NON-REVENUE WATER: MOST SUITABLE BUSINESS MODEL FOR WATER SERVICES AUTHORITIES IN SOUTH AFRICA – UGU DISTRICT MUNICIPALITY

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ABSTRACT

Water is a critical resource in Southern Africa. The region thus needs to protect both the quality and the quantity of its water resources through robust water conservation and demand management (WC/DM) measures. Water demand management encompasses activities that aim to decrease water demand, improve the efficiency of water use and prevent the deterioration of water resources. Water conservation refers to policies, measures or consumer practices that promote the conservation of water resources. Water resources should be used wisely to secure a water supply that is of good quality and enough for South Africa's people and its natural environment, which provides the ecosystem that supports all forms of life.

When a water utility systems experience water losses, the amount of water available to consumers is reduced, making it difficult to satisfy demand. Water losses also occur as a result of inaccuracies in customer meters, data errors in the billing system and unauthorised consumption. Such losses result in non-revenue water (NRW), which is a serious threat to the water supply sector. NRW refers to the water that is produced and lost without generating revenue for the utility.

This research study investigated strategies that could be used to address the challenge of water losses, by developing a more suitable business model that could be incorporated into Ugu District Municipality (DM)'s existing NRW reduction strategies. The study was carried out in Amandawe and Umzinto zones of the District Municipality and it covered the period 01 March 2014 to June 2015.

The study objectives were made up of four components. The first was to identify and prioritise the implementation of NRW reduction strategies. This was achieved by identifying the pipes to be closed off, which were supplying a significant number of consumers. For those pipes that were not closed off, flow meters were installed to measure the flow into and out of a zone. The system was then tested for zero pressure by isolating all closed valves to ensure that

there were no potential feed-backs into the zone. Pressure gauges were set up on standpipes for routine pressure monitoring. The test was run at night (between 01.00 and 05.00 hours) when the system was under pressure. When the pressure dropped consistently, this meant that there was no feedback into a zone. Leaks were detected by logging the system in order to obtain night flows, which were analysed to determine the system behaviour.

The results for Amandawe Zone after implementation of the pressure management programme, indicated that the average zone's night pressure (AZNP) decreased from 7.38 bars to 5.95 bars. For Umzinto Zone, the AZNP dropped from 5.5 bars to 3.3 bars. The minimum night flows (MNFs) dropped from 34.80 m^3/hr to 15.20 m^3/hr in Amandawe Zone and from 6.4 m^3/hr to 1.70 m^3/hr in Umzinto Zone. The daily cost of excess night flow due to bursts was reduced from R2276.17/day to R862.61/day in Amandawe Zone and from R361.24/day to R40.46/day in Umzinto Zone, which provided huge savings.

The second objective was to identify the sources and causes of water losses in the study area by conducting field measurements and observations. This was achieved by physically inspecting the infrastructure using visual observation, mechanical listening sticks, correlators, ground microphones and system loggers. The following indicators were used to physically identify underground leaks: unusually wet surfaces in landscaped areas, pools of water on the ground surface, noticeably green, soft and mouldy areas surrounded by drier surfaces, a notable drop in water pressure or flow volume, unexplained sudden increase in water demand or water use at a fairly steady rate for several billing cycles, cracks in paved surfaces, potholes or sink holes and the sudden appearance of dirty water in the main distribution system.

For this study, the water losses in the system were found to be as a result of various causes including leaks, aging infrastructure, high pressure in the system, damaged pipes and illegal connections, among others.

The third objective was to construct a water balance in order to determine the key performance indicators for the NRW reduction strategies. This was achieved by determining the system input volume (SIV), billed authorized consumption (BAC), unbilled metered consumption (UMC), unbilled unmetered consumption (UUC), real losses (RL), apparent losses (AL) and IWA Key Performance Indicators. Bulk and domestic meter readings were used to calculate the components of the water balance. The results of the water balance indicated that there was a decrease in the SIV from 904 kL/day to 523 kL/day in Amandawe Zone and from 382 kL/day to 221 kL/day in Umzinto Zone. The physical water losses were reduced from 611 kL/day to 377 kL/day in Amandawe Zone and from 93.8 kL/day to 45.8 kL/day in Umzinto Zone. The NRW was reduced from 659 kL/day to 395 kL/day in Amandawe Zone and from 94.2 kL/day to 46.2 kL/day in Umzinto Zone.

The fourth objective was to develop the most suitable business model for Ugu DM based on the results arising from the first three objectives. Ugu DM needs to ensure both operational and financial efficiency. Operational efficiency could be achieved by minimising real water losses through reviewing water services standards, developing district metering areas, pressure management, leak detection and repair, reservoir control to stop overflows and pipe replacement programs. Financial efficiency could be achieved by carrying out regular meter testing and calibration, securing database integrity, managing illegal connections, ensuring that all customer connections have meters and ensuring that the tariff structures were cost reflective in order for the municipality to cover costs and generate revenue.

Findings of this study could assist other water utilities operating under similar conditions. The implementation of this study's results could have positive economic, social and environmental effects on Ugu DM. It was concluded that rezoning, pressure management and leak detection were the most critical NRW reduction strategies as they had a positive impact on the system. The main causes of leaks in the system were identified as aging infrastructure, high pressures in the system, and illegal connections. All the critical KPIs of IWA water balance responded positively after the implementation of the strategies by reducing. The operational and financial efficiencies were identified as critical for a WSA to develop a business model that could sustain itself.

DECLARATION BY STUDENT

I hereby declare that this thesis for the degree of Master of Engineering in the Department of Civil Engineering and Surveying at the Durban University of Technology is my original work and it has not been submitted previously to any other institution of higher education. I further declare that all the sources cited and quoted are indicated and acknowledged in the references.

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DEDICATION

This thesis is dedicated to my family who have contributed positively to my life. To my late father Mr Malan Thomas Gumbi and my late sister Thenjiwe Gumbi who always encouraged me to pursue my studies and who would have loved to see me through this one; may their souls rest in peace.

A special thank you to my mother Mrs Isabel Thembalihle Gumbi for babysitting when I was away from home and to my brothers Sihle and Bonga Gumbi for their continued encouragement that motivated me to press on.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF EQUATIONS

CHAPTER ONE: BACKGROUND

1.1 Introduction

Water is one of the most important drivers of all kinds of development in the world. It is critical for maintaining health, growing food and creating jobs as well as ensuring that the integrity of the natural resources is maintained. Further, since water is also a critical natural resource, it is important that global water issues are addressed together with other related resources. For example, many parts of the world experience preventable diseases which are caused by water pollution (Dzwairo *et al.* 2006; Rossi 2015). Problems relating to access are linked to dam construction, irrigation development or flood control, among other factors. Limited access to a safe water supply results in huge costs to any society, especially vulnerable groups, while a growing world population and economic growth are pushing the limits of available water resources (Dzwairo, Otieno and Ochieng 2010). Despite the importance of water, many people still lack access to improved water services and even more do not have access to consistently safe drinking water (Dzwairo *et al.* 2006; Choi *et al.* 2014).

While Southern Africa is a region with a scarce water resource, water still needs to be considered as a significant subject in the region's developmental processes, where water demand management (WDM) currently receives far less attention than supply management (Dziedzic and Karney 2014). There is still a lack of awareness with regard to water resource management and water conservation. Politicians have not taken the lead in addressing this critical issue despite the fact that water drives development in any country within the region.

At the national scale it is estimated that South Africa might not have sufficient water to match demand in the years to come (Otieno and Ochieng 2004). For example, continuing industrialisation like mining and urbanisation will put additional pressure on the available water sources if urgent measures are not taken to address this (Dzwairo, Otieno and Ochieng 2010).

According to the Department of Water Affairs (2013) the water sector is confronted by numerous challenges, the most significant of which are; water demand management; inequality; water re-use; accessibility; economic impact; fights over water and safety; water quality issues; distribution strategies and participation of all stakeholders. Therefore in order to address these challenges there needs to be serious intervention by all stakeholders especially to cut down NRW and to manage demand. Although marked improvements have been recorded in most water utilities in the developed world in terms of water distribution system (WDS) efficiency by reducing unaccounted-for-water (UAW), these have been very slow in developing countries (Mutikanga 2012).

NRW is defined as the difference between the amount of water that is pushed into the distribution system, i.e. system input volume (SIV) and the billed authorised consumption (Gonzalez-Gomez, García-Rubio and Guardiola 2011). On the other hand, when the volume of losses is constant, the percentage of NRW then varies largely with consumption, i.e. water use increases without a change in the volume of losses. This leads to a reduction in the NRW percentage. This technical challenge can be addressed by not calculating NRW as a percentage against the total consumption, but in relation to losses in each metered connection per day which is recommended by the International Water Association (Alegre 2006). The NRW in South African municipalities is currently estimated at 36.8% (McKenzie, Siqalaba and Wegelin 2012). Although it is acknowledged that this figure could still be improved, it also needs to be recognised that South Africa’s percentage is within the world average value of 36.6% (McKenzie, Siqalaba and Wegelin 2012).

The implementation of strategies like WDM ensures that the environment is protected while savings are made in the revenue resulting in better service delivery. However, most utilities address the shortage of water by enhancing the water supply from a new source before considering any other options (Arlosoroff 1998; De Gois, Rios and Costanzi 2015). Enhancing new water source(s) requires huge capital investment. Hence this option is mainly adopted by utilities that are more focused on the supply side than on managing demand. A paradigm shift is thus required from traditional, supply oriented management to demand management (De Gois, Rios and Costanzi 2015). Reducing water losses delays the need to augment a system by extending the level of service of the existing infrastructure. Furthermore, reduction in leaks and bursts result in reduced operational costs. This ranges from water treatment to distribution, whilst an improvement in billing also leads to an increase in revenue collection. All these options are part of the NRW strategies.

1.2 Water supply in South Africa

The phrase "water for development" refers to the crucial role that water plays in alleviating poverty and fulfilling people's constitutional right to have uninterrupted access to good quality drinking water. Contrary to this, historically, development of South Africa's water resources focused on supporting the country's wealthy agricultural and industrial sectors rather than alleviating poverty particularly in rural areas. For example by the end of the 19th century, most of South Africa's water supply was earmarked for commercial farming (Department of Water Affairs 2013).

A sufficient supply of water is required if South Africa is to achieve its economic growth targets. These targets should be accomplished without putting at risk the ecological sustainability of the country's water resources (Dzwairo 2011). Furthermore, providing clean drinking water to every person is an important developmental goal that should be made possible by the government. Water scarcity has been identified in South Africa's major urban centres. As these centres are the anchors of the country's economy, the Department of Water and Sanitation (DWS) is expected to invest largely in the diversification of its water mix as this will avoid severe water shortages from negatively impacting the country. In addition to traditional ways of augmenting schemes, there are two major ways that this can be achieved. These are the treatment of wastewater effluent and sea water desalination for productive use. A key principle behind ensuring the availability of adequate local water provision is to reduce the cost of delivering water by keeping supplies close to the consumers.

The DWS undertook a water evaluation study referred to as a Water Reconciliation Strategy Study in order to bring about a balance between demand and supply of water (Department of Water and Forestry 2008). This exercise focused on areas with limited water and those experiencing fairly high levels of demand. The strategies aimed to ensure sufficient supply of water within the limitations of affordability, suitable levels of service to consumers, and the protection of present and future water resources. The implementation of the Reconciliation Strategies to different areas in the country ensured that the DWS dealt with demand while ensuring that the social, economic, or ecological aspects of water were not compromised.

It should be appreciated that whilst huge amounts of money have been used to build infrastructure to assure water supply, water conservation/water demand management (WC/WDM) also need to be given special attention. The implementation of water loss control and water use efficiency measures has better returns than supplementary supply-side interventions (Dawadi and Ahmad 2013). The most important source of water loss is ageing infrastructure that is worsened by poor operation and maintenance by Water Services Authorities (WSAs). This is a complex problem, which includes a lack of managerial and technical skills, and a shortage of funding.

The DWS needs to strengthen its regulatory efforts to maintain the water sector in order to turn around this difficult situation. This is even more fundamental when contamination of water resources occurs as a result of wastewater treatment works that are broken down (Fry, Schweitzer and Mihelcic 2014). Furthermore, whilst South Africa is doing everything in its power to provide water to its people, some water use patterns have negative impact to water resource quantity and quality (Fry, Schweitzer and Mihelcic 2014). The DWS is currently exploring mechanisms to change consumers' behaviour. These include, amongst other things, self-regulation, market-based instruments, regulatory instruments, and education and awareness campaigns (Xiao and Chun 2013).

1.3 Challenges faced by potable water suppliers in South Africa

Potable water suppliers in South Africa are confronted by a number of challenges. These include the climate, demand exceeding supply, water resources, equity, water quality, funding, lack of skills and politics.

1.3.1 Climate

Rainfall is erratic in South Africa hence depending on river flows for daily water supply is risky (Mukheibir and Sparks 2003; Ludwig, van Slobbe and Cofino 2014). As a result, half the mean runoff is captured in dams for later use. In his 2012 budget speech the then Finance Minister Pravin Gordhan stated “On current projections, South Africa’s water demand will outstrip available supply between 2025 and 2030”. This proves that if the water demand is not managed appropriately, the country will face a crisis in the very near future.

Figure 1 indicates the rainfall pattern for South Africa based on data for the 30 year period 1961 to 1990. It shows that the highest rainfall figure in the Umdoni Local Municipality (LM) over this period was between 351 mm and 400 mm in summer. This range has been decreasing over the years, negatively impacting on the water supply. Bhakar *et al.* (2015) noted that South Africa’s rainfall is unreliable and unpredictable and that this situation has been exacerbated by climate change.

1.3.2 Demand exceeding supply

In most areas of South Africa, demand exceeds local water supply, and this is managed through inter-basin water transfers. Many rural settlements do not have sufficient water resources to meet their basic needs and further ground and surface water resource developments are necessary.

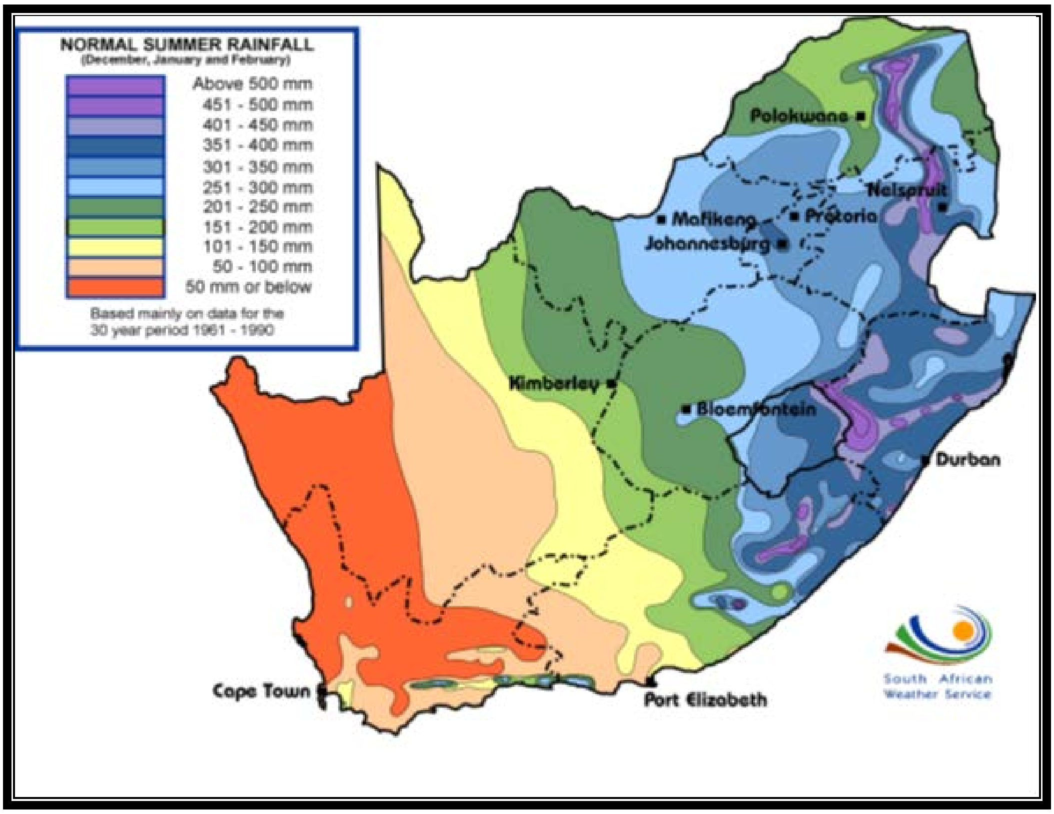


Figure 1: Rainfall pattern for South Africa (1961-1990)

Source: South African Weather Service (2015)

The Umzinto Water Supply System (WSS) cannot meet demand in the area. The design capacity for the Umzinto Water Treatment Works (WTW) is 12 ML/day but demand has always outstripped this capacity. As shown on Figure 2 average daily production in 2014/2015 year was above 12 ML/day. The demand on this plant was increased after new schemes were commissioned to receive potable water from Umzinto WTW. For example the Greater Vulamehlo scheme from Cedars Pump station to Dududu Reservoir was commissioned on 29 June 2013.

1.3.3 Water resources

Water resource management remains a challenge in South Africa. The country needs to build more dams in order to ensure supply even during drought periods. Water is a scarce resource which is moved, often between different provinces, through inter-basin transfers (Movik 2014). Management of South Africa's water resources includes river systems, water abstraction, catchment management, and water storage and return-flow management. Integrated management techniques are required to ensure that the water is reliable, safe and utilised to its full potential (Department of Water Affairs 2013).

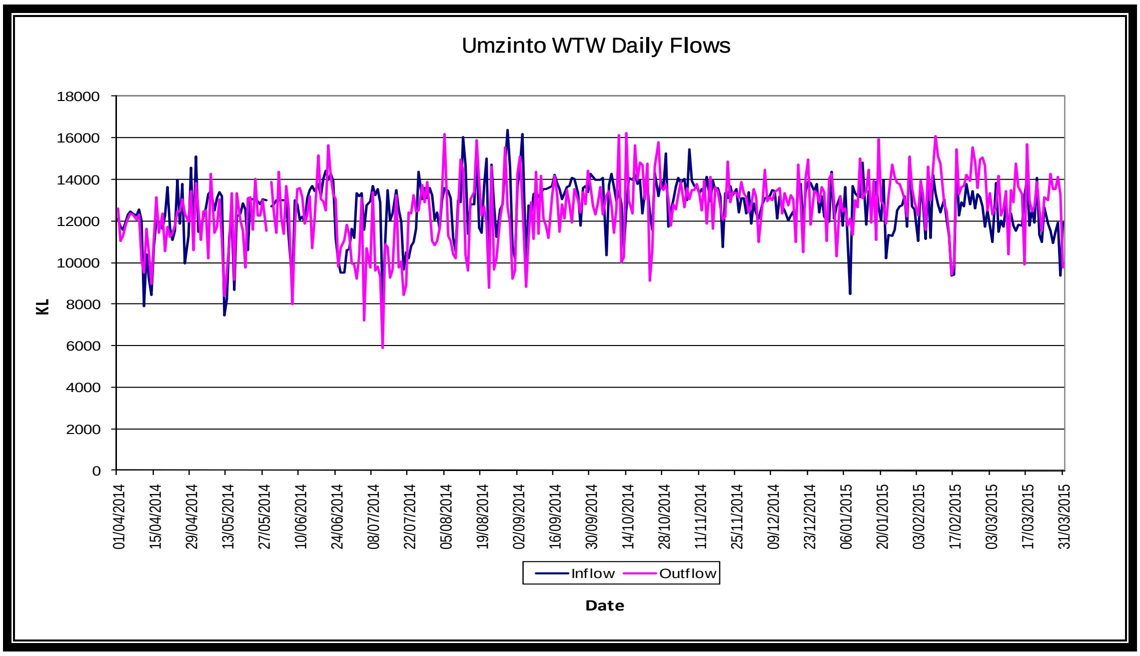


Figure 2: The daily flows for Umzinto Water System during 2014/2015

Source: Ugu District Municipality (2015a)

1.3.4 Equity

Government has put pressure on WSAs and municipalities to ensure that people have free access to basic water services. This has resulted in costs exceeding revenue, especially in rural areas where the majority of community members collect water from communal standpipes at no cost. The national government allocates an equitable share grant to local authorities to ensure that communities have access to basic services. This grant is a source of revenue for local authorities that provide free basic services. However, it is not sufficient for municipalities whose area of jurisdiction is predominantly rural, and whose population mainly relies on free basic services. Municipalities have to ensure that the cost of providing these services is covered by the grant and revenue from tariffs. By default, a portion of the grant is committed to operation and maintenance through payment of salaries and covering the water purification costs, among other items.

1.3.5 *Water quality*

Polluted water that cannot be used for drinking or other uses has the same effect as a reduced water supply (Mukheibir and Sparks 2003; Gebauer and Saul 2014). Protecting the quality of the water is a major challenge in South Africa. Drinking water must comply with the potable water quality standards specified in SANS 241:2011 (Department of Water Affairs 2013). Most water sources require treatment to comply with these standards and the DWS has adopted a risk-based management approach using the Blue Drop certification to assess water quality compliance (Department of Water Affairs and Forestry 2008). The DWS also regulates wastewater treatment works (WWTWs) and effluent release through risk-based assessment and the Green Drop certification process (Department of Water Affairs and Forestry 2008)

Water and wastewater quality issues are very important for any water services provider and need to be monitored closely in line with the Blue Drop and Green Drop standards (Department of Water Affairs and Forestry 2008). In order to ensure that this is achieved, Ugu DM has a two year contract from 2015/2016 until 2016/2017 with Umgeni Water to monitor water and wastewater treatment processes. A risk-based monitoring programme was developed to ensure that major possible risks are minimised. No major water quality issues were identified in the Umzinto WTW. Minor incidents that were reported were attended to in line with the municipality's Water Quality Incident Management Protocol (Ugu District Municipality 2015b).

1.3.6 *Funding*

Insufficient funding to construct new or upgrade existing infrastructure is a major challenge. This is due to the huge infrastructure backlog, especially in rural areas. In urban areas the challenge is aging infrastructure, which needs replacement. Although there are different sources of funding for water infrastructure, they are not sufficient. Aging infrastructure is cause for concern in many utilities as it causes dissatisfaction amongst customers affected by breakdowns. In an effort to find long-term solutions, the South African government adopted the Expanded Public Works Programme. This programme promotes service delivery while creating job opportunities for local community members. The programme has been implemented in all local government projects (National Planning Commission 2011).

1.3.7 Lack of skills

The lack of technical and management skills has been identified as one of the reasons for poor service delivery in most municipalities (International Water Association 2013). This poses a threat to water and sanitation service delivery and compliance with targets (International Water Association 2013). It also threatens the implementation of sustainable water resources management. In order to address this challenge, skills development initiatives have been identified as a priority (Dziegielewski 2011). Key role players in the water sector need to agree on a co-ordinated way to address skills shortage across the whole spectrum of education and training. The sector needs to also come up with incentives to attract people with the requisite technical skills. Many skilled technicians leave the country to take up more lucrative offers elsewhere.

A study conducted by the International Water Association (2013) noted that the lack of institutional memory within water utilities due to high staff turnover at management level is also a challenge. Top management changes within a short period of time, resulting in a lack of capacity to mentor young, inexperienced technicians (International Water Association 2013). Technicians that do not gain useful work experience do not make an optimal contribution to service delivery. Newly appointed civil engineering technicians tend to resign after a short period of time to pursue career opportunities elsewhere (International Water Association 2013).

1.3.8 Politics

Water is a basic need but because it is a scarce and critical resource it is politicised. Mehta (2014) study on water and human development noted that, access to water is a prerequisite, especially for the poor, in order to achieve basic health standards and for them to be economically active. It was further observed that it is the cultural norm for women and girls to collect water in the rural areas. This is a time consuming activity which prevents them from being involved in economic activities, attending school and enjoying a normal childhood (Mehta 2014). Water thus plays a very important role in the development of any economy. An adequate supply of safe and affordable water enables people to lead healthy lives and be able to contribute to the economy.

Bhakar *et al.* (2015) indicated that the scarcity of water is becoming worse due to the increase in demand resulting from, among other things, a growing population. They noted that the scarcity of water has a huge impact on the economic, political and social issues that need to be addressed by global and local leaders. Governments are charged with the responsibility of ensuring sufficient and safe drinkable water while ensuring that there is no negative impact on the environment (Bhakar *et al.* 2015). Thus the water management team and leadership need to work together to ensure that there is sufficient water for present and future generations.

1.4 Possible solutions to potable water supply challenges

1.4.1 Reducing water losses

Losing treated water is very costly and further delays access for those that are deprived of this resource. South Africa does not receive enough rain to satisfy competing demands for water. Therefore every effort should be made to prevent it from going to waste. Furthermore, reducing water losses not only enables a utility to save water but also the energy required to pump water.

Water can be lost in different ways, for example, through leakages, burst pipes, reservoir overflows, etc. Unreported water leaks can put strain on a system and cause loss of pressure. This can be addressed by implementing a leak detection and repair programme (Gonzalez-Gomez, García-Rubio and Guardiola 2011). Consumer awareness also plays a critical role in reducing water losses (Tindale and Sagris 2013). While the focus has traditionally been on the supply side, there has been a paradigm shift and demand management is now receiving attention (Gebauer and Saul 2014).

1.4.2 Operation and maintenance of infrastructure

The operation and maintenance of infrastructure is critical in ensuring an uninterrupted supply of water. A system that is not maintained experiences many supply challenges resulting in consumers going without water for prolonged periods of time. It is critical that water utilities have operation and maintenance budgets to enable them to carry out preventative maintenance instead of reactive maintenance (Ugu District Municipality 2013). Sufficient funding must be allocated to the repair and replacement of infrastructure that has reached the end of its design life. Replacing dysfunctional infrastructure without attending to the factors that have a negative impact on operation and maintenance is not the best option in the long term. If newly refurbished plants are not getting basic maintenance, they end up in a deteriorating state within five years (Wescoat Jr 2015).

The existing culture of poor maintenance in the water utilities needs to be replaced by a strategy that provides for sufficient technical and financial resources for operation and maintenance. The main benefits of maintaining infrastructure are significant reductions in infrastructure life cycle costs, as well as the ability to deliver an uninterrupted and satisfactory level of service to consumers (Roshani and Filion 2014).

1.4.3 Asset management

Asset management is crucial in ensuring an uninterrupted supply of water. It also enables an organization to examine the need for, and performance of, assets and asset systems at different levels. Analytical approaches can be applied to manage an asset over the different stages of its life cycle. This is from conception of the need for the asset, through to its disposal, including management of any potential-post disposal liabilities. If assets are managed properly, their whole life costs are minimised and their lifespan is increased. Asset management assists in making the right decisions and optimising the value of the assets. An updated asset register makes it easy to locate missing plant and equipment, and also to develop maintenance plans (Tu *et al.* 2015).

It is easier to carry out preventative maintenance on assets that are known than on those that are not known. This also avoids tedious supply chain management procedures which frustrate technical personnel working at remote sites. It becomes easier to identify infrastructure that is likely to fail on time and take the required remedial action to prevent interruptions in service delivery. Procurement plans can be prepared on time if there is an updated asset register in place, thus reducing downtime due to breakdowns. Proactive decision-making is possible on when to maintain, upgrade and operate the assets. This makes it easier to manage the assets until the end of their useful life (Tu *et al.* 2015).

1.4.4 Water demand management

Water demand management (WDM) is any measure that is implemented in order to reduce expected water use or demand (Vertommen, Magini and Cunha 2014). Water utilities can play an important role in managing water demand by making it part of the Water Services Development Plan (WSDP). South Africa still has a huge backlog in terms of water supply and this backlog can be reduced by means of a combination of building new infrastructure and the management of existing demand (Machethe 2011). A number of strategies can be adopted to reduce demand, including bulk metering, pressure management, etc. It is not practical to measure the amount of water used if the system is not metered; therefore, bulk metering is critical in WDM. Furthermore, WDM strategies should not be viewed as drought relief measures, but should be implemented even under normal circumstances.

Supply side management options are often easier to implement than demand management options. This is because demand management is a complex process that is usually implemented on live systems. However, it is cheaper to manage demand than build new infrastructure (Chen and Boccelli 2014). Managing demand through pressure management usually increases the life span of infrastructure. It is very important for a utility to understand the drivers of demand in order to manage it.

1.4.5 Water conservation

Water conservation refers to the minimization of loss and protection of water resources which also involves the efficient and effective use of water (Mandal *et al.* 2011). This requires that consumers understand the value of water and the long term effect of water wastage and change their behavior. The water sector cannot address water challenges without the co-operation of users; therefore, education is critical. If users are not educated about the importance of water conservation they may regard conservation measures as punitive. Other strategies to promote water conservation include installing prepaid meters, regulations and by-laws, and improving reticulation design and plumbing standards (Xiao and Chun 2013). The water utility could enter into negotiations with developers and offer incentives to those that can show that they are adopting water conservation methods in their developments.

1.4.6 Increased integration and coordination

There is a need for an increased integration and co-ordination among the various institutions in the water supply chain. If the planning processes adopted by DWS to develop water resources were to be integrated with the planning undertaken by water boards and WSAs, a number of challenges would be eliminated. There should be a flow of information between these institutions including the sector departments. This would ensure that all new developments are catered for in the WSDP. Situations where new infrastructure like schools, clinics etc., is not operational because no water is available, could be avoided.

1.5 Problem Statement

A water utility should be able to manage and control the challenge of NRW. This is done so that the future demand can be easily managed. If a utility reflects the correct figures for NRW it makes it easier for the system operators to determine the amount of water being lost and the amount of water attributable to its specific components. When a Water Services Provider (WSP) encounters water losses, the amount of water available to consumers is reduced and demand outstrips supply. Water losses also impact negatively on the finances of the WSP as the costs of producing and distributing water cannot be recovered.

Ugu DM needed to put in place a strategy to manage its water losses. After the development of the strategy it was possible to forecast potential savings and potential revenue increases; develop meaningful real and apparent loss reduction strategies and set realistic targets thus developing a business model for the municipality. The exact amount of NRW in Ugu DM was not known as at 2007 and this affected the planning processes. The lack of metering in many systems, big complicated systems and huge amount of leaks made it difficult for the systems to be managed. It was also difficult to identify water losses in Ugu DM water systems because there were always a delay between water usage, customer billing and the receipt of payment in the water distribution system especially those with a large customer base.

It was therefore important to carry out a study that could come up with a most suitable business model for the municipality and which could be implemented by other Water Services Authorities in South Africa. This was going to be achieved by implementing various NRW reduction strategies, identifying the sources and causes of water losses by conducting field measurements and by developing a water balance for the study area

1.6 Justification for the Study

Cosgrove and Rijsberman (2014) observed that the global water crisis is not due to the fact that there is not enough water, but because water is poorly managed. Both people and the environment suffer as a result (Magombo *et al.* 2015). Most governments subsidise water services especially to poor communities. Although this is done for noble reasons, people tend to waste services that are supplied free of charge (Cosgrove and Rijsberman 2014). There is thus a need for integrated water resources management (IWRM) that will maintain a balance between the quality and quantity of water (Dzwairo, Otieno and Ochieng 2010). Araújo et al. (2015) described IWRM as a process of co-ordinating the development and management of water resources and other related resources while at the same time addressing economic and social aspects.

Hughes et al. (2014) maintained that a resilient business model for water utilities could be achieved by implementing sound financial policies. The research added that utilities should be monitored and that financial performance policies should be adopted and targets set, thus suggesting that tariffs be increased in line with costs.

The current Masters research aimed to address some specific challenges on the management of existing water resources by implementing demand management strategies and promoting water conservation strategies. Although the study by Al-Ghuraiz and Enshassi (2005) recommended the development of a water tariff structure to ensure an improved service according to WHO standards, the technical aspects were just as important in achieving that goal. For an example, a leak in a low pressure system might not have as significant an impact as a leak in a system that is under pressure. The study did not view an increase in the tariff structure as a priority in revenue collection but rather, encouraged optimisation of the system. Reduced SIV would ensure that some of the water could be stored for periods when the supply was interrupted. Therefore implementation of the NRW strategies and development of the water balance were important for Ugu DM in order to come up with a more suitable business model.

1.7 Study Objectives

1.7.1 Main objective

To develop tools and strategies for water demand management that will assist in the development of a business model for Ugu DM.

1.7.2 Specific objectives

- To identify and prioritise the implementation of non-revenue water reduction strategies : rezoning, pressure management and leak detection;
- To identify the sources and causes of water losses in the study area by conducting field measurements;
- To construct an International Water Association (IWA) baseline water balance for the study area and determine the key performance indicators;
- To develop a more suitable business model for Ugu DM.

1.8 Research Methods

Water utilities need to develop more rigorous methods for measuring and controlling NRW. For the purposes of this study the following methods were implemented in order to reduce NRW:

- Development of District Metered Areas
- Implementation of the pressure management programme
- Implementation of the leak detection programme
- Calculation of the water balance in order to determine the NRW

1.9 Study Area

This study aimed to formulate a business model that could be used by Ugu DM to reducing NRW. Figure 3 shows the provinces within South Africa, highlighting Ugu DM as the WSA and the Umzinto WTW, whose data and infrastructure were used for the study.

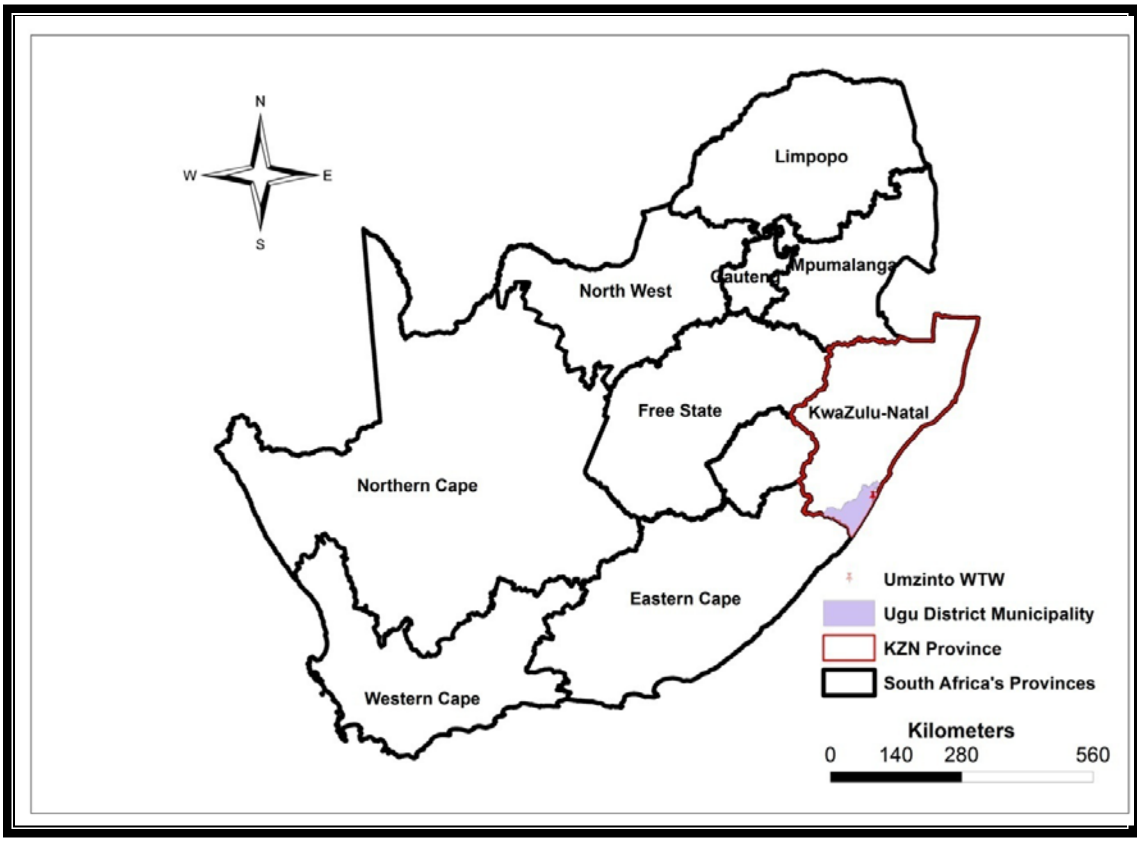


Figure 3: South African boundaries and Umzinto WTW
Source: Environmental Systems Research Institute (ESRI) ArcGIS 10.1 and Ugu DM GIS files

The Auditor General's report for the 2012/2013 financial year identified revenue management as one of the major problems that Ugu DM needed to urgently address. The following critical issues were identified as the reasons for the municipality receiving a disclaimer:

- Some people were illegally connected to the water systems;
- Some people were connected but meter information was not captured on the system to enable them to be billed;
- Some meters were old and were no longer working and needed to be replaced;
- Meter reading was a challenge as most readings were estimated by Meter Readers.

In light of this, the study aimed to come up with a NRW reduction strategy that could be used by the municipality to reduce UAW. The zones used for the study fall under Umdoni LM, as indicated in Figure 4.

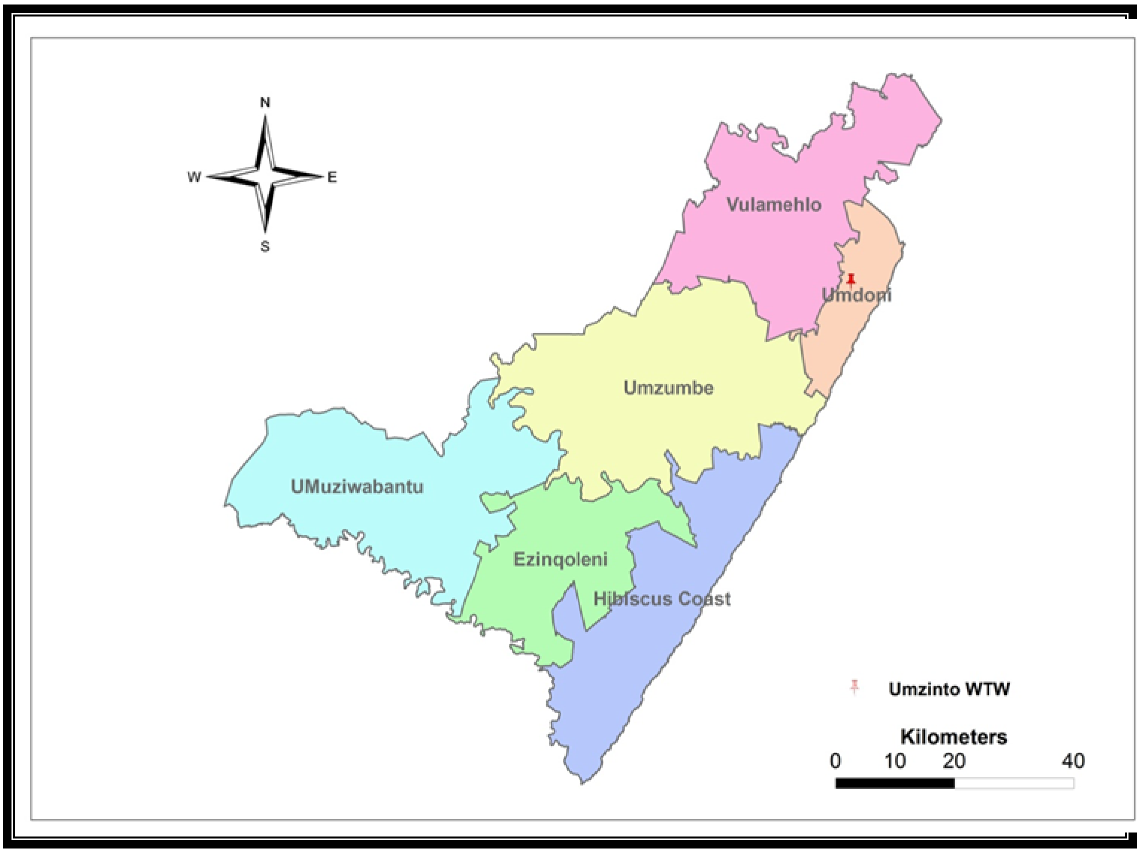


Figure 4: Local municipalities within Ugu DM and Umzinto WTW
Source: ESRI ArcGIS 10.1 and Ugu DM GIS files

1.10 Overview of the chapters

This dissertation is structured as follows:

- Chapter 1 introduces the study and provides an overview of water supply in South Africa. It highlights the research problem and the study's aim and objectives.
- Chapter 2 reviews the literature that is relevant to this study.
- Chapter 3 examines the study area.

- Chapter 4 discusses the methods and materials which were used to achieve the objectives of the study.
- Chapter 5 presents and discusses the results of the study.
- Chapter 6 provides conclusions and suggests recommendations for possible future research

1.11 Limitations of this study

This study focused on some specific technical aspects within Ugu District Municipality's business model, for only one of its water supply systems. Tariff structuring, although it is an important aspect within a utility's business model, was not included in this study because it fell outside of the scope of this Masters research.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

According to the National Planning Commission (2011), all South Africans will have affordable access to sufficient safe water before 2030. This refers to basic water services rather than private connections for each and every household. However, water supply services depend on the availability of adequate water resources (Wescoat Jr 2015). Water is the key to addressing the challenge of poverty and its' scarcity could also limit economic growth (Movik 2014). People in many areas in South Africa still walk long distances to fetch water from rivers. Socio-economic development is not possible without water (Fry, Schweitzer and Mihelcic 2014). Thus, it is critical for South Africa to eradicate its water supply backlog in order to improve citizens' socio-economic status. South Africa's water resources are without a doubt not adequate. The situation is exacerbated by the drought and the growing demands related to population growth and an economy that is developing.

Water is a valuable resource that must be used efficiently before considering developments of other new water resources. Most water utilities around the world are not as efficient as they are supposed to be in water usage. Huge volume of water that they produce do not realise its true potential, either in terms of supplying customers, or in terms of the utility's financial survival (Schouten and Halim 2010). Due to their limited water resources, developing countries require a paradigm shift in the use and conservation of water resources (Kingdom, Liemberger and Marin 2006; De Graaff *et al.* 2008; Mandal *et al.* 2011). South Africa is approaching full utilisation of its available water resources (Otieno and Ochieng 2004). Furthermore, the upgrade of water schemes can be expensive and is likely to be damaging to the environment.

Water utilities may not be able to eradicate all commercial and physical losses. However, developing countries, should be in a position to reduce physical losses substantially (Kingdom, Liemberger and Marin 2006; Omar 2013). Water demand management can be achieved by implementing strategies and tools to reduce losses. This is significant in the southern African region, which is experiencing regular droughts, floods and unpredictable and irregularly distributed rainfall (Conley 1995; Mwendera *et al.* 2003; Murray, Foster and Prentice 2012). It is also critical that demand management strategies such as reduction of water losses should be applied as they can affect demand through legal, structural, socio-cultural, and economic measures (Gumbo, Juizo and van der Zaag 2003; Xu *et al.* 2014).

The supply of water from many of the existing bulk supply systems in southern Africa has many challenges. This is characterised by operation and maintenance activities that are not adequate, high levels of UAW, insufficient tariffs, and billing errors and collection systems (Rothert and Macy 2000; Vertommen, Magini and Cunha 2014). These challenges cause extensive water wastage and do not create a true reflection of water demand. This negatively impacts the financial well-being of the WSPs that operate and maintain these systems (Rothert and Macy 2000; Bagatin *et al.* 2014).

Usually the augmentation of the water supply from a new source is considered as the priority solution to address the shortage of water (Arlosoroff 1998; Taft 2015). This is in spite of the improved quality of services, environmental benefits and financial savings that could be achieved from the implementation of the most basic forms of WDM (Rogers 2014). With the increasing number of people in many developing countries, water utilities need to urgently implement strong strategies and planned actions to ensure operational efficiency and decrease the gap in service delivery (Mugabi, Kayaga and Njiru 2007; Baldwin and Jeffrey 2014).

Many utilities in developing countries require management information systems that will be effective in order to allow adequate monitoring and evaluation. Many do not assess their own performance by collecting all the relevant data in order to plan operational improvements (Anzaldi *et al.* 2014). These utilities continue supplying until there is a problem where supply does not meet demand. Water demand is an important indicator that informs water distribution system (WDS) operators' decisions to adjust production and control pumps and valves (Chen and Boccelli 2014). Short term demand forecasts are encouraged as these can provide valuable information to distribution system operators in controlling the production, storage and delivery of drinking water.

2.2 Water demand management

WDM refers to any action that reduces average water usage that is in line with the protection or improvement of water quality (Tate 2000; Joustra and Yeh 2015). This could entail the implementation of a strategy to control water demand and usage. Such a strategy could be adopted in order to achieve various objectives in the supply area, including social equity, economic efficiency, environmental protection, social development, services and political acceptability and sustainability of the water supply (Rothert and Macy 2000; Daniell, Coombes and White 2014).

While water efficiency technology and equipment can assist utilities to meet the demand for water, it has become obvious that, in the future, fresh water supplies will not be adequate. This means that there is a need to explore non-traditional sources such as the desalination of seawater (Li *et al.* 2015). Demand forecasts are required to optimise WRM and to improve the planning and management of water infrastructure (Gomes, Sousa and Marques 2014).

2.3 Water Demand Management in South Africa

A water conservation and demand management strategy is fundamental in promoting water use efficiency. One of the reasons why South Africa is running out of water is because in the past the focus was on supply rather than also managing the demand. Chen *et al.* (2005) stated that in order to ensure that the supply meets the demand, water saving measures, irrigation efficiency improvement and cropping pattern optimisation should be implemented.

Therefore, in order to obtain optimal results, water conservation and water demand strategies should be implemented concurrently.

WDM is crucial in ensuring that the limited water that is available is optimised. However, Wescoat Jr (2015) recommended that WDM should be implemented together with the development of water resources, especially during dry seasons. This can also be achieved by prioritising the implementation of NRW water strategies, identifying the causes of water losses by conducting field measurements and developing a more suitable business model for the WSAs.

The Department of Natural Resources and Mines (2005) suggested the demand management strategies set out in Figure 5 for utilities that seek to ensure the establishment and implementation of effective WDM procedures:

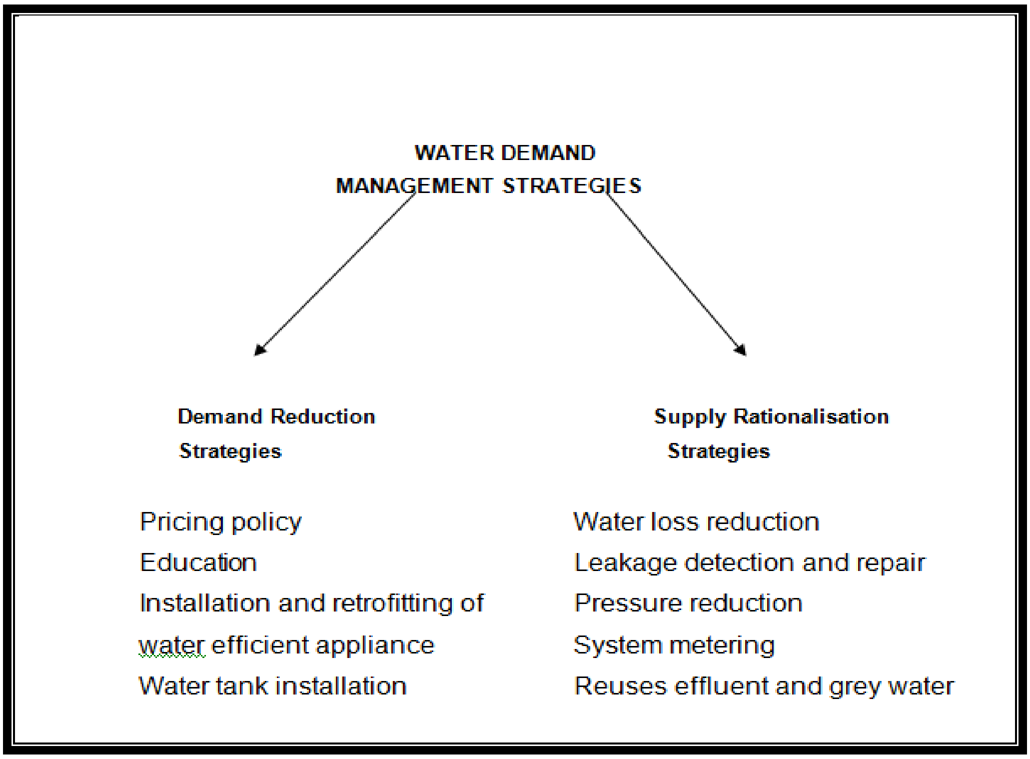


Figure 5: Water demand management strategies

Source: Department of Natural Resources and Mines (2005)

Like most other WSAs, the implementation of WDM at Ugu DM was done at systems level. When Manzungu and Machiridza (2005) conducted a research on the analysis of water consumption and prospects for implementing WDM in the city of Harare, they suggested that it be taken to household level. Technical standards, methodologies and guidelines should all be regarded useful tools when implementing water use and demand management strategies at all levels (Herbertson and Tate 2001; Romano and Kapelan 2014).

Herbertson and Tate (2001) stated that WDM offers many benefits, but also poses some risks to the stakeholders, general public and the environment. The benefits include decentralising accountability for water management to catchment level, and the participation of stakeholders at all levels in the development and implementation of water resources policies (Sultana and Loftus 2013). This means that policies can be implemented, with the stakeholders and users, who are mostly women (Mehta 2014). The challenge is that there is always a risk that stakeholders are not always keen, or sometimes able to participate in such procedures (Herbertson and Tate 2001; Da-ping, Hong-yu and Dan 2011). Because the implementation of WDM measures is sometimes politicised, some stakeholders are thus excluded (Sultana and Loftus 2013).

Many cities in the Southern African Development Community (SADC) region confront challenges in the WDM (Marunga, Hoko and Kaseke 2006; Swain 2015). Not only are they not able to meet their water requirements from the available resources but also the current utilisation is both ineffective and inefficient. This can be seen in the increasing of UAW in cities. Under such conditions, it is becoming increasingly expensive to extend water sources to meet the ever growing demand. In line with global trends, there is a need for the region to shift from traditional resource development to WDM (Marunga, Hoko and Kaseke 2006; Dawadi and Ahmad 2013).

2.4 Water Conservation Management

Water conservation is mainly about consumer awareness and education (Bagatin *et al.* 2014). Water demand and water conservation practices were described by Mathipa and le Roux (2009) and De Gois, Rios and Costanzi

(2015) as involving many factors such as consumer behaviour, knowledge and attitudes to water resources. Making users aware of the importance of saving water will contribute to ensuring that the future generations have sufficient water. In a study done by Mutikanga (2012) on water loss management universal water metering and sub-metering were recommended as a tool to promote water conservation.

Qaiser et al. (2011) evaluated outdoor water utilisation mechanisms along with return flow credits in relation to a number of different water conservation policies. The results indicated that conservation of indoor water use has much less impact in saving water because most of the water utilisation occurs outdoors. The study concluded that, water conservation was a promising option to reduce water demand. Similarly, reusing wastewater in different ways has a possibility of reducing the demand for a clean water supply. It was also noted that water reuse had become common in different countries over the past two decades. Most arid countries like Saudi Arabia, Qatar, Mexico, China, Singapore, Egypt, and Jordan are among the top countries reusing wastewater (Qaiser *et al.* 2011).

Singh (2012) noted that the water available on earth today is no different in quantity from what was available thousands of years ago. Water in all its forms, be it snow, rivers, rain, soil moisture, lakes, groundwater and other forms, constitutes a unit. There is a finite quantity of water on earth, and this is neither added to nor destroyed. No new water can be created but the quantity that is used in any manner reappears although perhaps not always in a re-usable form. Water conservation strategies may vary depending on the nature of the water use, i.e., domestic, irrigation or industrial.

According to Singh (2012), industries should adopt the following water conservation strategies: (i) review alternate production processes and technologies from a water consumption point of view; (ii) ensure sound plant maintenance practices and good housekeeping, minimising spills and leaks; and (iii) optimise treatment to achieve maximum recycling. All stakeholders have a role to play in the conservation of available water resources, including researchers, prominent citizens and citizen groups, non-governmental organisations (NGOs), scientists, media workers, urban planners, landholders and real estate developers, among others (Singh 2012).

2.5 Implementation of non-revenue water reduction strategies

A successful NRW reduction strategy does not rest solely on identifying priority areas of the network and the network operating policy, but also on introducing methodologies and policies to assess, monitor and control elements of NRW. Gonzalez-Gomez, García-Rubio and Guardiola (2011) conducted a study on the issues and challenges confronting water utilities in reducing NRW. One of the recommendations arising from this study was the need to understand the causes of NRW, and the factors which influence its components. According to Gonzalez-Gomez, García-Rubio and Guardiola (2011), once a review of the infrastructure and the operating practices has been carried out, the need to upgrade the network can be assessed. The aim of upgrading is to bring the infrastructure management to a level where municipal officials can begin reducing losses and improving network performance (Charalambous, Foufeas and Petroulias 2014). A number of NRW reduction strategies can be implemented in a water supply system; this study focuses on those discussed below.

2.5.1 Rezoning

District metering is a technique that is used to improve the management of a WDS. It involves dividing a WDS into smaller, manageable portions called District Metered Areas (DMAs). According to Alvisi and Franchini (2013), districts are obtained by closing the isolation valves connecting one DMA to another. Flow meters are installed in order to measure flows into the districts or zones. Scibetta *et al.* (2013) recommended the development of DMAs as a tool to simplify the WDS and make it more manageable. Furthermore, it was recommended that the division of the pipe network be managed as DMAs, in order to compute a water balance and measure water consumption by each group. The division of a pipe network in DMAs is usually achieved by a visual examination supported by technical experience. This approach, is easy to apply to small WDSs but difficult with large WDSs with thousands of user nodes and pipes (Scibetta *et al.* 2013).

According to Farley and Liemberger (2005), effective metering is a critical element of distribution system management, particularly for ensuring the measurement of flows into and out of each zone to provide data for the water balance calculation. Zonal flow monitoring is the foundation of active leakage management in DMAs (Farley and Liemberger 2005). De Paola *et al.* (2013) stated that, among the available approaches to pressure management, the use of DMAs allows for more accurate location of leakages in the water distribution network. This is achieved by monitoring the input and output discharges for each district (De Paola *et al.* 2013).

Gomes, Sousa and Marques (2014) provided the details on how to develop the DMAs. They discussed the influence of future water demand patterns on the DMAs' design and the benefits yielded by pressure management. It was noted that when dividing a large water network into a series of DMAs, the first important step is to close the valves to isolate a certain area and install flow meters. After the DMAs' design, if the pressure in the system is greater than the minimum pressure required for an adequate water supply, pressure management should be investigated at the DMAs' entry points in order to reduce water losses. In the event that the pressure in the system is lower than the minimum pressure required, the existing pipes should be replaced. New pipes could also be installed parallel to the existing ones to ensure that the maximum velocity allowed in each pipe of the network is not exceeded (Gomes, Sousa and Marques 2014).

2.5.2 Pressure management

Pressure management is one of the most important strategies to reduce NRW. According to Lambert (2012), pressure management is the exercise of managing water supply system pressures to the best possible levels of service, ensuring an adequate and efficient supply to legitimate uses and consumers. This is done by reducing unnecessary surplus pressure and eliminating transients and level controls that are out of order. It is by far the most effective and efficient method of controlling leakage (Roshani and Filion 2014). In cities with large numbers of multi-storey buildings, if pressure is maintained to supply the higher floors of tall structures, this will cause severe leakage on the distribution network (Pearson and Lambert 2013). It is essential to adopt regulations that require elevated gravity tanks in multi-storey buildings so that system pressures can be minimised (Gao *et al.* 2014).

Tricarico *et al.* (2013) stated that due to economic and energy crises, alternative energy sources have attracted much interest in many fields. The need to meet energy requirements at low cost has led to the application of strategies which could reduce consumption and enable the production of energy from novel sources. There has been much interest in such options in the operational management of WDSs which are by nature energy-intensive. Rainwater harvesting was recommended in order to save energy by De Gois, Rios and Costanzi (2015). Tricarico *et al.* (2013) found out that using pumps operating as turbines which replaced the existing pressure reducing valves (PRVs) in the network reduced pressure on the WDS while saving energy.

Marunga, Hoko and Kaseke (2006) concluded in their study that a reduction in pressure resulted in reduced leakages. They recommended that PRVs should be installed in all areas that are subjected to high pressure and the implementation of the faulty meter replacement programme, to ensure the reduction of UAW. Monitoring the impact of pressure reduction should include night flows, estimates of leaked water and the impact on billed water. Chen and Boccelli (2014) recommended that a pipe replacement programme be implemented together with the WDM measures, as huge savings could be made from water loss reduction.

According to Lambert (2012) the benefits of pressure management include the following:

- Reduced water losses due to fewer surges and new leak frequencies;
- Improved service reliability due to fewer water supply interruptions, thus improving customer satisfaction;

- Extended useful life of infrastructure;
- Reduced operation and maintenance costs due to reduced pumping energy and repairs;
- Less consumption from pressure-related uses of water.

2.5.3 Leak detection

Charalambous, Foufeas and Petroulias (2014) identified four critical leakage control strategies; active leakage control, pressure management, the speed and quality of repairs and targeted renewal of infrastructure. These strategies need to be balanced in order to achieve the most cost effective leakage programme. Joustra and Yeh (2015) described the leakage reduction problem as a complex one that requires co-ordinated action in WDS management. They also recommended leak detection and repair, pipe replacement programmes and pressure management.

Rogers (2014) noted that leaks in WDSs are difficult to locate, especially where the infrastructure is underground. The study recommended leak detection in such situations. The development of DMAs simplifies the system to make it more manageable. While DMAs have little impact on the leakage level, they are the key to solving the problem. This is because leaks in the zone are easily identified in terms of their position and size. Detecting leaks in a big system is tedious and time consuming, resulting in some being neglected (Rogers 2014).

Joustra and Yeh (2015) maintained that governments have not paid sufficient attention to leakage problems and that limited resources are available for preventative measures. Adachi *et al.* (2014) noted that leakage is a cause of economic loss, and poses the risks of contamination and excessive environmental load in water resource and operational energy consumption. Inadequate maintenance of WDS has serious consequences. This is especially critical in modern times, when society is facing serious water shortages. Thus, there is a need to adopt leakage management strategies (Joustra and Yeh 2015).

Xu *et al.* (2014) classified available leakage detection approaches into three categories: noise monitoring, and flow and pressure monitoring. In terms of noise monitoring, the leakage generates noise when water flows out through a burst or leaking pipe and when it flows past substances outside the pipe. When the noise propagates along the pipe and the ground, capturing the noise helps to find the leak. With flow and pressure monitoring, leakage can cause changes in the hydraulic characteristics, i.e. flow increases and pressure decreases, these are noticeable if the leak is large enough. This study also promoted rezoning because monitoring the flow and pressure of a DMA can make it easier to detect leakage. Other leak detection approaches suggested in this study included visual evidence such as water seeping or gushing out of the ground. Visual evidence is usually reported by the public and plays an important role in leak detection. It usually arises when the leak has been there for a long time. When such passive leakage detections are reduced a water utility improves its leakage management capability (Xu *et al.* 2014).

Water leakage control in distribution systems is a valuable activity that conserves the water resources (Xu *et al.* 2014). This is critical given the modern-day realities of limited water and climate change. In order to sustain urban development, water leakage control is essential in distribution systems. Despite the fact that many measures are available for leakage management, there is still much that remains to be done. This is in terms of developing and implementing more reliable pipe break prediction models in leakage monitoring, the development of low cost leakage detection and pressure regulation devices, the optimization of pipe maintenance strategies, and the establishment of updated decision support systems. The water savings associated with the reduction of energy consumption would sustain urban development which is why leakage has to be reduced (Rogers 2014; Xu *et al.* 2014).

2.6 Sources and causes of water losses

There are two kinds of losses, real and apparent (Charalambous, Foufeas and Petroulias 2014). Real or physical losses are losses from the network system, including leakage, high pressure in the system and storage overflows. According to Charalambous, Foufeas and Petroulias (2014), such losses increase the water utility's production costs and strain water resources since this water is extracted and treated, but never reaches users.

Knobloch, Guth and Klingel (2014) conducted a study on automated water balance calculation for a WDS. Water losses were analysed by calculating the zonal water balance components and performance indicators. The causes of water losses were analysed by merging the results of the zonal water balance, pipe data and information on the environmental conditions (Knobloch, Guth and Klingel 2014).

Tindale and Sagris (2013) identified different causes of water losses in the system, including pressure in the system, the condition of the infrastructure, type of soil and ground conditions. Losses can be addressed by means of pipeline replacement, pressure management, leak detection and repair, reservoir monitoring, and meter replacement, among others (Tindale and Sagris 2013).

2.6.1 Leaks

There are many causes of leaks. Choi *et al.* (2014) identified repairs that are not done correctly as the main cause followed by leaks at the valves, connections and poor construction. Charalambous, Foufeas and Petroulias (2014) reported that, among many causes of water losses, leakage represents a considerable part and is one of the key issues to be addressed in improving the efficiency and effectiveness of water supply services. In most cases, pipes start to leak due to age; this results in insufficient water reaching the desired destination (Machethe 2011). Leakage is one of the critical components of the total water losses in a distribution system, and is made up of physical losses from pipes, leaking connections, and also from reservoirs that are overflowing (Farley 2001; Charalambous, Foufeas and Petroulias 2014). Leak management aims to reduce water that is lost in the distribution system through pressure management and leak detection methods.

2.6.2 Aging infrastructure

Aging water mains is one of the critical sources of water losses (Al-Barqawi and Zayed 2008). Lambert, Fantozzi and Thornton (2013) study found that the frequency of breakage and failure of pipes in water distribution networks increases over time. This is mainly due to the deterioration of infrastructure. Deteriorating water pipes increase operation and maintenance costs while the hydraulic network capacity and quality of service decrease. The rate at which the water mains deteriorate until they cause water losses is determined by different physical, environmental, and operational factors (Al-Barqawi and Zayed 2008).

- Physical factors include the pipe material, wall thickness, and pipe age, etc.
- Environmental factors include soil type, soil moisture, the presence of groundwater, climate, pipe location, and pipe backfill material, etc.
- Operational factors include internal water pressure, leakage, breakage, and operational and maintenance practices, etc.

Substantial capital investment is required to ensure that these factors do not affect the condition of the pipe and that deteriorating infrastructure is renewed.

2.6.3 High pressures

Lambert and McKenzie (2010) reported that surges and high pressure in the water pipeline have an effect in the rate at which new leaks take place. Flow rates from existing leaks are more reactive to average pressure with the exception of all-metal pipe systems with very high leakage rates. Pressure management is one of the most critical ways of managing leaks, particularly in systems with aging infrastructure. For large systems with different types of pipe materials, the relationship is usually approximately linear, and for all-plastic pipe systems the leak rates vary depending on the pressure. The leak rate becomes higher if the system is pressurised. Despite the serious impact of high pressure on water losses, traditional performance indicators for real losses do not include operating pressure (Lambert 2012). Some scholars argue that pressure should not be included in the performance indicators for real losses because:

- The average pressures in distribution systems are not easy to calculate;
- Incentives for utilities to carry out pressure management may be reduced (Lambert and McKenzie 2010).

2.6.4 Illegal connections

Seago and McKenzie (2007) noted that illegal connections tend to predominate in low income areas where billing is in place. Gonzalez-Gomez, García-Rubio and Guardiola (2011) observed that many WSAs are experiencing this problem. Some have responded by disconnecting all reported illegal connections and metering fire-fighting connections. However, disconnecting illegal connections in South Africa may be problematic as all people have the right to access to a basic amount of water.

For the purpose of this study, an illegal connection is defined as a situation where a consumer has connected directly onto a distribution pipeline or any other water source without the WSA's knowledge. It also occurs when a person with an existing metered service connection bypasses the meter and their consumption is more than the basic allocated amount. Another common form of illegal connection is where residents extend multiple individual household connections from a single standpipe connection. This usually results in capacity constraints since the original system was designed for standpipe use and not individual, metered connections (Seago and McKenzie 2007).

2.6.5 Meter under reading

The Environmental Protection Agency (2013) reported that the age of the meter and the quality of the water in an area determine customer meter inaccuracies. It is difficult to estimate the volume of water lost through meter under registration. According to the study, inadequate customer meters are usually found in lower income areas. Farley and Liemberger (2005) recommended that a meter audit programme be implemented simultaneously with a water-loss study programme in order to address meter inaccuracies by checking the following:

- The condition of the meters

- The reasons for faulty meters i.e. meter malfunction, vandalism, or illegal connections
- The accuracy of the meters
- The efficiency of the meter reading and revenue collection process

The Environmental Protection Agency (2013) noted that meter inaccuracies result in water being utilised, but not being accounted or paid for. These losses cost utilities revenue and do not provide correct information on customer consumption patterns.

2.6.6 Meter reading inefficiencies

According to Kingdom, Liemberger and Marin (2006) a significant portion of commercial losses is the result of mistakes in the meter reading and billing systems. This is not only due to poor technology, antiquated cadastres, and data-handling errors but also because the utility staff takes part in fraudulent practices. Most WSAs are experiencing the challenge of meter readers that do not read meters, but continue to estimate readings. This is mainly the case in rural areas where reading involves walking long distances to reach the meters.

The Environmental Protection Agency (2013) also observed that manually read systems are more labour intensive and have higher possibilities for mistakes. These mistakes result in data errors which affect billing and the accuracy of water audit. Since manual meter reading is labour intensive, it is mostly suitable for smaller water systems. The advantage of this system is that it has reduced initial meter costs and simple billing systems. Another advantage is that the utility's meter reader can be able to identify possible challenges before they affect the system and may locate unauthorized use as they are seeing every meter (Environmental Protection Agency 2013).

2.6.7 Reservoir overflows

Reservoir overflows form part of the real losses in the water balance. A study done by Seago and McKenzie (2007) found that most WSAs' storage systems were in fair condition. These WSAs did not believe that leakage from storage tanks formed a large portion of real losses. Reservoir overflows are often underestimated since much of the spillage occurs at night when no-one is aware of the leakage. Furthermore, most reservoirs in South Africa are of reasonable quality and leakage is thus regarded as a minor issue (Seago and McKenzie 2007; Baldwin and Jeffrey 2014). Reservoir overflows can cause much damage besides the loss of revenue because they can flow into properties. The water in reservoirs is treated water that is usually pumped because reservoirs are situated in elevated areas; this causes loss in the energy used for pumping.

South Africans need to be educated about the importance of water. While citizens have the right to safe water services, these services have to be paid for. Water cannot simply be drawn from rivers and supplied to communities; it first needs to be treated with chemicals that cost money. Further costs are incurred in the form of electricity and labour. Payment of water bills enables the delivery of clean water and the expansion of water services to those without access.

2.7 Measuring losses in the field

2.7.1 Data logging

Mutikanga (2012) conducted a data logging exercise that measured customer water use profiles using high precision master meters and continuously recorded the readings from the meter. Data logging is usually used to measure the flow and pressure on the system by installing loggers in the meters. It is critical that meters give accurate results. De Paola *et al.* (2013) obtained MNFs from pressure and flow measurements obtained using a data logger. The impact of pressure reduction should be critically monitored that it covers the night flows, estimates of leaked water and the impact on billed water.

The Environmental Protection Agency (2013) noted that data loggers are an alteration of audio leak noise detection recording. They combine a listening head with a digital recorder into a single sensor that can be attached to the system and left in place to operate over an extended period of time. On completion of the testing, the loggers are disconnected and their time-marked data is downloaded to specialized leak classification and detection software for analysis. More sophisticated loggers can be set to turn on and off, sampling only during the off peak periods. Some types of data loggers have radios that download data stored in them when required to, resetting themselves for follow-on recording (Lambert and McKenzie 2010; Environmental Protection Agency 2013). Data loggers can be a helpful and an economical means of taking uninterrupted measurements, especially for night flows (Environmental Protection Agency 2013; Pearson and Lambert 2013). They give the best results when used to detect leaks on cast iron, ductile iron, steel, concrete and transit pipe (Environmental Protection Agency 2013).

2.7.2 Measurement of minimum night flows

Mutikanga (2012) stated that before the development of the top-down water balance, it is critical that the bottom-up approach, which includes field investigations such as MNFs is conducted. The MNFs measurements for leakage assessment are usually carried out in DMAs due to the fact that they are mainly used to monitor and detect leaks in the WDS. The MNFs are usually measured between mid-night and 5 am; they are the lowest flows supplied to a hydraulically isolated supply zone. The water used at night is at its lowest level and the pressures in the system are relatively high; hence, a significant portion of the flow recorded during the period of the MNF is likely to be a leak. However, according to Mutikanga (2012), the MNFs method suffers from the following limitations:

- It does not reveal exactly how the leakage is distributed in the network;
- It is not very effective in systems with irregular supply and where there are no zones;
- It relies heavily on accurate estimation of the expected night flows;

2.8 An International Water Association baseline water balance

Key performance indicators for the water balance were identified by Seago and McKenzie (2007) and Van den Berg (2014) as follows:

- System Input Volume: this is the volume of water which has been produced from the WSAs own resources as well as bulk water imported from other sources that is pushed into the system.
- Authorised Consumption: this is the volume of metered and non-metered water that is consumed by people that authorised to do so and are registered customers. It includes water that has been exported and any other water that is used after the point of customer metering (Lambert, Fantozzi and Thornton 2013)
- Water Losses: this water represents the difference between System Input Volume (SIV) and Authorised Consumption and is made up of Apparent Losses and Real Losses
- Non-Revenue Water: this is the water that cannot be accounted for and is the difference between the SIV and Billed Authorised Consumption (BAC). It incorporates the unbilled authorised consumption; Apparent losses; and Real losses

2.8.1 Developing a water balance model

According to Lambert and McKenzie (2010), the best may of managing water losses is by developing a water balance and obtaining night flow measurements on a continuous. It is always recommended to have the water balance developed over a period of 12 months so that the results can be comparable and it should have the following:

- Detailed calculations of all water that flows into and out of a distribution system and the system records must be monitored;
- A programme to test and calibrate meters; and
- A space in between the reading of bulk meters and consumer meters.

The water balance calculation quantifies the volumes of total water in the supply system, authorised consumption and water losses (Lambert and McKenzie 2010). All water balance calculations are estimations to a certain extent because it is not easy to assess all the components with complete accuracy. There is a great possibility that they will be more reliable when input volumes are purchased, because all water will be measured through regularly maintained, accurate customer meters supplying properties that do not have storage tanks (Lambert and McKenzie 2010). Storage tanks can result in low flow rates through service connections, and these low flows may not register accurately on the customer's meter (Pena' and Poona 2013).

Best practice, as recommended by the IWA Performance Indicators Group is to allocate the level of confidence to each component of the water balance, incorporating both the level of reliability and accuracy (Alegre 2006; Lambert, Fantozzi and Thornton 2013). In some countries these level of confidentiality are checked on their own as part of the following process:

- All the components of the annual water balance are presented in volume per year.
- Real Losses are determined by identifying leaks as follows:
    - losses from very small leaks that have not been detected – these are usually leaks that have been there for long
    - losses from leaks and bursts that have been reported to the WSP – these are usually leaks that have been there for short periods
    - losses from bursts that are not reported but are discovered during leak detection exercises
    - overflows from service reservoirs.

- Methods in which the Real Losses can be assessed, besides from Water Balances, includes:
    - analysing night flows based on DMA data
    - registering the number and types of leaks and bursts and their flow rates and time that they took before being attended to

- doing calculations that take into account the background leakage and pressure.

Although physical losses only refer to losses before the point of customer metering, the losses beyond this point can sometimes be quiet considerable and deserve attention for the purposes of demand management (Lambert and McKenzie 2010). Table 1 indicates all the components of a water balance (Alegre 2006).

Table 1: Standard IWA Water Balance

Source: Alegre (2006)

System Input Volume	Authorised Consumption	Billed Authorised Consumption	Billed Metered Consumption	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorised Consumption	Unbilled Metered Consumption	Non Revenue Water
			Unbilled Unmetered Consumption	
	Water Losses	Apparent Losses	Unauthorised Consumption	
			Customer Meter Inaccuracies	
		Real Losses	Leakage on Transmission and Distribution Mains	
			Leakage and Overflows at Storage Tanks	
			Leakage on Service Connections up to point of Customer Meter	

The water balance for the study was calculated and developed according to Alegre (2006) following the steps as indicated below:

Step 1: System Input Volume (SIV) was measured through flow logging and meter readings

Step 2: the billed metered consumption (BMC) was derived from billing database

Step 3: Unbilled authorised consumption (UAC) was estimated from number of properties which were not in billing database but were served

Step 4: Billed authorised consumption (BAC) = BMC + UMC

The components of BAC were identified, calculated and summed up. These include Billed Metered Consumption, Free Basic Water, Public Standpipes and Tanker Delivered Volumes. The BAC is the Revenue Water in the water balance

Step 5: Real losses (RL) were measured through night flow analysis

Step 6: Water losses (WL) = SIV – BAC

Step 7: Apparent losses (AL) = WL – RL

Step 8: Metering inaccuracies (MI) = 3.5% of BMC

Step 9: Unauthorised Consumption (UC) = AL – MI

2.8.2 Key performance indicators for a water balance

Cosgrove and Rijsberman (2014) maintained that the management of water losses should be measured from three different viewpoints, namely technical, financial and water resources. According to Lambert and McKenzie (2010), the following are the KPIs for a water balance:

- **Technical Indicator for Real Losses = RL/Nc**
  The basic Technical Indicator for Real Losses is the annual volume of Real Losses divided by the number of service connections (Nc) (Lambert and McKenzie 2010).
- **CARL = Current Annual Volume of Real Losses/Nc**
  The CARL is determined during the development of the IWA water balance.
- **(UARL) = Unavoidable Average Real Losses**
  (A x Lm/Nc + B + C x Lp/Nc) x P
  Lm = Length of mains
  Nc = Number of service connections
  Lp = Length of private connections
  P = Average pressure
  The UARL are the lowest attainable annual real losses for a system that is well maintained.
- **Infrastructure Leakage Index (ILI) = CARL/UARL**
  ILI is the current annual real losses (CARL) divided by the unavoidable annual real losses (UARL). Well-managed systems in very good condition have ILI values close to 1.0, with higher values for older systems with infrastructure deficiencies (Lambert and McKenzie 2010).

2.9 Business models for Water Services Authorities

2.9.1 Fungibility of resources in the water sector

Due to an increase in the structural and physical scarcity of water there is a need for a deeper understanding of trans-boundary water conflicts (Zeitoun and Warner 2006). There are studies which contributed to this debate by investigating who gets how much of the water available, and how and why this occurs (Zeitoun and Warner 2006; Swain 2015). It is argued that the management of water resources is not achieved through water wars but through a suite of power-related plans and strategies (Zeitoun and Warner 2006; Fekete 2013). Understanding the intensity of the conflict over water is important in analysing the outcomes of competition over the use of water resources (Dzwairo, Otieno and Ochieng 2010). Zeitoun and Warner (2006) showed that diverse features of power are relevant to the analysis of trans-boundary water conflict. The act of engaging in competition over trans-boundary water resources, particularly when water is scarce, reveals each competitor's strengths and weaknesses (Zeitoun and Warner 2006; Mianabadi *et al.* 2014).

There are numerous underlying reasons for water-related controversy, including power struggles and competing development interests. All water disputes can be attributed to one or more of three issues: quantity, quality, and timing (Assadourian *et al.* 2005). The most obvious reason for water related conflict is competing claims for a limited quantity of water (Assadourian *et al.* 2005; Mianabadi *et al.* 2014). The degradation of water quality can cause disputes between the people who cause it and those affected by it. Further to this, water quality challenges can lead to public protest if they affect livelihoods and the environment (Assadourian *et al.* 2005). In terms of timing, the water flow timing is important in many ways; this is why the operational patterns of dams are often contested. For example, upstream users might release water from storage tanks in winter for hydropower production, while downstream users might need it for irrigation in summer (Assadourian *et al.* 2005; Swain 2015). It is important to maintain water flow patterns as they are crucial in supporting freshwater ecosystems that depend on seasonal flooding (Assadourian *et al.* 2005).

2.9.2 Financing water sector infrastructure

According to Ruiters (2012), efficient and productive infrastructure is critical for economic growth and competitiveness. The availability of water infrastructure and its timely implementation, financing and pricing are important factors in national economic growth and global competitiveness. Ruiters (2012) noted that government's role is to create a stable investment environment. This could be achieved through political commitment, consistency, a regular and predictable flow of deals, and suitable legislation. However, politicians tend to interfere with the financing of service delivery.

The financing of water sector infrastructure confronts too many challenges. The following are some of the challenges experienced by municipalities (Ruiters 2012; Daniell, Coombes and White 2014):

- Lack of sufficient funding to address backlogs, replace aging infrastructure and maintain existing infrastructure
- Lack of project management skills to manage Municipal Infrastructure Grant (MIG) projects
- Lack of appropriate planning for the project life cycle
- Technical reports and Environmental Impact Assessments get submitted late for approval
- Bad weather conditions
- The procurement process takes long because of the supply chain management regulations
- Failure to obtain approval of a multi-year capital budget
- Appointment of service providers who do not have skills to deliver the service
- Councils take too long to approve projects and budgets
- Amendments and changes to projects without taking into account the Integrated Developmental Programme (IDP) process

Financing the operation and maintenance of infrastructure is very critical because a well maintained system requires fewer repairs, incurs lower production costs and avoids compensation payments.

2.9.3 *Human resources*

The International Water Association (2013) conducted a study to assess human resource requirements in the water supply and sanitation sector. The on-going scarce skills shortage in the water sector is a threat to achieving water and sanitation delivery, meeting compliance targets and implementing sustainable WRM. All countries require the correct skills to manage water resources (International Water Association 2013). According to the International Water Association (2013), there is a shortage of mechanical, electrical and civil engineers in the urban water sector, due to the failure to replace aging engineers and key technical staff. Some skilled workers migrate to other countries due to economic considerations. The democratic government in South Africa has put skills development programmes in place to address historical shortages (Daniels 2007; International Water Association 2013). These challenges are being addressed through the Sector Education and Training Authorities (SETAs) and the general education system.

Increased productivity is an important strategy to overcome skills shortages (Daniels 2007; Choi *et al.* 2014). In diagnosing occupational skills shortages, it is impossible to determine whether the constraints faced by firms are binding in any way other than notional (Daniels 2007). South Africa requires highly qualified workers, but this is an expensive process (Daniels 2007; Cosgrove and Rijsberman 2014). Such workers need to be encouraged to remain in the country. Furthermore, firms need to ensure that foreign workers transfer their skills to local workers. Even if this is not achieved, the productivity gains associated with employing foreign skilled workers would help improve South African firms' competitiveness (Daniels 2007; International Water Association 2013).

2.9.4 Tariff structuring

One of the important factors affecting the design of the water tariff is affordability and citizens' ability to pay for improved water supply services (Al-Ghuraiz and Enshassi 2005). Since the dynamics and economic situation of each household vary significantly, before the introduction of new water tariff, vulnerable households should be taken into consideration. Some studies recommended that a cross subsidy technique should be used to assist underprivileged households that cannot be able to pay for the average price (Al-Ghuraiz and Enshassi 2005; Grafton, Chu and Kompas 2015). According to Al-Ghuraiz and Enshassi (2005), the easiest way to achieve this is a combined system that takes many blocks into consideration. The lower blocks are the social tariff, while the higher blocks consider economic factors. This ensures that rich households cross subsidize poor ones. A household with one subscription will be expected to use a separate subscription to benefit from social blocks.

Democratically elected municipal politicians are reluctant to address this politically sensitive issue directly, as it is believed that residents have the right to certain services including water (Daniell, Coombes and White 2014). Chen *et al.* (2005) stated that apart from technological means, economic means also play a very important role in the implementation of WDM. Appropriate pricing of water has proven to be a very effective tool that can change the public's attitude to water conservation that promotes economic efficiency and investment in new installations (Dzwairo, Otieno and Ochieng 2011). The most important part of a pricing strategy is fee collection and the use of economic incentives such as subsidies (Chen *et al.* 2005). A recommendation for the government to promote public information and awareness by establishing monitoring and management information systems at all levels was made by Chen *et al.* (2005) and Daniell, Coombes and White (2014). There is a need for clear accountability and co-ordination among institutions for water management. Water user associations also play a critical role in water billing and collection.

2.10 Ability and willingness to pay for water supply services

Supplying water poses a number of challenges, especially in municipalities that lack a sound business model. WSAs cannot be managed successfully if they do not have a suitable water pricing system because any improvement in the water supply service will have implications in the cost of this service (Al-Ghuraiz and Enshassi 2005). The culture of not paying for water services, which was a way of protesting against apartheid continues in the democratic era (Daniell, Coombes and White 2014). Even though township residents now own their residences, they still take advantage of the weaknesses in the municipal system and do not pay their water bills (Daniell, Coombes and White 2014).

Be that may, water pricing needs to be integrated with other measures to ensure that environmental, economic and social objectives are met in a cost effective manner (Al-Ghuraiz and Enshassi 2005; Swain 2015). Parallel to universal access is the issue of affordability and consumers' ability to pay for an improved water supply service. It is also very important to understand the level of the consumers' willingness to pay. Water supply policy should include mechanisms to predict consumers' response to a service they did not previously have access to. Willingness to pay refers to the maximum amount that a person would be willing to pay for a service rather than doing without it (Al-Ghuraiz and Enshassi 2005; Aidam 2015). As noted earlier, vulnerable households that cannot afford to pay the tariff are usually cross subsidised by rich households. The challenge in South Africa is how to provide water to households with little or no income. While morally defensible, a certain amount of free water, or free stand pipes, are very blunt instrument as they subsidise both the poor and the rich (Larsen 2014).

Finally, customer perceptions of water reliability and purity are important. They require that water be delivered and that this be done in a courteous manner. The level of customer service can be gauged from factors such as response time for serious leaks, and handling of account and other queries, etc. More general perceptions can be ascertained through targeted questionnaires and surveys (Larsen 2014).

CHAPTER 3: STUDY AREA

3.1 Introduction

This study focused on the Umzinto WSS which is situated in the Middle South Coast of KwaZulu-Natal. The Middle South Coast region is found along the Indian Ocean and extends from the Mkomazi River southwards to the Umtwalume River. It includes the Umzinto, Mpambanyoni, Mzumbe and Umtwalume quaternary catchments in the U80 tertiary catchment. This area falls under Umdoni LM which is one of the local municipalities under Ugu DM. The Umzinto and the Amandawe zones within the Umzinto WSS were identified for the study. The Umzinto Zone falls under ward 3 and Amandawe Zone falls under ward 5 of Umdoni LM. As indicated in Figure 6, both zones receive water from the Umzinto WTW.

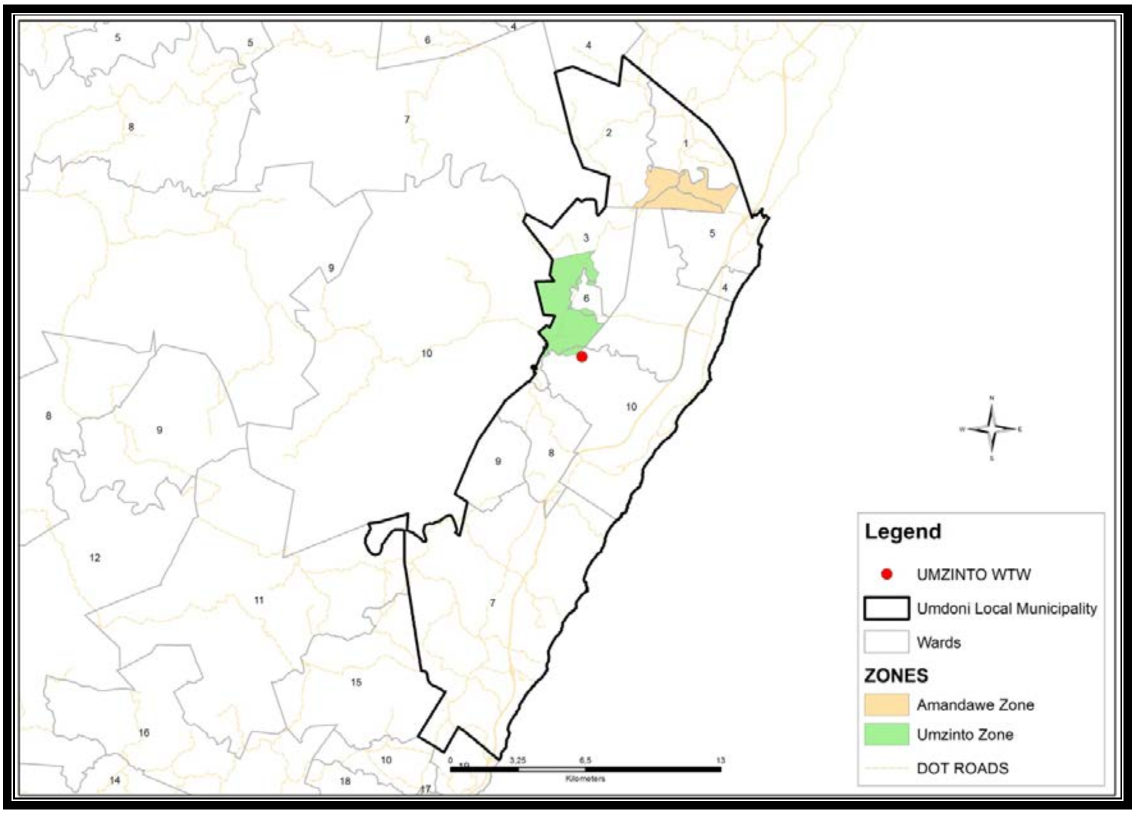


Figure 6: Umdoni LM, Umzinto WTW, and the Umzinto and Amandawe zones
Source: ESRI ArcGIS 10.1 and Ugu DM GIS files

Umzinto Zone lies between the Scottburgh and Pennington wards in Umdoni LM. It is named after the Umzinto River, which refers to its destructive nature during floods. The Umzinto WSS supplies Umdoni LM with water. Umdoni is a small municipality with a population of approximately 78 875 inhabitants (Statistics South Africa 2011). It covers an area of 236 km^2 and includes formal urban areas and informal settlements, which are the result of rapid urbanisation, where substandard or no infrastructure exists. Umzinto WTW is run by Umgeni Water and sells water to Ugu DM which is a WSP. As shown in Figure 7, the raw water sources for the Umzinto WSS are the Umzinto and EJ Smith dams.

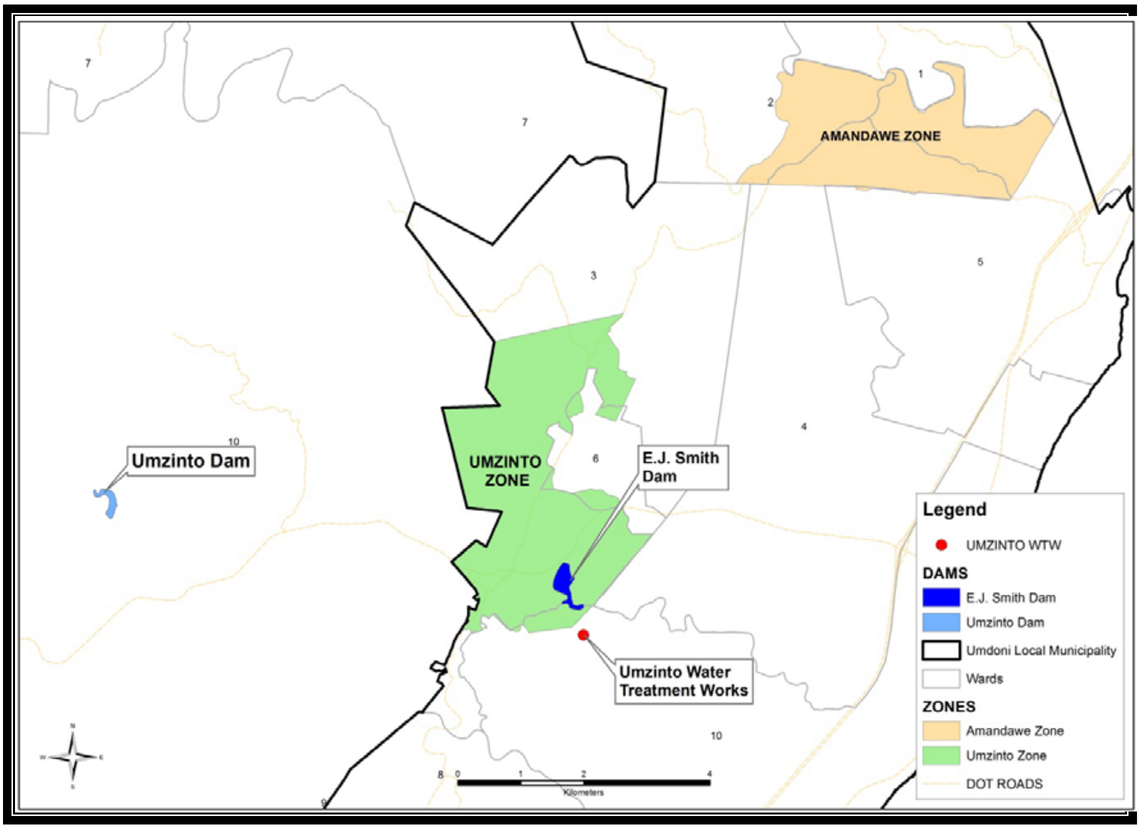


Figure 7: Raw water storage dams for Umzinto Water Supply System
Source: ESRI ArcGIS 10.1 and Ugu DM GIS files

The Umzinto WTW receives its raw water from the two sources shown in Figure 8. Water can either be released into the Umzinto River from the Umzinto Dam and abstracted through an abstraction system at Esperanza and pumped to the WTW, or pumped to the WTW directly from the EJ Smith Dam on the Mzimayi River.

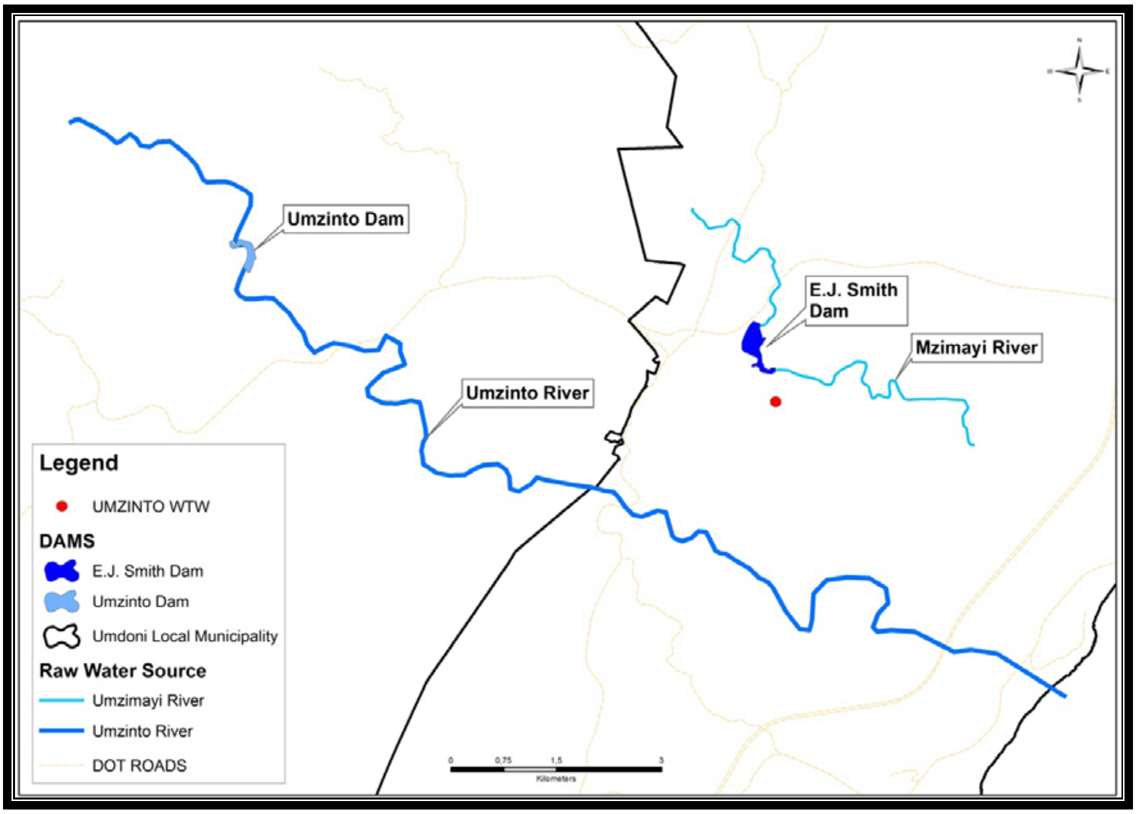


Figure 8: Raw water sources for Umzinto Water Treatment Works
Source: ESRI ArcGIS 10.1 and Ugu DM GIS files

3.2 Water Balance/Availability

The Umzinto WSS receives water from the Umzinto and EJ Smith dams. This system was in deficit by 0.73 million m^3/annum in the 2013/2014 financial year (Ugu District Municipality 2013). The urban and rural requirements include Umzinto, Hazelwood, Amalangeni, Amandawe, Kwa-Cele, Amahlongwa, Dududu, Kelso and Pennington. Sezela Sugar Millis one of the biggest users that have a huge demand due to the nature of its operations and abstracts water directly from Ifafa River for operational purposes. They obtain their potable water from Umzinto WSS. The water use registration with the DWS for the abstractions from both the Umzinto and EJ Smith dams is currently at 12 ML/day. The Umzinto and EJ Smith dams are currently under capacitated and unable to meet the supply requirements during low flow periods (Ugu District Municipality 2013). This poses a threat to the economy of the municipality because the coastal strip of the municipality is a holiday destination. The bulk water infrastructure in Umzinto and Amandawe zones are shown in Figure 9.

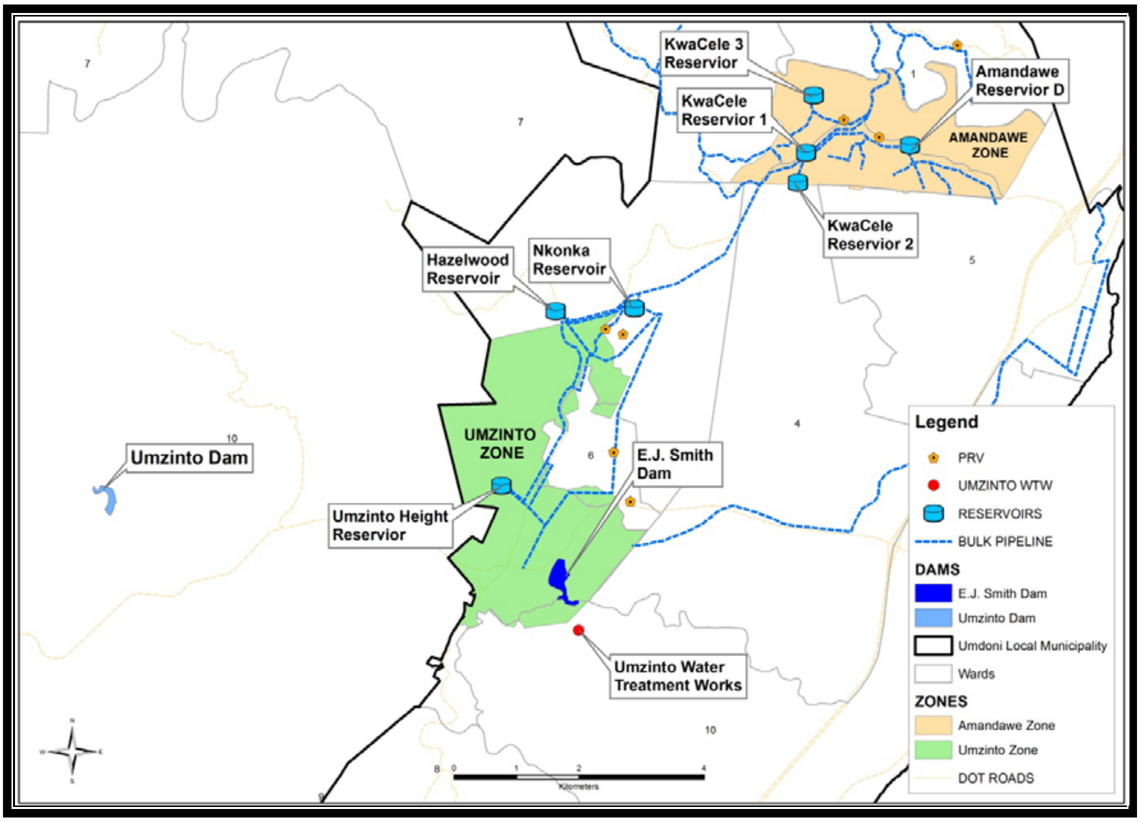


Figure 9: Bulk water infrastructure in Umzinto and Amandawe zones
Source: ESRI ArcGIS 10.1 and Ugu DM GIS files

3.3 Umzinto Water Treatment Works

The design capacity of the Umzinto WTW is 12 ML/day, and there are plans to upgrade it to a capacity of 18.2 ML/day. The supply of clean water from the WTW is currently restricted by the accessibility of raw water. The dams and the Umzinto WTW are belong to Ugu DM, but they are operated by Umgeni Water under a bulk service agreement with Ugu DM. Treated water from the Umzinto WTW is sold to Ugu DM as a bulk supply and Ugu DM is responsible for distribution to consumers. The characteristics of Umzinto WTW are shown in Table 2.

Table 2: Characteristics of the Umzinto WTW

Source: Umgeni Water (2012)

WTW Name:	Umzinto Water Treatment Works
System:	South Coast System
Maximum Design Capacity	12 ML/day
Current Utilisation	9.59 ML/day
Raw Water Storage Capacity	N/A
Raw Water Supply	12.24 ML/day
Pre-Oxidation Type	KMnO4
Primary Water Pre-Treatment Chemical	Polymeric Coagulant
Total Coagulant Dosing Capacity	None
Rapid Mixing Method	Conventional Paddle Flash Mixer
Clarifier Type:	Clari-Flocculator
Number of Clarifiers	3
Total Area of All Clarifiers	387 m^2
Total Capacity of Clarifiers	14 ML/day at 1.5 m^3/hr upflow rate, 19 ML/day at 2 m^3/hr upflow rate
Filter Type	Constant Rate Rapid Gravity Filters
Number of Filters	5
Filter Floor Type	Monolithic
Total Filtration Area of All Filters	127 m^2
Total Filtration Design Capacity of all Filters:	12 ML at 3.9 m^3/hr filtration rate, 15 ML/day at 5 m^3/hr filtration rate
Total Capacity of Backwash Water Tanks:	Nil
Total Capacity of Sludge Treatment Plant:	Nil
Capacity of Used Wash Water System:	Nil
Primary Post Disinfection Type:	Chlorine Gas
Disinfection Dosing Capacity:	12 kg Cl_2/hr including the Stand-By Unit
Total Treated Water Storage Capacity:	5 ML

Figure 10 shows the plan view of Umzinto WTW. The plant is surrounded by the sugar cane fields.

Figure 10: Umzinto Water Treatment Works
Source: Umgeni Water (2012)

3.4 Umzinto Water Supply System

The bulk supply system from the Umzinto WTW is owned and operated by Ugu DM. Umgeni Water has plans to augment this plant in the future as it is currently running at its maximum capacity. The treated water is pumped from the Umzinto WTW to Umzinto Heights Reservoir by the St Patrick's Booster Pump Station. Likewise, it is also pushed to the Hazelwood and Nkonka reservoirs by the Nkonka Booster Pump Station, while it also gets to the Esperanza and Ifafa reservoirs by the Ifafa Booster Pump Station.

There is also the South Coast Pipeline (SCP) which is a gravity line that feeds Ellingham reservoir and from there it flows to the Parkrynie reservoir. The same line has been extended to supply the Cabana and Kelso reservoirs and then to

Pennington reservoir. From the Pennington reservoir it is pumped via the Pennington Pump Station to the Umdoni reservoir. The Pennington reservoir also supplies Hilltops and Bazley reservoirs.

3.5 Existing Infrastructure and Yields

As shown in Table 3 the Middle South Coast Region has the Umzinto Dam on the Umzinto River and the EJ Smith Dam on the Mzimayi River as the raw water storage infrastructure. The EJ Smith Dam is fed by the Mzimayi River and has a capacity of 0.89 million m^3, while the Umzinto Dam is fed by the Umzinto River with a capacity of 0.42 million m^3. Both dams are for domestic use.

Table 3: Water resource infrastructure in the Middle South Coast Region
Source : Umgeni Water (2012)

Impoundment	**River**	**Capacity (million $m^{3)}$**	**Yield (million $m^{3/}$annum)**	**Stochastic Yield (million m^3/annum)**	**Stochastic Yield (million m^3/annum)**
			Historical	**1:20**	**1:50**
EJ Smith Dam	Mzimayi	0.89	0.9 (2.5 ML/day)	1.7 (4.7 ML/day)	1.2 (3.3 ML/day)
Umzinto Dam	Umzinto	0.42	1.6 (4.4 ML/day)	3.2 (8.8 ML/day)	2.0 (5.6 ML/day)

Figure 11 shows the Umzinto Dam at the spillway, where the water spills over from the dam to the abstraction point from where it is pumped to the Umzinto WTW. Figure 12 shows a plan view of the EJ Smith Dam, although the dam level was very low at the time the photograph was taken.

Figure 11: Umzinto Dam
Source: Umgeni Water (2012)

Figure 12: EJ Smith Dam
Source: Umgeni Water (2012)

The characteristics of Umzinto Dam are set out in detail in Table 4. These characteristics are divided into the catchment details and dam characteristics.

Table 4: Characteristics of Umzinto Dam

Source: Umgeni Water (2012)

Catchment Details	
Incremental Catchment Area:	51.6 km^2
Total Catchment Area:	51.6 km^2
Mean Annual Precipitation:	985 mm
Mean Annual Runoff:	6.91 million m^3
Annual Evaporation:	1 200 mm
Dam Characteristics	
Gauge Plate Zero:	125.3 mASL
Full Supply Level:	142 mASL
Net Full Supply Capacity:*	0.42 million m^3
Dead Storage:	0.0 million m^3
Total Capacity*:	0.42 million m^3
Surface Area of Dam at Full Supply Level:	0.0734 km^2
Dam Type:	Concrete
Material Content of a Dam Wall:	Concrete: 27 500m^3
Crest Length:	Spillway Section: 52 m
Type of Spillway:	Uncontrolled
Capacity of Spillway:	730 m^3/s
Future capacity once dam wall has been raised:	N/A

3.6 Water Conservation and Water Demand Management Measures

NRW reduction strategies needed to be implemented in the study area. The most critical strategies that made an impact were pressure management, leak detection and repair and consumer awareness campaigns. Once the NRW reduction strategy has been implemented, training is a critical requirement, as it would be useless for the municipality to adopt NRW strategies that cannot be operationalised due to a lack of knowledge and skills.

The detailed characteristics of the EJ Smith Dam are set out in Table 5. These characteristics are divided into the catchment details and dam characteristics.

Table 5: Characteristics of EJ Smith Dam

Source: Umgeni Water (2012)

Catchment Details	
Incremental Catchment Area:	15.84 km^2
Total Catchment Area:	15.84 km^2
Mean Annual Precipitation:	1060 mm
Mean Annual Runoff:	3.43 million m^3
Annual Evaporation:	1 240 mm
Dam Characteristics	
Gauge Plate Zero:	93.0 m ASL
Full Supply Level:	109.1 m ASL
Net Full Supply Capacity:*	0.89 million m^3
Dead Storage:	0.0 million m^3
Total Capacity*:	0.89 million m^3
Surface Area of Dam at Full Supply Level:	0.1724 km^2
Dam Type:	Concrete
Material Content of a Dam Wall:	Concrete: 3 800 m^3
Crest Length:	Spillway Section: 24.4 m
Type of Spillway:	Uncontrolled
Capacity of Spillway:	220 m^3/s
Future Capacity Once Dam Wall has been raised:	N/A

3.7 Water Losses

A preliminary assessment of the level of water use efficiency and the level of NRW in the Umzinto water supply scheme area indicated that total system losses were relatively high (Ugu District Municipality 2013). It was estimated that NRW in the supply area was approximately 31.5% of the raw water abstracted in 2013 (Ugu District Municipality 2013). These losses were due to high system pressures, leakages in the bulk and distribution infrastructure and the age of the bulk water supply infrastructure.

As the condition of the water infrastructure deteriorates due to a lack of proper maintenance, water losses will continue to increase (Department of Water Affairs 2013). It is estimated that the losses will increase annually to 41% of the raw water abstraction by 2030 (Ugu District Municipality 2013). The total current system losses or NRW from the Umzinto WSS area are estimated at 3.75 ML/day, at the water use and operating practices in 2013 (Pena' and Poona 2013). This is not significant by volume but is significant compared to treated water production.

CHAPTER 4: METHODS AND MATERIALS

4.1 Introduction

This chapter describes the methods used to collect the data for this study and how this data was analysed. This includes the research design, the instruments used to gather data and how the data was collected. The methods employed to achieve each of the specific objectives, the validity and reliability of the study, and the ethical considerations taken into account during the course of this study, are also discussed.

4.2 Research Design

Most of the data used for this study were primary data that were obtained in the field. This enabled the researcher to gather first-hand information on the topic. The advantage of this type of data was that the researcher had control over its quality and quantity.

An experimental quantitative research design was used. Data was collected in the field and analysed. The study results were interpreted to enable conclusions to be reached and recommendations to be made. Water from the supply point to the end user was calculated by reading meters from the supply point to household meters for a period of five months. Some of the data was obtained from desktop information that was readily available at the municipality. Loggers were used to obtain night flows and to calculate the amount of water lost at night due to leaks. DMA’s were created and PRV’s were installed. Visual inspections were done to identify visible leaks in the system and where leaks were identified, repairs were undertaken. Logging was done before and after implementation of the strategies.

4.3 Research Instruments

The data that were collected were used to create a water balance and water audits to calculate SIV, NRW, ILI, among other things in the system. PRVs were installed at various positions in the system while the researcher installed loggers in order to determine system behaviour. The researcher also installed loggers at the bulk meter in the Amandawe Zone and at selected PRV's in the system to determine the volume of water that entered the area in order to determine the losses. Correlators, ground microphones and listening sticks were used to detect leaks in the system, as part of field measurements.

The water balance was developed to determine the difference between the SIV and the output in the form of revenue and NRW. The NRW reduction master plan elicited information regarding the water demand management practices, the auditing of the water supply, water conservation measures and leakage management in all the municipal systems, including the Umzinto WSS.

4.4 Data Collection

The water consumption data used for the study were obtained from the revenue management system (RMS) used by the Ugu DM to bill customers. The RMS receives and processes billing information. It has a billing database from which it provided information on individual users, the stand size, value of the site, users and the value of improvements, suburb, water demand, land use and zoning. Data were also available for individual meters, zonal meters and fire meters in this system. These values were based on monthly water meter readings. Data for a period of five months were obtained in order to gain a true reflection of what was happening on the ground. The data were sufficient in terms of both quality and quantity in order to draw reasonable and reliable conclusions for the analyses.

While estimates were made in some instances during the logging of the system, the researcher also took actual readings for the preparation of the water balance. The reasons for the estimates included manual meter reading, which always had an element of human error due to visual misreading of the meter register. In some instances, the meters were underground, faulty, leaking, or not accessible (inside locked properties), etc. The other major challenge was that the meter readers were sometimes not reading meters, but capturing estimates into the devices.

Based on the figures that were captured, the billed metered consumption (BMC) was very high but this was not a true reflection of the situation. Due to the high number of estimated meter readings recorded and the associated estimated volumes. There were only two ways to confirm the actual reading; undertaking a detailed analysis of the billing database or verifying the real loss volume in the water balance through a data logging exercise. A data logging exercise was done by the researcher on the following sites: reservoirs and zonal meters. The municipality used to develop a water balance for all the systems added together but the water balance for the study focused on the study system only. The data obtained gave an indication of the water losses and assisted in achieving the study's objectives.

4.5 Research Methods for the Specific Objectives

4.5.1 Method for specific objective 1

Identification and prioritization of the implementation of NRW reduction strategies: rezoning, pressure management and leak detection

DMA's were developed in the system so that it was easier and simpler to manage them. This assisted in monitoring the water losses by comparing the amount of water that was billed and that which entered the zone. During the planning stage, each zone was divided into smaller DMAs that were simpler to manage. Small-scale distribution network maps were developed to clearly mark the boundaries. The maps identified:

- buildings that required water supplied at a pressure above the norm for the area;

- large and special customers;
- ground level contours.

Boundary valves in the DMA were closed and where the DMA boundary crossed a main, a meter was installed to allow the net night flow to be calculated. However, where possible, large distribution mains were excluded from the DMA to avoid the high cost of meter installations, and to improve the accuracy of the flow information.

After the DMA boundaries were designed, trial closure of the valves was undertaken to verify their efficiency and to identify those valves that needed to be replaced. It was critical to ensure that the valves were closing because one inefficient valve could compromise the leakage estimate of the DMA. A hydraulic network model was used to ensure that there were no unknown valves in the system. On completion of this exercise a zero pressure test was carried out. The supply to the DMA was closed and the pressure dropped towards zero. All boundary and divisional valves were checked to ensure that they were closed and faulty valves were replaced, after which the zero test was repeated. Figure 13 shows the zero pressure test equipment when the exercise was done on site at the Amandawe Zone. This test was done to ensure that the zone was not breached in any way.

Figure 13: Zero pressure testing on site

Source: Ugu District Municipality (2014)

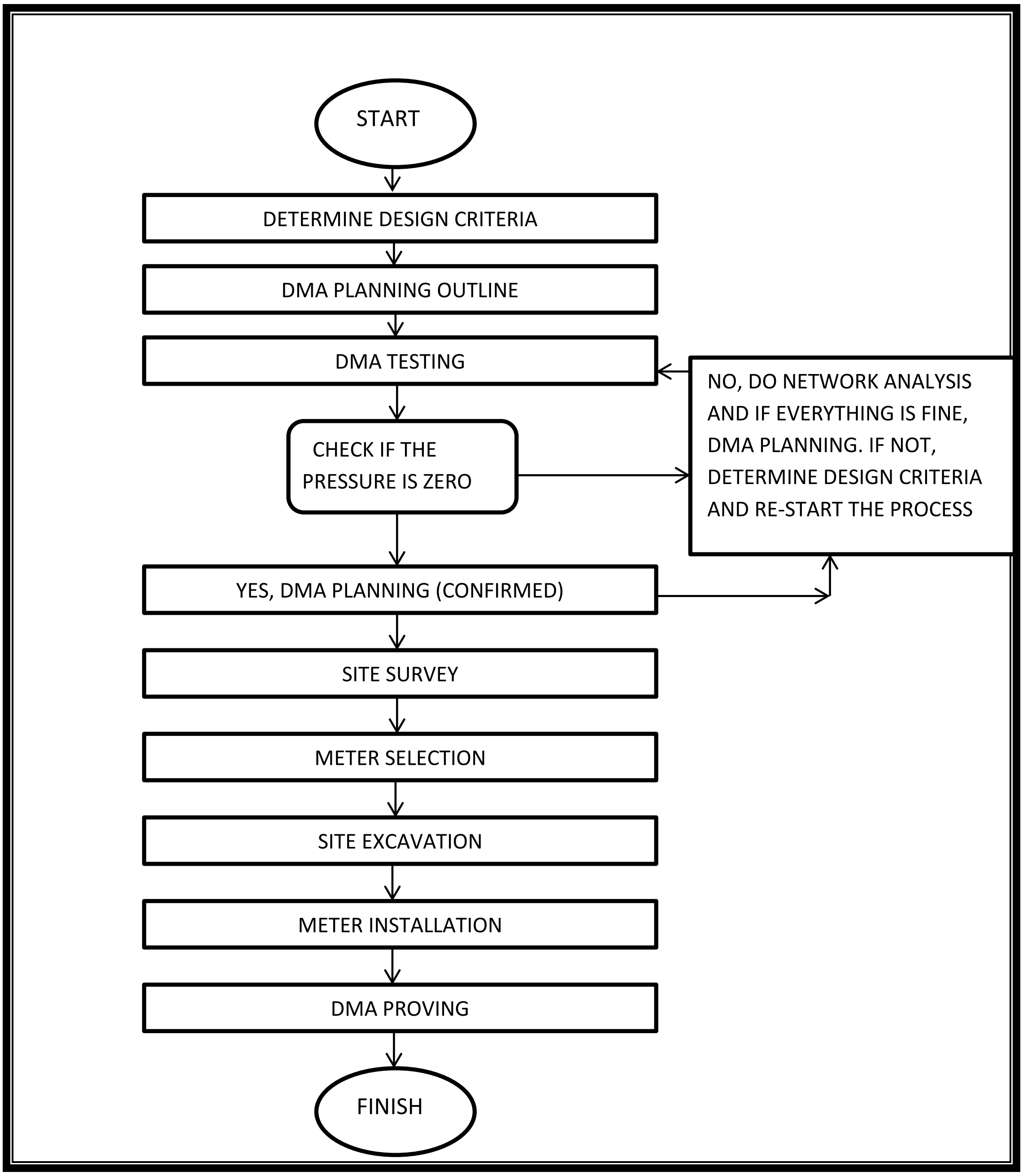
After the development of the DMA, the process of logging the system began in order to determine the MNFs. This involved logging the pressures and flows. An analysis of logged pressures was done to check the impact of implementing pressure management. The objective was to determine if this would have a negative effect on the system. Pressure control was implemented in the system by installing PRVs on the DMA's inlet. This was done to maintain optimal pressure in the network at all times and to automatically compensate for the reduced flow following the repair of leaks whilst maintaining the original operating pressures in the DMA. It also assisted with reducing the amount of water that could be lost due to the system being pressurised.

The steps involved in the design and planning of the DMA are shown in Table 6. It is critical to determine the suitable design criteria before the DMA planning. The main objective of a DMA is to simplify the system thus make it more manageable. Once the design criterion has been determined and the DMA testing done the network needs to be analysed in order to start with the planning process. It is critical that the DMA is tested to ensure that the zone is not breached. The pressure in the DMA after all the valves are closed should be zero and if there is pressure it means that there is an open valve which is boosting pressure. Once the site survey has been done the meter installation is done to complete the DMA.

The complete pipe work assembly was pressure-tested before installation took place. This was done so that leaks could be repaired before the installation. The PRV's were selected for minimum and maximum flow rates. Visual inspections, correlators and ground microphones were used by the researcher and the system operators to detect leaks in the system. The visual inspections were done by walking the lines. Correlators were used to detect leaks that were not visible. These electronic devices are used to locate leaks on pressured pipes when, the location of the leak is not known. The leak detector equipment was used as follows: when the pressurised water escaped from a pipeline it created a sound pressure wave, i.e. leak noise which travelled along the pipe from the exit point. The velocity at which the sound travelled within the pipe mainly depended on the pipe diameter and material.

Table 6: Stages in DMA design and planning

Source: Ugu District Municipality (2014)



The leak correlators used two sensors, which were attached to the pipe on either side of the leak point as shown in Figure 14. The distance between the two sensors and the pipe material was captured into the base unit.

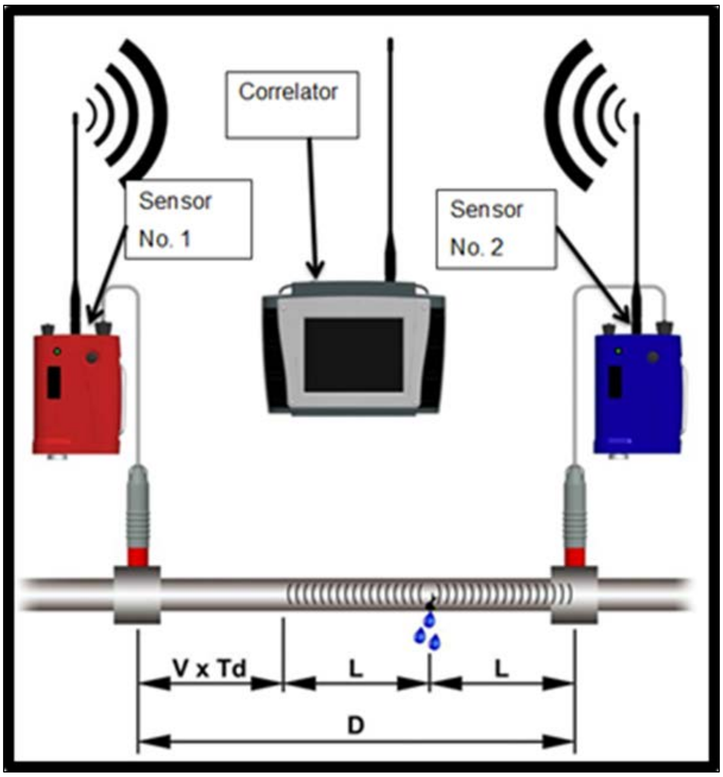


Figure 14: Correlator with two sensors on either side of the leak point
Source: HWM-Water Ltd (2014)

Each sensor recorded the sound and transmitted the data to a base unit, which measured the time difference between the leak noise signals arriving at each sensor. From the data, the base unit calculated the precise location of the leak. The leaks that were detected by this method were quickly repaired to avoid water losses.

Once the correlation had been completed the ground microphone was used to detect leaks. When the pressurised water leaked, it caused the pipe and surrounding material to vibrate. The vibration was transmitted along the pipe and through the surrounding material. Surprisingly, it was not always the biggest leaks that cause a lot of noise; a large break in the pipe usually produced a less clear noise than a small hole.

Figure 15 shows the ground microphone that was used to detect leaks at Amandawe Zone during the study. The electronic ground microphones and listening sticks amplified the noise generated by water escaping from buried supply pipes under pressure. They were useful in confirming the precise location of a leak following a correlation and prior to digging.

Figure 15: Leak detection using a ground microphone in Amandawe Zone
Source: Ugu District Municipality (2014)

4.5.2 Method for specific objective 2

Identify the sources and causes of water losses in the study area

The causes of water losses were identified by carrying out leak detection exercises on the system. The following were identified as signs that there were underground leaks:

- Unusually wet surfaces in landscaped areas and pools of water on the ground surface
- An area that was noticeably green, soft, and mouldy but surrounded by a dry surface
- A notable drop in water pressure or flow volume
- An unexplained sudden increase in water demand or water use rising at a fairly steady rate for several billing cycles
- Cracks in paved surfaces
- Potholes or sink holes

- A sudden problem with dirty water in the supply

The following types of leaks were found and repaired during the leak detection exercises:

- Bursts due to aged infrastructure
- Bursts due to high pressure in the system
- Bursts due to damaged pipes
- Leaks due to illegal connections that were not properly connected to the system

Furthermore, during the visual inspections, some reservoirs were found to be overflowing.

Leak management aims to reduce water losses from a water supply system through pressure management and leak detection. Before leaks can be managed, the network must be analysed to determine the extent of the leakage and its sources (Adachi *et al.* 2014). A pressure management programme was implemented at the UWS to reduce pressure in the water distribution system.

4.5.3 Method for specific objective 3

Construct an International Water Association (IWA) baseline water balance for the study area and determine the key performance indicators

The first crucial step in determining the amount of NRW and the management of water losses in potable water distribution systems is creating a clearly defined water balance (Lambert and Thornton 2012). To calculate the water balance, its components were measured while some were estimated. Difficulty may be experienced in computing water balances with reasonable accuracy, where a significant number of customers are not metered (Lambert and Thornton 2012). In such cases, authorised unmetered consumption can be obtained from sample metering of sufficient numbers of statistically representative individual connections of various categories, and/or by measuring inflows into discrete areas with uniform customer profiles (Lambert and Thornton 2012).

The following steps were followed to develop the water balance:

Step 1: Determining System Input Volume (SIV)

All bulk meter and water sales records were collected and the annual quantity of water that entered the system was calculated to determine the SIV. Some of the data were desktop information that was previously collected by the municipality. New data were collected to verify the available data.

Step 2: Determining Billed Authorized Consumption (BAC)

Billed Metered Consumption (BMC)

BMC represented the annual consumption of registered customers in different categories such as residential, commercial and industrial. The data were checked for billing and data handling errors.

Billed Unmetered Consumption (BUC)

The volume of BUC was obtained by estimating standpipe figures among other things. The estimations were based on previous figures, which were used where there were no meters. BAC is the sum of BMC and BUC as shown in Equation 1.

Equation 1

BAC = BMC + BUC

Step 3:The Unbilled metered consumption (UMC)

UMC was determined by comparing the electricity database with the water billing database and the valuation roll with the water billing database. The difference was assumed to be UMC.

Step 4: Unbilled unmetered consumption (UUC)

UUC includes the water used by the municipality for mains flushing and reservoir cleaning. UUC was determined by measuring how often the mains were flushed and the reservoir was cleaned, for how long and also the size of the infrastructure (Gonzalez-Gomez, García-Rubio and Guardiola 2011). UAC is the sum of UMC and UUC as indicated in Equation 2.

Equation 2

UMC + UUC = UAC (Unbilled Authorised Consumption)

Equation 3 shows the AC which is made up of BAC and UAC.

Equation 3

BAC + UAC = AC (Authorised Consumption)

Step 5: Real losses (RL) =mains leaks, service connection leaks and overflows (this information was obtained from the job cards).

Step 6: Apparent Losses (AL) = Metering inaccuracies (3-5% of total sales) + illegal connections (estimated).

Water Losses (WL) is the total of Real Losses and Apparent Losses as indicated in Equation 4.

Equation 4

WL = RL + AL

WL can also be calculated by removing the AC (Equation 3) from the SIV (step 1) as shown in Equation 5.

Equation 5

SIV – AC = WL

Revenue Water (RW) is the difference between the SIV and BAC as shown in Equation 6.

Equation 6

SIV – BAC = RW

NRW is the opposite of RW and can be calculated by removing RW from the SIV as shown in Equation 7.

Equation 7

SIV – R W = NRW

Step 7: IWA Key Performance Indicators

The percentage of the volume of NRW was obtained by dividing the NRW by the total SIV as indicated in Equation 8.

Equation 8

NRW/ SIV = %NRW

The inefficiency of use of water (IUW) was calculated by dividing the RL by SIV as shown in Equation 9.

Equation 9

IUW = RL volume/ SIV

IUW is the measure of how much NRW there is, due to leakage, apparent losses and UMC (Gonzalez-Gomez, García-Rubio and Guardiola 2011).

The Infrastructure Leakage Index (ILI) is a measure of how much leakage there is compared to the best scenario, which is 1 (Gonzalez-Gomez, García-Rubio and Guardiola 2011).

Step 8: CARL = Current Annual Volume of Real Losses/Nc (litres/service connection/day when the system is pressurised)

The sum of the annual volume of real losses was obtained from the municipality's records and the number of service connections, which was also available from the municipality.

Step 9: Unavoidable Average Real Losses (UARL):

Equation 10 was used to calculate the UARL.

Equation 10

(A x Lm/Nc + B + C x Lp/Nc) x P = UARL

Where:

A = 18, IWA factor

Lm = length of mains

Nc = number of service connections

B = 0.8, IWA factor

C= 25, IWA factor

Lp = length of pipe after meter

P = pressure in the system

The equation and its parameters, A, B and C are based on statistical analysis of international data, including 27 different water supply systems in 20 countries (Lambert and McKenzie 2010).

Step 10:

The infrastructure leakage index, which is one of the critical Key Performance Indicators (KPI's) for a water balance, was calculated using Equation 11**.**

Equation 11

CARL/UARL = Infrastructure Leakage Index (ILI)

4.5.4 Method for specific objective 4

Develop a more suitable business model for Ugu DM

In order to develop decision support tools and strategies to address water loss, it was critical to establish the amount of water being lost and how it was lost. The water balance, DMAs and pressure management were some of the key tools that were identified to achieve this. These instruments have worked well in developed countries and have been further developed, tested and customised for developing countries with water systems that are not as well-managed (Mutikanga 2012). The business model was developed after analysing the results of the study. The results from each objective indicated the direction that Ugu DM needed to take in terms of their business practices. The business model aimed to reduce the risks of water management.

4.6 Data Analysis

The data was analysed to ensure that reliable conclusions were made. Meter readings were taken before and after the implementation of the pressure management programme. Sufficient data was collected in terms of both quantity and quality to reach reliable conclusions. Most of the data used were primary data that were obtained in the field. The data were captured efficiently and sorted properly so that they were easily accessible during the analysis stage. Secondary stage data from the municipality were also used and analysed for credibility.

4.7 Validity and Reliability

Data used was collected over a period of five months in order to gain a true reflection of what was happening on the ground. The data were sufficient in terms of both quality and quantity in order to come to conclusions that were reasonable and reliable for the analyses. The instruments that were used to collect data were those that were being used in the industry at the time of the study. These were instruments like the meter reading devices, correlators, ground microphones and listening sticks for leak detection. There were few properties where estimated meter readings were used because the actual readings could not be obtained. The reasons for these estimates included meters that were underground, faulty, leaking not accessible etc. Logging was done using data loggers in order to measure the pressures and flows. An analysis of logged pressures was done to check the impact of implementing pressure management. This ensured that the data were valid and reliable. The credibility of the data was critical because it determined the outcome of the study after the data were analysed and results produced. The data reflected a true indication of what was happening in the field.

4.8 Ethical Considerations

The study complied with ethical codes of conduct and standards as laid down by the Durban University of Technology. Permission was obtained from Ugu DM to conduct the study on Municipality’s water supply system. The information obtained will be shared with the Municipality. All the information was treated with utmost confidentiality and was not shared with any entity other than the municipality.

CHAPTER 5: RESULTS AND DISCUSSION

5.1 Results and discussion for Specific Objective 1

Identify and prioritize the implementation of non-revenue water reduction strategies: rezoning, pressure management and leak detection

At the time of study which was 2014/2015, the system characteristics within the Ugu DM were as follows;

3 930 km of mains and reticulation
42 913 registered connections
289 service and command reservoirs
75 operating PRV zones
Estimated average zone pressure of 52 m

The Ugu DM is distinctly divided into three sectors of consumption urban, peri-urban and rural. Most existing PRV zones cover the coastal strip, which is majorly urban. It was therefore important to consider the effect of creation of zones within the peri-urban environment.

One DMA was created at Amandawe Zone and another was created in Umzinto Zone for the purpose of this study, as shown in Figure 16 and Figure 17 respectively. Since there were no existing distinct boundaries, this was prioritised by ensuring that the zones were tightly secured. This was in line with the recommendations from the study done by Alvisi and Franchini (2013), that zones are obtained by closing the isolation valves connecting one DMA to another. This was followed by pressure management and leak detection as De Paola *et al.* (2013) stated that the use of DMAs allows for more accurate location of leakages in the WDS. In addition, these selected zones represented the peri-urban supply system where limited pressure management was already undertaken. Logically assuming that the population served within the urban and peri-urban supply areas were equally distributed, it could be interpolated that a further 75 zones were feasible within the peri-urban systems.

The establishment of DMAs enabled the existing levels of leakage to be determined and, consequently, the prioritisation of leakage location activities. Zonal flow monitoring is the foundation of active leakage management in DMAs (Farley and Liemberger 2005). In Amandawe Zone, a PMZ was developed with a 100 m diameter PRV installed to control pressure.

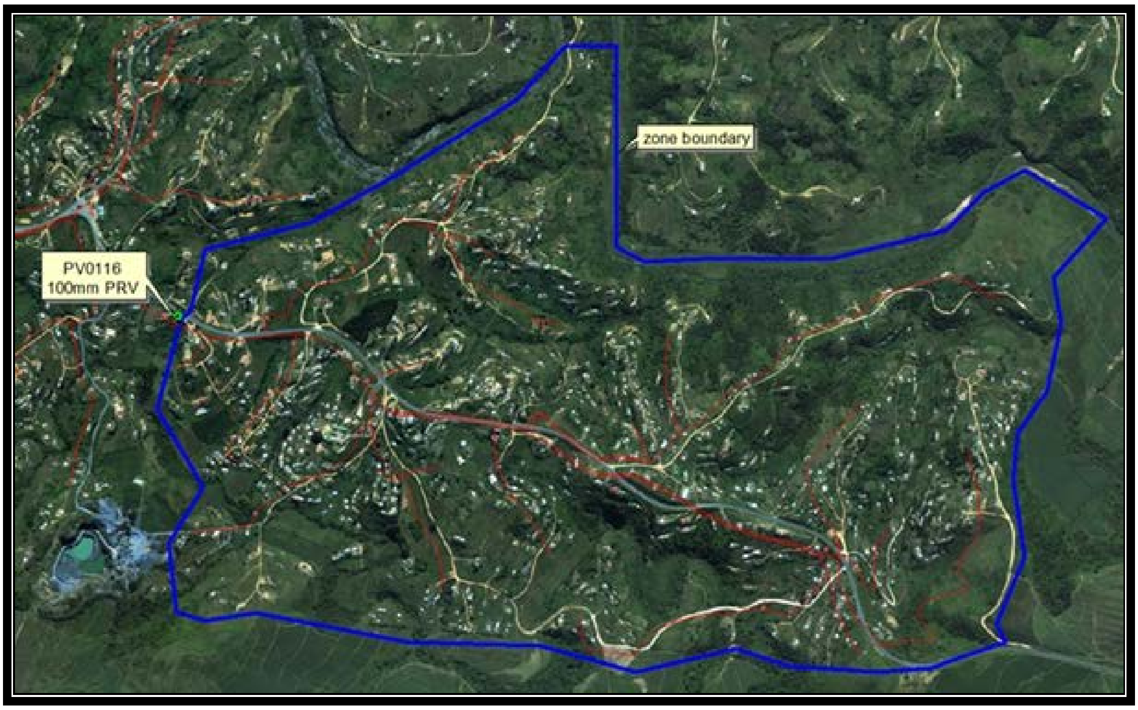


Figure 16: Amandawe PMZ Boundary Verification
Source: Ugu District Municipality (2014)

Figure 17 shows the Umzinto PMZ boundary. Two valves were installed in this zone i.e. 80 mm Master and 50 mm Slave PRVs. There is usually one valve that controls the zone and that is the master valve. It is the main supply valve of the zone. As explained by Scibetta *et al.* (2013) a DMA is easy to develop to a WDS but difficult with large WDSs with thousands of user nodes and pipes. Big zones like Umzinto Zone are also installed slave valves. The slave zone was installed to feed during the peak periods and to maintain the pressure at the critical points. How it works is that it shuts off during off peak and only opens during peak periods.

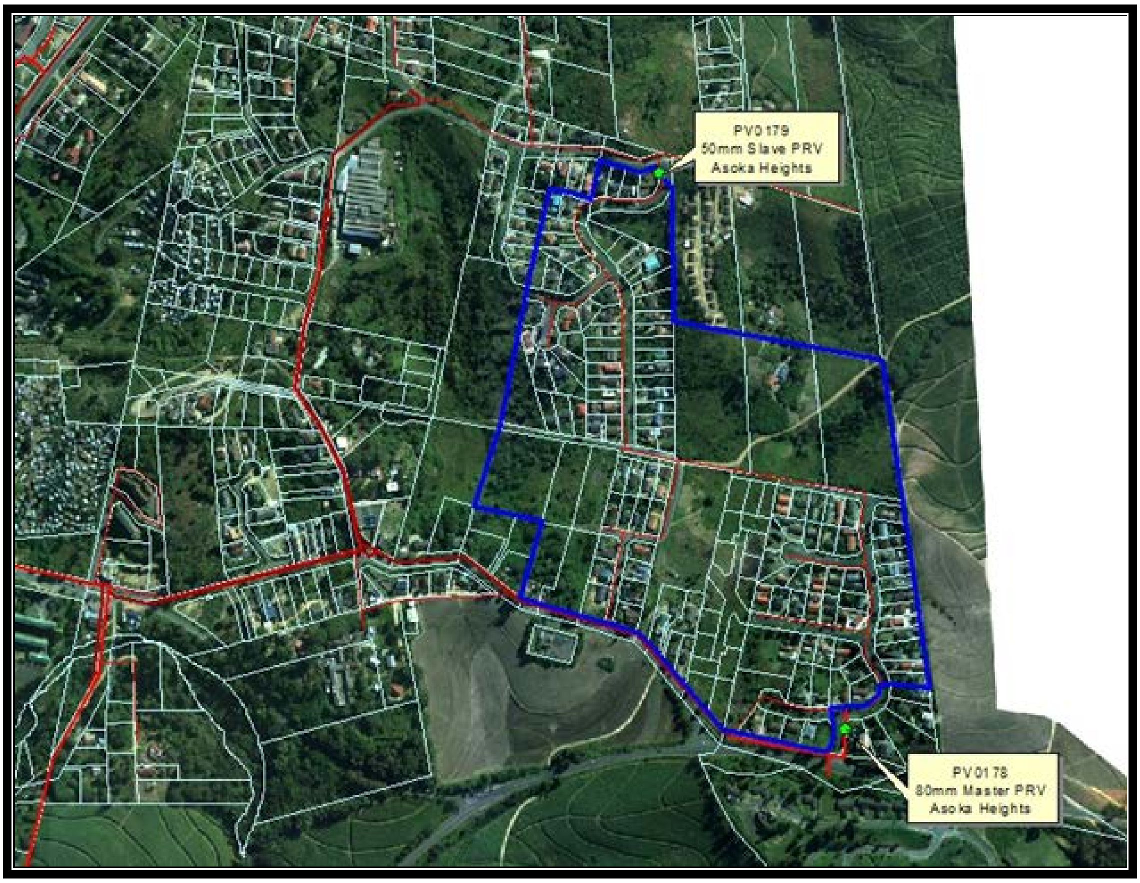


Figure 17: Umzinto PMZ Boundary Verification
Source: Ugu District Municipality (2014)

Figure 18 shows the completed PRV chamber in Umzinto PMZ. This chamber housed the 80 mm slave PRV in Umzinto Zone. There was a step ladder inside the manhole to ensure easier access by system operators during operation and maintenance. There were also ventilators to ensure the smooth flow of air inside the chamber. The chamber was lockable and could only be opened with a special key that belonged to Ugu DM. A valve marker post was erected near the chamber so that the operators are able to identify it easily during maintenance. The operations team also ensured that the area around the chamber was kept clean with no vegetation.

Figure 18: Completed PRV chamber in Umzinto PMZ
Source: Ugu District Municipality (2014)

5.1.1 Pressure management zone design (PMZ)

On completion of the DMA verification, the available zone data were used to design pressure management. Amandawe PMZ was designed as a single feed zone while Umzinto PMZ was designed with two feeds. This was justified by the drop in pressure when using a single feed as peak demand dropped pressure at the critical point below the desired pressure of 2 bars. When introducing a second feed, which was set to open only during peak demand times, more volume was accommodated inside the zone. The pressure reached the desired 2 – 6 bar within the zones.

In each zone, logging points were selected for pressure analysis, i.e. PRV position, critical point position and average zone pressure position.

The design sheet tables were presented as Table 7, Table 8 and Table 9. These sheets presented the state of the different zones before the development of the PMZ. There was information on the exact position of the zone with the name of the supply reservoir, top water level (TWL) of the reservoir, upstream and downstream pressures and desired new pressure among other things. The sheets have a space for approval by the WC/DM Manager and the Area Manager. The information collected and presented in these sheets informed the design of the PRV and the development of the zone.

Table 7: Amandawe PMZ design sheet

Source: Ugu District Municipality (2014)

Designer:	Thuli Mwelase		Manager WC/WDM approval:	signature	
Drawing number:	NRW/Amandawe/01			name	
Supply System:	North		Area Manager approval:	signature	
GIS Coordinates:				name	
GPS Make & Accuracy during measu	S 30° 15' 29.39"		No. of Properties	348	
	E 30° 43' 23.56"		Length of Mains controlled	15.67	km
(contour level)	Z 126	m AMSL	Pipe Size:	110	mm
Road Name:	Amandawe Road		Demand Category	Moderate to high	
Area/Suburb:	Amandawe		Fire Risk Category	Low risk group 2	
Nearest house number:	400m from Amahlongwa Junction		Maximum Anticipated Flow Rate: (with fire)	97.9	m^3/hr
Supply Reservoir:	Hazelwood Res		Continuous Anticipated Flow Rate: (with fire)	47.0	m^3/hr
Supply Reservoir TWL:	233	m AMSL	Fire Demand	30.0	m^3/hr
Logged Current Upsteam Pressure:	78.0	m	Proposed PRV Size:	100	mm
Theoretical Downstream Pressure:	35.0	m	Proposed PRV Series:	Full Bore	
Infrastructure Head Loss	29.0	m	Proposed PRV Seat:	Flat Disk	
Head Loss Thru' Valve	1.65	m	Flow Coefficient (Kv):	200	m^3/hr
Design Downstream Pressure:	36.7	m	Resistance Coefficient (ξ):	5.4	
Expected Savings	419.9	m^3/day			
Critical Point Details (1):			Critical Point Details (2):		
Address (1)	BPT		Address (2)	BPT	
Elevation (1)	152	m AMSL	Elevation (2)	152	m AMSL
Logged Current Pressure	63	m	Logged Current Pressure	63	m
Desired New Pressure	20	m	Desired New Pressure	20	m

The Amandawe PMZ design sheet as indicated in Table 7 has the exact location of the PRV in Amandawe Road. The zone was supplied by Hazelwood reservoir with a top water of 233 m above mean sea level (AMSL). The upstream pressure was 78 m and the design downstream pressure of 36.7 m. The number of properties was 348 and the length of mains was 15.67 km. The pipe size was 110 mm and the proposed PRV size was 100 mm. The maximum anticipated flow rate was 97.9 m^3/hr including a fire demand of 30 m^3/hr. The flow rate was obtained from the logging exercise. There were two critical points in the zone which were in the break pressure tank positions. Both points were at

152 m AMSL and had logged pressure of 63 m and the desired new pressure was 20 m. The expected savings were 419.9 m^3/day.

Table 8: Umzinto PMZ design sheet – master valve

Source: Ugu District Municipality (2014)

Designer:	Thuli Mwelase		Manager WC/WDM approval:	signature	
Drawing number:	NRW/Umzinto/01			name	
Supply System:	North		Area Manager approval:	signature	
GIS Coordinates:				name	
GPS Make & Accuracy during measu	X: 30° 18' 35.71"		No. of Cadastrals	159	
	Y: 30° 40' 47.69"		Length of Mains controlled	2.43	km
(contour level)	Z: 140	m AMSL	Pipe Size:	150	mm
Road Name:	Mercury Ave		Demand Category	Moderate to high	
Area/Suburb:	Asoka Heights		Fire Risk Category	Low risk group 2	
Nearest house number:	Lot 833		Maximum Anticipated Flow Rate: (with fire)	61.0	m^3/hr
Supply Reservoir:	Umzinto WTW		Continuous Anticipated Flow Rate: (with fire)	37.8	m^3/hr
Supply Reservoir TWL:	205	m AMSL	Fire Demand	30.0	m^3/hr
Logged Current Upsteam Pressure:	46.0	m	Proposed PRV Size:	80	mm
Theoretical Downstream Pressure:	27.0	m	Proposed PRV Series:	Full Bore	
Infrastructure Head Loss	19.0	m	Proposed PRV Seat:	Flat Disk	
Head Loss Thru' Valve	1.86	m	Flow Coefficient (Kv):	115	m^3/hr
Design Downstream Pressure:	28.9	m	Resistance Coefficient (ξ):	6.4	
Expected Savings	65.1	m^3/day			
Critical Point Details (1):			Critical Point Details (2):		
Address (1)	Lot 827		Address (2)	Lot 645	
Elevation (1)	140	m AMSL	Elevation (2)	140	m AMSL
Logged Current Pressure	46	m	Logged Current Pressure	39	m
Desired New Pressure	20	m	Desired New Pressure	20	m

The Umzinto PMZ design sheet of the master valve as indicated in Table 8 has the exact location of the PRV in Mercury Avenue. This zone was supplied direct from a reservoir in the Umzinto WTW with a top water level of 205 m AMSL. The upstream pressure was 46 m and the design downstream pressure of 28.9 m. The number of properties was 159 and the length of mains was 2.43 km. The pipe size was 150 mm and the proposed PRV size was 80 mm. The maximum anticipated flow rate was 61.0 m^3/hr including a fire demand of 30 m^3/hr. There were two critical points in the zone which were in the break pressure tank position. Both points were at 140 m AMSL and had logged pressure of 46 m and 39 m with the desired new pressure of 20 m in both points. The expected savings were 65.1 m^3/day.

Table 9: Umzinto PMZ design sheet – slave valve

Source: Ugu District Municipality (2014)

Designer:	Thuli Mwelase		Manager WC/WDM approval:	signature	
Drawing number:	NRW/Umzinto/01			name	
Supply System:	North		Area Manager approval:	signature	
GIS Coordinates:				name	
GPS Make & Accuracy during measu	X: 30° 18' 10.06"				
	Y: 30° 40' 3.22"		No. of Cadastrals	50	
(contour level)	Z: 150	m AMSL	Length of Mains controlled	2.43	km
			Pipe Size:	75	mm
Road Name:	Malibu Drv		Demand Category	Moderate to high	
Area/Suburb:	Asoka Heights		Fire Risk Category	Low risk group 3	
Nearest house number:	Lot 605		Maximum Anticipated Flow Rate: (with fire)	30.8	m^3/hr
Supply Reservoir:	Umzinto WTW		Continuous Anticipated Flow Rate: (with fire)	23.4	m^3/hr
Supply Reservoir TWL:	205	m AMSL	Fire Demand	21.0	m^3/hr
Logged Current Upsteam Pressure:	46.0	m	Proposed PRV Size:	50	mm
Theoretical Downstream Pressure:	27.0	m	Proposed PRV Series:	Full Bore	
Infrastructure Head Loss	3.0	m	Proposed PRV Seat:	Flat Disk	
Head Loss Thru' Valve	2.22	m	Flow Coefficient (Kv):	50	m^3/hr
Design Downstream Pressure:	29.2	m	Resistance Coefficient (ξ):	4.6	
Expected Savings	65.1	m^3/day			
Critical Point Details (1):			Critical Point Details (2):		
Address (1)	Lot 827		Address (2)	Lot 645	
Elevation (1)	140	m AMSL	Elevation (2)	140	m AMSL
Logged Current Pressure	46	m	Logged Current Pressure	39	m
Desired New Pressure	20	m	Desired New Pressure	20	m

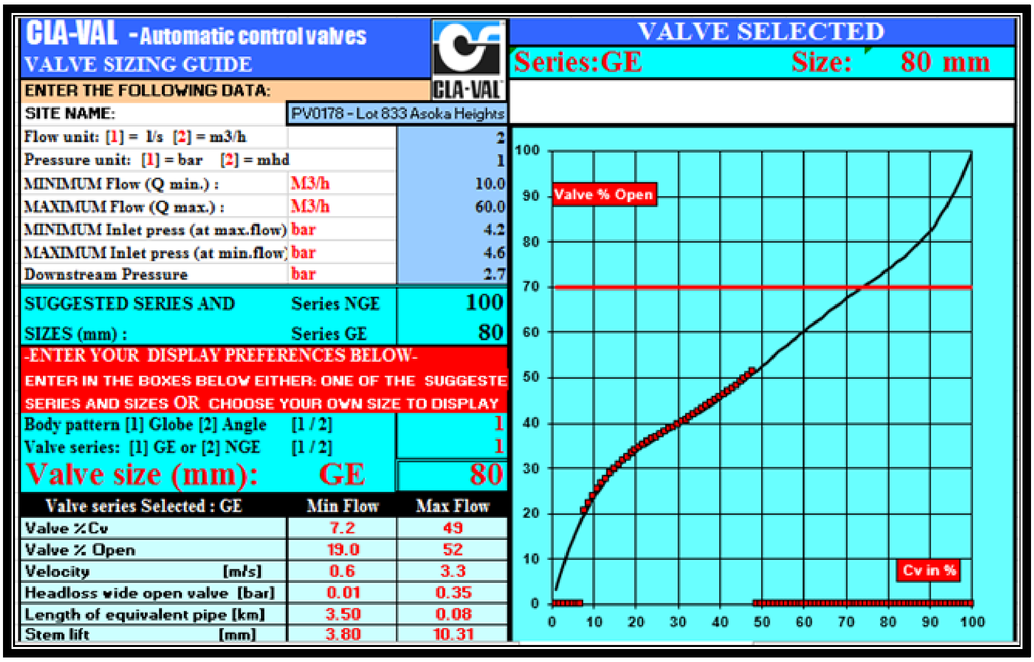
The Umzinto PMZ design sheet of the slave valve as indicated in Table 9 has the exact location of the PRV in Malibu Drive. The zone was supplied direct from a reservoir in the Umzinto WTW with a top water level of 205 m AMSL. The upstream pressure was 46 m and the design downstream pressure of 29.2 m. The number of properties was 50 and the length of mains was 2.43 km. The pipe size was 75 mm and the proposed PRV size was 50 mm. The maximum anticipated flow rate was 30.8 m^3/hr including a fire demand of 21.0 m^3/hr. There were two critical points in the zone which were in the break pressure tank positions. Both points were at 140 m AMSL and had logged pressure of 46 m and 39 m with the desired new pressure of 20 m in both points. The expected savings were 65.1 m^3/day.

5.1.2 Valve selection

The designed valves were subjected to size selection software developed by CLA-VAL, manufacturers of the reputable Clayton hydraulic control valves as shown in Table 10 and Table 11.

Table 10: Umzinto PMZ valve size, type selection and performance check – master valve

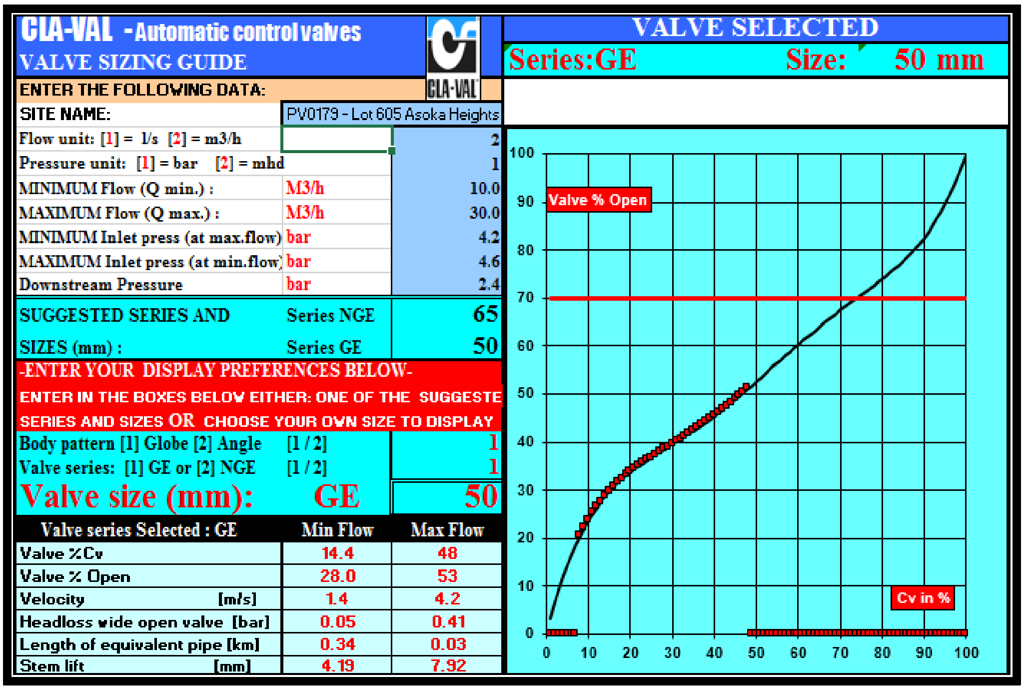
Source: Ugu District Municipality (2014)



CLA-VAL - Automatic control valves		
VALVE SIZING GUIDE		
ENTER THE FOLLOWING DATA:		
SITE NAME:	PV0178 - Lot 833 Asoka Heights	
Flow unit: [1] = l/s [2] = m3/h		2
Pressure unit: [1] = bar [2] = mhd		1
MINIMUM Flow (Q min.) :	M3/h	10.0
MAXIMUM Flow (Q max.) :	M3/h	60.0
MINIMUM Inlet press (at max.flow)	bar	4.2
MAXIMUM Inlet press (at min.flow)	bar	4.6
Downstream Pressure	bar	2.7
SUGGESTED SERIES AND	Series NGE	100
SIZES (mm) :	Series GE	80
-ENTER YOUR DISPLAY PREFERENCES BELOW-		
ENTER IN THE BOXES BELOW EITHER: ONE OF THE SUGGESTE		
SERIES AND SIZES OR CHOOSE YOUR OWN SIZE TO DISPLAY		
Body pattern [1] Globe [2] Angle	[1 / 2]	1
Valve series: [1] GE or [2] NGE	[1 / 2]	1
Valve size (mm):	GE	80
Valve series Selected : GE	Min Flow	Max Flow
Valve %Cv	7.2	49
Valve % Open	19.0	52
Velocity [m/s]	0.6	3.3
Headloss wide open valve [bar]	0.01	0.35
Length of equivalent pipe [km]	3.50	0.08
Stem lift [mm]	3.80	10.31

Table 11: Umzinto PMZ valve size, type selection and performance check – slave valve

Source: Ugu District Municipality (2014)



CLA-VAL - Automatic control valves		
VALVE SIZING GUIDE		
ENTER THE FOLLOWING DATA:		
SITE NAME:	PV0179 - Lot 605 Asoka Heights	
Flow unit: [1] = l/s [2] = m3/h		2
Pressure unit: [1] = bar [2] = mhd		1
MINIMUM Flow (Q min.) :	M3/h	10.0
MAXIMUM Flow (Q max.) :	M3/h	30.0
MINIMUM Inlet press (at max.flow)	bar	4.2
MAXIMUM Inlet press (at min.flow)	bar	4.6
Downstream Pressure	bar	2.4
SUGGESTED SERIES AND	Series NGE	65
SIZES (mm) :	Series GE	50
-ENTER YOUR DISPLAY PREFERENCES BELOW-		
ENTER IN THE BOXES BELOW EITHER: ONE OF THE SUGGESTE		
SERIES AND SIZES OR CHOOSE YOUR OWN SIZE TO DISPLAY		
Body pattern [1] Globe [2] Angle	[1 / 2]	1
Valve series: [1] GE or [2] NGE	[1 / 2]	1
Valve size (mm):	GE	50
Valve series Selected : GE	Min Flow	Max Flow
Valve %Cv	14.4	48
Valve % Open	28.0	53
Velocity [m/s]	1.4	4.2
Headloss wide open valve [bar]	0.05	0.41
Length of equivalent pipe [km]	0.34	0.03
Stem lift [mm]	4.19	7.92

CLA-VAL is a sizing software used to design the valve size. The program provides sizing, cavitation check and the range of opening during operation.

Ideally, a well-sized PRV will operate between 30% and 70% opening range. Both these PRVs were sized to operate at 52% opening. The results are presented in Table 10 and Table 11.

5.1.3 Zonal meter and PRV installation

Once the positions were confirmed, both the zone meter and PRV were designed to be installed within the same protective chamber. This was necessary for ease of analysing both flow and pressure instantaneously. Figure 19 shows the installation detail for the meter and PRV in one protective chamber. It includes details about the meter installation from the sump which was filled with stone and which will discharge excess water inside the trench. Thick mass concrete served as a foundation for the whole structure. The manhole was used to house the whole pipe work. The manhole wall was made up of bricks with vents at the top to allow for breathing space. The cover of the manhole was made of concrete with a locking and lifting mechanism and this was above ground level.

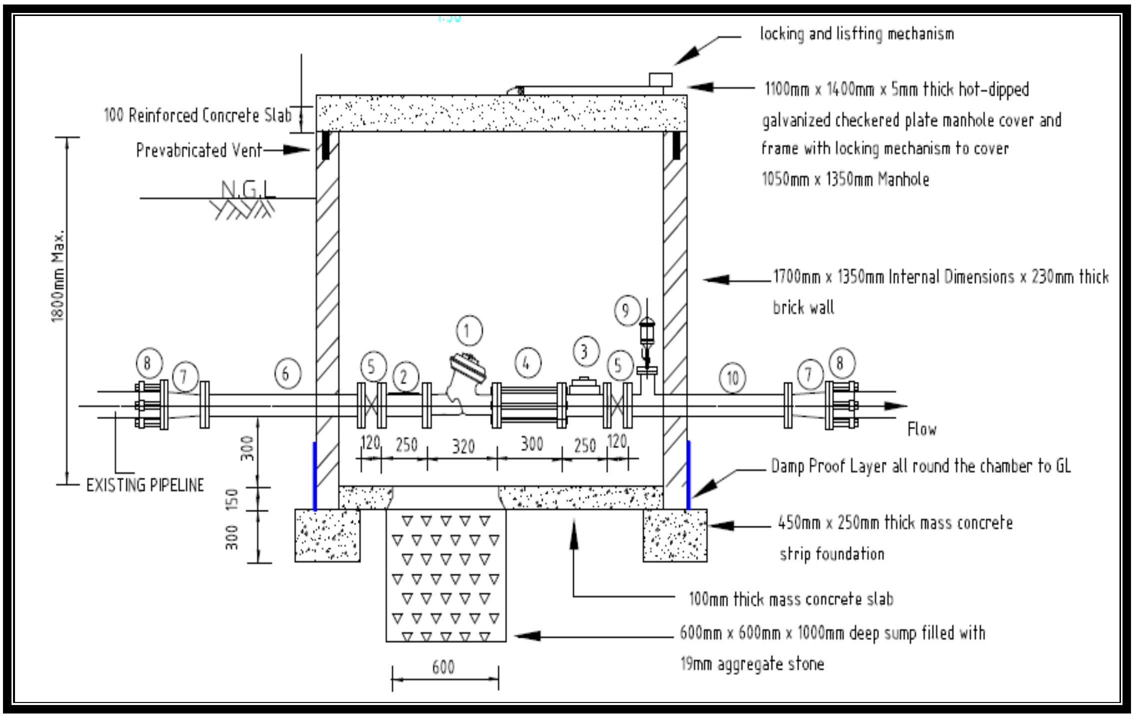


Figure 19: Typical installation detail for meter and PRV in one protective chamber

Source: Ugu District Municipality (2014)

Table 12 shows the pipe work schedule for a 100 mm PRV installation. It provided a detailed description of each part of the pipe work and the quantity. These are all the components of the meter and PRV installation as numbered in Figure 19.

Table 12: Pipe work schedule for 100 mm PRV installation
Source: Ugu District Municipality (2014)

No	Description	Quantit
1	100 mm diameter. Hydraulic control valve	1
2	100 mm diameter In-line strainer	1
3	100 mm diameter Flow meter	1
4	100 mm diameter. X 300 mm long dismantling joint	1
5	100 mm diameter Butterfly valve	2
6	100 mm diameter. X 750 mm long double flanged spool piece	1
7	150 mm x 100 mm double flanged reducer	2
8	150 mm diameter Coupling – compatible with existing pipeline	2
9	25 mm diameter RBX air valve	1
10	100 mm diameter x 750 mm Unequal Tee flanged all ends	1

5.1.4 PRV commissioning process

A flow chart for the PRV commissioning process was developed in order to minimise the negative impact of pressure reduction on the consumer, as shown in Table 13. It was critical to ensure that there was minimal supply interruption during the pressure management exercise. The main aim of the process was to alert the public on the reduction of pressure and the benefits thereof so that they support the programme. The process of community awareness was therefore started two weeks before the shutdown. Signage and boards were erected at the areas that will be affected notifying the people of the planned shutdown. Once the PRVs were erected and commissioned the zones were monitored to ensure that the pressure has been reduced and that the supply was not affected. In cases where the supply was affected the PRVs were adjusted. Two weeks after the final settings on the PRVs a report on the savings was prepared.

The actual drop in pressure at the PRVs was conducted after all necessary communications and contingencies had been put in place. Loggers were placed at the inlet of the zone by the PRV to measure flow and pressure, and at the average zone pressure and critical points of the zone to measure pressure.

Table 13: Flow chart of activities and responsibilities for planned pressure reduction

Source: Ugu District Municipality (2014)

Key Flow Chart Activity	**Time Relative to Actual**	**Interaction with Operations**	**Interactive with Customer**
Erection of Pressure Reduction Street	2 weeks before	Shutdown Notification	Shutdown Notification
Erection of interruption of Water Supply Sign Boards	48 hours before	PRV Commissioning	PRV Commissioning Notice
Commissioning of New PRV/ Reduction in Pressure		Shutdown Report	Shutdown Report
Monitoring of Consumer and Zone	48 hours after		
PRV Adjustment (if necessary)		PRV Commissioning Report	PRV Commissioning Report
Report on Savings	2 weeks after final PRV Settings		

5.1.5 PRV commissioning results

Figure 20, Figure 21 and Figure 22 present the flow and pressure profiles in the zones after the implementation of pressure management. After the commissioning of the PMZs the pressure and the flow in both zones dropped especially at night as indicated in the profiles. This was an indication that there was high amount of NRW before the implementation of pressure management. There was high flow of water under high pressure which could have been avoided thus reducing the NRW.

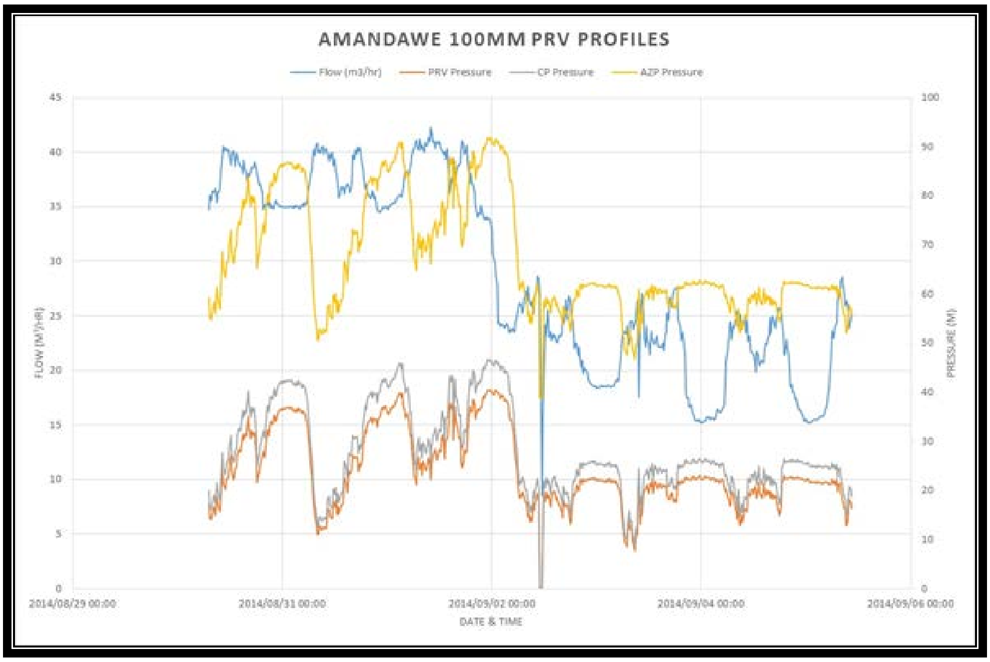


Figure 20: Commissioning flow and pressure profiles – 100 mm Amandawe PMZ

Source: Ugu District Municipality (2014)

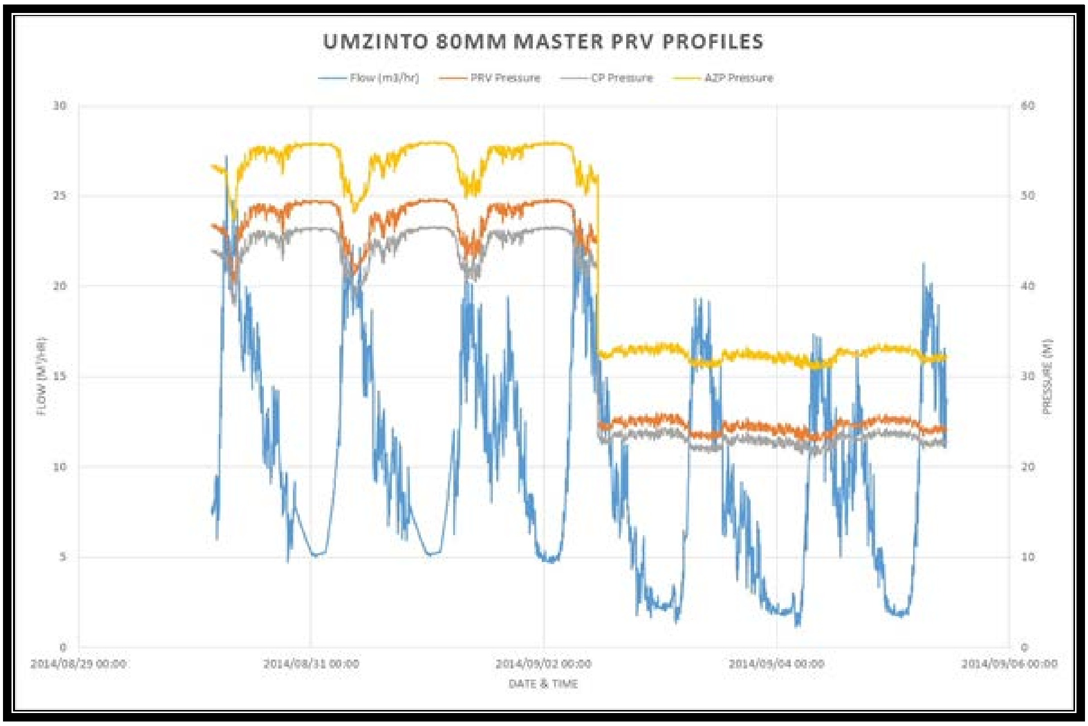


Figure 21: Commissioning flow and pressure profiles – 80 mm Umzinto PMZ

Source: Ugu District Municipality (2014)

Figure 22: Commissioning flow and pressure profiles – 50 mm Umzinto PMZ

Source: Ugu District Municipality (2014)

Note: This PRV is set to open only during peak periods whenever there is excessive demand in the zone.

Table 14 and Table 15 are specific PRV's commissioning reporting sheets. These sheets were critical for future management of the zones. They present information on the system behaviour after the development of PMZs where there were savings in the SIVs in both zones. The MNFs were also reduced thus reducing NRW as was desired. Automatically this means that the leakages were immediately reduced with the reduction in pressures.

Table 14 is the commissioning report sheet for the 100 mm Amandawe PRV. The supply reservoir for this zone is Hazelwood reservoir with a top water level of 233 m. The pipe size is 110 mm and the installed PRV is 100 mm. The expected upstream static pressure is 78 m and the design downstream pressure is 36.7 m. The maximum anticipated flow rate is 17 m^3/hr. There were two critical points both at 152 m and have pressure of 20 m and 23 m respectively. The SIV before the PRV controller was 980 m^3/day and after the installation of the PRV it was 773 m^3/day giving savings of 207 m^3/day. The MNFs before the PRV installation was 26.7 m^3/hr and after the PRV installation it was 16.3 m^3/hr giving the savings of 10.4 m^3/hr.

Table 14: PRV commissioning report sheet – 100 mm Amandawe PRV
Source: Ugu District Municipality (2014)

Operational Area:	North	Client:	Ugu District Municipality			Field test completed:	Yes	Aug-14
System:	Umgeni Bulk	Designed by:	Thuli Mwelase			Field test Successful:	Yes	Aug-14
Area:	Amandawe	Approved by:	Malibongwe Luswazi			Report submitted to:	Malibongwe Luswazi	
Supply Reservoir:	Hazelwood Res		Installed PRV Size:	100	mm	Design standard used:	20 - 60	mH_2O
Supply Reservoir TWL:	233	AMSL	Pipe Size:	110	mm	Number of Cadastrals:	348	
JOAT PRV Number:	PV0116		PRV Series:	Full Bore		GIS Ref: X:	30o 15' 29.39"	
Road Name:	Amandawe Road					Y:	30o 43' 23.56"	
Nearest House/Lot Number	400m from Amahlongwa Junction		Cavitation check:		Pass	Z (Elev):	126	AMSL
Expected Upstream Static Pressure:		78.0	mH_2O	Maximum Anticipated Flow Rate (including fire flow):			97.86	m^3/h
Design Downstream Pressure:		36.7	mH_2O	Minimum Anticipated Flow Rate:			17	m^3/h
Critical Point Details (1):	Address:		BPT					
	Elevation:		152	AMSL	Pressure: 20	mH_2O	:	2014/08/01
Critical Point Details (2):	Address:		BPT			Prv controller		Installed
	Elevation:		152	AMSL	Pressure 23	mH_2O	:	2014/08/01
SIV Before PM		980	m^3/day	Q_{mnf} Before PM			26.7	m^3/h
SIV After PM		773	m^3/day	Q_{mnf} After PM			16.3	m^3/h
Savings		207	m^3/day	Savings			10.4	m^3/h

Table 15 is the commissioning report sheet for the 80 mm Umzinto Master PRV which is located at Mercury Avenue. This zone is supplied direct from a reservoir in the Umzinto WTW with a top water level of 205 m AMSL. The pipe size is 150 mm and the installed PRV is 80 mm. The expected upstream static pressure is 46 m and the design downstream pressure is 28.9 m. The maximum anticipated flow rate is 61.005 m^3/hr including the fire flow and the minimum anticipated flow rate is 8 m^3/hr. There were two critical points both at 152 m and have pressures of 20 m and 23 m respectively. The SIV before the PRV controller was 281 m^3/day and after the installation of the PRV it was 189 m^3/day giving savings of 92 m^3/day. The minimum night flow before the PRV installation was 4.7 m^3/hr and after the PRV installation it was 1.7 m^3/hr giving the savings of 3.0 m^3/hr.

Table 15: PRV commissioning report sheet – 80 mm Umzinto Master PRV
Source: Ugu District Municipality (2014)

Operational Area:	North	Client:	Ugu District Municipality			Field test completed:		Yes	Aug-14	
System:	Umzinto System	Designed by:	Thuli Mwelase			Field test Successful:		Yes	Aug-14	
Area:	Asoka Heights	Approved by:	Malibongwe Luswazi			Report submitted to:		Malibongwe Luswazi		
Supply Reservoir:	Umzinto WTW		Installed PRV Size:	80	mm	Design standard used:		20 - 60	mH_2O	
Supply Reservoir TWL:	205	AMSL	Pipe Size:	150	mm	Number of Cadastrals:		159		
[illegible] PRV Number:	PV0178		PRV Series:	Full Bore		GIS Ref:	X:	30o 18' 35.71"		
Road Name:	Mercury Ave						Y:	30o 40' 47.69"		
Nearest House/Lot Number	Lot 833		Cavitation check:		Pass		Z (Elev):	140		AMSL
Expected Upstream Static Pressure:		46.0	mH_2O	Maximum Anticipated Flow Rate (including fire flow):				61.005		m^3/h
Design Downstream Pressure:		28.9	mH_2O	Minimum Anticipated Flow Rate:				8		m^3/h
Critical Point Details (1):	Address:		Lot 827							
	Elevation:		140	AMSL	Pressure:	20	mH_2O		:	2014/08/15
Critical Point Details (2):	Address:		Lot 645				Prv controller			Installed
	Elevation:		140	AMSL	Pressure	23	mH_2O		:	2014/08/15
SIV Before PM		281	m^3/day	Q_{mnf} Before PM				4.7		m^3/h
SIV After PM		189	m^3/day	Q_{mnf} After PM				1.7		m^3/h
Savings		92	m^3/day	Savings				3.0		m^3/h

Table 16 is the commissioning report sheet for the 50 mm Umzinto Slave PRV which is located at Malibu Drive. This zone is supplied direct from a reservoir in the Umzinto WTW with a top water level of 205 m AMSL. The pipe size is 75 mm and the installed PRV is 50 mm. The expected upstream static pressure is 40 m and the design downstream pressure is 29.2 m. The maximum anticipated flow rate is 2 m^3/hr. There were critical points both at 140 m and have pressures of 20 m and 23 m respectively. The SIV before the PRV controller was 101 m^3/day and after the installation of the PRV it was 33 m^3/day giving savings of 68 m^3/day. The MNF before the PRV installation was 1.7 m^3/hr and after the PRV installation it was 0.0 m^3/hr giving the savings of 1.7 m^3/hr.

Table 16: PRV commissioning report sheet – 50 mm Umzinto Slave PRV

Source: Ugu District Municipality (2014)

Operational Area:	North	Client:	Ugu District Municipality			Field test completed:		Yes	Aug-14	
System:	Umzinto System	Designed by:	Thuli Mwelase			Field test Successful:		Yes	Aug-14	
Area:	Asoka Heights	Approved by:	Malibongwe Luswazi			Report submitted to:		Malibongwe Luswazi		
Supply Reservoir:	Umzinto WTW		Installed PRV Size:	50	mm	Design standard used:		20 - 60	mH_2O	
Supply Reservoir TWL:	205	AMSL	Pipe Size:	75	mm	Number of Cadastrals:		50		
Number:	PV0179		PRV Series:	Full Bore		GIS Ref:	X:	30o 18' 10.06"		
Road Name:	Malibu Drv						Y:	30o 40' 3.22"		
Nearest House/Lot Number	Lot 605		Cavitation check:		Pass		Z (Elev):	150		AMSL
Expected Upstream Static Pressure:		46.0	mH_2O	Maximum Anticipated Flow Rate (including fire flow):				30.75		m^3/h
Design Downstream Pressure:		29.2	mH_2O	Minimum Anticipated Flow Rate:				2		m^3/h
Critical Point Details (1):	Address:		Lot 827							
	Elevation:		140	AMSL	Pressure:	20	mH_2O		Date:	2014/08/15
Critical Point Details (2):	Address:		Lot 645				Prv controller			Installed
	Elevation:		140	AMSL	Pressure	23	mH_2O		Date:	2014/08/15
SIV Before PM		101	m^3/day	Q_{mnf} Before PM				1.7		m^3/h
SIV After PM		33	m^3/day	Q_{mnf} After PM				0.0		m^3/h
Savings		68	m^3/day	Savings				1.7		m^3/h

5.2 Results and discussion for Specific Objective 2

Identify the sources and causes of water losses in the study area by conducting field measurement

5.2.1 Night flow analysis –Sanflow

The logged night flow and pressures from the zone inlets were analysed and Sanflow, a program developed by the South African Water Research Commission, was utilised for the analysis of night flows. Figure 23 shows the distribution of flow components across a flow profile and the fact that not all MNF is regarded as losses. MNF is divided into normal night use, background losses and excess night flow. Background losses and excess night flow are inherent in any reticulation system, and are a function of the length of the mains, number of connections, number of properties and pressure. Sanflow utilises these parameters to calculate the individual components.

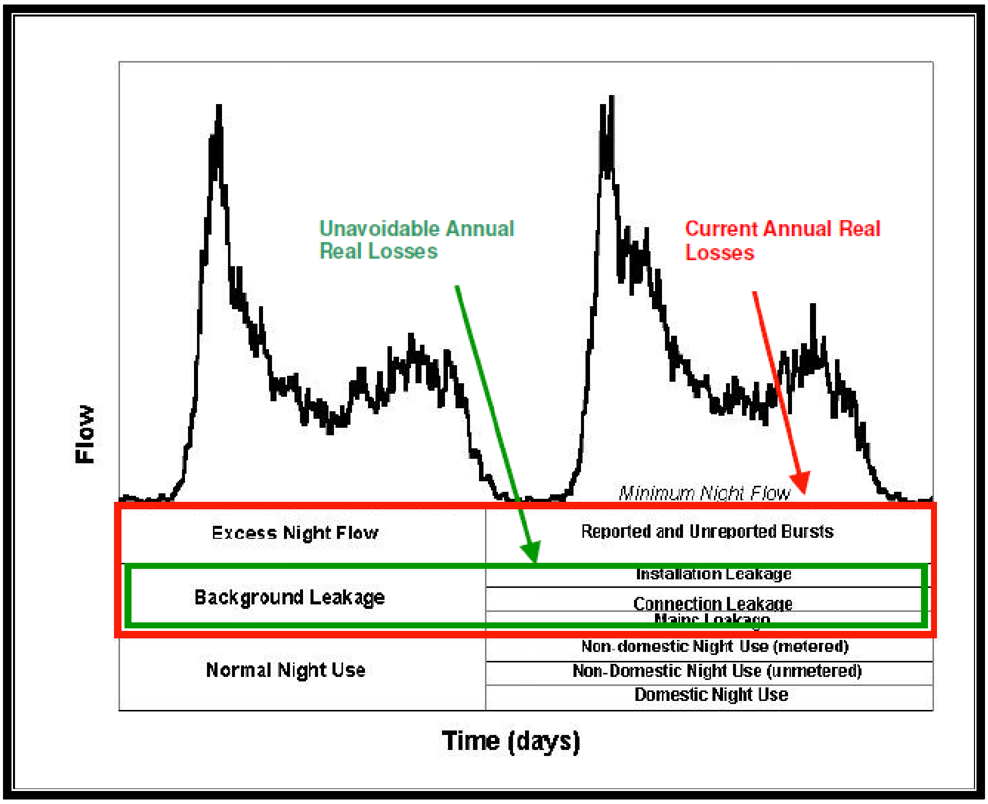


Figure 23: Typical reticulation networks' flow profile distribution

Source: Ugu District Municipality (2014)

Table 17 tabulates the results from the two PMZs after the intervention. These results indicate that there was a decrease in the average zonal night pressure in both PMZs by 14.3 m (73.8 m to 59.5 m) in Amandawe Zone and by 22 m in Umzinto Zone (55 m to 33 m). There was a huge decrease in the MNF in both areas; in Amandawe Zone it dropped by 19.6 m^3/hr (34.8 m^3/hr to 15.20 m^3/hr) and in Umzinto Zone by 4.7 m^3/hr (6.4 m^3/hr to 1.7 m^3/hr). The excess night flows were also reduced by 18.7 m^3/hr from 30.11 m^3/hr to 11.41 m^3/hr in Amandawe Zone and by 4.24 m^3/hr (4.78 m^3/hr to 0.54 m^3/hr) in Umzinto Zone. Using the marginal cost of R3.78 at the time of the study (2014), the cost of excess night flow due to bursts was reduced by R1413.56/day (R2276.17/day to R862.61/day) in Amandawe Zone and by R320.78/day (R361.24/day to R40.46/day) in Umzinto Zone. The financial analysis indicated a payback period of 12.9 months, making the intervention viable.

Table 17: Amandawe and Umzinto PMZs SANFLOW analysis results
Source: Ugu District Municipality (2014)

Sub-district/ Zone	**Amandawe PRV Zone - Pre NRW Reduction**	**Amandawe PRV Zone - Post NRW Reduction**	**Umzinto PRV Zone - Pre NRW Reduction**	**Umzinto PRV Zone - Post NRW Reduction**
Ave. Zone Night Press. Metres (AZNP)	75.1	59.1	55.8	33.4
Exceptional night use > 0.25 m^3/hr	0.0	0.0	0.0	0.0
Measured Min. Night Flow in l/sec	9.67	4.22	1.78	0.36
Measured Min. Night Flow in m^3/hr	34.80	15.20	6.40	1.30
Excess night flow in m^3/hr	30.53	11.73	4.10	0.50
Excess as equivalent number of Service bursts ESPB's	15.7	6.7	15.7	6.7
Marginal cost of water supply cents/m^3	378	378	378	378
Daily Cost of excess night flow due to bursts (Rand/day)	2308.35	886.69	309.96	37.80
Length of Mains in metres (L)	15670	15670	2430	2430
Number of Connections (C)	262	262	160	160
Number of Properties (N)	290	290	160	160
Estimated Population (P)	2320	2320	1280	1280
% of Commercial Properties	0	0	0	0
Length of Mains per Connection L/C in metres	50.3	50.3	15.2	15.2
Estimated minor night use m^3/hr	1.39	1.39	1.10	0.40
Estimated background night flow in m^3/hr	4.27	3.47	2.30	0.80
Average Flow Q_{avg} (m^3/hr)	37.20	20.80	15.40	9.10
Comparative Ratio Q_{avg}/Q_{mnf}	1.07	1.37	2.41	5.35
Cost of Rezoning	R 550 000.00			
Savings/day	R 1 421.66			
Repayment Period (months)	12.90			

Table 18: Average Zonal Pressure (AZP) Calculations

Source: Ugu District Municipality (2014)

Zone Ref	Length of Mains (km)	Service Conns (Ns)	Properties (Np)	Ns/Np	Density of Conns/km mains	Avg Logged Pressure Pavg (m)	Ns x Pavg (conns x meters)	Lm x Pavg (km x meters)
Amandawe ANZP before Pressure Management								
Amandawe Zone 1	3.1	63	76	0.829	20.323	71	4473	220.1
Amandawe Zone 2	4.2	71	81	0.877	16.905	76	5396	319.2
Amandawe Zone 3	5.8	69	71	0.972	11.897	81	5589	469.8
Amandawe Zone 4	2.57	59	70	0.843	22.957	65	3835	167.05
Totals	15.67	262	298	3.521	18.021		19293	1176.15
No. of zones	4	4	4		18		73.6	75.1
	System density of conns <20/km so best system AZP =						75.1	
Amandawe ANZP after Pressure Management								
Amandawe Zone 1	3.1	63	76	0.829	20.323	58	3654	179.8
Amandawe Zone 2	4.2	71	81	0.877	16.905	57	4047	239.4
Amandawe Zone 3	5.8	69	71	0.972	11.897	64	4416	371.2
Amandawe Zone 4	2.57	59	70	0.843	22.957	53	3127	136.21
Totals	15.67	262	298	3.521	18.021		15244	926.61
No. of zones	4	4	4		18		58.2	59.1
	System density of conns <20/km so best system AZP =						59.1	
Umzinto ANZP before Pressure Management								
Umzinto Zone 1	0.5	33	35	0.943	66	63	2079	31.5
Umzinto Zone 2	0.6	38	40	0.95	63.333	44	1672	26.4
Umzinto Zone 3	0.7	35	35	1	50	66	2310	46.2
Umzinto Zone 4	0.6	50	50	1	83.333	53	2650	31.8
Totals	2.4	156	160	3.893	65.667		8711	135.9
No. of zones	4	4	4		66		55.8	56.6
	System density of conns >20/km so best system AZP =						55.8	
Umzinto ANZP after Pressure Management								
Umzinto 1	0.5	63	76	0.829	126	41	2583	20.5
Umzinto 2	0.6	71	81	0.877	118.333	22	1562	13.2
Umzinto 3	0.7	69	71	0.972	98.571	41	2829	28.7
Umzinto 4	0.6	59	70	0.843	98.333	30	1770	18
Totals	2.4	262	298	3.521	110.309		8744	80.4
No. of zones	4	4	4		110		33.4	33.5
	System density of conns >20/km so best system AZP =						33.4	

5.2.2 Mains leaks and bursts

i. Comparative Ratio – Qavg/Qmnf

This is a dimensionless ratio that gives a quick indication of the severity of leaks and bursts within a PMZ. A comparison of average flow and the minimum night flow in a normal residential reticulation system is undertaken as a snap-shot. The further the value is from the unit '1', the healthier the PMZ is, while the opposite indicates a zone that has a high level of leaks and bursts. Based on the results provided in Table 17 there was an improvement of the comparative ratio after the development of both PMZs. In Amandawe PMZ there was slight improvement from 1.07 to 1.37 and in Umzinto there was a noticeable improvement from 2.41 to 5.35. Amandawe PMZ proved to have high level of leaks and bursts which were identified during leak detection and were fixed.

ii. Amandawe PMZ

Before NRW reduction strategies were initiated, the mains leaks and bursts were 30.11 m^3/hr (an equivalent of 0.53 L/km/sec). After NRW reduction intervention, this was reduced to 11.41 m^3/hr (an equivalent of 0.2 L/km/sec). The comparative ratio increased from 1.07 to 1.37. However, this indicates that a relatively high leakage and bursts rate still existed within the zone and that more leak detection and repairs could be undertaken in a cost effective way. NRW reduction interventions included in this analysis were pressure management and leak detection and repair management only. No billing improvements were considered for this parameter. The resultant flow profile indicated potential for further reductions.

iii. Umzinto PMZ

Before NRW reduction strategies were initiated, the mains leaks and bursts were 4.78 m^3/hr. After the reduction intervention, this was reduced to 1.7 m^3/hr. The comparative ratio increased from 2.41 to 5.35. This indicated a zone that had minimum leaks and bursts, and that it would not be economical to undertake active further leak detection and repairs. This zone only needed to be monitored to maintain the status quo. Similar to Amandawe PMZ, the NRW reduction interventions included in this analysis were pressure management, leak detection and repair management only. No billing improvements were considered for this parameter.

The huge drop in the MNF after the development of the PMZs indicated that there were water losses in both zones. The excess night flows were also reduced tremendously. Usually the consumption is very minimal at night and especially since both zones were residential zones which were not supposed to be active at night. This was also confirmed by the leaks that were discovered by visual inspections and ground microphone and the correlator.

Xu *et al.* (2014) classified available leakage detection approaches into three categories: noise monitoring, and flow and pressure monitoring. All three approaches were used to identify the sources and causes of leaks in the two zones. Tindale and Sagris (2013) identified different causes of water losses in the system, including pressure in the system, the condition of the infrastructure, type of soil and ground conditions. Tindale and Sagris (2013) identified different causes of water losses in the system, including pressure in the system, the condition of the infrastructure, type of soil and ground conditions. Most of the bursts identified in Umzinto and Amandawe zones were caused by the aging AC pipes, high pressures and some were due to leaks in the connections. There were few instances where the reservoirs were found to be overflowing due to the faulty level controllers and these were replaced.

The causes of water losses were analysed by merging the results of the zonal water balance, pipe data and information on the environmental conditions like ground conditions, soil type, climate etc (Knobloch, Guth and Klingel 2014). The same criterion was used to determine the causes of water losses in both zones.

5.3 Results and discussion for Specific Objective 3

Construct an International Water Association (IWA) baseline water balance for the study area and determine the key performance indicators

Information was captured on the system before and after the intervention so that a comparison could be made. Table 19 provides detailed information on the system before and after the intervention. After implementation of the NRW reduction strategies, the results indicated that there was improvement in the performance of the system. NRW in Umzinto PMZ dropped by 48 kL/day (94.2 kL/day to 46.2 kL/day); real losses were reduced by 97.2 kL/day (117.1 kL/day to 19.9 kL/day); metering inaccuracies by 3.9 kL/day (9.9 kL/day to 6 kL/day) and the ILI by 2.1 (4.3 to 2.2). Amandawe PMZ's NRW was reduced by 264 kL/day (659 kL/day to 395 kL/day); real losses dropped by 426 kL/day (727 kL/day to 301 kL/day); metering inaccuracies by 4 kL/day (7 kL/day to 3 kL/day) and ILI by 4.8 (11.2 to 6.4).

The ILI is a performance indicator for the benchmarking of physical losses, while real losses include leakage on the distribution mains and service connections and overflows from reservoirs. The SIV decreased in both areas, indicating that the bulk metering was not giving actual figures. In Umzinto PMZ the SIV decreased by 161 kL/day (382.2 to 221.2 kL/day), with NRW reduction of 3.7% (24.6% to 20.9%). In Amandawe PMZ the SIV dropped by 381 kL/day (904 to 523 kL/day) and the NRW indicated an increase of 2.8% (72.8% to 75.6%).

The different KPIs were measured before and after the intervention in line with the objective and they are presented in Table 19. In Umzinto PMZ the water losses dropped by 48 kL/day (93.8 kL/day to 45.8 kL/day), with the inefficiency of use going down by 22% (31% to 9%). In Amandawe PMZ the water losses dropped by 234 kL/day (611 kL/day to 377 kL/day), with the inefficiency of use reduced by 23% (80% to 57%). The CARL in Umzinto PMZ went down by 607.8 kL/day (732.1 kL/day to 124.3 kL/day) and the UARL also decreased by 598.6 kL/day (168.75 kL/day to 56.25 kL/day. Amandawe PMZ also had the CARL going down by 1431.8 kL/day (2440.5 kL/day to 1008.7 kL/day) and the UARL reduced by 60.02 kL/day (217.01 kL/day to 156.99 kL/day). The KPIs indicate that the intervention had positive impact in the zones where it was implemented.

Table 19 presented the water balance information for the Amandawe Zone before the intervention. The billing information that was used to develop this water balance was for the period from 01 April 2014 to 30 August 2014.

Table 19: System characteristics before and after NRW reduction intervention strategies
Source: Ugu District Municipality (2014)

	Amandawe PRV Zone System Characteristics		Umzinto PRV Zone System Characteristics	
	Pre NRW Reduction Intervention	Post NRW Reduction Intervention	Pre NRW Reduction Intervention	Post NRW Reduction Intervention
Component	Kl/day	Kl/day	Kl/day	Kl/day
System Input Volume	904	523	382.2	221.2
Billed Metered Consumption	193	75	284.0	171.0
Metered Municipal Consumption	-	-	-	-
Free Basic Water Standpipes	53	53	4.0	4.0
Billed Authorised Consumption	246	128	288.0	175.0
Unbilled Unmetered Consumption	-	-	-	-
Unbilled Metered Consumption	47	18	0.4	0.4
Unbilled Authorised Consumption	47	18	0.4	0.4
Unauthorised Consumption	(123)	74	(33.3)	19.9
Metering Inaccuracies	7	3	9.9	6.0
Apparent Losses	(116)	76	(23.3)	25.9
Mains and Distribution Leaks	545	225	87.8	14.9
Reservoir Overflows	-	-	-	-
Service Connection Leaks	182	75	29.3	5.0
Real Losses	727	301	117.1	19.9
Water Losses	611	377	93.8	45.8
Non-Revenue Water	659	395	94.2	46.2
Real Losses %	80.4%	57.4%	30.6%	9.0%
Water Losses %	67.6%	72.1%	24.5%	20.7%
Non-Revenue Water %	72.8%	75.6%	24.6%	20.9%
No. of Connections	298	298	160	160
Length of Mains	16	16	2	2
AZP	75	59	56	33
Population	2 384	2 384	1 280	1 280
Night Use %	0.00%	0.00%	0.00%	0.00%
Unauthorised Consumption (% BMC)	-63.72%	98.92%	-11.72%	11.67%
PRVs installed	1	11	1	11
Inefficiency of Use	80%	57%	31%	9%
WUE (l/capita/day)	0.2	0.3	0.6	0.4
Nc/Lm	19.02	19.02	65.84	65.84
Current Annual Real Losses (CARL) (l/conn/day)	2440.5	1008.7	732.1	124.3
Unavoidable Annual Real Losses (UARL) (l/conn/day)	217.01	156.99	168.75	56.25
Infrastructure Leakage Index (ILI)	11.2	6.4	4.3	2.2
Night Day Factor	21.8	21.8	22.1	22.1

Table 20 presented the water balance information for the Amandawe Zone before the intervention. The billing information that was used to develop this water balance was for the period from 01 April 2014 to 30 August 2014.

Table 20: Amandawe PMZ IWA Standard Water Balance – Pre-NRW reduction intervention

Source: Ugu District Municipality (2014)

<table>
<tr><td rowspan="9">System Input Volume
904 m^3/day
± 3,0%</td><td rowspan="4">Authorised Consumption
293 m^3/day
± 7,5%</td><td rowspan="2">Billed Authorised Consumption
246 m^3/day
± 8,1%</td><td>Billed Metered Consumption
193 m^3/day
± 10,0%</td><td rowspan="2">Revenue Water
246 m^3/day
± 8,1%</td></tr>
<tr><td>Billed Unmetered Consumption
53 m^3/day
± 10,0%</td></tr>
<tr><td rowspan="2">Unbilled Authorised Consumption
47 m^3/day
± 20,0%</td><td>Unbilled Metered
47 m^3/day
± 20,0%</td><td rowspan="7">Non-Revenue Water
659 m^3/day
± 2,8%</td></tr>
<tr><td>Unbilled Unmetered
- m^3/day
± 20,0%</td></tr>
<tr><td rowspan="5">Water Losses
611 m^3/day
± 2,6%</td><td rowspan="2">Apparent Losses
-116 m^3/day
± -5,1%</td><td>Illegal Consumption
-123 m^3/day
± -4,8%</td></tr>
<tr><td>Metering Inaccuracies
7 m^3/day
± 3,5%</td></tr>
<tr><td rowspan="3">Real Losses
727 m^3/day
± 2,0%</td><td>Mains and Dsitribution Leaks
545 m^3/day</td></tr>
<tr><td>Reservoir Overflows
- m^3/day</td></tr>
<tr><td>Service Connection Leaks
182 m^3/day</td></tr>
</table>

Table 21 presented the water balance information for the Amandawe Zone after the intervention. The billing information that was used to develop this water balance was for the period from 01 September 2014 to 31 March 2015.

The SIV was reduced by 381 m^3/day (904 m^3/day to 523 m^3/day). The water losses were reduced by 234 m^3/day (611 m^3/day to 377 m^3/day) while the NRW was reduced by 264 m^3/day (659 m^3/day to 395 m^3/day). Illegal connections also showed to be increasing thus adding to the water losses. Seago and McKenzie (2007) noted that illegal connections tend to predominate in low income areas where billing is in place.

Table 21: Amandawe PMZ IWA Standard Water Balance – Post-NRW reduction intervention

System Input Volume 523 m³/day ± 3,0%	Authorised Consumption 146 m3/day ± 5,1%	Billed Authorised Consumption 128 m3/day ± 5,1%	Billed Metered Consumption 75 m³/day ± 5,0%	Revenue Water 128 m³/day ± 5,1%
			Billed Unmetered Consumption 53 m³/day ± 10,0%	
		Unbilled Authorised Consumption 18 m3/day ± 20,0%	Unbilled Metered 18 m³/day ± 20,0%	Non-Revenue Water 395 m³/day ± 3,6%
			Unbilled Unmetered - m³/day ± 20,0%	
	Water Losses 377 m3/day ± 3,7%	Apparent Losses 76 m3/day ± 16,3%	Illegal Consumption 74 m³/day ± 16,8%	
			Metering Inaccuracies 3 m³/day ± 3,5%	
		Real Losses 301 m3/day ± 2,0%	Mains and Dsitribution Leaks 225 m³/day	
			Reservoir Overflows - m³/day	
			Service Connection Leaks 75 m³/day	

Amandawe Zone is a rural area where the employment rate is still very low but the majority of the properties have private connections and are being billed. The most common form of illegal connections that were identified in this zone was where the residents extended their connections from a single standpipe connection. This usually results in capacity constraints since the original system was designed for standpipe use and not individual, metered connections (Seago and McKenzie 2007). The same challenge is experienced in this zone as the demand in the zone is more than the supply.

Table 22 presented the water balance information for the Umzinto Zone before the intervention. The billing information that was used to develop this water balance was for the period from 01 April 2014 to 30 August 2014.

Table 22: Umzinto PMZ IWA Standard Water Balance – Pre-NRW reduction intervention

Source: Ugu District Municipality (2014)

System Input Volume 382.2 m^3/day ± 4.0%	Authorised Consumption 288.4 m^3/day ± 4.9%	Billed Authorised Consumption 288.0 m^3/day ± 4.9%	Billed Metered Consumption 284.0 m^3/day ± 5.0%	Revenue Water 288.0 m^3/day ± 4.9%
			Billed Unmetered Consumption 4.0 m^3/day ± 5.0%	
		Unbilled Authorised Consumption 0.4 m^3/day ± 5.0%	Unbilled Metered 0.0 m^3/day ± 20.0%	Non-Revenue Water 94.2 m^3/day ± 6.0%
			Unbilled Unmetered 0.4 m^3/day ± 5.0%	
	Water Losses 93.8 m^3/day ± 6.0%	Apparent Losses -23.3 m^3/day ± -22.1%	Illegal Consumption -33 m^3/day ± -15.4%	
			Metering Inaccuracies 9.9 m^3/day ± 3.5%	
		Real Losses 117.1 m^3/day ± 2.0%	Mains and Dsitribution Leaks 87.8 m^3/day	
			Reservoir Overflows - m^3/day	
			Service Connection Leaks 29.3 m^3/day	

Table 23 presented the water balance information for the Umzinto Zone after the intervention. The billing information that was used to develop this water balance was for the period from 01 September 2014 to 31 March 2015.

Table 23: Umzinto PMZ IWA Standard Water Balance – Post-NRW reduction intervention

System Input Volume 221.2 m^3/day ± 4.0%	Authorised Consumption 175.4 m3/day ± 4.9%	Billed Authorised Consumption 175.0 m3/day ± 4.9%	Billed Metered Consumption 171.0 m^3/day ± 5.0%	Revenue Water 175.0 m^3/day ± 4.9%
			Billed Unmetered Consumption 4.0 m^3/day ± 5.0%	
		Unbilled Authorised Consumption 0.4 m3/day ± 5.0%	Unbilled Metered 0.0 m^3/day ± 5.0%	Non-Revenue Water 46.2 m^3/day ± 4.9%
			Unbilled Unmetered 0.4 m^3/day ± 5.0%	
	Water Losses 45.8 m3/day ± 5.0%	Apparent Losses 25.9 m3/day ± 8.6%	Illegal Consumption 20 m^3/day ± 11.2%	
			Metering Inaccuracies 6.0 m^3/day ± 3.5%	
		Real Losses 19.9 m3/day ± 2.0%	Mains and Dsitribution Leaks 14.9 m^3/day	
			Reservoir Overflows - m^3/day	
			Service Connection Leaks 5.0 m^3/day	

The SIV was reduced by 161 m^3/day (382 m^3/day to 221 m^3/day). The water losses were reduced by 48 m^3/day (93.8 m^3/day to 45.8 m^3/day) while the NRW was reduced by 48 m^3/day (94.2 m^3/day to 46.2 m^3/day). Another form of illegal connection is described as when a person with an existing metered service connection bypasses the meter and their consumption is more than the basic allocated amount (Gonzalez-Gomez, García-Rubio and Guardiola 2011). There were a lot of such experienced in Umzinto Zone including businesses which were bypassing the meters and using more than their quota.

After the data was extrapolated, a medium term water balance for the entire municipality was prepared. Table 24 presented the water balance information for the entire Ugu DM before any interventions can be implemented. The data utilised covered the period July 2014 to June 2015.

Table 24: Entire Systems' IWA Standard Water Balance – Pre-NRW reduction intervention

Source: Ugu District Municipality (2014)

System Input Volume 112 957 m³/day ± 10.0%	Authorised Consumption 81 425 m³/day ± 9.0%	Billed Authorised Consumption 80 706 m³/day ± 9.1%	Billed Metered Consumption 72 702 m³/day ± 10.0%	Revenue Water 80 706 m³/day ± 9.1%
			Billed Unmetered Consumption 8004 m³/day ± 10.0%	
		Unbilled Authorised Consumption 719 m³/day ± 5.2%	Unbilled Metered 410 m³/day ± 5.0%	Non-Revenue Water 32 252 m³/day ± 26.7%
			Unbilled Unmetered 309 m³/day ± 10.0%	
	Water Losses 31 533 m³/day ± 27.3%	Apparent Losses 6 159 m³/day ± 133.6%	Illegal Consumption 3 614 m³/day ± 227.6%	
			Metering Inaccuracies 2 545 m³/day ± 2.0%	
		Real Losses 25 374 m³/day ± 10.0%	Mains and Dsitribution Leaks 20 807 m³/day	
			Reservoir Overflows 127 m³/day	
			Service Connection Leaks 4 440 m³/day	

Table 25 presented the projected medium term water balance if pressure management is implemented by developing at least 75 more zones.

Table 25: Entire Systems' IWA Standard Water Balance – Medium Term Projected

Post-NRW reduction intervention

System Input Volume 105 929 m³/day ± 5.0%	Authorised Consumption 82 771 m³/day ± 4.5%	Billed Authorised Consumption 81 948 m³/day ± 4.5%	Billed Metered Consumption 74 004 m³/day ± 5.0%	Revenue Water 81 948 m³/day ± 4.5%
			Billed Unmetered Consumption 7 944 m³/day ± 5.0%	
		Unbilled Authorised Consumption 823 m³/day ± 5.1%	Unbilled Metered 480 m³/day ± 5.0%	Non-Revenue Water 23 981 m³/day ± 15.7%
			Unbilled Unmetered 343 m³/day ± 10.0%	
	Water Losses 23 158 m³/day ± 16.3%	Apparent Losses 7 796 m³/day ± 47.3%	Illegal Consumption 5 206 m³/day ± 70.9%	
			Metering Inaccuracies 2 590 m³/day ± 2.0%	
		Real Losses 15 362 m³/day ± 5.0%	Mains and Dsitribution Leaks 12 597 m³/day	
			Reservoir Overflows 77 m³/day	
			Service Connection Leaks 2 688 m³/day	

The percentage errors were calculated using Equation 12.

Equation 12

% error of C = SQRT ((A*% error of A/1.96) ^2+ (B*% error of B/1.96)^2)*1.96/C

Where:

A + B = C

Table 26 presents a summary of comparisons of the key performance indicators (KPI). It shows the current and projected KPI values before and after implementation of the NRW reduction interventions, respectively.

Table 26: Selected Pre and Post-Projected NRW Reduction Intervention KPIs for Ugu DM

Source: Ugu District Municipality (2014)

Key Performance Indicator	**Current KPI Value**	**Projected KPI Value (with Intervention)**
Water Resources:		
Inefficiency of use of Water		
Resources (RL/SIV) %	22%	15%
Operational:		
Water losses		
(m^3/service connection/year)	268.2	184.8
Water losses		
(litres/service connection/day)	734.8	506.3
Current Annual Real Losses		
(m^3/service connection/year)	215.8	122.6
Current Annual Real Losses		
(litres/service connection/day)	591.3	335.8
Unavoidable Annual Real Losses		
(m^3/service connection/year)	45.5	34.3
Unavoidable Annual Real Losses		
(litres/service connection/day)	124.6	93.9
Apparent Losses		
(m^3/service connection/year)	52.4	62.2
Apparent Losses		
(litres/service connection/day)	143.5	170.4
Infrastructure Leakage Index	4.7	3.6
Financial:		
Non-Revenue water by Volume (%)	28.6%	22.6%

5.4 Results and discussion for Specific Objective 4

Develop a more suitable business model for Ugu DM

From the results that were obtained in the Umzinto and Amandawe PMZs, the following the following issues were identified:

- There was no emphasis on the operation and maintenance of the existing infrastructure. The municipality was experiencing challenges in revenue management. This indicated that there was a need for the municipality to concentrate on operational and financial efficiencies.
- Operational efficiency could be achieved by implementing the following interventions in order of priority :

❖ Immediate interventions

- Implementation of the pressure management programme. Pressure management will ensure that water losses are reduced. Consumption will immediately drop if pressures are reduced. In the event that there is a burst in the system, less amount of water will be wasted as compared to a burst in a pressurised system. The life span of the infrastructure will be increased if the system pressures are reduced. The overall benefit of all these positives is that the operation and maintenance costs will be reduced.
- Development of the DMAs to simplify the systems and make them more manageable. By developing the DMAs the systems will be simpler to operate thus avoiding high operational costs by reducing water losses.
- Implementation of the leak detection and repair programme. Physical losses are a major contributor to the water losses and if they can be reduced the water losses will reduce quite substantially. The Leak Detection and Repair Programme will ensure that physical losses are reduced.

❖ Long term interventions

- Review of the water services standards that would assist with optimising the systems and increase customer satisfaction. It is very critical for a WSP to ensure that there are set KPI's that must be met in order to ensure good quality service to the customers. The water services standards will ensure that the performance of the WSP is measurable and if there are any shortcomings they are easy to identify and improve.

- Reservoir level control to stop overflows. The overflows result in an increase in physical losses and sometimes they cause damage to infrastructure. A scada system is recommended to ensure that the system can be managed remotely.
- Implementation of the pipe replacement programme. Aging of pipes is one of the challenges in most WSPs. Huge water losses are experienced due to aging infrastructure.

- Financial efficiency could also be enhanced by implementing the following interventions in order of priority:

❖ Immediate interventions

  - Using the correct actual readings to bill customers. Customers should be billed using actual information at least once every three months. According to (Kingdom, Liemberger and Marin (2006)) a significant portion of commercial losses is the result of mistakes in the meter reading and billing systems. This was identified as one of the challenges in Ugu DM where the Meter Readers would not get the actual readings on the meters but would provide estimates. By addressing this challenge the BAC will be increased.
  - Conducting a meter audit programme to ensure that a household that is connected to a water supply is known and that it receives monthly bills as a matter of urgency. Currently the municipality does not have an accurate number of consumers that are connected to the water supply. The meter audit programme will ensure that the BAC is increased and the apparent losses are reduced.
  - Ensuring database integrity where there is correct customer information and each customer is linked to the correct account. This was identified as one of the challenges experienced by Ugu DM; there is a need for the municipality to implement a data cleaning exercise in its database. Currently some customers are linked to wrong accounts leaving them being billed wrongly and some not being billed at all. By implementing a data cleaning

exercise the UAC will be reduced because everyone who has an account with the municipality will be billed correctly.

- Long term interventions
  - Managing illegal connections by ensuring that there is a clear policy that indicates how such connections will be addressed as well as how the policy will be enforced. Illegal connections also contribute to the apparent losses thus reducing them subsequently increases the municipality’s revenue.
  - Meter testing and calibration in cases where customers require such services, especially during disputes between the municipality and the customer. Some customers end up not paying if there is a dispute and the municipality is unable to test and calibrate meters to ensure reliability of readings. The metering inaccuracies would also be reduced if such services were available in the municipality.

Based on the results for all the objectives, operational efficiency and financial efficiency are the main pillars of a business model to be adopted by Ugu DM. By implementing these two important aspects of improving service delivery the municipality will enhance revenue management. For any organisation to be able to sustain itself as a business it must ensure an improved level of service to keep the customers satisfied, thus enhancing revenue generation. Most municipalities fail to manage these aspects because there are a number of external and internal influences in a municipal environment. However, municipalities need to be managed like businesses in order for them to be sustainable

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Identify and prioritise the implementation of non-revenue water reduction strategies: rezoning, pressure management and leak detection

Rezoning was critical in simplifying the water system for easier operation and maintenance. Pressure management was easier to implement in a DMA and leaks were easier to detect. NRW was significantly reduced by addressing pressures in the system and could also increase the lifespan of the infrastructure. The amount of SIV was also reduced after the implementation of the strategies.

Although there were many NRW reduction strategies to choose from, it was concluded that rezoning, pressure management and leak detection were the most critical ones as they had a positive impact in the system. These strategies were the most recommended in a system that had never had any intervention before. They stabilised the system immediately after implementation. However, they needed operation and maintenance after implementation in order to ensure that they remained effective. Lack of operation and maintenance could have meant a waste of money used to implement the intervention strategies because lack of maintenance could have left them ineffective. The other important aspect of implementing the strategies was the training or the transfer of skills. It was concluded that even with the implementation of the strategies, if there were no trained personnel to operate them, they would have not been effective. If the zones were breached and the PRVs not maintained, the system would have gone back to its original condition before the intervention.

Identify the sources and causes of water losses in the study area by conducting field measurement

Night flows indicated that there were leaks and bursts in the systems which ran for long periods of time without being attended to. Leak detection was conducted in order to identify these leaks. It was concluded that the leaks were mainly caused by aging infrastructure, high pressure in the system, illegal connections and reservoir overflows. Ugu DM did not have a clear policy on illegal connections which had a huge impact on unbilled unauthorised consumption. Pressure management contributed a lot towards reducing the amount of water losses. Most service connections that were identified to be leaking were connected illegally to the municipal mains. It was concluded that these connections were done by unqualified Plumbers and because they were illegally done, the consumers could not report them to the municipality. Although the reservoir overflows were not many, they were also a challenge which needed to be addressed by Ugu DM.

Construct an International Water Association (IWA) baseline water balance for the study area and determine the key performance indicators

The water balance indicated that although there was improvement in terms of NRW after the implementation of the different strategies, the operation and maintenance of the infrastructure was critical. From the results of the study it was concluded that the ILI, inefficiency of use and water losses were reduced after the strategies were implemented. All the critical KPIs of IWA water balance were recorded before and after the intervention and it was noted that the intervention had positive effects in the system. It was also concluded that the NRW, CARL and UARL responded positively to the strategies by going down. Similar challenges could be addressed in other zones by implementing the same strategies.

Develop a more suitable business model for Ugu DM

Based on the results from the field measurements it was concluded that one of the biggest challenges confronting municipalities is achieving operational and financial efficiency while ensuring the provision of water and sanitation services. Municipalities should be managed as businesses in that consumers should be satisfied with the service and they should generate revenue from the service they offer. The service should be of an acceptable standard and revenue enhancement strategies should be linked to debt collection and credit control strategies. It was therefore concluded that operational and financial efficiencies were critical for a WSA to develop a business model that could sustain itself.

6.2 Recommendations

The following recommendations were made:

- Bulk metering should be instituted in all the different systems so that they are easier to maintain and operate as opposed to operating big complicated systems which are difficult to manage.
- Adequate resources should be made available for operation and maintenance in order to ensure operational efficiency.
- Water conservation campaigns need to be conducted to create awareness among communities.
- Further research could be conducted on the impact of tariff structures on revenue collection, revenue enhancement and debt recovery strategies.

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