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School of Environmental sciences

Department of Geography and Geo information Science

AN EVALUATION OF URBAN HOUSEHOLD WATER DEMAND AND CONSUMPTION IN VHEMBE DISTRICT: A CASE STUDY OF MAKHADO LOCAL MUNICIPALITY, LIMPOPO, SOUTH AFRICA

BY

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A research dissertation submitted to the Department of Geography and Geo-information Science, in partial fulfilment of the requirements for the degree of Masters of Environmental Science, University of Venda

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April, 2016

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DECLARATION

I, Luvhimba Ramulongo, hereby declare that this dissertation submitted to the Department of Geography and Geo-Information Sciences for the award of Master's in Environmental Sciences degree at the University of Venda, has not been previously submitted for a degree at this or any other institution. This is my work in design and execution, and all reference materials contained herein have been duly acknowledged.

Signature _____ Date: 23/08/2016

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DEDICATION

To my Mother (Sylvia Avhurengwe Ramulongo), Dad (Seth Madia Ramulongo), Siblings (Thavha and Masindi Ramulongo) and my Son (Sirai Ramulongo).

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I would like to thank and honour my heavenly Father for the strength and wisdom he gave me during the course of this research.

The study reported in this dissertation could not have been possible without the help of many people and organizations. My indebtedness and sincere gratitude goes to my supervisors, Dr P.M Kundu, Dr N.S Nethengwe and Prof A. Musyoki for their meticulous supervision, patience, continuous guidance, cooperation, encouragement and comments on the drafts, which were crucial for the successful completion of this study.

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To my Parents, my brother (Thavha) my sister (Masindi), and my son (Sirai) thank you so much for your support.

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Abstract

Water demand already exceeds consumption in many parts of the world, and more and more areas are expected to experience this imbalance in the near future. Water is required for agricultural, industrial, household, recreational and environmental uses. Demand for water use is rapidly increasing due to continuously increasing populations, especially in the developing world and due to growing awareness of environmental, health and recreational issues. This study aims to evaluate urban household water demand and consumption in the Makhado Municipality. Vhembe District is endowed with water sources; however the municipality is facing challenges with supplying water to its residents. This study employed a mixed methodical design, including quantitative, qualitative and GIS. The methodology in chapter three is arranged according to objectives one to four. Self-administrated surveys were used to evaluate the nature of water demand and consumption; systematic sampling was used to obtain households where the questionnaires were administered. The extent of water consumption in the municipality was calculated using a calculation adapted from Garg, (2011). Key informant interviews were carried out; these involved open discussions with individuals who are very knowledgeable about the research problem. These included officials from the Vhembe District and Makhado Local Municipality. EPANET was used to assess the simulation of water distribution and improve the understanding of the movement of water within the municipality. A strategic framework for water supply was designed in order for the Makhado Local Municipality to achieve sustainable water supply.

Keywords: EPANET; Infrastructure; population growth; water consumption; water demand; water distribution systems; water supply

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List of Abbreviations

DWAF – Department of water affairs and forestry

EXT – Extension

GIS – Geographic information system

GLS – General Logistics System

LCA – Life cycle assessment

N.D.A – National development Agency

NEERI – National Environmental Engineering Research Institute

NEPAD – New partnership for Africa's development

PPP – Private Public Partnership

PRV – Pressure Relief bulb

RSA – Republic of South Africa

RWS – Raw water sources

SADC – South African Development community

SPSS – Statistical package for Social Sciences

SSR – Standard Schedule of Rates

SWOT – Strength, Weakness, Opportunities, Threats

U.N – United nations

UNDP – United nations development plan

UNESCO – United nations education, scientific and culture organisation

UNESCO-IHE – United Nations Educational, Scientific and Cultural Organisation's Institute for Hydrological Education

UN-HABITAT – United Nations Human Settlement Programme

USGS – United States Geological Survey

VDM – Vhembe District Municipality

WDM – Water demand management

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CHAPTER 1: INTRODUCTION

1.1 Background of the study

It is globally recognized that many countries are entering an era of severe water shortage. In spite of the fact that national water policies of many countries place household and industrial water needs at a high priority level, there are issues that limit the availability of water at the point of consumption, resulting in water stress conditions (UNESCO, 2003).) UNESCO further pointed out that more than two-thirds of the world's population is estimated to be urban dwellers by 2025 and currently at least 170 million still do not have access to safe drinking water. Urban water authorities and water planners in many countries are struggling to satisfy the growing urban water demands and at the same time failing to achieve sustainable urban water system (Khatri and Vairavamoorthy, 2007). As a result of the rapid rate of urbanisation throughout Africa, many African cities face mounting challenges of providing their increasing population with adequate and sustainable water services.

According to the Water Research Commission 2008, South Africa is a semi-arid, water stressed country, with an annual rainfall of about 450 mm, which is well below the world average of about 860 mm. Water availability across the country is faced with three major challenges which include, uneven spatial distribution and seasonality of rainfall, relatively low stream flow in rivers most of the time, and the location of major urban and industrial developments remote from the country's larger water courses. South Africa is the 30th driest country in the world and has less water per person than countries widely considered being much drier, such as Namibia and Botswana (Water Research Commission, 2008).

The Constitution of South Africa Act, 108 of 1996, and specifically its Bill of Rights enshrine the basic right of access to sufficient water, as well as a safe and healthy environment (RSA, 1996). Despite of this Act many parts of the country have reached the point where all easily accessible freshwater resources are fully utilised, and it is imperative that all South Africans recognise this situation so that the necessary steps can be taken to assess current and future demand for water (RSA 1996).

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In South Africa, for instance water polices have been designed and developed whereby the Constitution requires water service providers to meet their constitutional responsibility to provide sufficient water services to the community, whereby each person is entitled to 50-100 litres per day regardless of his ability to pay for it and 25 litres of free basic water (Water Research Commission, 2008). If ever this right of access to sufficient water services is compromised, it will mean that the rights of the people are being undermined. However, this is not upheld as most informal settlements and rural areas in South Africa routinely go without water (Water Research Commission, 2008).

Furthermore, the Water Services act, 108 of 1997 outlines the responsibility of government departments to meet the water needs of the community. The act provides an outlined regulatory framework within which water related services should be provided. It also provides the basic guidelines for the management of the country's water resources (RSA, 1997). The National Water Act, 36 of 1998, also delineates how the water resources need to be protected, used, developed, conserved, managed and controlled (RSA, 1998). Regardless of these policies and acts, the effective provision of drinking water is one of the major challenges confronting South Africa's public sector since the country entered into a phase of multiracial governance in 1994 (Kido, 2008).

According to the Integrated Development Plan of 2013, the Makhado Local Municipality is one of the four local municipalities comprising the Vhembe District Municipality, Limpopo, South Africa. Integrated Development plan further indicated that the Makhado Local Municipality is located within the western part of the district, approximately 100km from the Zimbabwean border along the N1 Route. The municipal area is 8567, 38km² in size and 97.4% of the municipality is rural and only 2.6% of the municipal area is urban. The major towns include Makhado town, Dzanani, Waterval, Vleifontein and Vuwani.

The Makhado Local Municipality has entered into an agreement with the Vhembe District to be its water service authority and provider. The district purchases bulk raw water from the Department of Water Affairs, the district then processes the water and cleans it for reticulation. The sources of water in the district are eleven (11) dams. However, the main sources are Nandoni, Albasini and Vondo dam, which supply most of the areas in the district. In spite of this, the existing bulk water supply is unable to cope with the demand for water provision.

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The problem of water supply is also attributed to the fact that water resources and schemes that are in place are old and were intended to serve a smaller population, especially those staying in proclaimed areas (Integrated Development Plan, 2013). Municipalities, including Makhado are faced with major challenges of supplying their residents with water. Too many illegal connections have mushroomed around the municipal area and they tend to use purified water without paying for it, for example, car washes and brick work.

Many more people are still using water for gardening in an excessive manner, and in most cases, without paying for it. Thus, there is a need to install pre-paid water metres in each and every household in the municipal area in order to save water. Pre-paid water metres have only been installed in the urban areas and some citizens have volunteered to have them installed in their homes (Vhembe District Municipality, 2013).

1.2 Statement of the problem

According to the U.N.'s Millennium Development Report of 2005, the urban population was projected to exceed the rural population in developing regions of the world. Urban populations were growing at more than 3% per annum in 2007. People who live in urban areas lack more access to improved water supply infrastructure (Choguil, 1996).

South Africa is facing a serious water crisis as municipalities across the country are finding it hard to meet water demands. Municipalities within the country such as Sunrise Park near Rustenburg, Majakaneng in Brits and Malamulele in Limpopo, have been trying to combat the inadequacy of water supply (Water Research Commission, 2008). According to a water study by the institute for security studies, there is great uncertainty regarding the future of water demand and supply in South Africa which will result in an unsustainable gap between supply and demand for many years (Gleick, 2003).

In addition, South Africa is also losing over 1.5 billion cubic metres of water a year due to faulty piping infrastructure that has outlived its lifespan (Cilliers, 2014). Vhembe District is well-endowed with water sources, particularly with the Nandoni Dam, which has been constructed with a catchment area of 1 380km^2 and a net storage capacity of 164 cm^3 (Integrated Development Plan, 2013). The Vondo, Albasini and Damani dams are also potential water suppliers which derive their water from Luvhuvhu catchment which is 5 941km ^{2}, with an annual mean precipitation of 608 mm (Water Research Commission, 2008).

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Despite this level of endowment, the communities in the Makhado Local Municipality sometimes go for weeks without being supplied with water and where there is a provision of water it cannot meet their daily household needs.

The Integrated Development Plan (2013) further stated that most people in the municipality rely on water from a tanker truck system. However, the trucks are now out of service. Therefore there is a need to understand the role of the district as the water service provider in the context of institutional, operational and technical management systems. Similarly, the effectiveness of sustainable water supply strategies needs to be addressed. Makhado has the second biggest economy in Vhembe District (Local Economic Development Strategy, 2013) and the infrastructure is developing drastically for example the Elim mall and Makhado crossing and such developments attracts people to the municipality especially Makhado town which is the main industrial node.

According to Statistics South Africa (2011), Makhado Local Municipality has an annual population growth of 1.4%. The growing population exerts pressure on the existing infrastructure which brings up the issue of whether the existing water infrastructure is sufficient for the growing population. Therefore, there is a need to analyze the relationship between population growth, existing infrastructure and water demand.

1.3 Research aim and specific objectives

1.3.1 Research Aim

The aim of the study is to evaluate urban household water demand and consumption in the Makhado Local Municipality and apply a water distribution model for planning, operation and maintenance.

1.3.2 Specific research objectives

The specific research objectives are to:

(i) identify the different sources of water in the Makhado Local Municipality and determine the relationship between household water demand and consumption;

(ii) identify the operational, technical, institutional challenges of water supply in Makhado Local Municipality;

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(iii) assess the water distribution in Makhado Local Municipality; and

(iv) develop a strategic framework for municipalities in Vhembe District to enable them to achieve sustainable water supply to different water users.

1.4 Research Questions

These questions have been formulated to assist in achieving the stated research objectives:

(i) What are the salient characteristics of water demand and consumption for in Makhado Local Municipality?

(ii) What are the operational, technical and institutional water supply challenges facing Makhado Local Municipality?

(iii) How best can EPANET be applied in order to assess urban water distribution systems in Makhado Local Municipality?

(iv) What strategic framework can be used to achieve sustainable water supply and distribution to the different water users in Makhado Local Municipality?

1.5 Delimitation of the research of study area

1.5.1 Delimitation of the study

This study focused on Makhado Town, as it is the political, administrative and commercial area in the municipality.The study was limited to Makhado urban area and did not take into consideration the greater Makhado area. The water sources and water supply challenges were looked at a Municipal level and as for the water distribution and water demand and consumption were looked at a local level being Makhado New Town. To analyse the water distribution system the study took pressure, pipe length, and diameter into consideration due to the unavailability of detailed maps of the water distribution systems.

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1.5.2 Description of study area

Makhado is one of the four municipalities in Vhembe District (figure 1.1) with 38 wards. In terms of population, Makhado has the second largest population out of the four municipalities falling under the Vhembe District (Integrated Development Plan, 2013). The municipality has a total population of 516 031, with an annual growth of 1.4% which spread across 134 889 households (Vhembe District Municipality, 2013). The Municipality is made up of five formal towns namely, Makhado, Vleifontein, Vuwani, Waterval and Dzanani with about 279 villages.

The majority of the population resides in the rural areas and most areas are underdeveloped with large open spaces which are used for farming purposes (Vhembe District Municipality, 2013). There are approximately 10 478 farms in the area. Makhado has scattered rural villages which function only as residential areas, the majority of these settlements are very small, with less than 10 000 people, and according to the 2011 census Makhado Town was identified as an urban area (Statistics South Africa, 2011). Most areas or much land in the municipal area falls under tribal ownership. Specifically, about 90% of municipal land is under tribal ownership. About 6% is exclusively owned by the state and only 4% is privately owned (Integrated Development Plan, 2013).

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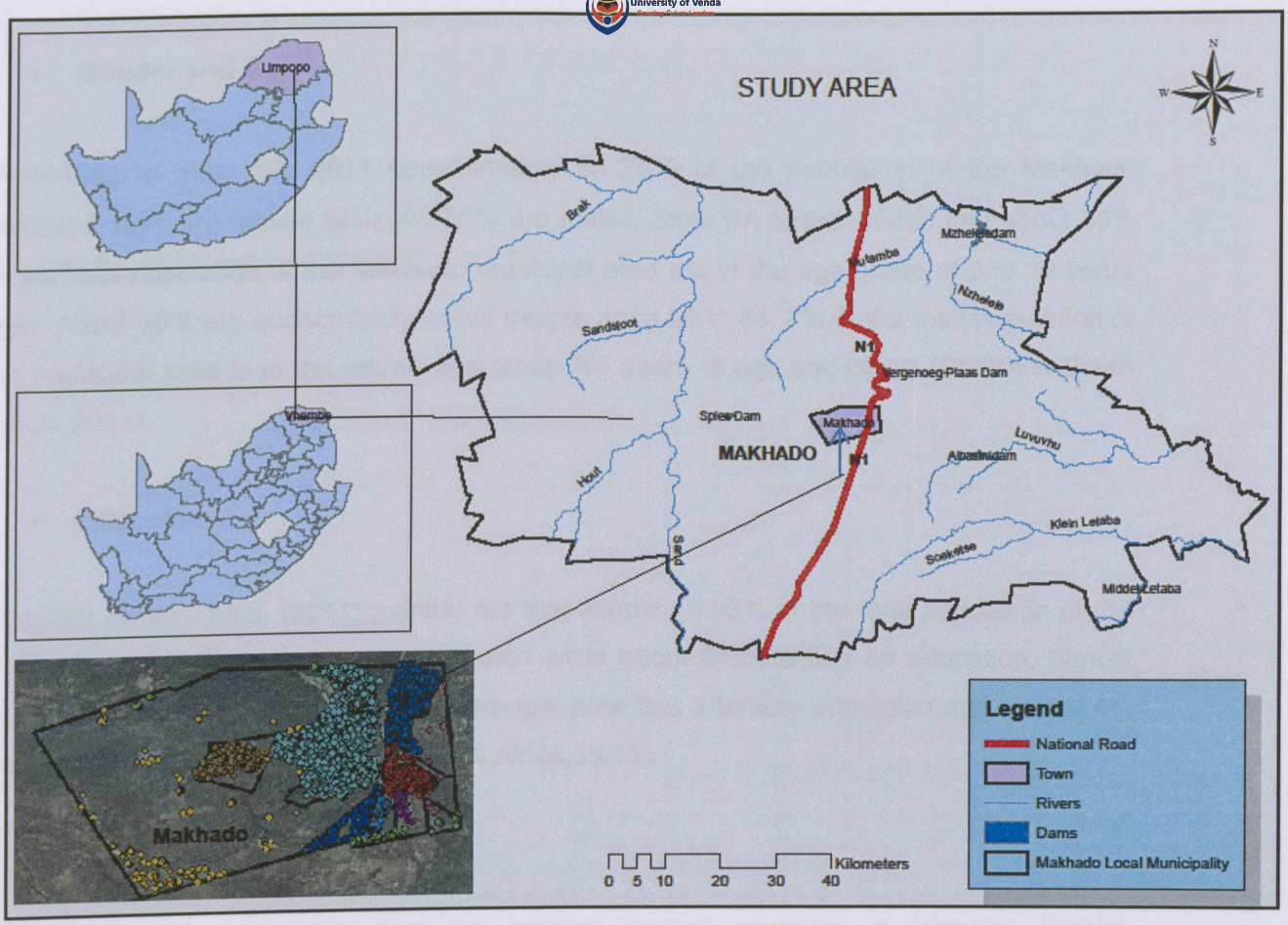


Figure 1.1: Showing Makhado Local Municipality

Source: Author, 2015

- **Climate and Rainfall**

The climate of the Makhado municipal area ranges between 18 degrees Celsius in the mountainous areas to 28 degrees Celsius in the rest of the area, with an average of 25, 5 degrees Celsius. Maximum temperatures usually occur during the month of January while the minimum temperatures usually occur in July (Integrated Development Plan, 2013). Makhado receives its highest rainfall in January to February with an annual rainfall of 450mm in the low-lying plains to 2 300mm in the Soutpansberg. The general average rainfall for the Municipal area ranges between 450mm to 800mm. The areas on the northern part of Soutpansberg have less rainfall than the lower western foothills and central and eastern high lying areas of the mountain itself (Integrated Development Plan, 2013).

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- **Gender and Age**

According to Stats SA, 2011 approximately 54.25% of the population of the Makhado municipal area are female while 45.75% are males. Stats SA further stated that about 35% of the total population of the Makhado municipal area are in the age group of 0 to 19 years age. About 58% are economically active people aged 20 to 64. 7% of the total population of the municipal area is in the retired age group (65 years of age and older) (Statistics South Africa, 2011).

- **Education**

Statistics South Africa, (2011) pointed out that almost 18.93% of the total population of the Makhado municipal area has no education while about 81.07% has an education. Almost 8.93% of the total population of the municipal area has a tertiary education and almost 4% has learning disabilities (Statistics South Africa, 2011).

- **Major economic activities**

Makhado Local municipality has the second biggest economy in Vhembe District. Agricultural activities are most common in Makhado which demand more water than other sectors in the municipality. Makhado Local Municipality currently contributes about R8 billion to the economy of South Africa. It is the second largest contributor to Vhembe District Municipality economy, contributing 37% and only surpassed by Thulamela Municipality which contributes 43%.The municipality is able to produce agricultural products that feed its people. However, some products are marketed throughout the country and even exported. The agricultural sector in the Makhado municipal area is made up of small-scale farmers and commercial farmers.

The small-scale farmers engage in various irrigation schemes that belong to various associations. The area is one of the major producers of Macadamia Nuts in Limpopo Province, with a planted area of 5661.07 hectares and also a major producer of avocados with a total planted area of 3005.65 hectares (Vhembe District Municipality, 2013). The main problem with these irrigation schemes is that they do not function optically and efficiently due to problems ranging from lack of market of capital equipment. Hence, these irrigation schemes require the support of the local government in running their business.

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In traditional rural areas within the villages, the economic sector is relatively small, with only a few local businesses, but a substantial number of people. They usually exhibit a natural growth potential if positively stimulated. The informal sector street trading is one of the most popular business ventures in Makhado, Elim. Most of the products that are sold in the streets are fruit and vegetables. Therefore, agriculture, with the irrigation sector in particular, is the main base of the economy of the region.

- **Water supply**

Vhembe District is a water service authority and provider. The goal of Vhembe District as a water service authority is to supply every household with an adequate and reliable water supply and to manage the water services in an affordable, equitable and sustainable manner. Makhado has a relatively limited supply of both the ground and surface water (Integrated Development Plan 2013).

The area is comprised of few catchments areas which are stressed by high demand of water for development activities such as agriculture, human consumption and mining. In some areas within the municipality boreholes are drying up and the water consumption level at the Air Force Base is extremely high. Many semi-urban settlements in the world, such as Makhado town currently have basic water supply facilities or have access to potable water supply that falls below the minimum quality or quantity standards set by the government (DWAF, 2008). In addition water management in the district faces the challenge of imbalance between the supply and demand for water.

According to Jenkis (2007), the Luvuvhu catchment forms part of the large Limpopo system which flows for about 200 km, into Mozambique. The Luvuvhu River and some of its tributaries, including the Mutshindudi and Mutale River, rise in the Soutpansberg mountains. The Luvuvhu River flows for about 200 km through a diverse range of landscapes before it joins the Limpopo River.

Dams in the Luvuvhu River catchment include the Albasini dam and the smaller Mambedi, Tshakuma, Damani, Vondo, and Phiphidi dams which were constructed around the year 1952. The Department of Water Affairs (DWA), 2013, has identified that the yield of the Albasini dam has deteriorated over the years. As a consequence the dam is over-allocated. However, the Nandoni dam is currently being constructed in the middle section of the eastern part of Luvuvhu River which will feed water to the Albasini dam.

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1.6 The significance and justification of the study

South Africa, like many other countries is facing water crises and by 2030 demand is expected to exceed supply. Inadequate water supply has been identified in the major urban centres, and the department needs, to reach a point where it must invest heavily in the diversification of its water to avert serious water shortages that could impact adversely on our economy (DWAF, 2008). This study is important, mainly because it attempts to help strengthen the existing strategies of water supply; in addition, it comes up with a strategic framework that will enable the municipality to achieve sustainable water supply.

The study will also help contribute to the existing body of knowledge on the existing water situation in the municipality. Access to water was one of the key needs identified by poor communities in 1994, and according to the Water Service act of 2001, it was stated that basic water supply should be a minimum of 25 litres per person per day or 6 kilolitres per household per month within 200 metres of household and effectiveness (DWAF, 2008).

The right to water is also about practical choices such as; the water resource, correct technical choices, building relationships with communities, education and awareness raising, sustainable finances (DWAF, 2008). Therefore, there is a need to look at whether the municipality is providing its residents with basic water and also to identify the institutional arrangements of water supply in the municipality. This study will therefore be very useful to the district as it will also attempt to bring out the relationship between water supply and demand in the municipality which will ultimately guide the regional development practice in the municipality.

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1.7 Organization of the Dissertation

The dissertation is organised around six chapters as follows: This chapter (Chapter one), consists of the introduction, a statement of the research problem, research aim and objectives, delimitation of the study, description of the study area, significance and justification of the study and the conceptual framework. Chapter two is a review of literature relevant to the study. Chapter three entails the research methodology, which includes the research design, sampling method, method of data collection and analysis as well as ethical considerations. Chapter four focuses on the presentation and analysis of the results. Chapter five gives a detailed discussion of the study findings and Chapter six provides the key conclusions and recommendations.

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CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

It is widely recognized that many countries are entering an era of severe water shortage. In general, water supplies in cities are usually supply driven; meaning that whenever there is a water shortage the solution has to rely on the capital investment in new treatment and distribution networks. However, faced with the realities of rapidly growing populations and increasing urbanisation and the increasing scarcity of capital for new water supply development projects, this approach alone is failing to keep up with the increasing demands (UNESCO, 2003).

The scarcity of water resources has brought into focus the urgent need for planned action to manage water resources effectively as it is widely acknowledged that water is a major limiting factor in the socio-economic development of a world with a rapidly expanding population (Vairavamoorthy *et a*l, 2008). Rapid development of science and technology and expansion of economic scale has caused human demand for water to increase. The use of water resources today is unprecedented. Large-scale storage facilities are built by humans. They also dig canals, and transfer inter-basin water by using advanced engineering technology and scientific knowledge. As water resource demand increases, pressure increases on the water supply. Therefore, the water crisis is a "bottleneck" in the flow of a sustained, healthy and coordinated development of South Africa; water security problems have become increasingly prominent.

On the one hand, there are debates on whether policies aimed at reducing water consumption should use price or non-price methods (DWAF, 2013). On the other hand, increase in supply requires several years of planning and large amount of capital investments before the water is available. In light of these challenges, governments are determining strategies that promote water conservation, particularly with residential consumers. Currently, South Africa is using water within 98% of their natural supply's limits. Unfortunately, they are not using it efficiently. In addition, South Africa is also losing over 1.5 billion cubic metres of water a year due to faulty piping infrastructure that has outlived its lifespan (DWAF, 2013).

Ideally, broken pipes would be replaced and updated as necessary; however, funds may not be available to help accomplish this task. This chapter therefore reviews the nature of water demand and consumption, Institutional, technical and operational challenges in water supply, water distribution system including WADISO and EPANET water distribution

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applications. Furthermore, it entailed spatial analysis of household water supply and demand and Strategic framework for achieving sustainable water supply.

2.2 The nature of water demand and consumption

The demand for water among industries and agriculture worldwide is increasing significantly due to population growth and economic development. Freshwater consumption worldwide has doubled since World War II and is expected to increase by 25% by 2030. Agriculture accounts for more than two-thirds of global water use, including as much as 90%, in developing countries (Water Research Commission, 2008).

The world population is expected to increase from 6.6 billion currently to 8 billion by 2030 and over 9 billion by 2050 (Water Research Commission, 2008). Totsuka *et al.*, (2004) pointed out that one of the most common approaches of controlling water demand to cope with inadequate water resources is the use of intermittent supplies by physical cut-off for most of the day and limiting the consumer's ability to collect water. In South Asia it is estimated that at least 350 million people receive service only for period of a few hours daily and nearly all Indian cities are reported to operate intermittent systems.

There are several factors that affect the demand for residential water of households. Some of these factors are income of households, price of water, household size, age and sex composition of the family members and weather variables like temperature and precipitation (Arbues *et al.*, 2003). Families with children could be expected to use more water as children require frequent sanitations, outdoor uses by children and teenagers might be higher, while retired people might have saving and disciplined water use behaviours (Nauges and Thomas, 2000). However, Lyman (1992) found that retired people tend to spend more time at home and do more gardening, which is associated with more water use.

According to the USGS 2015, a female should use 273.07 litres a day, a male should use 164 litres a day, a child should use 161.21 litres and a retired person should use 401.38 litres a day but in India households with a high income are said to consume 250-600 litres a day per person whereas low income households consume 40 litres a day per person, but a universal standard has been put into place by the United Nations of 50 litres of water per person per day which can only be used for personnel hygiene and cooking.

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Table 2.1 shows water use within a household per person per day without considering the standard of 50 litres a day per person. This table 2.1 was derived by the USGS, 2015.

Table 2.1: Average water usage in a typical household per day, USGS (2015)

Water use	Litres/day
Bathing	118
Shower	16
Brushing teeth	3
Hand and face wash	3
Dish washer	53
Dish washing by hand	26
Clothes	82
Washing machine	132
Drinking water	2
Outdoor watering	138
Toilet flush	10

Source: USGS 2015

However, according to the BIS 1172.1993 of India, Vishwanath (2013), the average usage of household water per day is as follows as seen in table 2.2:

Table 2.2: Water usage in a typical household per day, BIS 1172.1993 of India,

Water use	Litres/day
Bathing	55
Toilet-flushing	30
Washing of clothes	20
Washing the house	10
Washing utensils	10
Cooking	5
Drinking	5

Source: Vishwanath (2013).

According to the UNDP (2005), a human being needs 50 litres of water per day in order to prepare meals and personal hygiene. This is necessary in order to avoid diseases and retain efficiency. However, many people in Africa get 20 litres of water a day which is the same quantity of water when having a shower for 1.5 minutes.

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In Germany water consumption per person amounts to 121 litres which is enough for body hygiene, laundry, drinking, toilet and cooking (Safe Drinking Water Foundation).

For drinking and cooking each person needs 5 litres a day. In general many people in the world exist on 10 litres of water a day which is just enough for one toilet flush. Amarasinghe *et al* (2007) study shows that demand for water in India is projected to surpass its availability in some regions of the country demand already exceeds supply. The study further showed that current consumption in the country is approximately 581 trillion litres, with irrigation requirements accounting for most of the water use followed by domestic use. Amarasinghe further pointed out that the rapid increase in population, urbanization and industrialisation have led to a significant increase in water consumption. In the next decade the demand for water is expected to grow by 20% whereby industrial requirements are projected to double from 23.2 trillion litres to 47 trillion litres.

In India the design of water supply systems has been done using certain standards. Currently the standard used is BIS.1172.1993 which was reaffirmed in 1998. A community with a population of 20 000 to 100 000 should get 100 to 150 litres per head per day and a community with a population over 100 000 should get 150-200 litres per head per day.

This study will use the standard set by the constitution of South Africa of 50 litres a day per person, and will also consider the standard set by India, BIS.1172.1993 of 150 litres a day per head as the study is looking at urban areas and urban areas tend to use more water because of their life style and technology. Table 2.3 and 2.4 below gives a guide to average water use based on the number of occupants. It is based on figures provided by Consumer Council Water Use (2015).

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Table 2.3: Average water use based on the number of occupants, Consumer Council Water Use (2015).

Number of People Living at Home	Annual water usage in cubic metres
	Low / Average / High
1	45 / 66 / 100
2	55 / 110 / 136
3	82 / 136 / 175
4	110 / 165 / 210
5	136 / 182 / 245
6	155 / 200 / 265

Table 2.4: Average water use by water metre calculator, Consumer Council Water Use (2015).

Number of people living at home	Annual water usage in cubic metres	Litres per day
1	54	149
2	101	276
3	134	367
4	164	450
5	191	523
6	216	592
7	239	655

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A study carried in California USA confirmed that there was an increase of income and water consumption increased by 3% (Safe Water Drinking Foundation, 2015) whereas Zhou *et al.*, (2000) also found a positive correlation between income and water consumption. Millock and Nauges (2010) also established that the families with high income consumed more water in terms of showering and bathing and they also found that these families own more than one dishwasher.

According to Safe water drinking foundation 2001, Canada a person uses 335 litres a day, Americans use 380 litres a day per person, Israel consumes 280 litres per person a day and Palestine consumes only 60 litres a day per person. Countries like Canada are using ten to twenty more water than is necessary to meet their human needs. In developing countries, 20 to 30 litres of water person per day is considered adequate for basic human needs but in Canada they generally use that amount of water in one or two flashes. Safe water drinking foundation 2001 further pointed out that in Canada on average a person uses 1 420 m^3 of water in year water in year which is equal to the amount that would flow from a kitchen if left running for almost three months.

However according to the safe drinking water foundation 235 litres per person a day is perfectly adequate and this water consumption can be achieved through water conservation measures.
In Canada the high price of water is to encourage them to use less water, on the other hand they are willing to pay more for their water as waterborne illnesses are becoming more common (OEDC, 2001).

The Water Research Commission (2000) also found that increased urbanisation, population growth and living standards have been major drivers in the increase of urban water use in the past century. The amount of urban water use depends on the climate, level and efficiency of public supply services, as well as patterns and habits of water use by the population. The relationship between population and water supply systems has not been balanced for over recent decades, especially in southern countries.

In addition, urban water use is not evenly distributed over time, as households and services tend to demand more water during hot and dry periods. , further showed that seasonal variations in population, due to tourism, influences the amount of water used at a particular time. In western and accession countries, urban households and industries that are connected to public water supply use around 100m3/capita/year.

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South African households use about 250 litres of water a day, that amounts to 7 500 litres a month, which is already more than the monthly free water allowance every household receives from the municipality. South African households consisting of three children and two parents would then use on average 37 500 litres of water a month. Most of the water is used for gardening as seen in figure 2.1.

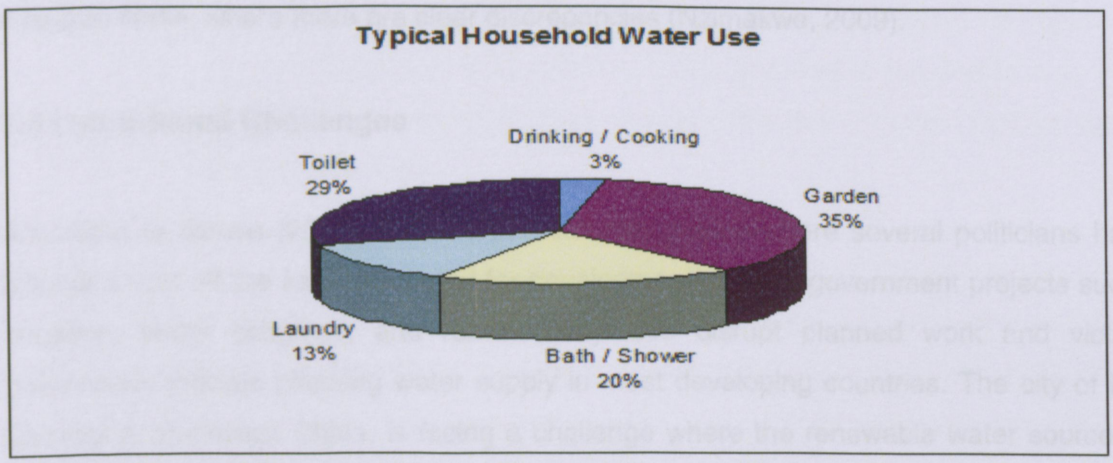


Figure 2.1: Household water consumption in South Africa (Water Research Commission, 2011).

However, previous research by the Department of Water Affairs and Forestry (2004), shows that current population in the country projects that the population will grow to 53 million people in 2025. The implication from a water demand perspective is that the domestic share of water use will shift from the current 27% to between 30% to 35% of the total national use. Urban water demand in South Africa accounts for 96% of urban demand due to the large urban centres present in the country. South Africa and Botswana account for 95% of rural demand in the basin due to the rurally populated nature of both of these countries within the basin (DWAF 2004).

According to Basson *et al* (1997), household water demand in Limpopo province is driven largely by rising income levels and population growth, as well as a national drive to improve basic living conditions. Projections for 2030 indicate that household demand will account for 3.6 billion cubic metres, with the wealthiest population accounting for half of total withdrawals. At the same time, demand from industries such as mining and power generation will be increasingly significant by the year 2030 and the demand could amount to 3.3 billion cubic metres (Basson, 1997).

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The highest urban water demand and population is in the southwest portion of the Limpopo River Basin, in the Crocodile (West) and Marico, which require approximately 80 % of total urban water demand in the four water management authorities. This is mainly because of the urban development in the Johannesburg and Pretoria areas. Despite the formalized legislative measures and comprehensive policy strategies not much has come to the promise of proper water services for all. This is true especially in the rural areas of the poorer province of South Africa, such as Limpopo as well as the Eastern Cape and parts of KwaZulu-Natal, where there are clear discrepancies (Nzimakwe, 2009).

2.3 Institutional Challenges

According to James (2002), there is political interference where several politicians harass officials to cut off the funds allocated for development of large government projects such as irrigation, water schemes, and roads. They also disrupt planned work and victimise government officials affecting water supply in most developing countries. The city of He-Xi Corridor in Northwest China, is facing a challenge where the renewable water sources are insufficient to meet the growing demand due to disrupt planned work and political interference (UNDP, 2005).

Another challenge facing the city is the non-viable and unplanned schemes, for example water supply schemes, which do not have assured water in the source, or which do not have favourable cost benefit ratios, are sometimes taken up for implementation purely for political considerations. Water schemes are announced by politicians and even foundations stones are laid, but there has been no exploration or thinking about the scheme by competent authorities about their feasibility and relevant departmental such as environmental, clearances. Due to political pressure, officials are often forced to implement the schemes, leading to further problems or incompletion, and hence, to a wastage of valuable national resources (UNDP, 2005).

Studies have shown that there is a low quality construction of water schemes due to, institutionalised corruption where contractors pay bribes to get contracts which have led to poor quality construction. These contractors try to reduce the quality of construction for example, in using less than required cement in concrete or substandard materials to make up their profit margins (United Nations, 2005). This leads to dangerous construction, and collapsing structures.

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The study also pointed out that the contractor associations engage in counter tendering. The contractor who gets the bid either shares the profit with the others, or shares the benefit by awarding sub-contracts. In such instances, the awardee will also have to share the profit with local politicians and government officials who are not knowledgeable about the project.

The Constitution of South Africa Act, 108 of 1996, and specifically its Bill of Rights enshrine the basic right of access to sufficient water, as well as a safe and healthy environment (RSA, 1996). Furthermore, the constitution obliges water service providers to meet their constitutional responsibility of providing sufficient water services to the community. If ever this right of access to sufficient water services is compromised it will mean that the rights of the people are being undermined.

The Water Services Act, 108 of 1997, outlines the responsibility of the government departments even more. The Act provides an outlined regulatory framework within which water-related services should be provided. It provides the basic guidelines for the management of the country's water resources (RSA, 1997). The third major piece of current legislation is the National Water Act, 36 of 1998, that delineates how the water resources need to be protected, used, developed, conserved, managed and controlled.

This is primarily guided by two principles of sustainable development and for the benefit of everyone in South Africa (RSA, 1998). Despite the formalized legislative measures and comprehensive policy strategies not much has been implemented for proper water services for all. This is evident especially in the rural areas of the poorer provinces of South Africa, such as Limpopo, the Eastern Cape and parts of KwaZulu-Natal, where there are clear discrepancies (Nzimakwe, 2009).

In view of the above it appears that the there is a serious problem in implementing plans for an effective framework to ensure that the country's water resources are protected, used, developed, managed and controlled in a sustainable and equitable manner (Thompson, 2006). This presents a problem that seems to be prevalent at the level of local government structures and raises issues about the extent to which the municipality is playing its parts to improve local water infrastructure.

A municipality is entitled to charge a consumer for using water and incorrect billing is likely to occur. A water bill can be incorrect for many reasons such as the municipality has not recorded that metres have changed within a premises, and continues to bill the consumer based on estimated charges in relation to a metre that has been removed and replaced by

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another metre. Another common cause of incorrect billing for water charges stems from the city failing to account for the number of households at the property in multi-dwelling settings, (Gladwin, 2015).

2.4 Technical Challenges

Water scarcity is more severe in Africa and the problem does not lie with lack of resources nor precipitation but in water distribution systems. Intermittent systems are designed based on low per capita allocation, but the networks that are designed for a day-long continuous supply scenario become insufficient for this demand and as a result severe pressure losses occur, creating a generally low pressure in the network.

Inequitable distribution of the available water, intermittent systems are generally water starved and consumers try to collect as much water as possible during supply hours (NEERI, 1994). The quantity that is possible to collect is directly related to pressure at the outlets. Since pressures vary greatly in the network, there is a large disparity between the amount collected by consumers in high-pressure areas and those in low-pressure areas.

With regard to water quality deterioration, when the networks are empty and unpressurized for prolonged periods of time, it is possible for the contaminants to enter the pipes through leaks in the supply pipes. The situation is particularly serious in cities with unhygienic disposal where sewage flows in open ditches close to water distribution pipes.
In Delhi, an intermittent supply and the proximity of water and sewage pipelines were the prime suspects of a paratyphoid fever outbreak in 1996 (Yepes *et al*, 2000). In four Indian town districts between 27% and 76% of samples tested positive for faecal coliforms under intermittent supply (NEERI, 1994).

Urban growth, particularly in the developing world, is set to increase dramatically in the coming decades. A decade of literature with data aggregated at the global or national level has shown that water is less available on the African continent than in Europe, Asia, North America or Latin America; that population increases will reduce per capita water availability; and that conflict or cooperation could result as different water users (Johnson *et al*, 2002).

Johnson *et al*, 2002 further stated that the growing cities in Africa and Asia will continue to face worsening water stresses, as urban water users require more energy and water, putting strain on weak infrastructure and delivery systems. Overall, less than a quarter of the households indicated having any problem with the water supply.

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Most complains are centred on the colour and taste of water and the study further showed that 6% indicated irregularity of water supply where water is being cut off as the major problem experienced with the water system.

The residents emphasised the need to be informed of such water cut offs. These comments point out the importance of adequate communication between the water supplier and its customers, because how water supply interruptions are managed and experienced by water users is likely to influence willingness to pay for the service. Another problem related to supply stoppages is that immediately after an interruption, the water tends to be turbid. This forcers water users to let the water run until it clears, which results in a waste of water (Johnson *et al*, 2002).

Residents also face problems such as the metre readings do not correspond with the municipal water report. A resident in Polokwane said: *"I am unemployed and am at home 24 hours a day. I can confirm that in the past six months, the municipality has not taken water metre readings in Westenburg. I also know this because whenever the water metre reader comes, I take the readings with him to ensure he writes the correct readings. No one came recently to take any readings."* (Boksveld Review, 2015)

2.5 Operational Challenges

Totsuka *et al* (2004) stated that the initial estimate based on the Standard Schedule of Rates (SSR) already included a profit margin for the contractors. Rights and allocations have caused a large number of authorized irrigation projects to proceed slowly and hence overshoot their estimated costs due to inflation.

This has not only led to continued hardship to the expected beneficiaries and the frustrations due to unfulfilled expectations, but also to a lack of belief in governmental and political promises.

In South Asia it is estimated that at least 350 million people receive service only for period of a few hours daily and nearly all Indian cities are reported to operate intermittent systems. One of the most common approaches of controlling water demand to cope up with inadequate water resources is the use of intermittent supplies by physically cut-off for most of the day and limiting the consumer's ability to collect water (Totsuka *et al.*, 2004).

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Long delays in implementing planned irrigation projects, a combination of lack of sufficient fund allocation despite of a higher agreed budget and political conflicts over water, a water supply canal project in South India, initially estimated at Rs. 4 crores was hiked to Rs. 30 crores, at the instance of government officials, acting in connivance with local politicians. Rothert (2000) found that the delivery and use of water from many of the existing bulk and retail supply schemes in Namibia are characterised by inadequate operation and maintenance activities and high levels of unaccounted water, inadequate tariffs, and poor billing and collection systems.

This poor water management causes extensive water wastage, creates an incorrect and grossly exaggerated picture of the true demand for water and is impacting negatively on the financial well-being of the service providers operating and maintaining these schemes. It is also often the direct cause of government's failure to supply an adequate water supply to all. Contamination of water is another serious crisis facing municipalities whereby they fail to supply water to their residents because the water is contaminated. In 2002 Peru showed that many municipal drinking water supply systems had high indices of coliform faecal bacteria, and insufficient chlorination of the water, this caused a cut-off of water to the residents because Vibrio cholerae was detected in at least three drinking water supply systems and in river and coastal waters at various places in Peru. Epidemic strains of Vibrio cholerae were also found in rivers in Chile, Mexico, Guatemala and El Salvador.

Despite the potential improved quality of service, financial savings and environmental benefits that would build up from the implementation of the most basic forms of water demand management (WDM), the first remedy to overcome the shortage of water has usually been supplemented to the water supply from a new source (Arlosoroff, 1999). In parallel to this uncontrolled supply of water to high volume users, there is still a large proportion of the population in these countries without access to convenient, reliable and safe basic domestic water supply. Regardless of the endowment of water, this paper will bring forth an argument that residents will still be supplied with inadequate water if the infrastructure is not up to standard or built considering the population size, as the South African government is committed to ensuring that everyone has access to a functioning basic water supply service though this objective has not yet been achieved in all respects.

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2.6 Water distribution systems

Water distribution systems are essential to modern civilization, and their inadequacy places absolute limitations on economic growth, social development and health. The purpose of municipal water delivery systems is to transport potable water from a water treatment facility to residential consumers, for use as drinking water, water for cooking, water for sanitary conditions, and other water uses in a domestic environment (American Water Works Association, 1989). Water supply is also essential for business and industry to operate in a municipal environment.

A water system has two primary requirements: firstly it needs to deliver adequate amounts of water to meet consumer consumption requirements. Secondly, the American Water Works Association (1989), states that water system needs to be reliable; the required amount of water needs to be available 24 hours a day, 365 days a year.

When designing a piped system, the aim is to ensure that there is sufficient pressure at the point of supply to provide an adequate flow to the consumer. For example, in England and Wales, water companies are required to supply water to a single property at a minimum of 10 m head of pressure at the boundary stop tap with a flow rate of 9 l/min (OFWAT, 1999). This minimum pressure increases as the number of properties supplied through a single service pipe increases.

According to Khatri and Vairavamoorthy (2007), urban water authorities and water planners in many countries are facing a challenge to satisfy the growing urban water demands, while at the same time achieving sustainability of the urban water system. It has been shown that conventional approaches to urban water management for providing these essential services are costly, often inefficient, and are not integrated.

Therefore, Khatri and Vairavamoorthy (2007) further pointed out that there is a need to find better ways of improving the urban water systems to enable better sustainability of these systems. In order to identify the potential ways to improve the urban water system, a detailed assessment has to be done. A detailed assessment was done at Alexandria's urban water system using a life cycle assessment; the LCA was carried out using SimaPro software using Eco-Indicator 99, according to ISO-14040-1997, to assess the environmental burdens resulting from the current situation of the system (Masaoud, 2002). This assessment played a vital role in assessing the urban water systems in a holistic way that enables the identification of critical processes and the potential improvements of the system.

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The assessment found that about 68% of Alexandria's urban water system is not sustainable and needs improvement.

According to Nelson (2011), a survey was conducted by the government's urban development ministry in India, which highlighted the failure of officials to improve basic infrastructure to keep up with the pace of the growing population in the country's major cities. The country was found to be focused on 1 405 cities in 12 of India's biggest states, and it was found that over 700 had a water supply management system. Nelson, (2011) also pointed out that while half the cities were without water, four in five had water for less than five hours per day.

In Maharashtra, one of India's wealthiest states and home of the country's financial capital Mumbai, only two of 249 towns and cities had an uninterrupted water supply while most had no drainage system. In Karnataka, only half of 52 towns were served by a sewerage system, while in Andhra Pradesh, 86 of 124 towns had neither sewerage systems nor running water. According to the United Nations and World Water Assessment Programme (2003), 64% of the African population have access to treated water supply; In addition this region has the lowest proportional coverage in the world. The situation is most dreadful in rural areas, where coverage is only 50% compared with 86% in urban areas.

Therefore the United Nations, (2003) stated that there is a need for urgent development of infrastructure in Africa, and any technique which enables this to be done more easily, more reliably, and at a lower cost, is worth earnest consideration. However, they further stated that the first step to improving global water security is improving water access in regions that are the most water scarce and densely populated.

South Africa has a population of 51 million people with 60% living in urban environments and 40% living in rural settlements. Due to lack of water infrastructure in the rural settlements, 74% rely on groundwater. However, water resources in South Africa are comprised of three sources; namely, surface water (77%), return flows (14%) and groundwater (9%). There is a 98% assurance level, which suggests that in the future demand will exceed supply, and this is a source of vulnerability that needs to be addressed in the country (Jacobs *et al*, 2004).

The Water Sector Department of South Africa is aware of the irregularities of the water distribution systems in the country, where people reside adjacent to water sources and yet have no access to the water (Jacobs *et al*, 2004). Jacobs *et al.,* (2004), further pointed out that a balance needs to be struck between large and small-scale infrastructure projects in

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the country, where a community can be serviced by existing large-scale infrastructure. Where a community cannot be serviced by a large-scale infrastructure project due to the cost of such an intervention, then small-scale schemes must be planned and implemented.

Limpopo Province has a water service delivery system which is performed by eleven water services authorities in Limpopo via 64 drinking water supply systems. The main water service providers in Limpopo are Magalies and Lepelle Northern Water. These water services abstract and treat raw water and supply it in bulk to the municipal networks (Boroto, 2011). A total design capacity of 803.4 is available for drinking water supply in Limpopo Province and the distribution of drinking water takes place via 64 supply systems.

Boroto's (2011), study showed that 64 systems were assessed during the 2010 and 2011 assessment cycles. During the assessment it was found that smaller systems have collapsed into centralised systems and larger systems have been divided into various smaller supply systems. The Department is tracking these changes attentively to ensure that all systems are continuously being monitored. Municipal drinking water quality management in Limpopo varies from excellent to unsatisfactory, while 28% of the systems need urgent attention as seen in figure 2.2. The overall business of drinking water supply and quality management in the province is not up to standard as yet, although pockets of excellence are certainly evident.

All communities should have access to at least a minimum level of services. This is not a goal but a constitutional obligation. The imbalances that still exist regarding equal access to water services should be addressed through the development of new infrastructure and refurbish existing infrastructure (Bekink, 2006). Demand and supply water simulations models would help in this regards.

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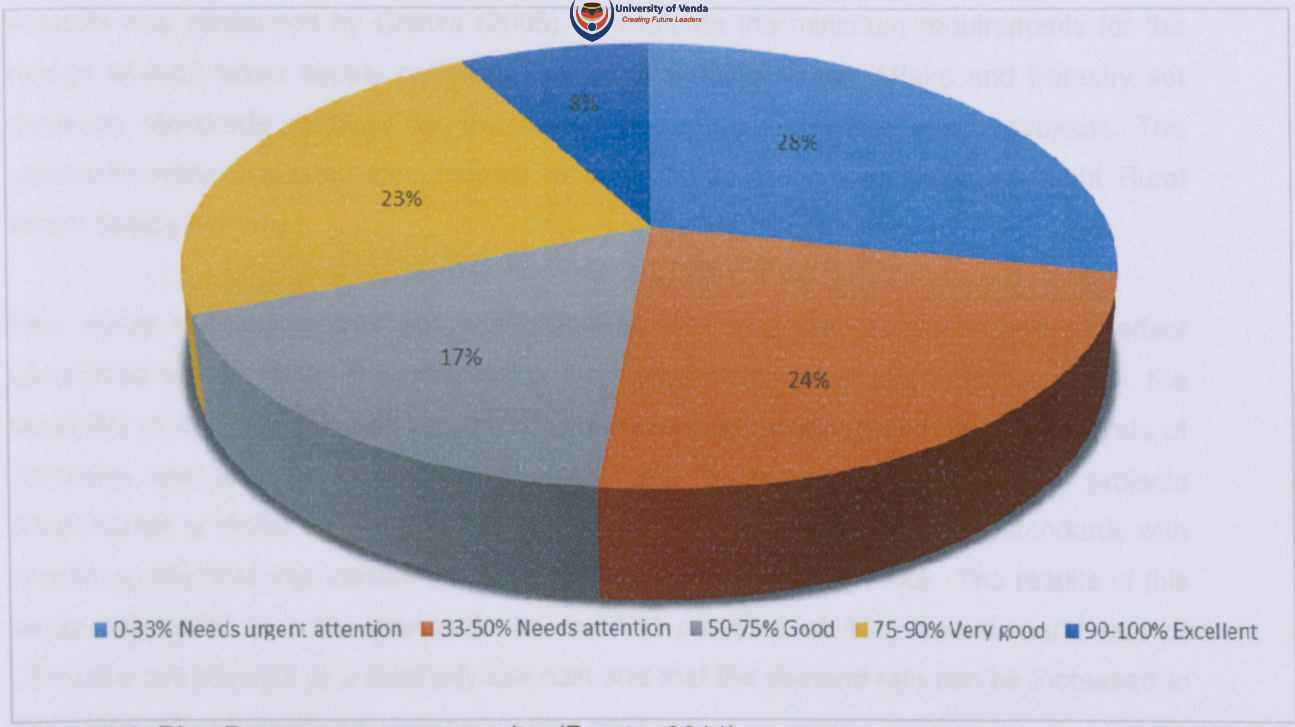


Figure 2.2: Blue Drop assessment results, (Boroto, 2011)

2.7 Water simulation models

Water distribution networks play an important role in modern societies and the operation being directly related to the population's well-being. However, to guarantee good service levels in a sustainable way the water supply systems performance must be evaluated and different models can be incorporated to achieve this (Farley, 2003).

2.7.1 WADISO application

According to the GLS engineering software, WADISO is a comprehensive application built for the analysis and optimal design of water distribution systems. The programme performs steady state and time simulation analysis, with the capability to optimise pipe, pump and tank sizes for planning purposes, as well as water quality modelling.

The programme originated from the WADISO public domain model developed by Prof. Johannes Gessler of Colorado State University for the army corps of engineers. The basic WADISO was substantially improved by the South African-based software development company responsible for development and support of WADISO in South Africa. The improvements were in regard with: friendliness and speed as well as interfacing with other application software such as water quality analysis. WADISO now includes a seamless interface to the public domain EPANET programme module for all modelling aspects.

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A study was conducted by Chirwa (2005), to investigate the minimum requirements for the design of rural water supply projects. The Department of Water Affairs and Forestry set minimum standards required for the design of rural piped water supply projects. The standards were evaluated with respect to capital pipe cost using Nooightgedacht Rural Water Supply scheme.

This study considered that the application of the minimum standards has an effect associated with the cost. The main aim of the study was to investigate in terms of cost, the feasibility of applying the minimum standards on residual pressure of 10m, demand rate of 25l/c/day, and abstraction rate of 10/l/min in the design of rural water supply projects (Department of Water Affairs and Forestry, 2003). Analysis of the minimum standards with respect to the cost was calculated using WADISO SA as a design tool. The results of this study suggested that the standards on residual pressure of 10m and demand rate of 25/l/c/day are feasible at a relatively low cost and that the demand rate can be increased to 50/l/c/day without significant increase in pipe cost.

The standard on abstraction rate of 10l/min showed that it is too high to be achieved at a relatively low capital cost. However, it was further found that high costs can be overcome with the use of non-site storage tanks which can be used to meet the standards of 10l/min. The introduction of on-site storage tank resulted in the residual pressure of 10m not being available to the user at the tap but will nonetheless be available at the connection point, which could be utilised for upgrading at a later stage.

2.7.2 EPANET APPLICATION

EPANET is a computer programme developed by the United States Environmental Protection Agency's that performs extended period simulation of hydraulic and water quality behaviour within pressurised pipe networks. A network consists of pipes, nodes (pipe junctions), pumps, valves and storage tanks or reservoirs.

EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of chemical species throughout the network during a simulation period comprised of multiple time steps. In addition to chemical species, water age and source tracing can also be simulated (Rossman, 2000).

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EPANET is designed to be a research tool for improving the agency understanding of the movement and fate of drinking water constituents within distribution systems. It can be used for many different kinds of applications in the distribution systems analysis. Sampling programme design, hydraulic model calibration, chlorine residual analysis, and consumer exposure assessment are some examples. EPANET can help assess alternative management strategies for improving water quality throughout a system. In addition, EPANET assumes that all pipes are full at all times (Rossman, 2000). EPANET views the water distribution system as a network containing nodes and links, where the nodes are connected by links. Figure 2.3 illustrates a node-link representation of a simple water distribution network.

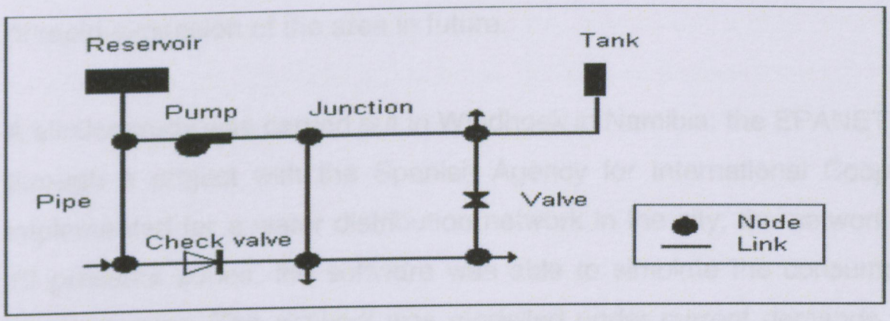


Figure 2.3: Physical components of a water distribution system (Rossman, 2000).

A study was conducted by Arunkumar and Mariappan (2011), for water demand analysis of public water supply in municipalities in India using EPANET 2.0 software. The aim was to provide effective planning, development and operation of water supply and distribution networks, which is one of the most essential components of urban infrastructure. A number of factors, ranging from population expansion to inadequate existing facilities, are believed to be responsible for the frequent shortage in water supply to the metropolis. The study delineated the areas within the municipality that are un-served and under-served by the municipality.

Using the EPANET 2.0 water model software, the demand for the under-served and un-served area was calculated. A framework for taking management decisions such as an extension of the supply network and location of new facilities was given. During the analysis, it was found that the system showed a negative pressure while running the same network for intermittent supply. The Chennai and Avadi Municipal Water Supply and Sewerage Board are concerned that they are not providing water for 24 hours to their consumers.

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According to Wagner *et al* (1988), a study was carried out in India using the EPANET software in the design of the N.D.A water distribution network. This study was used to carry out the hydraulic analysis of the distribution network in the study area. The results obtained, verified that the pressures at all junctions and the flows with their velocities at all pipes are feasible enough to provide adequate water to the network of the study area.

In addition, the following situation was observed in the distribution pipeline network, which in future can cause inadequate supply of water to the area. It was observed that the pipes connected to the tanks as distribution pipes to the other pipes have smaller diametres. It was observed that the network on the topographical map does not have a wider coverage of water distribution to some parts of the area; this as well, can cause a water crisis as a result of rapid expansion of the area in future.

A similar study was carried out in Windhoek in Namibia, the EPANET software was acquired through a project with the Spanish Agency for International Cooperation. EPANET was implemented for a water distribution network in the city; the network was been divided into 12 pressure zones, the software was able to simulate the consumption patterns for each pressure zone. The network was modelled under current demands. The peak demand for the entire distribution system was simulated for future demands predictions (Brinkman *et al*, 2004).

Adeniran and Oyelowo (2013) conducted an empirical analysis of the water distribution network at the University Of Lagos, Nigeria using EPANET. The current conditions of water supply and distribution at the University of Lagos were examined. It was found that the network of the University was designed and constructed in 1982, when the population was about 12 000. The current population of the University is around 85 000 while there is no significant improvement made in water distribution network.

The pressures at the nodes are generally low and the quantity of water flowing in some pipes is inadequate. A major defect in the network is the fact that Tank No. 1, which is the biggest and at the highest elevation, is not being put to optimum use currently. The analysis concluded that the performance of the existing distribution network is inefficient and recommends appropriate improvement.

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At the city of Mutare a study was carried out by Marunga and Hoko *et al* (2005) using EPANET 2.0 to model the pressure distribution within the zones of different supply flow and pressure patterns obtained by varying pressure. Nodal elevations were estimated from contoured layouts. The base demand from the nodes was calculated basing on a consumption of $1m^3$ per stand per day. The researcher also determined the minimum PRV pressure using EPANET to ensure that a minimum residual pressure of 10m is maintained in the system for peak hourly flows.

The demand pattern was obtained from logged flow data. The results of the study showed that a negative pressure was obtained at the highest node whilst the lowest node had a pressure of 21.66m at a PRV setting of 30m. The study further showed that to ensure an acceptable minimum pressure it should be between 40m and 50m; however, for the actual modelled results, 50m was found to be the minimum pressure which gives a residual head of more than 10m at a peak hourly flow of 25 litres per second.

EPANET was used at Yeoville water supply system in Johannesburg by Van Zly and Haarhoff (2007). The main aim of the study was to investigate the reliability of the Yeoville reservoirs under various conditions. Various performance measures were calculated for the different reservoir capacities, including the number of pipe failures and the behaviour of consumer demand using the public domain software EPANET. Pipe failures were implemented by closing and opening pipes using EPANET controls. The study found that the reservoir capacities of 20 Ml (4, 7 h AADD) and 30 Ml (7 h AADD), average down times are 18 minutes per annum (2, 2 hours every 7, 3 years) and 5 minutes per annum (1, 2 hours every 14, 5 years) respectively.

This increase in reliability was partly due to a reduction in the average failure duration, but mainly due to a significant reduction in the failure frequency. It is clear that the current reservoir capacity of 106 Ml will provide a high level of reliability although at 25 hours of AADD it is considerably smaller than the South African design guideline requirement of 48 hours of AADD. These results have shown that the reservoir's reliability is good, even though it is significantly smaller than the South African design guidelines require.

In this study EPANET will be used to analyse the current water system, the analysis will be based on the junctions, pipe length and reservoir as it is the information available. The junctions will take elevation and demand into account, pipes will take length, diametre and roughness into account and the reservoir will take the total head into account.

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The results will be based on pressure at each junction and the flow and velocity in each pipe. The size of the pipe diametre will be taken into account.

2.8 Spatial analysis of household water supply and demand

A spatial analysis of household water supply capacity and demand was conducted in the towns of Amherst and Clarence, New York, 2007. Spatial network models were constructed in Geography Information Systems (GIS) for simulations.

Baseline data of household water consumption per person per day, population distribution, and transportation capacity of water main utility lines were collected for the model simulation (Amherst Industrial Development Agency, 2005). The results indicated that as the network extended eastward, to southeast part of Amherst and three of the four sub-regions in the Town of Clarence it encountered the discrepancy of supply capacity in meeting the accumulated household water demand as seen in figure 2.4.

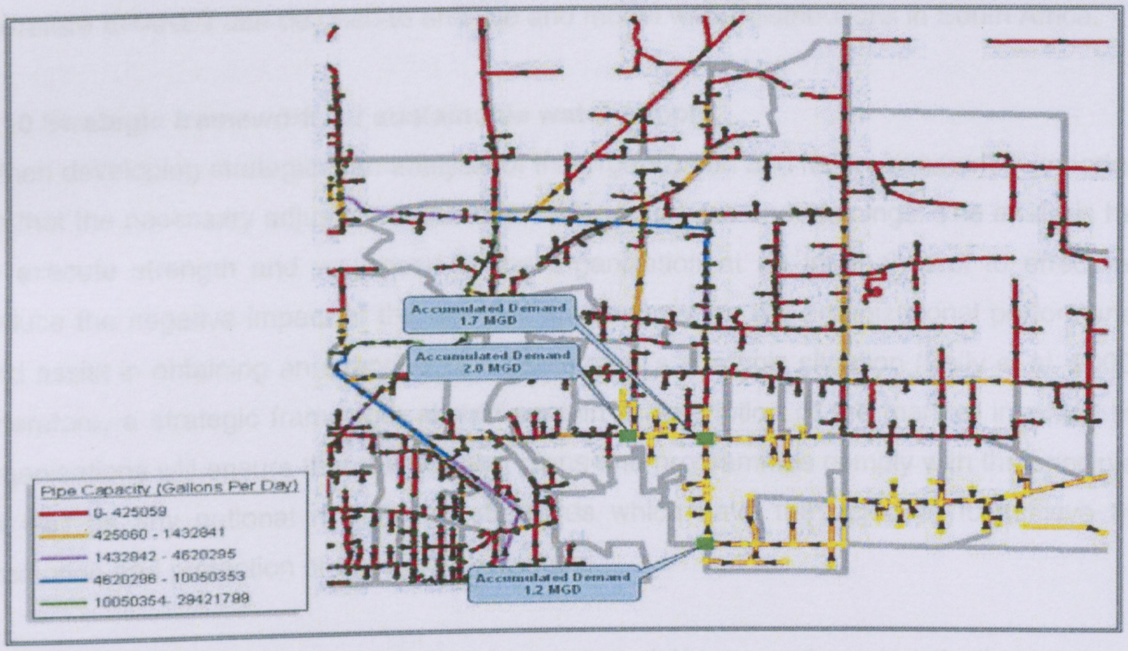


Figure 2.4: Spatial simulation of household water demand in Southeast Amherst, (2001).

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2.9 Justification for the use of EPANET

EPANET will be adopted in this research because it can be used for general public and educational use and it is available free on-line, whereas with WASIDO SA the installation of 1 000 pipes and 1 000 nodes is US$ 3500. EPANET is not only free but it requires relatively small computer space of 2 megabites to operate and has unlimited number of pipes that can be analysed. Secondly unlike WADISO SA, 100 megabites are needed for operation and the calculation capacity is limited. EPANET has become a popular tool for analysing simple and complex water distribution networks in both developed and developing countries.

The simulation capabilities of EPANET have been used by both researchers and professionals in the design, operations and improvement of several water network distribution systems. EPANET will be used to analyse the existing municipal drinking water distribution network of the Makhado town and recommendations and improvements will be based on the output of the analysis. Lastly WADISO SA now includes a seamless interface to the public domain Finally, the EPANET programme module for all modelling aspects therefore EPANET can be used to analyse and model water distributions in South Africa.

2.10 Strategic framework for sustainable water supply

When developing strategies, an analysis of the organization and its environment is important so that the necessary adjustments can be made to address shortcomings. The analysis has to execute strength and weakness of the organization at an internal level to effectively reduce the negative impact of the external environment on the organizational performance and assist in obtaining an overview of a department's strategic situation (Baily et al, 2000). Therefore, a strategic framework should contain a description of the manner in which the organisations will ensure that the policies, plans and programmes comply with the principles as well as any national norms and standards which have the objective to achieve the promotion and protection of the water resources.

Strength refers to what the institution is good at doing or a characteristic that gives an important capability. The organization's strengths are important because they can be used as the cornerstones of strategy and basis on which to build a competitive advantage. A good strategy needs to aim at reduction of organization's vulnerability.

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In the municipality the strengths can relate to resources, skills, competence, capability, political stability, economic growth, sound revenue base, approved programmes and policies, good governance. Weakness refers to something the organization lacks or does poorly, or conditions that put it at a disadvantage (Baily *et al.*, 2000).

Opportunity reflects a possible change in the world outside an organization's immediate environment. Opportunities should typically improve its prospects to achieve specific goals. They need to be utilized because they are important avenues for growth and have a potential for securing competitive advantages.
Threat relates to an unfavourable situation which threatens the ability of the organization to compete or to meet its needs. Good strategies are aimed at grasping the organization's best growth opportunities and creating a defence against threats to its competitive position (Baily *et al.*, 2005).

According to Sarté (2006), careful water management and planning is essential for sustainable in the phase of population growth as well as decreasing and deteriorating local groundwater supplies, in Loreto a town found in California, Mexico. This requires a consideration a range of possibilities, including supply side options to augment existing potable sources, and demand side alternatives to reduce the amount of water drawn from the aquifer. A decision support framework can facilitate a universal approach to identifying and planning for implementation of the most appropriate solutions.

To develop the means for ensuring sustainability, a dynamic multi-criteria analytical (MCA) framework is employed in order to structure and inform water management decision-making, as seen in Figure 2.5, and propose an approach for effective implementation. This framework will be useful in this study as it can guide the Makhado Local Municipality in developing a framework as it don't have a strategic framework to achieve sustainable water supply.

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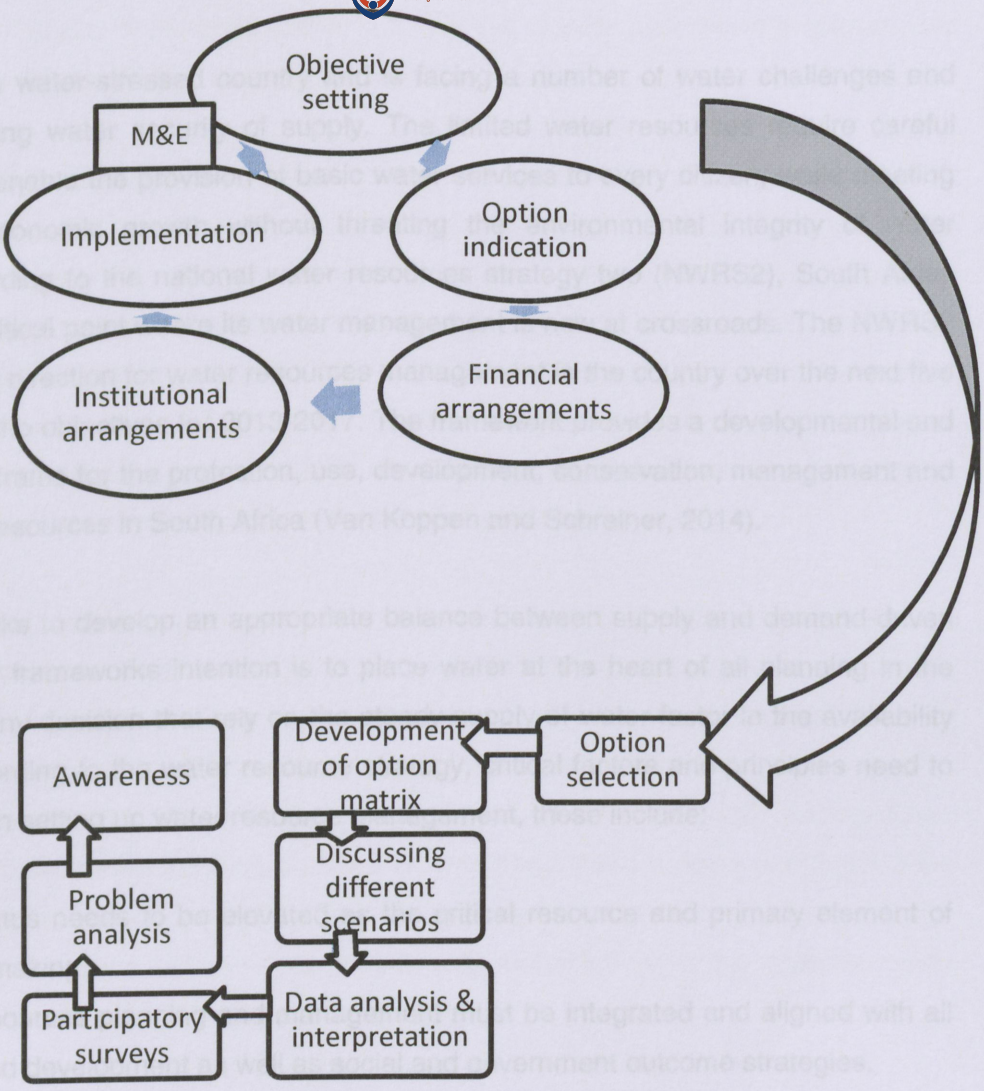


Figure 2.5: Framework implemented in Loreto for sustainable Water Supply (Sarté, 2006)

The city of Windhoek in Namibia adopted an integrated water demand management strategy in 1994 and in the same year started the implementation. The strategy includes policy issues, legislation, technical Issues, public education and awareness programmes (Held *et al.*, 2000).

The city of Windhoek later developed a billing system for all households that utilise the municipal services. It was mainly meant for billing services, providing statements and for debt collection. However, this programme was not flexible enough, later the Metreman software package was purchased to improve the management of the water metre inventory and to start a metre replacement programme. Various reports can now be generated which include; the highest consumers, query list for maintenance of metres.

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South Africa is a water-stressed country and is facing a number of water challenges and concerns, including water security of supply. The limited water resources require careful management to enable the provision of basic water services to every citizen, while meeting the needs of economic growth without threating the environmental integrity of water resources. According to the national water resources strategy two (NWRS2), South Africa has reached a critical point where its water management is now at crossroads. The NWRS2 sets the strategic direction for water resources management in the country over the next five years guided by the objectives for 2013-2017. The framework provides a developmental and transformational frame for the protection, use, development, conservation, management and control of water resources in South Africa (Van Koppen and Schreiner, 2014).

The NWRS2 seeks to develop an appropriate balance between supply and demand-driven approaches. The frameworks intention is to place water at the heart of all planning in the country so that any decision that rely on the steady supply of water factor in the availability adequately. According to the water resource strategy, critical factors and principles need to be identified when setting up water resource management, these include:

- Water status needs to be elevated as the critical resource and primary element of decision making.
- Water resources planning and management must be integrated and aligned with all growth and development as well as social and government outcome strategies.
- Water is everybody's business. Water management requires active water sector involvement, accountability, commitment and ownership. It will require effective partnerships and teams.
- Water management is a complex business which requires improved sector management, governance, control, co-ordination and leadership.
- Water is not only a technical business. It also needs to include business principles and approaches such as sustainable management, financial management, service delivery and customer care, institutional arrangements, communication and continuous tactical and strategic planning.
- A priority is to invest in people and associated skills and capacity building – from the public to national government.
- Improved water sector knowledge, research, monitoring and evaluation are key aspects of the extended business.
- The issue of water security has put new emphasis on the concepts "value chain" and "life cycle". In the planning and the provisioning of water, the challenge in many

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cases is not just a resource issue but rather a supply and delivery issue. This requires holistic and integrated management and governance.

According to the National Water Resource Strategy of 2004, South Africa also interacts with a number of African countries outside the SADC region, and with countries elsewhere in the world, to develop partnership in water management matters that could be of mutual benefit. The main objective of these interactions include the promotion and advancement of the new partnership for Africa's development (NEPAD). A number of water resources practitioners from other countries have worked with the department in terms of training and technical assistance. The organisation stated that it will continue to seek assistance from other countries to achieve its goals of equity and sustainability in water management.

There are existing policies and legislation of government that urge municipalities to implement water service programmes. The municipalities need to act in accordance with government policies and legislation to establish structures needed at the local level to support and implement comprehensive strategies. In recognition of the water demand of communities in South Africa, a continual supply is entrusted to all local municipalities. Therefore to what extent are the municipalities incorporating these policies and legislations because if the municipalities are not acting pro-actively in implementing effective water resource strategies, they will almost certainly fail to respond effectively to the water demands and the community will certainly lose confidence in them.

Due to costs and inefficiencies in government, Mission 2017 believes that the time it would take to replace all the necessary pipes and water infrastructure could be greatly reduced if the private sector helped with the repairs through PPP's. In this strategy, the South African government would give out several small contracts to local construction companies and have each company replace the pipes in a given region. To ensure that the pipes are replaced quickly incentives can be used that allow the government to pay the company less if they finish beyond a given deadline. With multiple groups working on the project and each group having a small region, the pipes would be replaced faster.

South Africa will face serious water problems if steps are not taken to increase the country's efficiency of water use or ability to distribute water to its people. Mission 2017 on global water security believes that the solutions outlined above, including the use of water metres and truck delivery routes, will greatly reduce the amount of water being wasted or lost.

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Though this particular composition of solutions may be unique to South Africa, there are several other countries around the globe that are suffering from similar or related issues to the same or worse extents. Mission 2017 believes it can combat the water issues of any given country by applying the appropriate combination and scale of their solutions.

2.11 Conceptual Framework

The conceptual framework shows that water demand exceeds water consumption in the Makhado Local Municipality. In addition many of the urban infrastructures, such as water mains, streets, sewer lines, were planned and constructed based on the population distribution and economic development at the time of establishment. Consequently, the infrastructures may encounter stress or potential stress as the impact of spatial patterns of population distribution and economic development change with time. In light of this, it is very important that the water service providers evaluate their water distribution networks related to current population and examine how effective their roles and responsibilities as water providers are being played. If the outcome of the evaluation shows that the available infrastructure is not sufficient for the current population, then the lever will tilt towards the water demand and this situation will show that the environment is unsustainable. When water consumption is greater than water demand the lever tilts towards water consumption and this will show that the environment is sustainable, showing that the Vhembe District can supply it residents with sufficient water on a daily basis.

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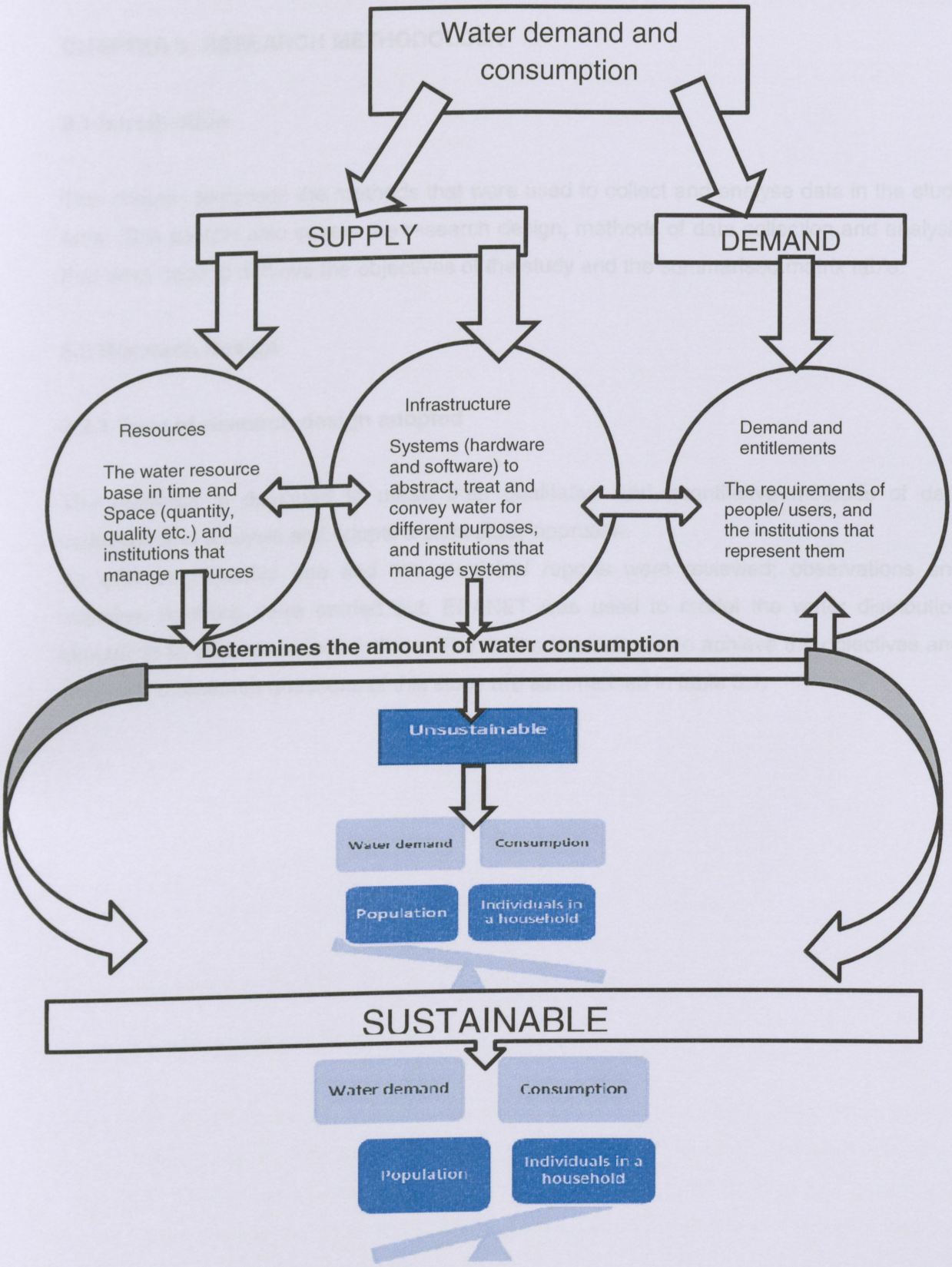


Figure 2.6 : Conceptual framework

Source: Researcher, 2014

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CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses the methods that were used to collect and analyse data in the study area. This section also covers the research design, methods of data collection and analysis that were used to achieve the objectives of the study and the summarised matrix table.

3.2 Research Design

3.2.1 Type of research design adopted

The research is designed to utilise both qualitative and quantitative methods of data collection and analysis and adopts a case study approach.

To address objective one and two municipal reports were reviewed; observations and interview methods were carried out. EPANET was used to model the water distribution simulation to address objective three. The methods employed to achieve the objectives and answer the research questions of this study are summarised in table 3.1.

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Table 3.1: Summary of Research Questions, Methods and Procedures, Unit of Analysis and Data Analysis.

Research question	Methods and procedures	Unit of analysis	Data analysis
What are the salient characteristics of water demand and consumption in Makhado Local Municipality?	Questionnaires and Census 2011 data Metre readings Calculation by Grag	Households	SPSS GIS
What are the operational, technical and institutional water supply challenges facing Makhdo Local Municipality?	Interviews Review Municipal reports Observations	Municipal water manager Makhado Local Municipality Water sources, leakages, services areas	SPSS Content analysis Visual analysis and ground truthing
How best can EPANET be applied in order to assess urban water distribution systems in Makhado Local Municipality?	Run an Epanet Model	Water distribution system	EPANET

3.2.2 Sampling procedure

- **Research Target Population**

The study was conducted in Makhado Municipality covering four urban areas; which include New Town, Old town, Eltivilas and Makhado Park which all fall under the Makhado town. This study focused on Makhado Town, as it is the political, administrative and commercial area in the municipality. To address objective one, two and four the unit analysis was the water managers within the Municipality.

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The relationship between water demand and consumption and objective three the unit analysis was the Households within Makhado New Town (922) and it was selected purposively because the data was available and reliable. The Questionnaires were administered to adults only preferably the head of the household.

- **Sampling Method**

Purposive sampling was used to identify the relevant officials which are officials within the water sector. The main goal of purposive sampling is to focus on particular characteristics of a population that are of interest, which will able to answer the research questions. According to Black (2004), systematic sampling is a statistical method involving the selection of elements from an ordered sampling frame. The most common form of systematic sampling is an equal-probability method. Systematic sampling starts by selecting an element from the list at random and then every k^{th} element in the frame is selected. Using this procedure each element in the population has a known and equal probability of selection. The researcher used this method to obtain a sample interval of the households where the questionnaires were be administrated.

This is calculated as follows:

K= N/n

where *n* is the sample size,

and *N* is the population size.

K= 922/129

K=7

- **Sample size and Sampling frame**

According to McDaniel and Gates (2010), a sample size is a representation of a group or subset of all the members of a population of interest, while sampling is a process of obtaining information from a subset of a large group. A sampling frame is a list of study cases in a population, or the best estimation of them. White (2003) offers the following table as an indication of what the size of a sample ought to be for any scientific social research (Table 3.2). The Household count in New Town is 922 therefore guided by white's table the researcher took 14% of the households in order to get a sample size.

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Table 3.2: Statistical rules used for indicating the sample size of the study Source: (White, 2003)

Population size	Percentage suggested	Number of respondents
20	100%	20
30	80%	24
50	64%	32
100	45%	45
200	32%	64
500	20%	100
1000	14%	140
10 000	4.5%	450
100 000	2%	2000
200 000	1%	2000

Table 3.3: The study population sample, Source: Author, (2015).

	Makhado New Town
Household size	922
% of household sampled	14%
Sample size	129

Steps in selecting a systematic random sample:

- Calculate the sampling interval (the number of households in the population divided by the number of households needed for the sample)
- Select a random start between 1 and sampling interval
- Repeatedly add sampling interval to select subsequent households

Table 3.4: The sample interval, Source: Author, (2015).

	Makhado New Town
Household size	922
Sample size	129
Sample interval	7

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From the table 3.4, the following can be interpreted; Makhado New Town has 922 households, a sample size of 129 and sample interval of 7 which means in every 7th house a questionnaire will be administered. In a case there was no one available the researcher would pay a visit again.

3.2.3 Ethical Considerations

Ethical considerations were duly followed and permission sought and obtained before visiting the field. Permission was obtained from the corporate service section at Vhembe District. The purpose of the study was explained to the General Manager of corporate services that issued the letter gave permission to conduct field work in Makhado Local Municipality Consent forms were also administered and fully explained to the participants. The participants were also informed that they were free to withdraw from participation when they felt the need to do so.

3.3 Data collection

3.3.1 Research data collection techniques

In order to address the study objectives, the following instruments were used to collect the required research data.

3.3.2. Self-administered Questionnaire

According to Lancaster, (2005), the importance of the interviews is that the participants describe the conditions under which they actually live. The researcher can base the results on the opinions of the participants having personal experience. Self-administered surveys are a good choice for this research because they reduced the chance of being biased. The intention of the structured questions determined the nature of water demand and consumption in Makhado urban areas. The structured questions looked at aspects such as how much water is demanded by the residents and how much water they consume.

A systematic sampling method was used in order to obtain the households in which questionnaires were administrated. A sample interval was obtained by dividing the number of households where questionnaires were administrated by the total number of households. The interviews with the participants were translated and transcribed. According to Collis and Hussey (2003), in-depth information can fruitfully be derived from structured interviews and probing.

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3.3.3 Calculating the actual water consumption and demand

Derived data sets ware used to measure the selected individual use of water using existing metre readings.

According to Grag, 2011 the actual water consumption is calculated as follows;

Household average consumption = (Maximum rate of daily water consumption) × (by number of people in the household), where the average daily water consumption per person is calculated as:

(Monthly water consumption) ÷ (no days in a month) ÷ (no of people in the household)

The amount of daily water consumption was obtained from the municipality as they record metre readings of every household every month. In order to get a wider overview of the actual consumption, a survey was done for two months. This calculation helped the researcher to identify whether the residents are being provided with the minimum water provision of 100 litres a day per person and also relate the consumption with India's BIS 1172.1993 Standard of 150 litres a day per person

.

For the purpose stated above, 100 litres was used as a demand constant value for the entire town. The 100 litres was chosen because the constitution requires water service providers to meet their constitutional responsibility to provide sufficient water services to the community, whereby each person is entitled to 100 litres per day. Therefore the 100 litres was used as a demand constant factor. The same was done with the Indian's standard of 150 litres a day per person. The Standard of 150 litres a day was chosen because this study is looking at an urban area and such areas tend to use more water due to their life style and technologies within their households.

Other standards from UN, USGS and Germany was also considered. This calculation was able portray the relationship between demand and consumption and also to see whether demand exceeds consumption or vice versa.

In this study water demand was calculated as follows:

WD = Population*demand value

Municipality average Demand = (Constant demand value (100/150 litres) × (by total population)/1000000 (mega litres)

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Town average demand = (Constant demand value (100/150 litres) × (by total population)/1000000 (mega litres)

Household average Demand = (Constant demand value (100/150 litres) × (by number of people in the household).

3.3.4 Key Informant Interview

This study conducted key informant interviews, which involved an open discussion with individuals who were very knowledgeable about the research problem. This included officials from the Vhembe District as they are the water services providers. Purposive sampling was used to identify the relevant officials.

The main goal of purposive sampling was to focus on particular characteristics of a population that were of interest, which would able to answer the research questions. They provided in-depth information on the water sources and challenges facing the municipality in supplying its water. The managers were asked to elaborate more on the service areas and water distribution systems in the district and the researcher requested a reticulation network to verify the description of the water systems.

The researcher recorded minutes and also used a tape recorder to capture the information. Diagrams were drawn in order to have a clear overview of the distribution systems. This allowed the researcher to develop a water coverage diagram with its distribution networks. According to Lancaster, (2005) basic interviewing is one of the important techniques for collecting data. The method of asking questions and getting answers is acknowledged as being one of the most effective ways of collecting data.

3.3.5 Application of EPANET

The EPANET 2 toolkit (Rossman, 2000) is a powerful package used to solve many research and industrial problems in the field of water distribution systems. EPANET was used to model simulation water distribution and improve the understanding of the movement of water within the municipality.

EPANET was also used to track the flow of water in each pipe, the pressure at each node. In order to carry out the analysis and simulation of the municipal water distribution network, the following information was obtained from the records of the various units and departments of the municipality as seen in table 3.5.

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Table 3.5: Data needed for the water distribution network analysis

TYPE OF DATA	SOURCE
Population data	Stats SA
Water supply records (2014)	Municipality
General layout map of the municipality	Municipality
Existing water distribution layout map	Municipality and water affairs

To model the water distribution system a basic description of the network on how the system works was modelled. A hydraulic analysis will then be run to view the results. The description of the network will be in the following format as seen in table 3.6.

Table 3.6: Showing the description of a water distribution system

Input	Out put
Junction • Elevation(m) • Demand • Initial quality (If looking at water quality) Pipe • Length (m) • Diametre (mm) • Roughness(mm)	Junction • Pressure(m) Pipe • Flow (l/s) • Velocity(m/s) • Head loss
Reservoir • Total Head(m)	Reservoir • Net flow (l/s) • Elevation (m) • Pressure (m)

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3.3.6 Document Review

According to Mouton (2003), secondary data, is data collected by someone other than the user. Common sources of secondary include censuses, organizational records, maps and air photographs, unpublished sources.

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The importance of secondary data collection is that it can answer questions the researcher is asking and does not have to do his or her research. It can also be compared to primary data to check if the research is valid and reliable and it can help the researcher to formulate research questions.

The secondary data method that was used in this study is document analysis whereby the researcher reviewed municipal reports and records. The review of municipal reports was essential to find out the water sources and its distribution systems including institutional arrangements of water supply. The review pointed out the roles and responsibilities of each, any person involved in water resource management in the municipality, and how the municipality operates its water supply. This information assisted in strengthening the strategic framework that was developed by the researcher to achieve sustainable water supply within the District as it is the water provider.

3.4 Data analysis

According to Adèr (2008), data analysis is a process of inspecting, cleaning, transforming, and modelling data with the goal of discovering useful information, suggesting conclusions, and supporting decision making. Several of methods of data analysis were employed to execute tasks that follow below.

3.4.1 Water sources

Visual analysis was used to analyse the description of the of water source. Municipal reports were interpreted and ground truthing was be done in order to confirm what the report says. The analysis of images also had an input for the description.
The reports and observations obtained enabled the researcher to outline all water sources found in Makhado Municipality. From this information the researcher was able to outline all the water sources found in the Makhado Local Municipality.

3.4.2 Water Demand and Consumption

GIS was used to analyse the relationship between water demand and consumption. The analysis was able to tell the researcher whether there is a balanced relationship between demand and consumption or whether demand exceeds consumption or consumption exceeds demand.

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The criteria to determine the relationship was: consumption- demand (constant value) = (- value) this means that there is a deficit because the amount was smaller than what is required. The researcher then can say that demand exceeds consumption. Consumption- demand (constant value)= (+ value) this means that there is a surplus because there is an amount left over after using what is needed, the researcher then can say that consumption exceeds demand. To get a wide overview of the relationship the analysis was carried out over three months and the results will be overlaid.

3.4.4 Questionnaires

In this study, the generated data from the administered questionnaires were analysed and simplified using Microsoft Excel (Excel 2010) and statistical procedures of Statistical package for Social Sciences (SPSS 21.0). The data were first coded, defined and labelled and fed in Microsoft Excel and were exported to SPSS program to generate descriptive and inferential statistics. The variables were summarised by determining the frequency of each code within the question and the analysis were undertaken for the sampled settlement.

The data are presented in graph of cluster columns, pie charts and simple tables and contingency tables to clearly show the results. A non-parametric test (Chi-square test) was done to determine the nature of the relationship among presence of children in a household and frequency of cooking sampled area. Monthly expenditure and household size was also test to see if there is any relationship associated. A Mann-Whitney Test was conducted to test if there is a statistically significant difference exists between the amounts currently being paid for water services in the study area and the amount the residents are 'willing' to pay.

3.4.5 Key informant interview

Content analysis was used to study the empirical reports on institutional, operational and technical arrangements, to identify whether the arrangements, include the following aspects; guiding principles and legislation for water distribution and the departments within the water scheme.

Roles and responsibilities of every person involved in water resource management were identified and the researcher also identified how the municipality incorporates members of the public into water resources management, the content analysis was guided by Dr. Klaus's six questions of addressing content analysis:

- Which data are analysed?
- How are they defined?

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- What is the population from which they are drawn?
- What is the context relative to which the data are analysed?
- What are the boundaries of the analysis?
- What is the target of the inferences?

3.4.6 Water distribution network in the study area

Using the EPANET software the researcher analysed the water distribution network in terms of the pressure at each node quantity of flow and head loses in the various pipelines, and the resulting residual pressure at various demands in the network junctions and the sources from which water is pumped to.

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CHAPTER 4: PRESENTATION OF RESULTS AND ANALYSIS

4.1 Introduction

The chapter presents the analysed data that were acquired using administered questionnaires, field observations, and EPANET as well as satellite images. The data is presented using graphs, tables, charts and images. The presentation of the results for the study is organised from objective one to four.

4.2 Water sources in Makhado Local Municipality

The municipal reports revealed that the main source of surface water is the Albasini Dam with a water capacity of 25.6 m^3 as seen in figure 4.2. The Nandoni dam which is anticipated to supply the municipal area with water from July 2016 has a water capacity of 164 m^3. The current water supply to the Makhado cluster is not sufficient to supply water requirements against current and future water requirements. From the interview it was established that the district is endowed with water sources yet the water infrastructure is old and it is well beyond its lifespan, consequently, it is not able to cope with the current demands of local residents. According to the municipal reports the current available water sources located within the Makhado Municipal area are as follows in figure 4.1:

Albasini Dam	Tshakhuma Dam	Mutshedzi Dam
Nzhelele Dam	Vondo Dam	Tshitale Dam
Middle Letaba Dam	Ledig boreholes (VDM)	Makhado Town groundwater well field (to the south and west of the town)
Vleifontein boreholes	Air Force Base boreholes (under management of DPW)	Sinthumule/Kutama boreholes (under VDM)

Figure 4.1: Water source in Makhado Local Municipality

Source: Makhado Local Municipality Annual report 2012/2013

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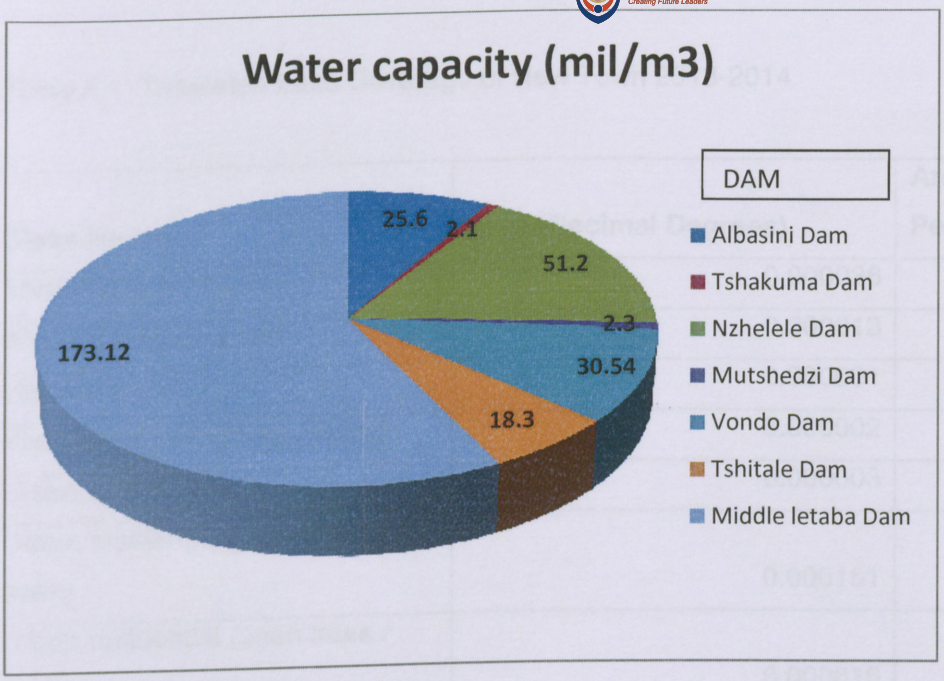


Figure 4.2: Water capacity of dams found in Makhado Local Municipality

Source: Makhado Local Municipality Annual report 2012/2013

Land-cover is a key information requirement for a wide range of landscape planning, inventory and management activities, such as environmental resource management (Geoterraimage, 2015). Change detection is an inherent capability of land cover data that can be used to determine environmental change over time such as water distribution increase or decrease. The datasets utilized in this study are the 1990 and 2013-14 (30m resolution) land cover products. These are a standardized and directly comparable set of national land cover datasets which can be used to determine landscape change in South Africa over a 20 year period (Geoterraimage, 2015).

In the New Town area of Makhado, the area tabulation of pixel data utilizing of 2013-14 land-cover dataset, (Table 4.1) show that the majority of the area is urban residential or urban built up which amounts to over 75% of the land cover. In fact, only about 17% of the area is principally covered by natural vegetation. None of the coverage in this area is a significant water bodies. The figures in Table 4.2 on the other hand, show that in 1900 the land cover in New Town was only 52% of human settlements whereas vegetation cover was 48%.

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Table 4.1: Tabulated Land Coverage of New Town 2013-2014

Class Name	Area (Decimal Degrees)	Area Percentage
Thicket /Dense bush	0.000036	15.65217391
Woodland/Open bush	0.000013	5.652173913
Low shrubland	0.000001	0.434782609
Plantations / Woodlots mature	0.000002	0.869565217
Urban commercial	0.000003	1.304347826
Urban residential (dense trees / bush)	0.000151	65.65217391
Urban residential (open trees / bush)	0.000016	6.956521739
Urban residential (low veg / grass)	0.000005	2.173913043
Urban built-up (dense trees / bush)	0.000001	0.434782609
Urban built-up (open trees / bush)	0.000002	0.869565217

Table 4.2: Tabulated Land Coverage of New Town land coverage in 1990

Class Name	Area (Decimal Degrees)	Area Percentage
Thicket /Dense bush	0.00006	25.97402597
Woodlan/Open bush	0.000035	15.15151515
Low shrubland	0.000001	0.432900433
Plantations / Woodlots	0.000007	3.03030303
Settlements	0.000122	52.81385281
Grasslands	0.000006	2.597402597

The encroachment of the human settlements onto natural vegetation landscapes between 1990 and 2013 can be clearly seen in figure 4.3. Though the spread of human settlements is not significant looking at a 20 year time period it is significant when looking at the amount of natural vegetation lost due to population increases in the area.

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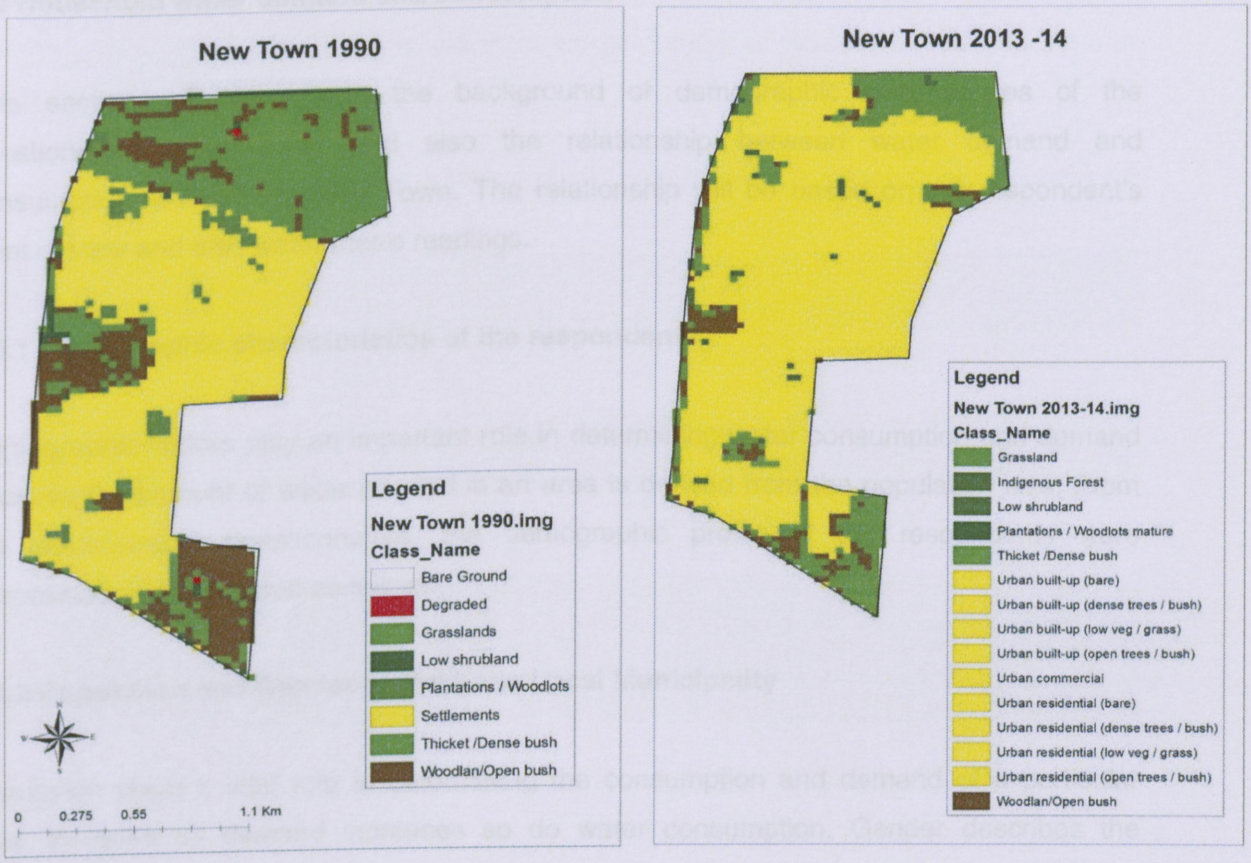


Figure 4.3: Comparison of New Town 1990 and 2013-14

Table A in appendix D shows water bodies namely; seasonal water, permanent water and wetlands only amount to about 0.3% of the Makhado Municipality landscape in 2013-14. The majority of the area is thickets, woodland and grassland. On the other hand Table B appendix D displaying Makhado Municipality in 1990, gives evidence that the water bodies inclusive of wetlands and other waterbodies amounted to 0.5% of the areas land cover. Human settlements in 1990 were only amounting to 3.4% of the areas land cover. In contrast to 2013-14 human settlements now make up 4.74 % of the area including all types of urban settlements.

There has been a loss of water bodies in the Makhado Municipality in a 20-year period. The central parts of the Municipal area have had a greater loss of wetlands. The eastern part, though still having wetlands in 2013 – 2014 has experienced a decrease as well. Overall, extensive wetland areas that were abundant in 1990 have to some extent been diminished or completely depleted. Therefore the main source of water that the municipal area relies on are the dams with a total capacity of 303.16 mil/m^3.

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4.3 Household water demand and consumption

This section will bring forth the background of demographic characterises of the questionnaire respondents and also the relationship between water demand and consumption in Makhado New Town. The relationship will be based on the respondent's point of view and also water metre readings.

4.3.1 Demographic characteristics of the respondents

Demographic factors play an important role in determining water consumption and demand because the amount of water needed in an area is derived from the population size. From the administrated questionnaires, the demographic profile of the respondents were determined and presented as follows:

4.3.2 Population and Gender of Makhado Local Municipality

Population plays a vital role in determining the consumption and demand of a particular area, because as demand increases so do water consumption. Gender describes the characteristics between men and female in a socially constructed society. The role of gender is crucial in this study as males and females play different household duties. Men are mainly responsible with supporting the family financially, while women are responsible with the management of the household.

In the 15-year period from 1996-2011, Makhado Local Municiaplity has experienced a steady rise in its population size, with a population rise of approximately 60 433 (a 13% population growth over the 15 year period). Table 4.3 and Figure 4.4 show that there has not been any significant change in the population composition in terms of gender, with males only rising by 1% in the 15 year period. Table 4.3 also shows that, the rate of increase in the number of households clearly outpaced the rate of population growth, with the average number of individuals dwelling in a household decreasing from 5.170 in the year 1996 to 3.826 in the year 2011.

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Table 4.3: Population of Makhado Local Municipality from the year 1996-2011, showing the percentages of males and females and the average number of people per dwelling, Source: (Stats SA, 2011).

	1996	2001	2011
Female	250 676 (55%)	273 589 (55%)	279 236 (54%)
Male	204 922 (45%)	220 674 (45%)	236 795 (46%)
Total	455 598	494 263	516 031
Households	88 119	108 672	134 889
Average No. of people per household	5.170	4.548	3.826

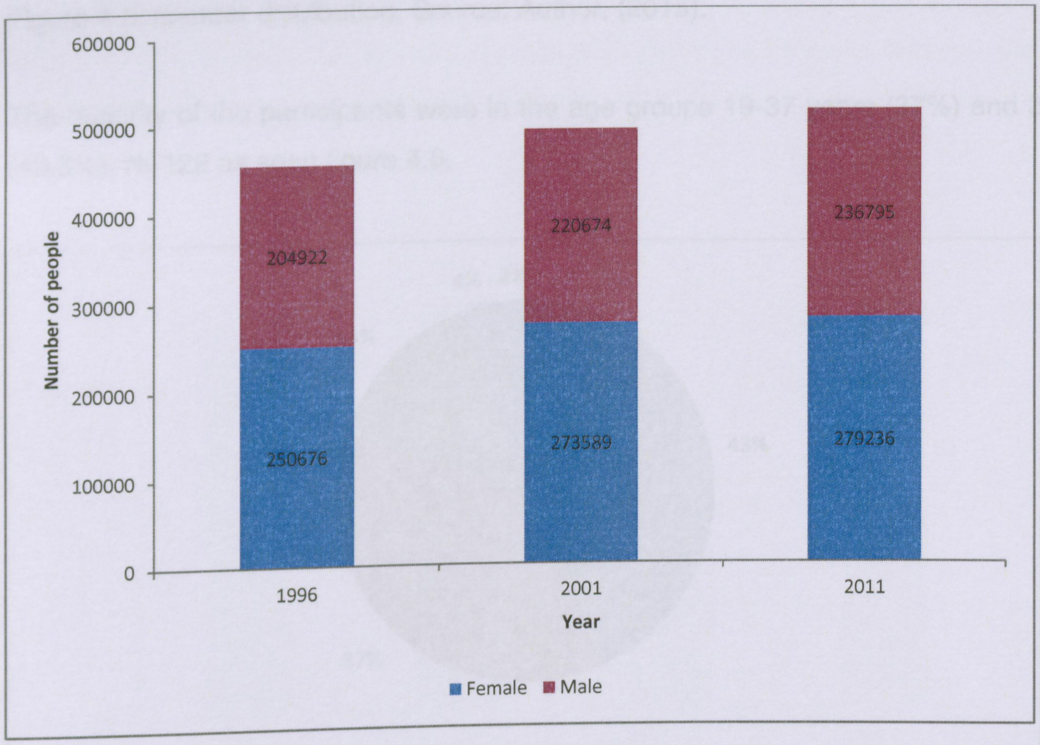


Figure 4.4: Trends in the population of Makhado Local Municipality showing the female and male proportions, Source: (Stats SA. 2011).

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The total number of participants was 129 and among the participants, 68 (53%) were males and 61 (47%) were females N=129 as seen figure 4.5.

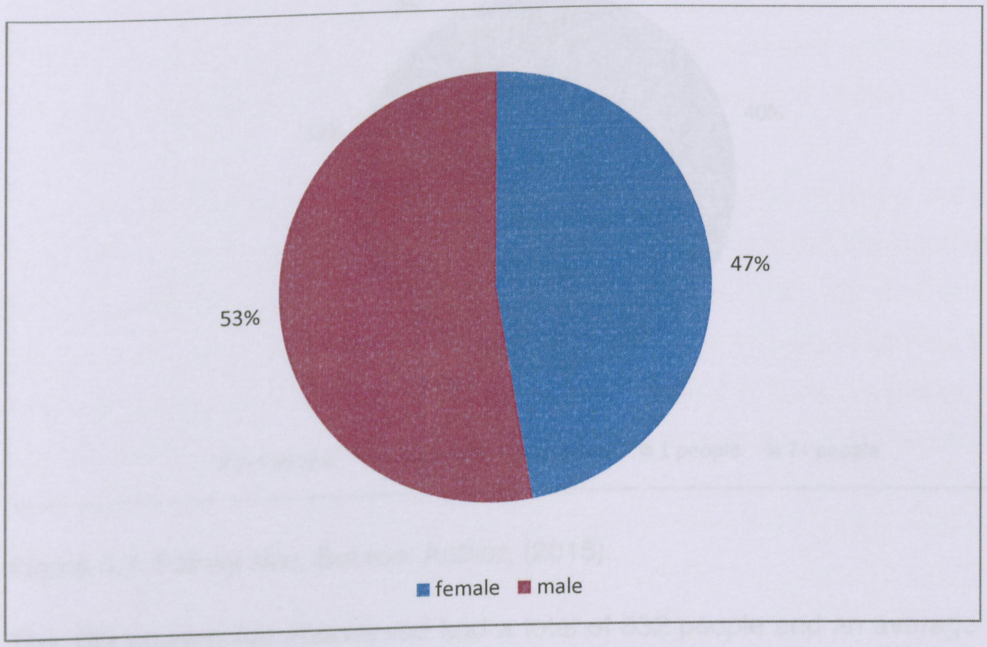


Figure 4.5: Gender distribution, Source: Author, (2015).

The majority of the participants were in the age groups 19-37 years (37%) and 38-55 years (43.3%), N=129 as seen figure 4.6.

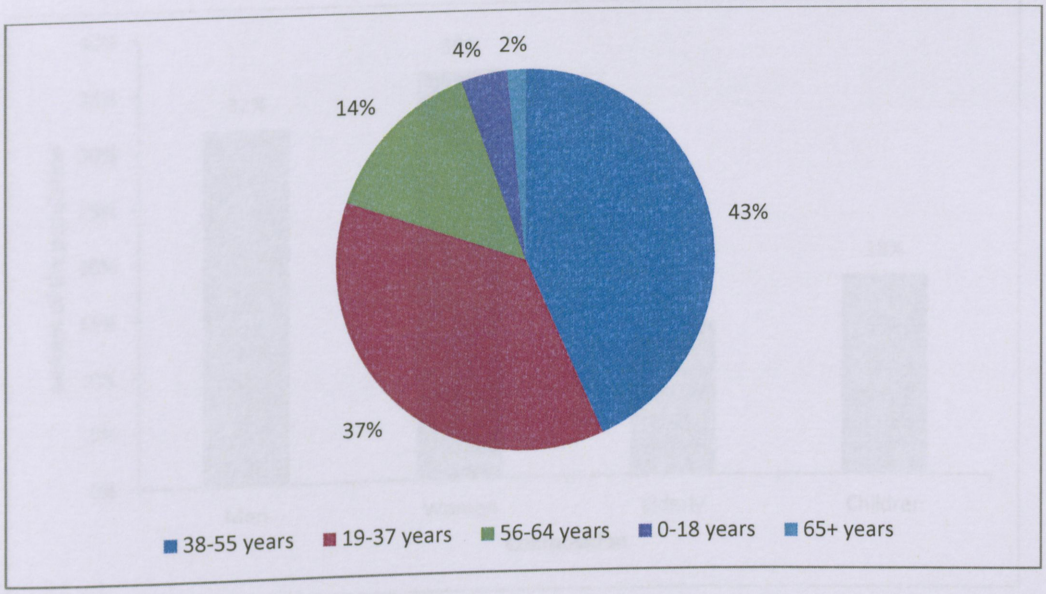


Figure 4.6: Age distribution of the sample, Source: Author, (2015).

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The majority of the households were composed of 3-4 people (40%) and 5-6 people (33%), N=129 as seen in figure 4.7.

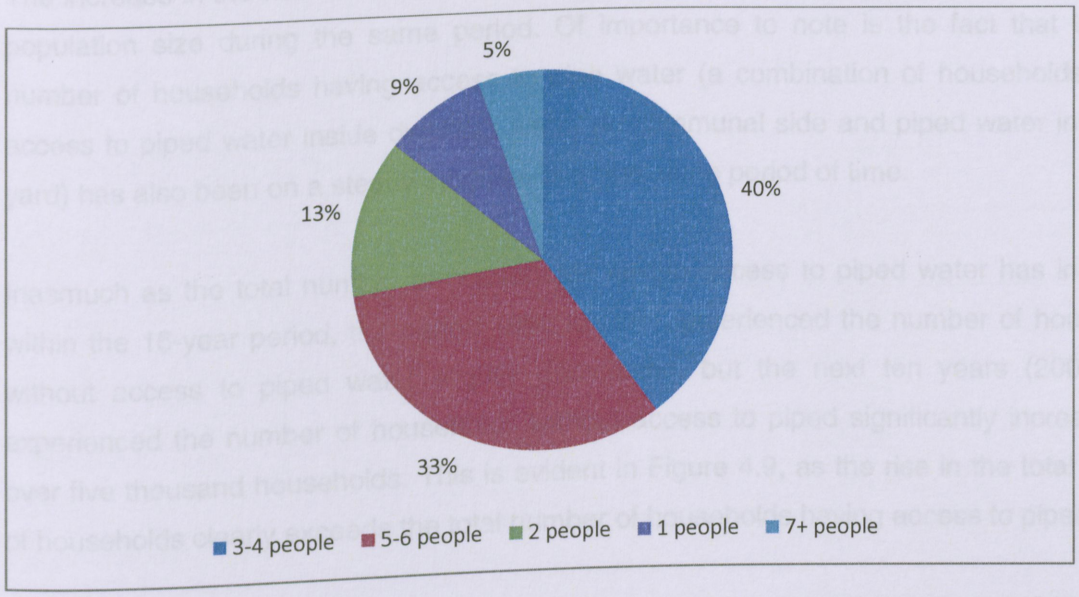


Figure 4.7: Family size, Source: Author, (2015).

The 129 households interviewed had a total of 532 people and an average of 4 people per household. The families/households were dominated by women (36%) followed by men (32%). Children made up 18% of the population composition in the families and the elderly were the smallest population making up 14% of the families composition, as seen in figure 4.8.

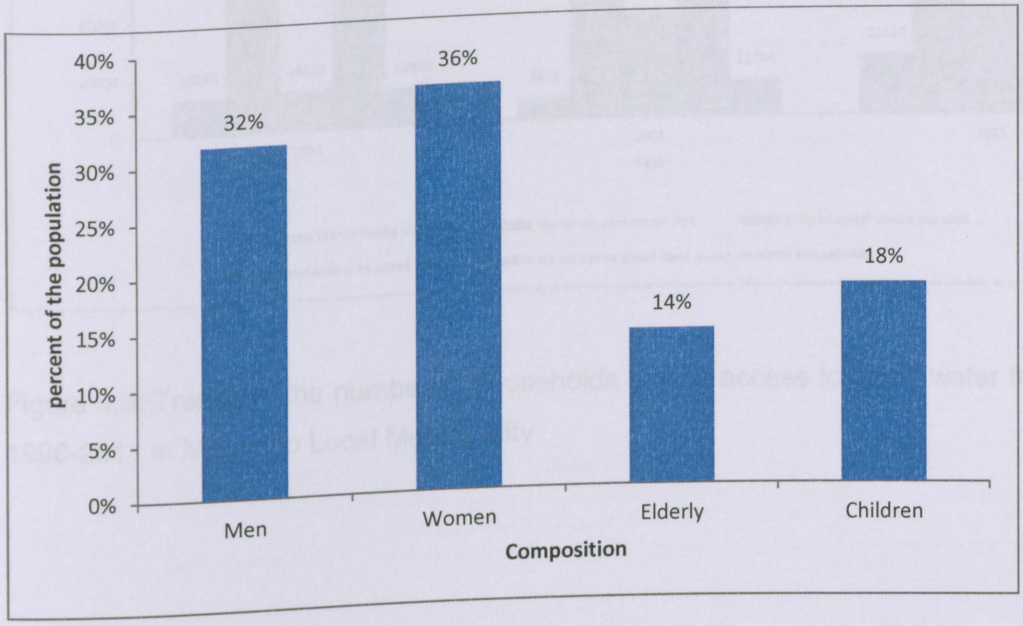


Figure 4.8: Population composition, Source: Author, (2015).

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Figure 4.9 shows that Makhado Local Municipality has been seeing a steady increase in the number of households in the 15-year period (1996 to 2011) for which data was available. The increase in the number of households also corresponds to the increase in the Municipal population size during the same period. Of importance to note is the fact that the total number of households having access to pipe water (a combination of households having access to piped water inside dwelling; water on communal side and piped water inside the yard) has also been on a steady increase over the same period of time.

Inasmuch as the total number of households having access to piped water has increased within the 15-year period, the period 1996 to 2001 experienced the number of households without access to piped water slightly decreasing, but the next ten years (2001-2011) experienced the number of households without access to piped significantly increasing by over five thousand households. This is evident in Figure 4.9, as the rise in the total number of households clearly exceeds the total number of households having access to piped water

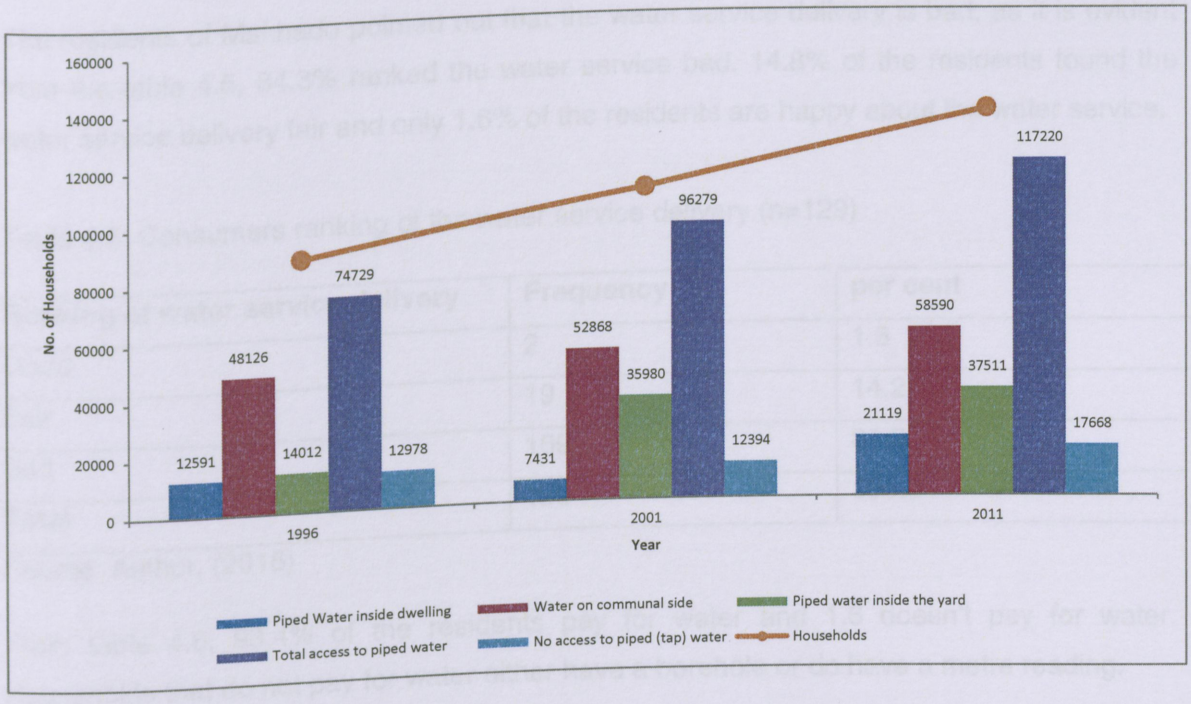


Figure 4.9: Trends in the number of households having access to piped water for the period 1996-2011 in Makhado Local Municipality

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Based on the findings in table 4.4, at most 38.3% of the households need 150 litres a day, at least 14.8% of the households needs 200 litres a day. 26.6% of the households need 100 litres a day and 20.3% of the households need 50 litres a day.

Table 4.4: Households' daily water needs N=129.

Households' daily water needs	Frequency	per cent
50 litres	26	20.3
100 litres	34	26.6
150 litres	49	38.3
200 litres	20	14.8
Total	129	100.0

Source: Author, (2015).

The residents of Makhado pointed out that the water service delivery is bad, as it is evident from the table 4.5, 84.3% ranked the water service bad. 14.8% of the residents found the water service delivery fair and only 1.6% of the residents are happy about the water service.

Table 4.5: Consumers ranking of the water service delivery (n=129)

Ranking of water service delivery	Frequency	per cent
Good	2	1.6
Fair	19	14.2
Bad	109	84.3
Total	129	100.0

Source: Author, (2015)

From table 4.6, 98.4% of the residents pay for water and 1.6 doesn't pay for water. Households that do not pay for water either have a borehole or do have a metre reading.

Table 4.6: Residents paying for water services (n=127)

Do you pay for water service?	Frequency	per cent
Yes	125	98.4
No	2	1.6
Total	127	100.0

Source: Author, (2015).

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Most of the residents feel that they are paying an excessive amount for the water services and 4.8% feel that it's fair, as seen in figure 4.7.

Table 4.7: Opinion on water service charges (n=127)

Opinion on the water charges	**Frequency**	**per cent**
too much	121	94.4
Fair	6	4.8
Total	127	100.0

Source: Author, (2015).

Up to 93.9% of the residents are willing to pay if the municipality is to improve its water service and 6.1% indicated that they are not willing to pay even though improvements were to take place, as seen in table 4.8.

Table 4.8: Service delivery and willingness to pay (n=114).

Would you be happy to pay for water if the municipality were to improve?	**Frequency**	**Per cent**
Yes	107	93.9
No	7	6.1
Total	114	100.0

Source: Author, (2015)

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Up to 95.2% of the residents pointed out that the district is not delivering as a water service provider as seen in figure 4.9 and only 4.8% feel that the district is delivering as they can go for weeks without water.

Table 4.9: Opinion on the District as a water service provider (N=124).

Besides the service fees, do you think the District is delivering as a water service provider?	**Frequency**	**per cent**
No	118	95.2
Yes	6	4.8
Total	124	100.0

Source: Author, (2015).

When asked how long they have been paying for water services, a total of 121 respondents out the 129 sampled responded to the question. From the 121 respondents, the minimum number of years respondents have been paying for water services was 1 year and the highest (maximum) was 26 years and on average the respondents have been paying for water services for approximately ten years, as seen in table 4.10

Table 4.10: Descriptive statistics for Q2A on duration of payment for water services.

Sample size	**Mean**	**Minimum**	**Maximum**
121	10.29	1	26

Source: Author, (2015).

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Findings of the study indicated that on average, each household pays R414-40 for water services. The highest amount paid by any household per month was found to be R1 300-00 and the lowest was R100-00, as seen in table 4.11.

Table 4.11: Descriptive statistics for Q3 on household monthly expenditure on water services

Sample size	Mean	Minimum	Maximum
124	415.40	100	1300

Source: Author, (2015).

When asked how much they are willing to pay for water services, the maximum any household indicated they were willing to pay was R700-00, the minimum was R60-00 and the mean amount the households are willing to pay is R244-76, as seen in table 4.12. A Mann-Whitney Test was conducted to test if a statistically significant difference exists between the amounts currently being paid for water services in the study area and the amount the residents are 'willing' to pay. A two-tailed P value < 0.0001, considered extremely significant was found, indicating that there is a statistically significant difference between what the households are currently paying and what they are willing to pay.

Table 4.12: Descriptive statistics for Q6 on how much households are willing to pay for water services.

Sample size	Mean	Minimum	Maximum
105	244.76	60	700

Source: Author, (2015).

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Each bar represents the mean amount (R), error bars showing the standard error and (*) represents a statistically significant difference (Mann-Whitney Test at P -0.05). There is a huge gap between what is currently being paid and willingness to pay, as seen in figure 4.10.

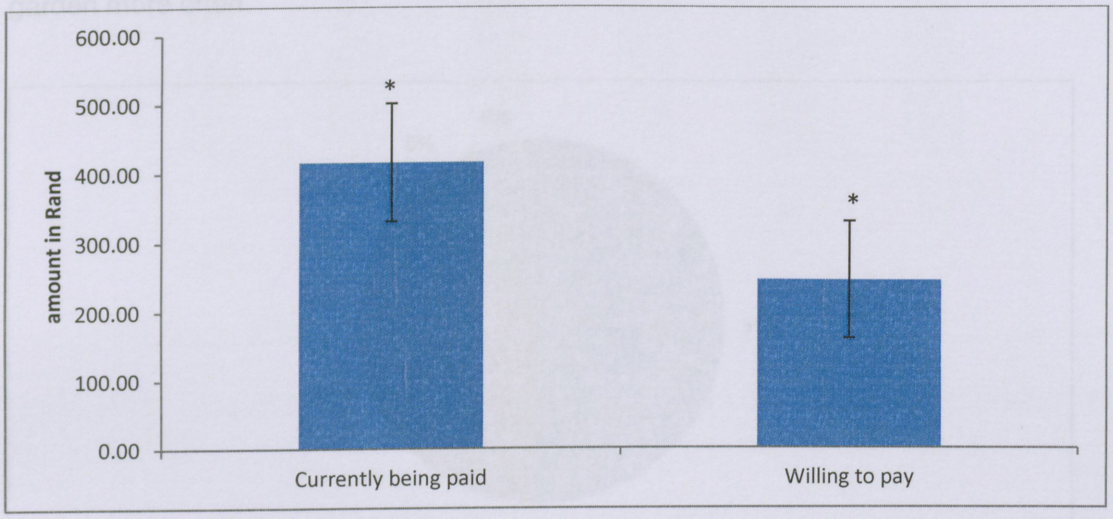
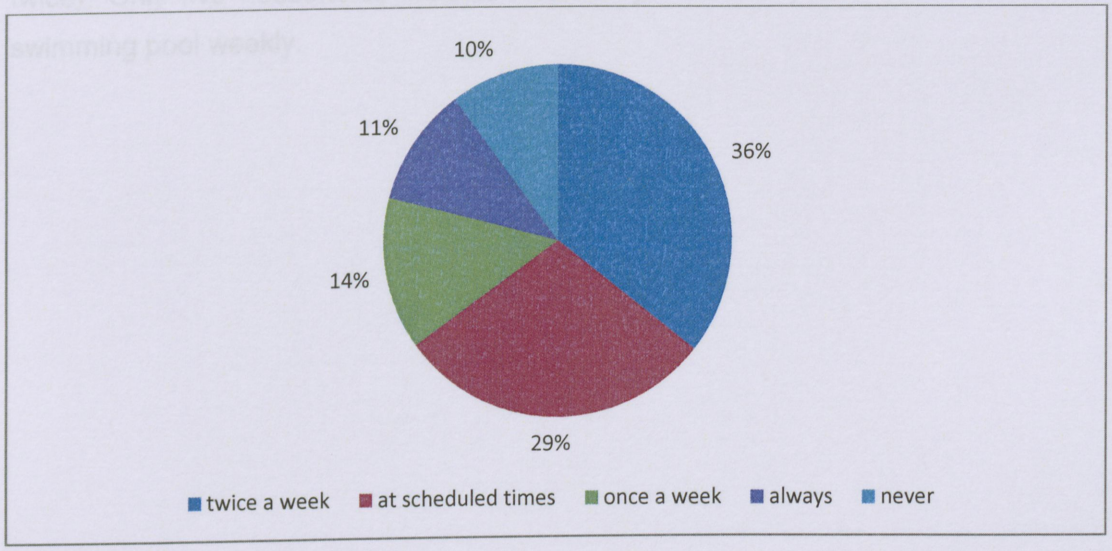


Figure 4.10: A comparison of amount currently being paid by households for water services and the amount they are willing to pay for the service (in Rand), Source: Author, (2015).

Thirty six per cent of the households indicated that they get water twice a week and a further 29% said they get water daily but at scheduled times, whilst 14% said they get water one a week. 11% of the households which participated in the survey indicated that they have running water always and 10% said they do not get running water at all, as seen in figure 4.11.



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Figure 4.11: Availability of tap water, Source: Author, (2015).

The major use of water in the households was cooking and bathing (51%), followed by laundry and cleaning (38%), then gardening and car washing at 6%, as seen in figure 4.12. The residents pointed out that if they were supplied with sufficient they would water their garden more often.

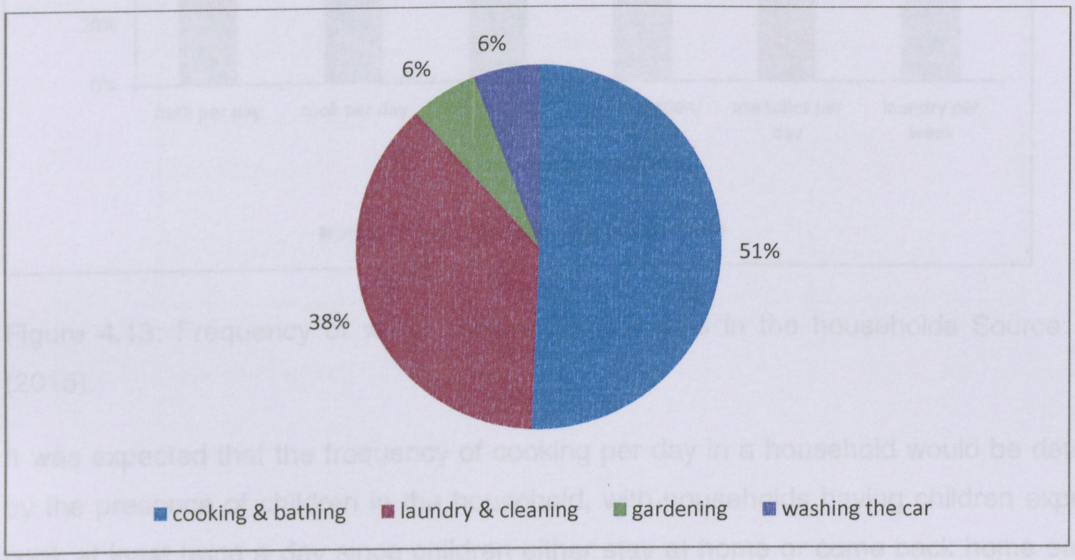


Figure 4.12: Main uses of water in households, Source: Author, (2015).

Findings of the study in Figure 4.13, show that the majority of the individuals (63%) bath on average twice daily, 24% bath once daily and only 13% indicated that they bath as much as thrice per day. Cooking, which was found to be the main water use in Figure 4.13, is practiced once to twice a day (with 39% saying they cook once and 53% of the households twice). Only five households indicated that they clean daily and two households fill the swimming pool weekly.

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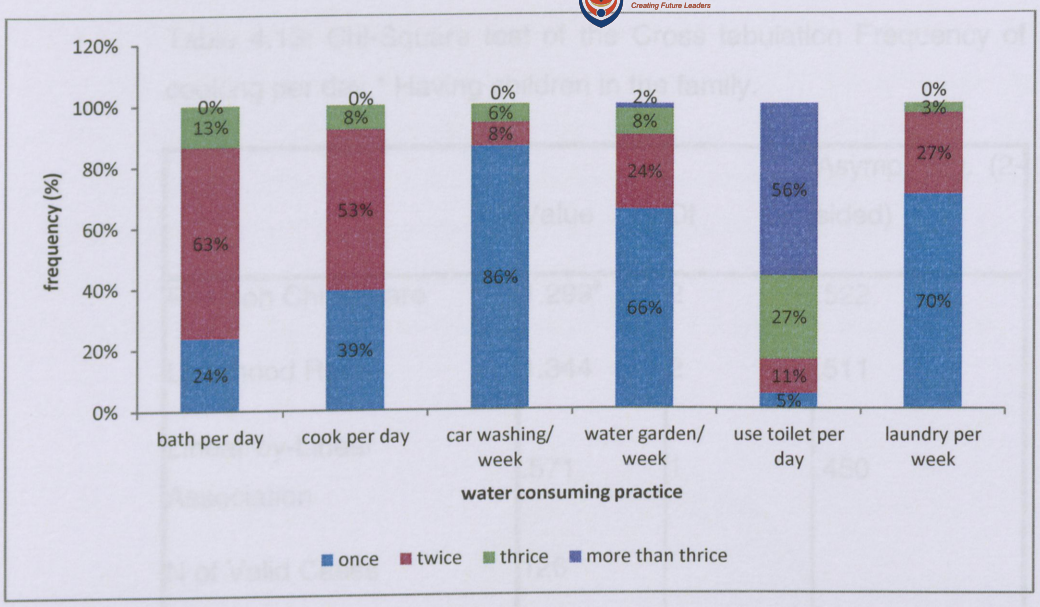


Figure 4.13: Frequency of water consuming practices in the households Source: Author, (2015).

It was expected that the frequency of cooking per day in a household would be determined by the presence of children in the household, with households having children expected to cook at least twice a day since children either stay at home or come back home early from school. However, a Cross tabulation with Chi square indicated that there is no association between the two variables (the Significance was found to be 0.522, which is greater than 0.05, indicating that there is no association between the frequency of cooking and the presence of children in the household, P-0.05), as seen in Table 4.13.

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Table 4.13: Chi-Square test of the Cross tabulation Frequency of cooking per day * Having children in the family.

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.299[a]	2	.522
Likelihood Ratio	1.344	2	.511
Linear-by-Linear Association	.571	1	.450
N of Valid Cases	126		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 7.15. Source: Author, (2015).

Most families cook twice a day as seen in figure 4.14.

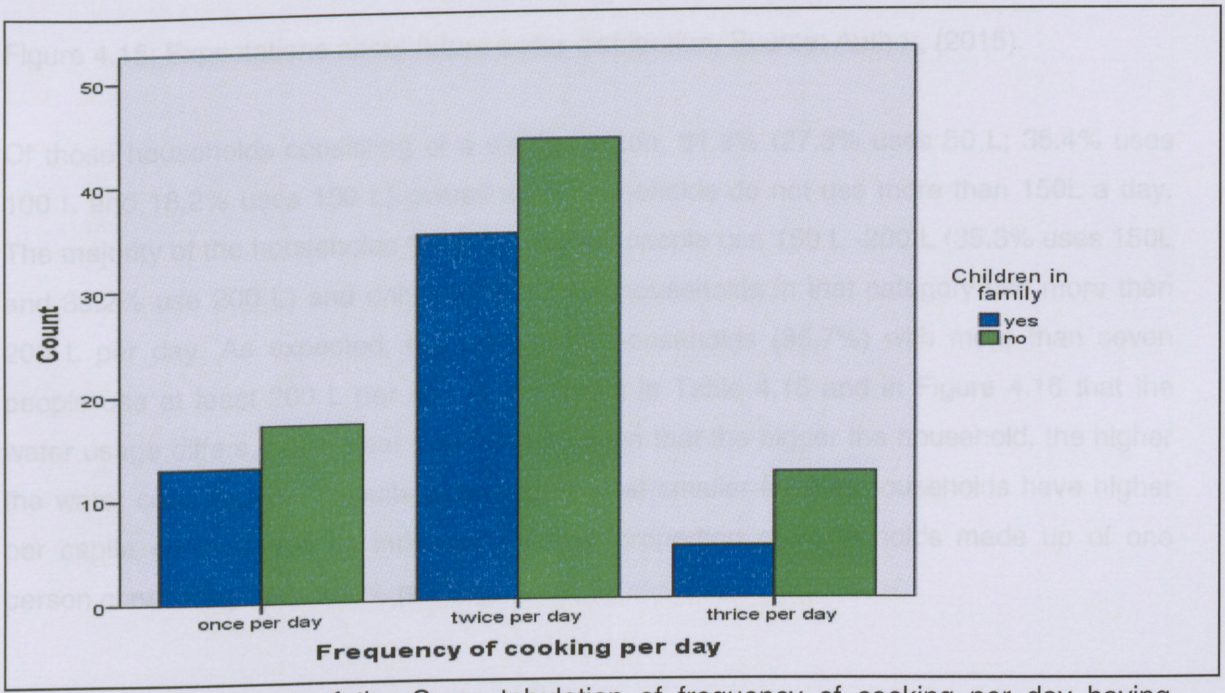


Figure 4.14: Bar chart of the Cross tabulation of frequency of cooking per day having children in the household, Source: Author, (2015).

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When asked about their expectations about water distribution in the future, the majority of the households (61%) hope to have running water at all the times, with majority mentioning that they are paying hence they deserve the service as seen in figure 4.15. Seventeen per cent of the participants indicated that besides having running water, they also want quality healthy water; 9% said the situation will never change; 5% said they want affordable rates; 4% indicated that they want the municipality to improve in the manner in which they run the different aspects of the water delivery services and 3% had other expectations

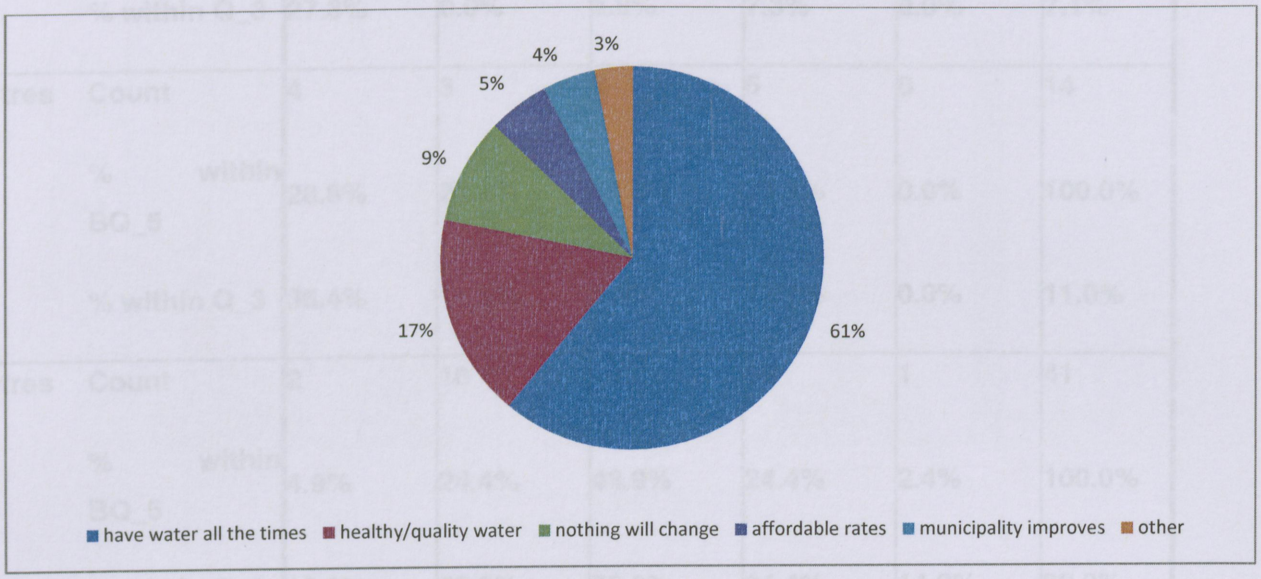


Figure 4.15: Expectations about future water distribution, Source: Author, (2015).

Of those households consisting of a single person, 81.9% (27.3% uses 50 L; 36.4% uses 100 L and 18.2% uses 150 L) overall such households do not use more than 150L a day. The majority of the households (74.5%) with 3-4 people use 150 L -200 L (35.3% uses 150L and 39.2% use 200 L) and only 15.7 % of the households in that category use more than 200 L per day. As expected, the majority of households (85.7%) with more than seven people use at least 200 L per day. It is evident in Table 4.15 and in Figure 4.16 that the water usage differs, but a clear trend can be seen that the bigger the household, the higher the water consumption. Results also suggest that smaller families/households have higher per capita consumption as indicated by high proportion of households made up of one person consuming up to 150 L per day

Table 4.14: Households' approximate daily water needs family size Cross tabulation, Source: Author, (2015).

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		Q_3					Total
		0-1 people	1-2 people	3-4 people	5-6 people	7+ people	
50 litres	Count	3	0	3	3	0	9
	% within BQ_5	33.3%	0.0%	33.3%	33.3%	0.0%	100.0%
	% within Q_3	27.3%	0.0%	5.9%	7.3%	0.0%	7.1%
100 litres	Count	4	3	2	5	0	14
	% within BQ_5	28.6%	21.4%	14.3%	35.7%	0.0%	100.0%
	% within Q_3	36.4%	17.6%	3.9%	12.2%	0.0%	11.0%
150 litres	Count	2	10	18	10	1	41
	% within BQ_5	4.9%	24.4%	43.9%	24.4%	2.4%	100.0%
	% within Q_3	18.2%	58.8%	35.3%	24.4%	14.3%	32.3%
200 litres	Count	1	1	20	4	0	26
	% within BQ_5	3.8%	3.8%	76.9%	15.4%	0.0%	100.0%
	% within Q_3	9.1%	5.9%	39.2%	9.8%	0.0%	20.5%
> 200 litres	Count	1	3	8	19	6	37
	% within BQ_5	2.7%	8.1%	21.6%	51.4%	16.2%	100.0%
	% within Q_3	9.1%	17.6%	15.7%	46.3%	85.7%	29.1%
Total Count		11	17	51	41	7	127

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% within BQ_5	8.7%	13.4%	40.2%	32.3%	5.5%	100.0%
% within Q_3	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

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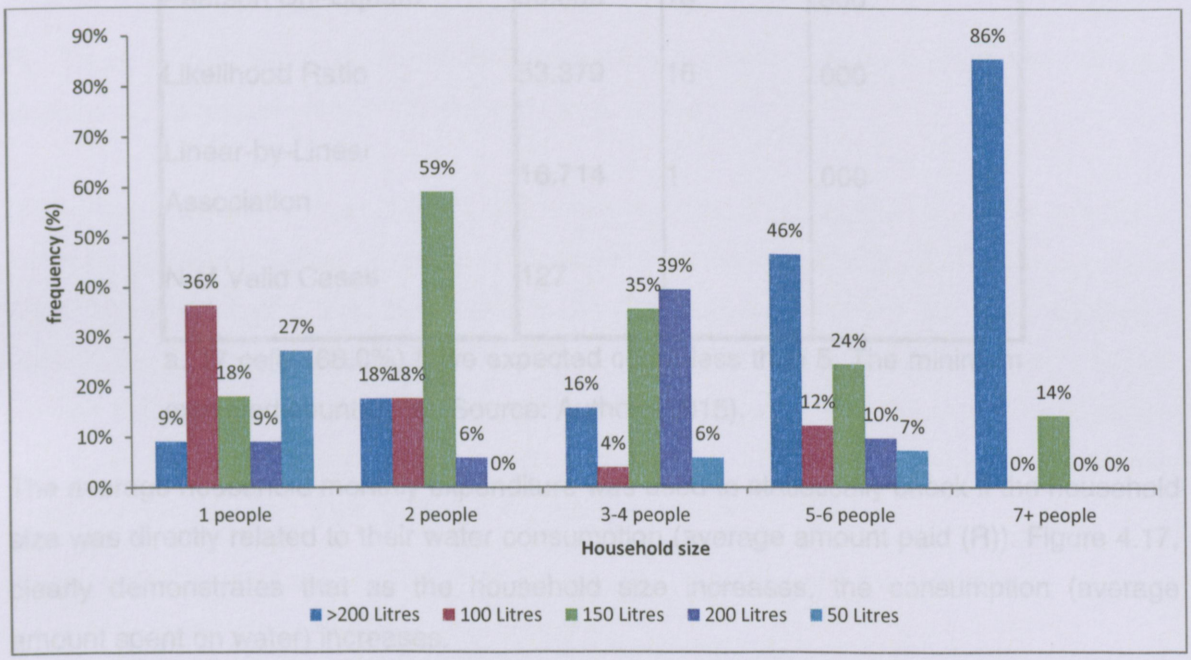


Figure 4.16: Bar chart of the Cross tabulation of Household approximate daily water needs * family size, Source: Author, (2015).

A Chi-square ($\chi 2$) test was used to test for statistically significant association between household size and approximate water consumption. A Significance value of 0.000, which is way less than 0.05 indicates a strong association between the two variables; household daily water needs and household size as seen in table 4.15.

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Table 4.15: Showing Chi-Square Tests for the Cross tabulation Households' approximate daily water needs * family size.

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	56.656[a]	16	.000
Likelihood Ratio	53.379	16	.000
Linear-by-Linear Association	16.714	1	.000
N of Valid Cases	127		

a. 17 cells (68.0%) have expected count less than 5. The minimum expected count is .50. Source: Author, (2015).

The average household monthly expenditure was used to statistically check if the household size was directly related to their water consumption (average amount paid (R)). Figure 4.17, clearly demonstrates that as the household size increases, the consumption (average amount spent on water) increases.

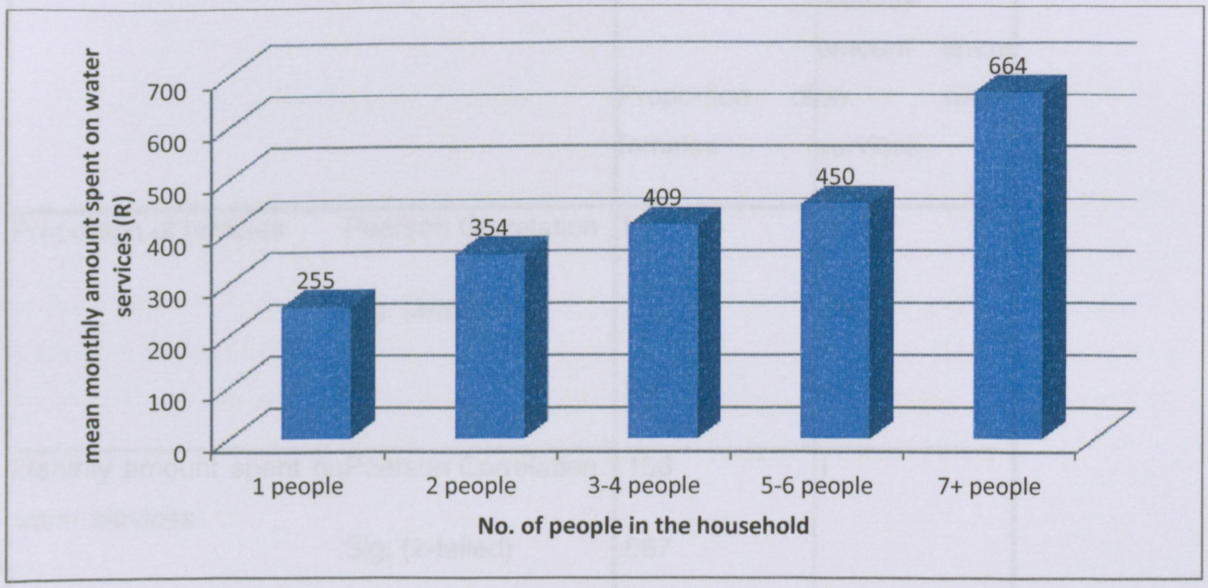


Figure 4.17: Relationship between household size and monthly expenditure on water services, Source: Author, (2015).

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In 122 households which indicated the monthly amount they spend on water services, the study checked if the proportion of adult females had a significant relationship with the amount of water used monthly by a household *i.e.* does a higher adult female proportion results in higher monthly water consumption of a household. It should be realised that monthly expenditure on water services was used as an indicator of the household's monthly water consumption. A Pearson correlation coefficient was used based on the following hypothesis:

H_0: There is no statistically significant correlation between a family's proportion of adult females and a household's monthly water consumption.

A Pearson Correlation value of 0.156 which is less than 0.3 indicated a very weak correlation between the two variables of concern. To test the hypothesis, the Sig (2-Tailed) value was used. Since the alpha level was 0.05, a Sig (2-Tailed) value below our level signified a statistically significant relationship, as seen in table 4.16 In this particular case, a Sig (2-Tailed) value of 0.087 which is greater than 0.05, indicated that there is no statistically significant relationship between family's proportion of adult females and household's monthly water consumption, thus we accepted the null hypothesis.

Table 4.16: Correlations proportion of females in the family and the average amount a household spends on water services.

		Proportion of females	Monthly amount spent on water services
Proportion of females	Pearson Correlation	1	.156
	Sig. (2-tailed)		.087
	N	122	122
Monthly amount spent on water services	Pearson Correlation	.156	1
	Sig. (2-tailed)	.087	
	N	122	122

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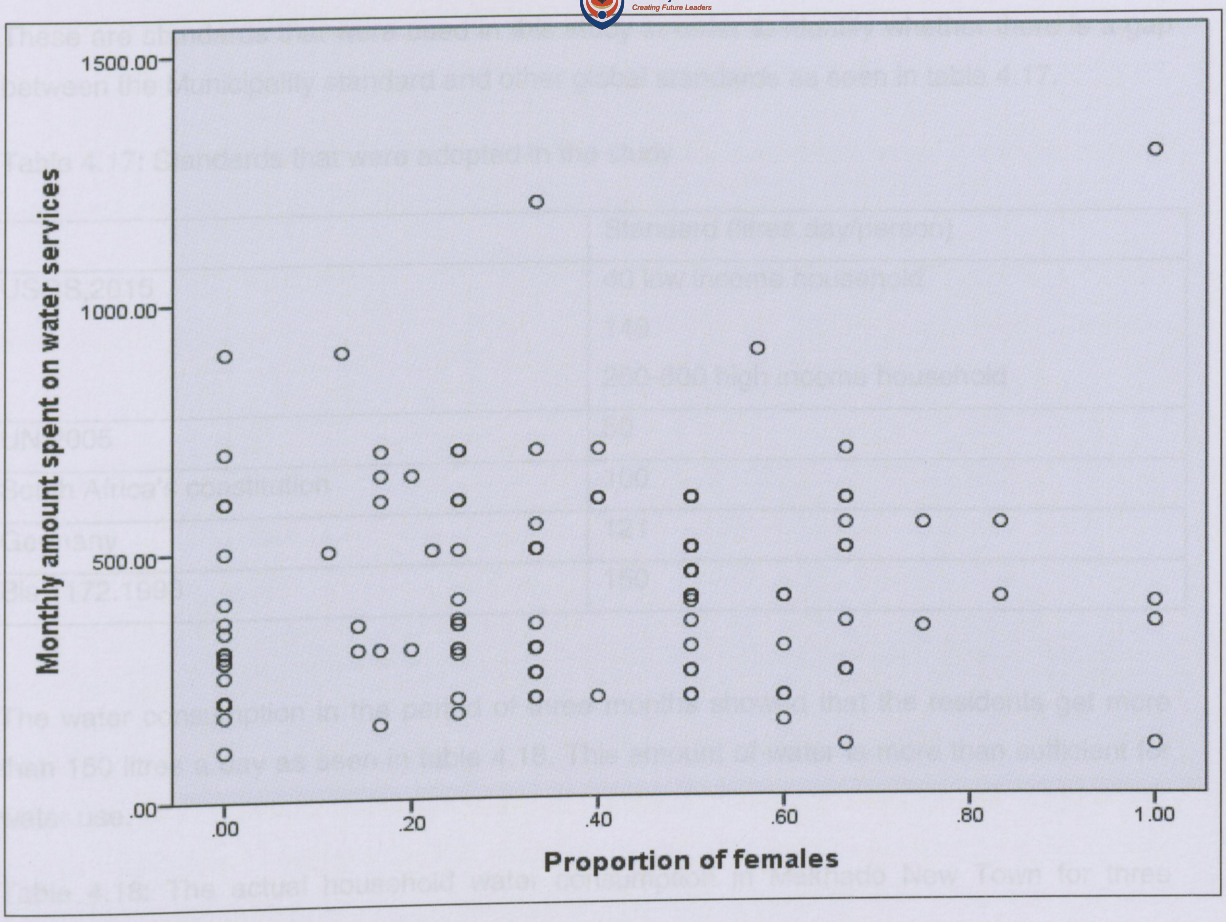


Figure 4.18: Scatter plot of Household's proportion of female's vs average monthly expenditure on water service, Source: Author, (2015).

- **Actual consumption and demand**

Metre readings were obtained from the Makhado Local Municipality for the following months; August, September and October (see appendix D). The readings were used to see the actual consumption and to identify whether the residents are being supplied with the minimum requirement of 100 litres thou other standards where considered to also see if there is a gap between the constitutions standard and other global standards. The readings would also help identify whether demand exceeds consumption or vice versa.

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These are standards that were used in this study in order to identify whether there is a gap between the Municipality standard and other global standards as seen in table 4.17.

Table 4.17: Standards that were adopted in the study

	Standard (litres day/person)
USGS,2015	40 low income household 149 250-600 high income household
UN,2005	50
South Africa's constitution	100
Germany	121
Bis 1172.1993	150

The water consumption in the period of three months showed that the residents get more than 150 litres a day as seen in table 4.18. This amount of water is more than sufficient for water use.

Table 4.18: The actual household water consumption in Makhado New Town for three months

Consumption litres/day/person	August (%)	September (%)	October (%)	Average for three months (%)
<100	0.7	2.3	8.5	3.8
<150	15.7	16.4	23.4	8.14
>150	84.3	83.59	76.6	81.4

Source: Author, (2015).

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There wasn't much of a gap between Makahdo New Town and other global standards as seen in table 4.19.

Table 4.19 Relationship between Makhado New Town household water consumption and global standards

Consumption litres/day/person	August (%)	September (%)	October (%)	Average for three months (%)
<40	-	-	0.7	0.7
<121	5.4	9.3	16.4	10.3
<149	15.6	16.4	23.4	16.1
250-600 <425	39.8 88.2	39.8 89	32 89	37.2 88

Source: Author, (2015).

The District should supply the following litres per day in order to satisfy the residents (The total population size was multiplied with the standard divided by 1 000 to get mega litres), also provided on a household level as each household differs in composition as seen in table 4.20. Only urban areas which are associated with high income qualify to be supplied with 425 litres a day per person as in India and this standard has been adopted in this study.

Table 4.20: Demand figures based on different standards

Standards litres/day/person	Municipality (Mega litres)	MakhadoTown (Mega litres)	Household (litres)
100	51,6	2.5	See appendix D
150	77,4	3,8	See appendix D
425	219,3	10, 7	See appendix D

Source: Author, (2015).

Water consumption was established using municipal water metre readings as seen in figure 19-30. The consumption within the New Town was also used to compare with other standards i.e Bis 1172.1993, USGS 2011 and Germay ; the municipality does meet the minimum standard of the South African constitution of supplying 100 litres a day per person as only 3.8% of households are receiving less than 100 litres a day per person. Compared to other standards the municipality does meet the minimum requirements as the average of household water consumption per person a day is 225.13 litres a day.

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Figure 4.19

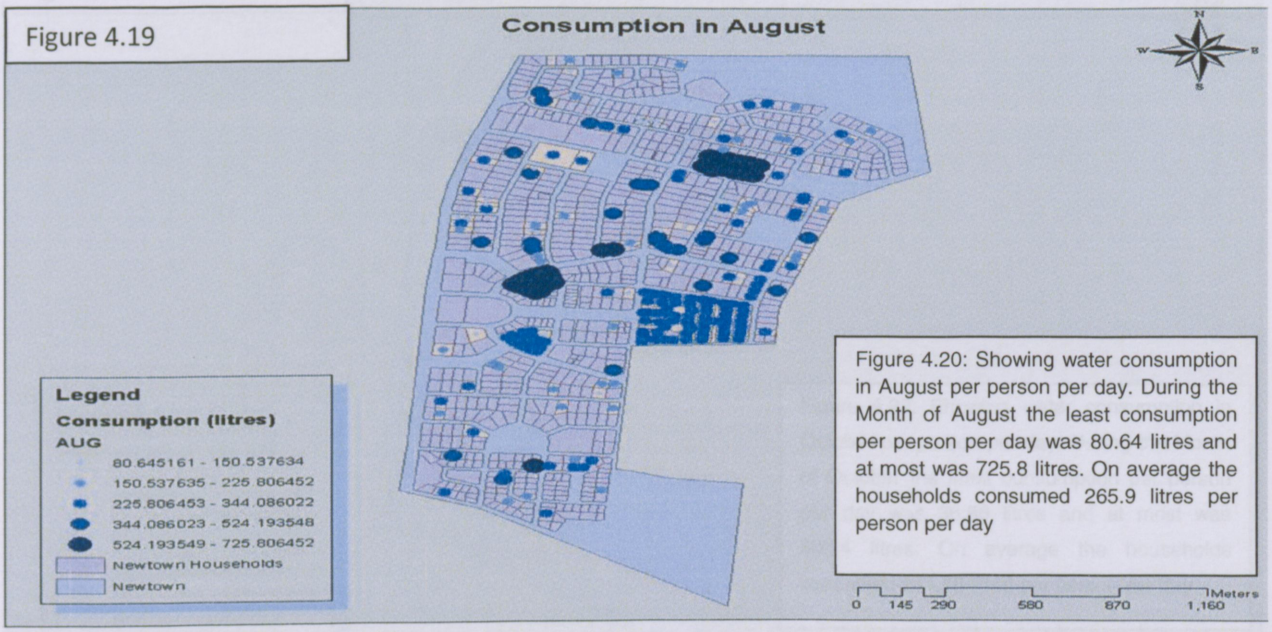


Figure 4.20: Showing water consumption in August per person per day. During the Month of August the least consumption per person per day was 80.64 litres and at most was 725.8 litres. On average the households consumed 265.9 litres per person per day

Figure 4.20

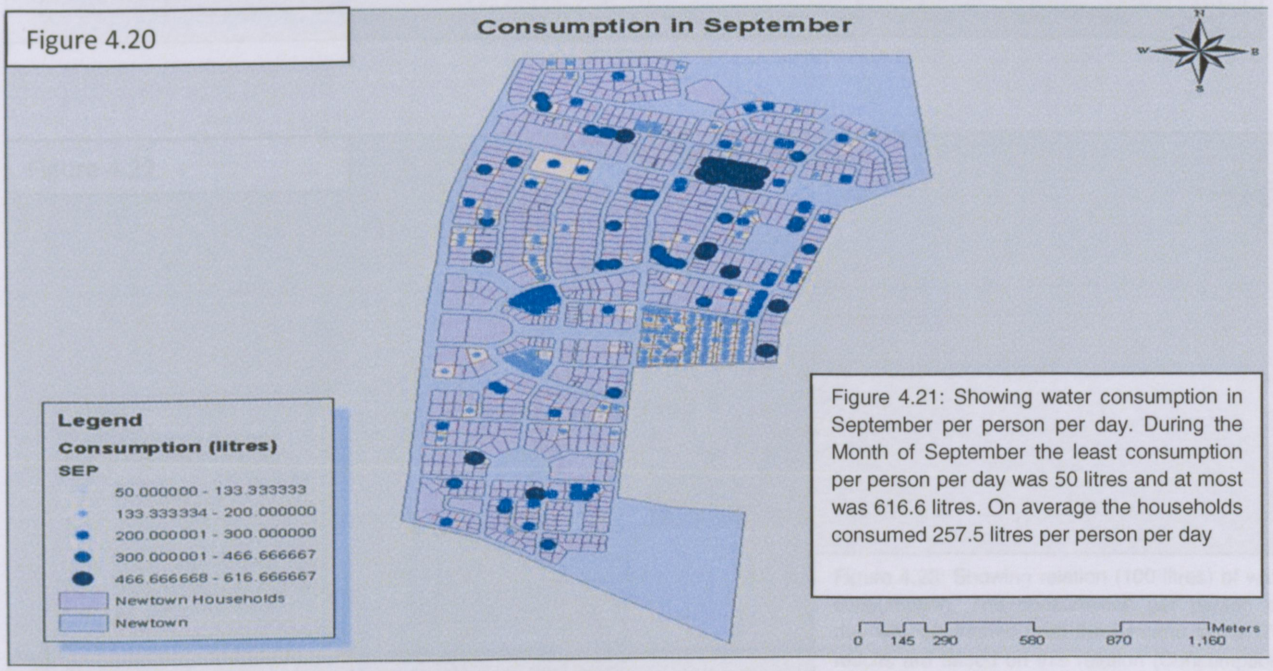


Figure 4.21: Showing water consumption in September per person per day. During the Month of September the least consumption per person per day was 50 litres and at most was 616.6 litres. On average the households consumed 257.5 litres per person per day

Source: Author (2015)

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Figure 4.21

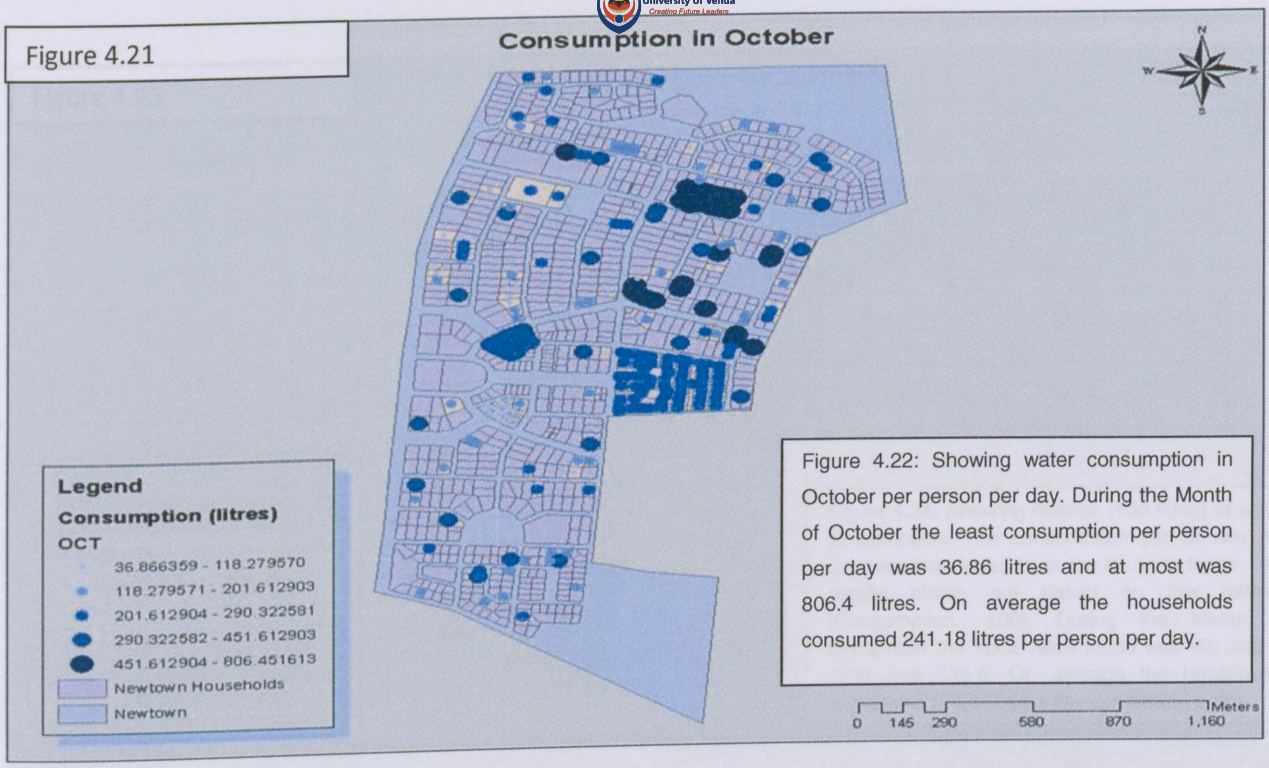


Figure 4.22: Showing water consumption in October per person per day. During the Month of October the least consumption per person per day was 36.86 litres and at most was 806.4 litres. On average the households consumed 241.18 litres per person per day.

Figure 4.22

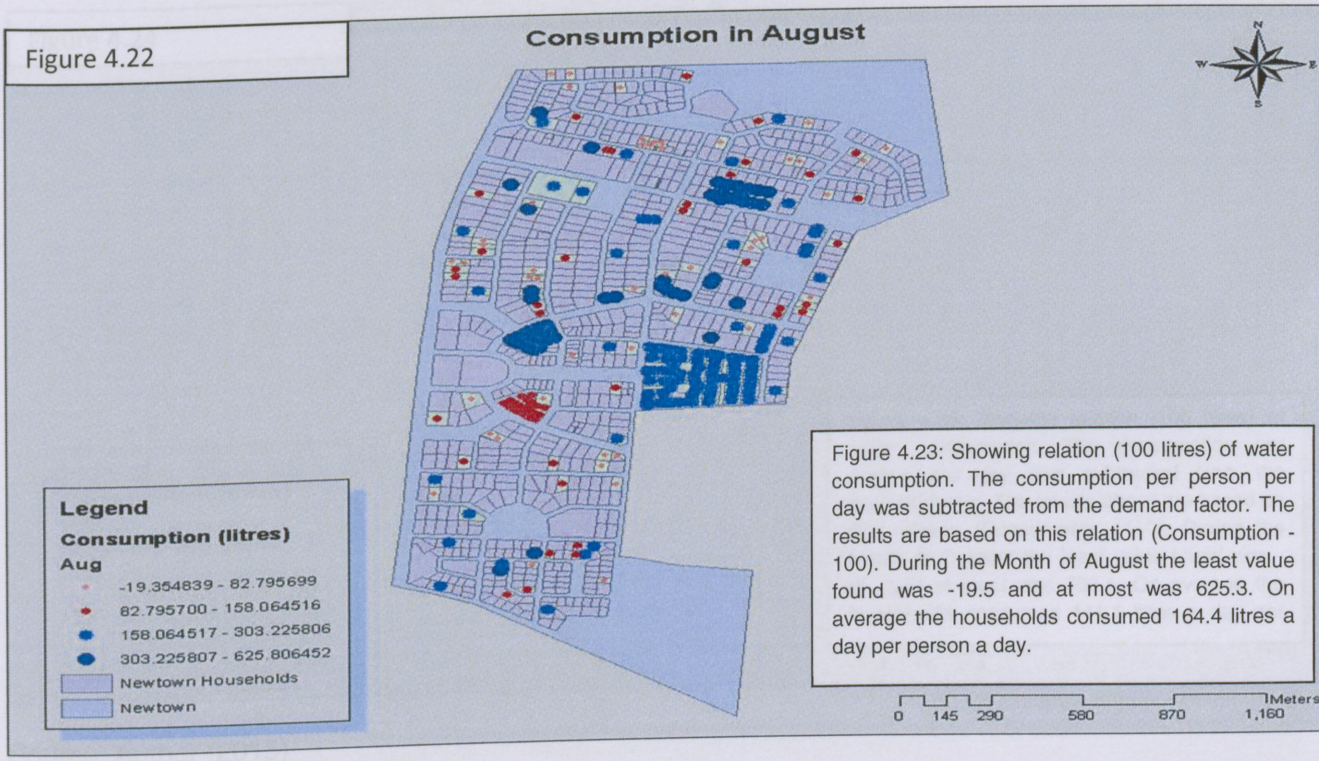


Figure 4.23: Showing relation (100 litres) of water consumption. The consumption per person per day was subtracted from the demand factor. The results are based on this relation (Consumption - 100). During the Month of August the least value found was -19.5 and at most was 625.3. On average the households consumed 164.4 litres a day per person a day.

Source: Author (2015)

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Figure 4.23

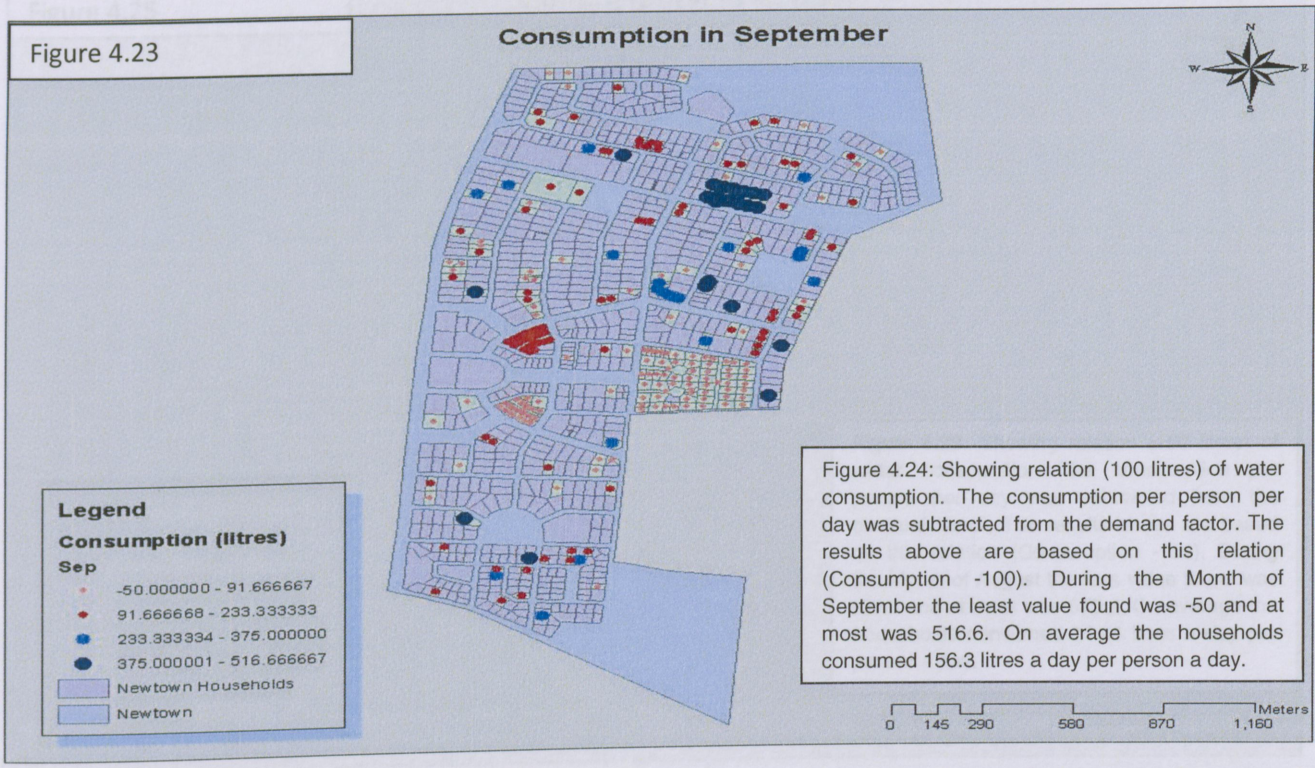


Figure 4.24: Showing relation (100 litres) of water consumption. The consumption per person per day was subtracted from the demand factor. The results above are based on this relation (Consumption -100). During the Month of September the least value found was -50 and at most was 516.6. On average the households consumed 156.3 litres a day per person a day.

Figure 4.24

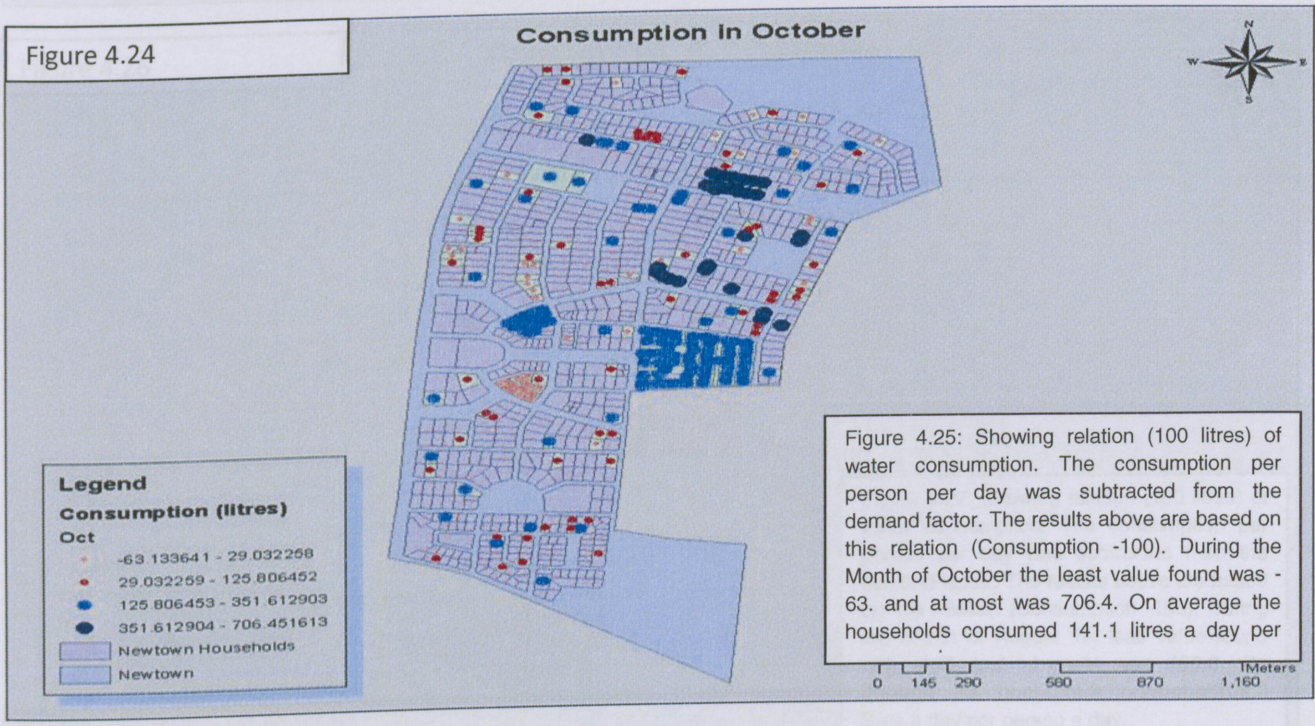


Figure 4.25: Showing relation (100 litres) of water consumption. The consumption per person per day was subtracted from the demand factor. The results above are based on this relation (Consumption -100). During the Month of October the least value found was -63. and at most was 706.4. On average the households consumed 141.1 litres a day per

Source: Author (2015)

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Figure 4.25

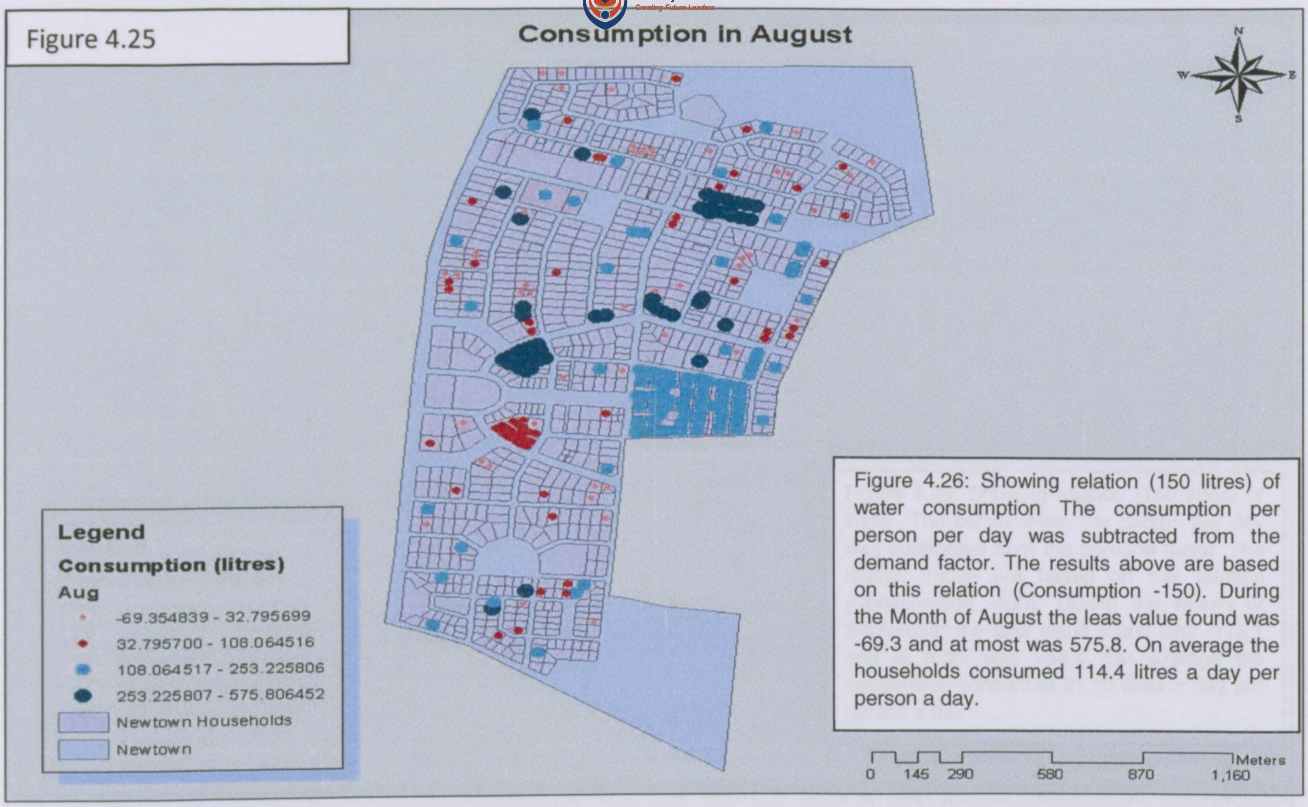


Figure 4.26: Showing relation (150 litres) of water consumption The consumption per person per day was subtracted from the demand factor. The results above are based on this relation (Consumption -150). During the Month of August the leas value found was -69.3 and at most was 575.8. On average the households consumed 114.4 litres a day per person a day.

Figure 4.26

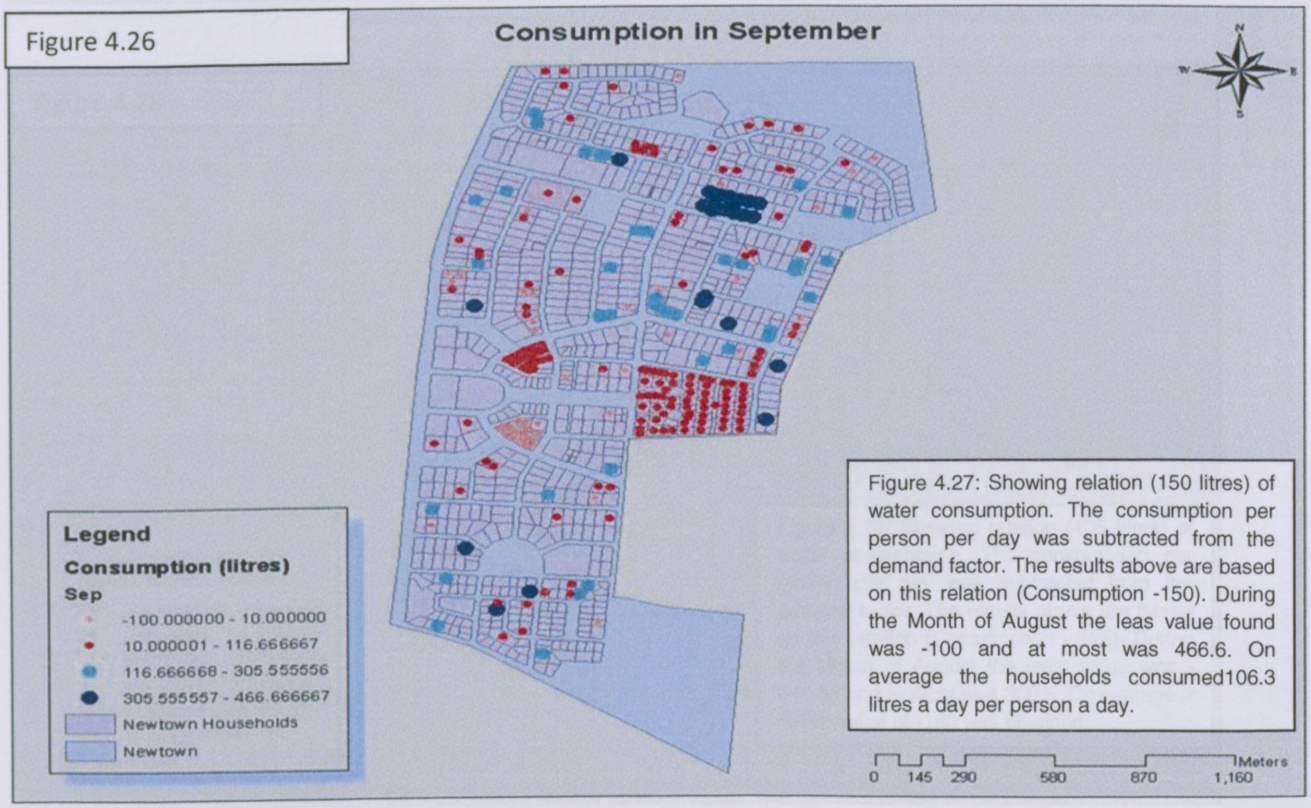


Figure 4.27: Showing relation (150 litres) of water consumption. The consumption per person per day was subtracted from the demand factor. The results above are based on this relation (Consumption -150). During the Month of August the leas value found was -100 and at most was 466.6. On average the households consumed106.3 litres a day per person a day.

Source: Author(2015)

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Figure 4.27

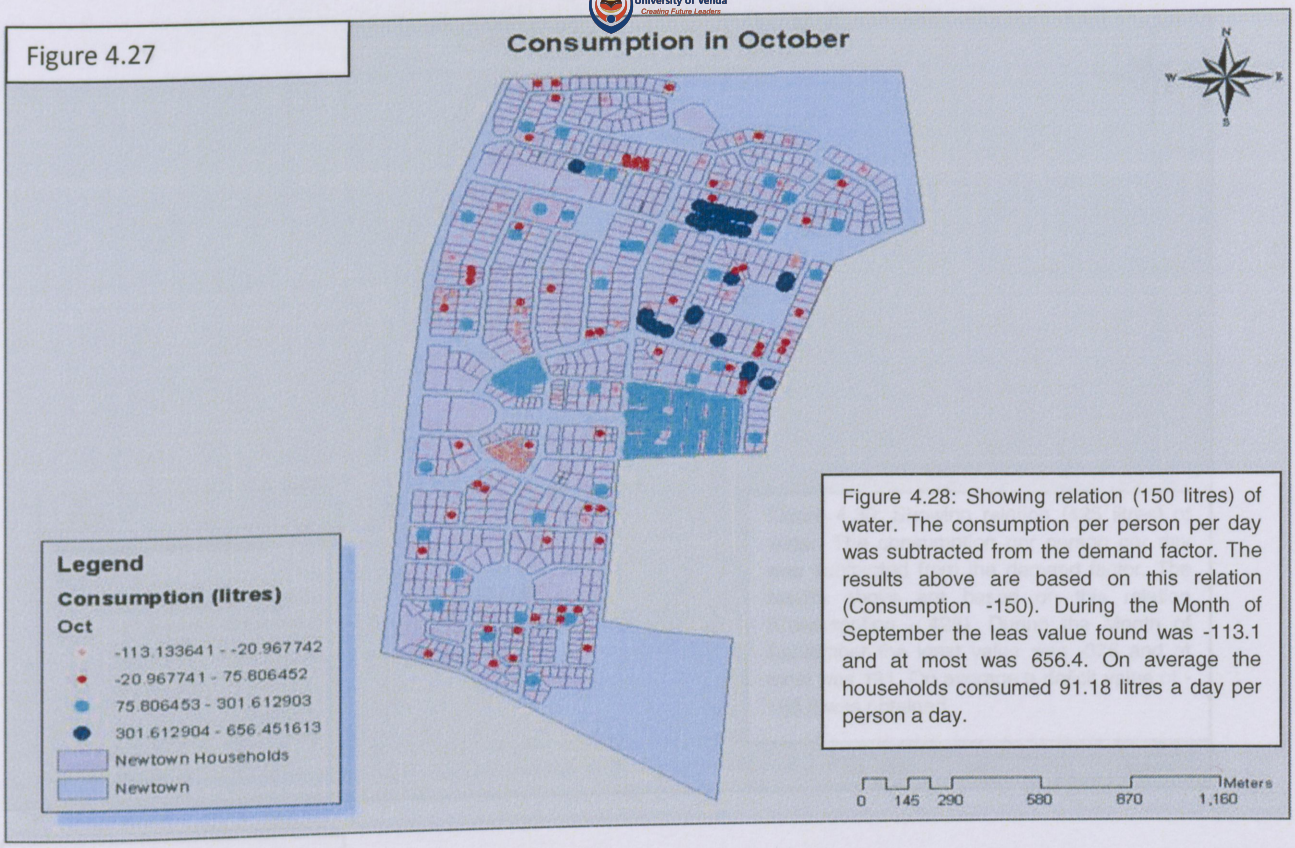


Figure 4.28: Showing relation (150 litres) of water. The consumption per person per day was subtracted from the demand factor. The results above are based on this relation (Consumption -150). During the Month of September the leas value found was -113.1 and at most was 656.4. On average the households consumed 91.18 litres a day per person a day.

Figure 4.28

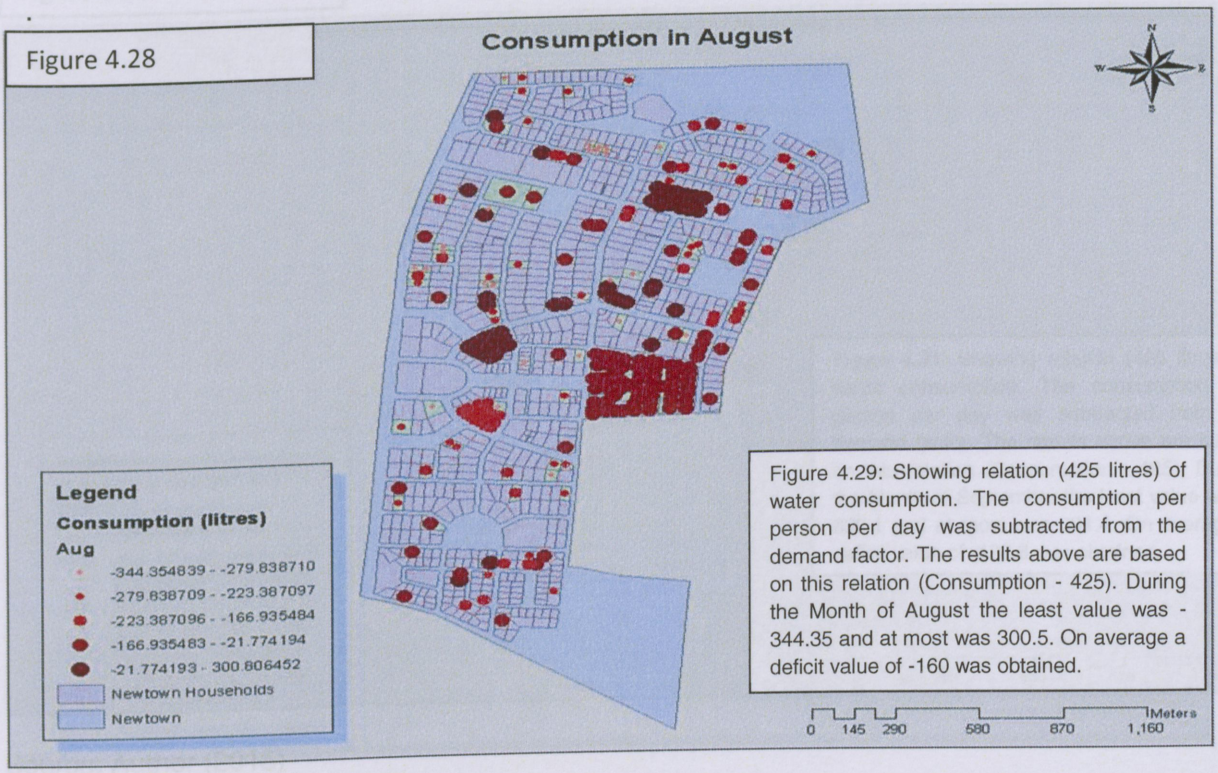


Figure 4.29: Showing relation (425 litres) of water consumption. The consumption per person per day was subtracted from the demand factor. The results above are based on this relation (Consumption - 425). During the Month of August the least value was -344.35 and at most was 300.5. On average a deficit value of -160 was obtained.

Source: Author (2015)

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Figure 4.29

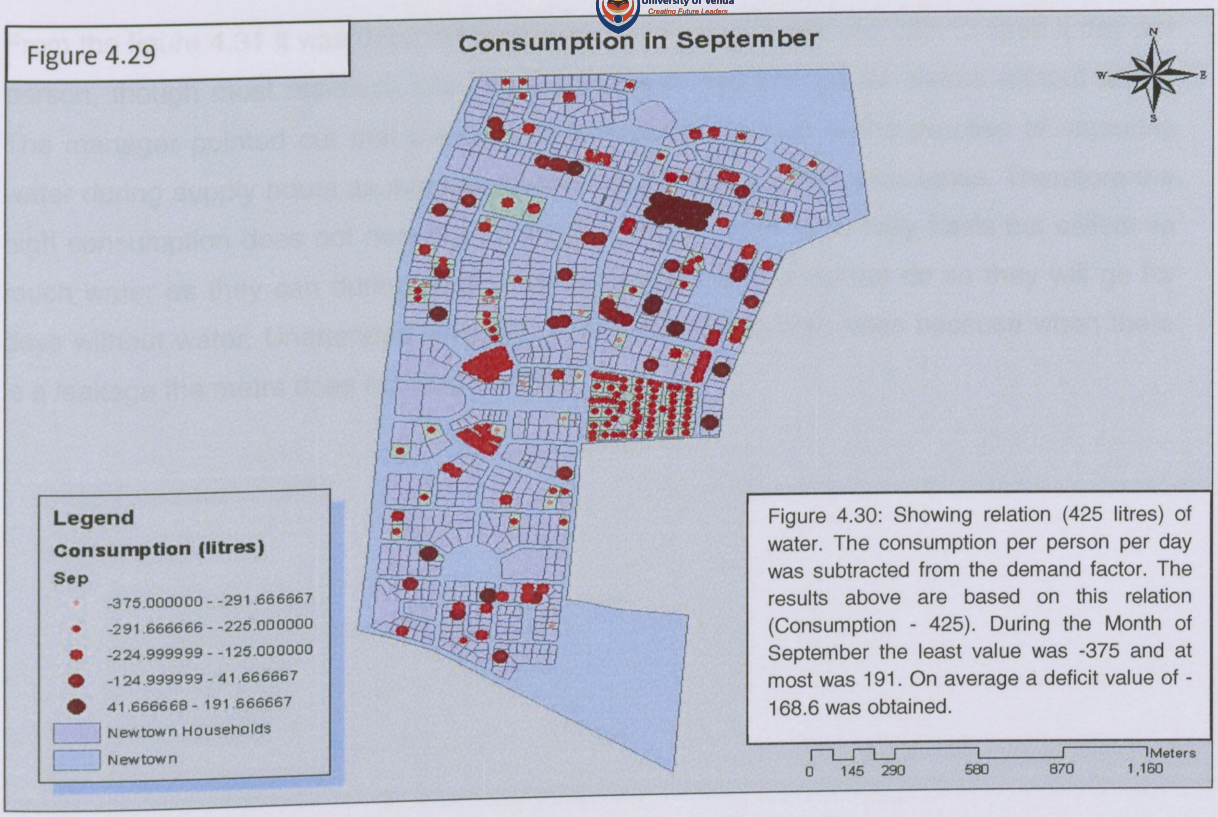


Figure 4.30: Showing relation (425 litres) of water. The consumption per person per day was subtracted from the demand factor. The results above are based on this relation (Consumption - 425). During the Month of September the least value was -375 and at most was 191. On average a deficit value of -168.6 was obtained.

Figure 4.30

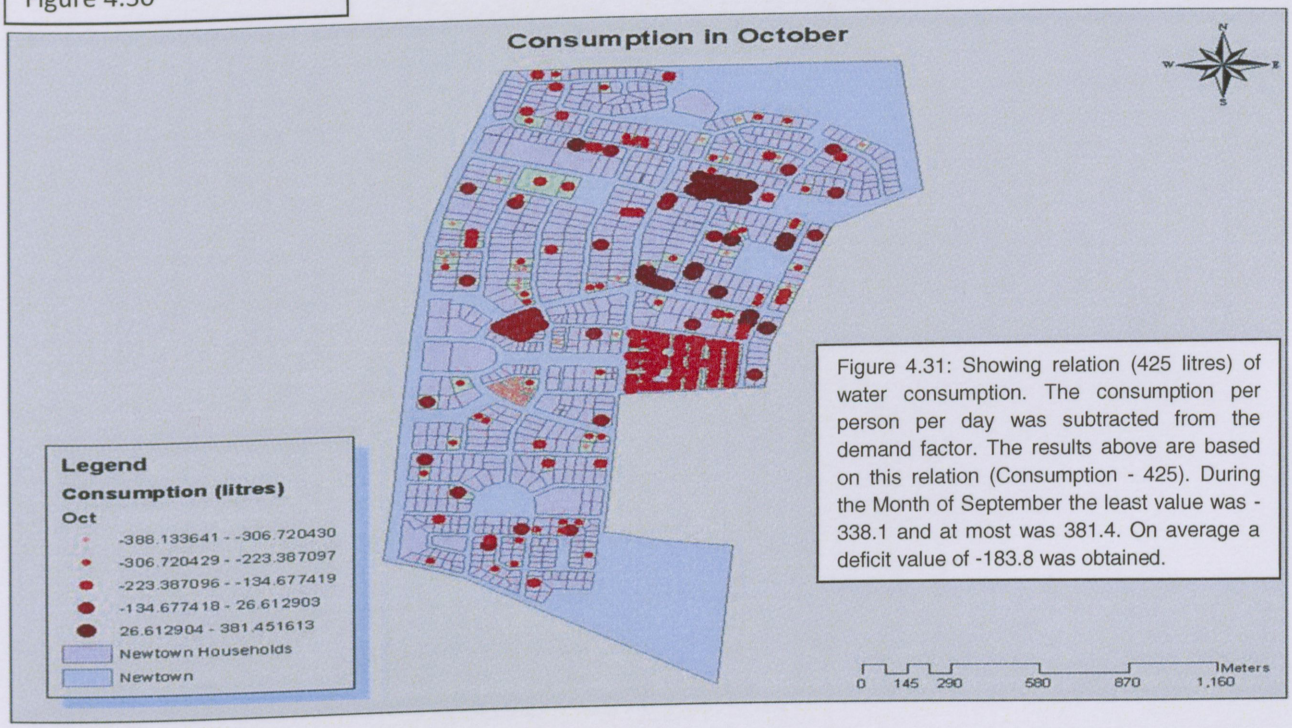


Figure 4.31: Showing relation (425 litres) of water consumption. The consumption per person per day was subtracted from the demand factor. The results above are based on this relation (Consumption - 425). During the Month of September the least value was -338.1 and at most was 381.4. On average a deficit value of -183.8 was obtained.

Source: Author (2015)

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From the figure 4.31 it was depicted that most of the households use 225.13 litres a day per person, though most residents still emphasised that they can go for weeks without water. The manager pointed out that the high consumption was due to the practise of capturing water during supply hours as most residents capture using 2 000 litres tanks. Therefore the high consumption does not necessarily mean they get water on a daily basis but collect as much water as they can during supply hours because if they do not do so they will go for days without water. Unattended leakages also contribute to high rates because when there is a leakage the metre does not stop reading.

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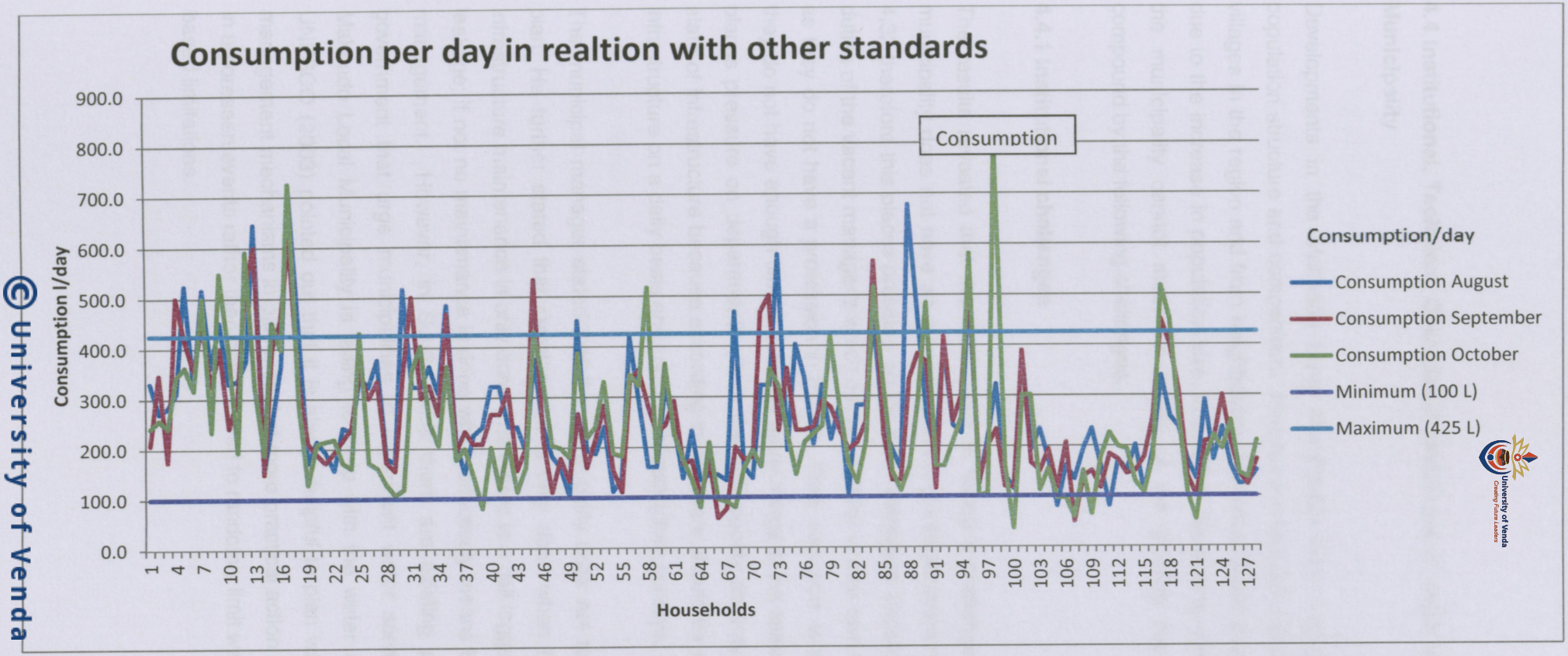


Figure 4.31 showing consumption per day in relation with the South African standard of 100 litres a day person and the standard of India for urban high income areas of 425 litres a day per person, Source: Author (2015).

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4.4 Institutional, Technical, Operational challenges of water supply in Makhado Local Municipality

Developments in the Makhado Local Municipality have brought changes in the local population structure and composition. People have migrated to Makhado from the outlying villages in the region and from neighbouring countries. Water demand now exceeds supply due to the increase in population size. In addition, the ageing water supply infrastructure of the municipality cannot meet the needs of the growing population. This situation is compound by the following challenges.

4.4.1 Institutional challenges

The results revealed that the municipality is facing a challenge of shortage of staff, the municipality does not have an administration and infrastructure manager as seen in figure 4.32 therefore this places pressure on the other managers because they end up performing duties of the vacant manager's which causes a delay in their own work and mismanagement as they do not have a profession in the job. Their own work is also not up to standard as they do not have enough time to manage many things at the same time. This challenge also places pressure on departments within the municipality as they cannot keep up with the state of infrastructure because according to law there should be a section that monitors the infrastructure on a daily basis and conduct infrastructure surveys.

The municipal manager stated that the municipality does not have a maintenance action plan. He further stated that maintenance is only done when there is a crisis, meaning infrastructure maintenance is only done when there is a call logged in reporting a fracture or leakage; if not no maintenance is done which effectively means the municipality does crisis management. However, in South Africa there are existing policies and legislation of government that urge municipalities to implement water services programmes yet the Makhado Local Municipality is failing to keep with the water services programmes and UNESCO (2003) pointed out that it is always helpful to plan water supplies with demand management mechanisms in-place, so that more practical action can be taken by managers in unforeseen events rather than being forced to randomly limit water supplies due to supply-based limitations.

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The municipal manager added that their main project in hand is to refurbish the water scheme but as for when this would be done he cannot tell as the municipality does not have funds for the refurbishment. The pressing challenge of receiving the funds is that the Albasini dam will be decommissioned as the new Nandoni line will be supply water to the municipal area and it is anticipated for July 2016. Therefore the government does not see it as a priority to give the funds to the municipality as the new line will be in use by July 2016, although the project is facing hiccups due to politics where each member working on the project wants to benefit from it, in a sense that they want the new line to supply their home towns even if the towns were not in the municipality plan.

The municipality has a social development section in order to find out the communities water needs. Unfortunately this development was only on paper; it has never been implemented therefore the municipality does not conduct water needs related to the community nor do they have a section that performs water demand surveys although the manager mentioned that they are looking at having the water demand and consumption surveys.

Basically the municipality is not aware of the residents water needs and does not have the a documentation that guides them on how to supply water to their residents, that is why some areas have water at all times and some have no water at all; politics does play a role because it is likely that areas where politicians stay have water at all times. There was agreement established during the apartheid era which was seen as an income generating venture, the agreement is that the municipality should supply the Kutama jail with water 24\7 at 120 litres per second, this agreement has led to water stress in the municipality because cut-offs have to be made in order to supply the jail with water.

According to the Constitution of South Africa Act, 108 of 1996 provision should be 200m from the household, 50-100 litres per day, access to a water source should at least be 98% of the time and the flow availability of water supply should at least be 10 litres per minute at a communal tap yet these goals are not meet by municipality. The residents in Makhado get water from 4:30 am till 12:00 pm and again at 16:00 pm till 21:00 pm because the pump pressure cannot sustain the demand by all sectors so they have to do some cut-offs in order to suppress the pressure from the pumps bearing in mind that the pipes that are in use have been in use since 1960 and have not been replaced.

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It is important to note that WDM does not always suggest that water usage should be reduced but within the SADC region there are many households that do not have access to an adequate volume of potable water resulting in too little water usage. Vhembe District Municipality (VDM) is currently conducting major repairs to fix a massive leakage between the Albasini water scheme and the Mowkop reservoir in Makhado (Louis Trichardt). As a result, water supply has to be shut down between 14:00 and 16:00 pm.

The water distribution section should have a water service provider according to law; water service association which is responsible for the control of water distribution, DWAF which is responsible for the resource management, district manager which is responsible for the treatment work and the local manager which is responsible for the commend outlet distribution. However, the Makhado Local Municipality is failing to separate water distribution administration and water service provider causing a conflict of interest.

Makhado consumes water that is provided by Vhembe District Municipality, then Vhembe bills the municipality every month for the water, but because of the incapability of officials, they cannot sustain the service provision. The ward Councillor noted that the district is unaccountable, incompetent and unresponsive because locals can go for days without water. This situation arises because it takes 48 to 72 hours to appoint a service provider to attend a leakage, because they do not have competent people or sufficient people to manage the crisis.

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Departments within the water supply scheme in Makhado

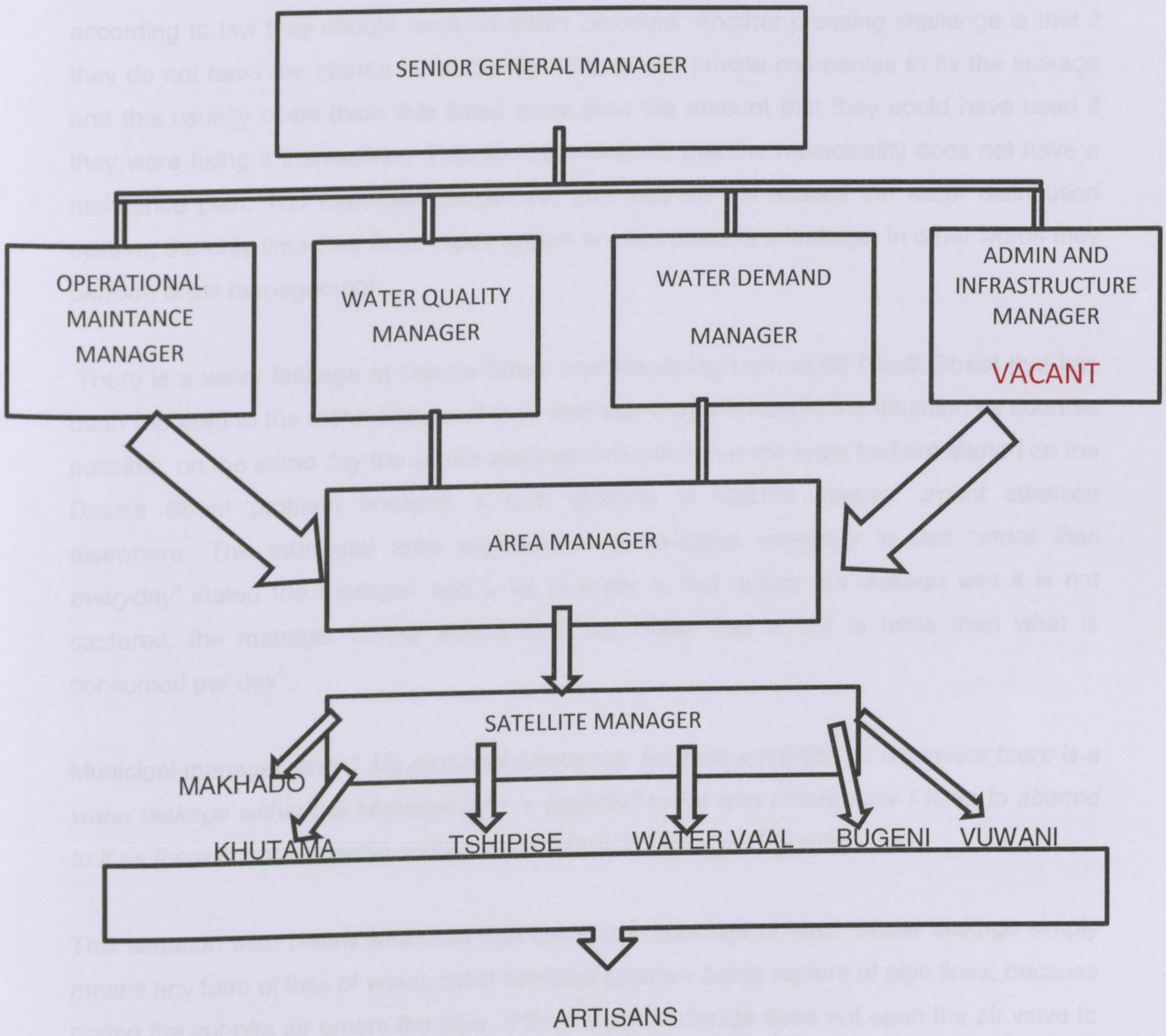


Figure 4.32: Departments within the water supply scheme in Makhado

Source: Makhado Local Municipality Annual report 2012/2013

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4.4.2 Technical Challenges

From the interview with the senior general manager it emerged that to adress a leakage depends on the source and availablity of spares in hand, so when the parts are not available repairing the leakage can take days and large quantities of water is lost but according to law they should respond within 24 hours. Another pressing challenge is that if they do not have the spares in hand they have to use private companies to fix the leakage and this usually costs them five times more than the amount that they could have used if they were fixing it themselves. This can also indicate that the municipality does not have a maintance plan. The manager pointed out that they do not assess the water distribution system; the only time they fix or repair a pipe is when there is a leakage, in other words they perform crisis management.

There is a water leakage at Dassie Street and Vondeling farm at 60 Rissik Street that has been reported to the technicians and they said that they will handle the situation as soon as possible, on the same day the senior manager indicated that the team had not started on the Dassie Street problem because a bulk pipeline of 400mm needed urgent attention elsewhere. The municipal area experiences a leakages everyday in fact "*more than everyday*" stated the manager and a lot of water is lost during the leakage and it is not captured, the manager further stated that "the water that is lost is more than what is consumed per day" .

Municipal manager said: " *My personal phone has become a hot line as whenever there is a water leakage within the Municipality it is reported to me and unfortunatly I have to attened to it as there is not a specific section that deals with leakages.*" (Peter)

This situation also clearly indicates that there is a shortage of staff. Water leakage simply means any form of loss of water, most common problem being rupture of pipe lines, because during the cut-offs air enters the pipe. If the person in charge does not open the air valve to release the air a rupture is likely to occur because the air places pressure on the pipe line.
The manager pointed out that the real reason behind the leakages is the ageing infrastruture because it cannot sustain the pressure within the network. The municipal area used the increase of pressure as a strategy in order to statisfy the residents. This means that the residents receive small quantity of water because the pressure has been reduced.

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Another challenge facing the municipality is ageing infrastructure; according to the senior manager ever since 1960 the pipes have not been replaced. He emphasised that the current infrastructure is too old and it is well beyond its lifespan. Effectively, in Makhado town the inadequate water supply can be attributed to lack of infrastructure maintance. Although the municipality has a plan on board to refurbish the water scheme, they do not have the required funds as the government does not see it as a priority as the Nandoni line will be in use from July 2016.

The residents in the municipal area will have to face this water crisis until the Nandoni line is ready for use. The senior manager also stated that water backlog is another pressing challenge; he said that the backlog is caused by the reduction of water levels in dams due to climate change. The reduction of water level causes mud to enter the pipe causing a backlog and whenever there is a blockage in the pipe it makes it difficult for water to flow and water accumulates in one area causing pressure on the pipe and eventually the pipe will burst. It is for this reason that most parts of the eastern side of the town usually experience a water backlog. He also pointed out that the municipality closes the pipe lines at 14:00 pm until 16:00 pm and during this period air is accumulated in the pipes so air valves have to be opened before switching the pumps on so that the air is released in order to reduce pressure in the pipe line. As mentioned the municipality is pressured with a lot of work therefore at times they forget to open the air valves before switching the pipes, therefore the air causes pressure in the pipe line resulting in rupturing.

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Respondent said: "*I don't see the need to pay for water services because our needs are not satisfied, because I can go for weeks without water but the rates at the end of the month are so high*". (John)

The other challenge affecting the municipality is vandalism of taps. Most people in the community remove the taps and sell them to scrap metal outlets.This is a major crisis in Tshikota where people steal water taps ecspecially during the night. The municipality used to operate cut-offs automatically but due to theft of machines they have to do the cut-offs manually. The removal of taps reduces the rate of water supply to residence because there will not be a source of providing water. Whenever there is load shedding there is no single drop of water and the municipality is reluctant to buy generators because of the theft in the municipal area.

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The manager emphasised that every week there is a report of theft and this discourages them from replacing the stolen equipment. He also noted that there are subdivisions of stands whereby a house is turned into a guest house therefore more water is needed, or a stand is divided into three without acknowledeging the municipality and this causes cut-offs of water to some households and they can go for weeks without water .

Most residents in Makhado park have sub-divided their stands because they have turned their households into guest houses in order to generate money. The manager also highlighted that there is illegal water connections mostly by farms near Albasini dam, whereby they channel the water to their farms which causes a decrease in water capicity. The illegal connections to pipelines also causes water shortages due to water wastage from leakages.

The senior manager stated that different water users will have to pay for the cost to manage the water resources and to provide the necessary water services. The rapid population growth and constant migration in the municipalty in search of economic opportunities and security have had a graet impact on settlement expansion. This expansion has led to illegal pipe connections causing water shortages due to water wastage from leakages, which is responsible for weak water pressure or there being no water at all for the Municipality

.

Respondent said: "*I personally don't see the municipality worker's coming to get the metre readings on a monthly basis, like in June I was away for two weeks but the amount that was sent at the end of the month didn't make sense to me as it was more than what I usually pay when I am home full time. I am totally unhappy with the municipal service as i don't know what I am paying for we can go for weeks without water but at the end of the month we get high rates*". (Mpho)

4.4.3 Operational Challenges

One of the most common approaches of dealing with water demand to cope with inadequate water resources is the use of intermittent supplies by physically cut-off foremost of the day and limiting the consumers' ability to collect water. In the Makhado town the agreement that was established during the apartheid era that the municipality should supply the jail with water 24\7 and with 120 litres per second, has led to water stress in the municipality because some cut-offs have to be made in order to supply the jail with water. As a result, a

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water supply programme has been put in place where water has to be shut down between 14:00 and 16:00pm.

Therefore the municipality supplies water from 4:00 am until 9:00 am and 16:00 pm until 21:00 pm. This is a fixed operation frame for the municipality until the Nandoni line is in use.The residents in Makhado capitalize on the water by filling up their personal tanks during the supply hours, this places pressure on the Makhado operational section because during the supply hours the residents collect excessive amount of water most households in the town have tanks of 2 500 litres.

Respondent said: "*I collect as much water as I can during supply hours because you never know water tomorrow holds as we can go for days without water and whenever there is provision of water it is either dirty or comes out a very low pressure*" (Queen)

The manager emphasised that the residents capture more than what they need per day, yet he understands why because there are days where there is no water at all due to maintenance challenges. He further stated that this capitalisation is straining the municipality because the reservoirs can never get full because a lot of water is captured by the residents during the supply hours; this is why some areas do not have water at all because there is not enough water to supply.

As mentioned that from 14:00 pm until 16:00 pm the pipe lines are closed because the municipality is filling the reservoirs with water as they get emptied during the supply hours of 4:00 am- 9:00 am. The manager further pointed out that the reservoirs will never get full due to this capitalisation. The water supply crisis in the municipality is evident as in 2012 the North Gauteng High Court ordered the municipal manager to restore water to the community of Makhado within 90 days.

The water shortage in Tshikota and Makhado town drove the high Court to order the municipal manager because some sections of Makhado had been without water for months. The Tshikota residents could only get water from the hydrant or local school which has a borehole. The cost for the water at school is a rand a litre, which makes bathing, cooking, washing clothes quite impossible. The irony of this is that while residents suffer in the municipality, leaks are not being attended to and a lot of water is being lost.

Respondent said: "For *the past three years I have been buying water to drink and cook because the water is so dirty that you can only bath with it*" (Rinae)

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4.5 Water distribution in Makahdo New Town

The main source of water supply in the Makhado Local Municipality is the Albasini dam which has different systems and three pumping stations with each having scour valves and air relief valves. The first pumping station is 15km away from the plant, the second pumping station being 5 km away from the first station and the third pumping station being ± 800m away from the main reservoir. The main reservoir in Makhado Newtown is the Mowkop reservoir with a density of ten mega litres, each pump station has two small pumps and one big pump, the two small pumps feeds water to the station and the big pump feeds water to the next pump station.

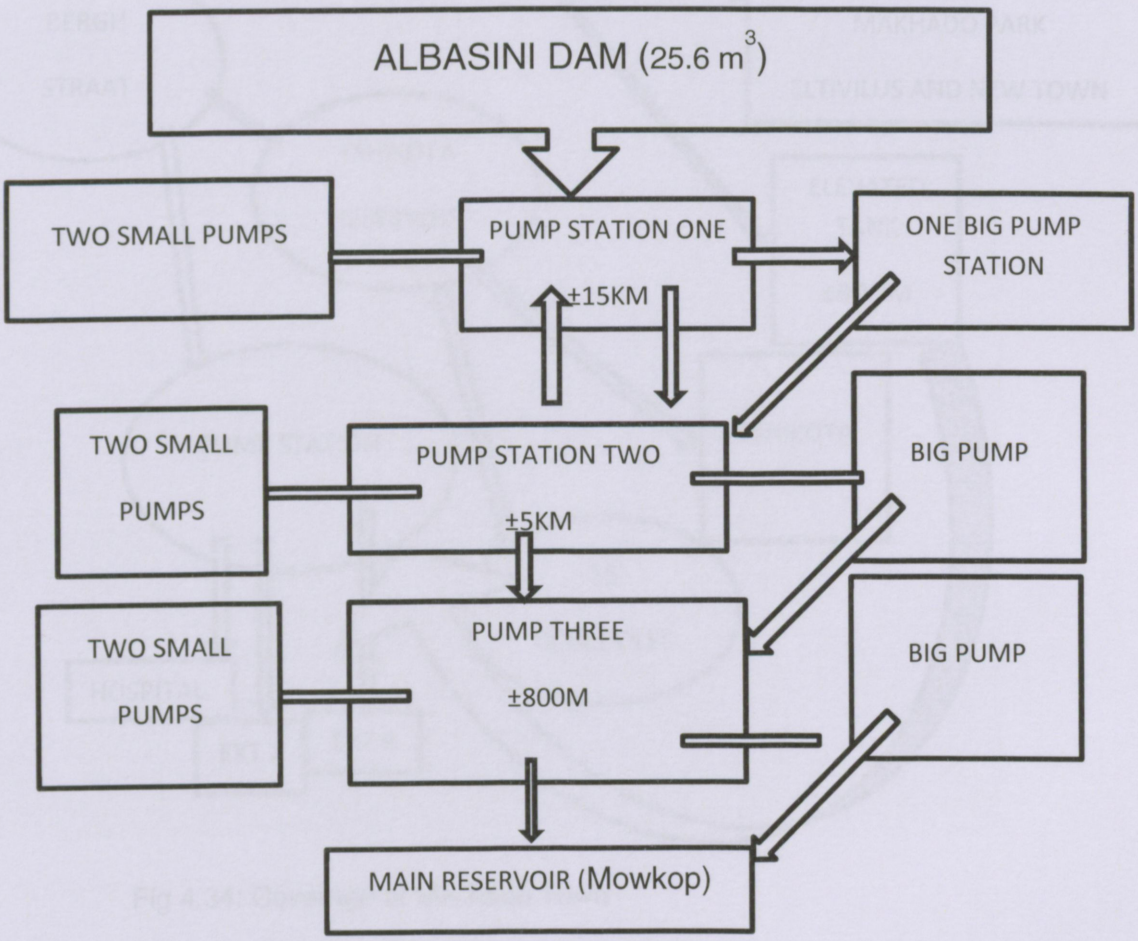


Figure 4.33: Water distribution in Makhado Town

Source: Makhado Local Municipality Annual report 2012/2013.

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The coverage of Makhado town consists of a main storage known as the Mowkop reservoir with 12 mega litres which supplies water to the prison, eastern part of the town, Makhado Park, Eltivilus and New Town. Mowkop feeds water to an elevated tank which is ±800M and bergh straat which has a gravity belt which supplies water to the pump station, the pump station and bergh straat is responsible for supply water the hospital, extension seven (ex7) and extension nine (ex9). The gravity belt also feeds water to the Tshikota reservoir which supplies water to Tshikota and Tshikota boreholes, (fig 4.34).

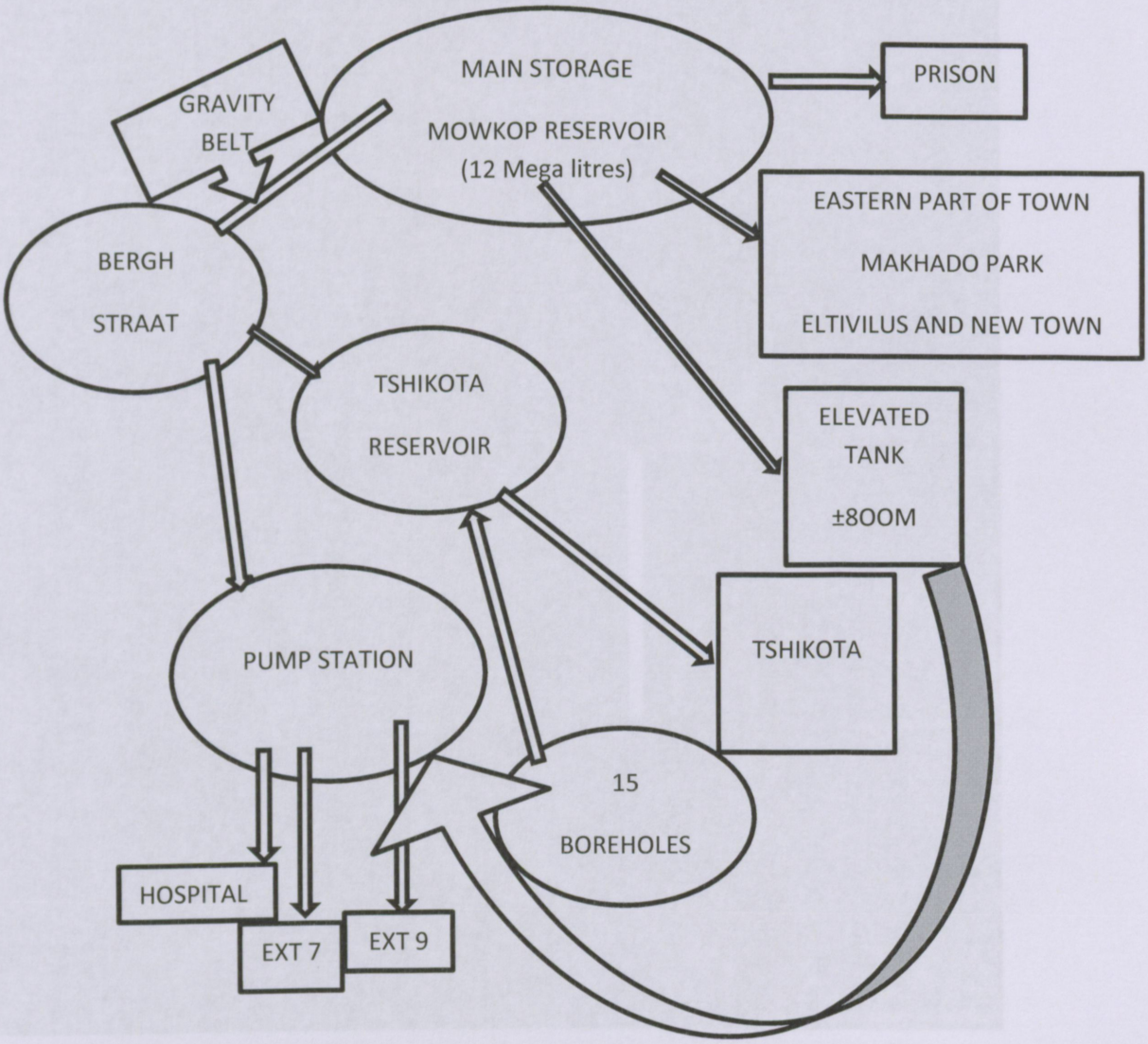


Fig 4.34: Coverage of Makhado Town

Source: Makhado Local Municipality Annual report 2012/2013

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The Makhado Local municipality water infrastructure was constructed in 1960 and is still in use to date; this infrastructure has not been refurbished and is failing to cope with the current demands of the local residents. Figure 4.35 shows the current water distribution.

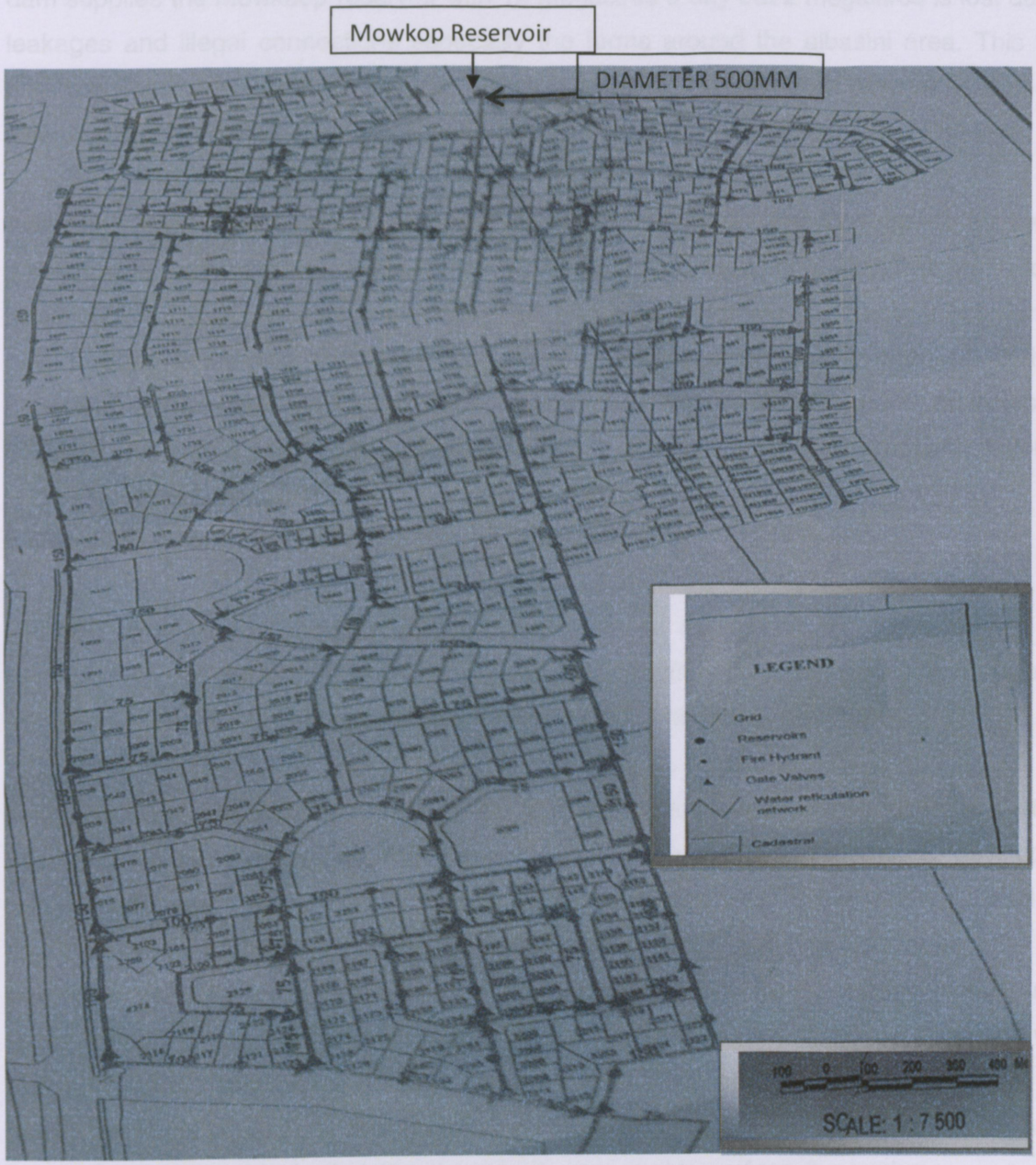


Figure 4.35: Water distribution network in New Town

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According to the municipal report, the Albasini dam has a water capacity of 25.6 mega litres, there are three pump stations between the dam and the mowkoop reservoir with a diametre of 315mm. The pipelines which are made of asbestos are 20.8km away from Mowkoop. The dam supplies the Mowkoop reservoir with 12 megalitres a day but 2 megalitres is lost due to leakages and illegal connections especially the farms around the albasini area. This was noted in September 2014 as they did an operation check to establish what is causing the loss of water. Mowkoop has a water capacity of 12 mega litres, pipe diametre of 500mm.

According to the findings during fieldwork, residents pointed out that they can go for weeks without water and whenever there is provision it cannot sustain their daily needs as water is provided for a short period and in some cases at a very low pressure. The manager further pointed out that the pipe lines were constructed in 1960 and have never been refurbished, he further emphasised that Makhado town is mushrooming at a very fast pace, as also seen in New Town (figure 4.3) and the infrastructure cannot keep up with the current population.

4.6 Results from EPANET which was used in this study

EPANET is a water distribution model designed to be a research tool for improving the understanding of movement of drinking water that constituents within distribution systems. This model was used to analyze the water distribution in Makhado New Town.

Makhado Local Municipality is one of the four municipalities comprising Vhembe District. Makhado is a municipality that attracts most tourists in the district and it is rapidly developing with most economic activities taking place within the municipality. The manager pointed out that the water distribution system was constructed in 1960, and these developments and attractions which result as pull factors placed a need to analyse the current water distribution system. According to the water research commission most municipalities are struggling with lack and deteriorating infrastructure. An analysis of the water distribution system in the municipality was carried out through the use of EPANET, a computer aided tool. New Town is a suburb found in Makhado town, the suburb was used to perform the analysis.

Based on the information that was available from the municipality, the pressure at each node was obtained, whereby there is a negative pressure it clearly indicated that the system is unable to meet the given demand or the pipeline network is damaged. The pipe lines in the municipal area are made of asbestos and In accordance with best practices in pipeline analysis, the Hazen-Williams friction factor for asbestos cement pipe is 140 (Hazen-WilliamsCoefficients-EngineeringToolBox).

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The purpose of a system of pipes is to supply water at adequate pressure and flow. However, pressure is lost by the action of friction at the pipe wall. The pressure loss is also dependent on the water demand, pipe length, gradient and diametre.

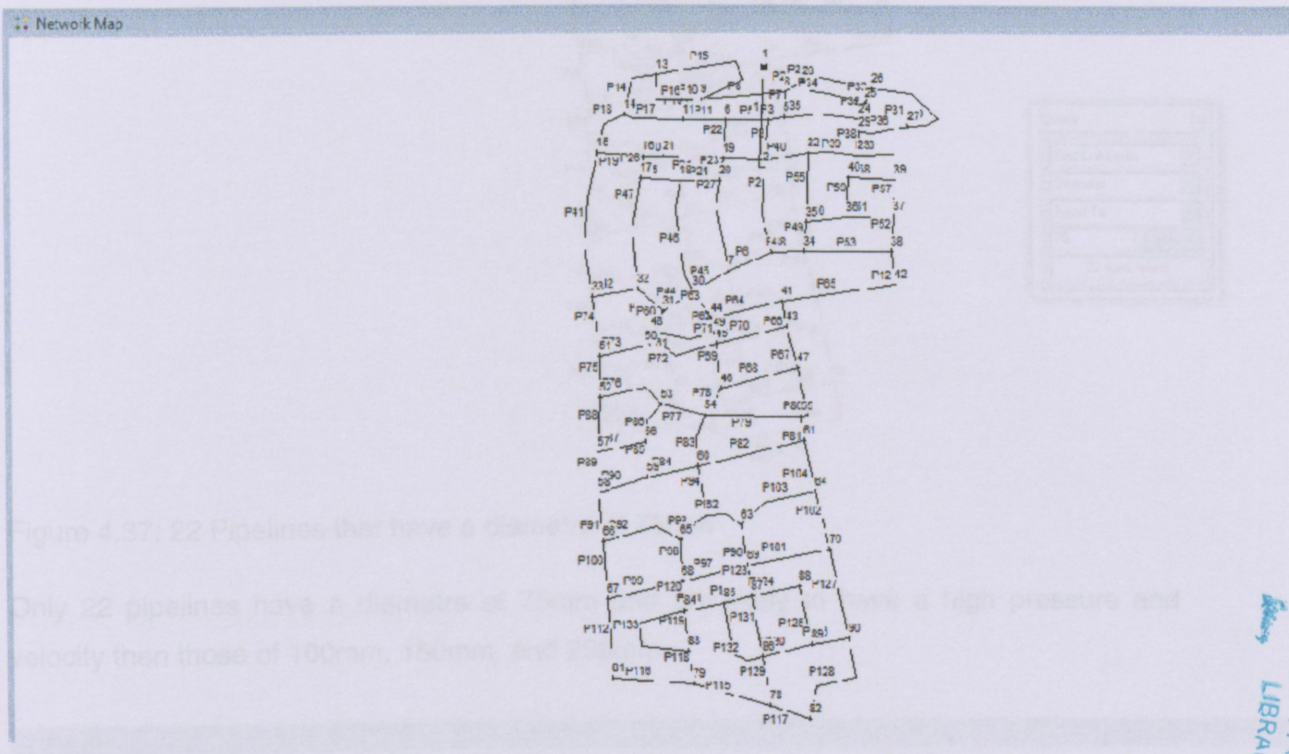


Figure 4.36: Skeletonization of New Town water distribution network on EPANET Platform

Figure 4.36 shows the water distribution system of Newtown found in Makhado town, the skeletonization shows the Reservoir, pipes and junctions the attributes to these inputs can be found on appendence D.

Based on the results as seen in figures 4.37-4.40 the greater the diametre the lower the velocity within the pipeline. The diametre of 75mm as a velocity of 67.94 m/s, 100 mm has a velocity of 38.22 m/s, 150 has a velocity of 16.99 m/s and 200 has a velocity of 9.54 m/s whereas the flow is a continuity of 0.3 l/s. The results obtained showed that only 22 pipelines have a diametre of 75 which means that they are likely to get water at a higher pressure, 41 pipelines have a diametre of 100mm, 54 pipelines have a diametre of 150mm and 2 pipelines have a diametre of 200mm which are likely to get water at a low pressure. Therefore the results obtained verified that the pressure at most of the junctions and the flow with their velocities is not feasible enough to provide adequate water to the network area of the study.

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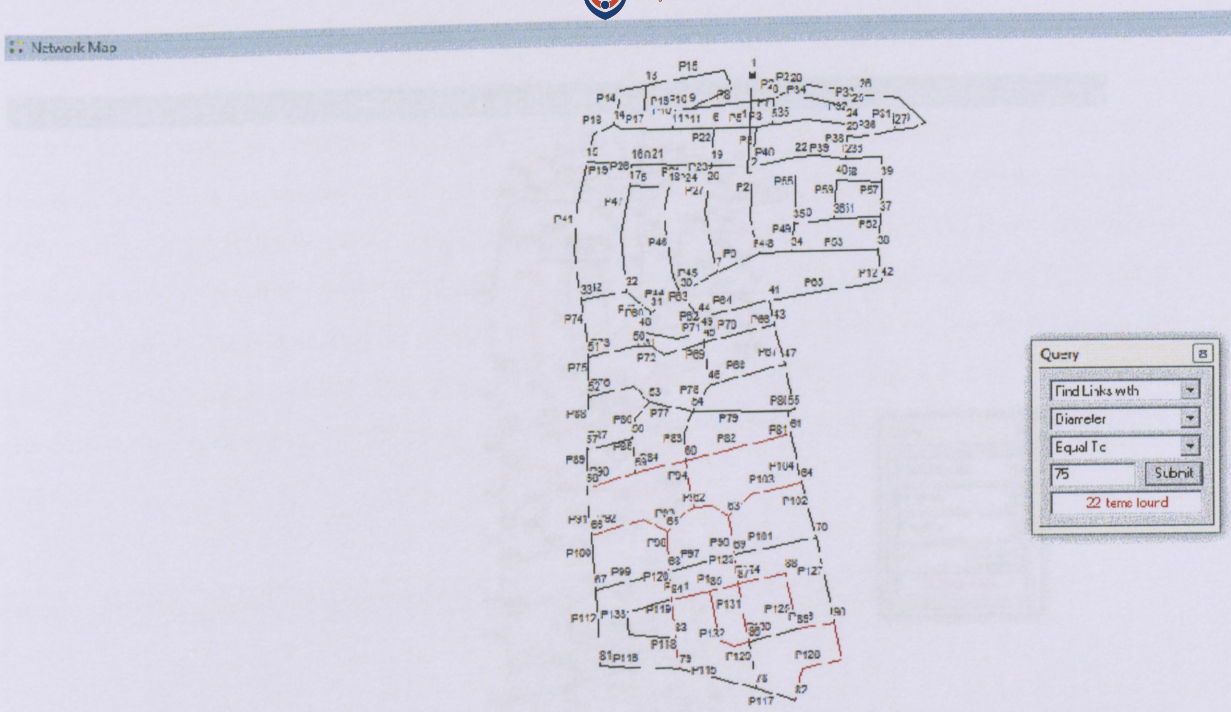


Figure 4.37: 22 Pipelines that have a diametre of 75mm

Only 22 pipelines have a diametre of 75mm and are likely to have a high pressure and velocity then those of 100mm, 150mm, and 200mm.

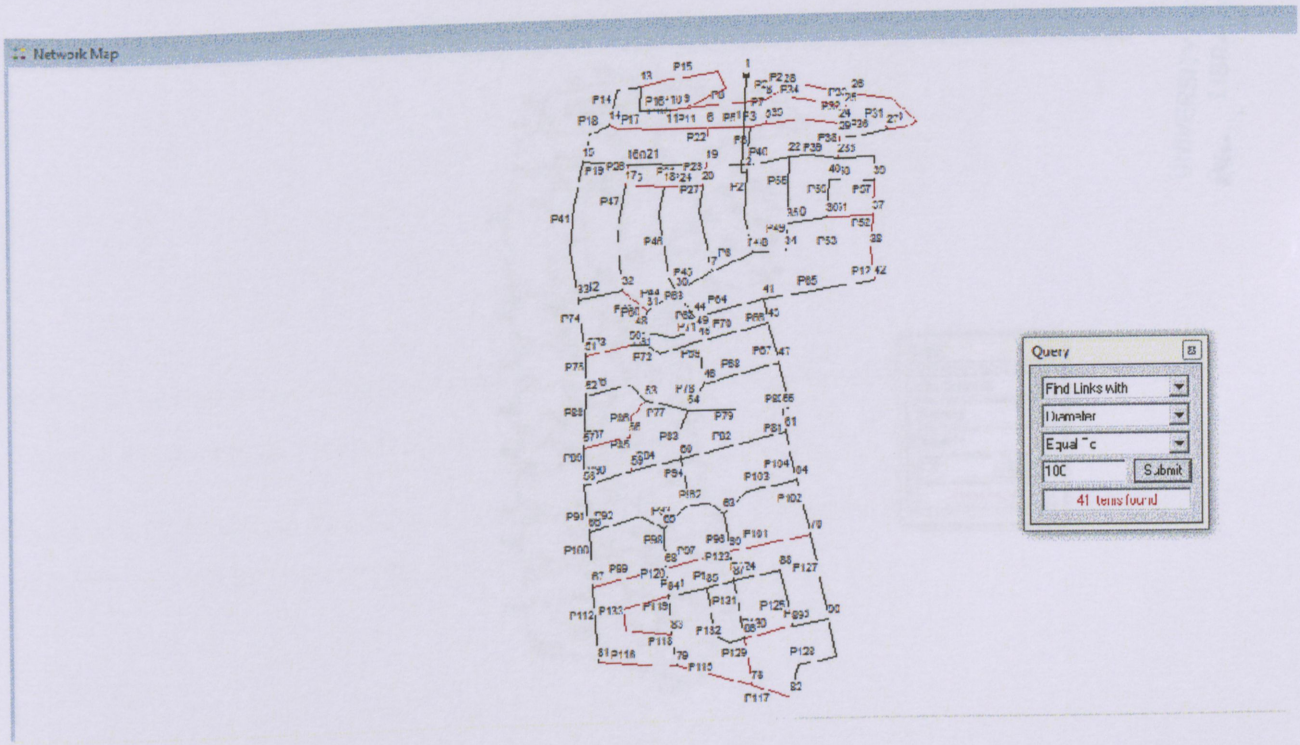


Figure 4.38: 41 Pipelines that have a diametre of 100mm

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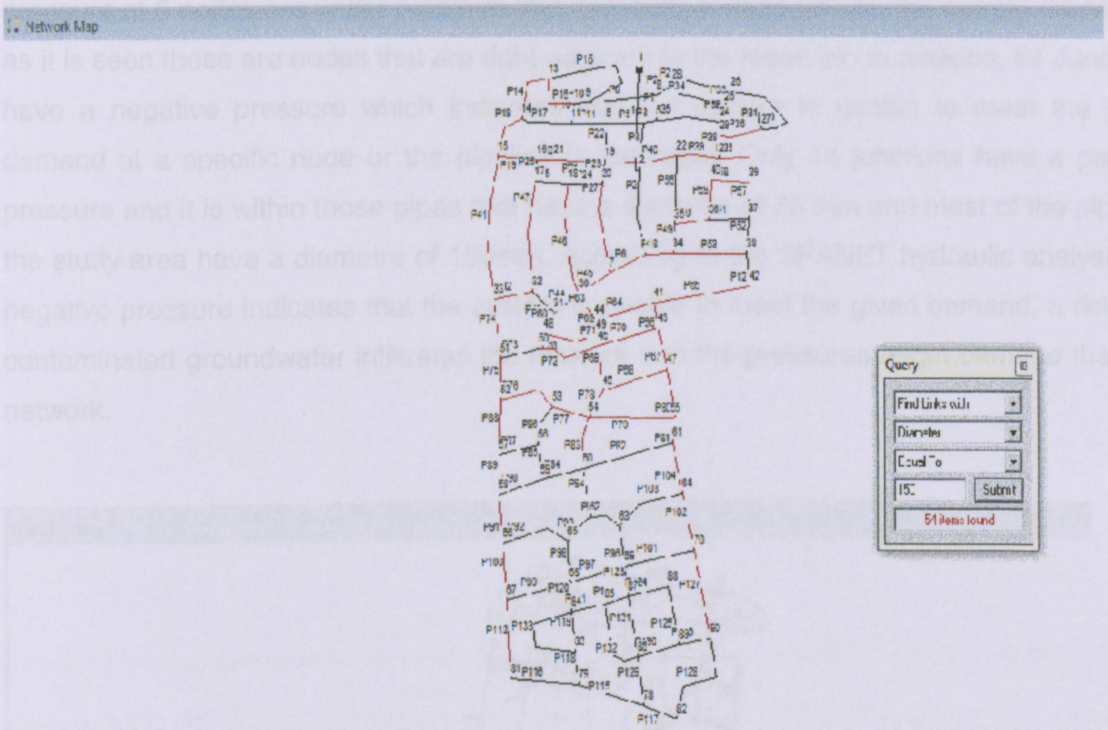


Figure 4.39: 54 pipelines that have a diametre of 150 mm

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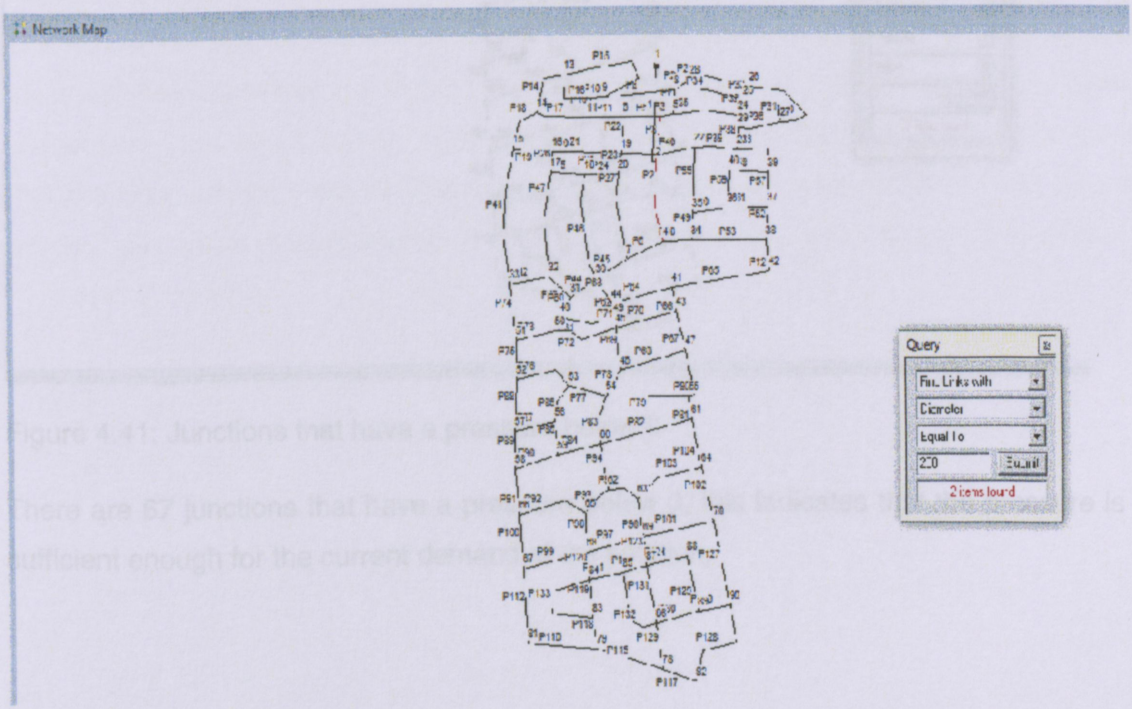


Figure 4.40: 2 pipelines that have a diametre of 200mm

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Based on the results obtained as seen in figures 4.41-4.42 it has been verified that the pressure at 6 nodes are under pressure that they cannot keep up with the current demand at as it is seen these are nodes that are right adjacent to the reservoir. In addition, 67 Junctions have a negative pressure which indicates that the system is unable to meet the given demand at a specific node or the pipeline is damaged. Only 14 junctions have a positive pressure and it is within those pipes that have a diametre of 75 mm and most of the pipes in the study area have a diametre of 150mm. According to the EPANET hydraulic analysis the negative pressure indicates that the system is unable to meet the given demand, a risk that contaminated groundwater infiltrates the network and the pressures might damage the pipe network.

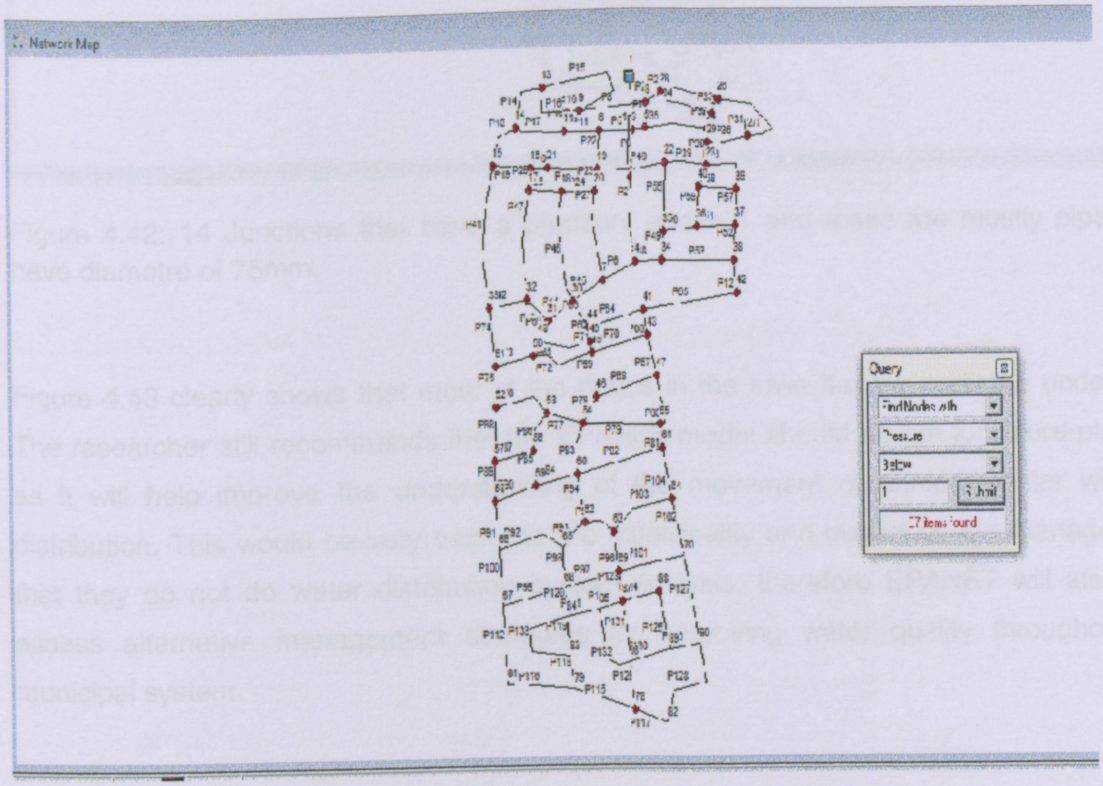


Figure 4.41: Junctions that have a pressure below 0

There are 67 junctions that have a pressure below 0, this indicates that the pressure is not sufficient enough for the current demand at the junction.

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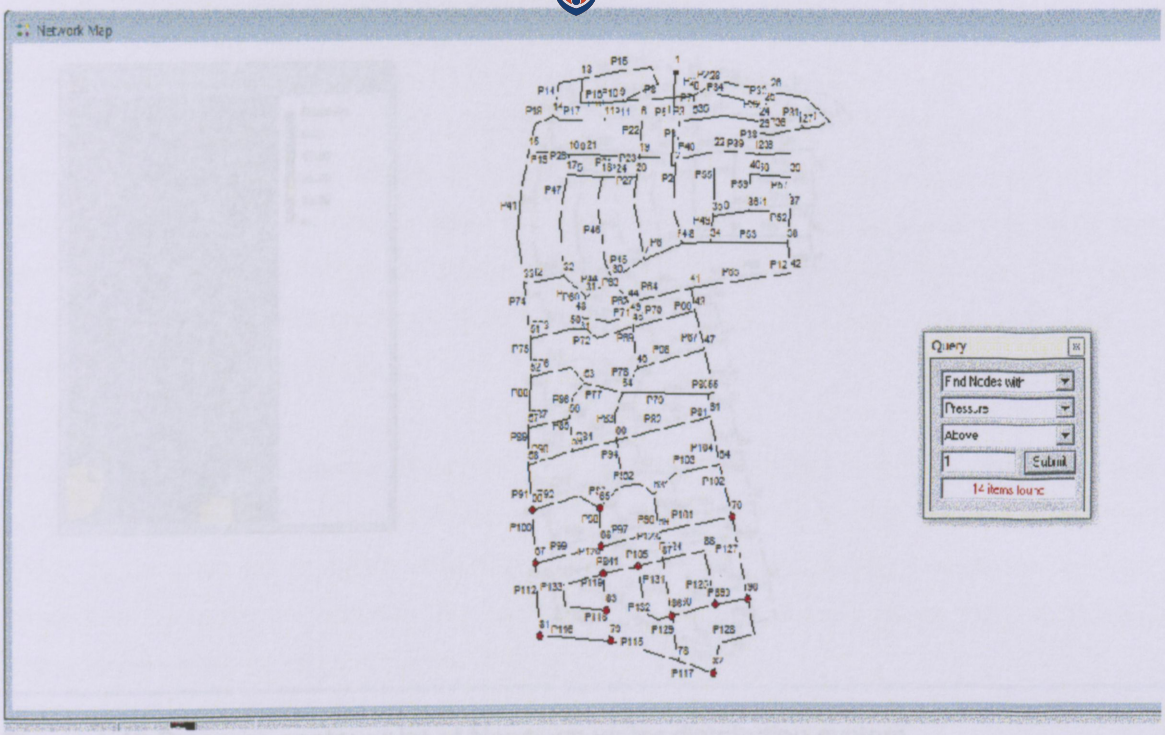


Figure 4.42: 14 Junctions that have a pressure above 1 and these are mostly pipes that have diametre of 75mm.

Figure 4.43 clearly shows that most of the nodes in the town have a pressure under 8 m, The researcher still recommends that the EPANET model should be run for future planning as it will help improve the understanding of the movement of drinking water within a distribution. This would be very useful to the municipality and district as the manager said that they do not do water distribution system analysis, therefore EPANET will also help assess alternative management strategies for improving water quality throughout the municipal system.

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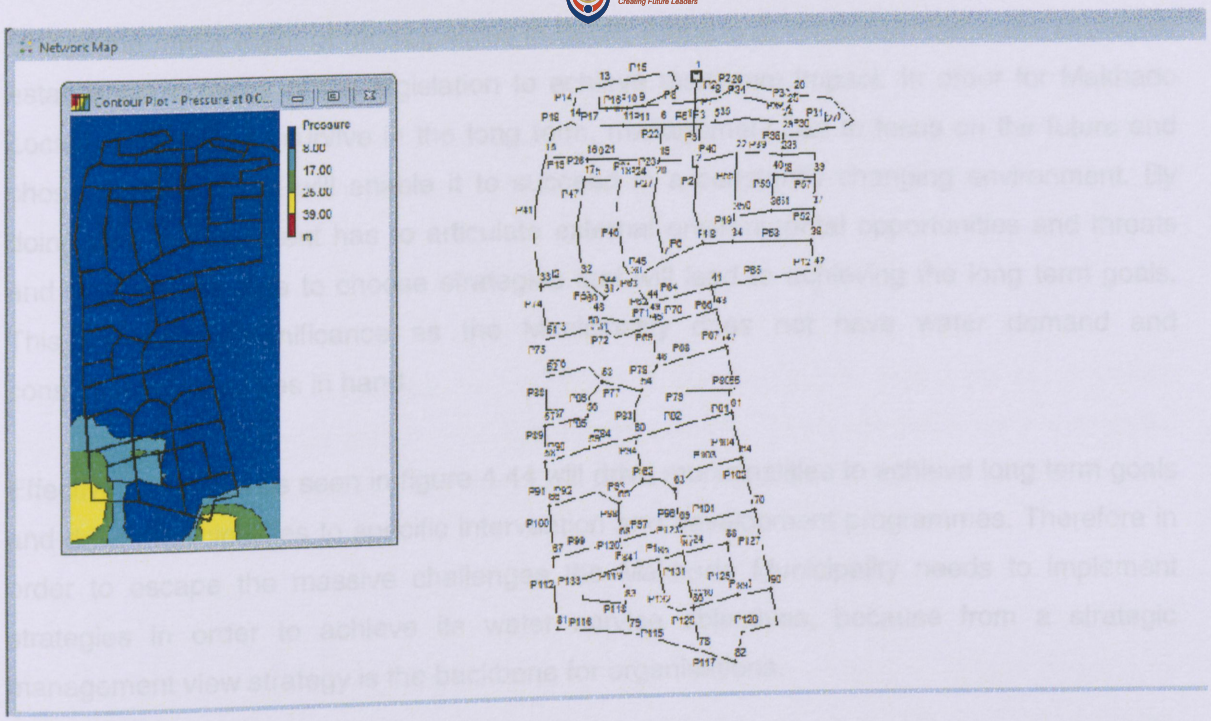


Figure 4.43 Pressure contour plot of Newtown water distribution system

4.7 Strategic Framework to achieve sustainable water supply

In South Africa there is much legislation that includes the regulation of water services. The country's water laws were subject to change after 1994 in order to address equitable access to water for all the country's people and to provide appropriate control over the available water resources. The legal framework in respect of water service delivery includes policies, strategies, laws and approaches, as well as mechanisms to deal with integrated water resource management. It is therefore necessary to put in place an effective framework to ensure that the country's water resources are protected, used, developed, managed and controlled in a sustainable and equitable manner over the long term for the benefit of all. According to Thompson, (2006), a framework should include the provision of the necessary services and economic benefits for people, plants and animals.

It is important for an alignment to be achieved between policies, legislation and strategies within the water services sector that is the only way in which water service delivery will ultimately be improved. It is stated that, in terms of the Municipal Systems Act, No 32 of 2000, the municipality must give priority to the basic needs of the local community and ensure that all members of the local community have access to at least the minimum level of basic municipal services (RSA, 2000).

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One of the major tasks of municipalities in South Africa is to implement the water strategies established in terms of the legislation to achieve maximum impact. In order for Makhado Local Municipality to survive in the long term, management has to focus on the future and chose strategies that will enable it to succeed in a constantly changing environment. By doing this, management has to articulate external environmental opportunities and threats and from this be able to choose strategies that will lead to achieving the long term goals. This will be of significance as the Municipality does not have water demand and consumption strategies in hand.

Effective strategies as seen in figure 4.44 will drive municipalities to achieve long term goals and drive municipalities to specific intervention and development programmes. Therefore in order to escape the massive challenges the Makhado Municipality needs to implement strategies in order to achieve its water service objectives, because from a strategic management view strategy is the backbone for organisations.

When developing strategies, an analysis of the organization and its environment is important so that the necessary adjustments can be made to address shortcomings. The analysis executes strength and weakness of the organization to reduce the negative impact. The aim of a strategic analysis is to form a view of the key influences on the present and future wellbeing of the organization and what opportunities are afforded by the environment and competencies of the organization (Baily et al, 2005).

4.7.1 Elements of swot analysis

- **Strengths**

The municipality is well endowed with water sources and a economic magnet as developments are taking place and offer a variety of services.

- **Weaknesses**

The municipality has out-dated facilities, work methods and poor relations with certain segments of the community. The water infrastructure is not conducive to proper service delivery. The municipality does not have a maintenance plan and its strategic framework is not effective. Another weakness is the prolonged vacant positions within the water sector.

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- **Opportunities**

The municipality can take advantage of the wealth and local assets, agriculture development, partnership with other stakeholders and tourist potential of attractive areas and facilities.

- **Threats**

There is shortage of resources, vandalism and theft of pipes, high rate of migration, mushrooming of informal settlements and water pollution. The municipal area is also faced with illegal connections and cutting of metre readings as well as shortage of staff and lack of finance.

It is clear that in order to improve the current state of affairs, various initiatives need to be taken in terms of implementing well-coordinated strategies and mechanisms. Effective water resource management is dependent on all water users and water managers must play their part. The government alone cannot deliver; in order to implement strategies it is important for communities to understand how the water cycle works and how their actions can create impacts on the cycle. In contrast it is also important to understand the context of water resources in the municipality and the challenges it is facing.

The Municipality has to first identify a problem and analyse the problem so that they can find the extent of the problem before tackling it, because some problems need adjustments and some need a new foundation. Revision the guiding principles and policies is crucial in order to identify the gap that has caused the problem, the municipality can decide to amend the existing strategies or rework on them guided by the SWOT analysis. It is very important to have a capacity building and expertise among practitioners in the water sector which will promote networking among education and training to water service providers and users. This can be guided by the framework programme for education and training in water which will provide institutional support initiated by the South Africa Qualifications Authority Act, 1995 and Skills Development Act, 1998.

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4.7.2 Elements of strategies

- **Public consultation, education and awareness**

Public consultation, education and awareness creation can drive a municipality to achieve its goal, and the only way to achieve their goal is by satisfy the community and that can be done by involving them. For water users and stakeholders to effectively contribute to water resources management they need to be aware of these issues and difficulties, have an understanding of what is required and also voice out their concerns which will guide the strategy plan. This campaign can be guided by guidelines that were developed by the national water resource strategy for public participation in water-related issues to ensure a consistent approach throughout the country.

- **Water education programme**

The water education programme will raise the level of understanding of water issues, promote resource conservation among the public, integrate water-related education into the educational curriculum and establish partnership with all stakeholders within the water sector and involve communities in water campaigns such as Water Week which is celebrated in March every year.

- **Communication programme**

A communication programme including both consultation of community and stakeholders will ensure that the consumers' needs and expectations are understood and satisfied. It is not really possible to achieve a sustainable water supply without considering building capacity within the municipality, in order to ensure an effective management and a sustainable water supply competency from the operator's imperative for water operations and maintenance. Training is not enough, there is a need to develop skills of integrating water managers and if new skills or ideas are going to be employed, then institutions and individuals need incentives to change their practices and approaches.

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- **Water research**

Water research is very important as it is fundamental to understand the municipal water resources and the community needs, which will be the municipal drive to achieve sustainable water supply. The approach to invest in research can be guided by the water resources management and water use and waste management. To ensure that the research results are relevant they can be guided by the water resource objectives whereby the strategic areas are maximised by addressing the relationship between water and society, water and the economy, water and health, and water and the environment. The research should include a survey addressing water needs which will focus on consumption and demand so that the municipality can keep up and be aware of the situation in their area. Resources-directed measures should be carried to focus on the quality of water resources and source-directed controls which will measure the limits and constraints that must be imposed on the use of water resources to achieve the desired level of protection.

- **Involving community members**

Involving community members in decision making is one ideal way of making them value their resources and surroundings because they will have played a role. Involving community members should be ideal because the decisions made would be concrete in terms of stratification as the strategies put into place correlates with their concerns and by doing so it builds confidence within a society and a respective relationship between community members and the government.

The Municipality should treat the citizens as customers by listening to their views and taking account of them in making decisions, should treat them with consideration and respect and make sure that the promised level and quality of service is always of the highest standard and respond sympathetically when standards of service fall below the promised standard. At the end of the day effective water resources management is dependent on all water users the government cannot achieve this alone, therefore a relevant partnership needs to be established. It should include all councillors, representatives from various structures of the community and all government departments and relevant officials because the municipality's dream of a better life will not be realized without the participation of the local community. A community plays a vital role in managing and developing the environment.

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There is a need to make the community feel sensitive about environmental sustainability and environmental protection. In contrast, environmental education needs to be extended to local people, to help them learn the most secure ways of protecting the environment. The strategic framework should be aimed to achieve effective control, protection, conservation, development and sustainable management of the municipality's water resources.

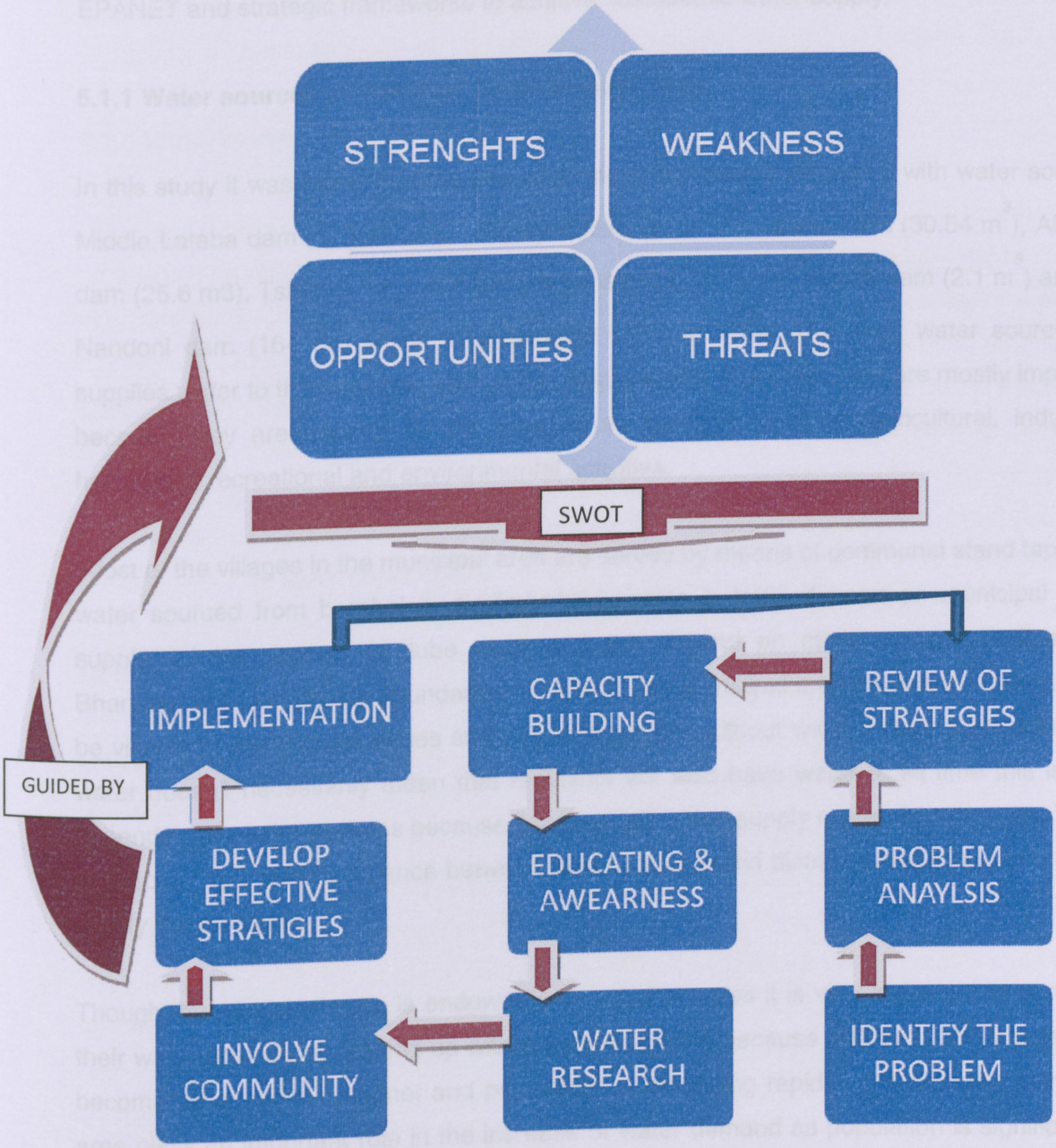


Fig 4.44: A Strategic framework to achieve sustainable water supply

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CHAPTER 5: DISCUSSION OF FINDINGS

5.1 Introduction

This chapter discusses the findings of the results on urban household water demand and consumption, institutional, technical and operational challenges, water distribution systems, EPANET and strategic frameworks to achieve sustainable water supply.

5.1.1 Water sources in Makahdo Local Munucipality

In this study it was found that the Makhado municipal area is abundant with water sources; Middle Lataba dam (173.12 m^3), Nzhelele dam (51.2 m^3), Vondo dam (30.54 m^3), Albasini dam (25.6 m3), Tshitale (18.3 m^3), Mutshedzi dam (2.3 m^3), Tshakuma dam (2.1 m^3) and the Nandoni dam (164 m^3) which is anticipated for July 2016. The main water source that supplies water to the Makhado town is the Albasini dam. Water sources are mostly important because they are needed for life to exist as water is used for agricultural, industrial, household, recreational and environmental activities.

Most of the villages in the municipal area are served by means of communal stand taps with water sourced from boreholes, similarly households in India depend on municipal water supply, 21.4% depend on tube wells and 6.7 depend on other sources (Bajipai and Bhandari, 2001). With this abundance of water in the municipal area the residents should not be victims of water crisis issues such as going weeks without water. Having abundance of water doesn't necessarily mean that residents will also have water at all time this is also dependent on water systems because it is the means that supply residents with water. There is need a need to be a balance between water sources and distribution systems in order to satisfy the residents.

Though the municipal area is endowed with water sources it is very important to conserve their water sources by coming up with supply strategies because Makhado Municipality has become an economic magnet and population is increasing rapidly. Development within an area plays an important role in the increase of water demand as population is significant in determining water consumption and demand. As population increase so does consumption which brings forth the emphasis that supply strategies are very significant to avoid water sources from depleting.

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5.1.2 Population and gender

In this study there is no statistically significant correlation of households' monthly water consumption amongst households with females and children, because the residents in the municipal area do not receive water in such a manner that they can use it as they should i.e. the water that they receive they have to use it sparingly because water provision is not guaranteed on a daily basis as in India more than two-fifths of a household pointed out that the supply of the municipal water is not predictable at all (Shaban and Sharma, 2007).

5.1.3 Water demand and consumption

Water consumption and demand varies from one household to the other due to a number of factors such as family size, level of education, life style, income and gender. Makhado Town is an economic hub of the district and developments are taking place therefore people with high income prefer to stay there as statistics South Africa (2011) indicated that 41.2% of the people in the Makhado town get a monthly income of at least R25, 633.33. Therefore this area is likely to use more water due to the high income. It is ideally that areas with high income tend to use more water as they are exposed to technology and high life styles unlike in areas of low income. Jacobs and Haarhoff (2004) also found that household size has a positive effect on water consumption.

Most of the residents in New Town use their water for cooking and bathing but in India bathing consumes the highest amount of water followed by toilets, washing clothes and the lowest consumption of water being for drinking and cooking (Shaba and Sharma, 2007) unlike in New town where cooking and bathing consume the highest amount of water. Household water consumption also varies according to the time of day and the day of the week. Water usage generally peaks in the morning when people wake up and get ready for work or school, in the afternoon when they return home as they have to prepare meals and bath. In this context, the most important thing is to increase water use in these households to at least 25 but preferably to 50 l per person per day which is believed to be adequate by world's standards for drinking water and ensuring acceptable hygiene and sanitation (Gleick, 2000).

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On average the household water consumption per person a day in New Town is 225.13 litres a day which is more than enough as a basic need, but in n Canada a person uses 335 litres a day, Americans use 380 litres a day per person, Israel consumes 280 litres per person a day and Palestine consumes only 60 litres a day per person. There is a huge gap between the municipal water readings and resident's response as they pointed out that they can go for weeks without water but the municipal records says that they get 225.13 litres a day.

Such mistakes are likely to occur whereby a municipality over charges the residents for water services such as in Polokwane the water metre readings on the municipal account did not agree with the actual readings on their water metres (Bosveld Review, 2015). The municipality should reach to an agreement that the residents should take their own water metre readings and submit them to the municipality monthly to avoid misunderstandings.

When residents are not satisfied with a service within a municipal area they will not be willing to pay for the service as they will reach to a point that they are paying too much for nothing and there will never be an understanding between them. In order to have harmony within a municipality the resident's desires need to be met without compromising the municipality.

5.1.4 Institutional Challenges

The Municipality has entered into an agreement to supply the Kutama jail with water 24/7, this agreement has caused water shortage within the Makhado Town as they have to perform cut offs. The Municiaplity does not have a water strategies which can be very useful to plan water supply and demand management mechanisms so that more practical action can be taken by managers in unforeseen events rather than being forced to haphazardly limit water supplies due to supply based limitations. It was found that in India 85% of urban population has access to drinking water but only 20% of the water meets the minimum health and safety standards (Kumar *et al.*, 2005).

There is a shortage of staff with the Makahdo water sector and this makes it so difficult to get a task completed to standard because the quality is compromised, in order for a task to be of quality it needs to be done by a relevant person who has a profession in the job. This is why the municipality is facing a lot of problems and are not able to fix the crisis in time as the relevant person is not available to perform the task. It is significant for Municipalities to have their departments in place and have the relevant people to perform the tasks to avoid compromising quality of services especially in the public sector whereby they have to provide services to their residents.

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5.1.5 Technical Challenges

As in the Makhado Municipality they are still struggling with minimising water losses as the manager said they do not have spares in hand therefore they rely on companies to fix the leakages and in some instances it can take days to fix a leakage and most leakages are caused by the ageing infrastructure. Currently in Maputo unaccounted water is estimated to be 60%. A major part of the losses occur in pipes and household connections due to ageing and poor maintenance of the system (Gumbo *et al.*, 2003).

This study also pointed out that water loss is also due to illegal connections especially by farms around the Albasini area who extract a lot of water which can amount to 2 mega litres a day. Shortage of water is clear and conclusive but this doesnt mean there should be a limit in supply options only such as developing the next source of water, but also consider demand strategies, such as minimising water losses, improving the efficiency of water use necessitates and the understanding of how water is used and in what ways can water be saved. It is also important to involve community memebers by educating about water, how to react when there is a water leakages because the community plays an important role in saving and conserving water. How people think and react within an environment is also dependent on how they are treated, that is why in environmental related issues it is important to keep a good relationship with the residents as they are the ones that live in the environment. Thses residents can either destroy or conserve the environment, it would be a good initiative to allow them to be part of any planning and decision making.

5.1.6 Operational Challenges

The municipality supplies water during certain times in order for the reservoir to fill up but if there is no electricity there will not be any water provision as they do not have a generator during the supply hours the residents capture as much water as they can because they never know what tomorrow holds for them, currently most residents have tanks of 2 500 litres which they use in order for them to cope the water situation although the manager feels that the residents are costing the municipality by doing this. When the water supply is not sufficient, consumers find ways to cope with the situation like construction of storage tanks and alternative water supplies.

These alternatives can get to a point where it strains the municipality as the resources will be compromised because at that point the residents want to satisfy their needs and would do anything please their desires.

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Residents pointed out that they can go for weeks without water thou the metre readings says otherwise, In South Asia it was estimated that at least 350 million people receive water only for period of a few hours daily and nearly all Indian cities are reported to operate intermittent systems (Totsuka *et al.*, 2004). In seven cities of India 18% of the households reported that water is available 24 hours, 27% reported that water is available for a few hours twice a day and 21% reported that water comes for a few hours in two days (Sharma, 2007). Water is needed on a daily basis, without water in a household much cannot be done as it's required for cooking, bathing and drinking. If water is compromised so is the life of people because water is required for survival as a human body cannot function without water. The municipalities need to put their water strategies as a priority and make sure that at least the residents get sufficient water to sustain their daily needs.

5.1.7 Water distribution

The water distribution infrastructure in Makhado New Town was constructed more than 50 years ago which served a smaller population, what does not put the municipality to sleep is that it is too old for its lifespan and needs to be refurbished but they cannot achieve this goal due to institutional challenges. The purpose of a water distribution is to provide adequate and reliable water supply to its users and operation and maintenance are the two things that are needed to continuously keep the water infrastructure in a good state. The fact that the public depends on water distribution sytems for water places an impotant responsiblity on the municipality and its employees. Population plays an important role when desiging or refurbushimg a water distribution system because the system should be able to satisfy the populations needs ecspacially with the pressre that they receive the water. The application of EPANET showed that most of the pressures at the nodes within the system were negative as it's unable to meet the given demand.

Pressure plays a significant role within a water distribution system as it determines the amount at which the residents will get their water because if there is competition of water at a certain node they are likely to get very little water. Without proper planning and investments residents face severe limitations access to municipal services.

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5.1.8 Strategic Framework

The Municipality does not have a strategic frame work for water supply, this is evident to why there is water crises in the Municipality yet it is endowed with water sources. The strategic framework should be aimed to achieve effective control, protection, conservation, development and sustainable management of the municipal's water resources. Though capital is to be an effective means of managing demand, water providers need to know how price information is incorporated into the water use for decision-making within the water sector and in what ways it interacts with other factors in the decision process. Without strategies in hand within a department it is very difficult to offer services to locals as management will be compromised.

The success of household water demand management strategies is dependent on how well we understand how people think about water and water use. The community contributes a lot in achieving sustainable water supply and demand as water conservation is more apparent when individuals believe that water is scarce and when they observe that other consumers are also conserving water. It is very significant to involve community members when developing a strategic frame work of water supply because they will feel the significance of the strategy as they were part of it. Therefore as much as the residents of Makhado municipal area do not get adequate water they should also have an understanding on how to use the little water they get and also help the municipality in conserving the water by reporting water leakages. Having a strategic framework within a department makes it easier to deal with challenges as they will be dealt with according and guided by principals as ensuring sustainable water supply has become a common challenge.

Despite of potential water strategies, for a Municipality to say they are sustainable it is when there is a balance between supply and demand. Due to the rapidly growing population Municipalities should rather focus more of the supply management rather than demand management.

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CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

The study evaluated urban household water consumption and demand in Makhado Local Municipality. The objectives of the study were to determine the relationship between household water demand and consumption, identify institutional, technical and operational challenges, and assess the water distribution and to develop a strategic framework in order to achieve sustainable water supply. From the findings of the study the following conclusions are made:

6.2 Conclusions

6.2.1 Water sources, household water consumption and demand

Based on the findings the municipality does meet the minimum standard of the South African constitution of supplying 100 litres a day per person as only 3.8% of households are receiving less than 100 litres a day per person. Compared to other standards the municipality does meet the minimum requirements as the average of household water consumption per person a day is 225.13 litres a day. Therefore on a minimum requirement the municipality consumption does exceed demand. New Town is associated with high income such an area is likely to demand more water therefore looking at the maximum standard of 250-600 litres a day only 37.2% of the households uses 250-600 litres a day.

Due to the associated characteristics of a high income area it should be provided with 250-600 litres a day per person but not even half of the residents are being supplied with this standard therefore in this case demand exceeds consumption. Based on the scale of 425 litres a day only 12.6% households have been supplied with this amount which is not even half of the population therefore demand does exceed consumption on this scale and ideally the town should be supplied with this scale due to its associations as it is a town of high income

The total population at Makhado town is 25 352 and the Mowkoop reservoir has a total capacity of 12 megalitres. In order for the municipality to satisfy the needs of the town on the 100 litre scale it should supply 2.5 megalitres a day and the reservoir capacity can supply for 5 days. If it is to supply 150 litres a day it should supply 3.8 megalitres and the reservoir capacity can supply water for 3 days.

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If it is to supply 245 litres it should supply 10.7 mega litres a day and the reservoir capacity can supply for a day. It can be clearly stated that the town is endowed with water but the residents still can go for weeks without water and this is due to the ageing infrastructure. Based on the municipal metre water records it is pointed out that on average a person in Makhado New Town consumes 225.13 litres a day yet it contradicts with their views as they pointed out that they can go for weeks without water, therefore there is a need to look into this contradiction as they also pointed out that they get high rates though they go for weeks without water.

6.2.2 Institutional challenges

The municipality does not have a strategic framework that regulates water supply in the municipality, it was pointed as the municipality does not a water maintains plan, the municipality only attends to a crisis when it is reported, in other words the municipality performs crisis management. The crisis management is also enforced by the shortage of staff and competent people. The infrastructure of the municipal is old and beyond its lifespan, it has been used since 1960 and no upgrade has been done. The municipality is struggling to get funds to refurbish the infrastructure because of the Nandoni construction as it is believed that the Nandoni line will solve the water crisis and is anticipated for July 2016.

The municipality entered into an agreement with the Kutama prison during the apartheid era and they are finding it difficult to reverse this agreement. The Municipality saw this agreement as a venture of generating money for the municipality, the agreement is that the municipality supplies the jail with 120 litres person 24/7. This agreement has cost the residents as they can go for hours without water as cut-offs have to be made in order to fulfil the agreement.

6.2.3 Technical challenges

The municipality is facing a challenge of responding to water leakages as they do not have spares in hand nor the competent people, they use private companies to deal with their leakages and this is very costly. The ageing infrastructure is the result of leakages and the backlog is also a contributing factor, as mud accumulates in the pipes and eventually the pipe will burst. The stealing of water taps is a major stumbling block and it becomes expensive for the local municipality to constantly replace the taps that are simply stolen. To

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solve this problem workshops should be held, to inform the public about taking responsibility for protecting public property.

Rapid population growth and constant migration within the municipality has had a great impact on the expansion of settlements. Residents connect their pipes illegally to the main water pipe. The illegal connection to pipelines causes water shortage due to water wastage from leakages, this is responsible for weak pressure or a situation where there is no water at all.

6.2.4 Operational challenges

The municipality cannot operate their water as they wish because they are deprived by the infrastructure because it cannot keep up with the demand. The infrastructure in place was for a small populations so with the rapid growth it cannot keep up. The municipality as to do cut-offs so that they can fill up the boreholes and reservoir that is why the resident gets water from 4am- 9am and 16pm-21pm. The municipality loses a lot of water during these hours because residents capitalize on the water by fill up their personal tanks of up to 2 500 litres and by doing so the municipality finds it very difficult to fill up their reservoirs and boreholes. This is why the municipal area can go for longer cut-offs because the reservoirs are being filled and this process can drag because of the ageing infrastructure.

6.2.5 Water distribution system

Water supply is an essential requirement for all people, determining how much water is needed is one of the first steps of satisfying the demand. Providing water is never free, water needs to be collected, stored, treated and distributed. The rapid population growth and constant migration in the Municipality in search of economic opportunities and security have had a great impact on the expansion of the settlements. Based on the key findings the municipal infrastructure is too old and cannot keep up with the demand. Proper and legal action needs to be done in order to achieve sustainable water supply in Makhado Local Municipality.

6.3 Recommendations

The recommendations are made based on the key findings of the research. The study recommends the management and mitigation strategies that can be used by the Municipality to achieve sustainable water supply.

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6.3.1 Capacity building

An organisation needs skills to overcome challenges, therefore this study recommends that there is a need to develop the skills of the integrating water managers, several organisations such as the UNESCO-IHE, have started developing courses that are adapted to equipping new managers. New managers are needed on board especially with the operation on management of infrastructure in the municipality but at the same time, a new curriculum is urgently needed for individuals to look at water from a more holistic point of view guided by the national water resources strategy capacity building task team.

The Makhado Local Municipality is faced with a challenge regarding its shortage of skills which are an important factor in ensuring that the water services objectives are achieved. The team should promote a network among education and training service providers and users in line with the skills development Act, 1998.

Mbeki (2007), stated that it is important that we work out sustainable programmes around the development of our human resources, sharing of skills in the development and strengthening of our industries. Human resources development is viewed as an essential factor to build the potential of people for sustainable service delivery. Skilled participants have a direct impact on the successful implementation of municipal strategies and capacity building must be viewed as an on-going process.

.6.3.2 Public consultation, education and awareness creation

A public consultation will promote a participation by water users and stakeholders in all aspects of water resources management in their areas of operation. A relevant partnership needs to be established. Water users and stakeholders need to effectively contribute to water resources management. It must include all councillors, representatives from various structures of the community and all government departments and their relevant officials. The stakeholders should form committees that must make contributions towards addressing water issues and ensuring a healthy and stable water resource base.

Stakeholders must be inspired to feel and act within the spirit and vision of the municipality. In terms of section 16(1) of the Municipal Systems Act, 32 of 2000, a municipality must develop a culture of municipal governance that complements formal representative government with a system of participatory governance in order to encourage and create conditions for the local community to participate in the affairs of the municipality.

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Environmental education is crucial in the municipality as people need to be aware of issues and difficulties of water and have an understanding of what is required. The Education programme will raise awareness among the communities that water is a scarce and precious resource and develop responsible attitudes towards its use and conservation. In order to achieve this, programmes need to be extended to schools so that learners are exposed to practical projects enabling them to understand the values affecting the role of water in their lives and what they can do to use water carefully. It is important to put emphasis on awareness programmes that could improve the ideal use of water and safeguard sustainable water supply.

The municipality should share their knowledge and understanding in their communities so that they can have the same level of understanding. The programme can work closely with provincial education and environmental authorities to ensure consistency of application and integration of the educational system. No country can become water sustainable unless the people in that country become committed to ensuring their own water security. To this end, Mission 2017 proposed a plan that will educated consumers and citizens and involve locals with water development projects.

6.3.3 Water research

Water research is fundamental because it will assist the municipality to understand its water resources and also help contribute to future developments. The research can include water demand surreys in order to understand the extent of demand in the municipal area. Research will also help the municipality to keep track of the water situation and contribute to decision making. The municipal research approach can be developed through four water centred keys; water resources management, water linked ecosystem, sustainable water use for agriculture, water use and waste management.

6.3.4 Basic service infrastructure upgrade

The water resource capacity of Makhado Local Municipality is already under stress. There is a need this capacity to be increased or upgraded immediately to satisfy the growth in demand for water services. Respondents, who were asked for their views in the research of this study, were of the opinion that the available water infrastructure is not capable of dealing with water demands.

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The following needs to be done:

- Ageing pipes must be replaced;
- The existing storage facilities must be expanded;
- The maintenance programme must take care of leakages; and
- The municipality must develop automated metre readings which will report directly to the municipal records every month.

6.3.5 Enforcement of the municipal water supply by-laws

The municipality needs to have water services by-laws to ensure a healthy environment for the water supply and to impose penalties if any of the by-laws are violated. It is clear that the residents feel that they are paying excessive amount of money, therefore there is a need to develop water payment service laws which the community understands. For instance both municipality and households should take metre readings and keep record of the readings in case of payment crises.

For the municipality to be financially viable it must ensure that its main income is derived from its own resources, in order to become less dependent on other sources and to achieve long-term sustainability. The municipality does not have a strategic framework for water supply therefore there is a need to develop one so that the municipality can manage its water resources and be able to overcome any shortcomings. The Municipality can adopt the functions by Le Rox (2005).

According to Le Roux (2005:), the functions of the municipalities include:

- To develop and implement by-laws (to ensure that relevant environmental aspects are governed within a legal framework);
- To ensure that they are enforceable;
- To maintain executive functions (including co-operative governance arrangements with other spheres of government); and
- To maintain the protection or conservation function.

Still et al (2008), recommended that the model water services by-laws should contain the following main provisions:

- Municipal consent for the installation of new pipes and fittings;
- Standards pertaining to the quality and installation of pipes;
- Powers of the municipal authority to prevent wasteful use of water or to impose restrictions on the use of water in the event of water shortages, drought or floods;
- Prohibitions on the waste of water by consumers;

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• Requirement of regular water audit by water users who consume more than 3650 kilolitres per annum; and
• Water demand management (water savings measures).

6.4 Further research

It is clear that the current water infrastructure in Makhado is too old and it is well beyond its lifespan. It is not able to cope with the current demand of local residents. The municipality has to now direct its efforts towards service delivery and infrastructure planning. There is a need for a multidisciplinary approach to the study on water demand and consumption, particularly one using engineering tools to assess the water distribution system in the municipality. This assessment will assist with future decision making when the system is to be refurbished.

The engineering tools should take the population and demand into account. There is also a need to look at the water quality as residents are complaining about the quality of water as most pointed out that they cannot even drink the water supplied to them, they actually buy water for drinking. Additionally, a study in the same discipline can design a water distribution system that can assist the municipality to achieve sustainable water, again population and demand should be the driving factors. As there is rapid economic development in the municipality there will also be a need to conduct a demand analysis in other sectors which will assist in the allocation of water distribution.

Providing enough water to meet everybody's needs may be difficult in the short term, so water can be made available in stages by continuous check-ups such as talking to various users (especially women) as they use most of the water in the households. This survey will be necessary as it will give a detailed demand of water in the area.

Therefore in order to satisfy the community's water needs, the municipality needs to know how many people are there, how much water does each individual need or use and communicate with people to confirm their priorities. People use water in different ways so the municipality needs to know the community's water needs to avoid supplying too little or too much water.

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Appendices

Appendix A: Permission to conduct research

VHEMBE DISTRICT MUNICIPALITY
PRIVATE BAG X5006, THOHOYANDOU, 0950
TEL: 015 960 2000, FAX: 015 962 1017
Website: www.vhembe.gov.za

Ref: 4/3

Enq: Mphaphuli T.K

Date: 04 November 2015

ATTENTION: RAMULONGO L

APPLICATION TO CONDUCT ACADEMIC RESEARCH: YOURSELF.

1. Your application dated 15 September 2015 is hereby acknowledged.
2. It is with pleasure to inform you that your request for evaluate research for water readings at Makhado is hereby granted.
3. Please contact the HR Manager at 015 960 2097 in order to arrange the starting date.
4. Trusting that you will find the above in order.

Kind Regards

QUALITY IN SERVICE

2015/11/04

GM: CORPORATE SERVICES **DATE**

"A developmental municipality focusing on sustainable service delivery and socio-economic development towards an equal society"

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Appendix B: Questionnaire

Household Survey (Questionnaire)

The following household questionnaire will be distributed to the community of New Town in Makhado Local Municipality of Limpopo Province regarding the state of water consumption and demand.

Ethical considerations: The aim of this questionnaire is to collect data for academic purposes. Participation is voluntary and respondents can withdraw at any time. Respondents will not be exposed to any form of harm either physically or psychologically. The privacy and identity of the respondents will be safeguarded. This implies that the information will be kept confidential. I would appreciate if you could provide answers to these questions to the best of your ability. NB: Please, Provide answers and cross(x) in the appropriate box next to the question.

Name of Town ☐ **Questionnaire ID** ☐ **Date**.....

SECTION A: Demographic information and socio-economic characteristics

1. Sex

Male	1	
Female	2	

2. Age

0-18	1	
19-37	2	
38-55	3	
56-64	4	
65+	5	

3. What is the number of people in the household?

1	1	
2	2	

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3-4	3	
5-6	4	
Other (specify)	5	

4. What is the composition in the household? E.g. Men=5 Woman=1 Elderly=0 Children=2

		Number of composition
Men	1	
Women	2	
Elderly	3	
Children	4	

5. For how long have you been living in the area?

1-5 years	1	
6-10 years	2	
11-15 years	3	
>16 years	4	

SECTION B: Household water consumption and demand

1. What is main source of drinking water in the household?

Public Tap	1	
Public Borehole	2	
Tap in the yard	3	
Municipal Water	4	
Other (specify)	5	

2. Do you have water all the time?

Never	1	
Once a week	2	

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Twice a week	3	
Always	4	
Other (specify)	5	

If not , what is the explanation from the authorities?
.....

3. What do you use your water mainly for?

Cooking and bathing	1		
Laundry and cleaning	2		
Gardening	3		
Washing the car	4		
Other (specify)	5		

Any addition.....

4. Explain briefly how frequently do you practice the following:

How many times do you bath per day?	1	2	3	>3
How many times do you cook per day?	1	2	3	>3
How many times do you wash your car per week?	1	2	3	>3
How many times do you water your garden per week?	1	2	3	>3
How many times do you use the toilet per day?	1	2	3	>3
What else do you use your water for and how many times per day/week do you do so?				

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5. **How much water does your household need on a daily basis? Remember according to law a person is entitled to 50 litres a day.**

50 Litres	1	
100 Litres	2	
150 Litres	3	
200 Litres	4	
> 200 Litres	5	

Section C: Water Service delivery

1. How would you rank the water service delivery? Is it good/ excellent, why?

Excellent	1	
Good	2	
Fair	3	
Bad	4	

2. Do you pay for water service delivery?

Yes	1	
No	2	

A. If yes, how long have you been paying for water service delivery?

.....

3. How much do you pay for water services?

A. Do you think the charge is too much or too little for the services being provided?

.....

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4. If you are not paying, will it not benefit you as a community to pay so that your District can buy better equipment to distribute clean water to your house?

5. If the municipality were to improve its water services, would you be happy to pay?

Yes	1	
No	2	

A. If no, why wouldn't you?

.....

6. If the charge is not affordable, how much are you prepared to pay for water services?

7. Besides the service fees, do you think the District is delivering as a water service provider?

8. What are your expectations about water distribution in the future?

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Appendix C: Interview Schedule

Study Site: _____

PREAMBLE: *Introduction, purpose and confidentiality statement read before any session.*

The interview questions to be directed to the Water and senior general manager. The purpose of these interviews is to understand the state of water demand, supply and consumption in terms of the service areas, water distribution systems and the guiding principles of water supply. The information obtained will be kept confidential and will only be used for academic purposes.

Questions for the water and infrastructure manager

1. Briefly state all the water sources that supply water to the residences and describe their distribution systems. Briefly point out all the services areas in the municipality.
2. Can you briefly elaborate on the state of water demand and consumption in the municipality?
3. Are there any water leakage problems in the municipality?
4. If yes, how fast do they respond to the leakage?
5. What causes leakages?
6. How often does the municipality replace water supply pipes?
7. How often does the municipality check for ageing infrastructure?
8. What is the state of technical personnel in the municipality?
9. What are the technical, operational and institutional challenges facing water supply?
10. How often do you take metre readings?

Questions for the senior general manager

1. Briefly outline the roles and responsibilities of each person involved in water resource management in the municipality.
2. What are the guiding principles and legislations in water distributions?
3. Water distribution involves different Departments and agencies, what measures are in place to enhance cooperation amongst the mentioned departments and agencies?
4. How does the municipality incorporate members of the public in the water resource management?
5. How often does the municipality conduct water distribution needs?

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Appendix D: Land cover in Makhado Municipality

Table A: Tabulated Land Coverage of Makhado Municipality 2013-2014

Class Name	Area (Decimal Degrees)	Area Percentage
Water seasonal	0.000062	0.008482751
Water permanent	0.001106	0.151321325
Wetlands	0.000857	0.117253504
Indigenous Forest	0.010988	1.503362316
Thicket /Dense bush	0.178093	24.36642746
Woodland/Open bush	0.286721	39.22875379
Grassland	0.141655	19.38103284
Low shrubland	0.005751	0.786843527
Cultivated comm fields (high)	0.001656	0.226571532
Cultivated comm fields (med)	0.005241	0.717066063
Cultivated comm fields (low)	0.003402	0.465456735
Cultivated comm pivots (high)	0.002642	0.36147463
Cultivated comm pivots (med)	0.00549	0.751133884
Cultivated comm pivots (low)	0.002342	0.320429063
Cultivated orchards (high)	0.012069	1.651263177
Cultivated orchards (med)	0.004631	0.633606742
Cultivated orchards (low)	0.002034	0.278288947
Cultivated subsistence (high)	0.000584	0.079902038
Cultivated subsistence (med)	0.006311	0.86346192
Cultivated subsistence (low)	0.006202	0.848548697
Plantations / Woodlots mature	0.014496	1.983321818
Plantation / Woodlots young	0.001566	0.214257862
Plantation / Woodlots clearfelled	0.000179	0.024490522
Mines 1 bare	0.000068	0.009303662
Mines 2 semi-bare	0.000174	0.023806429
Mines water seasonal	0.000004	0.000547274
Mines water permanent	0.000007	0.00095773
Erosion (donga)	0.001605	0.219593786
Bare none vegetated	0.000254	0.034751914
Urban commercial	0.000274	0.037488285

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Urban industrial	0.000053	0.007251384
Urban informal (dense trees / bush)	0.000007	0.00095773
Urban informal (open trees / bush)	0.000018	0.002462734
Urban informal (low veg / grass)	0.000001	0.000136819
Urban residential (dense trees / bush)	0.0005	0.068409279
Urban residential (open trees / bush)	0.000077	0.010535029
Urban residential (low veg / grass)	0.00005	0.006840928
Urban residential (bare)	0.000005	0.000684093
Urban school and sports ground	0.000044	0.006020017
Urban smallholding (dense trees / bush)	0.000035	0.00478865
Urban smallholding (open trees / bush)	0.000114	0.015597316
Urban smallholding (low veg / grass)	0.000008	0.001094548
Urban smallholding (bare)	0.000001	0.000136819
Urban sports and golf (dense tree / bush)	0.000045	0.006156835
Urban sports and golf (open tree / bush)	0.000012	0.001641823
Urban sports and golf (low veg / grass)	0.000003	0.000410456
Urban township (dense trees / bush)	0.000069	0.009440481
Urban township (open trees / bush)	0.000106	0.014502767
Urban township (low veg / grass)	0.000058	0.007935476
Urban township (bare)	0.000001	0.000136819
Urban village (dense trees / bush)	0.006056	0.828573188
Urban village (open trees / bush)	0.009473	1.296082201

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Urban village (low veg / grass)	0.017009	2.327146854
Urban village (bare)	0.000057	0.007798658
Urban built-up (dense trees / bush)	0.000138	0.018880961
Urban built-up (open trees / bush)	0.000259	0.035436007
Urban built-up (low veg / grass)	0.000182	0.024900978
Urban built-up (bare)	0.00005	0.006840928

Table B: Tabulated Land Coverage of Makhado Municipality 1990

Class Name	**Area (Decimal Degrees)**	**Area Percentage**
Indigenous Forest	0.008189	1.120292214
Thicket /Dense bush	0.152426	20.85256577
Woodlan/Open bush	0.285532	39.06206821
Low shrubland	0.012525	1.713476613
Plantations / Woodlots	0.020058	2.744025063
Cultivated commercial annual crops non-pivot	0.013659	1.868612939
Cultivated commercial annual crop pivot	0.004127	0.564592254
Cultivated commercial permanent orchards	0.011655	1.594456681
Cultivated subsistence crops	0.026984	3.691533168
Settlements	0.024985	3.418060933
Wetlands	0.002823	0.38619916
Grasslands	0.149528	20.45610627
Mines	0.000498	0.068128651
Waterbodies	0.000836	0.114368579
Bare Ground	0.000238	0.032559476
Degraded	0.016907	2.31295402

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OBJECTID		Type	Number	August consumption	Household consumption/day	Consuption/person/day	September consumption	Household consumption/day	Consumption/person/day	Oct consumption	Household consumption/day	Consumption/person/day	No of people
3359	1	WATE	911700	41	1322.6	330.6	25	833.3	208.3	30	967.7	241.9	4
3360	2	WATE	102625	42	1354.8	271.0	52	1733.3	346.7	40	1290.3	258.1	5
11672	3	WATE	25854	35	1129.0	282.3	21	700.0	175.0	30	967.7	241.9	4
11680	4	WATE	604252	29	935.5	311.8	45	1500.0	500.0	32	1032.3	344.1	3
11717	5	WATE	655	65	2096.8	524.2	50	1666.7	416.7	45	1451.6	362.9	4
11753	6	WATE	604253	60	1935.5	322.6	64	2133.3	355.6	59	1903.2	317.2	6
11776	7	WATE	934767	64	2064.5	516.1	54	1800.0	450.0	62	2000.0	500.0	4
11908	8	WATE	764258	45	1451.6	362.9	39	1300.0	325.0	29	935.5	233.9	4
16511	9	WATE	414	28	903.2	451.6	24	800.0	400.0	34	1096.8	548.4	2
20285	10	WATE	604055	41	1322.6	330.6	29	966.7	241.7	50	1612.9	403.2	4
20287	11	WATE	602589	52	1677.4	335.5	45	1500.0	300.0	30	967.7	193.5	5
20288	12	WATE	118	35	1129.0	376.3	47	1566.7	522.2	55	1774.2	591.4	3
20290	13	WATE	222	40	1290.3	645.2	36	1200.0	600.0	20	645.2	322.6	2
20319	14	WATE	384	29	935.5	155.9	27	900.0	150.0	35	1129.0	188.2	6
20356	15	WATE	934921	8	258.1	258.1	12	400.0	400.0	14	451.6	451.6	1
20358	16	WATE	764271	34	1096.8	365.6	41	1366.7	455.6	37	1193.5	397.8	3
20524	17	WATE	764276	45	1451.6	725.8	37	1233.3	616.7	45	1451.6	725.8	2
25227	18	WATE	602631	42	1354.8	451.6	30	1000.0	333.3	27	871.0	290.3	3
28942	19	WATE	764275	32	1032.3	172.0	38	1266.7	211.1	24	774.2	129.0	6
28973	20	WATE	400673	40	1290.3	215.1	34	1133.3	188.9	39	1258.1	209.7	6
29043	21	WATE	764241	36	1161.3	193.5	31	1033.3	172.2	40	1290.3	215.1	6
33763	22	WATE	933479	44	1419.4	157.7	52	1733.3	192.6	61	1967.7	218.6	9
37551	23	WATE	934769	45	1451.6	241.9	39	1300.0	216.7	32	1032.3	172.0	6
72013	24	WATE	285	29	935.5	233.9	29	966.7	241.7	20	645.2	161.3	4
72039	25	WATE	177	32	1032.3	344.1	32	1066.7	355.6	40	1290.3	430.1	3
72042	26	WATE	629560	60	1935.5	322.6	54	1800.0	300.0	32	1032.3	172.0	6
72174	27	WATE	604276	35	1129.0	376.3	30	1000.0	333.3	15	483.9	161.3	3
80580	28	WATE	604273	28	903.2	180.6	26	866.7	173.3	20	645.2	129.0	5
80603	29	WATE	602635	32	1032.3	172.0	28	933.3	155.6	20	645.2	107.5	6
80637	30	WATE	602628	48	1548.4	516.1	32	1066.7	355.6	11	354.8	118.3	3
85327	31	WATE	602633	10	322.6	322.6	15	500.0	500.0	11	354.8	354.8	1
89042	32	WATE	102628	20	645.2	322.6	18	600.0	300.0	25	806.5	403.2	2
89100	33	WATE	629573	45	1451.6	362.9	39	1300.0	325.0	31	1000.0	250.0	4
89129	34	WATE	871	48	1548.4	309.7	40	1333.3	266.7	32	1032.3	206.5	5
89269	35	WATE	142	60	1935.5	483.9	56	1866.7	466.7	45	1451.6	362.9	4
89333	36	WATE	456	39	1258.1	209.7	35	1166.7	194.4	33	1064.5	177.4	6
89335	37	WATE	934848	28	903.2	150.5	42	1400.0	233.3	37	1193.5	198.9	6
93925	38	WATE	272464	28	903.2	225.8	25	833.3	208.3	18	580.6	145.2	4
97687	39	WATE	272736	30	967.7	241.9	25	833.3	208.3	10	322.6	80.6	4

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97706	40	WATE	276	40	1290.3	322.6	32	1066.7	266.7	25	806.5	201.6	4
97707	41	WATE	713	30	967.7	322.6	24	800.0	266.7	11	354.8	118.3	3
97708	42	WATE	14	30	967.7	241.9	38	1266.7	316.7	26	838.7	209.7	4
97709	43	WATE	15	45	1451.6	241.9	28	933.3	155.6	21	677.4	112.9	6
97710	44	WATE	12	36	1161.3	193.5	36	1200.0	200.0	30	967.7	161.3	6
97737	45	WATE	17	35	1129.0	376.3	48	1600.0	533.3	40	1290.3	430.1	3
97740	46	WATE	934702	15	483.9	241.9	13	433.3	216.7	21	677.4	338.7	2
97743	47	WATE	8732	34	1096.8	182.8	20	666.7	111.1	38	1225.8	204.3	6
37637	48	WATE	10	30	967.7	161.3	32	1066.7	177.8	37	1193.5	198.9	6
37739	49	WATE	9810	16	516.1	103.2	20	666.7	133.3	28	903.2	180.6	5
37765	50	WATE	217	14	451.6	451.6	8	266.7	266.7	12	387.1	387.1	1
42501	51	WATE	931334	30	967.7	193.5	24	800.0	160.0	34	1096.8	219.4	5
46335	52	WATE	764287	35	1129.0	188.2	39	1300.0	216.7	45	1451.6	241.9	6
46337	53	WATE	764301	30	967.7	241.9	34	1133.3	283.3	41	1322.6	330.6	4
46369	54	WATE	9842	21	677.4	112.9	28	933.3	155.6	35	1129.0	188.2	6
46412	55	WATE	764304	26	838.7	139.8	20	666.7	111.1	34	1096.8	182.8	6
46436	57	WATE	85	39	1258.1	419.4	30	1000.0	333.3	32	1032.3	344.1	3
46540	58	WATE	931332	45	1451.6	290.3	53	1766.7	353.3	50	1612.9	322.6	5
46569	59	WATE	764245	10	322.6	161.3	17	566.7	283.3	32	1032.3	516.1	2
54956	60	WATE	764240	30	967.7	161.3	41	1366.7	227.8	32	1032.3	172.0	6
54957	61	WATE	764259	30	967.7	322.6	22	733.3	244.4	34	1096.8	365.6	3
54959	62	WATE	48845	30	967.7	241.9	35	1166.7	291.7	28	903.2	225.8	4
54983	63	WATE	602697	30	967.7	138.2	35	1166.7	166.7	38	1225.8	175.1	7
55160	64	WATE	602690	36	1161.3	232.3	26	866.7	173.3	21	677.4	135.5	5
55168	65	WATE	602692	25	806.5	134.4	18	600.0	100.0	15	483.9	80.6	6
59617	68	WATE	602693	18	580.6	145.2	21	700.0	175.0	26	838.7	209.7	4
59645	69	WATE	602698	18	580.6	145.2	7	233.3	58.3	12	387.1	96.8	4
63362	70	WATE	604207	25	806.5	134.4	14	466.7	77.8	17	548.4	91.4	6
63398	71	WATE	764235	29	935.5	467.7	12	400.0	200.0	5	161.3	80.6	2
63429	72	WATE	934172	40	1290.3	161.3	42	1400.0	175.0	39	1258.1	157.3	8
63430	73	WATE	7779	30	967.7	138.2	38	1266.7	181.0	42	1354.8	193.5	7
63435	74	WATE	604325	10	322.6	322.6	14	466.7	466.7	5	161.3	161.3	1
63454	75	WATE	602623	10	322.6	322.6	15	500.0	500.0	11	354.8	354.8	1
63459	76	WATE	602621	36	1161.3	580.6	14	466.7	233.3	20	645.2	322.6	2
63465	77	WATE	531021	18	580.6	193.5	32	1066.7	355.6	21	677.4	225.8	3
63607	78	WATE	931070	25	806.5	403.2	14	466.7	233.3	9	290.3	145.2	2
63609	81	WATE	933477	42	1354.8	338.7	28	933.3	233.3	26	838.7	209.7	4
68252	82	WATE	809595	32	1032.3	206.5	36	1200.0	240.0	35	1129.0	225.8	5
68265	83	WATE	764233	40	1290.3	322.6	35	1166.7	291.7	30	967.7	241.9	4
68288	84	WATE	602622	20	645.2	215.1	25	833.3	277.8	39	1258.1	419.4	3

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71946	85	WATE	229	35	1129.0	282.3	28	933.3	233.3	35	1129.0	282.3	4
71947	86	WATE	934361	20	645.2	107.5	35	1166.7	194.4	31	1000.0	166.7	6
106319	87	WATE	934922	35	1129.0	282.3	25	833.3	208.3	16	516.1	129.0	4
106320	88	WATE	531037	35	1129.0	282.3	30	1000.0	250.0	26	838.7	209.7	4
106351	89	WATE	809596	28	903.2	451.6	34	1133.3	566.7	32	1032.3	516.1	2
106576	90	WATE	535937	30	967.7	241.9	27	900.0	225.0	41	1322.6	330.6	4
106577	91	WATE	71741	18	580.6	193.5	12	400.0	133.3	14	451.6	150.5	3
111086	92	WATE	424	29	935.5	155.9	24	800.0	133.3	21	677.4	112.9	6
111087	93	WATE	738	21	677.4	677.4	10	333.3	333.3	5	161.3	161.3	1
111092	94	WATE	736	29	935.5	467.7	23	766.7	383.3	18	580.6	290.3	2
114773	95	WATE	734	8	258.1	258.1	11	366.7	366.7	15	483.9	483.9	1
114859	96	WATE	739	35	1129.0	188.2	21	700.0	116.7	30	967.7	161.3	6
114862	97	WATE	737	25	806.5	403.2	25	833.3	416.7	10	322.6	161.3	2
114976	98	WATE	826	15	483.9	241.9	15	500.0	250.0	13	419.4	209.7	2
123353	99	WATE	604274	28	903.2	225.8	36	1200.0	300.0	32	1032.3	258.1	4
123355	100	WATE	604275	16	516.1	516.1	16	533.3	533.3	18	580.6	580.6	1
123420	101	WATE	31187	35	1129.0	125.4	35	1166.7	129.6	28	903.2	100.4	9
123540	102	WATE	946	20	645.2	215.1	18	600.0	200.0	10	322.6	107.5	3
123631	103	WATE	534937	10	322.6	322.6	7	233.3	233.3	25	806.5	806.5	1
128155	104	WATE	965	22	709.7	141.9	18	600.0	120.0	25	806.5	161.3	5
132020	105	WATE	8	25	806.5	115.2	25	833.3	119.0	8	258.1	36.9	7
132055	106	WATE	933387	36	1161.3	387.1	35	1166.7	388.9	28	903.2	301.1	3
132273	107	WATE	629833	18	580.6	193.5	15	500.0	166.7	28	903.2	301.1	3
136892	108	WATE	934706	29	935.5	233.9	18	600.0	150.0	14	451.6	112.9	4
3167	109	WATE	629470	27	871.0	174.2	29	966.7	193.3	24	774.2	154.8	5
3356	110	WATE	4712	5	161.3	80.6	7	233.3	116.7	6	193.5	96.8	2
3358	111	WATE	143693	25	806.5	161.3	31	1033.3	206.7	15	483.9	96.8	5
3361	112	WATE	762	25	806.5	134.4	9	300.0	50.0	11	354.8	59.1	6
3377	113	WATE	629476	36	1161.3	193.5	25	833.3	138.9	28	903.2	150.5	6
3380	114	WATE	980691	29	935.5	233.9	18	600.0	150.0	8	258.1	64.5	4
3436	115	WATE	931336	20	645.2	161.3	14	466.7	116.7	22	709.7	177.4	4
11718	116	WATE	798963	10	322.6	80.6	22	733.3	183.3	28	903.2	225.8	4
11749	117	WATE	813	32	1032.3	172.0	31	1033.3	172.2	37	1193.5	198.9	6
11779	118	WATE	6261	28	903.2	150.5	26	866.7	144.4	36	1161.3	193.5	6
11935	119	WATE	59146	25	806.5	201.6	18	600.0	150.0	16	516.1	129.0	4
11937	120	WATE	391	20	645.2	107.5	32	1066.7	177.8	20	645.2	107.5	6
11997	121	WATE	9059	24	774.2	193.5	31	1033.3	258.3	22	709.7	177.4	4
16488	123	WATE	102642	21	677.4	338.7	27	900.0	450.0	32	1032.3	516.1	2
20286	124	WATE	125521	8	258.1	258.1	12	400.0	400.0	14	451.6	451.6	1
20316	125	WATE	177	22	709.7	236.6	28	933.3	311.1	24	774.2	258.1	3
20321	126	WATE	809594	32	1032.3	172.0	25	833.3	138.9	20	645.2	107.5	6
20322	127	WATE	798928	25	806.5	134.4	18	600.0	100.0	10	322.6	53.8	6
20383	128	WATE	799000	36	1161.3	290.3	25	833.3	208.3	21	677.4	169.4	4
20497	129	WATE	798932	32	1032.3	172.0	38	1266.7	211.1	41	1322.6	220.4	6
20501	130	WATE	602666	22	709.7	236.6	27	900.0	300.0	18	580.6	193.5	3
25242	131	WATE	505814	20	645.2	161.3	25	833.3	208.3	31	1000.0	250.0	4
28975	132	WATE	507234	23	741.9	123.7	26	866.7	144.4	27	871.0	145.2	6
29023	133	WATE	114	35	1129.0	125.4	33	1100.0	122.2	38	1225.8	136.2	9
29024	134	WATE	241174	28	903.2	150.5	31	1033.3	172.2	39	1258.1	209.7	6

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Growing Future Leaders

	Type	Number	Consumption/ August	Demand	Relationship	Demand	Relationship	Demand	Relationship		Consumption september	Demand	Relationship	Demand	Relationship	Demand	Relationship		Consumption October	Demand	Relationship	Demand	Relationship	Demand	Relationship
1	WATE	911700	330.6	100	230.6	150	180.6	425.0	-94.4		833.3	100	733.3	150	683.3	425.0	408.3		806.5	100	706.5	150	656.5	425	381.5
2	WATE	102625	271.0	100	171.0	150	121.0	425.0	-154.0		666.7	100	566.7	150	516.7	425.0	241.7		725.8	100	625.8	150	575.8	425	300.8
3	WATE	25854	282.3	100	182.3	150	132.3	425.0	-142.7		616.7	100	516.7	150	466.7	425.0	191.7		709.7	100	609.7	150	559.7	425	284.7
4	WATE	604252	311.8	100	211.8	150	161.8	425.0	-113.2		600.0	100	500.0	150	450.0	425.0	175.0		591.4	100	491.4	150	441.4	425	166.4
5	WATE	655	524.2	100	424.2	150	374.2	425.0	99.2		566.7	100	466.7	150	416.7	425.0	141.7		580.6	100	480.6	150	430.6	425	155.6
6	WATE	604253	322.6	100	222.6	150	172.6	425.0	-102.4		533.3	100	433.3	150	383.3	425.0	108.3		580.6	100	480.6	150	430.6	425	155.6
7	WATE	934767	516.1	100	416.1	150	366.1	425.0	91.1		533.3	100	433.3	150	383.3	425.0	108.3		548.4	100	448.4	150	398.4	425	123.4
8	WATE	764258	362.9	100	262.9	150	212.9	425.0	-62.1		522.2	100	422.2	150	372.2	425.0	97.2		516.1	100	416.1	150	366.1	425	91.1
9	WATE	414	451.6	100	351.6	150	301.6	425.0	26.6		500.0	100	400.0	150	350.0	425.0	75.0		516.1	100	416.1	150	366.1	425	91.1
10	WATE	604055	330.6	100	230.6	150	180.6	425.0	-94.4		500.0	100	400.0	150	350.0	425.0	75.0		516.1	100	416.1	150	366.1	425	91.1
11	WATE	602589	335.5	100	235.5	150	185.5	425.0	-89.5		466.7	100	366.7	150	316.7	425.0	41.7		500.0	100	400.0	150	350.0	425	75.0
12	WATE	118	376.3	100	276.3	150	226.3	425.0	-48.7		466.7	100	366.7	150	316.7	425.0	41.7		483.9	100	383.9	150	333.9	425	58.9
13	WATE	222	645.2	100	545.2	150	495.2	425.0	220.2		455.6	100	355.6	150	305.6	425.0	30.6		451.6	100	351.6	150	301.6	425	26.6
14	WATE	384	155.9	100	55.9	150	5.9	425.0	-269.1		450.0	100	350.0	150	300.0	425.0	25.0		430.1	100	330.1	150	280.1	425	5.1
15	WATE	934921	612.9	100	512.9	150	462.9	425.0	187.9		450.0	100	350.0	150	300.0	425.0	25.0		430.1	100	330.1	150	280.1	425	5.1
16	WATE	764271	365.6	100	265.6	150	215.6	425.0	-59.4		416.7	100	316.7	150	266.7	425.0	-8.3		419.4	100	319.4	150	269.4	425	-5.6
17	WATE	764276	725.8	100	625.8	150	575.8	425.0	300.8		416.7	100	316.7	150	266.7	425.0	-8.3		403.2	100	303.2	150	253.2	425	-21.8
18	WATE	602631	451.6	100	351.6	150	301.6	425.0	26.6		400.0	100	300.0	150	250.0	425.0	-25.0		403.2	100	303.2	150	253.2	425	-21.8
19	WATE	764275	172.0	100	72.0	150	22.0	425.0	-253.0		400.0	100	300.0	150	250.0	425.0	-25.0		397.8	100	297.8	150	247.8	425	-27.2
20	WATE	400673	215.1	100	115.1	150	65.1	425.0	-209.9		388.9	100	288.9	150	238.9	425.0	-36.1		387.1	100	287.1	150	237.1	425	-37.9
21	WATE	764241	193.5	100	93.5	150	43.5	425.0	-231.5		383.3	100	283.3	150	233.3	425.0	-41.7		365.6	100	265.6	150	215.6	425	-59.4
22	WATE	933479	157.7	100	57.7	150	7.7	425.0	-267.3		366.7	100	266.7	150	216.7	425.0	-58.3		362.9	100	262.9	150	212.9	425	-62.1
23	WATE	934769	241.9	100	141.9	150	91.9	425.0	-183.1		355.6	100	255.6	150	205.6	425.0	-69.4		362.9	100	262.9	150	212.9	425	-62.1
24	WATE	285	233.9	100	133.9	150	83.9	425.0	-191.1		355.6	100	255.6	150	205.6	425.0	-69.4		354.8	100	254.8	150	204.8	425	-70.2
25	WATE	177	344.1	100	244.1	150	194.1	425.0	-80.9		355.6	100	255.6	150	205.6	425.0	-69.4		344.1	100	244.1	150	194.1	425	-80.9
26	WATE	629560	322.6	100	222.6	150	172.6	425.0	-102.4		355.6	100	255.6	150	205.6	425.0	-69.4		344.1	100	244.1	150	194.1	425	-80.9
27	WATE	604276	376.3	100	276.3	150	226.3	425.0	-48.7		353.3	100	253.3	150	203.3	425.0	-71.7		338.7	100	238.7	150	188.7	425	-86.3
28	WATE	604273	180.6	100	80.6	150	30.6	425.0	-244.4		346.7	100	246.7	150	196.7	425.0	-78.3		330.6	100	230.6	150	180.6	425	-94.4
29	WATE	602635	172.0	100	72.0	150	22.0	425.0	-253.0		333.3	100	233.3	150	183.3	425.0	-91.7		330.6	100	230.6	150	180.6	425	-94.4
30	WATE	602628	516.1	100	416.1	150	366.1	425.0	91.1		333.3	100	233.3	150	183.3	425.0	-91.7		322.6	100	222.6	150	172.6	425	-102.4
31	WATE	602633	806.5	100	706.5	150	656.5	425.0	381.5		333.3	100	233.3	150	183.3	425.0	-91.7		322.6	100	222.6	150	172.6	425	-102.4
32	WATE	102628	322.6	100	222.6	150	172.6	425.0	-102.4		333.3	100	233.3	150	183.3	425.0	-91.7		322.6	100	222.6	150	172.6	425	-102.4
33	WATE	629573	362.9	100	262.9	150	212.9	425.0	-62.1		325.0	100	225.0	150	175.0	425.0	-100.0		317.2	100	217.2	150	167.2	425	-107.8
34	WATE	871	309.7	100	209.7	150	159.7	425.0	-115.3		325.0	100	225.0	150	175.0	425.0	-100.0		301.1	100	201.1	150	151.1	425	-123.9
35	WATE	142	483.9	100	383.9	150	333.9	425.0	58.9		316.7	100	216.7	150	166.7	425.0	-108.3		301.1	100	201.1	150	151.1	425	-123.9
36	WATE	456	209.7	100	109.7	150	59.7	425.0	-215.3		311.1	100	211.1	150	161.1	425.0	-113.9		290.3	100	190.3	150	140.3	425	-134.7
37	WATE	934848	150.5	100	50.5	150	0.5	425.0	-274.5		300.0	100	200.0	150	150.0	425.0	-125.0		290.3	100	190.3	150	140.3	425	-134.7
38	WATE	272464	225.8	100	125.8	150	75.8	425.0	-199.2		300.0	100	200.0	150	150.0	425.0	-125.0		282.3	100	182.3	150	132.3	425	-142.7
39	WATE	272736	241.9	100	141.9	150	91.9	425.0	-183.1		300.0	100	200.0	150	150.0	425.0	-125.0		258.1	100	158.1	150	108.1	425	-166.9

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40	WATE	276	322.6	100	222.6	150	172.6	425.0	-102.4		300.0	100	200.0	150	150.0	425.0	-125.0		258.1	100	158.1	150	108.1	425	-166.9
41	WATE	713	322.6	100	222.6	150	172.6	425.0	-102.4		300.0	100	200.0	150	150.0	425.0	-125.0		258.1	100	158.1	150	108.1	425	-166.9
42	WATE	14	241.9	100	141.9	150	91.9	425.0	-183.1		291.7	100	191.7	150	141.7	425.0	-133.3		250.0	100	150.0	150	100.0	425	-175.0
43	WATE	15	241.9	100	141.9	150	91.9	425.0	-183.1		291.7	100	191.7	150	141.7	425.0	-133.3		250.0	100	150.0	150	100.0	425	-175.0
44	WATE	12	193.5	100	93.5	150	43.5	425.0	-231.5		283.3	100	183.3	150	133.3	425.0	-141.7		241.9	100	141.9	150	91.9	425	-183.1
45	WATE	17	376.3	100	276.3	150	226.3	425.0	-48.7		283.3	100	183.3	150	133.3	425.0	-141.7		241.9	100	141.9	150	91.9	425	-183.1
46	WATE	934702	241.9	100	141.9	150	91.9	425.0	-183.1		277.8	100	177.8	150	127.8	425.0	-147.2		241.9	100	141.9	150	91.9	425	-183.1
47	WATE	8732	182.8	100	82.8	150	32.8	425.0	-242.2		266.7	100	166.7	150	116.7	425.0	-158.3		241.9	100	141.9	150	91.9	425	-183.1
48	WATE	10	161.3	100	61.3	150	11.3	425.0	-263.7		266.7	100	166.7	150	116.7	425.0	-158.3		233.9	100	133.9	150	83.9	425	-191.1
49	WATE	9810	103.2	100	3.2	150	-46.8	425.0	-321.8		266.7	100	166.7	150	116.7	425.0	-158.3		225.8	100	125.8	150	75.8	425	-199.2
50	WATE	217	451.6	100	351.6	150	301.6	425.0	26.6		266.7	100	166.7	150	116.7	425.0	-158.3		225.8	100	125.8	150	75.8	425	-199.2
51	WATE	931334	193.5	100	93.5	150	43.5	425.0	-231.5		258.3	100	158.3	150	108.3	425.0	-166.7		225.8	100	125.8	150	75.8	425	-199.2
52	WATE	764287	188.2	100	88.2	150	38.2	425.0	-236.8		250.0	100	150.0	150	100.0	425.0	-175.0		225.8	100	125.8	150	75.8	425	-199.2
53	WATE	764301	241.9	100	141.9	150	91.9	425.0	-183.1		250.0	100	150.0	150	100.0	425.0	-175.0		220.4	100	120.4	150	70.4	425	-204.6
54	WATE	9842	112.9	100	12.9	150	-37.1	425.0	-312.1		244.4	100	144.4	150	94.4	425.0	-180.6		219.4	100	119.4	150	69.4	425	-205.6
55	WATE	764304	139.8	100	39.8	150	-10.2	425.0	-285.2		241.7	100	141.7	150	91.7	425.0	-183.3		218.6	100	118.6	150	68.6	425	-206.4
57	WATE	85	419.4	100	319.4	150	269.4	425.0	-5.6		241.7	100	141.7	150	91.7	425.0	-183.3		215.1	100	115.1	150	65.1	425	-209.9
58	WATE	931332	290.3	100	190.3	150	140.3	425.0	-134.7		240.0	100	140.0	150	90.0	425.0	-185.0		209.7	100	109.7	150	59.7	425	-215.3
59	WATE	764245	161.3	100	61.3	150	11.3	425.0	-263.7		233.3	100	133.3	150	83.3	425.0	-191.7		209.7	100	109.7	150	59.7	425	-215.3
60	WATE	764240	161.3	100	61.3	150	11.3	425.0	-263.7		233.3	100	133.3	150	83.3	425.0	-191.7		209.7	100	109.7	150	59.7	425	-215.3
61	WATE	764259	322.6	100	222.6	150	172.6	425.0	-102.4		233.3	100	133.3	150	83.3	425.0	-191.7		209.7	100	109.7	150	59.7	425	-215.3
62	WATE	48845	241.9	100	141.9	150	91.9	425.0	-183.1		233.3	100	133.3	150	83.3	425.0	-191.7		209.7	100	109.7	150	59.7	425	-215.3
63	WATE	602697	138.2	100	38.2	150	-11.8	425.0	-286.8		233.3	100	133.3	150	83.3	425.0	-191.7		209.7	100	109.7	150	59.7	425	-215.3
64	WATE	602690	232.3	100	132.3	150	82.3	425.0	-192.7		233.3	100	133.3	150	83.3	425.0	-191.7		209.7	100	109.7	150	59.7	425	-215.3
65	WATE	602692	134.4	100	34.4	150	-15.6	425.0	-290.6		227.8	100	127.8	150	77.8	425.0	-197.2		206.5	100	106.5	150	56.5	425	-218.5
68	WATE	602693	145.2	100	45.2	150	-4.8	425.0	-279.8		225.0	100	125.0	150	75.0	425.0	-200.0		204.3	100	104.3	150	54.3	425	-220.7
69	WATE	602698	145.2	100	45.2	150	-4.8	425.0	-279.8		216.7	100	116.7	150	66.7	425.0	-208.3		201.6	100	101.6	150	51.6	425	-223.4
70	WATE	604207	134.4	100	34.4	150	-15.6	425.0	-290.6		216.7	100	116.7	150	66.7	425.0	-208.3		198.9	100	98.9	150	48.9	425	-226.1
71	WATE	764235	467.7	100	367.7	150	317.7	425.0	42.7		216.7	100	116.7	150	66.7	425.0	-208.3		198.9	100	98.9	150	48.9	425	-226.1
72	WATE	934172	161.3	100	61.3	150	11.3	425.0	-263.7		211.1	100	111.1	150	61.1	425.0	-213.9		198.9	100	98.9	150	48.9	425	-226.1
73	WATE	7779	138.2	100	38.2	150	-11.8	425.0	-286.8		211.1	100	111.1	150	61.1	425.0	-213.9		193.5	100	93.5	150	43.5	425	-231.5
74	WATE	604325	322.6	100	222.6	150	172.6	425.0	-102.4		208.3	100	108.3	150	58.3	425.0	-216.7		193.5	100	93.5	150	43.5	425	-231.5
75	WATE	602623	322.6	100	222.6	150	172.6	425.0	-102.4		208.3	100	108.3	150	58.3	425.0	-216.7		193.5	100	93.5	150	43.5	425	-231.5
76	WATE	602621	580.6	100	480.6	150	430.6	425.0	155.6		208.3	100	108.3	150	58.3	425.0	-216.7		193.5	100	93.5	150	43.5	425	-231.5
77	WATE	531021	193.5	100	93.5	150	43.5	425.0	-231.5		208.3	100	108.3	150	58.3	425.0	-216.7		188.2	100	88.2	150	38.2	425	-236.8
78	WATE	931070	403.2	100	303.2	150	253.2	425.0	-21.8		208.3	100	108.3	150	58.3	425.0	-216.7		188.2	100	88.2	150	38.2	425	-236.8
81	WATE	933477	338.7	100	238.7	150	188.7	425.0	-86.3		208.3	100	108.3	150	58.3	425.0	-216.7		182.8	100	82.8	150	32.8	425	-242.2
82	WATE	809595	206.5	100	106.5	150	56.5	425.0	-218.5		206.7	100	106.7	150	56.7	425.0	-218.3		180.6	100	80.6	150	30.6	425	-244.4
83	WATE	764233	322.6	100	222.6	150	172.6	425.0	-102.4		200.0	100	100.0	150	50.0	425.0	-225.0		177.4	100	77.4	150	27.4	425	-247.6
84	WATE	602622	215.1	100	115.1	150	65.1	425.0	-209.9		200.0	100	100.0	150	50.0	425.0	-225.0		177.4	100	77.4	150	27.4	425	-247.6

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Demand within Makhado New town

No of people	100 Litres	150 Litres	425 Liters
4	400	600	1700
5	500	750	2125
4	400	600	1700
3	300	450	1275
4	400	600	1700
6	600	900	2550
4	400	600	1700
4	400	600	1700
2	200	300	850
4	400	600	1700
5	500	750	2125
3	300	450	1275
2	200	300	850
6	600	900	2550
1	100	150	425
3	300	450	1275
2	200	300	850
3	300	450	1275
6	600	900	2550
6	600	900	2550
6	600	900	2550
9	900	1350	3825
6	600	900	2550
4	400	600	1700
3	300	450	1275
6	600	900	2550
3	300	450	1275
5	500	750	2125
6	600	900	2550
3	300	450	1275
1	100	150	425
2	200	300	850
4	400	600	1700
5	500	750	2125
4	400	600	1700
6	600	900	2550
6	600	900	2550
4	400	600	1700

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4	400	600	1700
4	400	600	1700
3	300	450	1275
4	400	600	1700
6	600	900	2550
6	600	900	2550
3	300	450	1275
2	200	300	850
6	600	900	2550
6	600	900	2550
5	500	750	2125
1	100	150	425
5	500	750	2125
6	600	900	2550
4	400	600	1700
6	600	900	2550
6	600	900	2550
3	300	450	1275
5	500	750	2125
2	200	300	850
6	600	900	2550
3	300	450	1275
4	400	600	1700
7	700	1050	2975
5	500	750	2125
6	600	900	2550
4	400	600	1700
4	400	600	1700
6	600	900	2550
2	200	300	850
8	800	1200	3400
7	700	1050	2975
1	100	150	425
1	100	150	425
2	200	300	850
3	300	450	1275
2	200	300	850
4	400	600	1700
5	500	750	2125
4	400	600	1700

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3	300	450	1275
4	400	600	1700
6	600	900	2550
4	400	600	1700
4	400	600	1700
2	200	300	850
4	400	600	1700
3	300	450	1275
6	600	900	2550
1	100	150	425
2	200	300	850
1	100	150	425
6	600	900	2550
2	200	300	850
2	200	300	850
4	400	600	1700
1	100	150	425
9	900	1350	3825
3	300	450	1275
1	100	150	425
5	500	750	2125
7	700	1050	2975
3	300	450	1275
3	300	450	1275
4	400	600	1700
5	500	750	2125
2	200	300	850
5	500	750	2125
6	600	900	2550
6	600	900	2550
4	400	600	1700
4	400	600	1700
4	400	600	1700
6	600	900	2550
6	600	900	2550
4	400	600	1700
6	600	900	2550
4	400	600	1700
2	200	300	850
1	100	150	425
3	300	450	1275
6	600	900	2550
6	600	900	2550
4	400	600	1700
6	600	900	2550
3	300	450	1275
4	400	600	1700
6	600	900	2550
9	900	1350	3825
6	600	900	2550

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Appendix F: Showing attributes for the Junctions

Node ID	Pressure m
Junc 2	-25.00
Junc 3	-82.00
Junc 4	-72.00
Junc 5	-30.00
Junc 6	-33.00
Junc 7	-76.00
Junc 8	-77.00
Junc 9	-50.00
Junc 10	-48.00
Junc 11	-36.00
Junc 13	-207.00
Junc 14	-39.00
Junc 15	-40.00
Junc 16	-30.00
Junc 17	-25.00
Junc 18	-55.00
Junc 19	-25.00
Junc 20	-53.00
Junc 21	-29.00
Junc 22	-25.00
Junc 23	-21.00
Junc 24	-40.00
Junc 25	-40.00
Junc 26	-96.00

Node ID	Head m
Junc 2	1020.00
Junc 3	1020.00
Junc 4	1020.00
Junc 5	1020.00
Junc 6	1020.00
Junc 7	1020.00
Junc 8	1020.00
Junc 9	1020.00
Junc 10	1020.00
Junc 11	1020.00
Junc 13	1020.00
Junc 14	1020.00
Junc 15	1020.00
Junc 16	1020.00
Junc 17	1020.00
Junc 18	1020.00
Junc 19	1020.00
Junc 20	1020.00
Junc 21	1020.00
Junc 22	1020.00
Junc 23	1020.00
Junc 24	1020.00
Junc 25	1020.00
Junc 26	1020.00

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Node ID	Pressure m
Junc 22	-25.00
Junc 23	-21.00
Junc 24	-40.00
Junc 25	-40.00
Junc 26	-96.00
Junc 27	-52.00
Junc 28	-121.00
Junc 29	-25.00
Junc 30	-16.00
Junc 31	-17.00
Junc 32	-48.00
Junc 33	-47.00
Junc 34	-10.00
Junc 35	-32.00
Junc 36	-30.00
Junc 37	-20.00
Junc 38	-22.00
Junc 39	-36.00
Junc 40	-30.00
Junc 41	-10.00
Junc 42	-15.00
Junc 43	-15.00
Junc 44	-10.00
Junc 45	-30.00

Node ID	Head m
Junc 27	1020.00
Junc 28	1020.00
Junc 29	1020.00
Junc 30	1020.00
Junc 31	1020.00
Junc 32	1020.00
Junc 33	1020.00
Junc 34	1020.00
Junc 35	1020.00
Junc 36	1020.00
Junc 37	1020.00
Junc 38	1020.00
Junc 39	1020.00
Junc 40	1020.00
Junc 41	1020.00
Junc 42	1020.00
Junc 43	1020.00
Junc 44	1020.00
Junc 45	1020.00
Junc 46	1020.00
Junc 47	1020.00
Junc 48	1020.00
Junc 49	1020.00
Junc 50	1020.00

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Node ID	Pressure m
Junc 46	-20.00
Junc 47	-15.00
Junc 48	-4.00
Junc 49	-20.00
Junc 50	-20.00
Junc 51	-30.00
Junc 52	-25.00
Junc 53	-10.00
Junc 54	-4.00
Junc 55	-10.00
Junc 56	-17.00
Junc 57	-24.00
Junc 58	-17.00
Junc 59	-4.00
Junc 60	-4.00
Junc 61	-2.00
Junc 62	-5.00
Junc 63	-4.00
Junc 64	-10.00
Junc 65	4.00
Junc 66	9.00
Junc 67	18.00
Junc 68	4.00
Junc 69	0.00

Node ID	Head m
Junc 52	1020.00
Junc 53	1020.00
Junc 54	1020.00
Junc 55	1020.00
Junc 56	1020.00
Junc 57	1020.00
Junc 58	1020.00
Junc 59	1020.00
Junc 60	1020.00
Junc 61	1020.00
Junc 62	1020.00
Junc 63	1020.00
Junc 64	1020.00
Junc 65	1020.00
Junc 66	1020.00
Junc 67	1020.00
Junc 68	1020.00
Junc 69	1020.00
Junc 70	1020.00
Junc 78	1020.00
Junc 79	1020.00
Junc 81	1020.00
Junc 82	1020.00
Junc 83	1020.00

Junc 69	0.00
Junc 70	8.00
Junc 78	-2.00
Junc 79	4.00
Junc 81	30.00
Junc 82	30.00
Junc 83	8.00
Junc 84	20.00
Junc 85	18.00
Junc 86	6.00
Junc 87	-10.00
Junc 88	-5.00
Junc 89	2.00
Junc 90	10.00

Junc 82	1020.00
Junc 83	1020.00
Junc 84	1020.00
Junc 85	1020.00
Junc 86	1020.00
Junc 87	1020.00
Junc 88	1020.00
Junc 89	1020.00
Junc 90	1020.00
Resvr 1	1020.00

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Appendix G: Showing attributes for the Pipelines

Link ID	Length m	Diameter mm	Roughness	Status
Pipe P2	452.71	200	140	Open
Pipe P3	147.5	200	140	Open
Pipe P4	67.73	100	140	Open
Pipe P5	149.13	100	140	Open
Pipe P6	143.87	150	140	Open
Pipe P7	132.4	100	140	Open
Pipe P8	318.9	100	140	Open
Pipe P9	47.92	100	140	Open
Pipe P10	105.73	100	140	Open
Pipe P11	156.64	100	140	Open
Pipe P14	289.87	150	140	Open
Pipe P15	168.54	100	140	Open
Pipe P16	265.21	150	140	Open
Pipe P17	228.9	100	140	Open
Pipe P18	160.78	150	140	Open
Pipe P19	158.72	150	140	Open
Pipe P20	57.70	150	140	Open
Pipe P21	258.76	150	140	Open
Pipe P22	156	100	140	Open
Pipe P23	118.90	100	140	Open
Pipe P24	141.1	100	140	Open
Pipe P25	129.8	100	140	Open
Pipe P26	118.84	100	140	Open
Pipe P27	415.38	150	140	Open

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Link ID	Length m	ameter mm	Roughness	Status
Pipe P77	124.5	150	140	Open
Pipe P78	93.20	150	140	Open
Pipe P79	114.4	150	140	Open
Pipe P80	298.8	150	140	Open
Pipe P81	159.61	150	140	Open
Pipe P82	293.05	75	140	Open
Pipe P83	201.3	150	140	Open
Pipe P84	134.22	75	140	Open
Pipe P85	145	100	140	Open
Pipe P86	114.2	100	140	Open
Pipe P87	153.76	100	140	Open
Pipe P88	175.88	150	140	Open
Pipe P89	161.50	150	140	Open
Pipe P90	154.26	75	140	Open
Pipe P91	147.37	150	140	Open
Pipe P92	235	75	140	Open
Pipe P93	86.5	75	140	Open
Pipe P94	145.13	75	140	Open
Pipe P95	142.2	75	140	Open
Pipe P96	124.2	75	140	Open
Pipe P97	167.68	100	140	Open
Pipe P98	124.8	75	140	Open
Pipe P99	215.20	100	140	Open
Pipe P100	144.08	150	140	Open

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Link ID	Length m	Diameter mm	Roughness	Status
Pipe P100	144.08	150	140	Open
Pipe P101	212.7	100	140	Open
Pipe P102	145.06	150	140	Open
Pipe P103	232.88	75	140	Open
Pipe P104	143.79	150	140	Open
Pipe P112	218.07	150	140	Open
Pipe P115	190.53	100	140	Open
Pipe P116	293.33	100	140	Open
Pipe P117	141.2	100	140	Open
Pipe P118	99.91	75	140	Open
Pipe P119	107.75	75	140	Open
Pipe P120	95.16	75	140	Open
Pipe P121	88.92	75	140	Open
Pipe P122	95.16	75	140	Open
Pipe P123	95.16	75	140	Open
Pipe P124	121.1	75	140	Open
Pipe P125	145.5	75	140	Open
Pipe P126	124.5	75	140	Open
Pipe P127	176	150	140	Open
Pipe P128	208.44	75	140	Open
Pipe P129	123.91	100	140	Open
Pipe P130	124.5	100	140	Open
Pipe P131	145	75	140	Open
Pipe P132	96.5	75	140	Open
Pipe P133	112.5	100	140	Open
Pipe P12	140.2	100	140	Open
Pipe 1	403.34	500	100	Open

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Appendix H: Digital Images



Plate 1: Tanks (10 00 litres) that supply the hospital with water

Source: Field work, 2015



Plate 2: A 10 000 litres tank that the hospital uses for backup when there is no water

Source: Field work, 2015





Plate 3a and 3b: Water station of Nandoni water system

Source: Field work, 2015

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Plate 4a and 4b: Ageing infrastructure

Source: Field work, 2015



Plate 5: Abandoned pipes found at the Berg water system

Source: Field work, 2015

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Plate 6a and 6b: Three dams and tanks found at Bergh street

Source: Field work, 2015



Plate 7: Main dam found at Berg Street

Source: Field work, 2015

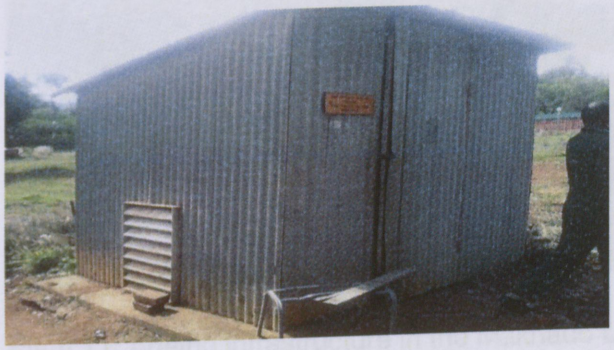


Plate 8: Main pump station that feeds water to extension 7 & 8 and the hospital

Source: Fieldwork, 2015

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Plate 9: Mowkop reservoir, 12 mega litres

Source: Field work, 2015



Plate 10: A pipe burst at the hospital due to ageing infrastructure

Source: Field work, 2015



Plate 11: Ageing infrastructure in the Makhado Local Municipality

Source: Field work, 2015

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Plate 12: Pumping station vandalised by thieves

Source: Field work, 201

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