OPTIMAL MODELLING OF NON-REVENUE WATER: A CASE STUDY OF LEBOHANG EXTENSION 9 AND 10 IN GOVAN MBEKI MUNICIPALITY, MPUMALANGA, SOUTH AFRICA

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DECLARATION

I, RV Mlangeni, student number 209095806, hereby declare that the research project titled "Optimal modelling of non-revenue water: a case study of Lebohang Extension 9 and 10 in Govan Mbeki Municipality, Mpumalanga, South Africa" and its contents represent an original work conducted by me under the guidance of Prof. GM Ochieng and that the research project has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Vaal University of Technology. All the information or resources used from other authors are duly acknowledged by means of complete references.

This research project is submitted to the Department of Engineering Civil and Building in Vaal University of Technology, Vanderbijlpark, in fulfilment of the requirements of MTech: Engineering, Civil.

I also declare that there is no conflict of interest regarding this research and/or any paper publication in relation to the completion for this research.

DEDICATION

This work is devoted to the team of Govan Mbeki Municipality, Water and Sanitation in Lebohang for their tireless and selfishness effort to avail information needed. I would especially like to thank Mr Percy Ntivana, my spouse Maki Mlangeni for her special love, kindness and support, as well as my parents, MM Mlangeni and TA Mlangeni for their support.

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ABBREVIATIONS AND ACRONYMS

DMAs – District metered areas

IWA – International Water Association

NRW – Non-revenue water

WSA – Water service authority

WSP – Water service provider

MNF – Minimum night flow

WRC – Water Research Commission

RW – Rand Water

BABE - Burst and background estimate

GMM – Govan Mbeki Municipality

WC – Water conservation

WDM - Water demand management

ABSTRACT

South Africa was declared a water scarce country with an annual runoff that is estimated to be less than 13 percent against the world average. South African municipalities are in position of providing accurate water balance data which is necessarily to measure the level of NRW. However, majority of them don't keep accurate records of their input volume or billed consumption. The study done by South African Water Research Commission which analysed 62 system has estimated total water losses (real and apparent) to be 31 percent of total supplied water. (McKenzie: 2014)

The global volume of non-revenue water (NRW) or water losses is overwhelming. Each year more than 32 billion m3 of treated water is lost through leakages from the distribution networks. An additional 16 billion m3 per year is delivered to consumers but not invoiced due to various reasons such as of theft, poor metering, inadequate billing systems, or illegal use. In some low-income countries this loss represents 50 -60 percent of water produced, with a global average estimated at 35 percent. Saving just this amount would supply water to an additional 100 million people without further investment in water production and distribution systems. (Simbeye I: 2010)

Many studies conducted proved that water loss in South Africa is generally considered high between 30 percent and 70 percent and the cause of these high losses is defined in various studies (McKenzie & Seago: 2007).

Many reasons have been tabled as contributing factors to the cause of high level of non-revenue water in general. The reasons include amongst others and not limited to poor planning, pressure management control, insufficient funds, and poor water network implementation. The factors further include inadequate actions in place to address optimization of services, leakage control, inadequate tariff, and collection systems. (Muhamad Shahbani Abu Bakar: 2005)

The major challenges towards efficient and effective water delivery to all urban people are usually poor governance, financial constraints, poor network design, poor customer services, and inadequate infrastructure. It is obvious that high levels of NRW result from volumes of water lost through physical leaks or administrative losses from poor customer accounting and billing. This seriously affects the financial sustainability of water service providers. (Simbeye I: 2010)

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CHAPTER ONE: INTRODUCTION

1.1 Background Information

Most of the world's population live in urban areas where water is supplied through a reticulated water pipeline system. Water supply systems in cities are continuously evolving to match the increase in demand arising from factors such as variation patterns of consumption, urban population influx and industrial development, among others. Thus, the necessity in meeting the demand of water has culminated in the need to readjust current systems to supply the world's population. This has resulted in complex interrelated systems that have proven difficult to partition, thereby having an adverse effect on the proper management of such systems. Partitioning the systems into isolated zonal areas, which are manageable dimensions, has become an important in contemporary water management dynamics. The existing designs were made without considering the future need for division, which is what worsens the situation (McKenzie, Siqabala, and Wegelin, 2012).

Water utilities, especially in the developing world, experience significant shortfalls in the volume of potable water fed into the supply systems and that is later billed to the consumers. This shortage is referred to as non-revenue water (NRW). NRW consists of the following elements:

- Physical / real losses
- Commercial / apparent losses
- Unbilled authorised consumption (McKenzie, Siqabala, and Wegelin, 2012).

Seago, McKenzie and Bhagwan (2006) highlight the WRC's various tools to manage NRW in South Africa. To encourage efficient use of the already scarcely available water resources and to support government legislation, the tools were considered and developed. The models that were first designed were for the UK Water Industry in the early 1990s, which are all created on the burst and background estimate (BABE) approach. Since the BABE philosophy has been proven to provide a modest and practical approach to the normally confusing problem of leakage from water supply systems, it has subsequently been largely embraced and implemented in most parts of the world. Figure 1 presents the main elements of the BABE methodology.

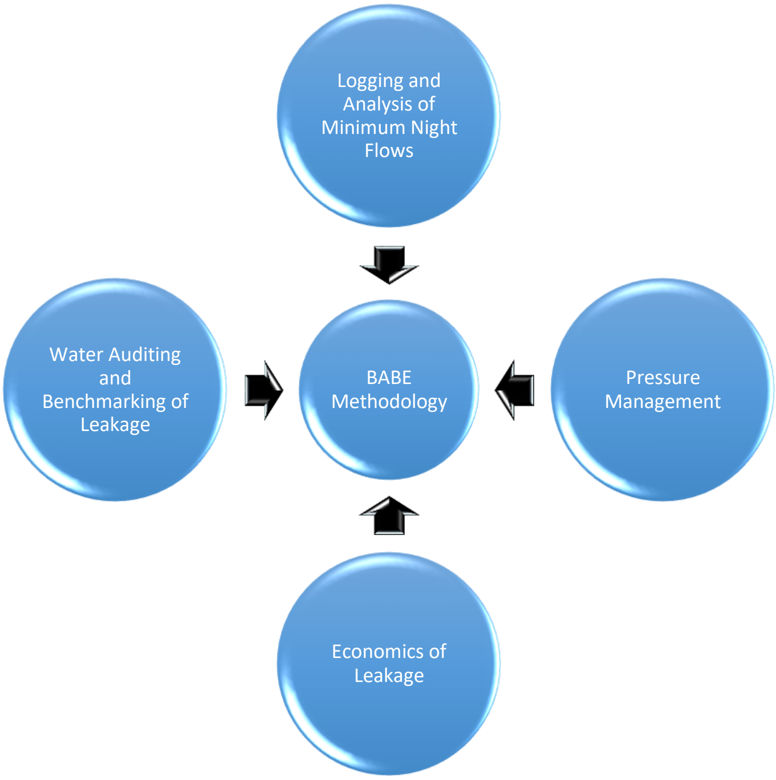


Figure 1 shows Main elements of BABE methodology

Source: Adapted from Seago, McKenzie and Bhagwan (2006)

Four models were developed to address the four key elements of the BABE methodology, as shown in Figure 1.

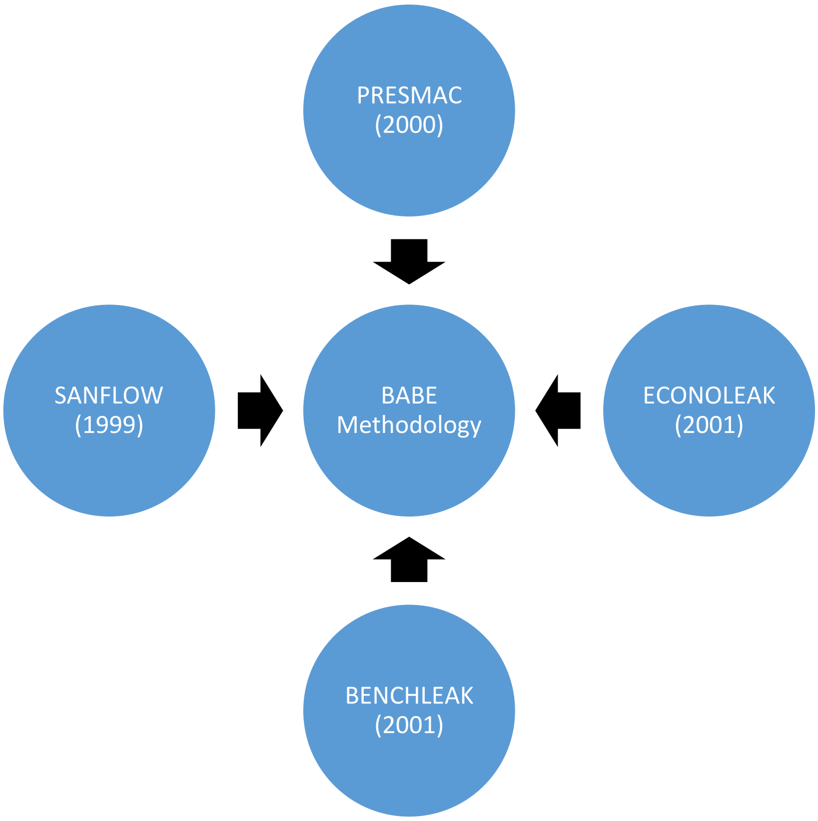


Figure 2 shows Models developed through WRC

Adapted from Seago, McKenzie and Bhagwan (2006)

According to Kayaga and Smout (2011), the zones are created as a priori and mapped on paper. Then, they are converted to a system of hydraulic models to forecast the outcomes in terms of their performance. Some of the identified flaws or disadvantages of this approach are:

- Difficulty in creating an optimal zone that could for instance depict the number of meters needed or the duration taken to detect water leakage located in the system.
- Before establishing a reasonably good zone many valuable time is wasted.

Recommended water demand management strategy is implemented unilaterally to the whole water network system. This strategy yields subjective results, given the drivers of NRW are many and differ from one region to another within the same urban water distribution system. Some of the most important drivers of NRW that may vary are; population concentration per kilometre of reticulation system, the water infrastructure type and the length of the distribution system. These drivers are as a result of urbanisation and settlement patterns in the localities where water services are rendered (van der Berg, 2014).

The one-size-fits-all approach disregards the point that every probable ZMA/DMA/LCZ is more appropriate for its own water demand management strategy, that is, accounts for its unique characteristics (Kayaga & Smout 2011). The water loss in network systems could be reduced by forming optimal ZMAs. However, currently, there is no ideal best sectorised and leakage control management tool for complex or improved water distribution networks aiming to monitor NRW, minimise leakage and ensure optimal control of network pressure (Kayaga & Smout 2011. There is, therefore, a need to invent systems that can enable the advancement of optimal management zones in a methodical and logical manner.

Following emerging scientific developments in this field of study, it is proposed to apply the approach/methodology developed by Sempewo, Parthirana and Vairavamoorthy (2011). The methodology is regarded as the best knowledge of the author, according to the recent literature review which is one of the latest attempts on the development of optimal DMAs.

1.2 Study area

Govan Mbeki Local Municipality formerly Highveld East Local Municipality is a South African local municipality situated in the Gert Sibande District Municipality of Mpumalanga. Lebohang is one of many old location situated in the municipality.

The GMM as other municipalities in South Africa, recognised the need to put more effort into minimising non-revenue water as part of its Integrated Resources Planning Strategy. The strategy should incorporate water conservation/water demand management as a key strategic attribute, as well as considering its contribution towards the objectives of the national water conservation/water demand management strategy. In this regard, the municipality’s turnaround strategy document (2014) aimed at commits to reduce non-revenue water, which is based on ensuring that the already scarce amount of water is well managed. In return, this will enhance consumer satisfaction and improve service delivery (Govan Mbeki Municipality. 2014)

Figure 3 presents the layout plan for GMM.

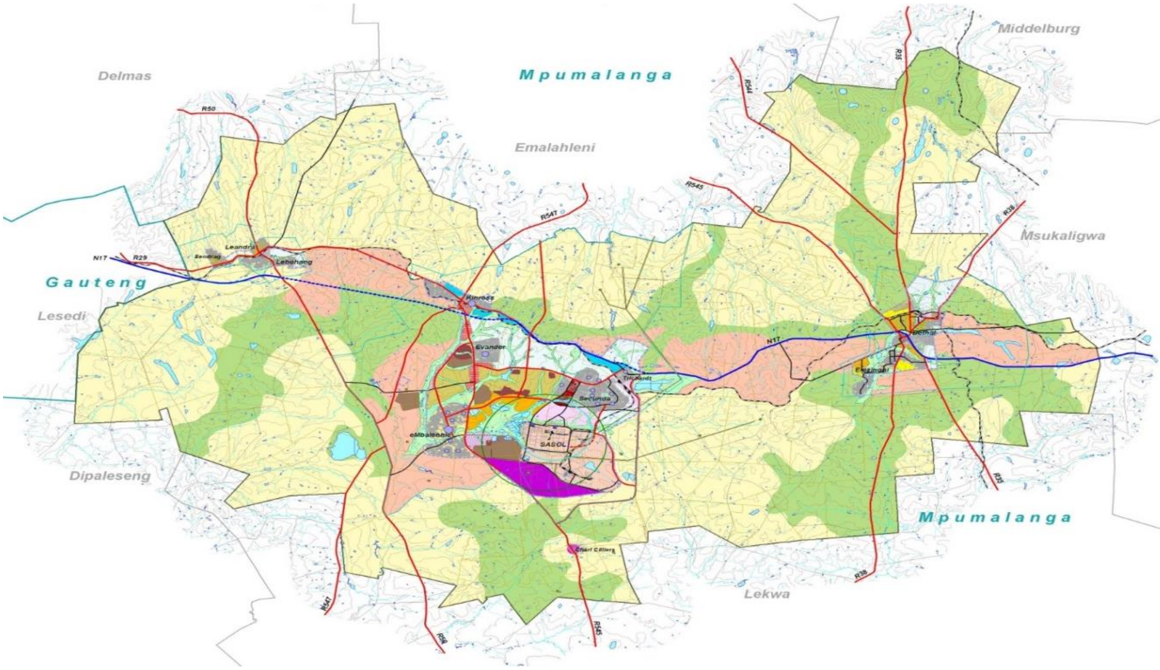


Figure 3 represent map depicting the location of GMM. (IDP GMM 2019)

1.3 Problem Statement

The WRC's report (cited in McKenzie *et al.* 2012), states that the data collected from 132 out of the total of 237 SA municipalities indicates that over 75 percent of the overall total volume of municipal water distributed reveals that the current level of non-revenue water estimated for the country as a whole, is 37 percent. Of the 37 percent, 25.4 percent is considered to be real losses through physical leakage.

There are various factors within the system that contribute to this high NRW in GMM, such as water pressure, aging infrastructure and illegal connections, to name a few. These factors vary from one location to the other within the same municipality. With the current practice, it is a generic case of one-size-fits-all whereby upon zoning, the same WDM strategy is applied across the municipality without consideration of the contextual uniqueness of each location. Figures 4 and 5 shows a graphical presentation of the global and local comparisons in non-revenue water.

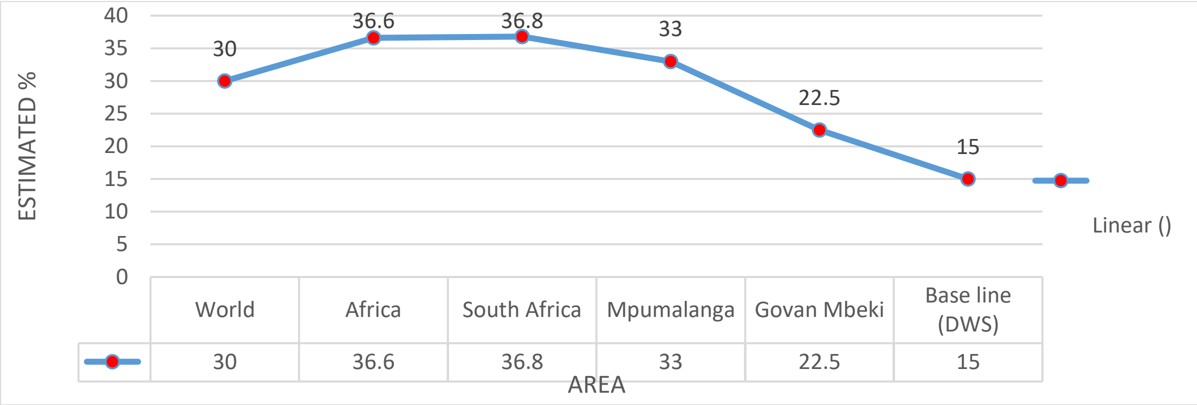


Figure 4 shows a global versus local comparison in NRW (cited in McKenzie *et al.* 2012. Bill Kingdom, Ronald Liemberger, Philippe Marin 2006.)

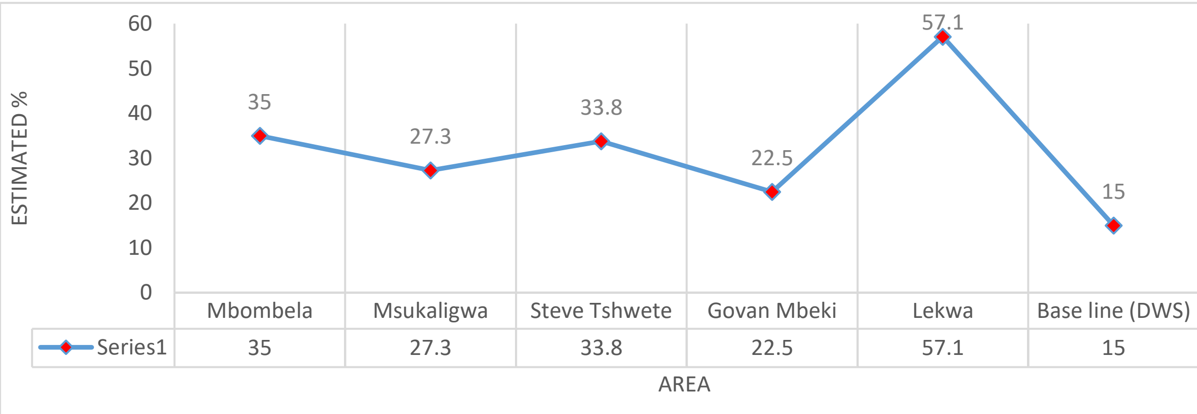


Figure 5 shows a localised comparison of NRW in the study area (cited in McKenzie *et al.* 2012.)

With the stated picture in mind, the purpose of this study is thus an attempt to develop region specific NRW models for two areas in Lebohang (Extension 9 and 10) that form part of the GMM. The aim is two-pronged, first, to demonstrate the challenge that might arise in viewing the status quo without being changed. Secondly, to develop an optimised and customised model that can be implemented by GMM as an effective tool for controlling non-revenue water per priority allocated budget (NRW).

Extensions 9 and 10 were chosen because of their identified stack variations as well as similarities in terms of the composition of the populace, age of infrastructure and the behaviour of the residents.

1.4 Research Questions

From the described scenario for modelling of NRW, typical research questions that would need to be addressed are as follows:

1. What is the current model or method used to address non-revenue water at GMM?
2. How has the current arrangement affected the overall performance of non-revenue water at GMM in the zonal area?
3. What benefit will the GMM have in implementing the proposed model in relation to planning of non-revenue water?

1.5 Research Objectives

1.5.1. Main Objective

The main objective of the study was to develop a model for non-revenue water to be used as a tool of priority in an optimised and purposeful comprehensive water conservation and water demand management for GMM. This will be achieved through the following specific objectives:

1.5.2. Specific Objectives

1 Developing optimised DMAs (or ZMA) for Lebohang Extensions 9 and 10 of the GMM.
2 Estimating the leakage in the network of each zone.
3 Conducting an analysis of NRW in a zonal area for three months with a view to draw similarities and contrasts.
4 Developing zonal area recommendations to be implemented by GMM as an effective tool for controlling non-revenue water per priority area.

1.6 Basic assumptions of the study

This study was based on the following basic assumptions:

- The data and required information to be available in the files or systems of the municipality. It was further assumed that historical data for meter reading be available or be sourced.
- The pressure management data by monitoring be made available and financial information on meter registration, including meter error, unmetered consumption, illegal consumption and water balance data of the supply system.

1.7 Limitations of the Study

In conducting this study, the researcher encountered a few limitations. First, it was difficult to access water balance data for 12 months in the financial year within which the study was undertaken. Furthermore, pressure- and asset management are both not applied in the municipality. Water meters were not calibrated, and the municipality had no plan to do it.

1.8 Definition of terminology

System input volume: The total volume supplied to the distribution system, both metered and unmetered. The volume of purchases should be taken into consideration and added.

Authorised consumption: The volume of both metered and unmetered used by registered customers. Water export, leaks, as well as overflows after the point of customer metering fall in this category. It also includes the requirement of the utility itself, e.g. the backwashing of filters.

Billed authorised consumption: It is the volume of water for which a bill has to be paid for both metered and unmetered consumption. This is recorded in the account system.

Unbilled authorised consumption: This represents the volume for which no bill has been paid for metered and non-metered customers.

Apparent losses: The total volume of water lost apart from physical factors. It includes inaccurate meters, unauthorised usage and wrong interpretation of data.

Real losses: The volume of water lost up to the customer metering point by all types of leaks. This includes bursts in pipes and fittings, overflows, leaks in mains and services, household communication pipe connections.

Bill metered consumption: The volume of recorded water consumption for which a bill is issued for payment. It includes domestic, commercial and industrial usage.

Bill non-metered consumption: It is the volume of water for which no bill has been issued, yet it is recorded in the billing system for which payment has to be effected.

Unauthorised consumption: Water theft, illegal connections, bypassed meters, bribery of meter readers all represent the volume of unauthorised consumption.

Metering inaccuracies: It is the total volume as a result of meter accuracies. Wrong data transmission, accounting errors and poor customer accountability fall in this category.

Leakage and overflow at utilities' storage: The water lost from inlet to outlet of the supplier's water storage infrastructure. This includes overflows and seepage.

Leakage on service connections up to customer's meter: The total water lost from the customer's service connections up to their meter. This is locally referred to as communication pipes.

Revenue water: It corresponds with billed authorised consumption. It is the money collected through successful sales of water.

Non-revenue water (NRW): It is the amount of water that remains unbilled, which entails no revenue generating. NRW is the sum of unbilled authorised usage and wastage or the difference between volume inputs and billed authorised consumption.

System pressure: Refers to water pressure in the internal wall surface of pipeline. measured in bars (1 bar = 10 meters head).

Water balance: Refers to a schematic chart showing the different components of volume of water supplied into the distribution system as well as volume of water lost and/or used within the distribution system.

Water audit: It is a periodic exercise of determining the volume of water supplied, consumed and lost in the distribution system, thereby providing a utility with information to make effective operation and maintenance, as well as investment decisions.

Water tariff: A set of procedural rules used to determine the conditions of service and the monthly bills for water users in various categories or classes.

MNF: Minimum night flow refers to a common method used to evaluate water loss in a water network.

Conclusion

This chapter provided the background of the study, aided by various graphical representations of the problem at hand. The study's objectives were listed, and key terminologies defined. non-revenue water appears to be a problem in many municipalities. The following chapter provides a review of literature on the research topic.

CHAPTER TWO: LITERATURE REVIEW

Creswell JW (2009) defines literature review as a written summary of the scholarly works that best describes the current and past state of information to justify a need for the proposal of a new study. Similarly, McMillan and Schumacher (2010) see literature review as a crucial part of research which links current knowledge and the research problem the researcher seeks to research. This chapter provides a review of the literature consulted in the process of conducting this study.

South Africa has eight metropolitan municipalities, 44 district municipalities and 226 local municipalities. (McKenzie, Siqabala, & Wegelin, 2012)

GMM had no official documentation on non-revenue water of their water system. It therefore triggered a necessity to collect general views on the issues to understand GMM situation in a scientific way.

Managing and reducing non-revenue water is an integral aspect of enhancing water consumption efficiency and minimising gaps in the demand and supply of water. Apparent water losses are more crucial when calculated in monetary terms as such a calculation is done at retail price levels. Water losses regarded as apparent include meter reading errors, unauthorised water usage, error in the acquisition of data as well as faulty estimations of unmetered usage. Metering error have been named the largest contributor to apparent water losses, which has subsequently made the phenomenon a highly researched subject (Ncube & Taigbenu: 2019).

Water constitutes a significant revenue generator for many municipalities. However, it is reported that approximately 41% of non-revenue water gets lost before reaching consumers. At 41%, South Africa's NRW situation is catastrophic. The current international best practice sits at 15% while the global average is 35% (Liedtke S, 2021). Even though South Africa is one of the water-stressed countries, it nevertheless loses an estimated R7bn each year to unbilled water (Blaine S, 2013)

The national average shows that 5 percent of non-revenue water is in the municipalities in categories A, B1, B2 and B3. The high population growth, deteriorating infrastructure and lack of capacity are challenges in Category B1 municipalities, which makes sense as to why the NRW is above the average. In category B2, the lower non-revenue water is as a result of towns that are easier to manage, with the result that the non-revenue water is under control. The data for category B3 municipalities varies considerably. The non-revenue water for Category B4 municipalities is considered very high due to socioeconomic conditions that hinder consistent bill settlement. The records show the volumes of water used are relatively small. (McKenzie, Siqabala, & Wegelin, 2012)

The main problems hindering a successful implementation of WC/WDM include:

- Poor planning
- Budget constraints and supply chain management issues
- Inappropriate technical solutions
- Lack of community acceptance or support
- Failure to realise own revenue generation and poor expenditure ability
- Poor billing techniques and metering
- Shortage of skills, training and low morale of personnel.

At a WISA conference held in October 2013 in Cape Town to discuss the challenges on NRW in South Africa, there was an emphasis on reducing pressure as one of the interventions to mitigate leakage. Cape Town Metro pointed out that pressure management has been recommended and effective tool to reduce water leakage in their municipality. Reduction on growth in water demand is as important as increasing the supply to its system. It is believed, based on the current planning assumptions, that by 2030, reducing water demand will reach an estimated 15 percent average. Targets are set for different areas based on their needs. To achieve a target, different programmes need to be put in place in the distribution networks for improvement of efficient domestic and commercial water use. There is a need for programmes that will support local and sectoral initiatives to lower water demand and improve water-use efficiency. This entails a clear and dedicated national water conservation and demand management programme and various sub-programmes with the focus on municipalities, industry and agriculture. For a guidance in approaches, the strategic planning decisions need to be actioned on general economic and social development, as well as environmental protection. (National Development Plan 2030)

According to IMESA (2011), it was discovered that municipalities are presenting a poor quality of or duplicate data, most especially smaller and rural municipalities. Some municipalities have no idea of their system volume and as a result, the observations on the topic of water demand management are ignored.

The high levels of non-payment for services in some parts of the country is one of the most substantial subjects prompting the non-revenue water in South Africa. Based on a document titled Local Government Budgets 2009/10 Financial Year Third Quarter Local Government Section 71 Report (2010), it was estimated that 20 percent of some areas which shows debtors of R44.8 billion over 90 days, of which ±30 percent or R13 billion is from NRW. The overall estimate would then increase to 47.7 percent if this component of water loss is included in the calculation of non-revenue water (Local government section 71 report, 2010).

The issue of non-revenue water has haunted most of the municipality. Funds are spent annually for new infrastructure to meet the demands instead of simply plugging the leaks. High water losses mean high pumping and high maintenance costs. (Miriam Chikwanda, 2011)

Physical (real) losses

Physical losses usually involve leakages that occur from the entire water distribution infrastructure. This is commonly due to poor management and lack of maintenance on the existing infrastructure as well as inferior quality of the material used in the construction of the distribution system network. This can further be defined as the annual volumes lost from supplying and distribution of water in the systems by means of all types of leaks, bursts and overflows on mains, reservoirs overflowing and service connections, until the meter point of the customer Physical losses contribute to the high percentage of NRW (McKenzie, Siqabala, and Wegelin, 2012).

Apparent losses

Commercial losses are caused by illegal connections, faulty meters, and inaccurate data management (for example, errors accruing from the point of data collection, capturing, manipulation etc.). Unbilled authorised consumption comprises water used for different purposes that are authorised, but not properly registered, water used for emergency services and the free provision of water to disadvantaged communities (McKenzie, Siqabala & Wegelin: 2012).

Unbilled authorised consumption

Unbilled authorised consumption becomes the third element of NRW. It is then recorded as the annual volume of unbilled metered and/or unmetered water recorded in a process by registered customers. The unbilled authorised consumption of water contributes the smallest portion of water balance in the water network distribution. (McKenzie, Siqabala, and Wegelin, 2012)

Formation of district metered areas (DMAs)

DMAs, ideally, are recommended to be in a zonal form within the network area. The steps below indicate how the DMA can be outlined for leakage management. The area of DMA, where possible, should include and not be limited to the following criteria:

- Area that can be easy to form a zone within the network
- There must be about 500 connections

When zoning, the services should not be degraded because of the process. If possible, one point of entry is advisable for the installation of water meters and not more than two entry points. They can be converted to other areas in a phased programme of NRW management (Drabble, 2017)

Understanding District Meter Areas

NRW reduction approach on activities are mostly initiated once the loss becomes visible or are reported by either means of reporting. The effective approach of managing the losses is through the establishment of the water teams and other means available to detect water losses within the network, reservoirs and illegal connections.

Active NRW management is easily managed where the system is zoned into smaller possible areas for which NRW can be calculated individually. These smaller areas, referred to as DMAs, should be hydraulically zoned for better management by the water managers in order to determine the volume of water lost within the DMA. Once the network is isolated, the NRW becomes easier to grasp as the system will be assessed 24/7 throughout the network. This zonal process, which is referred to as DMA, makes it easy for the water team to manage the network distribution. (Sam Drabble, 2017)

DMA establishment criteria and process

The design of the zonal area might be subjective in a sense that the result might differ based on how they are being interpreted during the design process. In designing the zonal areas, some points may be observed as part of the criteria in identifying the areas. These criteria include:

- Size of zonal area should generally be between 1,000 and 2,500 of connections
- Certain number of valves to be closed for zonal purpose
- Certain number of flow meters that will be used to measure inflows and outflows, preferably fewer
- Ground-level difference for pressure purpose
- Easily visible topographic for boundary marking
- The water service provider should ensure that the water supply to all customers is not tampered with during the process. (Sam Drabble, 2017)

DMAS in practice.

Water teams and supervisors will ensure that all pipes into and out of the DMA are either closed or metered by ensuring a zonal test as follows:

- Close all metered inlets.
- Check if the water pressure within the zonal area drops to zero, since no water should be able to enter the area.

Sectoring is a process of dividing the areas by means of isolation and having smaller workable areas. This helps to understand the problems in the area much easier than the bigger area. However, as stated earlier, there is currently no standardised ‘prototype’ methodology to carry out sectoring. The recommendations on a maximum zone size of approximately 2000 connections have been embraced throughout the world to the extent that this is often considered a prerequisite to any other WDM intervention, which was the made by the International Water Association’s (McKenzie 2014).

It is important to introduce the process of step-testing, which is the process of closing isolated boundary valves in order to mark the targeted network area. This way, the process of monitoring the night flow during the sectoring process, small zones of high leakage can be easily identified. This is a common practice; however, it has been neglected by many municipalities (McKenzie 2014).

Figure 6 portrays the concept of zoning as applied in the development of DMAs.

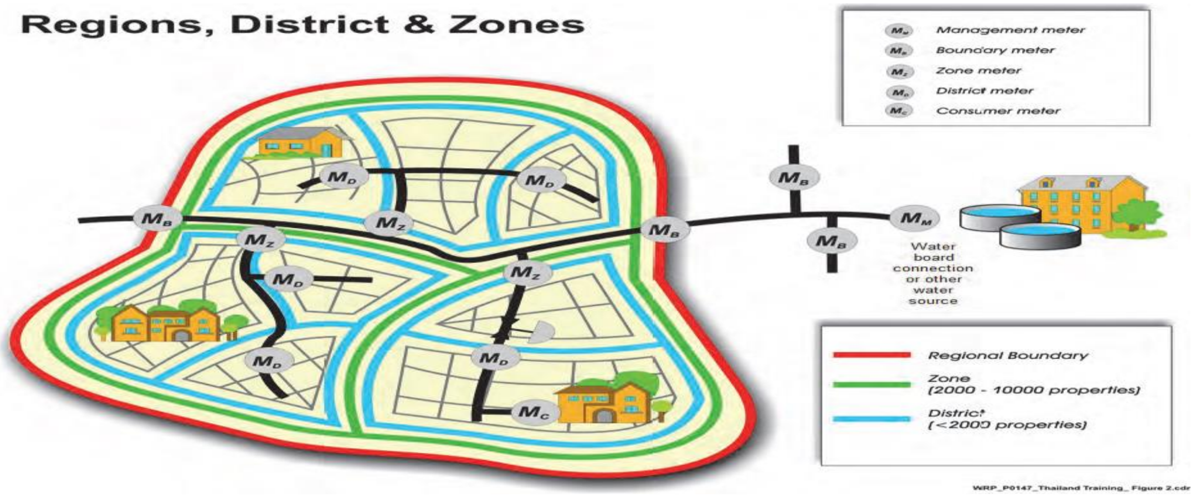


Figure 6 shows the concept of zoning (McKenzie 2014).

Splitting or zoning large areas to the smaller zones does not immediately reduce water loss; rather, it makes it easy to measure and monitor the losses. It provides a better understanding on how water losses can be tackled if they are considered to be excessive and in need of some form of action (McKenzie 2014).

The input data to be used in the models will be obtained as per a demarcated District Meter Area (DMA) or Zone. The purpose of creating DMAs is to have zones that are easily managed. Currently, the size of a manageable zone is minimised to pipe length and number of connections. Based on the tolerable leakage run time, the maximum DMA size is recommended to be three days (Yates C.D and Donald G.M 2005). Kayaga and Smout (2011) recommend that a size of between 150 to 200 hydrants, 2500 water connections, or 30 km of main water pipe should be used to demarcate a manageable DMA. As previously stated, their recommendations shall be adopted in this study. However, it should further be noted that size ideally depends on the water network, other factors and the level of leakage and these factors shall also be taken into consideration.

Table no: 1

Non-Revenue Water Problems in a Nutshell	**Non-Revenue Water Solutions in a Nutshell**
NRW includes water not billed because of leakage, illegal use, inadequate measurement, and free (authorised) use.	Governance and tariffs must be tackled first.
NRW averages 35% of production in SA cities	Leak detection equipment comes last, not first.
High NRW is connected to low piped water coverage.	Repair visible leaks.
There is a need to determine whether physical losses (leakage) are maintained to mask the illegal use and sale of water.	Make water team responsible for small zones (caretakers).
Illegal supply of water can revenue equal to legal sales.	Meter all production and consumption properly.
Consumers pay for water authority inefficiencies.	Add district metering.
A precious and scarce resource is being wasted.	Provide incentives for utility staff performance.
Unnecessary investments in production are made.	Explore links to water vendors.

The common perception is that NRW levels are higher in developing countries than in developed ones. However, very little data have been documented in reviewed literature to reflect the actual figures . The probable reasons presented for this occurrence are that developing countries lack sufficient tools to monitor the condition and performance of their infrastructure and evaluate the amount of NRW. However, there is a lack of advanced reporting systems that could acquire and collate data on the performance of the water services. Because of these inadequacies, the NRW data, so presented, is usually either not readily available, unreliable and/or inaccurate. The International Benchmarking Network for Water and Sanitation Utilities (IBNET) records 35 percent as the average NRW figure for developing nations (IBNET 2015).

However, due to the unreliability of reported data by inefficient utilities, the overall NRW levels actual figure in the developing world is more in the range of 30 to 60 percent of the water produced. Different studies estimate that 60 to 80 percent of the NRW is a result of physical losses in the distribution network. According to a report by the WRC, NRW for municipalities of categories A, B1, B2 and B3 fall within 5 percent of the national average (McKenzie *et al.* 2012), with the national average being 37 percent, as shown in Figure 7 below.

Municipalities in Category B1 have high population growth, dilapidated infrastructure, and water management skills shortages. These factors could be the probable reasons for the NRW percentage of 41.3 percent, which is above the national average. On the contrary, category B2 municipalities have a NRW figure of 30.5 percent, which is below the national average. The fact that these municipalities service urban areas is often cited as the reason for this, as it is believed that such areas are easier to manage compared to rural areas. According to (McKenzie *et al.* 2012) and with reference to Figure 1, the data for category B3 municipalities vary extensively. However, the NRW for municipalities in Category B4 is high because of low-cost recovery and poor services.

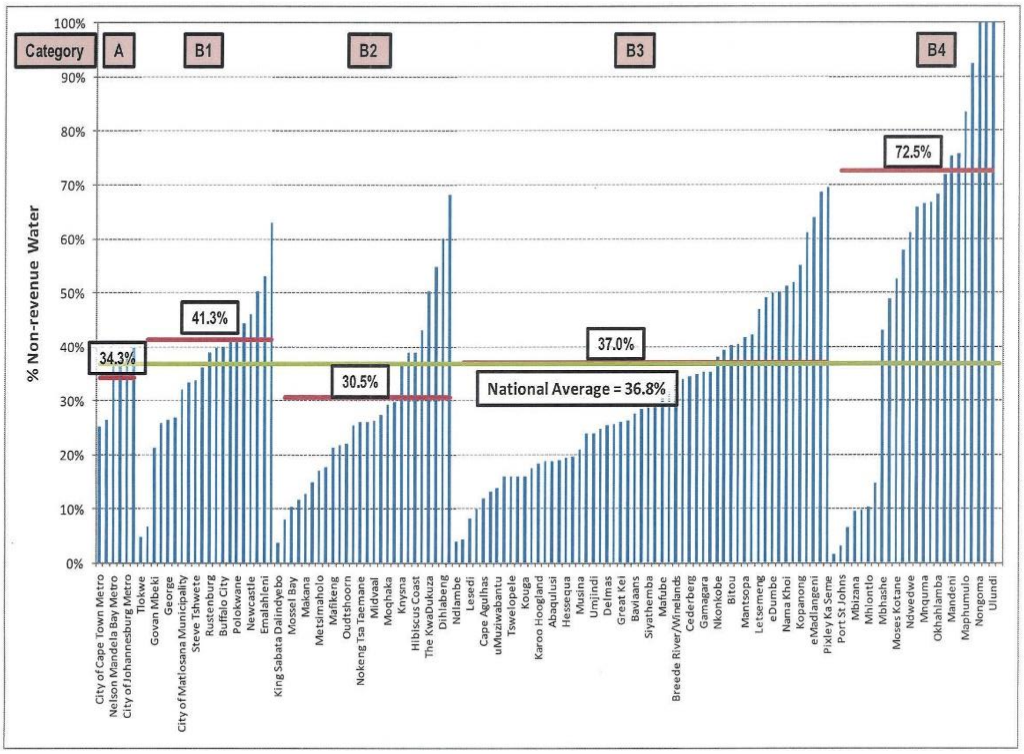


Figure 7 shows percentage of non-revenue water per municipality category
Source: Adapted from McKenzie *et al.* (2012)

The volumes of potable water consumed are relatively low, resulting in low impact on errors on NRW figures (McKenzie et al., 2012). Figure 7 presents NRW percentages in South Africa's municipalities against the national average values

The current South African legislative framework provides actual incentives for productive water usage and penalties for inefficient use. This approach is seen to have a long-term water conservation and demand management benefit. For instance, it could lead to an increase in the levels of control of NRW (McKenzie *et al.* 2012).

There is a dire need to extend NRW management programmes to minimise water losses throughout the value chain of water supply due to the runaway water losses in most municipal water supply systems. As an implementation process, the main areas of attention are catchment areas, the raw water supply systems (considered as upstream) and the internal reticulation systems (considered as downstream). For optimal performance, proper maintenance should also be done on the raw water extraction system and storage, which includes intakes, canals, dams, mains and pumping stations. The drive for water conservation and water demand management calls for a shift in paradigm from the traditional/conventional NRW management parameters to a holistic NRW management that extends the scope of focus beyond the traditional NRW management parameters. In the latter case, the target and challenges are to reduce successfully water losses in the entire water supply value chain. (McKenzie *et al.* 2012).

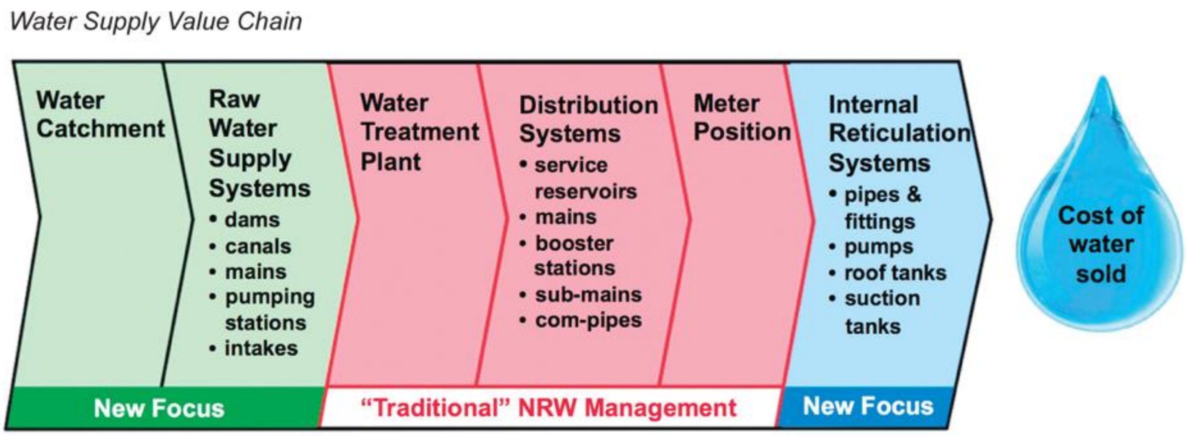


Figure 7 shows focus areas in a NRW management paradigm shift (McKenzie *et al.* 2012).

Table 2 indicates details of the various WRC BABE-based models (McKenzie 2014)

Model	Details
SANFLOW	This is a model designed to give an indication of the apparent water loss in a zone based on the evaluation of the minimum night flow.
PRESMAC	This is a model developed to estimate the probable pressure management system in a pressure zone according to information obtained from logged flow and pressures for a period of 24 hours.
BENCHLEAK	The model establishes the levels of NRW in a zone metered area or a water utility. The model output is based on IWA recommendations with respect to the minimum level of leakage
ECONOLEAK	The model is used to determine the ideal frequency for performing active leakage control
HDF	This model is used to determine the hour day factor for a discerned zone metered area. The model is complimentary to PRESMAC which is used for pressure management.

Challenges in BABE methodology applications

As observed in Table 2, an important characteristic in all the models is the zoning or delineation of zone metered area (ZMA). Other literature refers to ZMA as leakage control zones (LCZ) or district meter areas (DMAs), which are basically segmented sections of the water distribution network delineated into manageable areas or sectors. For many water utilities, the segmentation has become a critical factor, in that the ZMA/LCZ/DMAs could be used for:

- The management of NRW
- Regulation of system pressure
- The asset management of water distribution system infrastructure
- Equitable distribution of water during scarcity scenario or water rationing (rationing of supply in scarcity instances such as drought). Seago, McKenzie & Bhagwan (2006)

The greatest challenge in the delineation of the ZMA lies in the arbitrary nature in which it is done. In the current practice, the zoning differs from one country to another based on local knowledge (indigenous information) and experience gained from practice.

The pressure management is one of the most important components in the strategy of water leakage management. The amount of water leakage in either reticulation or supply networks is caused by a role played by the pressure from water pumps, or water gravitating to the lower areas. There is a good correlation between the flow of water leakage rate and the pressure. (McKenzie 2014).

The occurrence of new water pipe bursts is also a derivative of pressure. The rate in which the pressure is applied in a water pipe is directly proportional to the leakage it may cause.

Pipe burst occurrence is usually as a result of water pressure level and pressure cycling. To evaluate the correct level of management and control of pressure in a precise water infrastructure, a number of issues will be investigated, such as:

- identification of the possible zones, points for installation, desktop study to collect points from customers.
- evaluation of the types of customer and control restrictions through demand investigation.
- collecting of data on pressure and flow from the inlet and on zonal points.
- performing a model potential benefit by making use of specialised models.
- determination of the relevant control valves and control devices; and
- evaluation of the costs incurred and benefits of the process. (McKenzie 2014).

There are various approaches for decreasing water pressure in the water system, which include brake pressure tanks and flexible speed pump controllers. Pressure reducing valves (PRVs) are types of valves used and installed at tactical points in the water network to control the water pressure of the water network. PRV is commonly used to sustain a stable downstream pressure irrespective of the flowrate or upstream pressure instabilities in an ordinary condition. The PRVs will be placed inside a DMA, not far from the flow meter. For the protection of the meter from the turbulence caused by the valves, it is suggested that PRVs be placed downstream of the meter to ensure the meter's accuracy (Simbeye 2010).

Observation

Observation might also involve measurements and analysis of human behaviour, which then requires more subjective assessments of what is actually happening and being measured. Observation techniques result in precise measurements that are amenable in quantitative data analysis (Scheyvens & Storey, 2003).

Quantitative Data

This is the data that signify a quantity of some sort by means of questions like, How much? How big? How many? “These are questions that usually stimulate a numerical answer”. The advantage here is that the quantitative data “can be verified and replicated” (Scheyvens & Storey 2003).

The quality of the data collected: Attention should be exercised to ensure credibility of the data collected. According to Scheyvens and Storey (2003), cultural context can affect the data validation if care is not exercised.

Qualitative data

Qualitative research seeks to fulfil three aims, first to understand the world through interacting with, empathising with and interpreting the actions of its actors. Again, qualitative methods tend to collect data in the natural settings rather than artificial and constructed context. Thirdly, it tends to generate theory rather than testing it. (Scheyvens and Storey, 2003)

Conclusion

The presentation in this chapter already points out that the majority of activities are involved in the management of NRW in any water network distribution. The process of NRW management involves the assessment and measurement of all the various components of NRW as stipulated in the chapter. The procedures and processes will ensure the success of the intended results in dealing with the topic of NRW by means of DMA isolation.

CHAPTER THREE: Study/Research tools

3.1. Introduction

Rajasekar, Philomonthan & Chinnathambi 2012, regard methodology as a map that shows how research is to be done by the researcher. In addition, according to (Dawson C, 2009) regards it as a general guiding principle by which research is carried out. We learn from the aforementioned scholars that methodology is the thread that holds a research study together—without which, research will not be feasible.

3.2.The process flow in the research methodology

The research process is divided into four (4) distinct stages as depicted in Figure 8

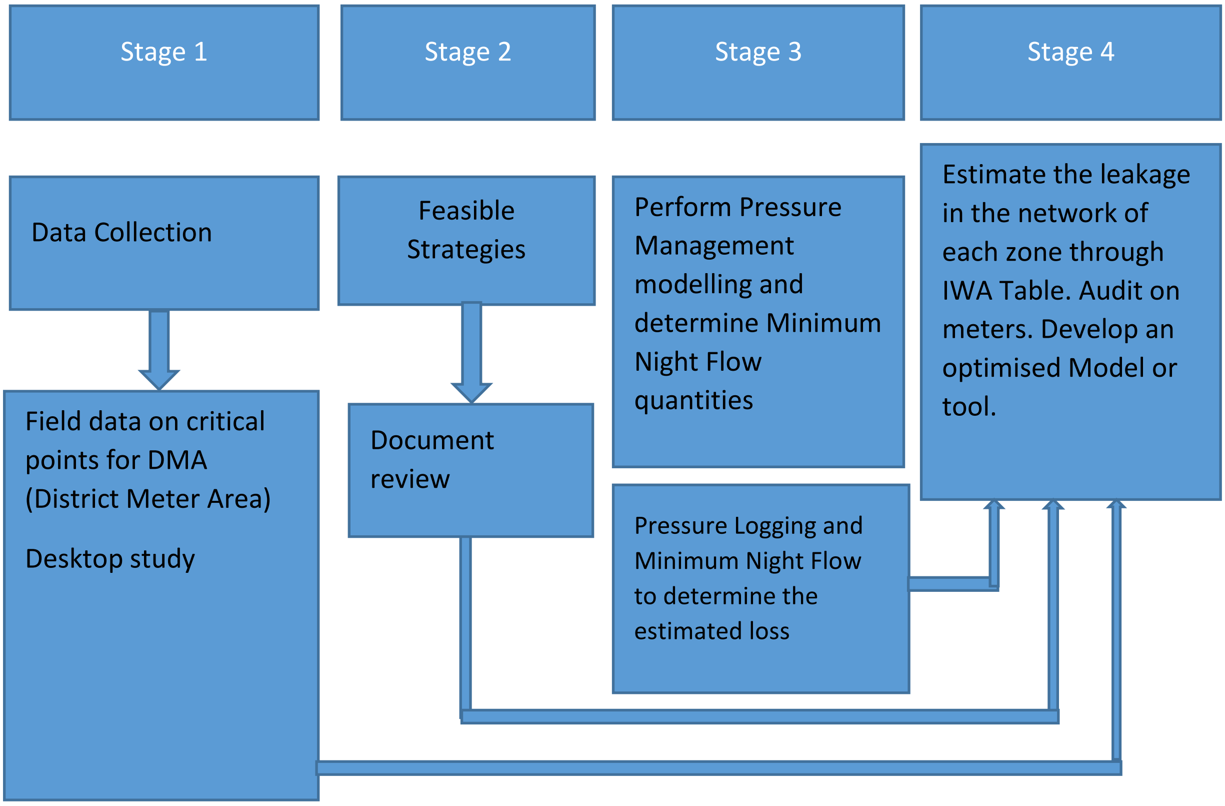


Figure 8: Stages in the research process

3.3. Parameters for optimisation

3.3.1. Minimum night flow

Loggers are connected to the water meters for the purpose of measuring MNF. Both loggers and water meters are placed in a chamber constructed for safety reasons.

A mechanical flow meter of Sensus, Hannover, Germany (Type: WP-Dynamic 100) accuracy was fitted at the inlet of each zonal meter. The flow meter then gets connected to a data logger inside the brick chamber that was constructed to ensure protection to the equipment installed.

Data then gets uploaded later into the system then transferred into an Excel spreadsheet for plotting. The data was taken for a week for before retrofitting and another seven days after retrofitting.

3.3.2. Pressure management

A water pressure gauge was used as an instrument to measure various pressure in the system within the zonal areas. A water pressure gauge is a pressure measuring instrument that indicates the water pressure in a system. The pressure gauge gets connected or mounted to the tap and translates the force exerted on it into units such as Pascal, bar.

3.3.3. Call centre data information

The call centre information was collected by means of a desktop study. The community reports different challenges to the call centre, which requires attendance of service delivery team. The information collected from call centre of GMM was needed to assist in understanding the zonal area challenges.

3.3.4. Asset Register

The asset register of the municipality was used to confirm the condition of the infrastructure. The aim was to also check the impact of the leakages per zone.

3.3.5. IWA table

IWA was used to produce the results based on the uploaded information. The information was collected from the municipal finance, technical department and from the meter readers then inserted on the excel spreadsheet tables to produce a graph indicating the percentage losses. Annexure A shows the information.

3.4 Methodology

In this study, both qualitative and quantitative data collection were used in the observation process technique.

3.4.1 Types of Methodology

This research work was carried out by the use of two procedures: fieldwork and desk study. Each approach contributes differently to the success of the research work. Different tools and methods were used in carrying out the research. In this research, the following techniques were implemented for data collection purpose:

- Participant observation
- Interviewing
- Document review.

The fieldwork took place at GMM among the staff members dealing with the reticulation network. It started from March 2017 to June 2017, annexure A and H shows the information. GMM is a water service authority and receives water from Rand water as its contracted service provider.

Successful research depends on the process of both desktop study and fieldwork. This is due to the fact that paperwork and practical work on site can differ based on some errors, which gives a priority on both processes to be done.

3.5 Guides for data collection in the fieldwork

The information was obtain using previous information and interpreted against the actuals on site, annexures show the information.

- Health and safety issues

Health and safety were prioritised at all times when collecting information on site. Chambers were opened and closed properly using the special equipment in avoiding any danger on site.

- Contacts

The data collected over three months from March 2017 to May 2017 were used to paint a picture of the overall view of the area. A visit was made to the GMM team and its call centre to collect the relevant information to highlight the real issues around Lebohang. The unfortunate part was that most of the information was not easily accessible or available. Communication was done through e-mails, telephones, and WhatsApp, whenever the need arose.

- Document Review

The following documents were collected and used for review:

1. A review of the June 2017 NRW strategy developed by GMM;
2. Non-Revenue Water; Measurement and Reduction of NRW, June 2017;
3. Asset Management register;
4. The existing Organogram structure of GMM.

- Interview

Semi-structured and unstructured interviews

An unstructured interview was organised with the team of GMM to better understand plans to control real losses and the specific strategies they intended to use. The Superintendent: Water and the Senior Technician: Operations and Maintenance were engaged in a follow-up unstructured interview, as indicated earlier, to give an input on the topic of NRW. (Table 4)

- Observation

A visit was paid to GMM call centre to observe how they operate on a day-to-day basis. Annexure F shows the information collected on the day. The second part of the visit was on site where the zoning area was observed. This gave the researcher a chance to assess both performance of the water team and the system performance. During observation, it was critical for the team to understand and differentiate the terminology in dealing with water complaints like category on types of water complaint received.

The municipal technical team needs to have a clear understanding of NRW and how to assist in the reduction of water losses in the organisation. The result of NRW reduction can be part of the employee's incentives to encourage them to do more. The NRW awareness should form part of their toolbox session with examples on how this can be achieved. This should find an expression in both policy and by-law enforcement development review. Education and training should be prioritised to employees dealing with NRW, both technical team and finance, on how to prioritise issues relating to this subject. The benefit of this will be realised by an increase in revenue, which will improve both service delivery and finance collection.

The quicker the attendance to the water complaints such as pipe burst repairs, the more confidence the customer will have in the institution. This would further increase staff morale and promote efficiency and the willingness to pay their water bills by residents.

Stage 1

3.6 District Meter Area (DMA) sizing methodology (Sectoring)

In order to develop an optimised DMA, the study area water distribution network was isolated to monitor hydraulic performance by means of pressure data loggers and installing flow meters to obtain accurate data. Cost benefit analysis was carried out to prioritise the order of interventions to the DMAs based on detection of leakage return frequency, value savings, reduction of leakage levels and additional repair costs. Annexure H show the information.

3.7 Audit on call centre water complaints

The number of complaints reported to the call centre within a minimum period of three months from March 2017 to May 2017 was used to plot the zoned pattern to identify the highest area of complaints. (Annexure F)

The municipality has a call centre that is fully functioning with a three-shift system. The call centre receives complaints about the following areas, per region:

- Region 1: Bethel & Emzinoni
- Region 2: Trichardt, Lebohang, Evander, Kinross, Leandra and Eendraght
- Region 3: Embalenhle and Charl Cilliers.

The complaints were filtered by means of the description and out of that, the report generated on the system.

Stage 2

Determination of feasible strategies for optimising NRW management in the developed zones

This shall be accomplished through a comparative analysis as follows:

- comparison and analysis of different developed zones to identify the neediest zone or alarming zone in terms of prioritisation;
- comparison and analysis of NRW strategies from municipalities of the same grading will be done through document review; and
- source strategies from different municipalities of the same grade and analyse their data or efficiency.

Stage 3

Minimum night flow (MNF):

Based on the first principle, it is imperative to take note that it is only at the point of MNF that the consumptive usage can be estimated. The consumptive usage can be predictable from the population and average use per person per hour (normally 6 percent of population x10 ℓ/hour) mostly at the peak point of MNF. The water consumed from both small and large consumers will be taken into consideration in determining the actual consumption (McKenzie 2014).

Pressure logging and minimum night flow

Pressure logging was performed by zoning the areas. The data was collected based on the outcomes of the process.

Data logging was zoned to areas to check the minimum day/night flow and to present a pressure management model. The pressure was compared in scenarios to determine the best working scenario. The scenarios was compared with the DMA method to determine the best and more relevant method based on the budget (McKenzie 2014).

Stage 4

Estimate the leakage in the network of each zone

A proper water balance was done using the required information collected from the municipality. The water balances help provide a better understanding of the overall supply systems per region and per ward and also assist in the preparation of specific intervention strategies and cost/benefit calculations, which shall be dealt with in more detail. Table 3 presents the International Water Association's (IWA's) water balance model that was applied in this study. (R Liemberger and M Farley 2004)

Table 3: IWAs Water Balance Model

<table>
<tr><td rowspan="9">System Input volume Kl per annum</td><td rowspan="4">Authorised/ Approved Consumption Kl per annum (%)</td><td rowspan="2">Billed Authorised/Approved Consumption Kl per annum</td><td>Billed Metered Consumption inclusive of exported water</td><td rowspan="2">Potential Revenue/Income water Kl per annum (%)</td><td>Free basic Kl per annum</td></tr>
<tr><td>Billed Unmetered Consumption inclusive of non-functional meter</td><td>Revenue</td></tr>
<tr><td rowspan="2">Unbilled Authorised consumption Kl per annum (%)</td><td>Unbilled, Metered Consumption such as flat rate reading</td><td rowspan="7" colspan="2">Non-revenue water Kl per annum (%)</td></tr>
<tr><td>Unbilled Unmetered Consumption such as municipal parks</td></tr>
<tr><td rowspan="5">Potable water losses Kl per annum</td><td rowspan="2">Apparent Losses Kl per annum</td><td>Illegal Connections</td></tr>
<tr><td>Inaccuracies in customer metering</td></tr>
<tr><td rowspan="3">Real Losses Kl per annum (%)</td><td>Distribution Mains leakage</td></tr>
<tr><td>Overflows and Leakage at reservoir</td></tr>
<tr><td>Service Connection Leaks</td></tr>
</table>

The system input data was collected through bulk water meters and system output data was collected by means of domestic and commercial water meters. NRW was then recalculated to check the validity of the existing information. The telemetry systems was used to record the incoming/outgoing flows on the respective reservoirs to monitor the reservoir consumptions. (McKenzie 2014).

Audit of water meters:

The type of water meter used was audited and checked for accuracy. The reading was taken for three months (March 2017-May2017) for water balance purposes.

Develop an Optimised Model

The information collected from stage 1 to 3 will be used to address objectives 1,2 and 3.

To address objective (4) Developing zonal areas recommendations to be implemented by GMM as an effective tool for controlling non-revenue water per priority area, data collected based on objective (1) and (2) and (3) was analysed so that zonal recommendations could be developed.

Conclusion

The choice of methodology used was key as it informed the content of other data to be interpreted. The type of methods used guided the quality of the data produced.

CHAPTER FOUR: Analysis

4.1 Analysis of the research findings

The practice that the municipality is applying in dealing with NRW proves that the management is using a blanket approach in dealing with NRW in the municipality. The NRW management's focus is on the actual figures from the supply system input volume up to the consumer meter within the system. This is simply done by means of using inlet to outlet approach of measuring. The monitoring, evaluation and assessments are being observed as the method of measurements for the success or otherwise of any strategies that would be adopted. The focus on NRW is beneficial to the entire network system with the involvement of the municipal staff members.

Real Losses

Active Leakage Control:

The current arrangement focused mainly on responding to the water leakages and pipe bursts, as they are reported or identified through call centre or walk ins by the community members.

The use of MNF in an area of 500 households assisted by giving us an idea of the losses that may be experienced, which needed attention as they were contributing to the losses. This also assisted in understanding the relationship between zoning the area and applying the blanket approach, which proved that, based on the available budget, the municipality can now plan better with a clear vision. (Figure 8)

Apparent Losses

The recalibration of the existing meters, which is vital to warrant more certainty on the figures of the components of NRW, is not being practiced as it is required.

The water meter reading services is outsourced to a service provider, where the service provider is expected to take responsibility to the information collected. It was also reported that sometimes the community are being billed based on the average, which means that the meters were not read for certain periods, which discourages residents from paying their water bills.

4.1.1 Pressure Management:

The system of Extension 9 and 10 in Lebohang had no form of pressure management being carried out within the distribution network for monitoring. The pressure was measured, using manual instruments.

The following was implemented while doing the study for testing the system of Lebohang Ext 9 & 10:

- The water network was set for pressure management.
- The area was sectorised into four DMA's (zones) and coloured into different colours. (Annexture I)
- Interventions per zone was then carried out on the zones exhibiting increased non-revenue water percentages for the months in question.
- Base level of the reduction in NRW can then be conducted. The subsequent reduction may depend on the pipeline replacement, which is a long-term solution.

The pressure management was conducted and in various areas of four divided zones to collect the data. The data was captured in various points that represent the areas. The data collected varied from 2 to 5 bar which represent the entire zonal area.

4.1.2 Infrastructural management: (Annexure G)

Asset management is partially applied, which affects the correct update of asset register. It was reported that there was a programme of fixing communal meters on all commercial consumers connections, which currently was abandoned. This proves that infrastructural management procedures are not in place. Operation and maintenance plan is also not in place to assist the team on which items need to be replaced by when and this is realised only when pipe bursts are experienced. The infrastructure is not well managed and known, which subsequently affects the time taken to respond to the complaints. On other occasions after excavation, the team discovered that the material needed for repair was not available, which then needed to be ordered from suppliers. The volume of water loss and turnaround time increased while waiting for materials. The presence of an operation and maintenance plan plays an important role in identifying the asset per priorities.

The operations and maintenance plan plays a vital role in managing and controlling the infrastructure. This is achieved by actions focused on scheduling and establishing procedures.

The infrastructure maintenance needs to be achieved by performance of routine, preventive, predictive, scheduled and unscheduled actions aimed at preventing equipment failure or decline with the goal of increasing efficiency, reliability and safety (Sullivan, Pugh, Melendez: 2010)

4.1.3 Department of Water and Sanitation (DWS) IWA's Water Balance

The results of the IWA Water Balance (Annexure A) shows that with accurate information the correct results can be obtained, which may assist in reporting the correct figures of NRW. This can help in several issues, by alerting the management as to how much is being lost monthly and what need to be attended to immediately to avoid further losses.

The information in this case shows data collected for three consecutive months , which was March, April, and May 2017, for research purpose.

The spreadsheet from the Department of Water & Sanitation, (Annexture A) which was used for water balance calculations, plotted the following results for Leandra water system:

- March 2017 the NRW level is 11 percent
- April 2017 the NRW level is 19.9 percent
- May 2017 the NRW level is 23.7 percent

The variance shown from month to month is as a result of the fact that the municipality is not monitoring the level and impact of NRW on a monthly basis.

The amount can be quantified as estimation in Rands as follow for the month of March 2017:

- Out of 17 975Kl from System Input Volume
- The tariffs as per the Rand Water invoice R5.96/kl;
- The NRW for March 2017 becomes 1 975Kl x R5.96 = R11 771.00 as a loss to the municipality in one month and this multiply by 12 becomes R141 252.00 which is the money that were to be use for the improvement of the infrastructure for one financial year in one area.
- Municipal tariff cost as per municipal tariffs book for portable water becomes R21.25(domestic water consumption for more than 61kl/month)
- The NRW becomes 1 975 x R21.25 = R41 968.75 as a loss to the municipality in one month and this multiply by 12 becomes R503 625.00

This shows that a lot needs to be done in the municipality. This is a picture for one area out of many towns and townships within the same municipality, which are also not properly monitored. This calls for attention in dealing with NRW as this alone can help the municipality save a lot of money

The information collected in Lebohang Ext 9 & 10 shows the following based on the (Annexure I)

- The brown area - High water pressure with high water complaints. This area becomes a first priority area compares to other areas.
- The Blue area – High to medium water pressure. This area becomes a second priority area compares to other areas.
- Red area – Medium to low water pressure with low complaints recorded. This area becomes a third priority area compares to other areas.
- Green area – Medium to low water pressure with clinic and businesses around it. Low complaints recorded. This area becomes a fourth priority area compares to other areas.

The aim here is to analyse the data collected. Both the MNF and retrofitting information were analysed to check the impact on the zonal areas.

4.1.4 Minimum night flow

Loggers are connected to the water meters for the purpose of measuring MNF. Collection of information on MNF interpreted on before and after to determine the difference.

The flow meter then gets connected to a data logger inside the brick chamber that was constructed to ensure protection to the equipment installed.

GMM is among the listed municipality struggling to collect and pay Rand Water as their Water Service Provider. According to the statement issued by Rand Water on (Tebogo Letsie, 2020), the three municipalities currently struggling to pay Rand Water are Ngwathe Municipality in the Free State, GMM in Mpumalanga and Madibeng Local Municipality in the Northwest, which owes the institution millions of rands due to non-payment.

Rand Water spokesperson, Justice Mohale, notified the public that they have formally notified three of its municipal customers of their intention to reduce water pressure. The water pressure to the Ngwathe local municipality in the Free State will be reduced by 20 percent on Monday should the municipality fail to settle the arrears amount due to Rand Water. Rand Water further notified its customers that the arrears amounting to R5 239 395.42 is due for payment.

It has been recorded that GMM's water bill is R47 million. The municipality has been informed that its failure to pay the amount due will compel Rand Water to further reduce the flow of water supply by 20 percent. Rand Water indicated that further reduction of 20 percent will be implemented at the GMM. Madibeng Municipality is also one of the municipalities of which the reduction of 20 is planned to be implemented due to the same reason of non-payment.

The defaulting municipalities are aware that the offices of the Minister for Human Settlements, Water and Sanitation, the respective provincial MECs for Cooperative Governance and Traditional Affairs, as well the National Treasury, have been informed of the intended implementation of the credit control measures (Tebogo Letsie, 2020)

CHAPTER FIVE: Research Findings

This chapter unpacks the findings that were investigated through research exercise at Lebohang Ext 9 & 10 using the research methodologies discussed above.

5.1 Quantitative method

5.1.1 Interviews and Questionnaires (Annexure J)

The purpose of this questionnaires was to understand better the challenges experienced and compare them with the zonal area challenges with the intention to draw the similarities and contrast. This was to advise better when attending to the NRW causes in a zonal area.

The unstructured interview was organised with the team of GMM to better understand plans to control real losses and the specific strategies they intended to use. The Superintendent for Water and the Senior Technician, operations, and maintenance were interviewed as shown in the below table. (Annexure J)

Interview notes:

- A need for community awareness regarding water losses and revenue lost during the process
- A need for staff to be trained
- A need to prioritise the budget to areas that are mostly affected and avoid using a blanket approach.

5.1.2 Organogram of GMM

- The annexure D is the organogram of the technical team of GMM, which participates in the service delivery process and infrastructure improvement.
- The organogram was last reviewed in the 2014/15 financial year and is being used effectively to date.

5.1.3 Desktop study

A process audit on call centre information was conducted with data reflecting the status of water complaints, address and description of complaints for the purpose of the research.

Three months' report of water complaints for Lebohang Extension 9 and 10 were collected to show the type and description of water complaints reported see (Annexure F). This gave a picture of what needs to be addressed in the area. The other information of walk ins to the local office was not found, which is a limitation in this part of data collected.

The report in Annexure F shows the number of complaints received, of which most were water meters that are leaking. The walk ins complaint information was missing, which, according to the plumber, indicated that the walk ins mostly are pipe bursts of either 15mm, 25mm, 32mm and 63mm as well as main pipes and valves.

5.2 Qualitative method

The asset register verification (Annexure G)

The aim of this part was to expose the role played by the assets register and infrastructure maintenance in planning for NRW.

- The material used on site is both asbestos and PVC pipes for reticulation of Lebohang Ext 9 & 10. The condition of the material based on the observation and asset register proves that replacement needs to be prioritised.
- The Kent water meter was used for household within the section and on the main pipelines the 32mm and 63mm water meter were also used with isolation valves in each meter.
- It was found that the calibration of the water meter has not been done for the past five to 10 years

Observation

The observation was made while participating in the field work and few notes were made as follows.

Call centre information (Annexure F)

- Most of the water meters were old and were found to be leaking.
- Complaints were recorded and attended without being reported back to call centre if completed successfully or not.
- Wrong capturing due to wrong technical information submitted or description.
- The type of complaints captured gives an indication that the infrastructure needs serious attention.

Asset Management (Annexure G)

Asset management with the inclusion of all the aspects of the system management and operations it has been observed as a good engineering and business practice. In dealing with long-term economic leakage management and addressing clear objectives for most cost-effective way the need for asset management becomes necessary.

Physical losses

To understand the significance of deciding what to repair, replace, rehabilitate, or leave as is, the asset management system played a guiding role. The important factors of asset management are:

- Understanding the current assets performance
- Using the collected data for future planning

Asset management in Annexure G helped in understanding the deterioration pattern, which develops in time while dealing with the NRW assessment on the system. The usage of data from burst records helps prioritise pipe rehabilitation, renewal, or replacement, while planning on what asset to prioritise for replacement asset register becomes the important tool in budget process.

5.2.3 Retrofitting in Lebohang Ext 9 & 10

The purpose of this exercise was to do a comparison study on before retrofitting and after retrofitting the area. This was achieved by means of isolating the section and installation of data logging on retrofitting in Lebohang Ext 9 & 10. The area was then divided into four workable zonal area (Annexure H). The comparison was on both figures and financials.

The scope of work comprised the following items:

- Supply and installation of 5 x isolation valve with zonal meters (110mm Kentz meter) in Lebohang Ext 9 & 10
- Identification of 500 high users in Lebohang Ext 9 & 10
- Retrofitting for 500 high users in Lebohang Ext 9 & 10

Retrofitting

- Top 500 high users were used as for sampling using municipal information.
- The top 500 high users were identified and ranked.

Financial implication

The budget for retrofitting was R 183 462.00, excluding VAT with flow logging at main supply points.

Figure 9 shows the status quo prior to retrofitting

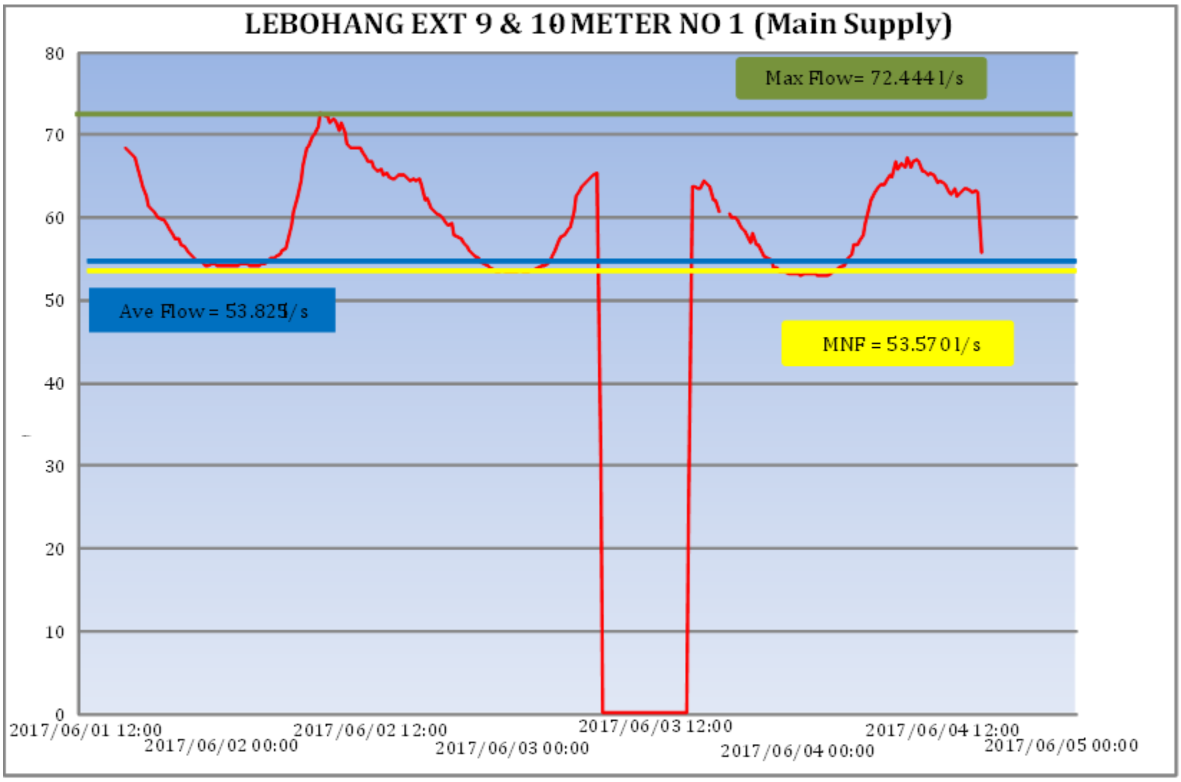
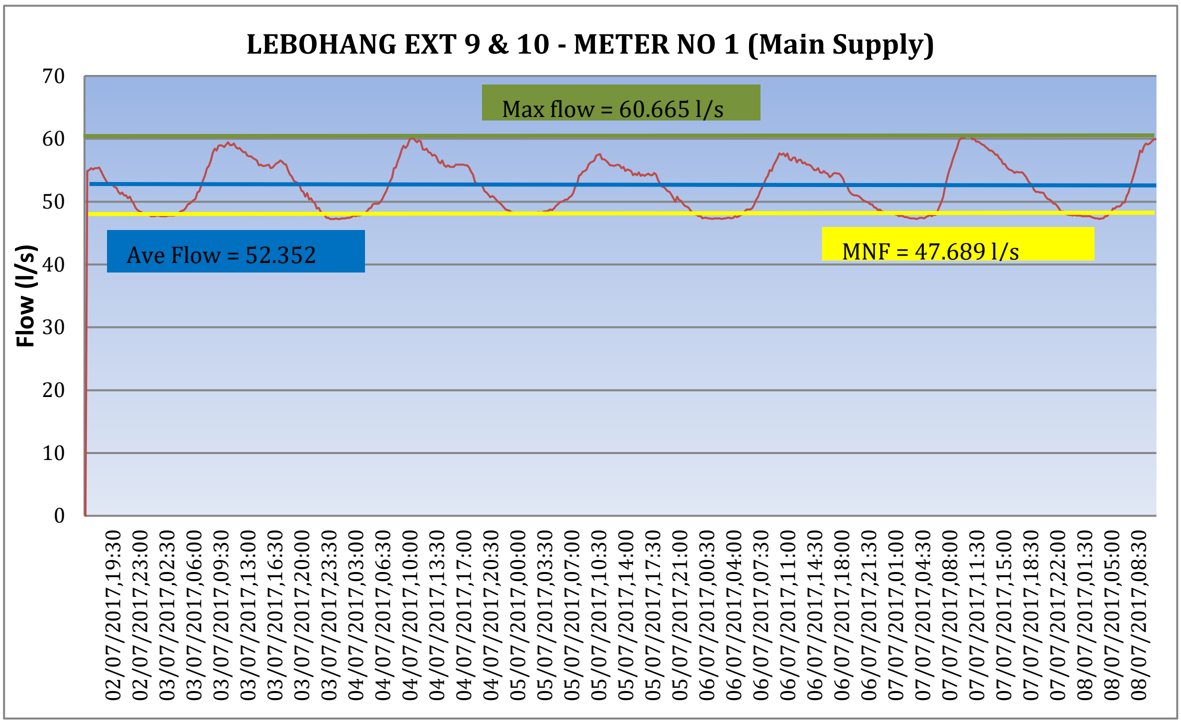


Figure 10 shows the status quo after retrofitting



Discussion based on the analysis results (outcomes)

- Based on the flow results from meter no 1, which is the supply point to Lebohang, the average minimum night flow prior to retrofitting was 53.570 l/s.
- The logging results for the same meter after the retrofitting indicate a minimum night flow of 47.689 l/s.
- There is a reduction of approximately 5.881 l/s over a period of 30 days.
- The minimum night flow is still high; however, it is evident from the results that the retrofitting of the 500 households had an impact and if more houses can be retrofitted, the municipality will save a significant quantity of water in this area.

Savings

Tariffs for the financial year 2016 – 2017 were utilised to calculate the savings:

Savings Per Year
= 5.881 x 86 400 / 1000
= 508.12 kl/day

= 508.12 x 365 days
= 185 436.22 kl
Tariff @ 11.39 R/kl
= 185 436.22 x 11.39
= R 2 112 426.03

Chambers shown on pictures were constructed on the isolated points in Lebogang Ext 9 and 10 area. For the area to be isolated water meters were installed with chambers for protection.

Chambers with isolated meter during retrofitting

5.2.4 Pressure management in Lebohang

This exercise was done manually using pressure gauge to compare pressure in different points within the research area of Lebohang Ext 9 and 10.

The scope of work

The scope of work consisted of the following activities:

- Taking pressure readings in different zones in Lebohang Ext 9 & 10
- Pressure management recommendations for Lebohang Ext 9 & 10

Current situation was,

The Lebohang network has two pressure regimes as follows:

- 65 percent of the areas fall in the average pressure regime (3 – 5 bars)
- 35 percent of the areas fall in the Low-Pressure Regime (below 3 bars)

The water first flow from the low areas and then filled the entire upper area until the whole system is pressurised.

The average pressure during the day varies between (2 – 5 bars) and night between (3.5 – 6 bars).

The proposed solution

- The proposed solution involved modelling the Lebohang network until the low-pressure areas are eliminated and the high-pressure areas are minimised through the following actions:
- Installation of isolating valves
- Installation of booster pipelines
- Installation of PRVs

The following were the major outcomes of this modelling exercise:

- Only 10 percent of the areas fall below 2 bars
- 29 percent of the areas fall between 2 and 3.5 bars
- 52 percent of the areas fall between 3.5 and 5 bars
- Only 10 percent of the areas fall above 5 bars

To achieve the above results the following specific network interventions, are recommended to be carried out:

- Installation of isolating valves
- Installation of zonal meters
- Installation of three sections of a 110 Ø pipeline totalling 1500m in length.

The benefits of implementing the recommendations will be as follows:

- The Lebohang network be set for pressure management
- The network be ready for a detailed WC & WDM intervention as a whole
- The Lebohang area be sectorised into 4 DMAs (zones)
- Interventions per zone can then be carried on the zones exhibiting increased non-revenue water percentages for the months in question.
- Base level of the reduction in NRW can then be conducted. The subsequent reduction may depend on the pipeline replacement which is a long-term solution

Permission was granted to publish the images attached in this section. Furthermore, some of them feature myself during the data gathering.

Exhibit 1: Pressure near reservoir

Exhibit 2: Pressure measured at the lower point of Ext 9

Exhibit 3: Lebohang Clinic

Exhibit 4: Leaking isolation valve inside the pump station

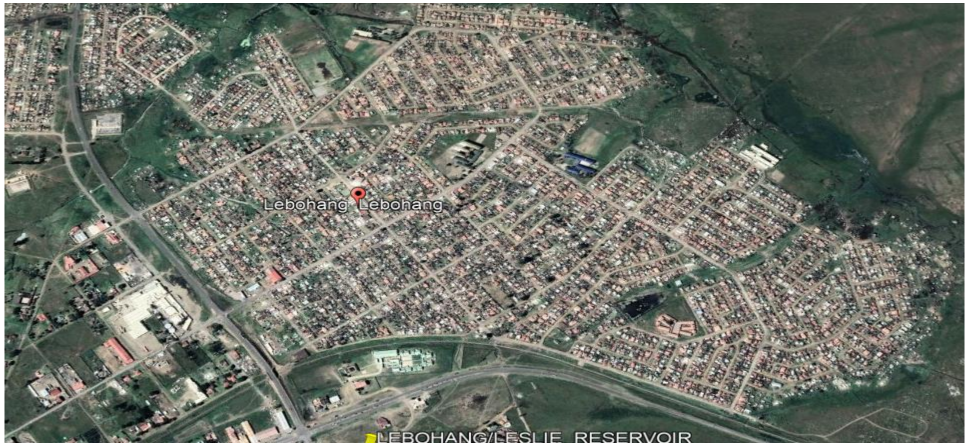
Exhibit 5: Pressure in Ext 10 measured (3 bars)

Exhibit 6: Pressure in Ext 10 measured (5 bars)

Exhibit 7: Pressure tower near reservoir

Damaged fence used as an illegal entrance

New replaced water meter



Lebohang Reservoir

5.2.5 Department of Water and Sanitation, Water Balance Table (Annexure A)

The available information was used to perform water balance. The purpose of water balance is to help the municipality to have a better understanding of the overall supply system, its losses and also assist in the preparation of specific intervention strategies and cost/benefit calculations. (Department of Water and Sanitation, Water Balance Table, May 2010)

The system input data were collected through bulk water meters and system output data were collected by means of domestic and commercial water meters. NRW was then calculated to check the validity of the existing information. The telemetry systems were found to be faulty and manual calculation was used to record the incoming/outgoing flows on the respective reservoirs to monitor the reservoir consumptions.

The attached annexure A, B & C contained the information relating to IWA information for Lebohang water supply. The Annexure A, B and C is attached showing the information relating to water balance.

Annexure A is the water balance calculation details

Annexure B is the Water and Sanitation IWA Annual Water Balance Spreadsheet - Baseline determination: Municipal Water Services.

Annexure C is the water balance definition of the key words used in the table.

The existing information was collected for three months, March, April and May 2017, for research purposes. The spreadsheet from the Department of Water & Sanitation was used for water balance calculations. To deal with Annexure B’s table, the municipal data with Rand Water data were collected and used for three consecutive months. The data plotted showed the results for Lebohang water system levels of NRW for three consecutive months as follows: (Annexure A)

- March 2017 the NRW level is 11 percent
- April 2017 the NRW level is 19.9%
- May 2017 the NRW level is 23.7% which this can increase based on the fact that the municipality is not monitoring the level and impact of NRW on a monthly basis.

The amount was quantified as estimation in rands as follow for the month of March 2017: (Annexure A)

- Out of 17975Kl from System Input Volume.
- The tariffs as per the Rand Water invoice R5.96/Kl.
- The NRW for only March 2017 becomes (17 975 * 0.11 = 1977Kl) then 1977kl x R5.96 = R11 782.00 as a loss to the municipality in one month and this multiply by 12 becomes R141 395.04 which is the money that were to be use for the improvement of the infrastructure for one financial year in one area.
- Municipal tariff cost as per municipal tariffs book for portable water becomes R21.25 (domestic water consumption for more than 61kl/month)
- The NRW becomes 1977 x R21.25 = R42 011.25 as a loss to the municipality in one month and this multiplied by 12 becomes R504 135.

5.2.6 Colour coded zoning per priority (Annexure I)

Zoning area was used to divide the area into four workable area. Hence, the objective of optimisation. The idea of zoning works better in relation to limited budget and prioritisation of the zoning areas.

The information collected was plotted against the four zonal areas in Lebohang Ext 9 & 10 and colours were used to identify the zonal areas (Annexure I).

- The brown area - High water pressure with high water complaints. This area becomes a first priority area compares to other areas.
- The Blue area – High to medium water pressure. This area becomes a second priority area compares to other areas.
- Red area – Medium to low water pressure with low complaints recorded. This area becomes a third priority area compares to other areas.
- Green area – Medium to low water pressure with clinic and businesses around it. Low complaints recorded. This area becomes a fourth priority area compares to other areas.

5.2.7 Summary of research findings

The responses obtained based on observations, interviews and site visits reveal the following:

- There is a lack of knowledge in most stakeholders participating in the topic of NRW
- Poor planning in addressing water losses, which paints a picture of prediction or estimation in budgeting for NRW
- Poor maintenance plan, which affects infrastructure development
- Priorities that need more attention than others in budgeting of municipal infrastructure
- Shortage of resources forces the maintenance team to adopt a culture of reactive maintenance rather than planning maintenance
- Neglected pressure tower, which could be used to augment the pressure
- Damaged fence around the reservoir and pump station, which poses a risk even if there is a security guard in the area.

Capacity Building

Most of the staff members, including the meter readers and maintenance team, need to be trained to understand NRW and the community at large. It is important to engage with the community to refrain from the illegal activities like illegal connections, by-passes and tempering with meter readings. which hamper service delivery as expected.

CHAPTER SIX: Conclusion and Recommendations

Attention was drawn to some key findings in this research with highlights to have some recommendations both to the water systems in Lebohang and for future research work within the municipality.

6.1 A holistic Approach

It was recommended that the approach of zoning the system to manage the NRW be adopted. The approach was based on the assessment and measurement of area which was sectorised. All assumptions were based on scientific analysis of the situation and available information.

This research has shown that the zonal area gave a better focus and understanding to the most vulnerable zone than the assumption of blanket approach. Once the area was properly zoned and monitored using zonal water meters. The approach then becomes easy to focus on other factors which assisted in prioritisation of zones.

The research proved that the following played an important role in identifying the area as per the priority of choice.

6.1.1 Pressure management

The data collected on the system in four divided zone shows that the pressure varied from 2-5 bar. It was noted further that average pressure during the day varies between (2 – 5 bars) and night between (3.5 – 6 bars)

This means that water build up from the low areas and then filled the entire upper area until the whole system is pressurised. The whole area of Lebohang Ext 9 & 10 have a pressure pattern of 65 percent of the area which falls in the average pressure regime of 3 – 5 bars and the 35 percent of the areas fall in the low-pressure regime below 3 bars.

This has further been interpreted where the higher area has low pressure and lower areas has high pressure regime.

The area where the pressure was high such as in brown area (Annexure I) it was mostly where there are pipe burst and leakages more than the area with low pressure such as green area (Annexure I)

The brown area took first priority in zoning based on the facts that the area is experiencing more pressure than others. This further means that the infrastructure located in the brown zone is at the disadvantaged because of pressure according to the research, hence it became the first priority zone.

The proposal of modelling the entire network of Lebohang until the low-pressure areas are eliminated and the high-pressure areas are minimised it becomes relevant. The solution of installation of isolating valves, Installation of booster pipelines and installation of PRVs are key to balance the pressure of four divided zones.

6.1.2 Minimum night flow

The process of retrofitting played an important role in separating the before effects and after efforts in the zonal area. The MNF variance of 5.881 l/s proved that water loss need to be managed, monitored and zoned for better results in the system. MNF exercise further becomes one of the important factors that cannot be ignored when managing NRW. Zoning of MNF to a workable area was key to give an indication of where the problem might be in addressing the NRW.

6.1.3 Call Centre Information

The information of the call centre used painted and clear picture in pointing out which area is more problematic than the other. It has similarly showed that the brown zone area is the area of concern with high number of complains reported. Annexure F

6.1.4 Assets register.

In a similar manner the asset registers also indicated that Lebohang infrastructure is old and need to be replaced or maintained. Annexure G

6.1.5 Non-Revenue Water

The NRW of Lebohang Ext 9 & 10 was achieved by means of using the three months (March 2017 to May 2017) data collected from finance at GMM. Annexure A shows the table with information used to calculate the NRW. The NRW was calculated for three months as shown in Annexure A.

6.2 Prioritisation of activities to be carried out.

Data was collected in conducting a comparative analysis in zonal areas with a view to draw similarities and contrasts.

Lebohang Extension 9 & 10 was divided into four manageable areas and summarised as follows.

- The brown area - High water pressure with high water complaints. This area became a first priority area compares to other areas. (Annexure I)
- The Blue area – High to medium water pressure. This area becomes a second priority area compares to other areas. (Annexure I)
- Red area – Medium to low water pressure with low complaints recorded. This area becomes a third priority area compares to other areas. (Annexure I)
- Green area – Medium to low water pressure with clinic and businesses around it. Low complaints recorded. This area becomes a fourth priority area compares to other areas. (Annexure I)

In addressing the challenges of Extension 9 and 10 per zonal areas of priority, the following recommendations are key.

- The brown area - high water pressure with high water complaints. This area became a priority area compared to other areas.
- Retrofitting of the brown zonal area per available budget.
- Addressing of the NRW related issues in the zonal area.

. It is further recommended that the pressure be balance by the following means:

- Installation of three sections of a 110 Ø pipeline totalling 1500m in length

This research also highlights the critical issues, which need to be addressed should a budget become available. The below recommendations should be addressed to resolve the pressure challenge exposed in the system.

- Implementation of the above scope of work, including the proposed budget estimated at R 3, 231, 881
- Implementation of an extensive Water Conservation and Water Demand Management strategy in line with WCWDM strategy
- Development of the water balance table per zone as well as an overall water balance table

6.3 The current research was set out to answer the following research questions:

Research question one:

What is the current model or method used to address non-revenue water at GMM?

The approach to addressing the level of NRW was previously not informed as most of the work was based on estimates. The method of zoning based on the collected information is proving that the areas have different challenges and can be prioritised per available budget.

Research question two:

How has the current arrangement affected the overall performance of NRW at GMM in the zonal area?

The process of retrofitting proved that water was lost in various ways such as faulty meters, leaking toilet cisterns and pressurised water systems. The MNF results proves that water has been lost prior the implementation of the retrofitting process.

The pressure variance in the system was observed being high in one zone and lower in another zonal area. NRW was carried out for three months and results are attached in Annexure A.

Research question three:

What benefit will the municipality have in implementing the proposed model in relation to planning of NRW at GMM?

The municipality will be in position to plan better with an idea of which areas need to be prioritised. The budget can be easily rein fenced for such an activity as they are clearly stipulated. The blanket approach should be easily eliminated, and focus can be on the affected areas per priority. Estimating the leakage in the network of zonal area in rands.

6.4 Conclusion

The research manage to demonstrate the importance of sectorisation by achieving the DMA in Lebohang Ext 9 and 10. It has further manage to calculate the percentage of NRW in the zone with some recommendations.

The following are noted in concluding the research:

Zonal area is the method that gets ignored by municipalities as it is not popular method however is the best and economical.

The four divided zonal areas came up with different results where similarities and contrast are outlined. The zonal areas can be prioritised and attended depending on the budget availability when planning for the areas. The zonal method simplified the approach in which the problems can be addressed. The NRW gets more realistic and more understandable in a zonal area.

6.5 Recommended Future Research work.

The current research only covered Lebohang Ext 9 and 10 and future research can cover the entire town and townships within the judistriction of GMM under the topic of management of NRW.

The recommended stakeholders for future works are:

- The Department of Water & Sanitation
- The customers or community members of Lebohang
- Management (top officers) dealing with water infrastructure
- The technical teams (technicians, plumbers, meter-readers)
- The commercial consumers (Businesses affected)
- Rand Water, as a water service provider

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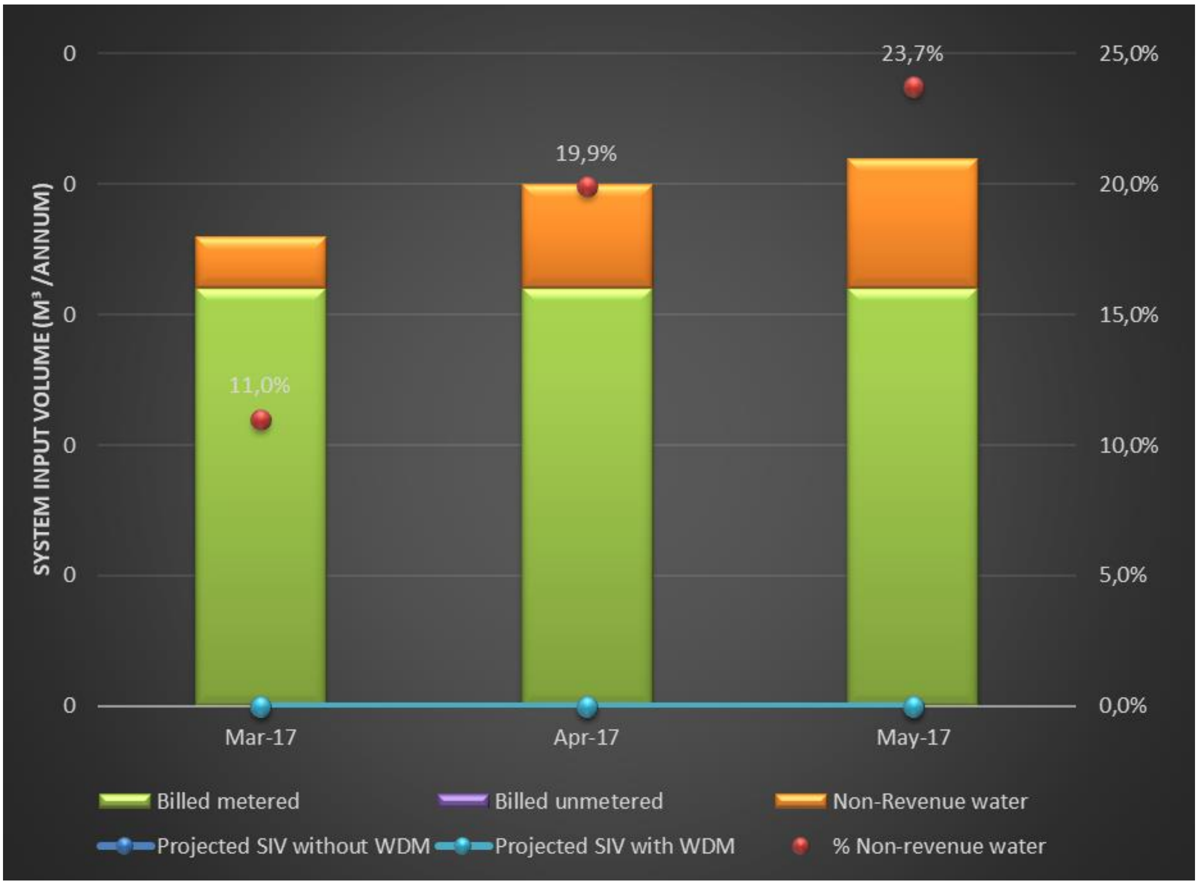
ANNEXURES

ANNEXURE A

ANNUAL WATER BALANCE SPREADSHEET - Baseline determination: Municipal Water Services											
Province	*Mpumalanga*							Information supplied by:			WSA
District Municipality	*Gert Sibande District Municipality*							Name	*Percy Ntivana*		Yes
Municipal Code	*MP307*							Position	*Superintendant*		
Municipality	*Govan Mbeki Local Municipality*							Telephone	*27174302255*		Category
Water Supply System	*Leandra Water Supply System*							Cellphone	*27 826 219 511*		*A*
Supply System No. (1,2,3..)	*1*							E-mail	ntivanap@govanmbeki.gov.za		
Settlements	*Lebohang Ext 9 & 10*									Target	Target
	Year ending	Mar-17	Apr-17	May-17	Jun-17	Sep-17	Oct-17	Nov-17	Dec-17	Jun-18	Feb-18
Population served	**No**	**31 553**	**31 553**	**31 553**							
Households served	**No**	**9 015**	**9 015**	**9 015**							
Connections - total	**No**	**9 015**	**9 015**	**9 015**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Connections - metered	**No**	**9 015**	**9 015**	**9 015**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Domestic (and non-domestic)	No	**9 001**	**9 001**	**9 001**							
Non-domestic	No	14	14	14							
Connections - unmetered	**No**	0	0	0	0	0	0	0	0	0	0
Households / connection	**No**	**1,0**	**1,0**	**1,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**
Length of mains	**km**	2	2	2							
Connections / km	**No / km**	**4 293**	**4 293**	**4 293**							
Average system pressure	**m**	**55**	**55**	**55**	**55**	**55**	**55**	**55**	**55**	**55**	**55**
Time system pressurised	**%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Apparent losses	**%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**
Consumer meter age	%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
Illegal connections	%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%
Data transfer	%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%
System input volume	**kl/annum**	**17 975**	**19 975**	**18 910**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Own sources	kl/annum	0	0	0							
Other sources (Rand Water)	kl/annum	17 975	19 975	18 910	0	0	0	0	0	0	0
Authorised Consumption	**kl/annum**	**16 208**	**16 183**	**14 620**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Billed authorised	**kl/annum**	**16 000**	**15 990**	**14 435**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Billed metered	kl/annum	**15 760**	**15 750**	**14 200**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Domestic	kl/annum	15 260	15 330	13 500							
Non-domestic	kl/annum	500	420	700							
Export volume	kl/annum	0	0	0	0	0	0	0	0	0	0
Billed unmetered	kl/annum	240	240	235	0	0	0	0	0	0	0
Unbilled authorised	**kl/annum**	**208**	**193**	**185**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Unbilled metered	kl/annum	8	8	8							
Unbilled unmetered (Water tanker)	kl/annum	200	185	177							
Water Losses	**kl/annum**	**1 767**	**3 792**	**4 290**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Commercial / Apparent losses	**kl/annum**	**353**	**758**	**858**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Physical / Real losses	**kl/annum**	**1 414**	**3 034**	**3 432**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
UARL	**kl/annum**	**145 540**	**145 540**	**145 540**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Potential real loss saving	**kl/annum**	**-144 126**	**-142 506**	**-142 108**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Revenue water	**kl/annum**	**16 000**	**15 990**	**14 435**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Non-Revenue water	**kl/annum**	**1 975**	**3 985**	**4 475**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
% Revenue water		**89,0%**	**80,1%**	**76,3%**							
% Non-revenue water		**11,0%**	**19,9%**	**23,7%**							
% Water Losses		**9,8%**	**19,0%**	**22,7%**							

ANNEXURE B

Department of Water and Sanitation (DWS) IWA's Water Balance Model



ANNEXURE C

IWA WATER BALANCE SPREADSHEET
Baseline determination: Municipal Water Services

Water Balance Definitions

Modified IWA Water Balance

<table>
<tr><td rowspan="9">System Input Volume</td><td rowspan="4">Authorised Consumption</td><td rowspan="2">Billed Authorised Consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Free basic Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorised Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non Revenue Water</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorised Consumption</td></tr>
<tr><td>Customer Meter Inaccuracies</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer Meter</td></tr>
</table>

Apparent Losses

Apparent losses or commercial losses are made up from the unauthorised consumption (theft or illegal use), plus all technical and administrative inaccuracies associated with customer metering. While it should be noted that the apparent losses should not be a major component of the water balance in most developed countries, it can represent the major element of the total losses in many developing countries. A systematic estimate should be made from local knowledge of the system and an analysis of technical and administrative aspects of the customer metering system.

Authorised Consumption

Authorised consumption is the volume of metered (authorised metered) and/or unmetered (authorised unmetered) water taken by registered customers, the water supplier and others who are implicitly or explicitly authorised to do so by the water supplier, for residential, commercial and industrial purposes.

It should be noted that the authorised consumption also includes 'water exported' and, in some cases may include items such as fire-fighting and training, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, building water, etc. These may be billed or unbilled, metered or unmetered, according to local practice.

Billed Authorised Consumption

Billed authorised consumption is the volume of authorised consumption which is billed by the WSA and paid for by the customer. It is effectively the revenue water which, in turn, comprises:

- Billed Metered Consumption;
- Billed Unmetered Consumption.

Non-Revenue Water

NRW water is becoming the standard term replacing unaccounted-for water (UFW) in many water balance calculations and is the term recommended by the International Water Association in preference to UFW. It is a term that can be clearly defined, unlike the unaccounted-for water term which often represents different components to the various water suppliers. NRW incorporates the following items:

- Unbilled (metered or unmetered) Authorised Consumption;
- Apparent / Commercial Losses; and
- Real / Physical Losses.

Real Losses

Real losses are the physical water losses from the pressurised system, up to the point of measurement of customer use. In most cases, the real losses represent the unknown component in the overall water balance and the purpose of most water balance models is therefore to estimate the magnitude of the real losses so that the WSA can gauge whether or not it has a serious leakage problem. The real losses are calculated as the difference between the total losses and the estimated apparent losses.

System Input Volume

The system input volume (SIV) represents the potable volume input to the water supply system from the WSA's own sources, (measured at the water treatment works outlet), as well as any water imported from other sources – corrected for known bulk metering errors.

Unbilled Authorised Consumption

The unbilled authorised consumption is the volume of authorised consumption that is not billed or paid for. The level of unbilled authorised consumption will vary from WSA to WSA and in some areas, virtually all water is metered and billed in some manner with the result that the unbilled authorised consumption is zero.

Water Losses

Water losses are the sum of the real and apparent losses and are calculated from the difference between the SIV and the authorised consumption. In most countries, the water losses were also considered to be unaccounted-for water (UFW / UAW) although, the exact definition of the UFW can vary from country to country and is therefore not being used.

Apparent Losses

Illegal connections	%	Water Quality	Meter age and accuracy	%	Data transfer	%
Very high	10%	Very poor	> 10 years	10%	Very poor	9%
High	8%	Poor		8%	Poor	7%
Average	6%	Average	5- 10 years	6%	Average	5%
Low	4%	Good		4%	Good	3%
Very low	2%	Very good	< 5 years	2%	Very good	1%

% Apparent Losses = (% Illegal connections + % Water Quality & meter age + % data transfer)

Volume Apparent Losses = % Apparent losses * Water losses

ANNEXURE D

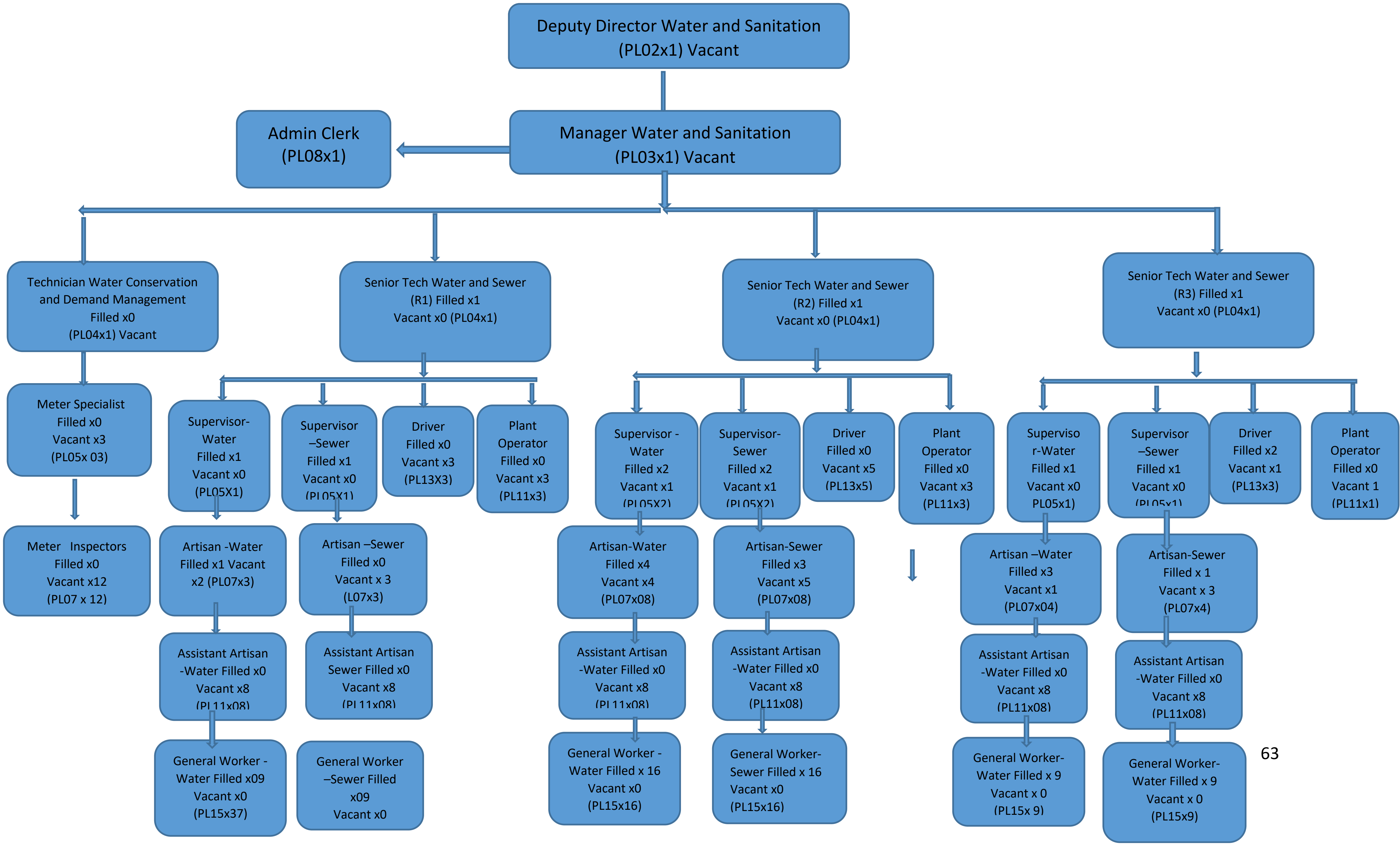
IWA WATER BALANCE SPREADSHEET
Baseline determination: Municipal Water Services

Water balance Calcualtion Details

A	Province	Province Name			
B	District Municipality	District Municipality's Name			WSA
C	Municipality	Municipality's Name	Municipal Code		Yes
D	Water Supply System	Name of the Water Supply System			Category
E	Water Supply System No. (1,2,3...)				B1
F	Settlements	Main demand centres in municipality			
G	Year	Data always based on rolling 12 months.			

H	Input Data	Population served	No	Population served at RDP or higher. Figures obtained from StatsSA, WSDP or DWA NIS
I		Households served	No	Households served at RDP or higher. Figures obtained from StatsSA, WSDP or DWA NIS
J		Connections - total	No	Calculated = K (Connections metered) + N (Connections unmetered)
K		Connections - metered	No	Calculated = L (Domestic) + M (non-domestic)
L		Domestic (and non-domestic)	No	All metered connections to domestic and non-domestic properties. Usually obtained from WSDP or finance dept.
M		Non-domestic	No	All metered connections to non-domestic properties if available and not included in L
N		Connections - unmetered	No	All unmetered connections. Obtained from WSDP.
O		Households / connection	No	Calculated = I (Households served) ÷ J (Connections - total)
P		Length of mains	km	Length of reticulation mains. Obtained from WSDP
Q		Connections / km	No / km	Calculated = J (Connections) ÷ P (Length of mains). Average = 50, Low cost housing areas up to 100.
R		Average system pressure	m	Average system pressure
S		Time system pressurised	%	Average percentage time the system is pressurised.
T		Apparent losses	%	Calculated = U (Meter age) + V (Illegal connections) + W (Data transfer error). Use 20% if no better info.
U		Consumer meter age	%	2% Good water & meters < 5 years to 10% for poor water & meters > 10 years. See table under definitions
V		Illegal connections	%	2% low percentage illegal connections to 10% for high percentage illegals. See table under definitions
W		Data transfer	%	1% Good data transfer to 9% for poor data transfer. See table under definitions
X	Water Balance Calculations	System input volume	kl/annum	Calculated = Y (own sources) + Z (other sources)
Y		Own sources	kl/annum	Potable water obtained from own surface and/or ground water resources
Z		Other sources	kl/annum	Potable water purchased from bulk water service providers, other municipalities, private institutions, etc.
AA		Authorised Consumption	kl/annum	Calculated = AB (Billed authorised) + AH (Unbilled authorised)
AB		Billed authorised	kl/annum	Calculated = AC (Billed metered) + AG (Billed unmetered)
AC		Billed metered	kl/annum	Calculated = AD (Domestic) + AE (Non-domestic) + AF (Export volume)
AD		Domestic (& non-domestic)	kl/annum	Total volume water, for past 12 months, metered and billed to domestic (& non-domestic) consumers
AE		Non-domestic	kl/annum	Total volume water, for past 12 months, metered and billed to non-domestic consumers
AF		Export volume	kl/annum	Total volume water, for past 12 months, metered and billed to other systems / municipalities
AG		Billed unmetered	kl/annum	Total volume water, for past 12 months, unmetered but billed to consumers.
AH		Unbilled authorised	kl/annum	Calculated = AI (unbilled metered) + AJ (unbilled unmetered)
AI		Unbilled metered	kl/annum	Total volume water, for past 12 months, metered but unbilled to consumers. Usually own use.
AJ		Unbilled unmetered	kl/annum	Total volume water, for past 12 months, unmetered and unbilled to consumers. Usually maintenance & fire
AK		Water Losses	kl/annum	Calculated = X (System Input Volume) - AA (Authorised Consumption)
AL		Commercial / Apparent losses	kl/annum	Calculated = AK (Water losses) x T (Percentage apparent loss)
AM		Physical / Real losses	kl/annum	Calculated = AK (Water losses) - AL (Commercial loss)
AN		UARL	kl/annum	Calculated = (18 x P (mains) + 0.8 x J (Connections) x R (Pressure) x S (time pressurised) x 365 ÷ 1000
AO		Potential real loss saving	kl/annum	Calculated = AM (Physical loss) - AN (UARL)
AP		Revenue water	kl/annum	Calculated = AB (Billed Authorised)
AQ		Non-Revenue water	kl/annum	Calculated = X (System Input Volume) - AP (Revenue water)
AR		Projected SIV without WDM	kl/annum	Projected demand without implementing WDM. Align with Reconciliation, All Town Studies or other.
AS		Projected SIV with WDM	kl/annum	Projected demand with implementing WDM. Align with Reconciliation, All Town Studies or other.
AT	Source of information			Source of information

ANNEXURE E


Deputy Director Water and Sanitation (PL02x1) Vacant
Manager Water and Sanitation (PL03x1) Vacant
Admin Clerk (PL08x1)
Technician Water Conservation and Demand Management Filled x0 (PL04x1) Vacant
Senior Tech Water and Sewer (R1) Filled x1 Vacant x0 (PL04x1)
Senior Tech Water and Sewer (R2) Filled x1 Vacant x0 (PL04x1)
Senior Tech Water and Sewer (R3) Filled x1 Vacant x0 (PL04x1)
Meter Specialist Filled x0 Vacant x3 (PL05x 03)
Meter Inspectors Filled x0 Vacant x12 (PL07 x 12)
Supervisor-Water Filled x1 Vacant x0 (PL05X1)
Supervisor –Sewer Filled x1 Vacant x0 (PL05X1)
Driver Filled x0 Vacant x3 (PL13X3)
Plant Operator Filled x0 Vacant x3 (PL11x3)
Artisan -Water Filled x1 Vacant x2 (PL07x3)
Artisan –Sewer Filled x0 Vacant x 3 (L07x3)
Assistant Artisan -Water Filled x0 Vacant x8 (PL11x08)
Assistant Artisan Sewer Filled x0 Vacant x8 (PL11x08)
General Worker -Water Filled x09 Vacant x0 (PL15x37)
General Worker –Sewer Filled x09 Vacant x0
Supervisor -Water Filled x2 Vacant x1 (PL05X2)
Supervisor-Sewer Filled x2 Vacant x1 (PL05X2)
Driver Filled x0 Vacant x5 (PL13x5)
Plant Operator Filled x0 Vacant x3 (PL11x3)
Artisan-Water Filled x4 Vacant x4 (PL07x08)
Artisan-Sewer Filled x3 Vacant x5 (PL07x08)
Assistant Artisan -Water Filled x0 Vacant x8 (PL11x08)
Assistant Artisan -Water Filled x0 Vacant x8 (PL11x08)
General Worker -Water Filled x 16 Vacant x0 (PL15x16)
General Worker-Sewer Filled x 16 Vacant x0 (PL15x16)
Supervisor-Water Filled x1 Vacant x0 PL05x1)
Supervisor –Sewer Filled x1 Vacant x0 (PL05x1)
Driver Filled x2 Vacant x1 (PL13x3)
Plant Operator Filled x0 Vacant 1 (PL11x1)
Artisan –Water Filled x3 Vacant x1 (PL07x04)
Artisan-Sewer Filled x 1 Vacant x 3 (PL07x4)
Assistant Artisan -Water Filled x0 Vacant x8 (PL11x08)
Assistant Artisan -Water Filled x0 Vacant x8 (PL11x08)
General Worker-Water Filled x 9 Vacant x 0 (PL15x 9)
General Worker-Water Filled x 9 Vacant x 0 (PL15x9)

ANNEXURE F

GMM CALL CENTRE REPORT

Created: 2017/03/01 12:11:43 PM MARCH 2017													
Item	**Complaint #**	**Assigned To**	**Complainant Name**	**Address**	**Mobile #**	**Complaint Type**	**Complaint description**	**Capture Date**	**Capture Time**	**Completed Date**	**Completed Time**	**Standby Name**	**Town**
96	153084	NTOMBI NKHOMA	WARD COMMITEE SESI	1197 1160 EXT 9	0711902172	W05	Water Connection: 15/20MM	2017/02/20	10:41			Sabelo	LESLIE
685	152324	MARIA MALAZA	MTHEMBU	3837 X 10	0793271196	W03	WATER METER LEAKING	2017/02/02	10:45				LESLIE
768	152927	MARIA MALAZA	WINNIE	1763 EXT 10	0818845125	W03	WATER METER LEAKING	2017/02/16	15:27			SABELO	LESLIE
Created: 2017/04/02 04:16:36 PM APRIL 2017													
Item	**Complaint #**	**Assigned To**	**Complainant Name**	**Address**	**Mobile #**	**Complaint Type**	**Complaint description**	**Capture Date**	**Capture Time**	**Completed Date**	**Completed Time**	**Standby Name**	**Town**
57	154433	NTOMBI NKHOMA	ROSINA	LEBOHANG LIBRIRY	0176830171	W04	NO WATER	2017/03/27	07:53			Sabelo	LEANDRA
68	154015	MILDRED KHUMALO	MBATHA	2480EXT 10	0608718154	W03	WATER METER LEAKING	2017/03/15	11:20				LESLIE
339	154237	MARIA MALAZA	MORIS	3924 X 10	0728424627	W03	WATER METER LEAKING	2017/03/22	10:12				LESLIE
340	154270	MARIA MALAZA	MORRIS	2770 EXT 10	0728424627	W03	WATER METER LEAKING	2017/03/23	07:32			Sabelo	LESLIE
341	154327	NTOMBI NKHOMA	MORRIS	3939 EXT 10	0728424627	W03	WATER METER LEAKING	2017/03/24	14:16			Sabelo	LESLIE
528	154204	MARIA MALAZA	LUCKY	1234 EXT 9	0764863082	W03	WATER METER LEAKING	2017/03/21	12:35			SABELO	LESLIE
604	154033	MILDRED KHUMALO	NOMVULA	EXT 9,1367	0782270351	W03	WATER METER LEAKING	2017/03/15	17:24			Nhlanhla	LESLIE
691	154456	NTOMBI NKHOMA	SIBANYONI	3812 EXT 10	0793271196	W16	WATER PIPE BURST CLOSE VALVE FOR CUSTOMER	2017/03/27	09:45			Percy	LESLIE
1 APRIL TO 2 MAY 2017													
Item	**Complaint #**	**Assigned To**	**Complainant Name**	**Address**	**Mobile #**	**Complaint Type**	**Complaint description**	**Capture Date**	**Capture Time**	**Completed Date**	**Completed Time**	**Standby Name**	**Town**
	154867	MARIA MALAZA	MORIS	EXT 10,3678	0728424627	W03	WATER METER LEAKING	2017/04/05	15:56	2017/04/23 9:11 AM			LESLIE

ANNEXURE G

SUMMARY OF ASSET REGISTER

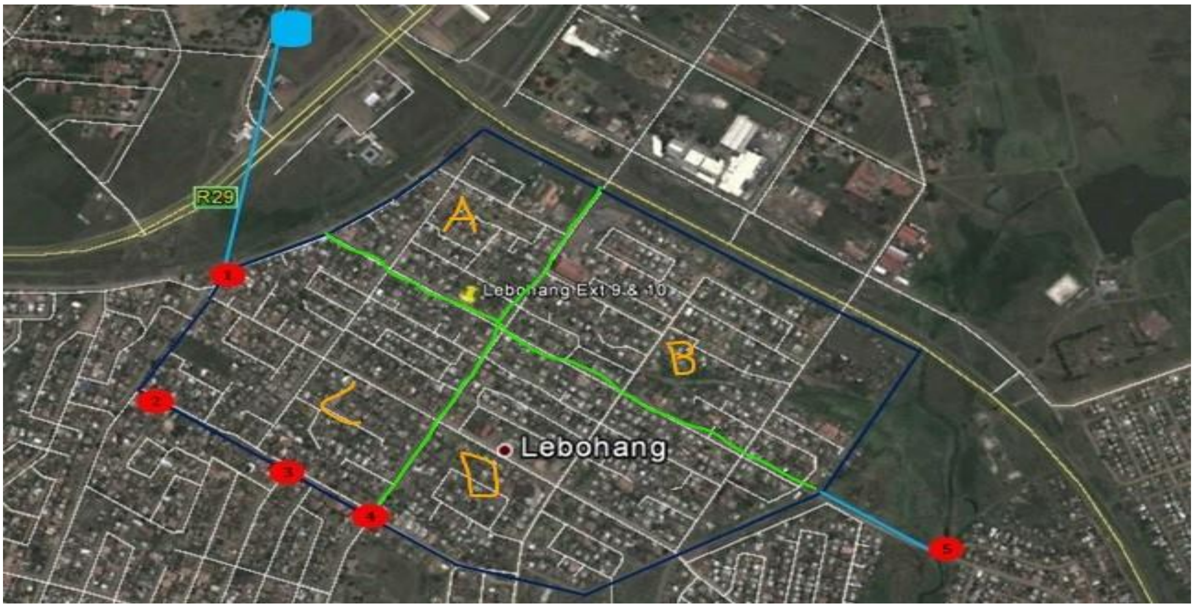
		CARRYING VALUE	COST					
		CARRYING VALUE - AS AT 30 JUNE 2015	CLOSING BALANCE 30 JUNE 2015	NEWLY IDENTIFIED ASSETS AT FAIR VALUE	ADDITIONS 2015/2016	DISPOSAL 2015/2016	TRANSFER 2015/2016	CLOSING BALANCE 30 JUNE 2016
INFRA								
	ROADS AND STORMWATER	479 210 580,29	1 807 846 955,33	-	3 631 001,03	-2 226 505,09	-	1 809 251 451,27
	ELECTRICITY	192 674 699,58	960 263 500,34	-	-	-243 763,01	2 205 358,00	962 225 095,33
	AIRPORT	50 795,32	337 450,00	-	-	-	-	337 450,00
	WATER	266 404 742,34	868 226 090,22	-	6 636 374,60	-720 550,29	85 706,02	874 227 620,55
	SEWERAGE	307 515 211,40	768 623 629,72	-	129 730,14	-	25 499 258,75	794 252 618,61
	CEMETERY	11 364 167,32	36 678 731,15	-	-	-	-	36 678 731,15
	Total	**1 257 220 196,24**	**4 441 976 356,76**		**10 397 105,77**	**-3 190 818,39**	**27 790 322,76**	**4 476 972 966,91**
	Register	1 257 220 196,24	4 441 976 356,75	-	10 397 105,77	(3 190 818,39)	27 790 322,76	4 476 972 966,90
	Difference	0,00	0,01		-	0,00	-	0,01

	2016 AFS	1 254 000 641,46	4 428 311 515,42		10 397 105,77	(3 190 818,39)	27 790 322,76	4 463 308 125,57
	Difference	3 219 554,78	13 664 841,33	-	0,00	(0,00)	0,00	13 664 841,33

ACCUMULATED DEPRECIATION				
CLOSING BALANCE 30 JUNE 2017	**DEPRECIATION 2017/2018**	**ACCUMULATED DEPRECIATION ON DISPOSAL 2017/2018**	**ACCUMULATED DEPRECIATION ON TRANSFERS 2017/2018**	**CLOSING BALANCE 30 JUNE 2018**
1 401 968 350,70	38 763 389,74			1 440 731 740,45
783 029 293,53	20 239 211,30			803 268 504,82
311 330,58	7 831,15			319 161,73
613 396 827,69	26 140 309,63			639 537 137,32
489 384 297,17	31 047 797,95			520 432 095,13
25 264 389,23	882 569,81			26 146 959,04
3 313 354 488,90	**117 081 109,59**	**-**	**-**	**3 430 435 598,49**
3 313 354 488,90	117 081 109,59			3 430 435 598,50
0,00	-0,00	-	-	-0,01

ANNEXURE H

Installation of Zonal Meters



ANNEXURE I

Coloured coded zones

ANNEXURE J

Questionnaires for staff members of GMM

TEAM	Questions asked,	Findings on Interview	Remarks
Manager Water & Sanitation	What types of challenges experienced during the period of a water pipe burst or leakage. What is your recommendation	Delay in attendance of complain due to shortage of the resources.	Operation and Maintenance Plan need to be developed to address and prioritise the challenges
Water Superintendent	What types of challenges experienced during the period of a water pipe burst or leakage. What is your recommendation	Shortage of the resources. Shortage of special material in place to replace asbestos pipe	
Artisan Plumber x 3	What types of challenges experienced during the period of a water pipe burst or leakage. What is your recommendation	Lack of training for emergency responses. Shortage of the resources. Need to educate community about water losses and water scarcity	
Lab Technician	What types of challenges experienced during the period of a water pipe burst or leakage. What is your recommendation	High turbidity to the consumer taps especially those near the pipe burst	Flushing of the water pipeline after fixing the pipe burst.
Lebohang Cllr	What types of challenges experienced during the period of a water pipe burst or leakage. What is your recommendation	The team takes too long to address the challenges. Water is being lost a lot while the team is making means to address the challenge.	Prioritise budget to address the challenges that are causing delays