AN INVESTIGATION OF THE NATURAL AND HUMAN INDUCED IMPACTS ON

THE UMDLOTI CATCHMENT

By

STRINIVASEN GOVENDER
(9903980)

Submitted in Fulfillment of the academic requirements for the degree of Masters of
Science, in the school of Environmental Sciences, Department of Geography, University
of KwaZulu - Natal (Westville Campus)

Supervisor

Dr. Srinivasan Pillay

30 DECEMBER 2009

FACULTY OF SCIENCE AND AGRICULTURE

DECLARATION 1 - PLAGIARISM

I, ……………………………………….……………………., declare that

1. The research reported in this thesis, except where otherwise indicated, is my original research.

2. This thesis has not been submitted for any degree or examination at any other university.

3. This thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.

4. This thesis does not contain other persons' writing, unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted, then:
    a. Their words have been re-written but the general information attributed to them has been referenced
    b. Where their exact words have been used, then their writing has been placed in italics and inside quotation marks, and referenced.

5. This thesis does not contain text, graphics or tables copied and pasted from the Internet, unless specifically acknowledged, and the source being detailed in the thesis and in the References sections.

Signed

…………………………………………………………………………

Declaration Plagiarism 22/05/08 FHDR Approved

As the candidate's Supervisor, I have approved this dissertation for submission.

………………
Dr. S. Pillay

FACULTY OF SCIENCE AND AGRICULTURE

DECLARATION 2 - PUBLICATIONS

DETAILS OF CONTRIBUTION TO PUBLICATIONS that f orm pa rt a nd/or i nclude research presented in this thesis (include publications in preparation, submitted, *in press* and published and give details of the contributions of each author to the experimental work and writing of each publication)

1. Water quality of the Umdloti River and estuary, KwaZulu-Natal (*in preparation).*

2. The impacts of dam construction on local livelihoods: the case of the Hazelmere Dam, Umdloti Catchment, KwaZulu-Natal (*in preparation).*

Signed:

ACKNOWLEDGEMENTS

To God Almighty, the creator of human kind: for giving me the strength and knowledge to complete my thesis during the most difficult time of my life.

I extend my heart felt gratitude and appreciation to Dr Srinivasan Pillay, for supervising this research. Your expertise, professionalism and constructive criticism was highly valuable and your understanding and tolerance for the completion of this research.

I owe a wealth of gratitude and appreciation to my loving wife, Ashendree Govender, thank you my love for all the support, understanding, tolerance and patience. You have been my pillar of strength and without your encouragement and love this dissertation would not be possible.

To my parents Mr. and Mrs. Krishnan Govender, thank you for giving me life. A special thank you to my mum Goonasundrie for all her love, support and encouragement throughout my academic career.

To my brothers Selvan Govender, Thinesan Govender and Kuvalen Govender thank you for being in my life and supporting me.

To my in laws, Mr. and Mrs. Lenny Govender and sisters in law (Yagendree and Shalene Govender) thank you for the love, support and encouragement you have provided me. It has really motivated and inspired me.

To Mrs. Sukinthra Dookie and Amith Dookie, thank you for being so kind and warm to me. Living away from home and in another town was very frustrating during my studies, but you have provided a wealth of love and support for which I am truly grateful.

To Nitesh, Eddie and Fathima, thank you for the transportation and assistance during the field research

To my directors Mr. Pat Reddy and Banothile Mthimkhulu, thank you for the support and encouragement.

To Colleen Moonsamy, Renelle Pillay, Shaun Naidoo and Krishnee Ramdass, thank you all the information and production of maps respectively.

To Mrs. Starling, your valuable information and time with the completion of the thesis is most appreciated.

I dedicate this thesis to my wife, Ashendree Govender and mother, Goonasundrie Govender.

ABSTRACT

The Umdloti River is relatively small but very important system that is located northeast of central Durban. This river flows pass the coastal town of Verulam and finally into an open/closed estuary, the La Mercy estuary. This fluvial system has a concrete gravity dam that is built in the upper reaches, the Hazelmere Dam, which supplies water to the north local council and surrounding districts under the supervision of Umgeni Water. The river is characterized by human activities, especially urbanisation and industrialization in the middle reaches and intensive agriculture (vegetables, sugar cane and banana plantations) along the catchment. The influence of anthropogenic factors within this catchment results from the dam construction, informal settlements, both commercial and subsistence agriculture, intensive industrial activity, accelerated urban developments, and recreational uses. Consequently there has been considerable concern regarding the impacts of these factors together with natural influences on the water quality and health status of this fluvial system. In this study water samples were taken and analysed for the following variables: nitrites; nitrates; ammonia; pH; *Escherichia coli*; sulphate; phosphate; total dissolved solids; chemical oxygen demand; biological oxygen demand; calcium and magnesium. The results indicate that the middle and the lower reaches of the Umdloti River are most impacted. Further, results from a questionnaire survey indicate that natural and human induced impacts have impacted negatively on the health status of the Umdloti River. The questionnaire survey also revealed that respondents benefited positively from the construction of the dam whilst the expropriation of land for the construction of the dam itself created much resentment to the prior land owners. The water quality data and the questionnaire analysis indicate overall natural and human induced impacts have had negative effects on the Umdloti River and the La Mercy estuary. It is necessary that local municipal authorities introduce corrective catchment management practices (outlined in the final chapter of the study) to enhance the water quality and health status of the river.

TABLE OF CONTENTS

CHAPTER THREE

STUDY AREA AND METHODOLOGY

CHAPTER FOUR

RESULTS AND DATA ANALYSIS

CHAPTER FIVE

DISCUSSION

CHAPTER SIX

RECOMMENDATIONS AND CONCLUSION

LIST OF FIGURES

LIST OF PLATES

Plate 3.1: The researcher and assistants takes GPS positioning for the water sample at the Hazelmere public boating zone.

Plate 3.2: Collection of water sample at the end of Wick Street (the main street in the town ends at the edge of the river) in Verulam.

Plate 4.1: Sand mining taking place in the lower part of the Umdloti river.

LIST OF TABLES

CHAPTER ONE

INTRODUCTION AND CONTEXTUALIZATION OF THE PROBLEM

1.1 Introduction

"From water is born all peoples of the earth. There is water within us, let there be water with us, Water never rests, when flowing above it causes rain and dew, when flowing below it forms streams and rivers. If a way is made for it, it flows along that path. And we want to make that path. We want the water of this country to flow out into a network reaching every individual-saying: here is this water, for you. Take it; cherish it as affirming your human dignity; nourish your humanity" (Kunene, 2002 cited in *White Paper on Water Policy, p 2, South Africa, 1997*).

Making reference to the above quotation it is noted that water is the most precious symbol of a country and according to Kantz and Kifferstein (2002), water is undoubtedly the most precious natural resource that exists on our planet without which life on Earth would be non-existent. It is essential for everything on our planet to grow and prosper and, although we as humans recognise this fact, we disregard it by polluting our rivers, lakes an ocean. It is therefore of paramount importance that we conserve, protect and utilise water in an environmentally sustainable way for the present and future generations.

According to statistics by Gray (1994), the total volume of water in the world remains constant but what changes is its quality and availability. In terms of the total volume, 97.5% of the world water is saline and 99.99% of this is found in oceans. This means that only 2.5% of the volume of water in the world is non-saline. However not all this fresh water is available for use by humans. About 75% of this freshwater is locked up in ice caps and glaciers with a further 24% located underground, which means that less than 1% of the total freshwaters is found in rivers, lakes and the soil, therefore only 0.01% of the world's water is present in rivers and lakes with another 0.01% present as soil moisture, but unavailable to humans (Gray, 1994).

South Africa is a semi-arid country with rainfall less than the world average and also very unevenly distributed across the country. Given a population of around 42 million each person has just over 1200 kilolitres (kL) of available freshwater. Within a few years population growth will take us below this level. Presently the population of this country uses more than half the total water that we can afford to use, while arid countries such as Namibia and Bostwana, which are much drier, use only 5-10% of their available water (White Paper on Water Policy, 1997).

According to Conley (1994), when compared to other countries around the world, South Africa is fortunate in its geographical positioning but with respect to water supply and availability the country is not quite fortunate. This is essentially important taking into account the recent water contaminations that occurred in certain parts of the country.

1.2 Contextualisation of the Problem

South Africa is extremely rich in natural resources except for water which is unevenly distributed in space and time. The annual rainfall in South Africa is below the world average and the country experiences high evaporation rates. Seasonal rainfall often occurs as high-intensity storms of short duration; the resulting runoff washes silt, and organic and inorganic material accumulated in the catchment, into water bodies. There are marked climatic gradients across the country and these have resulted in a wide variety of different types of aquatic ecosystems with biotas adapted to different water quality regimes and flow patterns. In many rivers, flow is strongly seasonal, and there is considerable year to year variability in flow rates. Many streams and rivers may dry up completely outside the rainy season, and reservoirs are prone to considerable changes in water level (DWAF, 1996).

 Freshwater resources around the globe are most at risk with respect to pollutant contamination. The University of Western Cape Department of Botany website notes that pollutant contamination includes the following:

- Sediments from incorrectly managed construction sites

- Salt from irrigation practices

- Toxic chemicals and wastes from industries

- Oil and greases

- Fetilizers, herbicides and insecticides from agricultural operations

- Defective septic systems

- Dumping of wastes close to water courses and,

- Faecal contamination from informal settlements in close proximity to the river Sourced from (www.botany.uwc.ac.za)

In South Africa, most river catchments suffer the consequences of at least some of the above contamination. In addition to the above, according to DWAF (1996), abstraction of water from, many rivers and streams for water supply purposes causes unnatural flow conditions which cause stresses on aquatic ecosystems. The biotas of ecosystems which are already stressed, for example due to flow regulation, are likely to be more susceptible to changes in water quality than those of unimpacted systems.

Consequently, in a country where water is a scarce resource, it has become increasingly important to ensure the optimum health and functioning of our aquatic systems. In this respect the study focuses not only on quantifying the water quality of the Umdloti system but also examines the impacts and repercussions of a large scale impoundment on human livelihoods in the upper part of the catchment.

South Africa does not get a lot of rain. Conley (1994), states that country receives only 500 mm a year, compared to the world average of 860 mm. This country is one of the thirty driest countries of the world, and to make sure that we have enough water to drink, to grow food and for industries, the government builds dams to store water and about half of the annual rainfall received is stored in dams (www.wrc.org.za).

Whilst water storage dams are absolutely essential and beneficial to the country, the construction and positioning of a particular dam can have serious environmental and social impacts on the surrounding environment and communities. The country's landscape is not well suited to dams. This is due to the presence of deep valleys and gorges in the escarpment regions whilst the central plateau is wide and flat. The result is that most dams of the escarpment are deep but narrow whilst dams on the plateau are shallow with a large surface area. The hot dry climate and large surface area of the latter type dams results in much evaporation of water from the dam (www.botany.uwc.ac.za).

According to McCully (1996), the majority of the world's dams have been completed within the last six decades and some of the environmental effects of the dams may only be realized hundreds of years after construction. The two main categories of environmental impacts of dams are:

- The impact due to the existence of the dam and the reservoir
- The impact due to the pattern of the dam operation.

The significance of this environmental disruption is that it tends to fragment the riverine ecosystem, isolating populations of species living up and downstream of the dam and cutting off migration and other species movement.

In South Africa annual rainfall is stored in 550 government dams with a total capacity of 37000 million m^3. The positive and negative impacts of dams are:

- Regulates river flow
- Reduces flooding

- Contributes to perennial flow as compared to seasonal flow

- Deposition of nutrients and the growth of aquatic plants allows for excess nutrients being removed.

- Thus water leaving the dams might be cleaner than water entering the dams.

A negative ecological impact is:

- Reduction in strong water flow reduces the rivers scouring ability thus leading to the silting of estuaries (www.botany.uwc.ac.za).

It has been observed that although KwaZulu-Natal is relatively water abundant, it has experienced water pollution problems due to the following:

- Sand mining

- Urbanization

- Dumping of waste

- Agricultural activities

- Faecal contamination

- Industrialization

- Point and non-point source pollution

The rivers in KwaZulu-Natal have to be managed well for the future for this life sustaining resource, however the province is undergoing rapid development. The North Coast has seen massive infrastructure, housing and industrial changes. Added to this is the new airport being constructed in the La Mercy area. There is little doubt that such rapid development will impact on all natural water systems in close proximity. One such

catchment in the province is the Umdloti River system which has a fairly large dam, the Hazelmere Dam constructed in its upper reaches an important town, Verulam, is situated in the middle reaches of the river as well as the Hazelmere waste water treatment plant. The Hazelmere Dam was constructed to regulate the flow of the Umdloti River in order to facilitate reliable water supply availability to the water uses in the area and in particular to cater for the rapidly increasing urban and industrial growth in the catchment. Water from the dam is supplied to the surrounding area by the North Coast Regional Water Services Corporation (NCRWSC) and they are the main consumers of urban and industrial water from the Hazelmere dam (White Paper Policy, 1978-1979).

This study is focused on the various impacts caused by man and nature on this water resource as well as the construction and positioning of the Hazelmere Dam and the impacts of its construction on landowners in the catchment.

1.3 Aim of the Study:

The aim of the study is to determine the influence of anthropogenic and natural impacts upon the water resources of the Umdloti Catchment and Estuary.
The study intends to provide a holistic analysis of the influence of natural and human induced impacts on water resources in the Umdloti Catchment.

1.4 Objectives of the study:

- To conduct a detailed study of the selected catchment and estuary in terms of its natural characteristics using aerial photography, topographical maps, photomaps and ground surveys;

- To determine the water quality of the Umdloti River along its length;

- To relate changes in water quality to anthropogenic (due to land-use changes) or to natural influences;

- To track historical development of the Catchment:

  - Prior to construction of the Hazelmere Dam,

  - Post construction of the Hazelmere Dam,

  - Upstream of the Hazelmere Dam,

  - Downstream of the Hazelmere Dam,

  - In the vicinity of the dam itself;

- To assess existing management strategies/policies and suggest improvements where appropriate.

1.5 Relevance of the study

Rivers are regarded as life-supporting systems which the humans, flora and fauna depend on. The choice of the study was influenced by the various natural and anthropogenic factors that have unfavorable impacts on rivers in South Africa, especially KwaZulu-Natal.

These i mpacts ha ve w ithin the l ast de cades i ncreased considerably due t o rapid development of t he r egion (urbanization a nd s ome i ndustrialization) a nd t he c hanging demographics of t hat i s e vident i n m uch of pos t-apartheid S outh A frica. T hese developments, changes and impacts have visible manifestation in numerous parts of the country and are notable in the KwaZulu-Natal north coast.

It is within this context that environmental and hydrological aspects of the Umdloti River will be e xamined a nd c hanges i n these as pects r elated to the cont ributing na tural and anthropogenic influences. In addition, t he impacts of t he construction of the H azelmere Dam, which caused major disruptions to local livelihoods, are investigated.

In view of the fact that the management of the U mdloti R iver is of vi tal importance for the current and further generations, the study will explore the extent on which potential solutions are formulated by exploring important policy development. Despite the fact that the study is examining natural and human induced impacts, relevant policies instituted by the D epartment of W ater A ffair and F orestry and t he D epartment of Environmental Affairs a nd t he e xtent t o w hich t hey are i mplemented t o pr otect a nd c onserve water resources w ill be c hecked. It i s t he further a im of t his r esearch t o pr ovide i nformation with r espect t o t he c onstruction of t he H azelmere D am a nd t he pos itive a nd ne gative impacts encounted in the surrounding communities of the catchment.

The nature of this study is academically useful in the sense it will form the platform for future studies so that updated scientific data will be ongoing as water quality changes all the time.

Water quality changes occur all the time due to natural and human impacts both in dams and rivers. The levels of pollutants and toxicity in the river, upcoming developments as well as the community responses with respect to dam construction might assist future water resource management personal, water and dam engineers and scientists to sustainably improve water systems.

1.6 Chapter Formation and Sequence

The second chapter of this dissertation focuses on the literature review with respect to water availability, rivers and dams and their positive and negative impacts, water policies and guide-lines. The third chapter provides a description of the study area and methodology adopted for the investigation. The fourth chapter encompasses the results from water analysis and the questionnaire survey. The fifth chapter comprises the discussion on the findings of this research, followed by the sixth and final chapter which provides the recommendations and conclusions to the study.

CHAPTER TWO

LITERATURE REVIEW: WATER QUALITY

2.1 Introduction

Water has always been a vital resource for man's existence. Its uses for domestic, agricultural, transport, industry and recreation immediately shows the extent to which it is an integral part of our life; even romantic properties have been ascribed to this unique substance. Water has long been recognized that its suitability for that purpose can be affected by other substances dissolved and or suspended in it (Wilson, 1974).

The year 2003 was declared UN International Year of Freshwater. Statistics indicated that twenty percent (20%) of the world's people lacked good drinking water and forty percent (40%) lacked adequate sanitation facilities, from the water available for human use, sixty nine percent (69%) is used for agriculture, twenty one percent (21%) is used for industry/power and ten percent (10%) is used for domestic purposes (Harrison, 2007).

Tolba (1992), states that as both the world's population and usable water supply are unevenly distributed, the local availability of water widely varies, and according to Harrison (2007), on a per capita basis, the figures vary across continents. North America withdraws seven times as much freshwater as Africa; the United States of America withdraws twenty percent (20 %); the United Kingdom withdraws seven percent (07%); Poland withdraws thirty three percent (33%), India withdraws fifty one percent (51%)

and Bangladesh withdraws seventy six percent (76%) of its renewable freshwater resources.

According to Harrison (2007), many developing countries are using up to forty percent (40%) of their renewable freshwater for irrigation and with population growth, pollution and climate change, the average supply of water per person is likely to drop by one-third over the next two decades thus causing a global crisis projected to occur between the years 2025 and 2050.

In a broad sense, pollution has been characterized as an alteration of our surroundings in such a way that they become unfavorable to us and our life. This characterization implies that pollution is not synonymous with the addition of contaminants to the environment but can also result from other direct or indirect consequences of human action (Stumm & Morgan, 1981). Therefore a balance is required between the use of water for human needs and the use of water for the survival of ecosystems on which people depend (www.awiru.co.za).

Exploration of natural resources is vital for human survival. As social, economic, and cultural circumstances have evolved, so too have the mechanisms and extent by which these resources have been utilized. Endeavors to exploit these opportunities to meet societal demands have demonstrated remarkable ingenuity and creativity. Over the last 5000 years, human modification has been the dominant form of disturbance to

the fluvial environment, exerting a greater influence than adjustments caused by climate changes, although extreme "natural" events continue to be a significant cause of change (Brookes, 1994; Knighton, 1998 cited in Gary *et al*., 2005).

2.2 General Fluvial Characteristics and Importance.

A fluvial system is the term used for a system of connected river channels in a drainage basin. The drainage basin or catchment area is the area that contributes water and sediment to the river system, and is bounded by a drainage divide (Bridge, 2005).

Rivers are highly complicated longitudinal ecosystem that sculptures the landscape which they flow through (Day *et al*. (1986), cited in *The South African National Scientific Programmes* Report No. 131). Rivers are a cherished feature of the natural world. They perform countless vital functions in both societal and ecosystem terms, including personal water consumption, health and sanitation needs, agricultural, navigational, industrial uses, and various aesthetic, cultural, spiritual and recreational associations (Brierley and Fryirs, 2005).

According to Day *et al*. (1986), a river consists of fast flowing erosive headwaters; slower-flowing, partly erosive, middle reaches; and slow flowing, low-lying, mature reaches where materials eroded in the upper reaches are deposited. There are three major riverine zones and the fourth zone includes an estuary. These stages are characterized as

follows; (1) Headwaters: the mountain stream, this water is characteristically clean and free of silt. The land in which the stream drains is rocky, steeply inclined and with very little soil. The river bed is boulder-strewn so that water is well oxygenated. The mountainous catchment area is largely rocky and resistant to weathering, leaching is minimal and the water is usually soft and of good quality for human use; (2) the middle reaches: as the stream enters the foothills its bed widens as more water arrives from tributaries. Water temperature increases, encouraging the growth of mosses, algae and some plankton occurs in sheltered backwaters. The water quality is poorer than in the mountain stream because of the longer stretches of rock and soil over which the water has flowed end route from the mountains thus allowing more leaching and water-borne debris from upstream. Oxygen levels may be lower even though rocks in the river bed may support a more extensive growth of microscopic algae. The invertebrate fauna consists largely of grazers and collectors. The organisms in this reach of the river are different from those occurring in the mountain stream, although adaptations for survival are similar because current speeds are still relatively high and the substratum mainly comprises of rocks and stones. The invertebrate fauna is more abundant and productive and grows faster, thus insect eating birds and fish are abundant; (3) The mature lower reaches: as the river flows onto the coastal plain it continues to widen while current speeds continue to drop as the gradient decreases. Day *et al*. (1986), further state that the heaviest particles of sediment drop out of the water column as the current slows, settling to cover stones and forming a relatively sandy or silty blanket on the riverbed. Finer particles settle out and the substratum becomes muddy. The water column may become noticeably less oxygenated, particularly in night because the water is richer in mineral

salts and also in nutrients that have leached in from river banks, infiltrated from ground water, washed down from upstream or released from dead plants and animals. Increasing levels of nutrients allow an abundant and luscious growth of plants such as reeds and bull-rushes. Increased sunlight and the slow flow in the river encourage the growth of phytoplankton and zooplankton. In the lowest reaches just above the estuary, the substratum becomes very muddy and rich in organic matter thus providing an excellent refuge and food resource and providing a habitat for many invertebrates, diverse avifauna and bottom-feeding fish, (4) the final stage of the river is the estuary and unlike the rest of the river this is a place where the seaward flow of water may stop entirely during periods of rising tides. Estuaries gain particulate matter and nutrients from both the river and the sea. Mclusky (1989), states that estuaries are vital feeding areas for many species of birds, especially waders and wildfowl, the locations of coastal fisheries or as fascinating areas which present challengers to our understanding of how animals and plants adapt to this environment, Day *et al*. (1986), cited in *The South African National Scientific Programmes* Report No. 131, further states that this, together with the wide banks developed by successive marine and riverine particulates deposits, means that estuaries are often among the most productive ecosystems known.

2.3 Environmental Problems of Rivers

In many parts of the world, human-induced degradation has profoundly altered the natural functioning of river systems. Sustained abuse has resulted in significant alarm for river health (defined as the ability of a river and its associated ecosystem to perform

natural functions). River health is a measure of catchment health, which in turn provides an indication of environmental and societal health. It is increasingly recognized that ecosystem health is integral to human health, and unless healthy rivers are maintained through ecologically sustainable practices, societal, cultural and economic values are threatened and potentially compromised (Gray *et al., 2005).*

2.4 Importance of Dams

The greater part of South Africa is semi-arid to arid and the narrow strip along the east and south coast is moderately wet. To enhance the standard of living and to further economic development the scarce water resources of the country have to be utilized as efficiently as possible. This policy has been evident ever since the first large dams were constructed in South Africa (Elges *et al*, cited in *Large Dams and Water*

Systems in South Africa).

Dams have two main functions. The first is to store water to compensate for fluctuations in the river flow or in demand for water and energy and the second function is to raise the level of the water upstream to enable water to be diverted into a canal or to raise the "hydraulic head"- the difference in height between the surface of a reservoir and the river downstream (McCully, 1996).

Significant advances in the design and construction of dams have been achieved over the past one hundred years due to the broadening of scientific information with respect to

geology, hydrology, natural and man-made properties, the loading to which a dam is subjected, new analytical methods, powerful computers, quality control during construction and instrument observations of structural behaviors of dams thus reducing the human errors (Veltrop, 1990 cited in *The World Bank Technical Paper No. 115*).

Dam engineering in South Africa followed the trends of standards and methodology developed in the United States of America and western european countries (Croucamp, 1994).

The International Commission on Large Dams (ICOLD) defines a large dam as one measuring fifteen meters or more from the foundation to the crest - taller than a four story building (McCully, 1996).

The first significant storage dams in South Africa were built during the second half of the nineteenth century. The International Commission on Large Dams (ICOLD) register (1988 update) indicates that four dams were completed in South Africa before 1900. This had increased to 458 by the end of 1992 (Croucamp, 1994).

Dams are needed to store water and make it available to populations distributed around the world as well as for the generation of electric power (Lyra, 1990 cited from *The World Bank Technical Paper* No. 115). According to McCully (1996), hydroelectric power provides nearly a fifth of the world's electricity. Other reasons for dam construction include reservoir fisheries and leisure activities such as boating.

South Africa has an impressive track record regarding the engineering of large dams, starting way back in the mid 1600 with the building of the Waegenaars Dam, which supplied water to ships passing through the Cape of Good Hope. Since then dam engineering in South Africa has come a long way (Asmal, 1994, cited in *Large Dams And Water Systems In South Africa*).

2.4.1 Dam Safety

According to Duscha (1990), cited in *The Word Bank Technical Paper No. 115*, there are differences in dam safety in developing nations that are driven by a number of factors, which can be categorized as socio-economic political factors rather than technical factors. These include the following: the technical, social, and economic sophistication of the country; the size of the country and its economic stature; the tenure of the development stage; the governing economic necessity at the time; the status of enabling legislation concerning dam safety, the power of enforcement or regulation granting responsible agencies; the value of life as derived from the culture of the nation; the cultural approaches to catastrophic events such as maximum floods and earthquakes, the staff capability and the resources dedicated to dam safety. With the above in mind it is also important to note that more and more dams are being built. However, over time, many of these dams are deteriorating.

Originally dams were built in areas remote from population centres. Today concerns about potential failure are increasingly important due to population concentrations in

vulnerable but limited areas downstream of the dam. This concern is the direct result of dam failures, such as the Buffalo Creek Coal Waste Embankment, Canyon Lake Dam, Baldwin Hills, Tobacco Falls, Lower San Fernando and Teton Dams in the United States, Malpasset Arch Dam in France, Vaiont Resevoir in Italy and Koyna Dam in India. Thus the safety of dams has become a public concern rather than the exclusive domain of engineers and government officials. (Veltrop, 1990 cited in *The Word Bank Technical Paper* No. 115).

2.4.2   Environmental Impacts of Dams

According to Rangeley (1990), cited in *The World Bank Technical Paper No.115*, the need to preserve the quality of the human environment has long since been in the minds of planners of storage reservoirs /dams. The emphasis on environmental factors has become much greater in recent years owing to the rapid increase in the number of dams, both under construction and planned; the greater population densities of the world, (including the river valleys where the storage dams are constructed); the scarcity of new land resources; greater pollution of river waters from agricultural chemicals and sewage, additional critical salt balance in river systems; and wider public participation in planning decisions.

Dams have a major environmental impact on river systems and the reservoir. Many of the impacts are due to the fact that most of the incoming sediment will be trapped and the supply and transporting patterns of sediments within the reservoirs and areas downstream

19

of the dam are thus interrupted. Other environmental impacts include the following: the loss of arable land, natural habitats, human settlements and archaeological sites in reservoir basin; water quality changes in the impounded water body in terms of the physical, chemical and biological characteristics; water quality in the river reaches immediately downstream of the dam in terms of the physical, chemical and biological characteristics, modifications of the river morphology and flow patterns in the downstream river reaches and modifications to the riverine ecosystem in the river reaches that side of the reservoir both upstream and downstream (Rooseboom *et al*., 1994, cited in *Large Dams and Water Systems in South Africa*).

According to McCully (1996), the main environmental impacts of dams are also due to the pattern of dam operation. These impacts may be superimposed on each other. The main environmental impacts are listed in the table 2.2 below:

Table 2.1 Main Environmental Impacts of Dams

IMPACT S DUE TO EXISTENCE OF DAMS AND RESERVOIRS	IMPACTS DUE TO PATTERN OF DAM OPERATION
1) Upstream change from river valley to reservoir	Changes in downstream hydrology: a) Change in total flows. b) Change in seasonal timing flows. c) Short-term fluctuations in flows. d) Change in extreme high and low flows.
2) Changes in downstream morphology of riverbed and banks, delta, estuary and coastline due to altered sediment load.	Changes in downstream morphology caused by altered flow pattern.
3) Changes in downstream water: effects of river temperature, nutrient load, turbidity, dissolved gases, concentration of heavy metals and minerals	Changes in downstream water quality caused by altered flow pattern.
4) Reduction of biodiversity (aquatic and terrestrial) due to the blocking of the movement of organisms.	Reduction in riverine/riparian/floodplain habitat diversity, especially because of elimination of floods.

Source: adapted from McCully, (1996)

2.5. The Hazelmere Dam

The planning of Hazelmere Dam, on the Mdloti River, culminated in a White Paper that was approved by Parliament in 1971 (White Paper K-'71). The white paper details the water availability and water requirements in the area at the time. This dam was needed to provide a reliable water supply to irrigation development and the rapidly growing urban and industrial users that were supplied at the time by the North Coast Regional Water Corporation and today by Umgeni Water. A number of alternative dam sites were examined, and Hazelmere on Blocks A and B of the farm Cottonlands 1575 was found to be the most suitable site (White Paper K-'71). This was followed by an investigation of various types of dams including an earth/rock-fill dam, a concrete buttress dam, a concrete gravity dam, and a concrete gravity dam with left bank earth-fill embankment. This report concludes that the most suitable structure would be a concrete gravity dam that would be completed in two phases. The first latter incomplete phase would create a Full Supply Level (FSL) at 85, 98 masl, and the second phase would raise the FSL by seven meters to 93, 00 masl. This was detailed in a second White Paper that was approved by Parliament in 1974 (White Paper O-'74). The first phase of the dam was completed in 1976. No Environmental Impact Assessment was required at the time, but relevant socio-economic aspects of the environment were considered in the planning of the dam (DWAF, 2007 cited in *The Resource Management Plan of Hazelmere Dam*).

The Hazelmere Dam is situated in a gorge on the Umdloti River, about 5km upstream (north-west) of the town of Verulam. The dam is situated in the Magisterial District of

Verulam ($29^o34'$ – $29^o36'$S; $31^o00'$ - $31^o02'$E). Access to Hazelmere Dam (northern bank only) is along a secondary (tarred) road (P100) which runs north from Verulam to Hazelmere for 8km, followed by 2km of minor (gravel) road (DWAF, 2007 cited in *The Resource Management Plan of Hazelmere Dam*).

2.5.1 Storage Capacity of the Hazelmere Dam

Various estimates have been made of the original storage capacity of Hazelmere Dam. These range from 21 million m^3 (Umgeni Water) to 24 million m^3. The capacity has been reduced by sedimentation to an estimated 16, 8 million m^3, representing about 23% of the natural MAR. While most of this loss has taken place on a gradual annual incremental basis, floods in September 1987 introduced large volumes of sediment into the impoundment that reduced the storage capacity of the dam by 10%. This, together with normal rates of sedimentation, has reduced the storage capacity of Hazelmere impoundment by twenty eight percent (28%). The flood of 1987 also resulted in a loss of some 2.5 million m^3 of storage capacity within a few days. The capacity of the raised dam is estimated to be 36 million m^3, representing about 50% of the natural MAR. In 1994 the historical firm yield of Hazelmere Dam was estimated to be 23 million m^3/a. The estimated historical firm yield for a raised dam was 31 million m^3/a. Estimates of future yield for the year 2050 range between 0 and 15.9 million m^3/a, depending on whether or not irrigation demands and ecological flow requirements are met. Hazelmere Dam has a low retention time and a high flushing rate (DWAF, 2007 cited in *The Resource Management Plan of Hazelmere Dam*).

2.6 Water Quality

The term water quality is used to describe the physical, chemical, biological and aesthetic properties of water that determine its fitness for a variety of uses and for the protection of the health and integrity of aquatic ecosystems. Many of these properties are controlled or influenced by constituents that are either dissolved or suspended in water (DWAF, 1996).

Presently the frequency of situations where water has been rendered unsuitable for normal use has increased significantly. Bacteria and other micro-organisms have contaminated drinking-water supplies, sometimes causing severe illness to town-folk; chemical pollutants have been detected in streams, endangering plant and animal life; sewage spills have occurred, forcing people to pre-treat their drinking water; pesticides and other chemicals have seeped into the ground and have harmed the water in aquifers; and run-off containing pollutants from roads and parking lots have affected the water quality of urban streams (Boyd, 2000 in Naidoo, 2005). It also important to note the various pollution spills that occur on the national roads by chemical and fuel carriers such as the following: oil; chemicals; diesel, petrol and paraffin. This chemical spill entering a storm water system or channels drastically alters the life of a river system negatively.

In South Africa far reaching economic, political, social and demographic changes have had major impacts on the water quality and this has resulted in a decline in the water quality (DWAF, 2003).

2.6.1   Human Impacts on Water Quality and Quantity

In addition to the natural environmental changes brought about by the geological and climatic changes, the environment has been significantly affected by human activities. These human induced environmental changes are proliferating in this modern era and thereby causing changes in the hydrological cycle. The human-induced changes affect water quality and quantity. These changes include: the construction of dams, transfer of water from one river basin to another; land drainage; channelization; embanking of streams and land cover changes such as urbanizations and the removal of forest cover. (Fox and Rowntree, 2000).

2.6.2   Decline in Water Quality

Decline in water quality has resulted in excess nutrients from sewage and soil erosion; pathogens from sewage; and heavy metals and synthetic organic compounds from industry, mining and agriculture; thermal pollution from power generation and industrial plants; radioactive substances; and turbidity problems caused by increased sediment loads or decreased water flow (Langford, 1990 in Brijlal, 2005).

In South Africa water resources are declining as a result of salination, eutrophication and pollutants from trace metals, micro-pollutants and bacteria. Organic and metal compounds enter surface and underground water through effluent discharges, leachate from solid waste disposal sites, agricultural and urban run-off and atmospheric fallouts.

Many of these compounds resist physical, chemical, and biological degradation and persist in the environment. Toxic, carcinogenic, mutagenic (producing genetic changes) or teratogenic (causing prenatal defects) contaminants can become hazardous, particularly during low flows. In addition the growth of informal settlements without adequate sanitation systems increases the risks of transmitting water borne diseases (Conley, 1994 cited in *The Large Dams and Water Systems in South Africa*).

According to the World Bank (2003), more than a billion people in low and middle income countries and fifty million people in high-income countries lacked access to safe water for drinking for drinking, personal hygiene and domestic purposes in 1995 (cited in *Water and Development,* www.awiru.co.za).

2.6.3 Water Pollution

Water pollution that includes biological, chemical and physical contamination is the result of human activities. Biological contamination results from human and animal wastes as well as some industrial processes. Feedlots, dairies and septic tank systems are the major sources of biological pollution. Bacteria are the most common organisms however viruses and other micro-organisms may also be present. Chemical contamination results from industrial processes and the use of pesticides and fertilizers in agriculture, however some chemicals occur naturally in water and other chemicals are introduced during water movement through geological material. Physical contamination results from erosion and disposal of solid waste. The most common physical contaminant

of water is suspended sediment, other contaminants include: organic material such as plant residues (Schwab *et al.*, 1993).

According to Novotny (2003), sources or causes of pollution can be classified as:

- Group one: human alteration of the status of a water body and its habitats that downgrades its integrity and creates pollution and,

- Group two: addition of allochthonous pollutant loads to the water body. This originates from outside the water body and includes both point and non-point sources of pollution.

Group one includes pollution and polluting activities that are more difficult to control. The cause of such alteration includes: hydraulic modification of water bodies, invasion of foreign species that were brought to the water bodies by people (e.g., water hyacinth, zebra mussels, sea lamprey); drainage of riparian wetlands to accommodate agricultural and urban development; urban development that changes the hydrology of a stream or stream corridor and causes stream bank erosion and reduces channel stability; *in situ* sediments that are contaminated by past human activities that are difficult to identify (Novotny, 2003).

Group two includes point and non-point sources of pollution. Point source of pollution is pollution that enters a waterway at discrete, identifiable locations (Novotny, 2003). The

discharge of waste or water containing waste is through a pipe, canal, sewer, sea outfall or other conduit (National Water Act 36 of 1998, Section 21f) and can be measured. The following includes point source pollution: municipal and industrial waste water effluents; runoff and leachate from solid waste disposal sites; runoff and infiltrated water from concentrated animal feeding and raising operations; run-off from industrial sites; storm sewer outfalls from large urban centers; combined sewer overflows; run-off and drainage water from active mines, both surface and underground (Novotny, 2003).

Non-point sources of pollution includes the following: return flows from irrigated agricultural land and orchards; agricultural run-off and infiltration, silvicultural run-off and run-off from logging operations, including logging roads and transportation; run-off from unconfined pasture and rangelands; urban run-off, small communities with storm sewers and run-off from settlements with no sewage facility; leaching of septic tanks; wet and dry deposition over a water source, flow from abandoned mines, including inactive mining roads, run-off and snowmelt (with or without deicing chemicals) from roads and highways; wetland drainage; mass outdoor recreation and gathering; land development; military training, maneuvers and shooting ranges (Novotny, 2003).

Industrial and agricultural pollutants common in South Africa are agricultural fertilizers, silt, toxic metals, litter, hot water, and pesticides. However, some of the most common pollutants come from urban waste water, particularly from informal settlements which lack sewage and water purification facilities (www.botany.uwc.ac.za).

2.6.4 Water-Born Diseases

Water-related diseases are among the most common causes of illness and death, affecting mainly the poor countries. More than three million people each year, mostly the more vulnerable segments of the population (children under the age of five) die from water-borne diseases such as gastro-enteritis and diarrhea which are caused by contaminated drinking water (www.awiru.co.za). Typhoid, cholera and gastroenteritis are transmitted by water contaminated with untreated sewage. Gastroenteritis is one of three main causes of death in South African children under the age of five and, between the years 1980 and 1987 over one million South Africans contracted cholera (www.botany.uwc.ac).

Sub-Saharan Africa experiences more than sixty percent (60%) of the 350-500 million annual malaria cases globally and eighty percent (80%) of all malaria deaths occurred in this region (Cohen, 2003, cited in *South African Journal of Continuing Medical Education*). In South Africa malaria is given high priority and is commonly distributed in the Northern Province, Mpumalanga, Northern KwaZulu-Natal and certain parts of the Northern Cape. Other water-borne diseases include bilharzias which are most common in the Northern Province, the lowveld and KwaZulu-Natal (www.randwater.co.za).

2.6.5 Solid Waste

Solid waste is often called the third pollution after air and water pollution and is that material which arises from various human activities and thereafter is normally discarded

as useless or unwanted. It consists of highly heterogeneous mass of discarded materials from the urban communities as well as the more homogeneous accumulation of agricultural, industrial and mining waste. The principle sources of solid waste are domestic, commercial, industrial and agricultural activities. The main constituents of urban waste are similar throughout the world, but the weight generated, density and the proportion of constituents vary widely from country to county according to the level of economic development, geographic location, weather and social conditions (Rao, 1991).

Rao (1991), further states that solid waste is classified and based partly on content and partly on moisture and heating value. The classifications are as follows;

- Garbage refers to the putrescible solid waste constituents produced during the preparation or storage of meat, vegetables, fruit, etc. These wastes have a moisture content of about seventy percent (70%) and a heating value of around 6 x 10^6 J/kg.

- Rubbish refers to the non-putrescible solid waste constituents, either combustible or non-combustible. Combustible waste includes paper, wood, scrap, rubber, leather etc. Non-combustible wastes are metals, glass, ceramics etc. These wastes contain a moisture content of about 25% and the heating value of the waste is around 15 x 10^6 J/kg.

- Pathological waste includes dead animals, human wastes etc. The moisture content is 85% and there is 5% non-combustible solids. The heating value is around 2.5 x 10^6 J/kg.

- Industrial waste includes chemicals, paints, sand, metal ore processing, sewage treatment sludge, etc.

- Agricultural waste includes farm animal manure, crop residues, etc.

2.2 Main Categories of Water Pollution

Dead organic matter	Urban garbage, Sewage run-off	Reduces Biochemical Oxygen Demand (BOD)
Pathogens	Human and animal excreta	Causes Cholera and cryptosporadiosis
Inorganic chemicals	Acids and metals	Acid disposal and mining contribute to water pollution
Sediment	Soil run-off	Reduces water quality

Table 2.2 Categories of Water Pollution (combined list from Botkin & Keller, 1995 and Cunningham & Saigo, 1990 in Naidoo, 2005)

The categories of water pollution as described above are a clear indication than humans are the leading agents of polluting the environment and consequently are associated with impacts on water quality once transported into a riverine system.

2.7 Ecosystems

Freshwater systems and ecosystem function are tightly linked to the watershed, or catchment of which they are a part (Hynes, 1975; Likens, 1984).

Aquatic ecosystems include numerous species, habitats and processes, all of which are interlinked and interdependent, and which require protection if healthy ecosystem structure and functioning are to be maintained. As a consequence of the complex and interlinked nature of aquatic ecosystems, the effects of changes in water quality on specific components of ecosystems are often indirect. A simple example of such indirect effects might be that a certain species of fish might disappear as a result of a change in water quality, not because the fish species itself cannot tolerate the change in water quality, but because the organisms that are its primary food source might be eliminated by that particular change in water quality. The complexity of determining the effects of changes in water quality on aquatic ecosystems is compounded by the fact that many of the cause-effect relationships are poorly understood or completely unknown. It is therefore often difficult to separate the effect of changes in water quality from other effects such as changes in flow regime or climatic changes (South African Water Quality Guidelines for Aquatic Ecosystems, 1996).

2.7.1 Ecosystems Services

Ecosystem services are defined as "the capacity of natural processes and components of natural or semi-natural systems to provide goods and services that satisfy human needs." These are generally grouped into four types of functions: production, provision of tourism opportunities, regulation, and the provision of habitats. Many components of ecosystems provide resources for direct human consumption including: water for drinking, fish and fruit to eat, reeds to thatch roofs, timber for building, peat and fuel wood for fires. The harvesting of ecosystem goods while respecting the production rate and the regenerative capacity of each species can provide sustainable benefits to human society. For example, in many areas fisheries rely heavily on healthy ecosystems and maintaining them is often a fundamental requirement for the local and national economy (Ramsar, 1998).

In many rural areas, water supply depends largely on water extracted from shallow boreholes or local springs. The aquifers and springs will provide water if areas of recharge are maintained and protected. Water-based ecosystems provide opportunities for recreation, aesthetic experience and reflection. Recreational uses include fishing, sport hunting, bird-watching, photography, and water sports. Judging by the fact that tourism is a leading world business, the economic value of these can be considerable. Maintaining the wetlands and capitalizing on these uses can be a valuable alternative to more disruptive uses and degradation of these ecosystems (Ramsar, 1998).

2.7.2   Estuaries

According to Chile (2007), estuaries are unique water systems; they are interface between fresh river water and saline coastal water (Cooper *et al.*, 1987). They have a high biological productivity, and are generally situated in densely populated areas, where often many pollution problems exist (Wim van Leussen, 1988). Estuaries form where a river meets the sea. They are that portion of a river system or a drainage system which has, or can have, interaction with the sea (Huizinga *et al.*, 1997). Unlike estuaries elsewhere, most South African estuaries particularly in KZN are prone to closure by sand bars or through catchment-derived sediments that block off the mouth for varying lengths of time (Heydon, 1989). During this closed phase direct interaction with the sea water within the estuary is derived from both the river and sea (Huizinga *et al.*, 1997) e.g. the Umdloti estuary.

2.8   The Physical, Chemical and Biological Characteristics of Water

Water quality is taken to be the combined effect of the physical, chemical and biological constituents of a sample of water for a particular use. For convenience, variables can be grouped in a number of ways. Perhaps the simplest, is to divide them into *physical* attributes such as temperature, turbidity, solids, biological oxygen demand (BOD), chemical oxygen demand (COD), and dissolved oxygen (DO). *Chemical* constituents are the alkalinity, nitrogen, phosphorous, etc. content of a sample of water. And finally, the

biological characteristic of water measures the total coliforms*, E. coli* content, etc

(Brijlal, 2005).

2.8.1 The Chemical and Physical Characteristics of Water

The following variables indicate the physical and chemical characteristics of freshwater

water systems. The material that follows has been sourced largely from *The South*

African Water Quality Guidelines for Aquatic Ecosystems (1996):

2.8.1.1 pH

The pH value is a measure of the hydrogen ion activity in a water sample. It is

mathematically related to hydrogen ion activity according to the expression:

pH = - log [H], where [H] is the hydrogen ion activity. Basically pH measures the degree

of acidity or alkalinity of a solution. For surface water, pH values typically range between

4 and 11. The relative proportions of the major ions, and in consequence the pH, of

natural waters, are determined by geological and atmospheric influences. Most fresh

waters, in South Africa, are relatively well buffered and more or less neutral, with pH

ranges between 6 and 8. Very dilute sodium-chloride dominated waters are poorly

buffered because they contain virtually no bicarbonate or carbonate, if they drain

catchments containing certain types of vegetation (for example, fynbos), the pH may drop

as low as 3.9 owing to the influence of organic acids (for example, humic and fulvic

acids). In South Africa such conditions are found in parts of the south-western and

southern Cape and in the coastal swamp forests of Natal (South African Water Quality Guidelines for Aquatic Ecosystems, 1996).

2.8.1.2 Ammonia

Ammonia may be present in the free, un-ionized form (NH_4+) or in the ionized form as the ammonium ion (NH_3). Both are reduced forms of inorganic nitrogen derived mostly from aerobic and anaerobic decomposition of organic material. They exist either as ions, or can be adsorbed onto suspended organic and inorganic material. Un-ionized ammonia (NH_3) is a colourless, acrid-smelling gas at ambient temperature and pressure. It is produced naturally by the biological degradation of nitrogenous matter and provides an essential link in the nitrogen cycle. The toxicity of ammonia is directly related to the concentration of the un-ionized form (NH_3), the ammonium ion (NH_4) having little or no toxicity to aquatic biota. Modifying factors may alter the acute toxicity by altering the concentration of un-ionized ammonia in the water through changes in the ammonia-ammonium ion equilibrium, or may increase the toxicity of the un-ionized ammonia to organisms (South African Water Quality Guidelines for Aquatic Ecosystems, 1996).

Ammonia is present in small amounts in air, soil and water, and in large amounts in decomposing organic matter. Natural sources of ammonia include gas exchange with the atmosphere; the chemical and biochemical transformation of nitrogenous organic and inorganic matter in the soil and water; the excretion of ammonia by living organisms; the nitrogen fixation processes whereby dissolved nitrogen gas enters the water and ground

36

water. Ammonia, associated with clay minerals enters the aquatic environment through soil erosion and bacteria in root nodules of legumes fix large amounts of nitrogen in the soil and this may be leached into surrounding waters (South African Water Quality Guidelines for Aquatic Ecosystems, 1996).

Ammonia is a common pollutant and is one of the nutrients contributing to eutrophication in aquatic systems. Commercial fertilizers contain highly soluble ammonia and ammonium salts. Following the application of fertilizer, if the concentration of such compounds exceeds the immediate requirements of the plant, transport *via* the atmosphere or irrigation waters can carry these nitrogen compounds into aquatic systems. Other sources of ammonia include: fish-farm effluent (un-ionized ammonia); sewage discharge; discharge from industries that use ammonia or ammonium salts in their cleaning operations; manufacture of explosives and use of explosives in mining and construction; and atmospheric deposition of ammonia from distillation and combustion of coal and the biological degradation of manure (South African Water Quality Guidelines for Aquatic Ecosystems, 1996).

2.8.1.3 Nitrites and Nitrates

Nitrite is the inorganic intermediate and nitrate is the end product of the oxidation of organic nitrogen and ammonia. Nitrate is the more stable of the two forms and is usually far more abundant in the aquatic environment. In view of their co-occurrence and rapid

inter-conversion, nitrite and nitrate are usually measured and considered together. Inter-conversions between the different forms of inorganic nitrogen are part of the nitrogen cycle in aquatic ecosystems. Inorganic nitrogen is primarily of concern due to its stimulatory effect on aquatic plants (South African Water Quality Guidelines for Aquatic Ecosystems, 1996).

Surface runoff from the surrounding catchment area, the discharge of effluent streams containing human and animal excrement, agricultural fertilizers and organic industrial wastes are the major sources of inorganic nitrogen which enters aquatic systems. In highly impacted catchments, the inorganic nitrogen arising from human activities can greatly exceed "natural" sources. In addition, many groups of bacteria are able to transform organic nitrogen to inorganic nitrogen during the decomposition of organic material. Inorganic nitrogen is seldom present in high concentrations in un-impacted surface waters. This is because inorganic nitrogen is rapidly taken up by aquatic plants and converted into proteins and other organic forms of nitrogen in plant cells. In South Africa, inorganic nitrogen concentrations in un-impacted, aerobic surface waters are usually below 0.5 mg/L but may increase to above 5-10 mg/L in highly enriched waters (South African Water Quality Guidelines for Aquatic Ecosystems, 1996).

2.8.1.4 Sulphate

Sulphate is the oxy-anion of sulphur in the +VI oxidation state and forms salts with various cations such as potassium, calcium, sodium, magnesium, barium, lead and

38

ammonia. This is a common constituent of water and arises from the dissolution of mineral sulphates in soil and rock, particularly calcium sulphate (gypsum) and other partially soluble sulphate material. The general limits for surface water is 5mg/L (DWAF, 1996) in aquatic systems.

2.8.1.5 Phosphate

According to Baird (1995), phosphate ions enters waterways from both point and non-point source pollution. Point sources are specific sites that discharge a large quantity of a pollutant, example phosphate as a component of human wastes in the municipality's untreated sewage. Non-point sources are entities such as farms; each provides a much smaller amount of pollution, for example phosphates from animal waste, fertilizers and wash-waters.

Phosphorus concentrations are usually determined as orthophosphates, total inorganic phosphate or total dissolved phosphorus (which includes organically bound phosphorus and all phosphates). Changes in trophic status accompanied by the growth of algae and other aquatic plants in rivers, lakes and reservoirs are the norms used to assess the effects of inorganic phosphorus on aquatic ecosystems. The most significant effect of elevated phosphorus concentrations is its stimulation of the growth of aquatic plants. Both phosphorus and nitrogen limit plant growth, and of these, phosphorus is likely to be more limiting in fresh water. The effect is dependent on the form of phosphorus present in the water, since not all forms are available for uptake by plants. Other factors, such as water

temperature, light and the availability of other nutrients, also play an important role in limiting plant growth. Inorganic phosphorus concentrations of less than 5 mg/L are considered to be sufficiently low to reduce the likelihood of algal and other plant growth (DWAF, 1996).

2.8.1.6 Calcium

The measurement of calcium ions in the surface water determines the 'hardness' of the water. Calcium ions form insoluble salts with anions, e.g., soaps thus forming froth in wash water. Most calcium enters water from either $CaCO_3$ in the form of limestone or from mineral deposits of $CaSO_4$ (Baird, 1995).

According to Day and King (1995), the key element essential for all living organisms is calcium. This is found in bones, teeth, mollusc, shells and crustaceans. Calcium is fundamentally important for muscle contraction, nervous activity, energy metabolism and a variety of other biochemical interactions. According to DWAF (1996), calcium strongly influences the absorption and toxicity of heavy metals.

2.8.1.7 Magnesium

Magnesium is an alkaline earth metal which reacts with oxygen and water to form magnesium oxide and magnesium hydroxide, respectively. This common constituent of water occurs as double positively-charged magnesium (II) ion (DWAF, 1996).

The measurement of magnesium ions in the surface water determines the 'hardness' of the water. The hardness of natural waters is an important characteristic as magnesium ions form insoluble salts (Baird, 1995). Magnesium is also a basic, essential element for plants (the central metallic ion in chlorophyll) and most other living organisms since it is a component of important enzyme co-factors (DWAF, 1996).

2.8.1.8 Chemical Oxygen Demand

The measurement of chemical oxygen demand (COD) is inappropriate for aquatic ecosystems however it is useful for determining water quality requirements of effluents discharged into aquatic systems and to measure the amount of oxygen likely to be used in the degradation of organic waste, however in aquatic ecosystems it is unlikely that all organic matter will be fully oxidized. The amount of suspended material in the water affects the saturation concentration of dissolved oxygen, either chemically, through the oxygen-scavenging attributes of the suspended particles, or physically through reduction of the volume of the water available for solution (DWAF, 1996).

2.8.1.9 Biological Oxygen Demand

The capacity of the organic matter in a sample of natural water to consume oxygen is called its biochemical oxygen demand, BOD. It is evaluated experimentally by determining the concentration of dissolved oxygen at the beginning and at the end of a period in which the sealed water sample is maintained in the dark at a constant

temperature, usually 20 degree celcius or 25 degree celcius. The BOD equals the amount

of oxygen consumed as a result of the oxidation of dissolved organic matter in the sample

(Baird, 1995).

Measurement of the biochemical oxygen demand (BOD) is inappropriate for aquatic

ecosystems, but is useful for determining water quality requirements of effluents

discharged into aquatic systems, in order to limit their impact (DWAF, 1996).

The general limit of BOD according to the United States Standards is 0.7mg/L (Baird,

1995).

2.8.1.10 Total Dissolved Solids

The total dissolved salts concentration is a measure of the quantity of all dissolved

compounds in water that carry an electrical charge. Since most dissolved

substances in water do carry an electrical charge; the TD salts concentration is usually

used as an estimate of the concentration of total dissolved solids in the water. The TD salt

concentration is directly proportional to the electrical conductivity (EC) of

water and because EC is much easier to measure than TD salts, it is routinely used as an

estimate of the TD salts concentration. Therefore, it has become common practice to use

the total dissolved salts concentration, as a measure for the total dissolved solids.

Electrical Conductivity (EC) is a measure of the ability of water to conduct an electrical

current. This ability is a result of the presence of ions in water such as carbonate,

bicarbonate, chloride, sulphate, nitrate, sodium, potassium, calcium and magnesium, all of which carry an electrical charge. Many organic compounds dissolved in water do not dissociate into ions (ionize), and consequently they do not affect the EC. Natural waters contain varying quantities of TDS as a consequence of the dissolution of minerals in rocks, soils and decomposing plant material. The TDS concentrations of natural waters are therefore being dependent on the characteristics of the geological formations which the water has been in contact with. The TDS concentration also depends on physical processes such as evaporation and rainfall. The TDS concentrations are generally low in rainwater, less than 1 mg/L. It is low in water in contact with granite, siliceous sand and well-leached soils-less than 30 mg/L. TDS is generally greater than 65 mg/R in water in contact with Precambrian shield areas; and in the range of 200-1100 mg/L in water in contact with Paleozoic and Mesozoic sedimentary rock formations (South African Water Quality Guidelines for Aquatic Ecosystems, 1996).

2.9.1   The Biological Characteristics of Water

According to Gray (1994), the biological characteristics of water are related primarily to the resident aquatic population of micro-organisms and impact directly on water quality. The most important impact is the transmission of disease by pathogenic organisms in water. Other important water quality impacts include the development of tastes and odours in surface waters, ground-waters, and the corrosion of heat transfer surfaces in cooling systems and water supply and wastewater management facilities.

2.9.1.1 *Escherichia coli (E. coli)*

According to Swerdlow *et al*., (1992) and De Nelion (1998), *E. coli* belongs to the Family Enterobacteriaceae. The family consists of fifteen genera, each of which is classified by serotyping its H and O antigens. Most *E. coli* that is found in human intestines is harmless but five pathogenic groups cause disease in humans.

E. coli are transmitted via the consumption of contaminated foods, unpasteurized apple juice and water. Other important transmissions are direct contact with animals, person to person, swimming in open lakes/rivers, well waters and municipal water systems. Verocytotoxin-producing *E. coli* produce potent toxins and thus cause severe diseases especially in infants, young children and the elderly (Pond, 2005). Table 2.3 below lists the five pathogenic groups causing disease in humans.

Table: 2.3 Pathogenic groups of *E. coli* causing disease in humans (Adapted from Kuntz
and Kuntz 1999) in Pond, 2005.

Classification of Infection	Abbreviation	Main Symptoms
Enteroaggregative *E. coli*	EaggEc	Diarrhoea
Enterohaemorrhagic *E. coli*	EHEC	Bloody Diarrhoea, HUS, Thrombotic thrombocytopenic purpura (TTP)
Enteroinvasive *E. coli*	EIEC	Bloody Diarrhoea
Enteropathogenic *E. coli*	EPEC	Diarrhoea
Enterotoxigenic *E. coli*	ETEC	Diarrhoea, Ileitis

2.10 Environmental Legislation in South Africa

Environmental legislation in South Africa is governed by the National Environmental
Management Act No. 107 of 1998.

This legislation provides for cooperative environmental governance by establishing
principles for decision making on matters affecting the environment, institutions that will
promote cooperative governance and procedures for coordinating environmental

functions exercised by organs of state; and to provide for matters connected therewith (National Environmental Management Act, 1998).

The act clearly states and tries to embody the following principles in ensuring that the environment is protected, conserved and preserved for future generations. They are as follows (cited in the *National Environmental Act, 107 of 1998, p 1-2*):

- Everyone has the right to an environment that is not harmful to his or her health or wellbeing;

- The State must respect, protect, promote and fulfill the social, economic and environmental rights of everyone and strive to meet the basic needs of previously disadvantaged communities;

- Inequality in the distribution of wealth and resources, and the resultant poverty, are among the important causes as well as the results of environmentally harmful practices;

- Sustainable development requires the integration of social, economic and environmental factors in the planning, implementation and evaluation of decisions to ensure that development serves present and future generations;

- Everyone has the right to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other

measures that prevent pollution and ecological degradation; promote conservation;

- Secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development;

- The environment is a functional area of concurrent national and provincial legislative competence, and all spheres of government and all organs of state must cooperate with, consult and support one another;

- That the law develops a framework for integrating good environmental management into all development activities;

- That the law should promote certainty with regard to decision making by organs of state on matters affecting the environment;

- That the law should establish principles guiding the exercise of functions affecting the environment;

- That the law should ensure that organs of state maintain the principles guiding the exercise of functions affecting the environment;

- That the law should establish procedures and institutions to facilitate and promote cooperative government and intergovernmental relations;

- That the law should establish procedures and institutions to facilitate and promote public participation in environmental governance;

- That the law should be enforced by the State and that the law should facilitate the enforcement of environmental laws by civil society:

With respect to the National Environmental Management Act, 107 of 1998, the following is important for pollution and waste in ensuring a sustainable environment (cited in the *National Environmental Act, 107 of 1998, p 9*):

- That the disturbance of ecosystems and loss of biological diversity are avoided, or, where they cannot be altogether avoided, are minimized and remedied;

- That pollution and degradation of the environment are avoided, or, where they cannot be altogether avoided, are minimized and remedied;

- That the disturbance of landscapes and sites that constitute the nation´s cultural heritage is avoided, or where it cannot be altogether avoided, is minimized and remedied;

- That waste is avoided, or where it cannot be altogether avoided, minimized and reused or recycled where possible and otherwise disposed of in a responsible manner;

- That the use and exploitation of nonrenewable natural resources is responsible and equitable, and takes into account the consequences of the depletion of the resource;

- That the development, use and exploitation of renewable resources and the ecosystems of which they are part do not exceed the level beyond which their integrity is jeopardized;

- That a risk averse and cautious approach is applied, which takes into account the limits of current knowledge about the consequences of decisions and actions; and

- That negative impacts on the environment and on people´s environmental rights be anticipated and prevented, and where they cannot be altogether prevented, are minimized and remedied.

2.10.1 Legislation in South Africa promoting safe waters

Water legislation in South Africa has been endorsed to prevent water pollution and water quality problems. The ministerial department that is custodian to the water resources in South Africa is the Department of Water Affairs and Forestry (DWAF), now called the Department of Water Affairs (DWA). The Minister of this department is empowered to act on behalf of the nation and has the ultimate responsibility to fulfill certain obligations relating to the use, allocation, protection and access to water resources.

2.10.2 The National Water Act

The National Water Act of 1998 is a comprehensive piece of legislation that replaces the previous ad hoc legislation. It is based on guiding principles which recognize the basic human needs of present and future generations (Fox and Rowntree, 2000).

This Act is to ensure that the Nations water resources are protected, used, developed, conserved, managed and controlled in ways which take into account among other factors the following (cited in the *National Water Act 36 of 1998, p 9-10*):

- Meeting the basic human needs of present and future generations;

- Promoting equitable access to water;

- Redressing the results of past racial and gender discrimination;

- Promoting the efficient, sustainable and beneficial use of water in the public interest;

- Facilitating social and economic development;

- Providing for growing demand for water use;

- Protecting aquatic and associated ecosystems and their biological diversity;

- Reducing and preventing pollution and degradation of water resources;

- Meeting international obligations;

- Promoting dam safety;

- Managing floods and droughts, and for achieving this purpose, to establish suitable institutions and to ensure that they have appropriate community, racial and gender representation.

2.10.3 The Water Services Act

Water Services Act (No. 108 of 1997) – This Water Services Act gives substance to constitutional requirements with respect to access, national norms and standards and the institutional framework for the provision of water services (DWAF, 2005).

2.10.4 Compulsory National Standards for the Quality of Potable Water

Compulsory National Standards for the Quality of Potable Water (2001, Regulation 5 of Section 9 of the Water Services Act) – requires that Water Service Authority's (WSAs) implement drinking water quality monitoring programmes to monitor, improve and report on drinking water service delivery (DWAF, 2005).

2.10.5 Strategic Framework for Water Services Compulsory National Standards for The Quality of Potable Water

This Strategic Framework for Water Services Compulsory National Standards for the Quality of Potable Water (2003) – contains guidelines for the provision of water services, including drinking water quality, and role of DWAF as sector regulator (DWAF, 2005).

2.10.6 Municipal Structures Act

Municipal Structures Act (No.117 of 1998) – This Act provides for functions and powers of municipalities and other local government structures, of which water services is one of many primary functions (DWAF, 2005).

2.10.7 The National Health Act

National Health Act (No. 61 of 2003) – This Act promotes fulfilling the rights of people of South Africa to an environment that is not harmful to their health or well being (DWAF, 2005).

2.10.8 The National Water Resources Strategy

The National Water Resources Strategy (2004) provides the framework within which water resources will be managed throughout the country. The National Water Resources Strategy also provides the framework within which all catchment management strategies will be prepared and implemented for water resources management in a water management area (DWAF, 2005).

3. Conclusion

 The above chapter has provided a detailed review of the various facets of water quality around the globe, the construction of dams and associated impacts, water borne disease and a wide range of water quality variables that forms the guiding principle to safe riverine systems, it is therefore noted, according to Baron *et al*. (2002), the riverine networks are literally the "sinks" into which landscapes drain, they are greatly influenced by terrestrial processes, including many human uses or modifications of land and water. Freshwater systems have specific requirements in terms of quantity, quality, and

seasonality of their water supplies. This is also determined by the construction of dams on the natural system and the associated impacts. The ratio of pollutant fluxes to natural fluxes increases with increasing activity of civilization. The quality of water bodies thus generally reflects the range of human activity within the catchment area (Stumm and Morgan, 1981). These include a wide range of anthropogenic activities. Even though there are numerous water management policies available, the level of implementation is questioned and in this regard society needs to ensure that they achieve the correct balance in the water mix in terms of the use of surface water, return flows, groundwater, rainwater harvesting, desalination and effluent re-use as water protection is undoubtedly the key to unlocking the growth and development in Africa (Hendricks, 2009).

CHAPTER THREE

STUDY AREA AND METHODOLOGY

3.1 Introduction

This study is interdisciplinary in nature and required the use of water quality sampling methods and analysis as well as map and questionnaire surveys. Scientific water sampling methods were administered in the collection of water samples followed by scientific laboratory analysis as well as social sampling methods adopted for the administration of the questionnaire survey. This allowed the researcher to present the findings in a scientific and systematic way in the form of graphs and tables. The analysis of maps for the Umdloti catchment allowed the researcher to ascertain geographic location as well as temporal developmental changes that have occurred in the catchment. This description will permit the reader a comprehensible and concise understanding of the research methodology adopted.

3.2 Study Area

The Umdloti River catchment is the chosen area for this study. This is a coastal river and is situated in the North Coast of Durban, KwaZulu-Natal (DWAF, 2001). The word mDloti has various meanings. According to Begg (1978), the meanings are as follows;

- the plough share;

- the violent river,

- The river of the wild tobacco plant.

The Umdloti River (Figure 3.1) rises at an altitude of about 823 meters in the Noodsberg area, about three miles east of Glenside where the catchment is bounded to the north by the Umvoti river system. This river has many tributaries, most of them rising in the rugged country made up by the Klein Noodsberg, Matabataba and Sleeping Beauty Hills to the west and by Ecameni Mountain, Goowene and the Amataba Mountains on the south western boundary of the catchment. Almost the entire upper and middle portions of the Umdloti catchment lies within the Inanda Location 4675 whose eastern boundary occurs almost ten kilometers inland from the coast. The river flows southwards at first and then turns east. The river passes through the town of Verulam as is crosses the coastal plain and finally enters the Indian Ocean (Brand *et al*., 1967). The Umdloti River ends at the La Mercy lagoon forming the Umdloti estuary.

This river lies in the Mvoti / Umzimkulu Water Management Area (WMA). About 5km upstream (north-west) of the Magisterial District of Verulam, a concrete gravity dam was erected, the Hazelmere Dam (DWAF, 2007). Harrison *et al*., (2000) indicated that the Umdloti estuary is a closed estuary whilst Begg (1984), indicated that it is frequently opened.

The Umdloti estuary (Figure 3.2) is 25 km north east of Durban. Access to the Umdloti mouth is via the N2 National Highway and also according to Begg (1978), access is through the township of Umdloti Beach, which lies immediately south of the lagoon.

According to Begg (1978), the characteristics of the catchment are as follows:

- The catchment has an area of 481-704km^2

- The river length is approximately 74-88km^2

- The river flow is perennial

- The Hazelmere dam is situated 20 km above the La mercy Lagoon and 4.5 km north of the town Verulam.

From available topographical maps and a complete visual survey, much of the catchment is under intensive sugar cane agriculture with some banana plantations downstream of the town of Verulam and limited vegetable agriculture. Apart from these, a considerable portion of the catchment is occupied by the town of Verulam and its surrounding residential areas and the Hazelmere waste water treatment works located below sampling point four (Figure 3.4). Other major land uses include the Hazelmere Dam and game reserve area as well as the site reserved for the La Mercy international airport which is nearing completion.
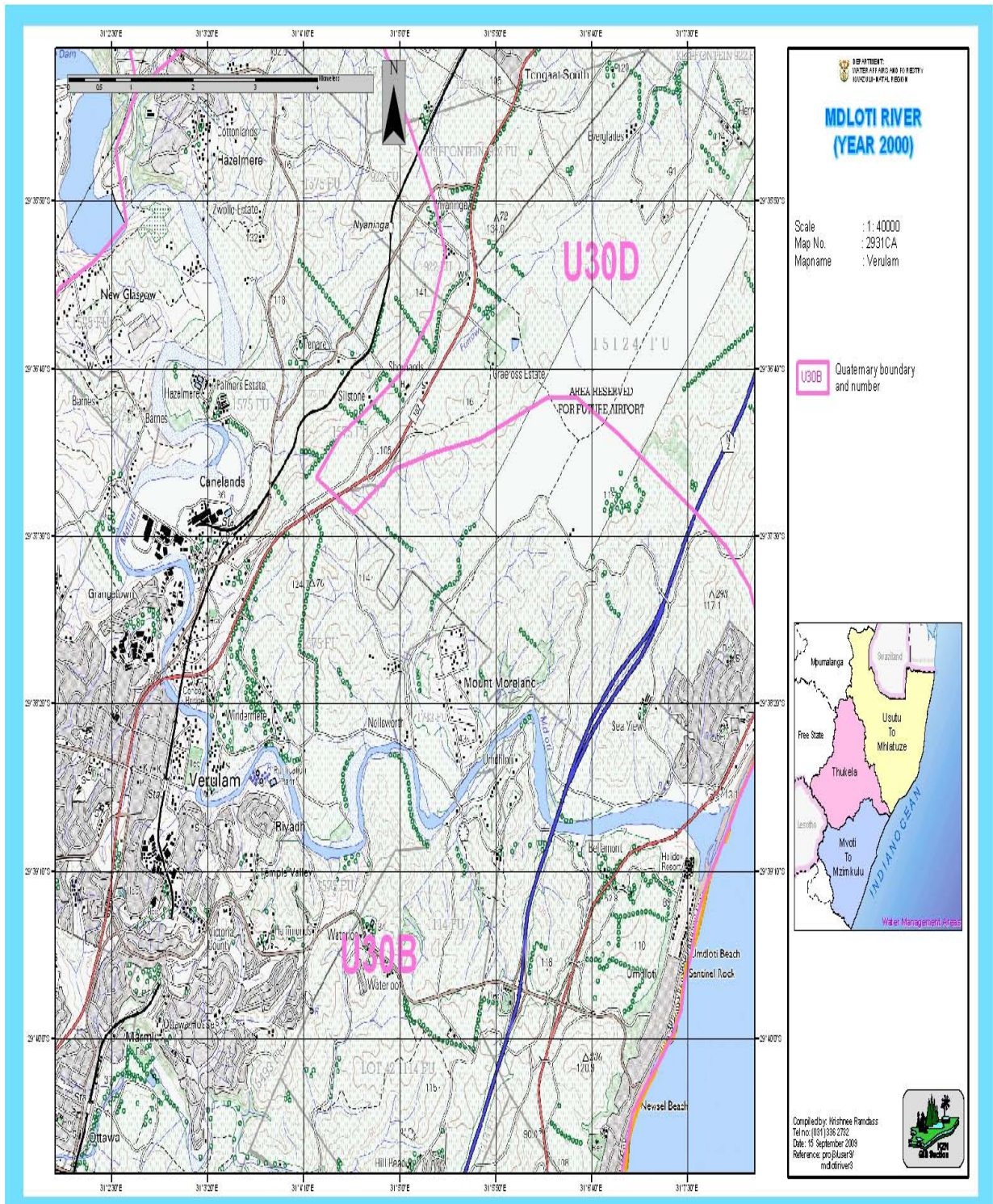
Source: DWAF, 2009

Source: Google Earth, 2009

Figure 3.2 The Umdloti Estuary

3.3.1 Physiographic Characteristics of the Umdloti Catchment

3.3.1.1 Drainage and Topography

The area contains numerous major and minor river valleys and tributaries resulting in various degrees of fragmentation, while the area surrounding the Hazelmere Dam forms a large bowl shape with a gently sloped terrain. The Hazelmere Dam and Umdloti River valley represent the topographical focal point of the study area, much of the steep topography is found on the river bends, while most of the flat slopes are located on the depositional side of the stream. The hydrology of the dam area and its surroundings are characterized by a large amount of perennial tributaries flowing in from the surrounding hills with the main inlet being the Umdloti River (DWAF, 2007).

3.3.1.2 Geology and Soils

The study area is underlain predominantly by tillites and associated rocks of the Ecca group, Dwyka formation (Figure 3.3). This is overlain by the dark grey shales of the Pietermaritzberg Formation, with Natal Group Sandstones and conglomerates present in the mid to upper reaches of the catchment. Additionally a number of dolerite intrusions in the study area, as well as a geological fault extending through the study area from north-east to south west (DWAF, 2007). According to Begg (1978), the river transverses Archaean Granite (Gneiss), Table Mountain sandstone, Dwyka conglomerates (tillities)

and Ecca shale. The first two meters of the Umdloti river deposits are made up of fine sand and below these are coarse fluvial sand and lenses of mud and clay.

The soils within the Umdloti Catchment include those derived from Natal group sandstones, Dwyka conglomerates, lower Ecca shales, Karoo dolerites, Stormberg basalts and alluvium. The soils all belong to the Umzinto soil systems, specifically the coastal lowlands and river valleys. Soil forms include Cartref, Glenrosa, Westleigh, Milkwood and Rensberg. All these soils have moderate to high erosion potential, specifically gully erosion (DWAF, 2007).

3.3.1.3 Climate and Vegetation

The Umdloti River and the Hazelmere Dam are situated in a high, summer rainfall region, with an annual precipitation level of between 800mm-1125mm. Summers are very warm, temperatures range from 25°C to 38°C. Winters are moderate with relatively cool days, with rare cold spells in the morning and at night, with temperatures ranging from 9°C to 19°C (DWAF, 2007).

The agriculture found in this water management area (WMA) includes large amounts of sugar cane (both dry land and irrigated), bananas, citrus (farmed near Stanger and Darnall on the north coast), vegetables, beef and dairy pastures. The majority of irrigation utilizes sprinkler irrigation systems, but there is some micro-irrigation along the coastline and a

few center pivots can be found in the Nottingham road area in the Mgeni catchment (DWAF, 2001).

Areas surrounding the dam contain remnants of indigenous vegetation; in particular on steep topography and cliff faces on the northern banks of the dam, the remainder of the natural area consists substantially of disturbed grassland. The steeper and therefore the less accessible valley sides of the river and the tributaries contain some indigenous vegetation, inclusive of the area surrounding the Priory (DWAF, 2007, cited in the *Resource Management Plan of Hazel mere*).

3.3.1.4 Bird, mammal, reptile and other life

The dam is home to over 220 species of birds. This is due to the excellent variety of habitat types, from water to forest to grassland to thorn-veld. White-backed Night Heron, Martial, Crowned and Black Eagle and even nesting Black Storks have been recorded. Mammals such as bush-pig have also been recorded, but larger mammals are absent. The reptile population of the dam is diverse and consists of snakes, monitor lizards and skinks (DWAF, 2007, cited in the *Resource Management Plan of Hazelmere*). During the 1980's 42 specimens of different species were captured - 28 types of fish, 8 types of prawns, and 6 species of crab were found in the estuary (Begg, 1984). According to Skelton (2000; cited in Goodman, 2000) one record of a Red Data Book Species (vulnerable in South Africa) of fish - *Redigobius bikolanus* or bigmouth goby was found in this estuary (Ahmed, 2005).
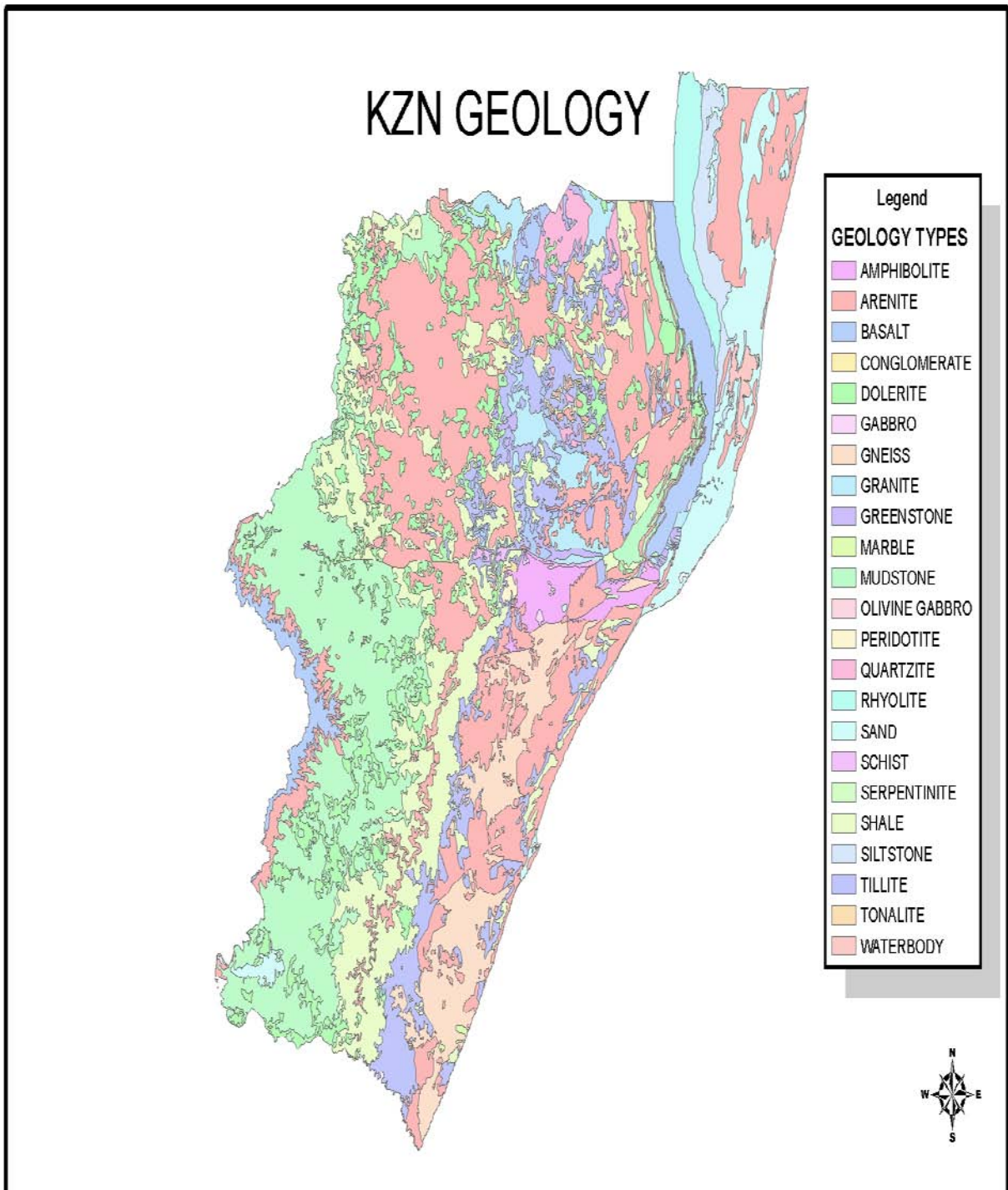
Figure 3.3: Simplified geological map of the KZN (from Ahmed, 1996) in Chile, 2007.

3.4   RESEARCH METHODOLOGY

3.4.1   Measurement of Water Quality

Water quality can be thought of as a measure of the suitability of water for a particular purpose. For example the quality of the water that humans need for drinking can be vastly different from the quality of water that some or our aquatic organisms like to live in. Water quality is assessed by looking at a number of characteristics such as its physical, chemical, and biological makeup. These include e.g. temperature, acidity (pH), dissolved oxygen, and electrical conductance (an indirect indicator of dissolved minerals in the water) (Gail, 2001), as well as those investigated in this study.

3.4.2   Water Quality Parameters

Water quality parameters provide important information about the health of a water body. These parameters are used to find out if the quality of water is good enough for drinking water, recreation, irrigation, and aquatic life (Murphy, undated).Water quality measurements include chemical, physical and biological parameters. Streams and rivers can be measured to determine the physical structure of the stream channel, the physical and chemical quality of the water, the presence of pathogenic organisms, and the type of biotic community they support. Examining these parameters and how they interact can be used to assess the overall condition of a waterway. Physical, chemical, and bacterial testing can indicate water quality, land uses, and specific pollutants that may be affecting

a waterway. These parameters measure the stream′s ability to support aquatic life and

whether the water is potentially harmful to humans. These measurements are "snapshots"

in time and may vary from day to day or even hour to hour. They indicate current

conditions or what is in the water at the time of sampling (www.3r2n.cfa.cmu.edu).

3.4.2.1 Physical Characteristics

The physical characteristics of water are pertinent to the characterization of the

stream/river habitat and will provide an insight as to the ability of the stream to support a

healthy aquatic community, and the presence of chemical and non-chemical stressors to

the stream ecosystem (Barbour, 1999). According to Spellman (1998), the most

commonly considered physical characteristics are temperature, taste, colour, odour,

turbidity and solids.

3.4.2.2 Chemical Characteristics

There are numerous chemical characteristics of water and according to Gray (1994), the

compounds that comprise the category of chemical characteristics includes the following:

hardness, nutrients, alkalinity, organic content, dissolved oxygen and inhibitory and toxic

compounds.

3.4.2.3 Biological Characteristics

 There are many small and often microscopic species which play a vital role in maintaining the health of a river. They are as follows: algae; diatoms (e.g. *Asterionella* species); Blue-green algae (e.g. *Anabaena* spp.); Green algae (e.g. *Spirogyra* spp.); three main types of protozoa; decomposers and scavengers; bacteria; viruses; and parasites (Porteous, 2000).

For the purposes of this study the bacterium, *Escherichia coli (E. coli)* was measured.

3.4.3 Sampling Locations

 The sampling locations were determined by first examining the Umdloti Catchment using aerial photography and an inclusive site visit where parameters were evaluated. This provided the researcher with a holistic understanding of the water course and the determinants of the twelve sampling points. The twelve sampling points were chosen on the basis of the river description and easy access to the water course due to safety and health reasons. The sampling points (Figure 3.4) were equally demarcated along the upper part of the Umdloti River, in the vicinity of the Hazelmere Dam and the lower part of the river, the La-Mercy estuary.
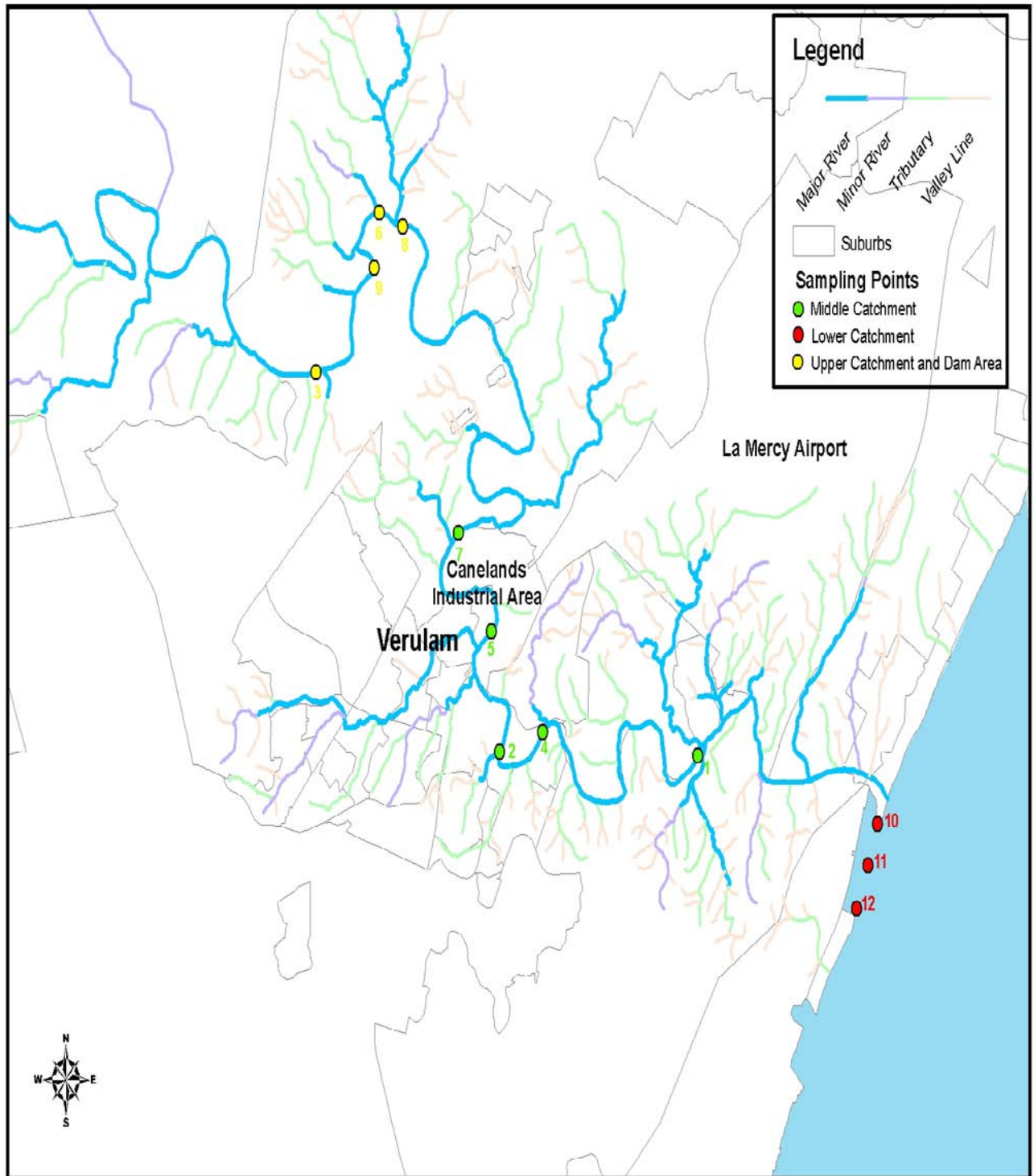
Figure: 3.4: Sampling points in the Umdloti River

3.4.4 Questionnaire Survey Method

Questionnaires represent the most common source of quantitative data. Questionnaires can be administered via post, with the help of e-methods or in person (Gustavsson, 2007). For this investigation the researcher interviewed individual persons.

The researcher adopted the purposive sampling method for this investigation. This sampling method is essentially strategic and entails an attempt to establish a good correspondence between research questions and sampling. The researcher sampled on the basis of wanting to interview people who are relevant to the research question (Bryman, 2004). This type of sampling technique was adopted due to the nature of the study area as many of the people that were directly affected during the construction of the Hazel-mere dam, may or may not be alive or have left the area. Interviews were conducted over three weeks due to time constraints, the availability of the respondents and poor road conditions.

3.4.5   Research Techniques Employed in the Study

The methodologies adopted for the investigation included sample collection, questionnaire survey and analytical analysis at an independent laboratory. The data obtained from the laboratory analysis is subsequently analyzed and represented statistically.

3.4.6 Collecting of Water Samples

According to Wilson (1974), the basic aims of sampling may be summarized as follows:

- To obtain a sample whose concentrations of determinants are identical to those in the water of interest at the time of sampling.

- To repeat the sample operation at times such that the required information on any changes in water quality is obtained.

- To ensure that the concentrations of the determinants in the samples do not change between sampling and analysis.

This would ensure that the intended purpose of the sampling has been completely achieved.

When collecting water samples the researcher or researchers need to adopt a high level of accuracy. This will ensure that proper water samples are collected. For this investigation the researcher took twelve (12) water samples on the Umdloti River (Figure 3.4).

The samples were collected in the following manner:

- 500 ml sterile glass sampling bottles were used for all collections. This was administered due to every sample being subjected to microbiological examination and this would also avoid contamination.

- The researcher also carried extra bottles for precautionary measures. This was done to ensure that should the bottles break or the bottle caps not seal properly the sampling process would not be hindered.

- The sample bottles were submerged into the river to a depth of approximately 30 cm, the same at every location, the required volume (100% of volume of sample bottle) attained and the bottles sealed and stored on ice.

- The sample bottles were filled to volume opposing oxidation or chemical reactions in the samples attributed to the presence of atmospheric oxygen.

- Each sample bottle was accurately labeled to indicate the GPS position at which the sample was taken, sample number and time taken of each sample.

- Each sample position was fixed using a GPS.

- Water samples were taken on a seasonal basis. In KwaZulu-Natal the distinct seasons are summer and winter therefore the sampling surveys were conducted during winter and summer of the study period.

- Once the sample collection had been completed, the twelve (12) water samples were transported in a cooler box to the Water and Wastewater Research Laboratory at the Durban Institute of Technology (DIT) for analytical analysis.

- This was of paramount importance to ensure that no chemical changes in the water quality take place.

Plate 3.1: The researcher and assistants takes GPS positioning for the water sample at the Hazelmere public boating zone.

Plate 3.2: Collection of water sample at the end of Wick Street (the main street in the town ends at the edge of the river) in Verulam.

3.4.7 Laboratory Analysis of Water Samples

According Raju (1995), examination of water in the laboratory provides information regarding the presence and concentrations of the varying impurities in water. Wilson (1974), also states that general precautions must be taken due to the fact that even when suitable analytical methods are available the following factors such as reagents, equipment and contamination may prevent the analyst from achieving the required accuracy.

Weiner and Matthews (2003), states that the water pollutants are measured in terms of milligrams of the substance, per litre of water (mg/L). Pollutant concentrations may also be expressed as parts per million (ppm), a weight/weight parameter. If water is the only liquid involved, ppm and mg/L are equivalent, as one litre of water weighs one thousand grams. For many aquatic pollutants, ppm and mg/L is equal, however, because some wastes might have specific gravity differing from that of water, mg/L is preferred measure.

The water samples collected as part of this investigation were taken to the Water and Wastewater Research Laboratory at the Durban Institute of Technology (DIT) and eThekwini Wastewater Management Laboratory for analysis for determination of the concentrations of the indicators utilized in the assessment.

For purposes of this investigation, the samples collected were analyzed for the following variables:

- Nitrites

- Nitrates

- Ammonia

- pH

- Total *E. coli*

- Sulphate

- Phosphate

- Total Dissolved Solids (TDS)

- Chemical Oxygen Demand (COD)

- Biological Oxygen Demand (BOD)

- Calcium

- Magnesium

The following variables have only been tested for summer due to financial reasons; however it does not impact negatively on the study. They are as follows; Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Calcium and Magnesium.

The following analytical procedures were carried out for the variables being tested. They are as follows:

- Nitrates, nitrite, ammonia, sulphate and phosphates were analyzed colorimetrically. In this technique the absorption of light by one or more components of a solution is used to measure the concentration, when the absorption of light occurs in the visible region of the spectrum (approximately 380-750 nm) the solution appears coloured and measurements can be taken (Wilson, 1974);

- TDS was measured gravimetrically. This technique measures filterable and non-filterable solids (Wilson, 1974). The principle of gravimetry is based on measuring a mass that is equal or directly proportional to the element being sought. The solids being weighed is obtained from a known volume of sample after evaporation, filtration, or precipitation (Degrèmont, 1991).

- Calcium and magnesium were measured using the Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES). According to Walsh (1997), and Skoog *et al.* (2004), the ICP-AES is presently acknowledged as a common method and technique for the analysis of elements. ICP-AES is one of the most commonly used methods in geochemical analysis, and it is unproblematic and easy to utilize. With regards to atomic spectra, different atoms emit and absorb different electromagnetic waves, at their specific and distinctive wavelengths. This enables the analyst to examine specific elements, without chemically separating them (Walsh, 1997, in Chile, 2007);

- pH, according to Gray, (1994) expresses the intensity of acidity or alkalinity of a solution and has been measured using a glass electrode which is sensitive to hydrogen ions in solutions;

- COD is analyzed using the dichromate sulphuric digestion (DWAF, 1996);

- Total *E. coli,* are usually analyzed by membrane filtration (0.45 *u*m diameter pore size), pour plates or by multiple fermentation techniques. Faecal coliform bacteria are all bacteria which produces typical blue colonies on m-FC agar within 20-24 hours of incubation at 44.5^{o}C. *Escherichia coli* are considered to be all the faecal coliforms which test indole-positive at 44.5^{o}C (DWAF, 1996).

3.4.8 Questionnaire Survey

Confidentiality, respect and patience for the respondents are the key factors in ensuring that questionnaire survey research is successful. This was outlined to each respondent before the question survey was administered.

Questionnaire surveys were conducted with 50 households of the informal and formal communities alongside the Umdloti River catchment. This survey was administered, in the form of an interview with each respondent. Questionnaires comprised of both closed and open-ended questions and the responses from the interviewees had to be recorded. A separate questionnaire was used for each respondent, however, some questions applied only to a specific sector of the sample (removal from the area of dam construction and expropriation of land). The overall response from the interviewees was good as they were enthusiastic to answer. The duration of the interview was approximately 25-30 minutes.

The questionnaire addressed the following aspects:

- Socio-economic/ demographic characteristics of respondents;
- Perceptions regarding the Umdloti River and water quality in general;

- Perceptions regarding the construction of the Hazelmere Dam

- Uses or activities that impact directly or indirectly on the river;

- Activities that are causing pollution in the Umdloti River

A copy of the questionnaire is attached in the appendix

Data was analyzed using Microsoft Excel. In analyzing the data, verbatim responses from the respondents was used. Some details of the respondents were used to contextualize the responses without compromising the anonymity of the respondents. Opinions may vary as to the accuracy and appropriateness of the criticisms and compliments.

3.4.9 Statistical Analysis of the Data

Aspects from both the chemical water quality study and the questionnaire survey were analyzed statistically. Much of the material was subjected to descriptive statistical analyses and others to statistical tests to ascertain the relationships between variables studied. For the chemical data, averages, standard deviation and standard errors were calculated and, where major differences in summer and winter values were observed, the T-Test, a powerful parametric test, was used to establish whether the differences between the two data sets was significant.

In the case of the questionnaire survey, data are presented in a series of tables and pie diagrams but some of these data are presented in contingency tables to facilitate hypothesis testing. In this case the Chi Squared (X^2) Test which is also a strong

parametric test was used. All statistical analyses in this study follow the methodology outlined in Hammond & McCullagh (1974).

3.4.10 South Africa Water Quality Guidelines

The South African Water Quality Guidelines for Fresh Water (1996) is essentially a specification for the surface water quality required to protect fresh water aquatic ecosystems; quantitative and qualitative criteria for chronic and acute toxic effects for toxic constituents; quantitative and qualitative criteria to protect ecosystem structure and functioning, for non-toxic constituents and system variables and quantitative and qualitative criteria to protect aquatic ecosystems against changes in trophic status in the case of nutrients (DWAF, 1996).

The Target Quality Range (TWQR) is a management objective which has been derived from quantitative and qualitative criteria. This is the range of concentration or levels within which no measurable adverse effects are expected on the health of aquatic ecosystems. These ranges assume life-long exposure and strive to protect South Africa's water resources by maintaining water quality within the TWQR (DWAF, 1996).

The Chronic Effect Value (CEV) is the level of a constituent at which there is expected to be a significant probability of measurable chronic effects to up to five percent (5%) of the species in the aquatic community. If such chronic effects persist for some time and or

occur frequently, they can cause death of individuals and disappearance of sensitive species from the aquatic ecosystems. This can have considerable negative consequences for the health of aquatic ecosystems, since all components of aquatic ecosystems are interdependent (DWAF, 1996).

The Acute Effect Value (AEV) is the level of the constituent above which there is expected to be a significant probability of acute toxic effects to up to five percent (5%) of the species in the aquatic community. If such acute effects persist for even a short while, or occur at too high a frequency, they can quickly cause death and disappearance of sensitive species or communities from aquatic ecosystems. This can have considerable negative consequences for the health of aquatic ecosystems, even for a short period (DWAF, 1996).

This water quality guideline, together with the limits set out in the TWQR, CEV, and AEV was used in this research to examine the water quality in the Umdloti River and to describe the sources of the water quality problems experienced. Not all the variables tested in this research are available on the South African Water Quality Guideline.

Secondary data was accessed via desktop research, the internet and the collection of material obtained by researching books, articles and journals and other appropriate literature.

3.5 Conclusion

Water quality sampling forms an imperative connotation for this research process. The analyzed samples will provide valuable information to the researcher, including other interested and affected parties, as to the extent of fresh water pollution of the Umdloti River. This will allow the researcher to comment accordingly about the results obtained and compared to the water quality guidelines set out by the Department of Water Affairs. The results according to the guideline and according to the category it falls within will determine an acceptable, chronic and or acute effect for this freshwater system. This concludes that water quality sampling and monitoring is essential in any freshwater system and is the most effective manner in determining the various physical, chemical and biological contaminants that are affecting water quality upstream, middle and downstream of river systems.

CHAPTER FOUR

RESULTS AND DATA ANALYSIS

4.1 INTRODUCTION

This chapter focuses on the water quality and questionnaire survey results and detailed discussion on the interpretation of the data and findings of the study. The results in this chapter is tabulated into graphs and tables divided into two sections. Section one is the statistical interpretation and discussion of water quality variables against the general limits set out by the custodian of water resources in South Africa, the Department of Water Affairs and Forestry (presently referred to as the Department of Water Affairs) and section two presents the results and statistical analysis from the questionnaire survey that was administered in the research.

4.2   Water quality analysis

As noted earlier the variables for which the laboratory analysis was undertaken included the following:

- Nitrites,
- Nitrate,
- Ammonia,
- pH,
- Total *E. coli*,
- Sulphate,
- Phosphate,

- Total Dissolved Solids,

- Chemical Oxygen Demand (COD),

- Biological Oxygen Demand (BOD),

- Calcium

- Magnesium

The table below (Table 4.1) provides a detailed layout of all the water quality data, averages, standard deviations and standard errors. The graphs that follow are presented in accordance with the analyzed water quality data in the upper, middle and lower parts of the Umdloti River. The sampling points of the upper, middle and lower reaches of the Umdloti River is presented as follows:

- Sampling points 3, 9, 6, 8 (upper catchment).

- Sampling points 7, 5, 2, 4, 1 (middle catchment).

- Sampling points 10, 11, 12 (lower catchment-estuary).

Sampling points in the upper (3, 9, 6, 8); middle (7, 5, 2, 4, 1) and lower (10, 11, 12) reaches of the Umdloti River

	3	9	6	8	7	5	2	4	1	10	11	12	AV	SD	SE
Nitrites (w)	0.47	0.38	0.4	0.41	0.5	0.5	0.4	0.59	0.44	0.42	0.52	0.55	0.46	0.0527	0.1521
Nitrites (s)	0.34	0.24	0.3	0.17	0.3	0.2	0.3	0.25	0.39	0.25	0.33	0.24	0.28	0.02	0.0057
Nitrates (w)	0.1	0.1	0.1	0.1	0.3	0.1	0.6	0.1	0.13	0.1	0.1	0.1	0.15	0.133	0.0384
Nitrates (s)	6.3	6.3	6.1	5.9	5.8	5.3	4.2	4.6	4.7	4.1	4.9	5.2	5.28	0.792	0.228
Ammonia (w)	0.5	0.5	0.5	0.5	0.5	0.5	2.3	1.1	0.5	0.5	0.5	0.5	0.7	0.532	0.153
Ammonia (s)	8.3	7.5	9.5	4.2	8.6	5.2	7.9	8.8	9.8	10.1	9.6	7.6	8	1.815	0.523
pH (w)	7.1	7.7	7.8	7.7	7.8	7.1	7.3	7.2	7.4	7.9	7.9	7.6	7.5	0.308	0.0889
pH (s)	6.8	6.4	6.2	6.5	6.4	5.7	5.7	6.3	5.3	6.2	5.9	6.4	6.1	0.42	0.122
Sulphate (w)	10	10	10	10	10	10	37	34	10	36	35	38	20.8	13.42	3.874
Sulphate (s)	5.9	6.7	18	5.6	16	5.8	6.8	26	4.9	6	15	41	13.1	11.04	3.18
Phosphate (w)	0.1	0.1	0.1	0.1	0.1	0.1	0.7	0.1	0.1	0.1	0.1	0.1	0.14	0.164	0.047
Phosphate (s)	1.2	0.1	1.2	0.89	1.2	1.3	1.8	3.2	3.8	2.9	2.1	2.8	1.87	1.097	0.316
E. coli (w)	3.4	2.9	2.5	3.2	3.5	2.6	2.6	4.6	3.1	2.3	3.6	3.3	3.13	0.623	0.179
E. coli (s)	6.3	4.1	4.2	4.3	5.8	4.7	4.9	7.1	5.7	3.8	4.5	4.2	4.96	1.023	0.295
TDS (s)	209	133	128	130	175	209	503	476	207	869	830	1063	411	335.5	96.8
BOD (s)	55	57	56	38	55	48	41	67	59	35	46	44	50.08	9.633	2.781
COD (s)	88	110	102	65	106	89	81	65	98	114	73	76	88.9	17.1	4.959
Calcium (s)	12	6	6.5	6	11	12	16	16	13	17	14	125	20.7	32.92	9.503
Magnesium (s)	8.5	5.8	5.6	5.5	8.1	8.5	8.6	9	8.5	25	18	150	21.75	40.78	11.77

W-winter

S-Summer

AV-Average

SD-Standard deviation

SE- Standard error

Table 4.1: Comprehensive table illustrating the values, averages, standard deviations and standard errors for the various parameters tested in the Umdloti Catchment.

The table above (Table 4.1) summarizes all data for the catchment on a seasonal basis (summer and winter) with the exception of TDS, BOD, COD, Ca and Mg that contains data only for the summer season. Summary statistics, mean standard deviation and standard error for the data are presented in the last three columns. From the table above and the graphs below it is evident that some variables show marked seasonal variations. Statistical analysis of these variations is presented in section 4.2.5 below and discussed further. The variables in the table above are grouped and presented in the graphs below to highlight their variability from upper to lower catchment and the possible reasons for these changes are discussed.

4.2.1 Nitrites, Nitrate and Ammonia (mg/L)
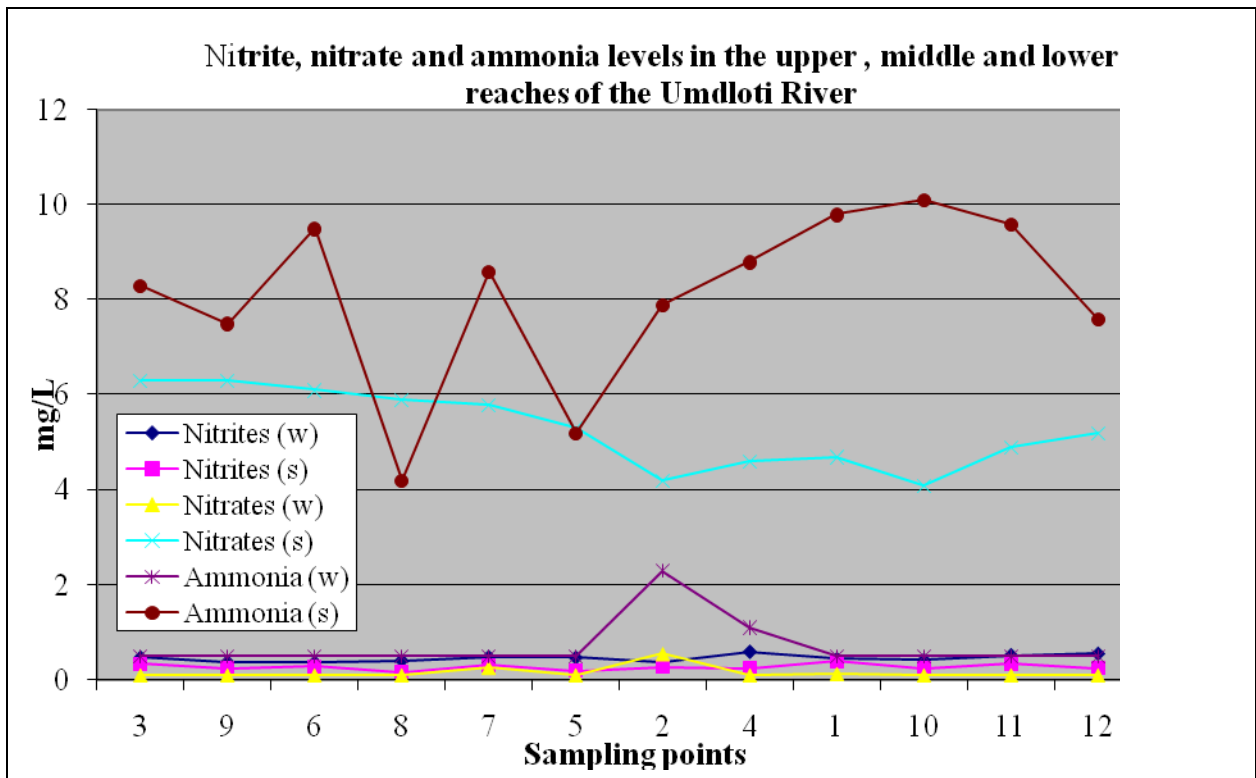
Graph 4.2.1: Nitrite, nitrate and ammonia levels for each of the two seasons

Nitrite concentration from table 4.1 above indicates that the average nitrite values is higher in winter as compared to summer. Sample point 12 is on the extreme end (south) of the estuary, indicated the highest nitrite value for winter and sample point 1 indicated the highest nitrite value for summer (graph 4.2.1). The general limit set by DWAF is 0.5mg/L therefore the average nitrite concentration for summer and winter are below the general limit.

Nitrate concentration from table 4.1 above indicates that the average nitrate values are highest in summer as compared to the average winter nitrate values. Sample point 3 shows the highest nitrate reading in summer and sample point two shows the highest nitrate reading in winter (graph 4.2.1). The Target Water Quality Range (TWQR), according to DWAF ranges from 6-10mg/L. The average of the nitrate values for winter is 0.15 and the average summer nitrate value is 5.28 hence the average summer and winter nitrate values are below the general limit.

Ammonia concentration from table 4.1 above indicates that the average ammonia values are highest in summer as compared to the average winter ammonia valves. Sample point 10 shows the highest ammonia reading in summer (graph 4.2.1). This is a common pollutant and is one of the nutrients contributing to eutrophication. The Target Water Quality Range (TWQR), according to DWAF is 7mg/L. The average of the ammonia valves for summer is 8.0 therefore the average ammonia values are beyond the limits of DWAF. Ammonia is a common pollutant and is one of the nutrients contributing to eutrophication.

4.2.2 pH

pH levels in the upper, middle and lower reaches of the Umdloti River
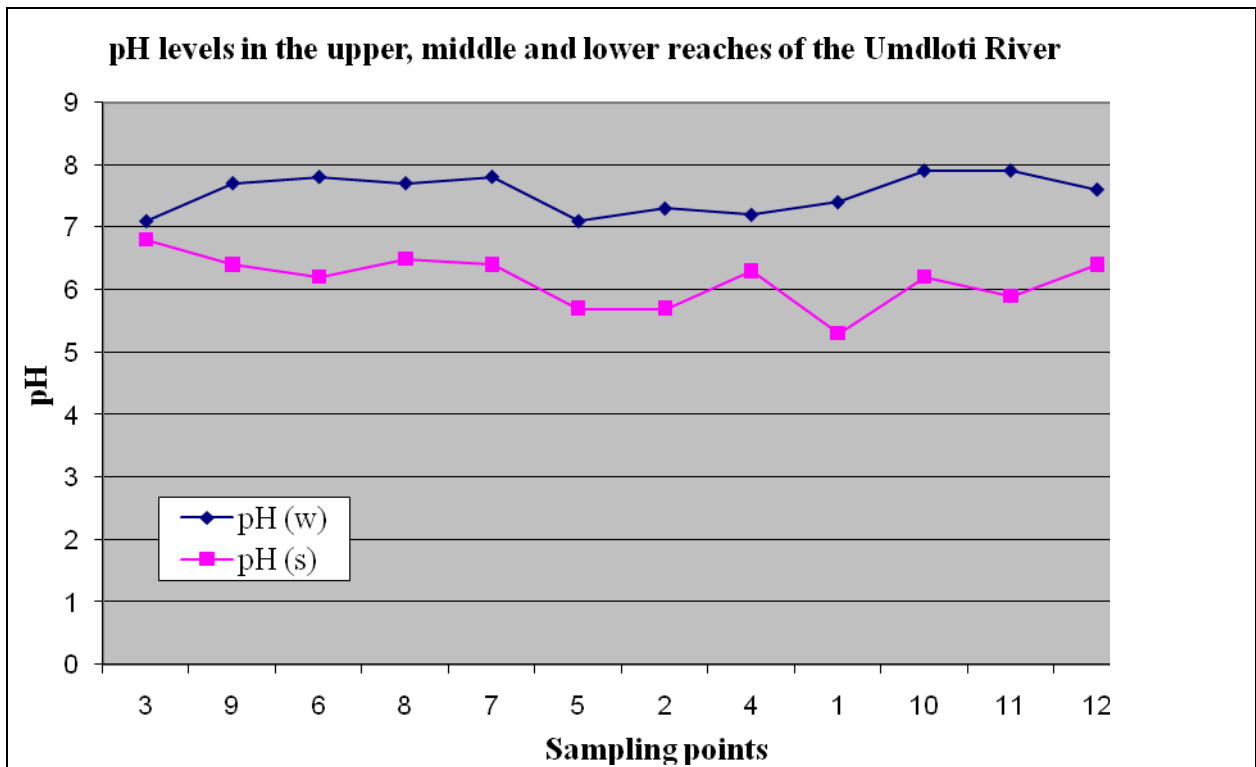
Graph 4.2.2: pH values for each of the two seasons

The pH of natural water is determined by geological and atmospheric processes and measured by the activity of hydrogen ions in a sample. pH levels from table 4.1 above indicate that the average pH values are highest in winter as compared to the average summer pH values. Sample point 10 and 11 shows the highest pH reading in winter and sample point 3 shows the highest pH reading in summer (graph 4.2.2). The Target Water Quality Range (TWQR) according to DWAF (1996), for pH ranges from 5.5 to 9.5. The pH values for all sampling points for both seasons are within the general limits. The average of the pH valves for winter is 7.5 and the average summer pH value is 6.1 hence the average pH values are within the limits of DWAF.

4.2.3 Sulphate and phosphate (mg/L)
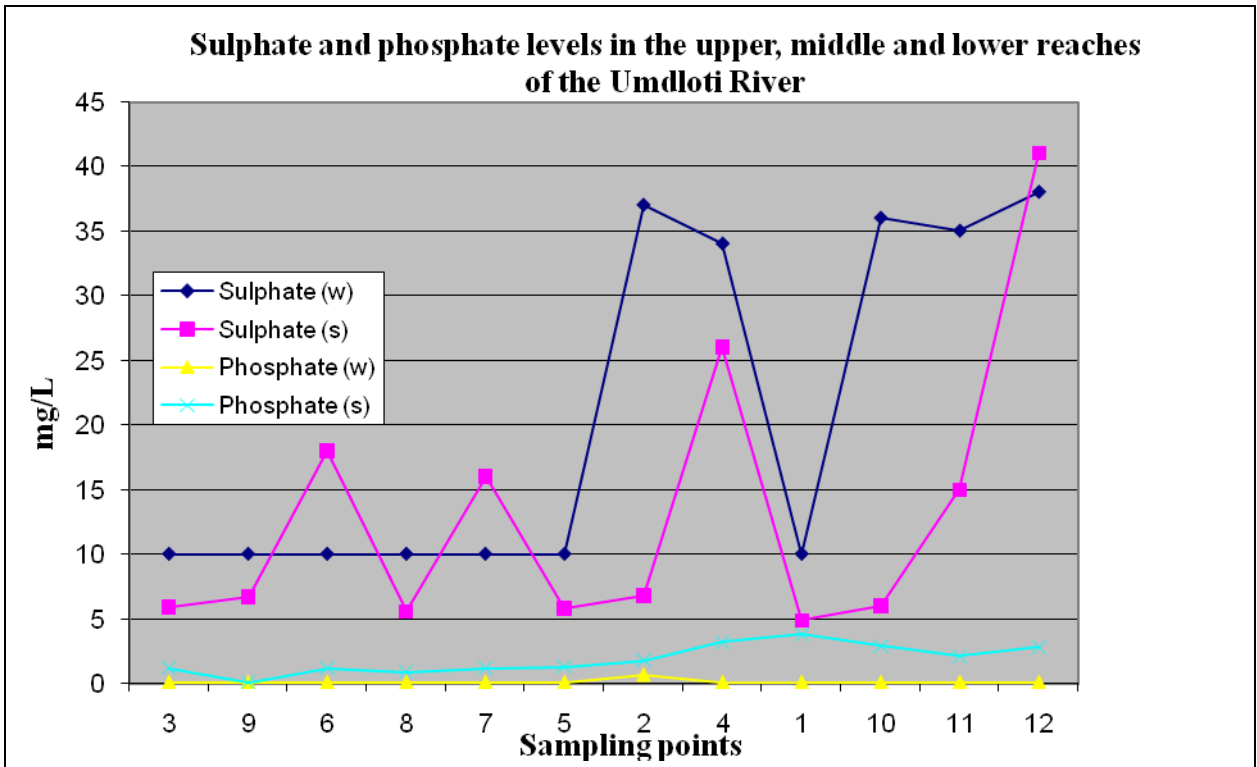
Graph 4.2.3: Sulphate and phosphate levels for each of the two seasons

Sulphate concentration from table 4.1 above indicates that the average sulphate values are highest in winter as compared to the average summer sulphate values. Sample point 12 shows the highest sulphate reading in winter and summer (graph 4.2.3). This could be attributed to the sampling point 12 being the last point at the La Mercy estuary. This is an open/closed lagoon. The average of the sulphate values for winter is 20.8 and the average value for summer is 13.1.

Phosphate concentration from table 4.1 above indicates that the average phosphate value is highest in summer as compared to the average winter phosphate value. Sample point 1

shows the highest phosphate reading in summer and sample point 2 shows the highest

phosphate reading in winter (graph 4.2.3). The Target Water Quality Range (TWQR),

according to DWAF for phosphate is 1.0 mg/L. Sampling points 8 and 9 in the summer

season are the only two points that fall within the DWAF general limit. The remaining

points in the summer season fall beyond the DWAF general limit. The average phosphate

values for winter is 0.14 and the average summer phosphate value is 1.87 hence the

average phosphate values for winter is within the limits of DWAF, and the average

summer phosphate value is beyond the limit of DWAF, however the average is neither

chronic or acute to cause a major water quality problem.

4.2.4 *Escherichia coli (E. coli)* (x10^6 cfu)
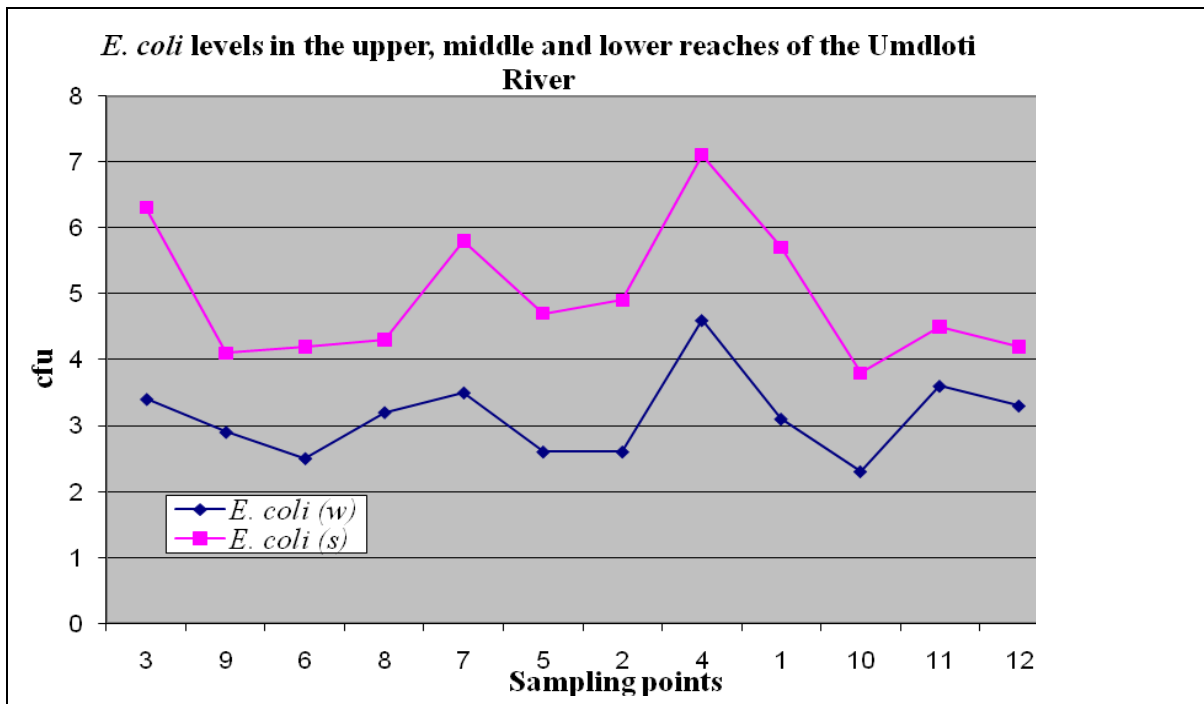
Graph 4.2.4: Total *E. coli* values for each of the two seasons

Escherichia coli usually comprise of approximately 97% of coliform bacteria in human faeces. *E. coli* values from table 4.1 above indicate that the average *E. coli* values are highest in summer as compared to the average winter *E. coli* values. Sample point 4 shows the highest *E. coli* reading in summer and winter (graph 4.2.4). The Target Water Quality Range (TWQR), according to DWAF for Total *E. coli* is 0 cfu/100ml. The average of the *E. coli* values for winter is 3.13 and the average summer *E. coli* value is 4.96 hence the average *E. coli* values for both seasons are far beyond the limits of DWAF.

4.2.5 Statistical analysis of seasonal variations in water quality

Since the data demonstrates wide seasonal variations (as seen in the graphs above), the t-test, a powerful parametric statistical test was used to ascertain whether these observed differences were significant.

The results of the calculations are presented in the table below:

Table 4.2.5.1: Results of t test analysis of seasonal variation of the water quality data.

	Nitrites	Nitrates	Ammonia	Sulphate	Phosphate	*E. Coli*
Calculated t	30.574	6.108	3.695	0.424	1.493	1.270
Critical t ; α = 0.5; *df* = 22	2.074	2.074	2.074	2.074	2.074	2.074
Reject / Accept H_o	Reject	Reject	Reject	Accept	Accept	Accept

In all cases, the null hypothesis H_o specifies that there is no significant difference in the means of the measured concentrations of the above variables on a seasonal basis (summer

and winter). Where the calculated value of t is greater than the critical value of t, then the null hypothesis is rejected.

The test indicates that such a difference is significant at the 95% confidence level for nitrites, nitrates and ammonia concentrations but not so for sulphates, phosphates and *E. coli*. Whilst there is basis for argument for seasonal variation for all the variables listed due to the human utilization of the catchment for development and agriculture, further study with a more detailed data set may reveal these variations.

4.2.6 Total Dissolved Solids (TDS) (mg/L)
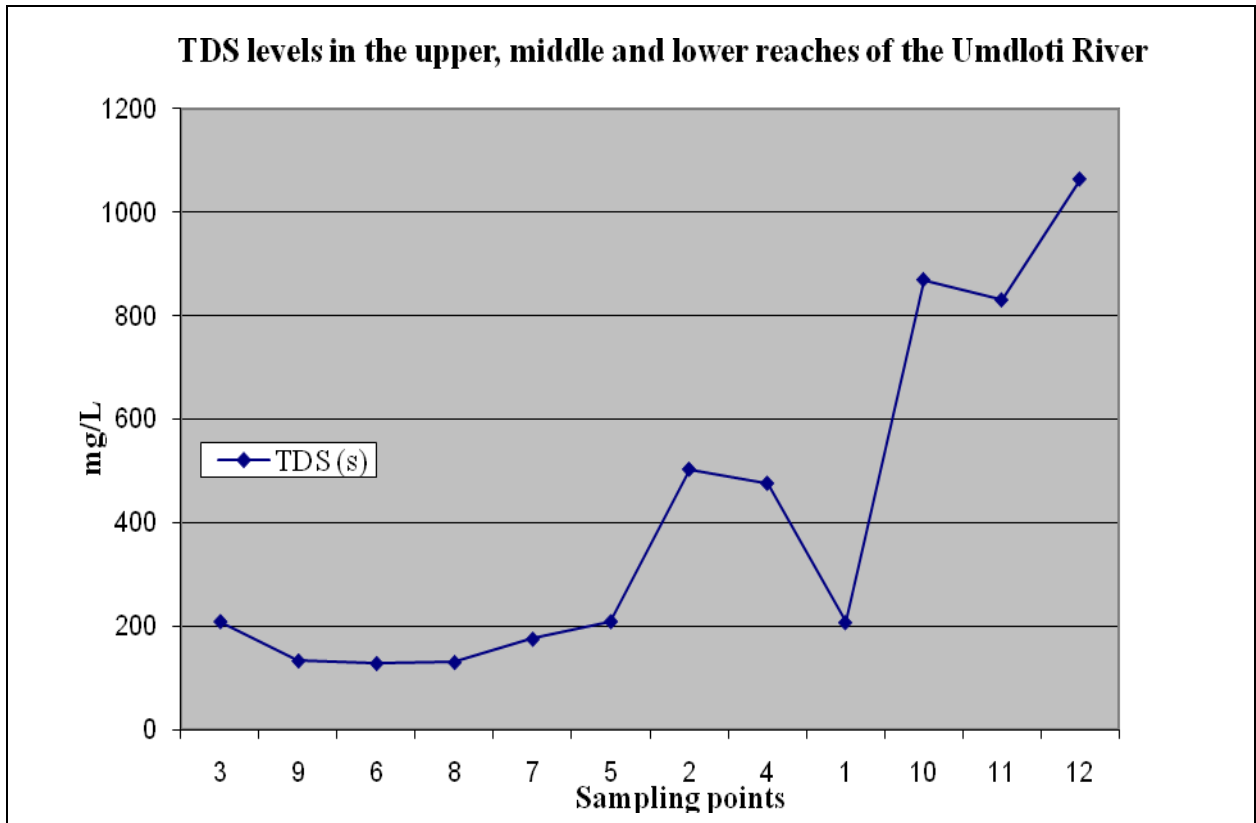
Graph 4.2.6: TDS values for summer

TDS concentration from table 4.1 and graph 4.2.6 above indicates only summer values. The highest TDS value in summer is sampling point 12 and the lowest TDS value is sampling point 6. The DWAF general limit for TDS is 200mg/L. According to DWAF, (1996) the Target Water Quality Range (TWQR) for TDS should not be changed by > 15% from the normal cycles of the water body under un-impacted conditions at any time of the year. Sampling points 6, 7, 8, and 9 are the only points where TDS values have not exceeded the DWAF general limit and the remaining of the sampling points (1, 2, 3, 4, 5, 10, 11, and 12) TDS value have far exceeded the DWAF general limit hence the average TDS value for summer is far beyond the general limit.

4.2.7 Biochemical Oxygen Demand (COD) and Chemical Oxygen Demand (mg/L)
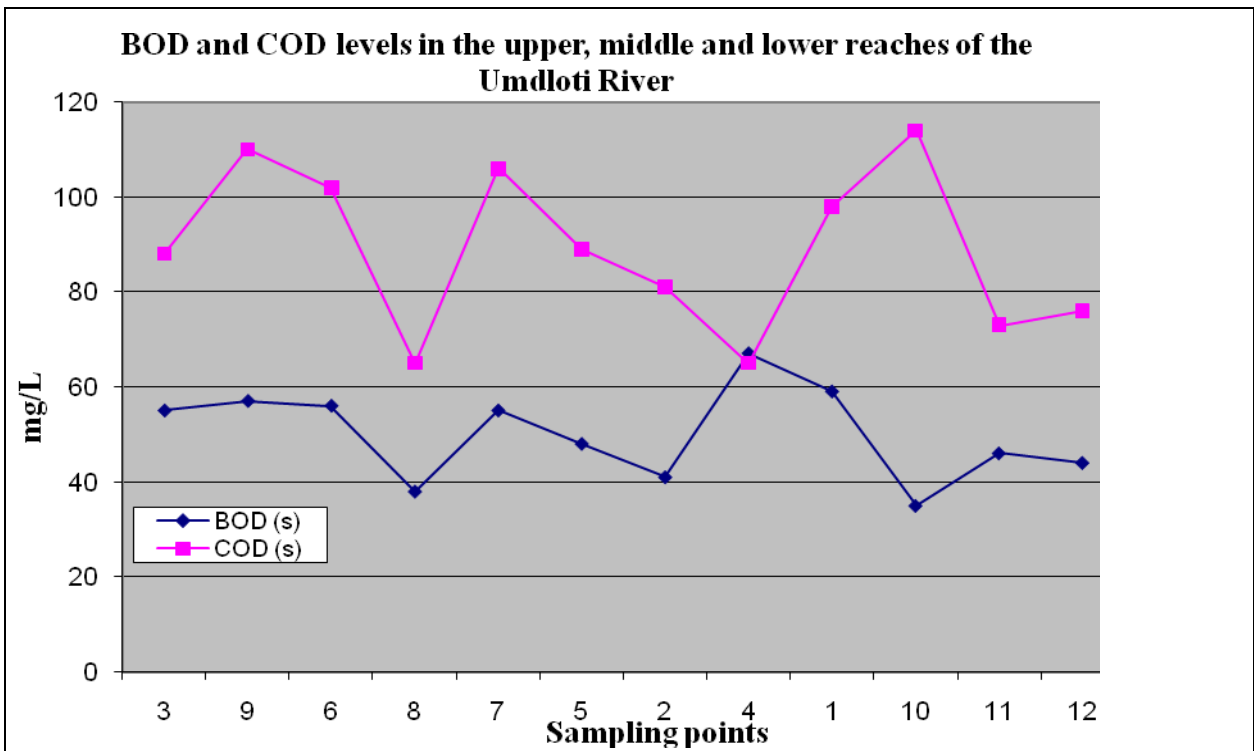
Graph 4.2.7: BOD and COD values for summer

Biological Oxygen Demand (BOD) is a measure of the oxygen used by microorganisms to decompose waste. If there are large quantities of organic waste present in the water supply, there will also be numerous bacteria present working to decompose this waste. In this case, the demand for oxygen will be high (due to all the bacteria) so the BOD level will be high thus BOD can be used as a measure to determine the extent that of water polluted with organic compounds (www.ciese.org). BOD concentration from table 4.1 and graph 4.2.7 above indicates only summer values. The highest BOD value in summer is sampling point 4 and the lowest BOD value is sampling point 10. Sampling point four is below the waste water treatment facility thus effluent that is released into the river is the contributing factor of the high BOD value. The average BOD value for summer is 50.08 and it far exceeds the United States Standards of 0.7mg/L.

According to DWAF (1996), the chemical oxygen demand is used as a routine measurement for effluents, and is the measure of the amount of oxygen likely to be used in the degradation of organic wastes. However in the aquatic ecosystems it is unlikely that organic matter will be fully oxidized. COD concentration from graph 4.2.7 above indicates only summer values. The highest COD value in summer is sampling point 10 and the lowest COD value is sampling point 4, however it is important to note that high levels of COD exist at sampling points 1, 3, 6, 7, 9. The DWAF general limit for COD is 75 mg/L hence the average COD value for summer is beyond the general limit.

4.2.8 Calcium and magnesium (mg/L)
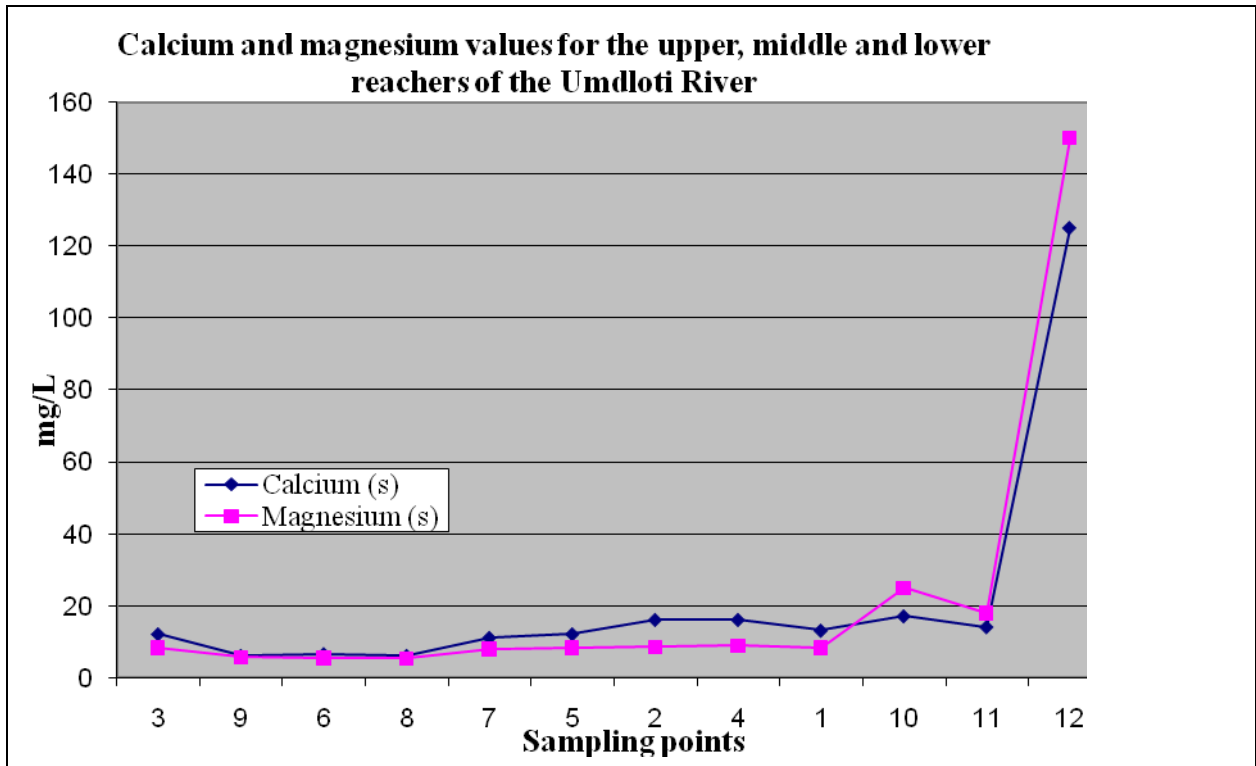
Graph 4.2.8: Calcium and magnesium values for summer

Calcium concentration from table 4.1 and graph 4.2.8 above indicates only summer values. The highest calcium value in summer is sampling point 12 and the lowest calcium value is sampling point 8 and 9 with an average of 20.70. The general limit set by DWAF is from 150-300mg/L. The calcium values throughout the sampling points are below the general limit set by DWAF.

Magnesium concentration from table 4.1 and graph 4.2.8 above indicates only summer values. The highest magnesium value recorded in summer is sampling point 12 and the lowest magnesium value is sampling point 8. The general limit by DWAF is from 4-10

92

mg/l for fresh water. The magnesium value for sampling points 1 to 9 are within the general limit, on the other hand sampling points 10-12 far exceeds the general limit. The average magnesium value for summer of 21.75 far exceeds the general limit.

4.3 Conclusion

The water quality analysis presented thus confirms that from the variables analyzed pollution exists in the Umdloti River as a result of human and naturally induced impacts in the upper, middle and lower reaches of the river. The variables that indicated levels of pollution are as follows: ammonia; sulphate; phosphate; *E. coli*; total dissolved solids; chemical oxygen demand; biological oxygen demand and magnesium for both summer and winter respectively. A detailed description of the consequence of pollution in the river is presented in chapter five.

4.4 Questionnaire survey analysis

Interviews via a structured questionnaire (Appendix 1) were conducted with 50 households of the informal community alongside the Umdloti River. The questionnaire survey analysis provides findings from the research in order to meet the research objectives and to provide insights into the perceptions residents in the vicinity of the Hazelmere Dam have about the dam. The results obtained from the fieldwork are in direct relation to the questions asked. These results are discussed further after each table/graph.

Table 4.4.1: Respondents Gender

	Respondents Gender	
	Count	Percentage
Male	38	76
Female	12	24
Total	50	100

The majority of the respondents were males. The reason for the female count being lower was due to the fact that the male felt he should answer the questions. The researcher also noticed that the females showed no objection to this and was content with the responses from their partners. It was evident that men saw themselves as the dominant figure in the household and thus the decision makers of the household.

Table 4.4.2: Respondents Age

	Age	
	Count	Percentage
<20yrs	0	0
20-29yrs	0	0
30-39yrs	8	16
40-49yrs	12	24
50-59yrs	15	30
60-69yrs	13	26
>70	2	4

The majority of the respondents ranged from 40-49years to 60-69yrs. Clearly, all respondents were over thirty years old. In terms of obtaining certain information about the catchment status prior and post construction of the Hazelmere Dam, this was viewed as potentially helpful by the researcher.

Table 4.4.3: Respondents Marital Status

	Marital Status	
	Count	Percentage
Single	6	12
Married	31	62
Divorced	3	6
Widowed	10	20
Other	0	0
Total	50	100

The majority of the respondents that totaled 62% were married, 12% of the respondents were single, and was content on being single, 20% of the respondents were widowed and 06% of the respondents were divorced. It was also interesting to note there are more males in the households than females, this excludes the respondent, however the difference is not drastic.

Table 4.4.4: Respondents duration in the Umdloti area

	Respondents duration in the Umdloti area	
	Count	Percentage
<10yrs	0	0
11-20yrs	12	24
21-30yrs	3	6
31-40yrs	0	0
>40yrs	35	70
Total	50	100

This information clearly indicates that the majority of the respondents (70%) have lived in the Umdloti area for more that forty years. The respondents that fall in the 11-20year category accounts for twenty four percent (24%) of the total respondents interviewed and six percent (06%) falls in the 31-40 year category. This fared well for the researcher due to the nature of the research project. It is best to gather information from an individual that has lived in the area for the longest period in time as this information is most valued.

Table 4.4.5: Employment Status

	Employment status	
	Count	Percentage
Employed	12	24
Self employed	21	42
Unemployed	5	10
Other	12	24
Total	50	100

It is evident from the table above that forty two percent (42%) of the respondents are self employed. This allows them to generate their own income from the various incomes generating activities they are involved in. The respondents did indicate that every day, month and year is different with respect to their monetary turnover. Twenty four percent (24%) of the respondents are employed and take home a set salary every month. It was very interesting to note that only 10% of the respondents interviewed were unemployed and 24 % of the respondents relied on other sources of income: investments, grants and monthly stipends from their children.
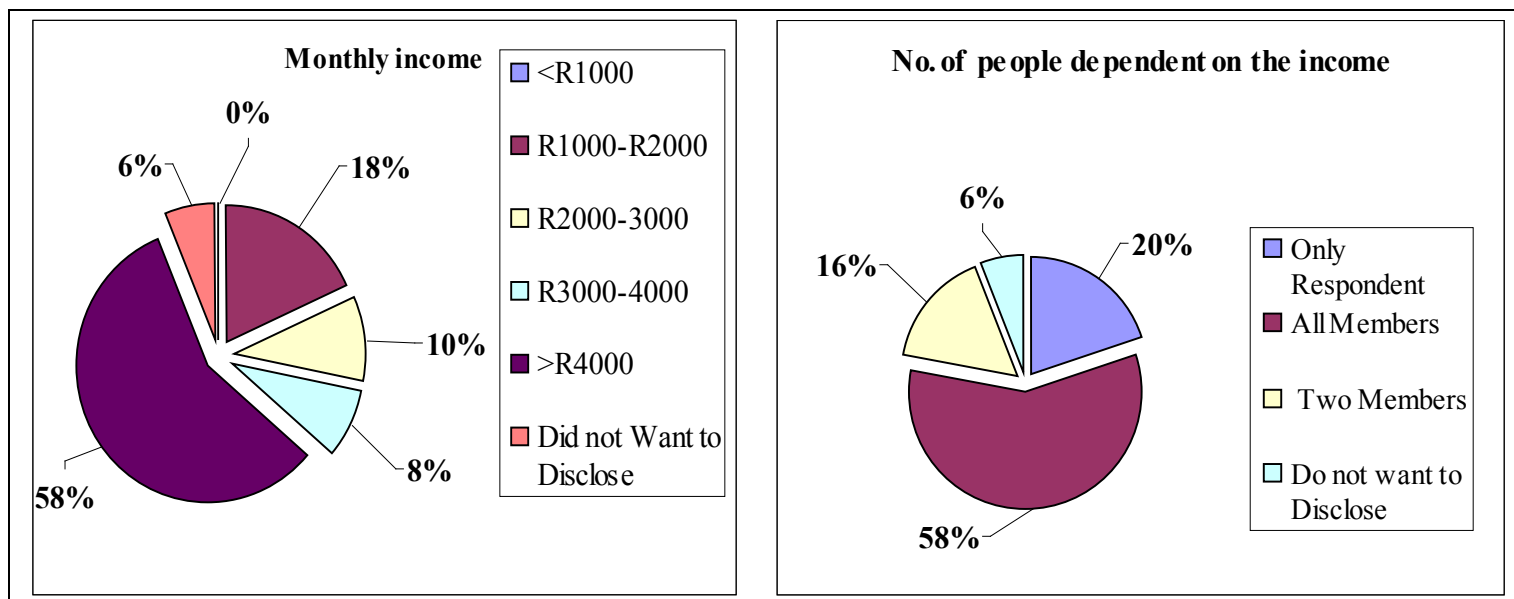
Figure 4.4.1: Pie charts illustrating monthly income of households and no. of people

dependent on this income.

The majority of the respondents interviewed (58%) earn a salary of more than R4000-00

a month. Eighteen percent (18%) of the respondents income is between R1000 and

R2000, ten percent (10%) of the respondents income is between R2000 and R3000 and

eight percent (8%) of the respondents income is between R3000 and R4000. The

researcher was unable to obtain monthly income information from six percent (6%) of the

respondents. Fifty eight percent (58%) of the respondents indicated that all members in

their households are dependent on their income. Twenty percent (20%) of the

respondents have no dependents on their income. Sixteen percent (16%) of the

respondents interviewed indicated that two members of their households are dependent

on the income. Six percent (06%) of the respondents interviewed did not want to divulge

how many people are dependent on the income. In summary 58% of the total respondents

survive with the average income, taking care of their dependents and maintaining their homes.

Table: 4.4.6: Illustrating the need for the construction of the Hazelmere Dam.

	Construction of the Hazelmere Dam	
	Count	Percentage
Storage and supply of water	44	88
Recreation	4	8
Provide good flow during winter months	2	4
Total	50	100

The table indicates that eighty eight (88%) of the respondents indicated that the construction of the Hazelmere Dam was to supply water to the neighboring towns; Verulam, La Mercy and Umdloti. Eight percent (08%) of the respondents indicated that the Hazelmere Dam was built for recreation reasons and four percent (04%) indicated that the dam was built to provide good flow of water during the winter months when the river runs low on water.

Table 4.4.7: Positive impacts of the construction of the dam

	Positive impact of the dam construction	
	Count	Percentage
Yes	32	64
No	18	36
Total	50	100

From the table above, sixty four percent (64%) of the respondents have benefited from the construction of the Hazelmere Dam, and thirty six (36%) of the respondents have not benefited from the construction.

Table 4.4.8: Negative impacts of the construction of the dam

	Negative impacts of the dam construction	
	Count	Percentage
Yes	18	36
No	32	64
Total	50	100

The results obtained indicate that thirty six percent (36%) of the respondents have been negatively impacted by the construction of the dam. This is due to the fact that there land was taken away and sixty four percent (64%) of the respondents were not affected negatively.

No. of respondents displaced as a result of the construction dam

20%

80%

☐ Displaced
■ Not displaced

Compensation for loss of property

12%

0%

88%

☐ Compensated

■ Not compensated

☐ Not sure

Satisfaction with compensation

12%

0%

88%

☐ Satisfied

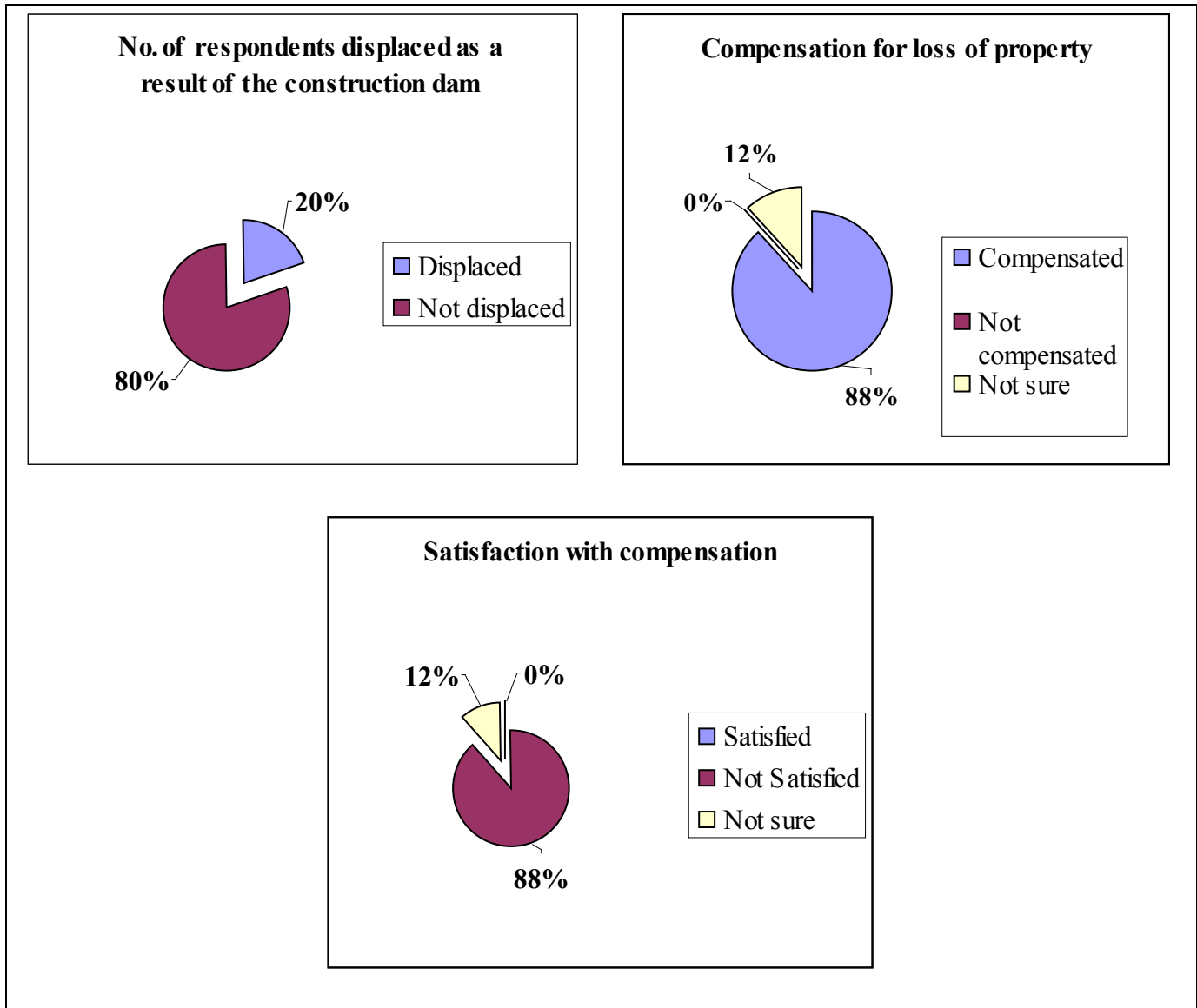■ Not Satisfied

☐ Not sure

Figure 4.4.2: Pie charts illustrating displacement, compensation of property and

compensation satisfaction as a result of the construction of the

Hazelmere Dam.

Twenty percent (20%) of the respondents interviewed indicated that they had to move

away from their land due to the construction of the Hazelmere Dam. This had made them

101

very unhappy and they had no choice in the matter. Eighty percent (80%) of the respondents were not displaced as a result of the construction of the Hazelmere Dam. From the information gathered thirty percent (30 %) of the total respondents interviewed had been compensated for their loss of property and four percent (04%) of the respondents were not sure, this is due to their parents passing away and they did not know whether compensation was made or not. It is also indicative that eighty eight percent (88%) of respondents that did receive compensation were not satisfied with the monetary value they received, however nothing can be done to rectify this problem as much time has passed and twelve percent (12%) of the respondents were not sure.

As mentioned in the methodology, contingency tables and the parametric X^2 test was used to ascertain the relationships between various variables under study. Table 4.4.9 below is the first of these:

Table 4.4.9: Contingency table relating employment status (Table 4.4.5) to perceptions about the construction of the Hazelmere Dam (Tables 4.4.7 and 4.4.8).

Response	Employed	Unemployed	Other	Total
Positive	30	5	3	38
Negative	3	0	9	12
Total	33	5	12	50

For the above relationship, the Null Hypothesis (H_o) is stated below:

Ho: there is no significant difference between employment status and response to the construction of the dam.

Calculated X^2 for the above relationship = 22.712 and at the 99.5% confidence level,

critical X^2 = 10.6, hence the null hypothesis is rejected and a significant relationship

between employment status and perceptions about the dam construction is confirmed.

From discussions with the respondents in the field it was clear that employed respondents

viewed the dam construction positively. This may be attributed to the greater

convenience with regard to piped water to homesteads. Respondents who were

unemployed clearly thought dam construction was positive whilst retired respondents

were mostly negative about the dam and reflected nostalgically about the "old days".

Table 4.4.10: Contingency table relating gender (Table 4.4.1) to perceptions about the construction of the Hazelmere Dam (Tables 4.4.7 and 4.4.8).

Response	Male	Female	Total
Positive	29	3	32
Negative	9	9	18
Total	38	12	50

For the above relationship, the Null Hypothesis is:

Ho: there is no significant difference between the gender of the respondents and response to the construction of the dam.

Calculated X^2 for the above relationship = 10.424 and at the 99.5% confidence level,

critical X^2 = 7.88, hence the null hypothesis is rejected indicating a significant

relationship between gender and impressions on the dam construction. Male respondents

particularly were positive about the dam and the benefits it brought whilst women were

generally not too impressed with the dam.

Table 4.4.11: Contingency table relating age (Table 4.4.2) to perceptions about the construction of the Hazelmere Dam (Tables 4.4.7 and 4.4.8).

Response	30-39	40-49	50-59	60-69	>70	Total
Positive	8	8	11	5	0	32
Negative	0	4	4	8	2	18
total	8	12	15	13	2	50

Ho for the above relationship states that there is no significant difference in response to the construction of the dam and age category.

Calculated X^2 for this relationship = 12.339 and at the 99.5% confidence level, critical X^2 = 14.9, confirming a significant relationship between age and the way in which respondents view the dam construction. Younger respondents tended to view the dam construction positively whilst older respondents in the sample thought otherwise. This again, is related to the older respondents nostalgia.

Table 4.4.12: Prime Use of Land

	Prime use of land before construction of the dam	
	Count	Percentage
Agriculture	20	40
Dense Vegetation	2	4
Not sure	28	56
Total	50	100

From the results obtained fifty six (56%) of the respondents were not sure about the prime use of the land before the construction, forty percent (40%) of the respondents

104

indicated that the land was use for agricultural purposes, and four percent (04%)

indicated that the land was inundated with dense vegetation.
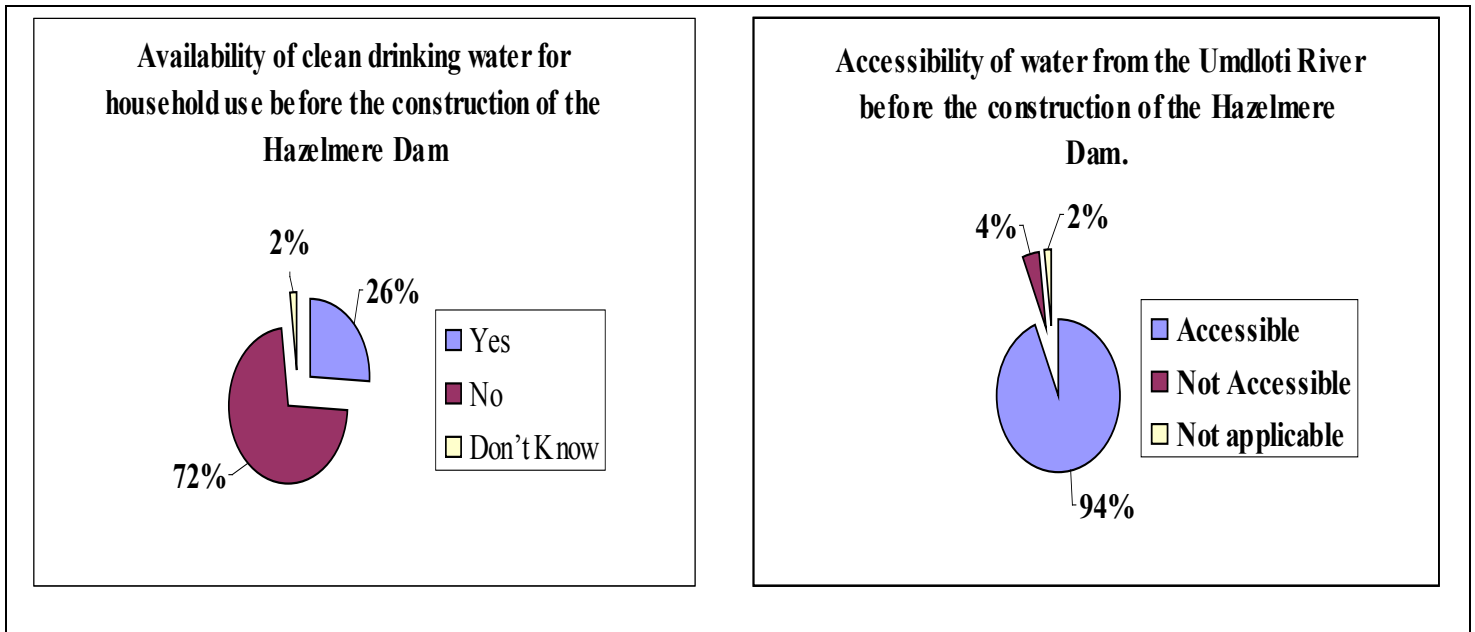
Figure 4.4.3: Pie chart illustrating availability of clean drinking water and accessibility of water

before the construction of the Hazelmere Dam.

From the chart above, twenty six percent (26%) of the respondents have indicated that

there was clean drinking water available for household use before the construction of the

Hazelmere Dam. Seventy two percent (72%) of the respondents indicate that there was no

clean drinking water available and two percent (02%) of the respondents indicated that

they did not know if there was clean drinking water available. The respondents were

asked where water was sourced from and seventy two percent (72%) of the respondents

indicated that water was taken from the Umdloti River. It was also interesting to note that

ninety four (94%) percent of the respondents have indicated that water from the Umdloti

river was quite accessible before the construction of the dam, to this date the water from the river is accessible to people in the area, the four percent (04%) of respondents that have indicated that water is not accessible is due to distance, they had taken the water from their neighbours that sourced water from the river via private transport. Two percent (02%) of the respondents indicated that the question was not applicable. In summary water from Umdloti River was accessible to the respondents prior and post construction of the Hazelmere Dam.

Table 4.4.13: Primary water source used in households

	Primary water source in Household	
	Count	Percentage
Communal tap	12	24
Piped Water	28	56
Borehole	3	6
River	4	8
Water tanker	2	4
Other	1	2
Total	50	100

From the table above, it is a clear indication that fifty six (56%) of the respondents use piped water (respondents homes are connected to a water system). Twenty four percent (24%) of the respondents rely on the communal tap for their water supply for household use, six percent (06%) of the respondents have their own borehole on their property for water supply, eight percentage (08%) of the respondents rely on river water to this date for their household use, a further four percent (04%) relies on water tanker services for

the supply of water for household use and the remaining two percent (02%) take water from their neighbour's for household use.

Table 4.4.14: Water quality problems with the various water sources

	Water quality problems experienced with the above mentioned sources	
	Count	Percentage
Yes	6	12
No	44	88
Total	50	100

From the information gathered eighty eight percent (88%) of the respondents indicated that they had not experience any problems with the water quality however the remaining twelve (12%) indicated that they had experience the following problems; water has an odour, it is green in colour and does not taste very well. The twelve percent (12%) of the respondents attributed these changes due to the major land use changes that are taking place in and around the Umdloti catchment as well as the waste water treatment works.

Table 4.4.15: Distance of water source from household

	Distance of water source	
	Count	Percentage
0-20m	0	0
20-40m	2	4
40-60m	0	0
80-100m	2	4
>100m	13	26
Not applicable	28	56
Total	50	100

From the table above twenty six percent (26%) of the respondents indicated that the water sources are more than 100m away from their households. This is the distance to carry water for household uses; nonetheless the respondents have been doing this for their day to day living. Four percent (04%) of the respondents indicated that the water source is 20-40 meters away, a further four percent (04%) indicated that the water source is 80-100m away and fifty six percent (56%) of the respondents indicated that it is not applicable due to households having piped water.

Respondents involvement in agricultural activities

48%   52%

☐ Yes
■ No

Water source used for this agricultural activity

12%
15%
15%
58%

☐ Umdloti River
■ Hazelmere Dam
☐ Rain Water
☐ Borehole
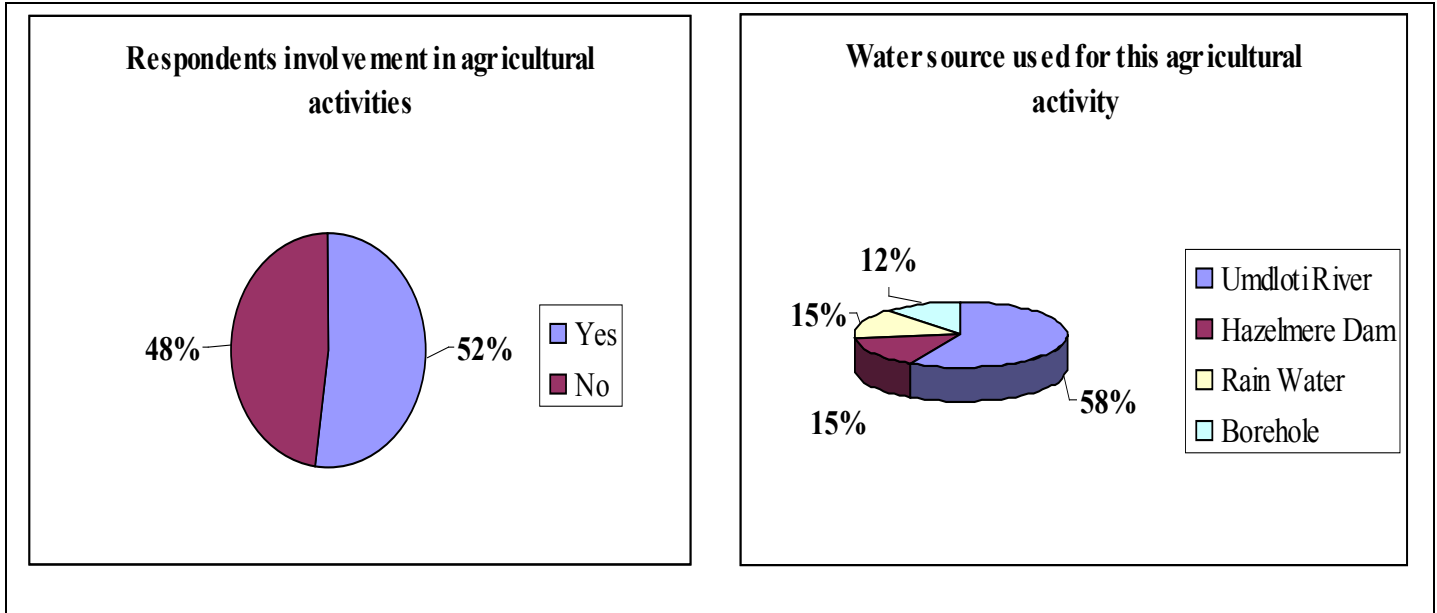
Figure 4.4.4: Pie charts illustrating number of the respondents involvement in agricultural

activities and water sources used.

From the information gathered fifty two percent (52%) of the respondents indicated that

they are involved in agricultural activities and forty eight percent (48%) of the

respondents are not involved in any agricultural activities. This is indicative from the

responses received that agricultural practices/activities are dominating in the Umdloti

catchment. Further responses indicated that thirty percent (30%) of the respondents rely

on water from the Umdloti River to practice agriculture, eight percent (08%) source water

directly from the Hazelmere Dam for their agricultural activities, a further eight percent

(08%) rely on rain water and the remaining six percent (06%) rely on their borehole

(ground water) for water supply for their agricultural activities.

Table 4.4.16: Sanitation facility availability

	Are there sanitation facilities available in the community	
	Count	Percentage
Yes	42	84
No	8	16
Total	50	100

Eighty four percent (84%) of the respondents in this community have sanitation facilities and sixteen percent (16%) of the respondents do not have sanitation facilities. These respondents live in the informal settlements in the Umdloti Catchment.

Table 4.4.17: Types of sanitation facilities

	Types of sanitation facility	
	Count	Percentage
Municipal sewer system	9	18
Septic tanks / Soak pits	33	66
Pit latrines	8	16
Total	50	100

From the results obtained only eighteen percent (18%) of the respondents have municipal sewer systems, sixty six percent (66%) of the respondents have septic tanks/soak-pits systems. Sixteen percent (16%) of the respondents have alternative sanitation facility that

is the pit latrine systems. The septic tank system and the pit latrine system are potentially a threat to ground water contamination.

Table 4.4.18: Alternatives that exist for sanitation purposes

	Alternatives that exist for sanitation purposes	
	Count	Percentage
Pit latrines	8	16
Total	8	16

From the respondents interviewed sixteen percent (16%) of the respondents have alternative sanitation facility that is the pit latrine systems; however the respondents have indicated that they merely dig a hole, excrete their fecal waste and cover it. This occurs at any place and time as and when the need arises, however a common pit-latrine is also shared near the households. This type of system is very unhealthy and this can result in major river health problems if the respondents excrete their wastes along the Umdloti River. This has no fault on the respondents due to their poor lifestyles.

Table 4.4.19: Are these sanitation facilities located in close proximity of

the river

	Are these sanitation facilities located in close proximity of the river	
	Count	Percentage
Yes	7	14
No	34	68
Not applicable	9	18
Total	50	100

From the above table it is clear that only fourteen percent (14%) of the respondents

sanitation facilities is in close proximity to the river. Sixty eight percent (68%) is not

situated near the river and eighteen percent (18%) of the respondents indicated that the

above was not applicable to them.

Table 4.4.20: If yes, what is the distance of the sanitation facility in proximity to the river?

	Distance of sanitation facility in proximity of the river	
	Count	Percentage
<10m	0	0
20-30m	0	0
30-40m	0	0
40-50m	4	8
>50m	3	6
Total	7	14

Eight percent (08%) of the sanitation facilities occurs between 40-50 meters of the

Umdloti River and six percent (06%) occurs more than 50 meters away. The closeness of

these sanitation facilities can and will have a direct impact on the water quality. High

level of *E. coli* in the river is indicative of fecal contamination.

Table 4.4.21: How is household waste disposed?

	How is household waste disposed	
	Count	Percentage
DSW	16	32
Personal transport to land fill	3	6
Dispose on property	31	62
Total	50	100

Currently thirty two percent (32%) of the respondents indicated that their waste generated

is transported by Durban Solid Waste (DSW) services, six percent (06%) of the

respondents transport their household waste to the local land fill sites and sixty two

percent (62%) of the respondents dispose their waste in a pit on their property. This waste

is burned. In summary the bulk of the respondents dispose their wastes on their property.

This is due to no wastes services in the area that they are living in. Wastes that are being

burned on the property of the respondents do not affect the surface water quality of the

Umdloti River.

Table 4.4.22: Are dumping sites in close proximity to the river?

	Are dumping sites in close proximity to the river	
	Count	Percentage
Yes	3	6
No	47	94
Total	50	100

It is evident from the table above that ninety four (94%) of the dumping sites in totality are not located near the Umdloti River, however six percent (06%) of the dumping sites are in close proximity to the river, even though only six percent (06%) of the dumping sites are in close proximity to the river, the types of wastes dumped can have a potential impact on the quality of the water however the above results are indicative that very little waste is dumped in close proximity to the river.

Figure 4.3.23: If yes, what is the distance of dumping site from the river?

	Distance of dumping site from the river	
	Count	Percentage
<20m	0	0
20-40m	2	4
40-60m	1	2
60-80m	0	0
>100m	0	0
Total	3	6

The above results specify that four percent (04%) of the respondents indicated that dumping sites are 20-40 meters away from the river and two percent of the respondents (02%) indicated that dumping sites are 40-60 meters away from the river. This is well within a buffer and could pose threats to the water quality of the Umdloti River in the future.

Table 4.4.24: Have you noticed any change in the river water quality due to dumping of waste.

	Change in river water quality due to the dumping of wastes	
	Count	Percentage
Water quality changed due to various forms of pollution	22	44
Sand mining	3	6
Did not notice any change	25	50
Total	50	100

From the information gathered forty four percent (44%) of the respondents indicated that the water quality has not changed solely to the dumping of wastes but from various forms of pollution and more recently the urbanization of the area. Water quality has been deteriorating from the last decade. It was also interesting to note six percent (06%) of the respondents have noticed a change in water quality due to the increase in sand mining activities in the Umdloti River. They have indicated that the sand mining is taking place

in an uncontrolled manner, and fifty percent (50%) of the respondents have not indicated any major changes in water quality of river.

Table 4.4.25: Contingency table relating employment status (Table 4.4.5) to assessment of water quality changes due to dumping (Tables 4.4.24)

Response	Employed	Unemployed	Other	Total
Yes	18	0	0	18
No	15	5	12	32
Total	33	5	12	50

Ho for the above relationship states that there is no significant difference in response to the change in water quality due to dumping and the employment status of the respondent.

Calculated X^2 for this relationship = 14.488 and at the 99.5% confidence level, critical X^2 = 10.6, hence the null hypothesis is rejected and a significant relationship between employment status and the respondents' assessment that water quality is impacted on due to indiscriminate dumping in the area is confirmed. Many of the working class respondents do travel for some distance along the river and have confirmed verbally that it is common to find litter and other pollutants along some parts of the Umdloti River and this obviously has enhanced their perception of a deterioration of water quality as a consequence.

Table 4.4.26: Contingency table relating age of respondents' (Table 4.4.2) to assessment of water quality changes due to dumping (Tables 4.4.24).

Response	30-39	40-49	50-59	60-69	>70	Total
Yes	3	5	8	0	0	16
No	5	7	7	13	2	34
Total	8	12	15	13	2	50

Ho for the above relationship states that there is no significant difference in response to the change in water quality due to dumping and age category of the respondent.

Calculated X^2 for this relationship = 10.823 and at the 99.5% confidence level, critical X^2 = 14.9, hence the null hypothesis is accepted confirming that age does not appear to play a role in determining the way in which respondents' viewed compromising water quality as a consequence of dumping. General perceptions during sampling did confirm the negativity towards some resident's apathy to dumping and pollution in general.

4.5 On site-observation analysis

On site observation analysis formed an integral part of this research as it allowed the researcher to experience first hand the various processes and activities that influence the water quality of the Umdloti River catchment. These images depicted below encapsulate the on-site observations followed by an analysis of these images.

Plate 4.1: Sand mining taking place in the lower reaches of the Umdloti River

Respondents from the questionnaire analysis have indicated that this is presently causing a major problem to land owners and the river. It is evident on the extreme right, the sand

mining activities taking place, a lush and dense banana plantation exists that sources water from the Umdloti River.

4.6 Maps dated from 1959, 1978, 1989, and 2000

4.6.1 Map dated 1959 (Figure 4.6.1.1)

The spit in this era is clearly well developed and has good interaction with the sea. The river has conspicuous meandering as it passes through the Caneland Industrial area and the town of Veulam. The area is well vegetative and the town La Mercy is virtually non-existent, no development in the Umdloti Beach area is evident. Developments in Tongaat and Ottawa are also evident.

4.6.2 Map dated 1978 (Figure 4.6.2.1)

The major change in the river morphology almost two decades later is the development of the Hazelmere Dam. Changes in the estuary have resulted in a narrow opening spit. The estuarine embankment is much longer. Increased population growth has occurred in this catchment. T here i s a di stinct a rray of bot h i ndustrial a nd ur ban de velopment in Canelands and Verulam respectively. M inor residential developments are evident in the Cottonlands and New Glascow. There i s i ncreased development i n the T ongaat ar ea including bot h r esidential a nd i ndustrial. A gricultural a ctivities a re very e vident, dominated by sugar cane farming. Residential developments in La Mercy had begun and the La Mercy airport had been demarcated as early as the year 1978.

4.6.3 Map dated 1989 (Figure 4.6.3.1)

A decade later the configuration of the estuary had changed. The well defined spit at the La Mercy lagoon no longer exists and this can be attributed to the 1984 cyclone and the 1987 floods. Tremendous sediment had been deposited downstream of the river thus altering the riverine system. Several developments both formal and informal are evident in Verulam, Cottanlands, Canelands, Tongaat, New Glasscow, Umdloti and La Mercy. Increased agricultural activities and industrial developments downstream of the dam are evident.

4.6.4 Map dated 2000 (Figure 4.6.4.1)

The m aps t hat f ollow i ndicate t he m ajor l and use c hanges t hat h ave occurred i n t he

Umdloti c atchment f rom 1959 t o t he year 2000. F rom 1978 de velopments of t he La

Mercy a irport run away i s e vident; c urrently t his a irport is ne arly completion with

increased r oad d evelopments t aking pl ace. It i s quite e vident from t he m aps that t he La

Mercy Lagoon/estuary has increased in size over time. The rapid urbanization along the

Umdloti River that includes; industries, residential areas, the town and agricultural lands

provides a clear indication that the Umdloti River is the prime water resource for the area

and much more development with the airport and the Cornubia Mixed Development are

set t o take pl ace s ubsequently c ausing s evere s tress on the w ater resource i n Umdloti

catchment.

4.7 Conclusion

The water quality criteria set out by the Department of Water Affairs was the guiding principles in determining the water quality of the Umdloti River and impacts that are associated with the change in water quality. This scientific and technical information provided an exceptional basis for the researcher when analyzing and interpreting the water quality data. The water quality data analyzed indicated that at the time water quality samples were taken for analysis the majority of the variable values was within the general limits of DWAF, however not all variables were measured against the general limits by DWAF.

The questionnaire analysis formed a direct relationship with the respondents regarding the socio-economic profile, the positive and negative impacts concerning the construction (prior and post) of the Hazelmere Dam, water quality and availability post and present of the dam construction and sanitation and waste disposal facilities.

The next chapter will present the researcher's final results from the findings of the water quality analysis and questionnaire survey.

CHAPTER FIVE

DISCUSSION

5.1 Introduction

The focus of this chapter is the discussion of the water quality analysis obtained from the laboratory and questionnaire survey results. The researcher discusses the water quality results obtained from the twelve sampling points and explains with reasons as to why the levels of each variable are so. This is compared with the general limits set by DWAF. A detailed discussion is also given with respect to the results obtained from the questionnaire survey. The overall results presented provide holistic perspectives of the natural and anthropogenic impacts on the Umdloti fluvial system.

5.2   Water quality characteristics

5.2.1 Nitrites:

Nitrite values for sampling points 4, 11 and 12 in winter are beyond the general limits of 0.5 mg/L set by DWAF. However, the levels were exceeded only by a small fraction. This could be attributed to the waste water treatments works above sampling point 4 and surface run-off from the surrounding sugar cane and agricultural fields along the lower reaches resulting in high nitrate levels in the estuary (sampling points 11 and 12). Statistical analysis conducted indicated that there is a significant difference in the means of the measured concentration of the nitrite variable on a seasonal basis. During summer

all s ampling points w ere well within the general limits a nd according to the D WAF, (1996), t his pr omotes m oderate l evels of s pecies di versity, r educes growth of a quatic plants or the presence o f blue-green algae growth hence no impacts w ere ca used t o the Umdloti River from a nitrite loading perspective.

5.2.2 Nitrate

High levels of nitrates in summer can be attributed to natural and human induced impacts such as: surface runoff from the Umdloti catchment area, the discharge of effluent into the stream containing traces of human and animal excrement, fertilizer leached from sugar cane fields, and organic industrial wastes which are the major sources of nitrogen that enters the aquatic system. The average measured nitrate concentrations for the Umdloti River are below the limit of 6-10mg/L set by DWAF, therefore there are no detrimental effects on water quality in the Umdloti River from a nitrate perspective. However, statistical analysis conducted indicated that there is a significant difference in the means of the measured concentrations of the nitrate variable on a seasonal basis.

5.2.3 Ammonia

According to DWAF (1996), ammonia is a common pollutant and is one of the nutrients contributing to eutrophication of water bodies. Commercial fertilizers contain highly soluble ammonia and ammonium salt and, if the concentration of such compounds exceeds the immediate requirements of plants, residual amounts may be transported *via*

the atmosphere or irrigation water into aquatic systems. This may be indicative for summer at the following sampling points (1, 2, 3, 4, 6, 7, 9, 10, 11 and 12). The high levels of ammonia that impact negatively on the Umdloti River during the summer season are attributed to commercial sugar cane farming, industrial activity and sewage discharge in the Umdloti Catchment. The results indicated that the average summer value exceeded the general limits set by DWAF (1996), of 7 mg/L but does not exceed the chronic effect limit of 15 mg/L. It was interesting to note that all sampling points in winter were well below the general limit. Statistical analysis confirmed that there is a significant difference in the means of the measured concentration of the ammonia variable on a seasonal basis. Importantly however, the distinct water quality changes recorded for summer caused relatively minor impacts on the aquatic system.

5.2.4 pH

The Target Water Quality Range (TWQR), according to DWAF (1996), for pH values for freshwater systems ranges from 5.5 – 9.5. Elevated pH levels were recorded at sampling points 6-12 during winter but all values for both seasons were well within the target quality range and posed no detrimental effects to aquatic biota.

5.2.5 Sulphates

High sulphate values recorded at sampling points 2 and 4 during winter are indicative of anthropogenic impacts from the industrial activity situated upstream and from the waste

water treatment works sited downstream of the town of Verulam respectively. Sampling points 10, 11 and 12 are situated at the La Mercy lagoon/estuary. According to DWAF (1996), the ideal sulphate concentration in surface waters is 5mg/L. Statistical analysis indicated that there is no significant difference in the seasonal means of the measured concentrations of the sulphate variable although all sampling points for both seasons (with the exception of sampling point 1 in summer) have exceeded this limit. This implies that sulphate concentrations are high throughout the year and may be attributed to the industrial activities in the catchment that uses sulphuric acid or sulphates in their processes as well as the excessive use of fertilizers with high sulphate content. The Umdloti River has no proper buffers for protection from these anthropogenic impacts on the catchment consequently high sulphate concentrations have impacted negatively on the Umdloti River.

5.2.6 Phosphate

Statistical analysis conducted indicated that there is no significant difference in the seasonal means of the measured concentration of the phosphate variable but the average summer values exceeded the DWAF (1996) general limit of 1mg/L. According to DWAF (1996), this can be attributable to point source discharge such as domestic and industrial effluent (this occurs in the middle and lower reaches of the Umdloti River) and from diffuse sources in which the phosphorous load is generated by surface and subsurface drainage, atmospheric precipitation, urban run-off and drainage from agriculture, in particular from land on which fertilizers have been applied. This would definitely apply

to the Umdloti catchment where major sugar cane, vegetable and banana farming is common.

5.2.7 *Escherichia coli (E. coli)*

Whilst statistical analysis conducted indicated that there is no significant difference in the means of the measured concentration of *E. coli*, the *E. coli* values for both seasons in all sampling points were far beyond the DWAF limits of 0 cfu/100ml. This implies that there are consistently high *E. coli* values throughout the year. Highs for sampling site 4 in summer and winter could be attributed to the waste water treatment works located just upstream and highs for the remaining points can be attributed to the poor sanitation of several informal settlements located variously in the catchment. The *E. coli* values for summer and winter have thus contributed negatively to the aquatic system of the Umdloti River. According to DWAF (1996), this may result in microbial infections for individuals using this water for domestic purposes.

5.2.8 Total Dissolved Solids (TDS)

According to DWAF (1996), high TDS values are as a result of evapo-concentration, usually greater than 1 100 mg/mR. Salts accumulate as water moves downstream because salts are continuously being added through natural and anthropogenic sources whilst very little is removed by precipitation or natural processes. Domestic and industrial effluent discharges and surface runoff from urban, industrial and cultivated areas as well as the

rock formation of the river bed are examples of the types of sources that may contribute to increased TDS concentrations. This is indicative in sampling points 2, 4, 10, 11, 12. The average TDS value for summer consequently exceeded the DWAF general limit of 200 mg/L, confirming high levels of pollutants in the middle and lower reaches of the Umdloti River as a result of natural and human induced impacts in the catchment.

5.2.9   Biochemical Oxygen Demand (BOD)

The potential for organic wastes to deplete oxygen is commonly measured as biochemical oxygen demand (BOD), and is measure of the amount of oxygen likely to be used in the degradation of organic waste (DWAF, 1996). BOD values at all sampling points were far beyond the general limits of 6-12 mg/L. Highest BOD value of 67 mg/L was measured in the sampling point 4, this is below the waste water treatment facility. The dissolved oxygen levels in the system are generally high when compared to the general limits for uptake by aquatic organisms. The high BOD levels can also be attributed to the informal settlement being located in and around the vicinity that contribute to the large amounts of non-biodegradable pollution as well as the industrial effluents from the industrial activities that occurs in the catchment. According to DWAF (1996), the depleted oxygen can cause both physiological and behavioural effects on the biota in aquatic systems.

5.2.10 Chemical Oxygen Demand

The COD values in all sampling points with the exception of sampling points 4, 8 and 11 are far beyond the general limit of 75 mg/L. It was interesting to note that high COD values were noticed in the upper, middle, and the lower reaches of the river. The dissolved oxygen levels in the system are generally high when compared to the general limits for uptake by aquatic organisms. As with BOD, the high COD levels can also be attributed to the informal settlement being located in and around the vicinity and contributing to the large amounts of organic pollution. Consequently anthropogenic influences in terms of limiting available oxygen for natural riverine functioning are considerable in the Umdloti River catchment. According to DWAF (1996), continuous exposure to concentrations of less than 80% of saturation dissolved oxygen can be harmful and could cause acute effects on the aquatic ecosystem.

5.2.11 Calcium

Calcium occurs in varying concentrations and together with magnesium is one of the main components of water hardness (DWAF, 1996). The reason for sampling point 12 having the highest calcium value is related to the La Mercy estuary; which is an open closed system. Sampling point 12 is located towards the end of the estuary where flocculation processes may have contributed to this peak in Ca concentration. For the remainder of the system, the measured average calcium value for summer is 20.70 mg/L which is below the DWAF limit of 150 – 300mg/L.

5.2.12 Magnesium

According to DWAF (1996), magnesium is an essential element for the growth of plant and other living organisms and does not pose a danger to the health of a river unless it exceeds the general limit of 4-10mg/L. The magnesium values for sampling point 10 to 12 (lower reaches of the river) far exceed these general limits. These sampling points are located in the estuary. On the other hand, magnesium values from sampling point 1 to 9 are within the general limits although they are elevated. The average magnesium value for summer is 21.75 mg/L and this far exceeds the general limit thus posing a threat to the riverine system as a result of industrial activities in the Umdloti Catchment.

5.3 Conclusion

The water quality analyses disclose that natural and human induced influences largely have negative impacts on the Umdloti River. The data indicates that the following variables: nitrite, ph, nitrate and calcium least impact the water in the upper, middle and lower reaches of the river, whereas ammonia, sulphate, phosphate, *E. coli*, TDS, COD and BOD impact negatively to a great extent in the upper, middle and lower reaches of the river. Nevertheless, all variables have no acute or chronic effect on the water quality in the upper, middle and lower reaches of the river. It can therefore be concluded from the water quality results that the middle and lower reaches of the river are most impacted by human induced impacts and least impacted by natural impacts as compared to the upper reaches of the Umdloti River. This is due to increased industrial and agricultural

activity, as well the scattered informal settlements along the catchment. Surface run-off from the industries, the town and neighbouring urban centres through the storm water drainage channels are also contributors to the level of pollutants found in the middle and lower reaches of the river.

5.4 Questionnaire Survey

In summary the people that live in this area are long-term residents, most having lived in the area for more than 40 years; however there is only a small percentage (6%) that has been resident in the area in the 21-40 year time period. The survey uncovered a strange hiatus in the 31-40 year period that recorded no residents and this is surmised as a consequence of the dam construction. Clearly, according to the results, nobody had moved into this area at that time. Subsequent to dam construction, other residents moved in and settled in the area. The direct effects of dam construction close to a residential area is therefore one of major disruption and generally it is the surrounding landowners who remain whilst others leave. New residents do not come in as such large scale construction work is too disruptive to normal living. From the respondents interviewed it is clear that this area surveyed has an improved economic status as compared to other communities. The study reveals a relative high level of actively employed respondents of sixty four percent (64%) in this area and this will have knock-on positive effects in terms of local development and improved standard of living and also, a possible decrease in criminal activities in the neighbouring communities of the Umdloti Catchment.

The respondents perception of the construction of the Hazelmere Dam on the upper

reaches of the Umdloti river was to supply water to the neighbouring towns; Verulam,

La Mercy and Umdloti. Eight percent (08 %) of the respondents indicated that the

Hazelmere Dam was built for recreation reasons and four percent (4%) indicated that the

dam was built to provide good flow of water during the winter months when water levels

in the river decreases. The latter would also protect and preserve the flora and fauna in

the riverine system.

In summary the construction of the Hazelmere Dam was favourable for sixty four percent

(64%) of the respondents. This provided good water supply for the people in the

neighbouring areas, as well as recreation and leisure activities in the vicinity of the dam.

Statistical analysis conducted indicated that younger and employed respondents viewed

the dam construction positively.

Thirty six percent (36%) of the respondents indicated that they had been negatively

impacted by the construction of the dam. This was as a result of their land being taken

away for the construction of the Hazelmere Dam. Unlike today before any major

construction takes place an environmental impact assessment has to be conducted. This

allows interested and affected parties to voice their opinions as well as this protects their

interest and rights, however at the time that the Hazelmere Dam was to be constructed no

environmental impact assessment was conducted and the people affected (36% of the

respondents) were not given any choice in the matter. Thus their land was expropriated

and a compensation given. This resulted in twenty percent (20%) of unhappy respondents

moving away from their land due to the construction of the Hazelmere Dam. The remaining sixteen percent (16%) of the respondents did not lose their land entirely. This is the land in which the dam is presently built on. From the information gathered thirty two percent (32 %) of the total respondents interviewed had been compensated for their loss of property and four percent (04%) of the respondents were not sure, this is due to their parents passing away and they did not know whether compensation was made or not however nothing can be done to rectify this problem as much time has passed. The prime use of the land before the construction of the dam included the following: forty percent (40%) of the respondents attributed the land primarily used for agriculture; four percent (4%) indicated that the land was inundated with dense natural vegetation; and fifty six percent (56%) of the respondents were not sure about the prime use of the land.

With respect to the availability of water prior to the dam construction, water was sourced from the Umdloti River (72% of the respondents). This was not clean or perhaps unable to use for drinking purposes however twenty six percent (26%) of the respondents indicated that the water was clean for domestic purposes. This could be possible in the river as very few urban and industrial activities or none did take place in that era thus contributing to virtually nil or minimal impacts from human induced activities.
For the majority of the respondents, water from the river was accessible prior and post construction of the dam (94% of the respondents). For the remainder of the respondents, water was not accessible due to the distance (4% of respondents); these residents obtained water from neighbours that had previously sourced water from the river via private transport.

Fifty six (56%) of the respondents received piped water (municipal piped water in their homes), twenty four percent (24%) of the respondents rely on the communal tap (municipal water) for their water supply for household use, six percent (6%) of the respondents have their own borehole on their property for water supply, eight percentage (8%) of the respondents rely on river water to this date for their household use, a further four percent (4%) rely on water tanker services for the supply of water for household use and the remaining two percent (02%) take water from their neighbours for household use. It was interesting to note that eighty eight percent (88%) of the respondents indicated that they had not experience any problems with the water quality from the above mentioned water sources, however the remaining twelve (12%) indicated that they had experienced the following problems; water had an odour; it was green in colour and, the water did not taste good. The twelve percent (12%) of the respondents attributed these changes due to the major land use changes (urbanization and industrialization) that are taking place in and around the Umdloti Catchment as well as the Hazelmere waste water treatment works. These can also be attributed to the high ammonia, sulphate, phosphate, *E. coli*, TDS, COD and BOD, Ca and Mg values in the middle and lower reaches of the river. A total of thirty percent (30%) of respondents have to walk more than 80 meters (80 m) away to source water for their household uses. This is a tedious process however the respondents have to do this for their day to day living. Four percent (4%) of the respondents are fortunate as the water source is merely 20-40 meters away and the remaining fifty six percent (56%) have piped water in their households.

The Umdloti Catchment is indicative of intense agricultural activities (sugar cane, vegetables and banana farming) and fifty two (52%) of the total respondents interviewed are involved in agricultural activities. High levels of ammonia, nitrate and sulphate values from the water quality analysis are indicative of large scale farming taking place (application of large volumes fertilizers resulting in surface run-off). Thirty percent (30%) of the respondents interviewed source water directly from the Umdloti River for irrigational purposes and this is indicative that the river is a vital resource for the agricultural practices taking place.

The informal settlements in the Umdloti Catchment (16% of respondents) that use the alternative sanitation facilities in close proximity to the river (more than 40 meters away) have contributed negatively to the water quality of the Umdloti River. This in indicative in all sampling points having high levels of *E. coli.* This could pose enormous heath treats to the surrounding people that are using this water source for domestic purposes.

The dumping and burning of wastes on the property of the respondents that are away from the river has no direct impact on the status of the water quality in the Umdloti River however the six percent (6%) of the respondents that do dump wastes can pose a threat to the water quality depending on the type of waste such as hazardous and non-biodegradable material. In summary forty four percent (44%) of the respondents indicated that the Umdloti River is not impacted heavily by the dumping of wastes, but threats emanate from various forms of large scale anthropogenic impacts. e.g. sand mining and industrial activity.

5.5 Conclusion

On-site observations, water quality analysis and the questionnaire survey thus conclude

that the influence of natural and anthropogenic impacts is contributing negatively to

water quality of the Umdloti River. The informal settlement's that are scattered along the

catchment have contributed to high *E. coli* levels in the river as does the waste water

treatment works. The increased urban, industrial and agricultural activities in the

catchment have impacted the middle and lower reaches of the Umdloti River negatively.

High levels of ammonia, nitrate, sulphate, phosphate, TDS, BOD and magnesium were

recorded. In summary the anthropogenic impacts has increasingly contributed to elevated

pollutant levels in the Umdloti River as compared to the natural impacts.

CHAPTER SIX

RECOMMENDATIONS AND CONCLUSION

6.1 Introduction

There exists an old and well-proven management principle that states, ***If you can't measure it, you can't manage it***. This principle applies as much to water resource management as it applies to managing any other kind of human endeavor. This principle is recognized explicitly in Chapter 14 of the National Water Act (NWA, Act No. 36 of 1998) (DWAF, 1998) that requires monitoring of water resource quality to be an integral part of water resources management in South Africa (DWAF, 2004).

There is widespread and growing opinion that the world faces an imminent and ever more serious water crisis. This opinion is shared by many of the professional involved in water management as well as much of the public at large, because these opinions are widely expressed. This crisis is presented not just in the sense that the scarcity will be so marked as to cause serious economic, political and social repercussions (Lee, 1999); it therefore becomes a pressing need for integrated water resource management.

Integrated water resource management is a cornerstone of the new approach to water resources management adopted in South Africa and required by the National Water Act 36 of 1998. Integration has to happen in several different dimensions, e.g. integration of the different components of the hydrological system (surface water, groundwater, estuaries, and wetlands) and integration between water resource quality, statutory,

economic, and social, objectives when making decisions about resource utilization. Water resource quality information users, who now have to make decisions and take actions that conform to the requirements of integrated water resources management, require both resource quality information, and often also, more sophisticated information concerning water resource quality (DWAF, 2004).

6.2 Recommendations

Fresh water systems in South Africa are experiencing dreadful conditions due to uncoordinated settlements, urbanization, industrialization and climate change. This has played a foremost role in the deterioration of the water quality of the Umdloti River catchment. As a result, the following recommendations can be made:

- The prevention of pollution needs to be addressed by all interested and affected parties in the Umdloti Catchment. Basic housekeeping for informal settlements, industries and urban development would be the most effective to protect this environment. Adverse effects of chemical and biological variables in the river will increase the risks in polluted waters thus causing severe health implications to humans as well as affecting the floral and faunal state of the natural resource.

- Public awareness campaigns in the form of plays and sketches should be organized by the Department of Water Affairs and Environmental Affairs for both

urban and rural communities in the Umdloti Catchment as both contribute to
pollution in the environment. This will prove good insight into pollution matters.

- Participative management among the Local Municipality (in the town of
  Verulam), NGO's, Department of Local Government, Department of Health,
  Department of Environmental Affairs, Department of Water Affairs and the
  Department of Housing must form a body to address the uncoordinated informal
  settlements, the alternative sanitation and waste disposal facilities that is being
  used, as this is causing increased levels of pollution in the Umdloti River. This
  type of facility is neither healthy nor eco-friendly and poses great treats not only
  to water quality and ecosystems but also humans.

- The catchment management forum should play an integral part of the Umdloti
  area, and this should be widely interacted with members of the public, local and
  regional government personnel to promote sustainable water resource
  management.

- Farmers in the area that are abstracting water from the Umdloti River for
  irrigation use must register this water use or apply for a water-use license.
  Compliance to this water use must be strictly adhered to. This will promote
  equitable allocation of water to all affected and will protect the quantity of water
  in the river due to the reserve determination thus promoting the aquatic life of the
  river. There must be controlled irrigation in the Umdloti catchment to prevent

144

excessive surface run-off resulting in increased levels of ammonia, nitrates, nitrites etc.

- Industrial effluents from industries particularly in the Canelands area should be recycled and re-used in the industrial processing activity rather than being discharged into the Umdloti River. This would minimize pollutant levels and not alter temperature levels in the river as well as retain aquatic life. It is also important to note that all industries in this catchment should register their waste water and must comply with the levels as stated in their waste discharge permit (if they are in possession of one), if this is not done the polluter pays principle must be enforced. This should be monitored on a monthly interval to ascertain whether pollutants in the waste water is fluctuating or decreasing and mitigations measures can be put in place.

- The authorizations of sand mining activities in the Umdloti River should be reviewed by the Department of Minerals and Energy, Department of Water Affairs and Department of Environmental Affairs due to uncontrolled mining that is taking place and causing major impacts on the water quality. The issue of monetary gain should be reconsidered as rehabilitation will not bring the sand mining site to its original state.

- The Hazelmere waste water treatment plant must be properly maintained and managed. The final effluent after the chlorination process and before the release into the Umdloti River should be monitored monthly. This effective method will ensure that strict levels of water treatment are adhered to as well as compliance from the general and special standard limits set by the Department of Water Affairs for waste water effluent.

- Alien vegetation along the river should be eradicated to maintain a healthy river system.

- The rigorous development in the Umdloti Catchment and surrounding areas should be reconsidered as this will contribute negatively to the Umdloti River and pose threats to the water availability and quality for future storage and supply.

- The local municipality in Verulam should also investigate the storm water system and the sewage system networks for irregularities such as illegal connection of the storm water line to the sewage system line. This will be most beneficial with respect to the prevention of sewage overflows from manholes as well as an excess in capacity of sewage treatment plant.

- Monthly analysis of water quality should be administered on the upper, middle (upstream and downstream of Hazelmere treatment plant; upstream and downstream of industrial area) and lower part Umdloti River. This resource monitoring must be managed in accordance with the following national monitoring programmes: the National Microbial Water Quality Monitoring Programme, the National Aquatic Ecosystem Health Monitoring Programme, the National Eutrophication Monitoring Programme, the Toxicity Monitoring Programme and the National Chemical Monitoring Programme. This will provide an in-depth and holistic understanding of the various natural and anthropogenic impacts that are disturbing the river system subsequently allowing remediation measures to be put in place to preserve and protect this natural resource.

- Finally the BLUE and GREEN SCORPIONS administered by national government should implement vigorous audits on all industries and the local municipality in the Umdloti Catchment to ascertain levels of compliance with respect to the National Environmental Act and National Water Act of South Africa.

6.3 Conclusion

The natural and anthropogenic impacts in the Umdloti Catchment are a clear indication that pollution in this area has increased over the years due to increased urban and industrial development as well as agricultural activities. The change in land use cover subsequently resulting in deterioration of water quality within the catchment is evident in the maps dated 1959-2000 as well as the main human disturbance to the river, the construction of the Hazelmere Dam. The perception of the public interviewed concluded that the Hazelmere Dam has positively impacted the majority of the respondents due to access of clean drinking water (piped water) as well as a recreation facility to the public, however the uncoordinated informal settlement have contributed to high *E. coli level*s in the river. The results emanating from the water quality analysis revealed that the middle and lower reaches of the river are most impacted as compared to the upper reaches.

It is therefore of paramount importance that the public trustee of the Nation's water resources, the Minister of Water Affairs and his Department, the Department of Water Affairs, has to manage South Africa's water resources to ensure continued adequate protection of freshwater system so that water supplies are of acceptable quality to all recognized users. From a water quality management point of view these recognized users consist of, five water user sectors; these being the domestic, agricultural, industrial and recreational water user sectors, as well as the aquatic ecosystem, (cited in *Water Quality Management of South Africa*, www.dwaf.gov.za). This will ensure that the Umdloti River

is protected and preserved for future generation however this process of change can only

be implemented efficiently once all recommendations have been met.

REFERENCES

Ahmed, F., 2005: The Impacts of Residential and Tourism Development on the KwaZulu Natal North Coast: Umhlanga Rocks to Salt Rock-Natal. Unpublished Master's Thesis. University of Durban Westville.

Baird, C., 1995: Environmental Chemistry, 2nd Edition, New York, p. 424-427, 454, 476-479.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling., 1999: Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Baron, et al., 2002: Meeting Ecological and Societal Needs for Freshwater. Ecological Applications 12: 1247-1260.

Bartram, J., Ballance, R., Undated. United Nations Environment Water Quality Monitoring: a practical guide to the design and implementation. http://books.google.co.za/books. (Accessed 06 January, 2009).

Begg, G., 1978: The Estuaries of Natal, Natal Town and Regional Planning Report. Vol. 41, p. 214-215.

Begg, G., 1984: The Estuaries of Natal, Part Two: Natal Town and Regional Planning. Report Main Series Report, Vol.55, p. 66-80.

Biochemical Oxygen Demand. http://encyclopedia.farlex.com/biological+oxygen+demand. (Accessed 12 June, 2009).

Brand, et al., 1967: Town and Regional Planning Commission and The National Institute for Water Research, C.S.I.R. Water Quality and Abatement of Pollution in Natal Rivers, Vol. 13.

Bridge, J. S., 2005: Rivers and Floodplains, Forms, Processes and Sedimentary Record, p. 1.

Brierley, G. J and Fryirs, K. A., 2005: Geomorphology and River Management, Application of River Styles Framework, United Kingdom, p. 208-209.

Brijlal, N., 2004: The Environmental Status and Health Status of the Umgeni Estuary, Unpublished Master's Thesis, University of Durban Westville.

Bryman, A., 2004: Social Research Methods 2nd Edition. Oxford University Press, New York, p.334-335.

Centre for Innovation in Engineering and Science Education (CIESE). http://www.ciese.org/curriculum/dipproj2/en/fieldbook/bod.shtml. (Accessed 15 June, 2009)

Chemical Characteristics of Water. http://www.abheritage.ca/abnature/environmental/water_chemical_characteristics.htm. (Accessed 09 June, 2009).

Chile, N. S., 2007: A Study of the Environmental (Natural and Anthropogenic) Impacts of Estuaries in KwaZulu Natal, South Africa. Unpublished PhD Thesis, University of KwaZulu Natal.

Cook, H. F., 1998: The Protection and Conservation of Water Resources, A British Perspective, London.

Croucamp et al., 1994: Large Dams in South Africa, South African Committee on Large Dams.

Dams i n S outh A frica. http://www.wrc.org.za/downloads/education/dams.SA.pdf. (Accessed 03 July, 2009).

David, K. and Brad, K., 2002: Water Pollution And Society. http://www.unmich.edu/~gs265/society/waterpollution.htm. (Accessed 03 March, 2007).

Day, J . A . a nd K ing, J M ., 1995: G eographical P atterns a nd t heir Origins i n t he Dominance of Major Ions in South African Rivers. S. Afr. J. Sci. 91: 229-306.

DEAT, 1998: National Environmental Management Act 107 of 1998

DWAF, 1996: South African Water Quality Guideline, Volume 7: Aquatic Ecosystems: Second Edition.

DWAF, 1996: S outh A frican W ater Q uality G uidelines, V olume 7: D omestic U se: Second Edition.

DWAF, 1998: National Water Act No. 36 of 1998.

DWAF, 2001: M voti to Umzimkhulu W ater M anagement A rea S ituational A ssessment, Appendix A. http://www.dwaf.gov.za/Documents/Other/CMA/Mvoti/SA_AppendixA_Mvoti.doc. (Accessed 21 January 2009).

DWAF, 2003: Water Quality Management Series, Operational Guideline No. U2. 1.

DWAF, 2004: S trategic F ramework f or N ational W ater R esource Q uality M onitoring Programmes, Resource Quality Services. http://www.dwaf.gov.za/iwqs/wrmais/National_Water_Resource_Quality_strategy_ed01 dr05_final.pdf. (Accessed 03 June 2007).

DWAF, 2004: R esource Q uality M onitoring. http://www.dwaf.gov.za/iwqs/iwqso/assess.asp. (Accessed 06 March 2009).

DWAF, 2005: A Drinking Water Quality Framework for South Africa.

DWAF, 2007: Annual Report Department of Water Affairs and Forestry. http://www.dwaf.gov.za/documents/AnnualReports/ANNUALREPORT2007.pdf. (Accessed 15 February 2009).

DWAF, 2007: W ater Reconciliation Strategy S tudy for K waZulu Natal C oastal Metropolitian Areas: First Stage Water Reconciliation Study. http://www.dwaf.gov.za/Documents/Other/RMP/Hazelmere/HazelmereRMPStake17Oct0 7. (Accessed 05 March 2008).

DWAF, 2008: Annual Report Department of Water Affairs and Forestry. http://www.dwaf.gov.za/documents/AnnualReports/ANNUALREPORT2008.pdf. (Accessed 15 February 2009).

Degremont, 1991. W ater T reatment H andbook, 6t h e dition, 1278 -1280. L avoisier Publishing, Paris, France.

Fox, R a nd R owtree, K., 2000: T he G eography of S outh A frica i n a C hanging W orld, United Kingdom, p. 37-40, 469.

Gail, E. C., 2001: Water Quality Measurement, Department of the Interoir/US Geological Survey. http://www.amlrnrm.sa.gov.au/Caring_for_Water_Seas/Water_Quality/Water_Quality Measurement.aspx. (Accessed 03 March 2009).

Gray, N F ., 1994: D rinking W ater Q uality. P roblems a nd S olutions. John W iley a nd Sons, Chichester.

Gustavsson, B., 2007: The Principles of Knowledge Creation, Research Methods in the Social Sciences. United Kingdom, p 48.

Guy, L. M., Shawki, B, and Herve, P., 1990: Dam Safety and the Environment. World Bank Technical Paper number 115.

Hammond, R and McCullagh, P., 1974: Quantitative Techniques in Geography, Oxford University Press, Oxford.

Harrison, M, R., 2007: Principles of Environmental Chemistry, United Kingdom, p. 80-81.

Hendricks, L. B., 2009: 5th World Water Forum Ministerial Roundtable: Making Water a Tool for Development in Africa: Closing Statement by Minister of Water Affairs and Forestry Sutluce Congress and Cultural Centre Istanbul, Turkey.

Hounslow, W. A., 1995: Water Quality Data: Analysis and Interpretation. New York.

Huffman, H., 1991: Waters in Motion: The Big Rivers Natural Region. The Natural Heritage of Indiana UP, 217-222.

IMIESA, 2004: The Official Journal of Municipal Engineering of Southern Africa, Vol 29, No. 3, p. 3-4.

Keeffe, J. H. O., 1986: The Conservation of South African Rivers, South African National Scientific Programmes Report No. 131, p. 1,15, 31-32.

Lee, T. R., 1999: Water Management in the 21st Century. The Allocation Imperative, p. 1.

Mangold, S., 2001: National Aquatic Ecosystem Biomonitoring Programme: An Implementation Manual for the River Health Programme – a hitch hiker's guide to putting the RHP into action. NAEBP Report Series No 15. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa http://www.dwaf.gov.za/iwqs/rhp/state_of_rivers_05.pdf. (Accessed 06 March 2009).

McCully, P., 1996: Silenced Rivers, The Ecology and Politics of Large Dams, United Kingdom, p. 11-30.

Mclusky, D. S., 1989: The Estuarian Ecosystem, 2nd Edition, United States of America, p. 1.

Murphy, S. F., und ated: Boulder Area Sustainability International Network. Natural Systems Basin Water Quality. http://bcn.boulder.co.us/basin/watershed/wqterms.html. (Accessed 09 June 2008).

Naidoo, K., 2005: The Anthropogenic Impacts of Urbanisation and Industrialization on the Water Quality, Ecology and Health Status of the Palmiet River Catchment in Durban, KwaZulu Natal. Unpublished Master's Thesis, University of KwaZulu Natal, Westville.

Novotny, V., 2003: Water Quality, Diffuse Pollution and Watershed Management, 2nd Edition, p. 31-34.

Pond, K., 2005: Water Recreation and Disease, Plausibility of Associated Infections: Acute Effects, Sequelae and Mortality, WHO, London, p. 65-67.

Porteous, A., (2000): Dictionary of Environmental Science and Technology, Biological Characteristics of Natural Waters. 3rd edition, John Wiley & Sons. http://openlearn.open.ac.uk/mod/resources/view.php?id=185886. (Accessed 09 June, 2009).

Precious w ater. http://www.botany.uwc.ac.za/Envfacts/facts/water.htm. (Accessed 10 January 2007).

Raju, B. S. N., 1995: Water Supply and Wastewater Engineering. New Delhi.
RAMSAR, 1998: C onvention on W etlands, S trategic A pproaches t o F reshwater Management.

Rao, C. S., 1991: Environmental Pollution Control Engineering, p. 289-396.

SAMJ, 2008: The South African Medical Journal of Continuing Medical Education, June 2008, Vol. 26, No. 6, p. 280.

Schwab, G . O ., Fangmeier, D . D ., E lliot, W . J ., F revert, R . K ., 1993: S oil a nd W ater Conservation Engineering, 4th Edition, p. 374-376.

Spellman, F. R., 1998: The Science of Water: Concepts and Applications

Stumm, W a nd M organ, J . J., 1981 : A quatic C hemistry. A n Introduction E mphasizing Chemical Equilibria in Natural Waters, 2nd Edition, p. 688.

Tolba, A. M., 1992: Saving Our Planet, Challengers and Hopes, London, p. 46.

USCGS: http://ga.water.usgs.gov/edu/waterproperties.html. (Accessed 15 March 2009).

Water and Development: http://www.awiru.co.za/pdf. (Accessed 14 July 2009).

Water Pollution and Disease
http://www.randwater.co.za/CorporateResponsibility/WWE/Waterpollution.aspx.
(Accessed 01 August 2009).

Water Q   uality M   anagement i   n   South   Africa:
http://www.dwaf.gov.za/Dir_WQM/wqm.htm. (Accessed 07August 2009).

Water Quality Parameters.
http://3r2n.cfa.cmu.edu/education/waterq/pdf/Water_Quality_Parameters.pdf. (Accessed
(06 June 2009).

White Paper Policy, South Africa, 1997.
http:www.polity.org.za/html/govdocs/whitepapers/water.html. (Accessed 01 July 2008).

Wilson, A. L., 1974: The Chemical Analysis of Water, General Principles and
Techniques, p. 1, 18, 86-89.

APPENDIX: QUESTIONNAIRE SURVEY

UNIVERSITY OF KWAZULU NATAL
FACULTY OF SCIENCE
DEPARTMENT OF ENVIRONMENTAL SCIENCE

QUESTIONNAIRE

Topic: An investigation of the natural and human induced impacts on the Umdloti catchment.

By
Strinivasen Govender

SECTION ONE

Respondents Background

1.1 Gender

Male	
Female	

1.2 Age

<20	20-29	30-39	40-49	50-59	60-69	>70

1.3 Marital status

Single	Married	Divorced	Widowed	Other

1.4 Number of members in households

Male	Female	Total

1.5 How long have you lived in this area? (Number of years)

<10yrs	11-20yrs	21-30yrs	31-40yrs	>40yrs

1.6 Employment status

Employed	Self Employed	Unemployed	Other

1.7 What is your average monthly income?

<R1000	R1000-R2000	R2000-R3000	R3000-R4000	R>4000

1.8 How many people in your household is dependant on this income.

_____

SECTION TWO

2.1 Why do you think that the Hazelmere dam had to be constructed?

_____
_____
_____

2.2 Did the construction of the dam benefit you in any way? Explain

_____
_____
_____

2.3 Have you been negatively affected by the construction of the dam? Explain

_____
_____
_____

2.4 Were you displaced as a result of the construction of the dam? Explain

_____
_____
_____

2.5 Did the local council compensate you for the loss of property?

Yes	
No	

2.6 What type of compensation was given? Explain

_____
_____
_____

2.7 Are you satisfied with the compensation?

Yes	
No	

2.9 What was the prime use of the land prior to the construction of the Hazelmere Dam?

_____
_____
_____

SECTION THREE

3.1 Was there clean drinking water available for household use before the construction of the Hazelmere dam?

Yes	
No	

3.2 If no, explain where clean drinking water was sourced from.

_____
_____
_____

3.3 How accessible was this water before the construction of the dam?

_____
_____
_____

3.4 Currently what is your primary water source used for the household

Sources	
Communal Tap	
Piped Water	
Borehole	
River	
Water Tanker	
Other	

3.5 Have you experienced any problems with the water quality from the above mentioned source? Explain

_____
_____
_____

3.6 How far is this water source (excluding piped) water from your household?

0-20m	
20-40m	
40-60m	
60-80m	
80-100m	
>100m	

3.7 Are you involved in any agricultural activities?

Yes	
No	

3.8 List your water source for this agricultural activity

_____

SECTION FOUR

4.1 Are there sanitation facilities in this community?

Yes	
No	

4.1.1 If yes, state what kind of facilities is available?

_____
_____
_____

4.1.2 If no, state the alternatives that exist for sanitation purposes.

_____
_____
_____

4.2 Are these sanitation facilities located in close proximity to the river

Yes	
No	

4.3 If yes, what is the distance in proximity to the river

<10m	
20-30m	
30-40m	
40-50m	
>50m	

SECTION FIVE

5.1 How is household waste disposed? Explain

_____
_____
_____

5.2 Are dumping sites in close proximity of the river?

Yes	
No	

5.3 If yes, what is the distance of these dumping sites from the river?

<20m	
20-40m	
40-60m	
60-80m	
>100m	

5.4 Have you noticed any change in the river water quality due to dumping of waste?

Explain.
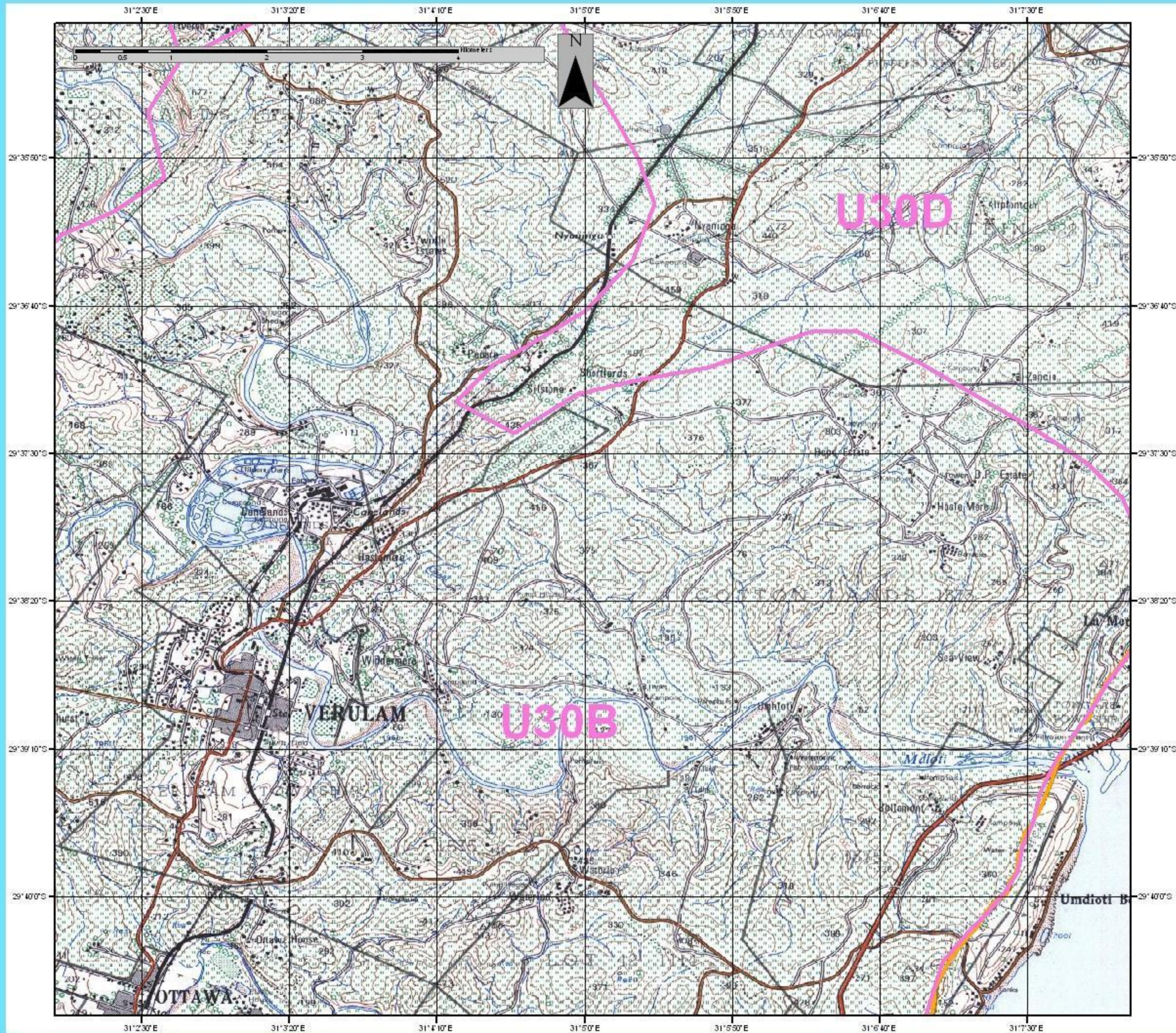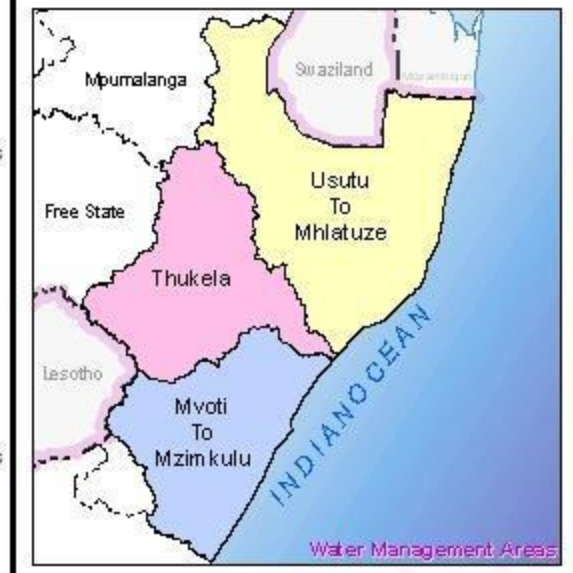
_____
_____
_____
_____

Figure 4.6.1.1: Umdloti Catchment dated 1959
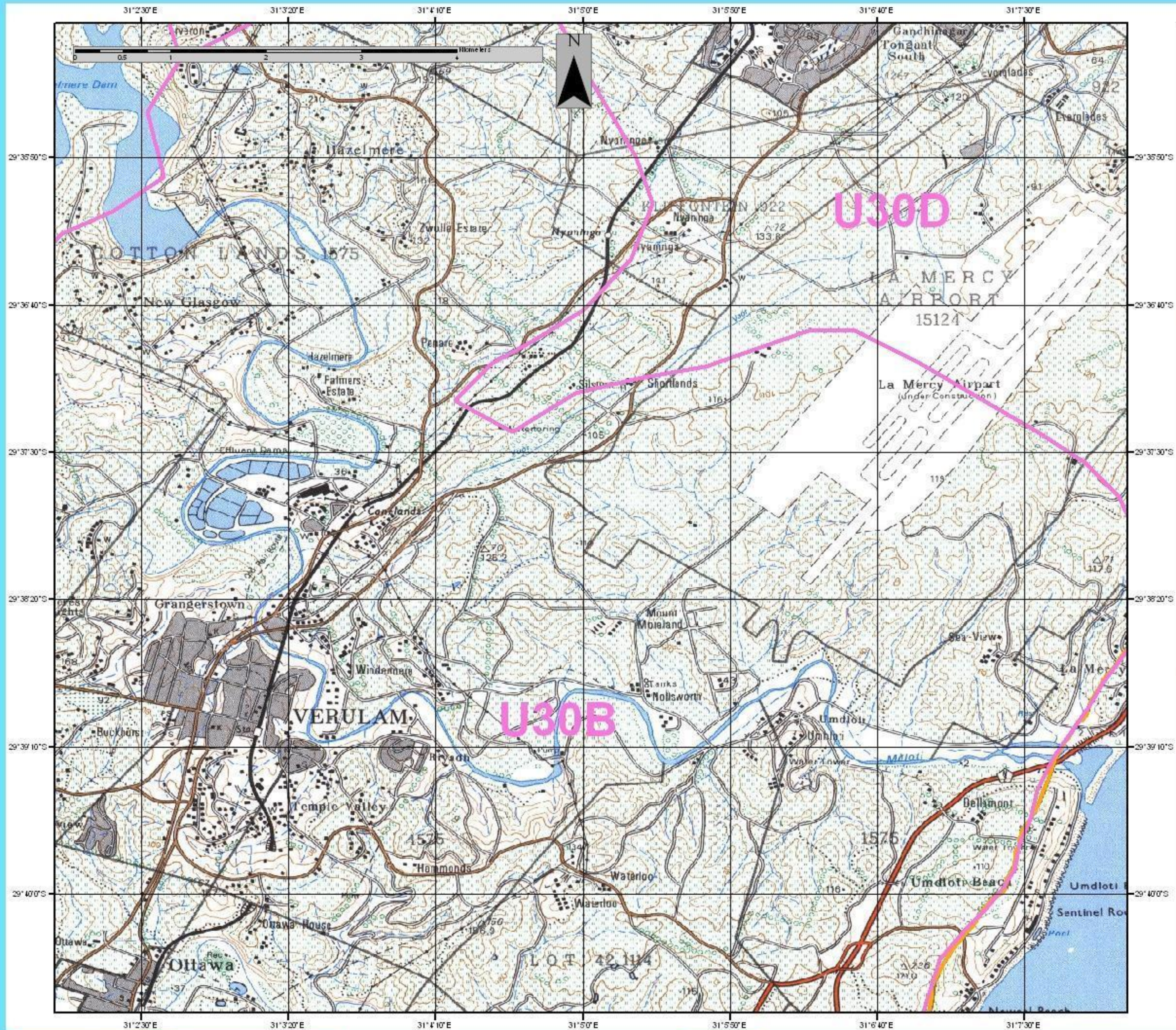
Source: DWAF, 2009
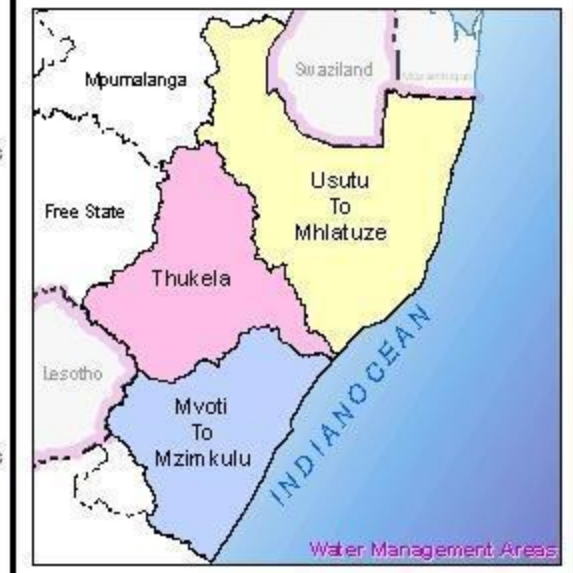
Figure 4.6.2.1: Umdloti Catchment dated 1978
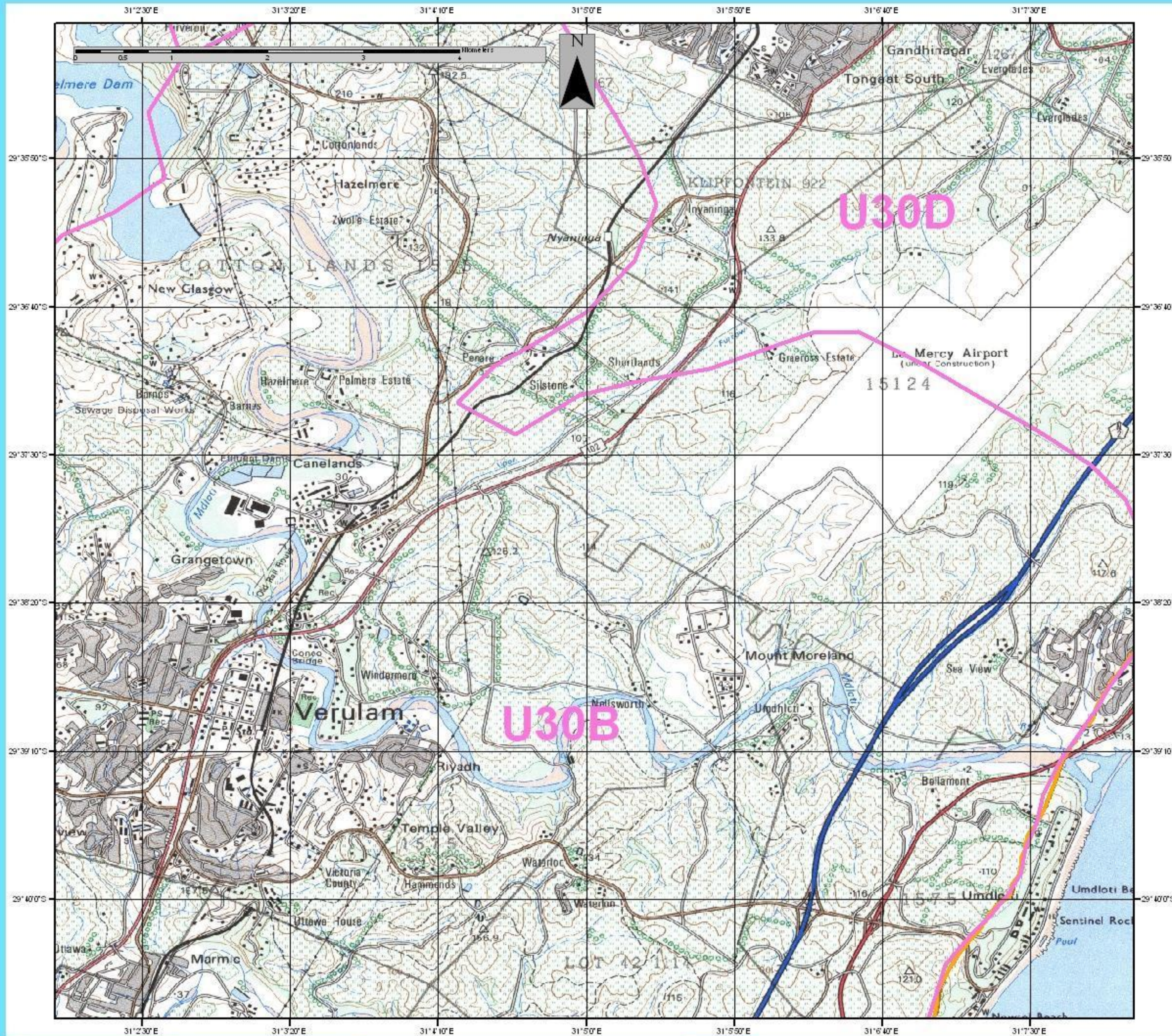
Source: DWAF, 2009

Figure 4.6.3.1: Umdloti Catchment dated 1989
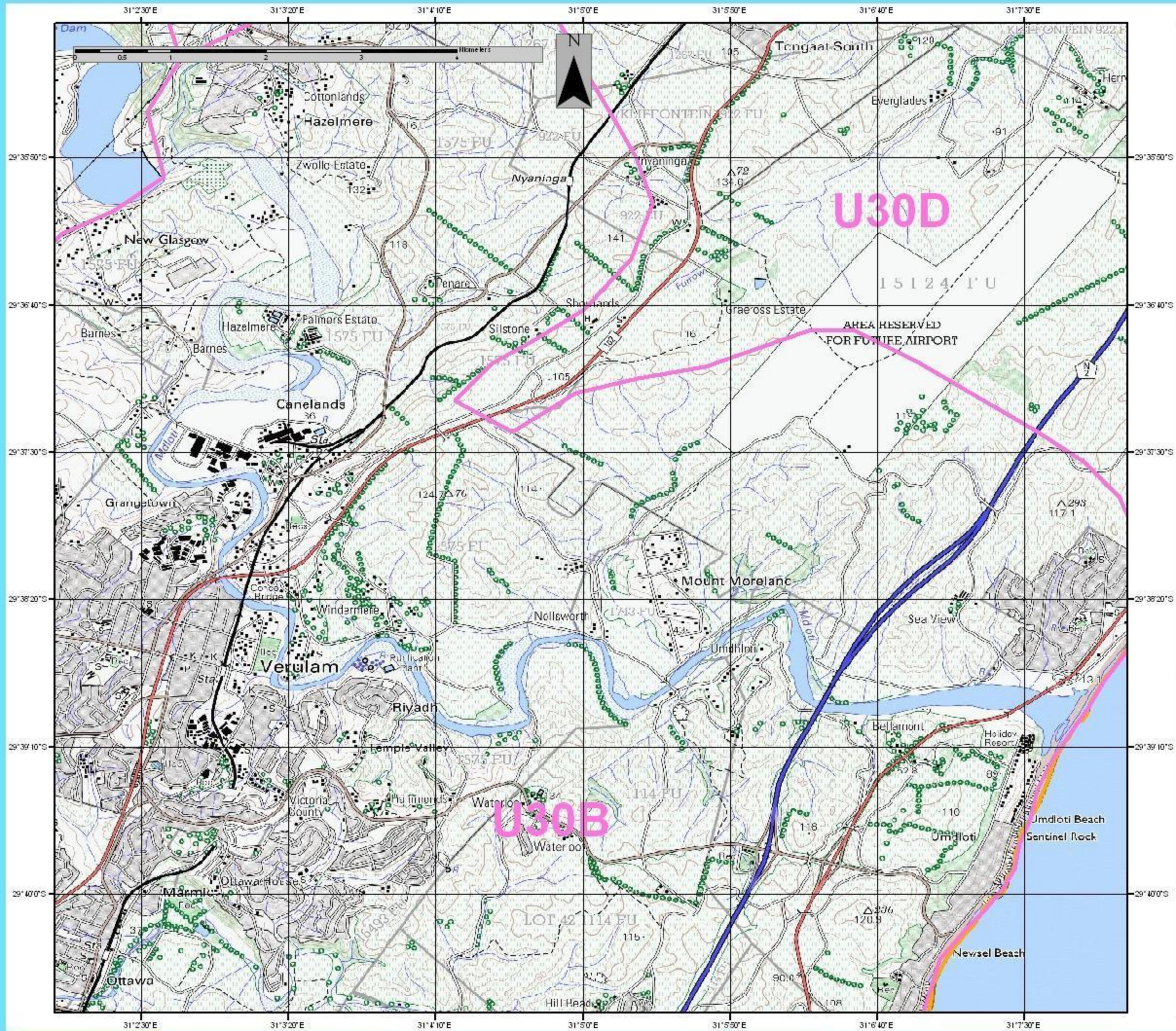
Source: DWAF, 2009

Figure 4.6.4.1: Umdloti Catchment dated 2000
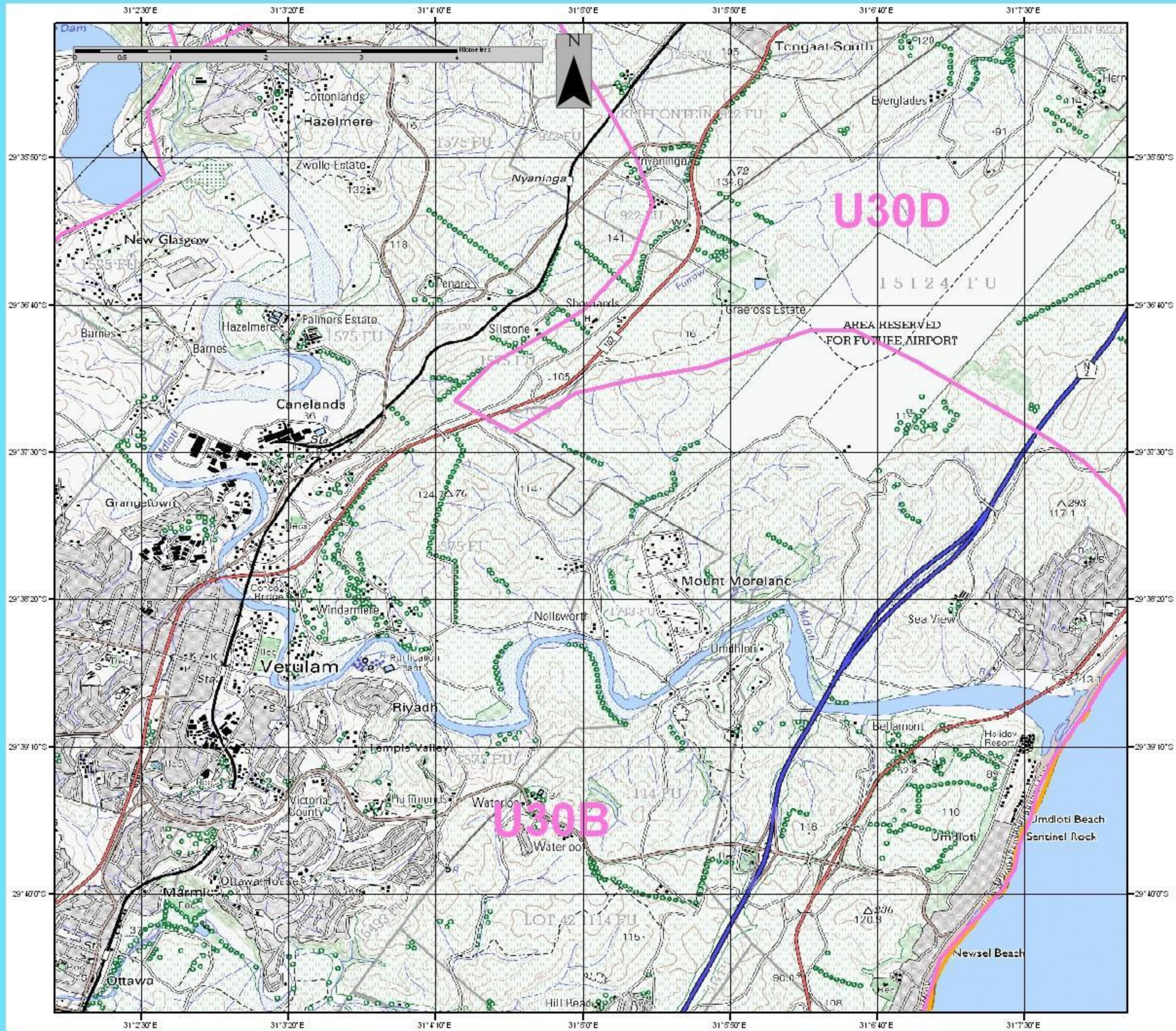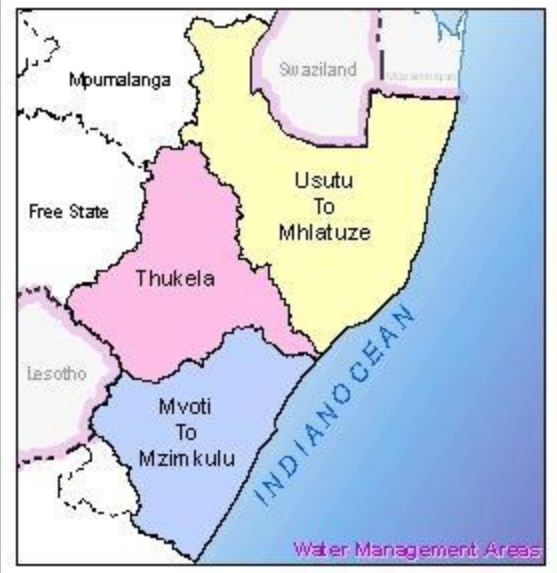
Source: DWAF, 2009

Figure 3.1: The Umdloti River and Hazelmere Dam.