0	27.0	16.0	25.0	45.0	19.7	1	10.4
Ca, mg/l	24.0	1.4	1.5	1.7	1.0	1.5	2.4	2.4	1.9	2.1	N.D.	N.D.	24.0	3.9	1	7.1
Mg, mg/l	5.0	2.7	4.0	1.9	1.4	2.7	1.1	7.5	8.9	4.9	N.D.	N.D.	8.9	4.0	1	2.6
Fe, mg/l	0.28	0.24	0.21	0.08	0.06	0.55	0.38	0.65	0.07	0.05	0.24	0.11	0.65	0.24	3	0.20
Mn, mg/l	0.60	1.44	0.51	0.25	0.62	0.53	0.99	1.43	0.66	0.28	0.74	1.45	1.45	0.79	4	0.44
Cd, mg/l	N.D	0.07	0.02	0.04	0.06	0.08	0.06	0.04	0.09	0.06	0.03	0.03	0.090	0.05	5	0.02
Zn, mg/l	0.26	1.13	0.03	0.02	0.01	0.07	0.03	0.03	0.03	N.D	O.03	0.03	1.13	0.17	1	0.35
Pb, mg/l	2.32	1.80	0.70	0.029	1.07	0.13	0.89	0.47	0.57	1.56	1.7	3.24	3.24	1.21	-----	0.95
Cu, mg/l	0.96	0.24	0.44	0.22	0.42	0.14	0.19	0.17	0.19	0.23	0.07	N.D.	0.96	0.30	2	0.26
Total Hardness, ($CaCO_3$ mg/l)	26.0	32.5	29.4	23.9	19.3	30.8	195.0	213.7	24.3	40.9	28.7	N.D.	213.7	60.4	3	71.5

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOEMSTIC WATER SUPPLIES, 1998)

A Sample Data for Umtata River at Site 10 – First Fall (After Tipini)
Date: Nov. 1999 – April 2000

Parameter	10/11/99	8/12/99	20/01/00	10/02/00	01/03/00	17/03/00	13/04/00	Maximum Value	Average Conc.	Substance Class	S.D
Time	14:03	13: 25	15:30	13:30	14:15	14:15	15:12				
Temperature, ^{0}C	22.4	24.3	25.5	26.5	22.8	19.8	20.5	26.5	23.1	-------	2.5
pH	7.5	7.5	7.5	7.9	7.3	7.1	7.3	7.9	7.5	1	0.2
Conductivity, µS/cm	127.0	127.4	212.0	326.0	87.4	75.9	112.0	326.0	152.5	1	88.1
TDS, mg/l	111.0	113.0	189.0	284.0	78.0	68.0	100.0	284.0	134.7	1	76.5
Turbidity, NTU	287.0	176.0	1000.0	45.1	62.2	3570.0	438.7	3570.0	797.0	5	1265.5
Total coliform, Counts/100ml	8400	4800	5000	1700	9100	7800	22500	22500	8471	5	6696.0
Faecal Coliform, Counts/100ml	3300	700	2000	100	3600	6900	15500	15500	4586	5	5307.3
Cl^-, mg/l	12.0	16.0	41.2	36.0	16.0	12.0	0.8	41.2	19.1	1	14.3
NO_3^- as N, mg/l	0.8	3.7	3.5	N.D	2.2	11.7	4.3	11.7	4.3	3	3.8
PO_4^{3-} as P, mg/l	0.27	0.25	0.58	0.68	0.46	0.97	0.57	0.97	0.54	------	0.25
SO_4^{2-}, mg/l	23.0	13.5	12.0	N.D	14.0	22.0	23.0	23.0	17.9	1	5.3
Ca, mg/l	N.D	15.0	44.0	49.3	98.7	67.3	18.0	98.7	48.7	3	31.5
Mg, mg/l	N.D	9.700	1.141	1.149	0.961	1.185	1.157	9.700	2.500	1	3.500
Fe, mg/l	N.D	0.06	1.45	0.14	0.11	1.24	0.27	1.45	0.55	3	0.63
Mn, mg/l	N.D	0.33	0.46	0.44	0.18	1.03	0.18	1.03	0.44	4	0.31
Cd, mg/l	N.D	0.06	0.03	0.04	0.04	0.05	0.15	0.15	0.06	5	0.05
Zn, mg/l	N.D	0.03	0.03	0.05	0.05	0.14	0.05	0.14	0.06	1	0.04
Pb, mg/l	N.D	0.94	0.05	0.06	0.03	0.07	0.48	0.94	0.27	-----	0.37
Cu, mg/l	N.D	0.49	0.21	0.23	0.17	0.28	0.07	0.49	0.28	1	0.13
Total Hardness, ($CaCO_3$ mg/l)	N.D	42.3	43.0	79.5	30.1	86.0	36.5	86.0	52.9	2	23.7

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOEMSTIC WATER SUPPLIES, 1998)

A Sample Data for Drinking Water

Date: 24/7/2000

Parameter	Holiday inn, Umtata	Southern Ridge	Shell Utracity Umtata	Max. Value.	Average Value.	Subst. Class	S.D
Time	7:58	12:04	12:15				
Temperature, ^{0}C	13:4	12:6	13:3				
pH	7.0	8.7	7.3	8.7	7.7	1	1.0
Conductivity, μS/cm	70.8	87.3	70.1	87.3	76.1	1	9.9
TDS, mg/l	63.0	78.0	62.0	78.0	67.6	1	9.2
Turbidity, NTU	0.1	0	0	0.1	0.05	2	0.08
Total coliform, Counts/100ml	10.0	8.0	2.0	10.0	6.7	2	4.6
Faecal Coliform, Counts/100ml	0	1.0	20.0	20.0	7.0	3	11.0
Cl^{-}, mg/l	9.0	8.2	7.8	9.0	8.3	1	0.7
NO_3^{-} as N, mg/l	<0.05	<0.05	<0.05	0.05	0.05	1	
PO_4^{3-} as P, mg/l	0.005	0.005	0.005	0.005	0.005	1	
SO_4^{2-}, mg/l	11.0	11.5	11.0	11.5	11.2	1	0.3
Ca, mg/l	0.25	0.23	0.30	0.30	0.26	1	0.04
Mg, mg/l	0.73	0.71	0.83	0.84	0.76	1	0.06
Fe, mg/l	0.02	0.02	0.05	0.05	0.03	2	0.01
Mn, mg/l	0.005	0.005	0.020	0.02	0.010	1	0.009
Cd, mg/l	0.004	0.004	0.005	0.005	0.004	1	0.001
Zn, mg/l	0.14	0.20	0.21	0.21	0.18	1	0.04
Pb, mg/l	0.08	0.07	0.06	0.08	0.07		0.01
Cu, mg/l	0.03	0.03	0.09	0.09	0.05	1	0.03
Total Hardness, ($CaCO_3$ mg/l)	18.3	22.5	16.1	22.5	19.0	1	3.3

N.D = Not Determined; S.D = Standard Deviation. OVER ALL CLASS OF WATER QUALITY FOR DOMESTIC SUPPLY = 5 (QUALITY OF DOMESTIC WATER SUPPLIES, 1998)

APPENDICES C & D

APPENDIX C

QUESTIONNAIRE ON USERS AND USES OF WATER IN THE UMTATA RIVER CATCHMENT

1. **Name:**

2. **Age:**

3. **Gender:**

4. **Education:**

5. **Occupation:**

6. **Company (if applicable):**

7. **Address:**

8. **Type of house if residential:** Please specify Brick and Tile [ ], shack [ ] or other [ ]

9. **Category of Water Users:**

Please tick the box that best describes you as a water user:

[ ] – Primary user of raw water to supply secondary users in the catchment (e.g, municipality)

[ ] – Primary user that uses raw water directly from the river

[ ] – Secondary user with his/her water supplies (Treated water). Please specify communal taps [ ], outdoor taps on individual plots [ ] or in-house taps [ ]

10. **Water Uses**

Please tick the box that best describes your water use:

[ ] – Domestic; Please specify drinking [ ], cooking [ ], Bathing [ ] or washing [ ]

[ ] – Agriculture; Please specify irrigation [ ] or live-stock watering [ ] or both [ ]

[ ] – Industry

[ ] – Conservation

[ ] – Recreation

[ ] – Any other (Please specify)

11. Acceptability of the State (i.e., condition) of the Water Source

a). What do you expect the water quality to be for your need(s)?

b). Does the quality of the water satisfy you need(s)? Please, answer yes or no.

c). What is your perception of the quality of your water source(i.e., the suitability) in terms of the followings? Is it good, acceptable or bad?

i) Taste [ ]
ii) Colour [ ]
iii) Smell [ ]
iv) Any other (please specify)

12. Have you or any member of your family or somebody you know suffered from any of the following water related diseases by using water from the river or water from any other source (please specify the other source)?

i) Diarrhoea [ ]
ii) Dysentery[ ]
iii) Cholera [ ]
iv) Infections, e.g. skin infection [ ]
v) Any other, Please specify, e.g., Typhoid [ ], hipatitis [ ]

END:

UPHANDO NGOKUCOCEKA KWAMANZI

IMIBUZA KUBASEBENZISI KUNYE NOKUSETYENZISWA KWAMANZI KUMLAMBO UMTATA

1. **IGAMA:**

2. **IMINYAKA:**

3. **ISINI:**

4. **IMFUNDO:**

5. **UMSEBENZI WAKHO:**

6. **IGAMA LENDAWO EKUQASHILEYO:**

7. **I ADLESI YENDAWO OHLALA KUYO:**

8. **UHLOBO LWENDLU:** Nceda cacisa (yeyezitena yeyamacanci yeyodaka)

9. **INDLELA AMANZI ASETYENZISWA NGAYO:**
   Nceda khetha ibhokisi eyona ithi ichaze indlela owasebenzisa ngayo amanzi:

   [ ] Abasebenzisi bamanzi avela emlanjeni bawacoce belungiselela abantu abazakuwasebenzsa (maspalati)

   [ ] Abasebenzisi bamanzi avela kanye emlanjeni engacocwanga.

   [ ] Abasebenzisi bamanzi asela ecociwe. Nceda cacisa (itepu zikawonkewonke; itepu ezingaphandle apha endlini; okanya itepu ezingaphakathi endlini.

10. **UKUSETYENZISWA KWAMANZI:**
    Nceda khetha ibhokisi ethi ichaze indlela othi uwasebenzise ngayo amanzi

    [ ] kwimisebenzi yasekhaya: Nceda cacisa; ukupheka; ukusela; ukuhlamba umzimba okanye impahla

    [ ] Kwezolimo: Nceda cacisa; ekuncencesleleni; okanye ekuseliseni izilwanyana okanye zombini ezingentla.

    [ ] Kulondolozo

[ ] kwezolonwabo; Ekulobeni.

[ ] Nayiphina enye indlela (yicacise)

11. IMIBUZO NGOKWAMKELEKA KWAMANZI OMLAMBO

a) Ulidele ukuba ubunjani bamanzi bubenjani ukuze bumelane nemfuno zakho?
b) Ingaba ubunjani buyazanelisa imfuno zakho? EWE OKANYE HAYI
c) Zithini ingcina zakho malunga nobunjani bamanzi omlambo ngokwezingongoma ? ingaba alungile; ayamkeleka; okanye akalungile kwaphela ?

i) Incasa
ii) Umbala
iii) Ivumba
iv) Okanye nayiphina enye into (nceda cacisa)

12. WAKHE WAGULA NA SESINYE SEZIZIFO EZINXULUMENE NAMANZI NGOKUTHI USEBENZISE LA MANZI ASEMLANJENI OKANYE WAKHE WEVA NAWUPHI NA OMNYE UMNTU OWAKHE WAGULA ZIZO OKANYE AMANZI AVELA KWENYE INDAWO (Nceda cacisa)

i) Ukuhambisa ngamandla ngezantsi
ii) Izifo ezibangela ukuhambisa kwesisu
iii) Ukuhambisa ngentla nangezantsi ngamanye amaxesha zide zibangele ukufa
iv) Izifo ezifana nesifo sesikhumba
v) Nasiphina esinye. Nceda cacisa.

ISIPHELO:

APPENDIX D
SUGGESTIONS ON ALTERNATIVE WATER TRAETMENT PROCEDURE

Boiling:

Water should be boiled for about one minute and kept in clean utensils, which can be closed. To avoid

Contamination by the bacteria on our hands, containers with handles should be used when drawing from it.

Use of Bleach Powder

When using bleach powder like Jik and others, measurements should be observed – pour a teaspoon of bleach to 20 – 25 litres of water and wait for four hour before use. Perfumed bleach should not be used in drinking water because it will give soapy taste.

Sedimentation

To use this method, two buckets are used. One bucket is made full of water and left for three days without touching to allow sediment and dirt to settle at the bottom of the water bucket. On the fourth day, clean water is poured carefully over sediment into the other bucket. This type of water can be used for cooking and the water containing sediment cab used for gardening.

Sunlight Pasteurization

The sun has the power to destroy bacteria found in water. Colourless glass or plastic bottle should be used so that sunlight will penetrate to reach the water inside the containers. The containers should be put in a sunny place the whole day before the water is used.

PHOTOS

Photo 1 : Tipini Location

Photo 2: Defecation at Open Places at Tipini

Photo 3: Livestock Watering at Umtata River

Photo 4: Washing and Livestock Watering at Umtata River

Photo 5: Europhication in Umtata River After the Sewage Works Discharge Point

Photo 6: Waste Disposal Site at Norwood Bridge near the Umtata Riverbank

Other related WRC reports available:

The health impact of waterborne viruses and methods of control in high risk communities

WOK Grabow, MB Taylor, JC Vivier, N Potgieter and MG Gaobepe

Infectious diseases are the most important concern about water quality. Authoritative estimates ascribe about 50 000 deaths per day in the world to waterborne and water-related infectious diseases. In addition to mortality, which affects mainly children in developing communities, waterborne diseases also have far-reaching socio-economic implications. Viruses feature prominently among the wide variety of pathogenic micro-organisms concerned.

Many enteroviruses are cytopathogenic, ie, detectable by cell culture propagation. However, some enteroviruses, notably coxsackie A viruses, are not detectable by cell culture. Detection of these viruses requires inoculation of newborn mice, or recently developed molecular techniques.

Recommendations for the control of waterborne viral diseases in high risk communities are, therefore, largely based on education and training regarding the collection and storage of indoor drinking water supplies. This addresses short-term immediate interventions at minimum cost. The need for supplying safe water closer to homes is also emphasised. This option is more expensive and will take longer to implement. The ultimate goal is to supply running tap water inside households, but this is the most expensive and time consuming option.

Report Number: 743/1/02 **ISBN: 1 86845 859 8**

The feasibility of using low cost modelling techniques to relate river water quality and diffuse loads to range of land uses

CE Herold and PH van Heerden

Non-point source pollution has been identified as a priority research area. There is limited information available locally to support non-point source quantification for management purposes. One of the major obstacles in increasing the database is the high cost associated with conventional methods of monitoring diffuse source loads.

A limited amount of water quality data has been collected at six sites in the Rietspruit catchment. Predominant land uses include:

- low-density formal residential/CBD
- high-density and informal residential
- industrial
- rural (dry land cultivation)
- undeveloped (nature reserve)

The daily time step NACL model was used to simulate flows at each monitoring site. A correction was applied to the date to make the modelled flows at the catchment outlet (RW station R6) coincide with those observed.

The strength of the methodology is demonstrated by means of an example of an assumed new high-density urban development. The potential for using the methodology in conjunction with GIS based land use data was also discussed. The methodology can be applied as a screening tool and be of some assistance in the determination of the water quality reserve.

Report Number: 796/1/01 **ISBN: 1 86845 753 2**

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