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THE IMPACT OF APPLICATION OF GIS TECHNOLOGY ON NON-REVENUE WATER LEVELS: A CASE STUDY OF NAROK WATER AND SEWERAGE SERVICES COMPANY.

BY

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F56/6811/2017

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A project report submitted in partial fulfillment of the requirements for the Degree of Master of Science in Geographic Information System in the Department of Geospatial and Space Technology of the University of Nairobi.

May 2019

Declaration

I Ronoh Kennedy, hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other university.

Ronoh Kennedy	……..	……..
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The project has been submitted for examination with my approval as University Supervisor.

Dr. - Ing. S.M. Musyoka	……..	……..
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Acknowledgement

Appreciation goes to Mr. Tarkash, Technical Manager NARWASSCO, for the great support and provision of most data and information for the development of this Research Project.

Let me also thank Mr. Stanley Kuyioni the Managing Director NARWASSCO for giving me a chance to use the company as a case study of my research project and allowing me to use the data that I required for successful completion of my study.

I will also not forget my family, my wife and my daughter for the humble time, and emotional support they gave me during the period I was doing this research project.

My Supervisor, Dr.-Ing. S.M. Musyoka, was also of great help in guiding me throughout my entire period of development and completion of my research project, let me also thank him very much.

Abstract

Non-Revenue Water (NRW) is the water loss that does not earn income/revenue to a Water Service Provider(s) and is lost through physical losses for example leakages/burst in the distribution system or commercially through water theft, malfunctioned water meters, and many others. NRW has been treated as a very serious issue in Kenya, and it is one of the key performance indicator used by Water Service Regulatory Board (WASREB) to rank the performance of the Kenya Water Service Providers.

Geographic Information System (GIS) technology provides many powerful tools that allow integration of many types of data (Raster and Vector) and also analyses spatial locations. Narok Water and Sewerage Services Company (NARWASSCO) adopted the use of GIS technology in the year 2015 for mapping of its distribution network which has really aided in management of NRW in the company hence there was a need for assessment of the impact of the technology on NRW management in relation to the NRW levels (Percentage water lost) to help in decision making.

A well-defined small area called District Metered Area (DMA) was chosen, then the quantifiable NRW management activities were identified from when the District Metered Area, was formed as well as the NRW levels. The changes were then assessed using a standard deviation calculated using Statistical Package for the Social Sciences (SPSS). The standard deviations were used to assess the intensity of change in NRW management activities and NRW levels for years 2013 to 2018 in relation to the improvement made on these activities after GIS implementations. The standard deviations were then used to show the impact of GIS technology on NRW levels taking into consideration any other factors of which, according to this study, it was mainly the number of connections (coverage). The identified NRW management activities were considered to affect the NRW levels differently; hence, the standard deviation for each was interpreted differently, which gave either positive or negative standard deviation. It was found that there was a significant standard deviation in NRW levels after implementation of GIS as compared to before, which depicted a high impact of the technology. The NRW reduced from 56% in 2013 to 25% in 2018, which is an acceptable level. It was also the same with all NRW management activities, which showed a positive standard deviation in relation to NRW levels. It can, therefore, be concluded that GIS technology has brought about a significant impact on the management of NRW in NARWASSCO and has made the NRW management easy and cost-effective in that most of the things can now be done in-office by anyone without even going to the field. It is therefore critical for any Water Service Provider(s) to adopt the GIS technology to help in the management of NRW to an acceptable level set by WASREB of 25%.

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Nomenclature

CBD	Central Business District
DMA	District metered Area
GIS	Geographic Information System
IWA	International Water Association
NARWASSCO	Narok Water and Sewerage Services Company
NRW	Non-Revenue Water
SPA	Service Provision Agreement
SPSS	Statistical Package for the Social Sciences
UFW	Unaccounted For Water
WASREB	Water Services Resource Authority Board
WRA	Water Resource Authority
WSPs	Water Service Provider(s)
WWD	Water Works Development Agencies

CHAPTER 1: INTRODUCTION

1.1 Background

Water utilities, otherwise known as Water Services Providers (WSPs) according to the Water Act 2016, is mandated to provide water and sewerage services in their areas of jurisdiction or as stated in the license. They are established by County Governments which may be a public limited liability company established under the Companies Act, 2015 or other body providing water services as may be approved by the Water Service Regulatory Board in compliant with the standards of commercial Viability set out by the board. Water Service Regulatory Board (WASREB) according to the Act, is mandated to protect the interest and rights of consumers in the provision of water services. It also mandated to license the Water Service Provider(s) through the Service Provision Agreement (SPAs) and Keeps the register of all licensed WSPs in the country.

Water Works Development Agencies (WWDA) is a body which was established under the Water Act 2016, which was earlier called Water Services Boards (The Water Act, 2002). Its mandate mainly includes undertaking the development, maintenance and management of the national public waterworks within its area of jurisdiction, provide technical services to Water Service Provider(s) or County Governments on request. It also carries out the waterworks and provide water services as a water service provider, until such a time as responsibility for the operation and management of the waterworks are handed over to a County Government, joint committee, authority of county governments or water services provider within whose area of jurisdiction or supply the waterworks is located (The Water Act, 2016).

According to WASREB impact report No. 9 of 2016, there are currently 8 Water Works Development Agencies (WWWD) in Kenya which includes Athi, Tana, Northen, Rift Valley, Lake Victoria North, and Lake Victoria South. The jurisdiction of this board are established according to the catchment areas as defined by the Water Resource Authority (WRA)

Narok Water Sewerage Services Company (NARWASSCO) is a WSP within Narok County under Rift Valley Water Works Development Agency. It is the only WSP within the County providing water and sewerage services. Currently its serving two towns, that is Narok town and Ololulunga town. It was established in the year 2006 as a limited liability company under the water sector reforms enshrined in the Water Act of 2002. The company by then was to serve only Narok Town which had only 900 connections. According to the WASREB impact report No.9 of 2016, NARWASSCO has increased the service area

since then from 900 to approximately 5000 Connections at the end of the financial year 2017/2018 and is now categorized as medium.

NARWASSCO started the implementation of GIS technology in the year 2015 with the help of JICA Volunteers, before then the company used to have their distribution network in the hard-drawn hard copy maps. Understanding the distribution network for a water utility in terms of pipes locations, sizes, pipe materials used, appurtenances locations and types, customer meter locations and date of installations help in the management of NRW (JICA,2014). NARWASSCO has fully implemented the GIS technology in the mapping of all the water distribution network, however the impact of the use of GIS technology for supporting NRW Reduction activities has never been documented and or assessed if the technology has brought an impact on NRW levels (The percentage of treated water loss in the distribution system).

1.2 Problem Statement

Narok Water and Sewerage Services Company, as the only licensed Water service Provider in Narok County, has been losing a significant percentage of treated water which could have been used to serve a bigger population than what it's serving now. NARWASSCO currently serves Narok town with a population of approximately 38,653 according to the 2009 census. The company currently serves 28,450 as reported in the financial year 2017/2018, which makes approximately 75% of the total population.

A high NRW level is detrimental to the commercial viability of any Water Service Provider (WSP) which makes them not able to run its day to day activities (WASREB, Impact Report No.9 of 2016). NARWASSCO recorded an NRW level of 44% in the financial year 2016/2017 according to the WASREB impact report No. 9, 2016, which is almost half higher than the set benchmark level of 25%. GIS technology was implemented in the year 2015 and one of the reasons for its implementations was to assist in the management of the NRW in the company. Since the application of GIS technology by NARWASSCO, there has been no documentation on the impact of the technology on NRW levels and some of the activities that contribute to the management of NRW.

1.3 Objectives

The overall objective of this study was to assess the impact of the application of GIS technology on Non-Revenue Water levels in Narok Water and Sewerage Services Company.

The specific objectives of the study were:

1. To identify the changes in NRW management related activities before and after the application of GIS technology in relation to NRW levels in NARWASSCO.

2. To assess the changes in NRW level before and after GIS technology implementation in NARWASSCO.

1.4 Justification for the Study

NARWASSCO may use the findings of this study to review the Non-Revenue Water (NRW) management activities by use of GIS technology, which will guide in decision making on exploring additional capabilities of GIS. In addition, other WSPs and other bodies which provide water services may adopt the strategies documented in this study to improve on management of NRW using GIS technology.

The Water Service Regulatory Board (WASREB) and the Ministry of Water and Irrigation may also use the findings of the study to formulate policies regarding the management of NRW towards attaining the target NRW Benchmark of 25%. The study will also add to the existing body of knowledge from which other researchers would base their studies.

1.5 Scope of work

The study only focused on NARWASSCO as a Water Service Provider in Narok County and it only focused on one zone within Narok Town scheme which is referred to as District Metered Area (DMA-zoned area with a master meter to measure the water that serves the households in that area only). The DMA that was chosen was Central Business District situated within Narok Town Scheme Area. Calculation of NRW levels was based on the equation in Section 2.2 and the financial years that were considered were five which were from 2013/2014 to 2017/2018. NRW management activities were also quantified for assessment of changes in relation to overall NRW levels in the company by using the identified Zone for the five financial years only. The NRW management activities that were of focus included: Total number of tested meters, the total number of meters sealed, the total number of meters tested, the total number of burst and leakages reported and repaired and the total number of dilapidated pipes replaced. An additional factor of the total number of connections was also of focus. The impact of the GIS technology was assessed only using the standard deviation of all the NRW management activities as well as considering the one for the number of connections.

1.6 Organization of the report

This report is organized into five chapters, References, and Appendices:

- Chapter one.

  This chapter is composed of the following sub-chapters that

- Introduction_ introduces the topic of the study quoting the previous studies.
- Background_ introduces the area of study.
- Problem statement _ States the problem that the study intends to solve.
- Objectives_ States what have to be done to solve the problem.
- Justification of the study_ States why the study is important and why it has to be done.
- Scope of work _It gives the limit of the study. States what to be done and what not to be done.

- Chapter Two – The literature review.
  - Mainly covers the previous research that has been done on the subject and the caps that need to be filled.
- Chapter Three – Materials and Methods.
  - This chapter gives specific methods and materials that were used in the study, the way analysis was done and the presentation of the results.
- Chapter Four - Results and Discussions.
  - This chapter gives the results of the study and Discussions of the results.
- Chapter five – Conclusion and Recommendations.
  - This chapter gives the conclusion in relation to the objectives of the study and also gives the recommendations in relations to the results of the study.
- References
  - Gives the list of references that have been quoted or referred to in the report.
- Appendices
  - Gives additional information that could help in understanding the study.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

According to the World Bank which stated that the Non Revenue Water is a very huge problem in Water Provision in the developing countries, water lost through leakage is about 45 million m^3/day and roughly 30 million m^3/day is lost through commercial losses, of which if this could be translated to allocating 100 liters per person per day the 45 million m3/day of leakage could serve roughly half the total population not currently being served by water (Kingdom et. al, 2006). World Health Organization (WHO)/UNICEF Joint Monitoring Programme (JMP) indicates that in 2008, nearly 900 million people lacked improved drinking water supplies (WHO/UNICEF, 2010) which have has resulted to this population is highly prone to diseases which are brought about by unsafe drinking water and also a huge burden on low-income countries.

The World Bank estimates the total financial losses in developing countries to be about $5.8 billion per year of which if this could have been conserved, it could have lead to providing water at about one-half to one-third of the cost of water production from new capital plants (World Bank, 1992).

It is not achievable to eliminate all the NRW in a Water Utility, but according to World Bank reducing by half the current level of losses in developing countries appears a realistic target which could generate an estimated additional $2.9 billion in cash every year for the water sector and potentially service an additional 90 million people without any new investments in production facilities nor drawing further on scarce water resources (Kingdom et. al,2006).

A high NRW level that is in any water utility indicates a poorly run water utility that lacks the governance, the autonomy, the accountability, and the technical and managerial skills necessary to provide reliable service to their population (kingdom et. al,2006).

Frauendorfer and Liemberger (2010) note that utility owners or companies need to be made sufficiently aware that they are “sitting on a goldmine” and that they need to sensitize their staff by informing them about the level, causes and cost of NRW, along with the potential for improvement so that comprehensive NRW management plan can be supported by them. As they also put it NRW is a good indicator for water utility performance. According to this statement, NRWtherefore is the main measurement of the performance of any water service provider in terms of management of this scarce resource (Water).

2.2 Definition of NRW

Caroline (2014) defined NRW as the difference between the volume of water put into a water distribution system and the volume that is billed to customers which comprise of three components:

- Physical losses which comprise leakages from all parts of the distribution system and overflows at the utility's storage tanks. All this can be caused by poor operations and maintenance, and lack of active leakage control, and poor quality of underground assets i.e pipeline and other fittings
- Commercial losses are caused by customer meter under-registration or malfunctioning, data-handling errors, and theft of water in various forms
- Unbilled authorized consumption - water used by the utility for operational purposes, water used for firefighting and water provided for free to certain consumer groups.

It is a good practice to assess all the components of Non-Revenue Water (NRW) in a standard format, that is why IWA(International Water Association,2006) developed International Water Balance structure and terminology (Alegre et al, 2002).) as shown in Table 2.2.1.

Table 2.2.1: The International Water Balance

System Input Volume	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorized Consumption	Unbilled Metered Consumption	Non-Revenue Water
			Unbilled Unmetered Consumption	
	Water Losses	Commercial Losses	Unauthorized Consumption	
			Metering Inaccuracies and Data Handling Errors	
		Physical Losses	Leakage on Transmission and/or Distribution Mains	
			Leakage and Overflows at Utility's Storage Tanks	
			Leakage on Service Connections up to Point of Customer Metering	

Source: International Water Association, (2006)

IWA tried to break the NRW into components that can be able to be quantified as shown in Table 2.2.1. The equation below shows how to calculate the NRW.

$$NRW = Total\ System\ Input - Billed\ Authorized\ Consumption$$

Where

- ✓ *Total System Input is the total water produced and put into the system*
- ✓ *Billed Authorized Consumption is the total volume of water billed*

Source: International Water Association, (2006)

It can also be represented in percentage as:

$$\text{NRW Level} = \frac{(\text{Total system input} - \text{Billed Authorized Consumption})}{\text{Total System Input}} \times 100\%$$

Source: International Water Association, (2006)

Initially, the NRW was referred to as Unaccounted For Water (UFW) (Farley et al, 2003) which was defined as water that is lost and is not accounted for (Jeffcoate et al,1987). This was difficult to measure in that different people could interpret it differently and use different formats, it is because of this that IWA came up with the International Water Balance structure which fully defines all the components of NRW.

2.3 Non-Revenue Water management

Developing countries are still facing harder difficulties to cope with their water losses even though there are steps forward that have been made in developing both technical strategies and operational management in dealing with NRW (Kingdom et. al, 2006). A report done by the South East Asian Water Utilities Network (SEAWUN) analyzing NRW levels of 47 water utilities across Indonesia, Malaysia, Thailand, the Philippines, and Vietnam, showed a results of average NRW of 30 percent which is still high even though this strategies mentioned by Kingdom et. al, (2006) have been put in practice.

According to World Bank database on water utility performance (IBNET, the International Benchmarking Network for Water and Sanitation Utilities, at www.ib-net.org) which contains data of more than 900 utilities in 44 developing countries (Farley et. al, 2003). The water utilities covered by IBNET registered an average NRW of 35 Percent although according to Farley et. al, (2003) the actual figure for overall NRW levels in the developing world is probably higher ranging from 40–50 percent of the water produced. This shows that developing countries loss on average half the total water produced and put into the system. A poorly managed business which leads to losses of the product they deal with will not survive for long in the market, (Kingdom et. al,2006), this statement relates to our water utilities which are every day losing large amount of treated water of which a lot of resources have been used to produce it. As Frauendorfer and Liemberger (2010) referred to this lost water as a ‘Goldmine’, losing water daily means losing money and resources which will render water utilities not sustainable and lack efficiency in water service provision. When this ‘goldmine’ is lost, water treatment and distribution cost increase, water sales decreases which leads to the reduction in substantial capital which might have been used to increase water coverage and meet the ever-increasing world population that needs to be served with clean and safe drinking water. This

according to Frauendorfer and Liemberger (2010) leads to a vicious cycle that does not address the core problem as shown in figure 2.3.1

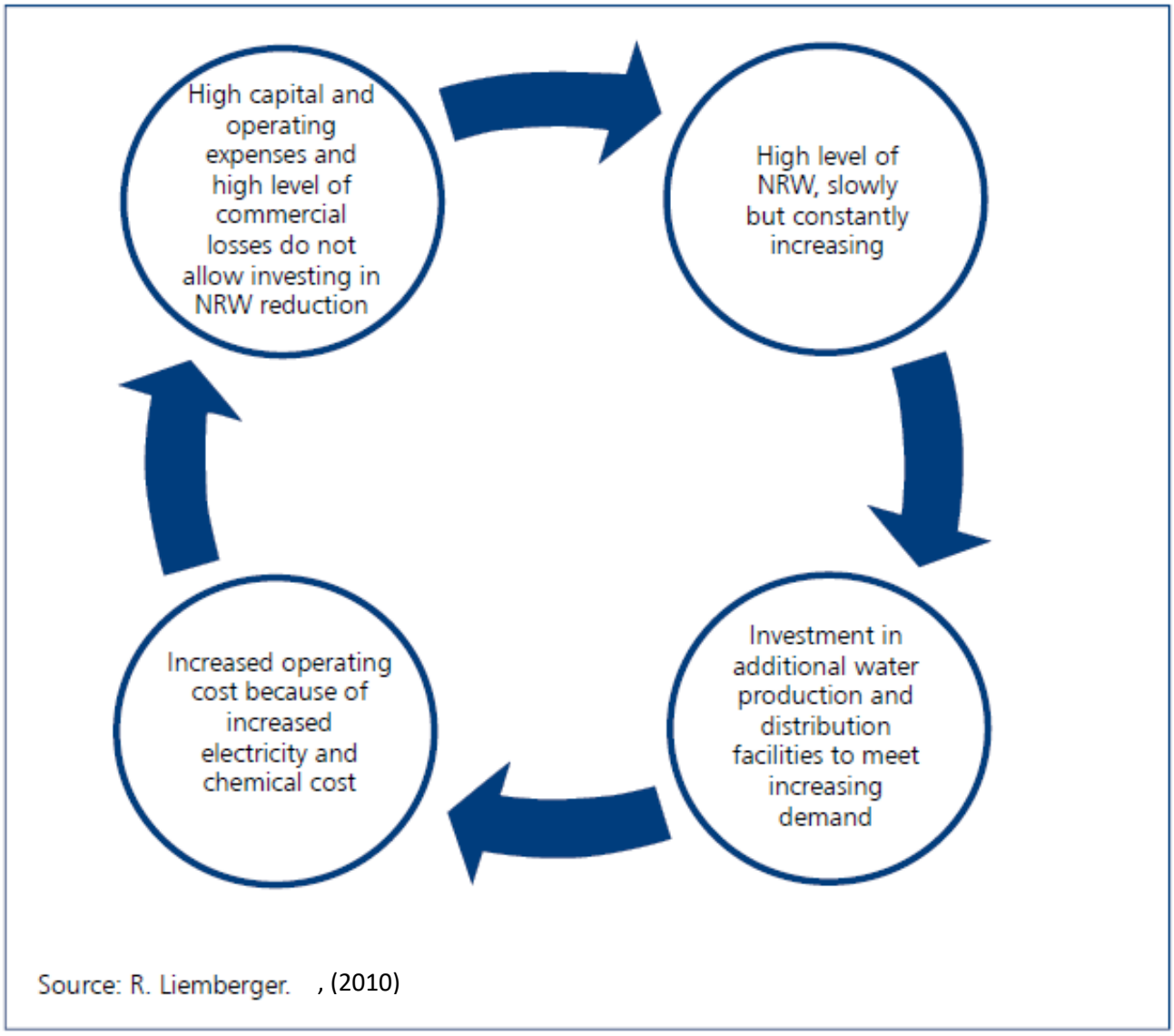

Figure 2.3.1: Vicious cycle of NRW, (2010)

Improving on the NRW levels means converting the above vicious NRW cycle into a virtuous cycle and therefore substantially improve the efficiency of any water utility.

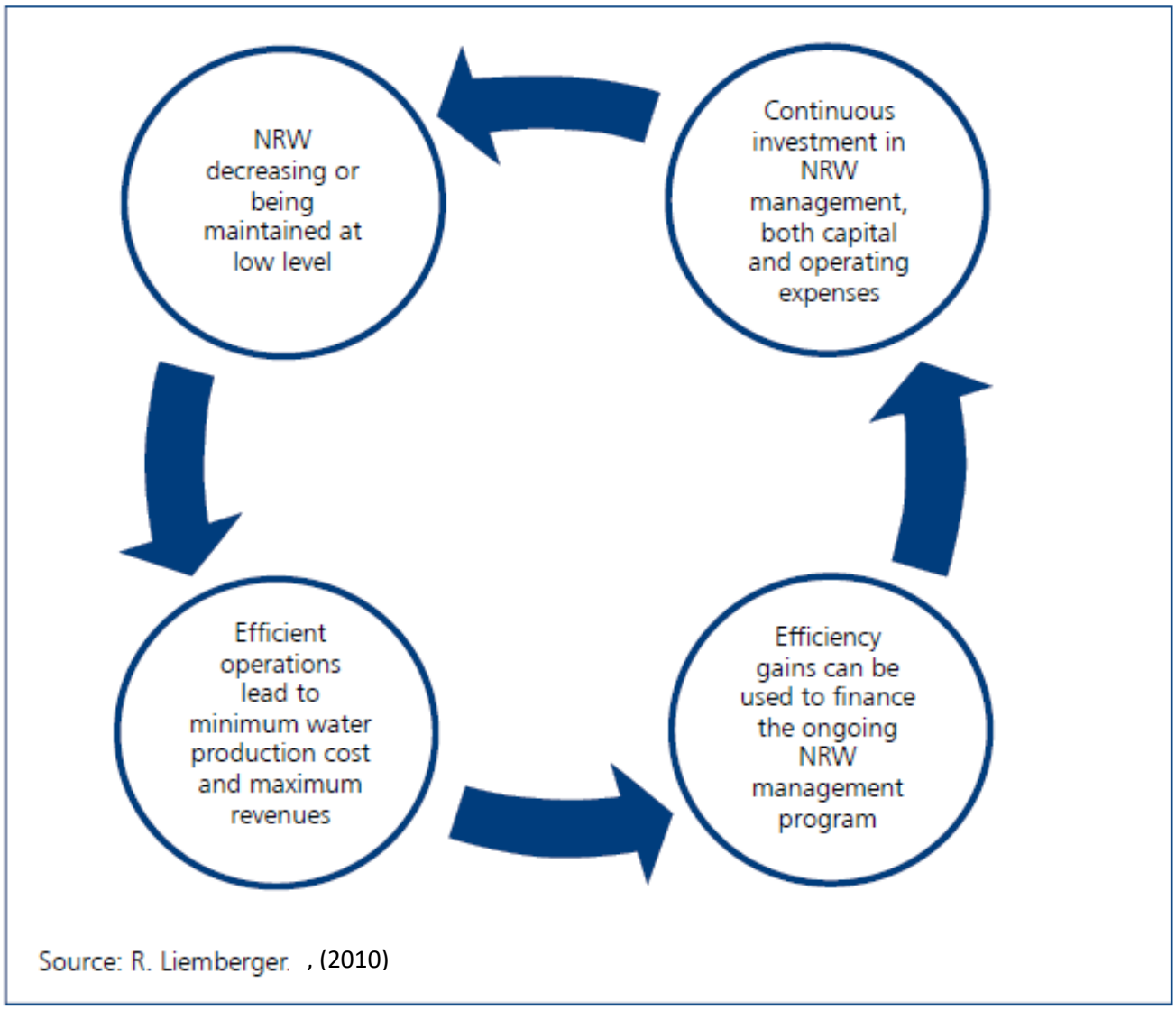

Figure 2.3.2: Virtuous cycle of NRW, (2010)

To attain this, therefore, there should be a political will and the full support of top management and in most cases, technical know-how at the utility level must also be improved (Frauendorfer and Liemberger, 2010). Some water utilities also may require outsourcing of experts for technical support if the staff does not have the technical know-how of what should be done for NRW management.

2.4 Non-Revenue Water in Kenya

Currently, NRW in Kenya has been treated as a very serious issue to address given that constitutional right of any Kenyan citizen to clean water is to be met. According to the WASREB impact report Issue No.10, the average NRW for all 88 Water Utilities in Kenya is 42% for the financial year 2016/2017 which is very high as compared to the benchmark of 25%.

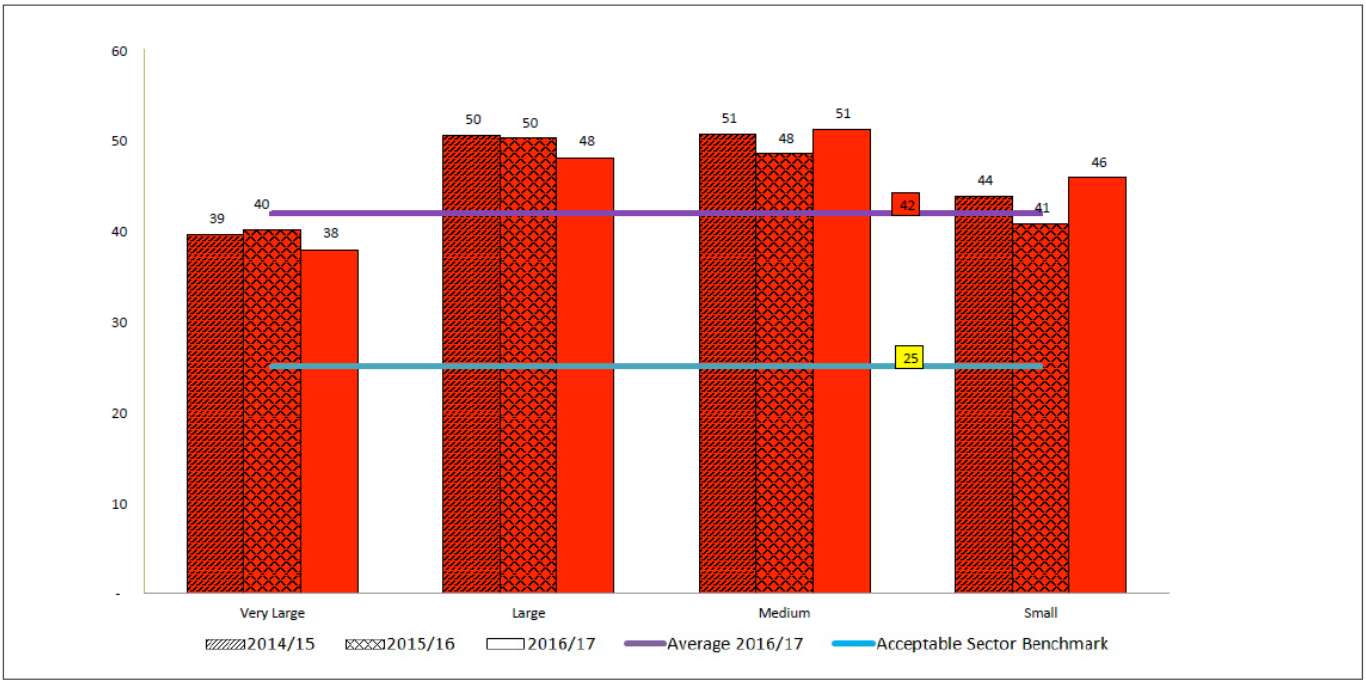

Figure 2.4.1: Non-Revenue Water in percentage (%)

Source: WASREB, 2018 IMPACT REPORT: A Performance Review of Kenya's Water Services Sector- 2015/2016 and 2016/17, Issue No. 10.

WASREB have categorized water utilities according to their sizes in terms of the population served i. e ranging from very large serving more than 35000 connections, medium category serving 5001 – 34999 connections and small category serving less than 5,000 connections.

According to Figure 2.4.1, the average Non-Revenue Water percentage of 42% was registered in the financial year 2016/2017 which when converted to monetary values is approximately 7.8 billion Kenya shillings. The report also continues to state that despite WASREB rolling out the NRW management guidelines, the uptake and implementation of NRW Management Standards have been very low. The main causes of this disturbing NRW levels according to the report include but not limited to :

- Use of Non-functional water meters.
- Use of fake water meters, pipes and any pipe fittings.
- Poor workmanship during the installation of meters, pipes, and fittings.

2.5 Water Balance

IWA defined an International Water Balance which is shown in figure 2.2.1, however, its components should be well for accurate calculation of NRW. According to Khin M.N, (2008) the following are steps to be followed in applying the IWA, (2006) water balance for NRW calculation.

a. **Determination of the System Input or Production Measure** - This is the measurement of the volume of water delivered into the distribution network which should be accurately metered to make the calculation of the annual system input should be a straightforward task. Ideally, the accuracy of the input meters is should be verified, using portable flow measuring devices or any other device.
b. **Authorized consumption measurement** – This category has two components, billed authorized consumption and unbilled authorized consumption. Billed authorized consumption includes billed metered consumption and billed un-metered consumption. Unbilled authorized consumption includes unbilled metered consumption and unbilled un-metered consumption.

The Design Manual Manual for Water Supply in Kenya (2005) recommends that only 5% of the water produced be used for cleaning/ backwashing water treatment plants Components of unbilled un-metered consumption should be identified and individually estimated.

c. **Determination of water Loss** - This is the NRW which include the commercial or apparent losses and physical or real losses (Ministry of Environment and Natural Resources, 2014).

2.6. GIS for Mapping Water Utility Infrastructure

GIS according to Esri Eastern Africa is defined as a computer-based system for gathering, managing and analyzing data. It also continues to state that it's able to integrate many types of data (Raster and Vector) and also analyses the spatial location and organizes layers of information into visualizations using maps and 3D scenes. This capability of GIS reveals deep insights into data which help users to make good decisions in any kind of work which it has been applied.

Any Water utility company needs to understand when what and where a particular thing is at any given time but without spatial data and tools for processing this data, they will not be able to manage most of their day to day activities that relate to spatial locations. GIS is a tool that has really helped the water utilities in management of most of its day to day activities while providing their water services to customers. For example, a customer whose water has been disconnected and have paid can be easily located if his/her location has been mapped and the reconnection of water will be done easily and within a very short time.

NRW is one of the factors that can be managed easily with the presence of spatial data, of which according to B. Charalambous (2007) spatial information of pipes networks, pressure distribution, faulty meters, low-quality meters as well as dilapidated network require urgent consideration when dealing with NRW management measures.

According to the research that was done by Kimathu D.M, (2014) which was a case study of Muranga Municipality showed that there is a need for spatially indexed data when dealing with curbing NRW in any water company if a target of 25% as set by WASREB is to be met. In this research, GIS was used to identify.

- Optimal routes – when attending to burst and leakages, the shortest route need to be identified to the valve(s) to be closed and also to the point where a burst and leakages have occurred.
- The Vulnerability of a region to the burst and leakages – changes in elevation which results in changes in pressure within a pipe distribution system need to be understood. This helped in identifying the kind of different materials that can be used in different zones in relation to the pressure.
- Pipe Network Prone to Bursts and Leakages – Burst record and locations can be used to assess the pipes prone to burst by assessing the frequent occurrence of burst in a given pipe.
- Connections served with long service lines – after mapping of the main lines and service lines, GIS was used to assess the difference with the number of bursts occurring in the long and short service lines.
- Pressure distribution within a zone –Pressure measured in pipes was used to come up with a pressure map to help in identifying the pipes or fittings that can sustain a certain pressure.
- Suitable locations for installing air releasing valves – To determine suitable locations for installing air valves, elevation data depicting the ground condition, slope data, pressure data as well as Euclidian distance of the pipe network were used.

The capability of GIS as stated above are mostly the main activities for NRW management as stated by Kimathu D.M, (2014) in his conclusion however the researcher did not show exactly how the application of this technology impacted on the NRW levels in his area of study.

CHAPTER 3: MATERIALS AND METHODS

3.1 Study area.

The study area was Narok County, Narok Town, Narok Water and sewerage Company (NARWASSCO)

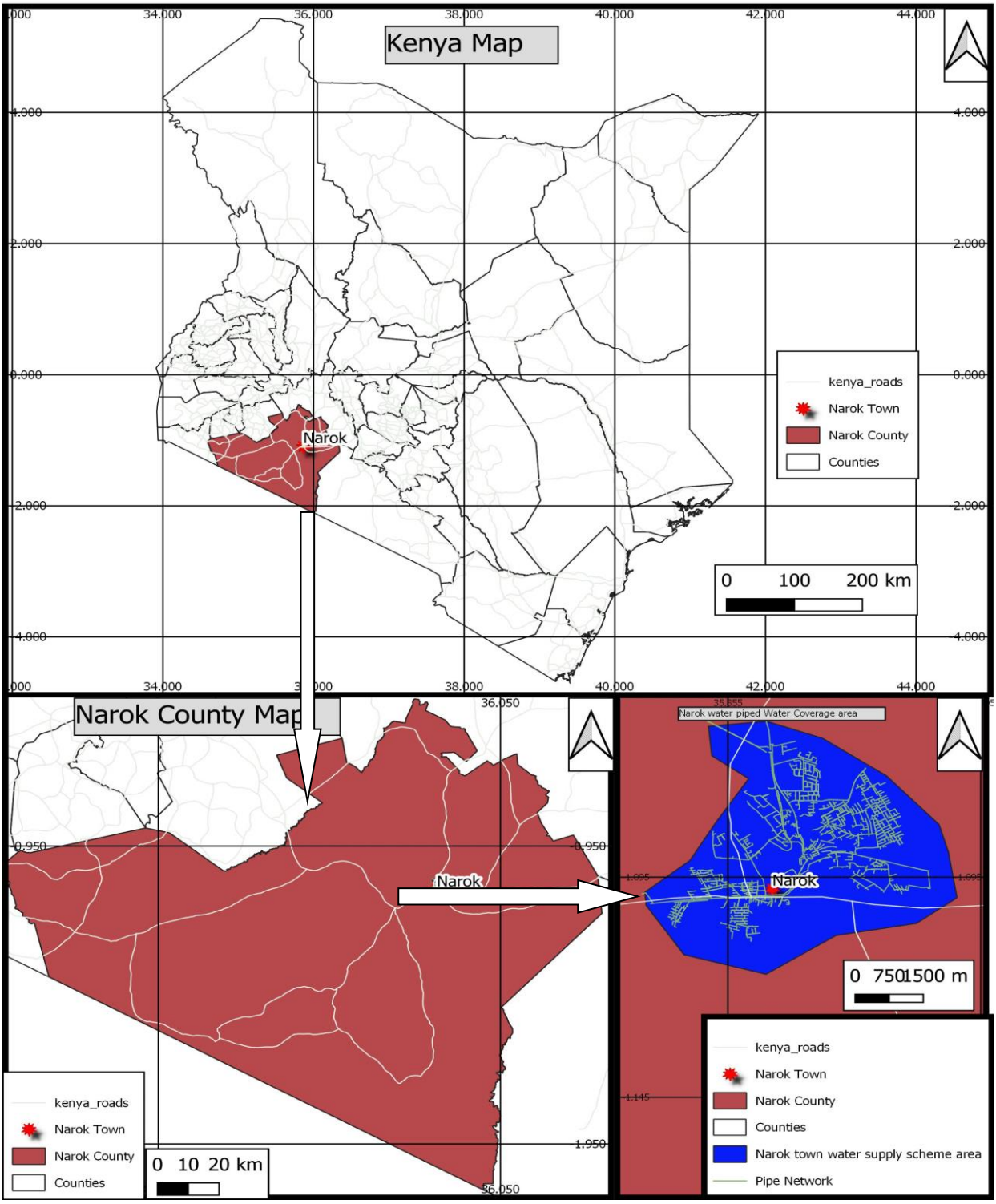

Figure 3.1.1 Study area (Narok Town)

Since the area of study was big, a small area within it was chosen to be used for the study. A well-defined area called District Metered Area (DMA) was identified from the available DMA's in the study area with the help of the company technical staff. The Central Business District (DMA) was chosen for the reasons that;

- ✓ The district metered area was the first to be formed hence data were available for 5 financial years as compared to others which were formed recently.
- ✓ It was fixed in terms of geographic coverage hence no much changes in the number of connections.
- ✓ All the data required were available and complete.

3.2 Data needs.

The data that were collected from included all the quantified NRW Management activities and NRW levels for five financial years 2013/2014, 2014/2015, 2015/2016 and 2017/2018 as in Appendix D2 which were found to have been kept in a hard copy.

The quantified NRW management activities that were mainly collected and the reason for consideration included:

a. The number of meters tested – the higher the number of meters tested meant reduced commercial losses through faulty meters.

b. The number of meters replaced – meters replaced means reduced faulty meters hence reduced loss of water through commercial losses.

c. The number of meters sealed – sealing a meter means reducing chances of water theft hence reduced chances of commercial losses.

d. The number of burst and leakages reported and repaired – the higher the number of burst and leakages the higher the physical losses and vis versa.

e. The number of dilapidated pipes replaced – replacing a dilapidated pipe means reducing the physical losses through leakages and burst.

The improvement in NRW management activities through GIS technology was also collected for all the years in consideration.

The average NRW levels in percentages were then calculated for each financial year using the Excel 2013 and are shown in Appendix D2.

1

3.3 Research materials.

The research materials that were used for the study included a Statistical Package for the Social Sciences software (SPSS) which was used for the analysis. All the data from the Table in appendix D2 were then summarized as shown in Table 3.3.1 for easy analysis. The year that the GIS was implemented was then identified for ease of comparison.

Table: 3.3.1 NRW Levels in relation to the quantified NRW management activities per financial year.

Financial Years (F/Y)	Average NRW per F/Y		NRW Management activities				
		Average No of Active Connections	No. Of meters tested	No of meters replaced	No. of meters sealed	No. of burst and leakages reported and repaired	No. of Dilapidated pipes replaced
2013/2014	56.84	170	**15**	**6**	**14**	**29**	**9**
2014/2015	56.14	170	15	9	25	28	12
2015/2016	48.83	189	14	6	26	15	35
2016/2017	33.75	178	10	7	25	15	22
2017/2018	25.08	69	7	4	9	9	7

3.4 Analysis.

A descriptive statistic was used in analyzing and was done using the SPSS. Table 3.3.1 was subjected to analysis using the SPSS. Figures that showed the trend of the changes in each dataset were also generated from Table 3.3.1 to guide in the interpretation. The main parameter that was calculated using the SPSS was standard deviations for all the NRW management activities, average NRW levels and the average number of active connections for the five financial years. Standard deviation is a measure of how the values or datasets for each financial year deviate from the mean value of all the datasets in each category. The standard deviation was used to show the intensity of change that occurred for NRW management activities, NRW levels and the number of active connections. The intensity of change will either be negative or positive. For example, the NRW management activity which showed a bigger standard deviation was taken to have more affected the NRW level either in a positive way or a negative way. This, therefore, meant each NRW management activity affected NRW Levels differently hence the changes were interpreted individually with the help of figures which were generated from the summarized Table 3.3.1 that showed the trend. Table 3.4.1 summarizes the analysis process and how the results were interpreted.

Table 3.4.1 Analysis process.

<table>
<tr><td>Step 1. Preparation of data</td><td colspan="2">Summarized data per financial year as shown in Table 3.3.1</td></tr>
<tr><td>Step 2.Calculation of Standard deviation</td><td colspan="2">SPSS – Standard deviation for data in Table 3.3.1</td></tr>
<tr><td colspan="3">Step 3. Identification of changes in NRW Management activities and their effects on NRW Levels</td></tr>
<tr><td rowspan="3"></td><td colspan="2">Calculations of the standard deviation of NRW Management activities</td></tr>
<tr><td>Higher standard deviations mean the higher intensity of change in the value of that particular parameter (Positive or negative to NRW Levels)</td><td>Lower standard deviations mean the lower intensity of change in the value of that particular parameter (Positive or negative to NRW Levels)</td></tr>
<tr><td colspan="2">Generating graphs from the summarized Table 3.3.1 for each NRW management activity to help in visualizing the trend of the changes before and after GIS implementation in relation to Standard deviations</td></tr>
<tr><td rowspan="4">Step 4. Assessment of the impact of GIS technology</td><td>Calculation of Standard deviation of NRW Levels before and after GIS implementation</td><td>Higher standard deviation means a higher intensity of change while lower standard deviation means a lower intensity of change (positive or negative)</td></tr>
<tr><td colspan="2">Generating a graph from the summarized Table 3.3.1 for the Average NRW levels and identification of a point when GIS technology was implemented to help in visualizing the trend of the changes.</td></tr>
<tr><td colspan="2">Identification of improvement/changes made on NRW Management activities using the GIS technology before and after its implementation</td></tr>
<tr><td colspan="2">Consideration of any other factors that affect NRW Levels apart from the NRW management activities</td></tr>
</table>

3.5 Presentation

The results were presented using graphs and tables. The standard deviation was calculated and presented in tables and graphs. The standard deviations for each NRW management activity were plotted for the five financial years to aid in visualizing the intensity of change among them. The NRW levels standard deviation graphs were plotted before and after the implementation of GIS to visualize the intensity of change.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Introduction.

This chapter presents the results/findings of the study. It presents results arising from the analysis of data collected using descriptive statistics. The findings are presented in tabular summaries and their trends discussed. In particular, it documents the impacts of GIS technology on the NRW levels since the technology was implemented and its effects on NRW management activities.

4.2 Results.

Table 4.2.1 shows the standard deviation for the NRW management activities and the average number of active connections for five financial years.

Table 4.2.1: The standard deviation for NRW levels and the NRW Mangement activities for financial years 2013/2014 to 2017/2018.

	Average NRW per F/Y	Average total no of active connections per F/Y	Total Number of tested meters per F/Y	Total Number of meters replaced per F/Y	Total Number of meters sealed per F/Y	Total Number of burst and leakages reported and repaired per F/Y	Total Number of Pipes Replaced per F/Y
Std. Deviation	**14.12906**	**48.81291**	**3.564**	**1.817**	**7.791**	**8.843**	**11.597**

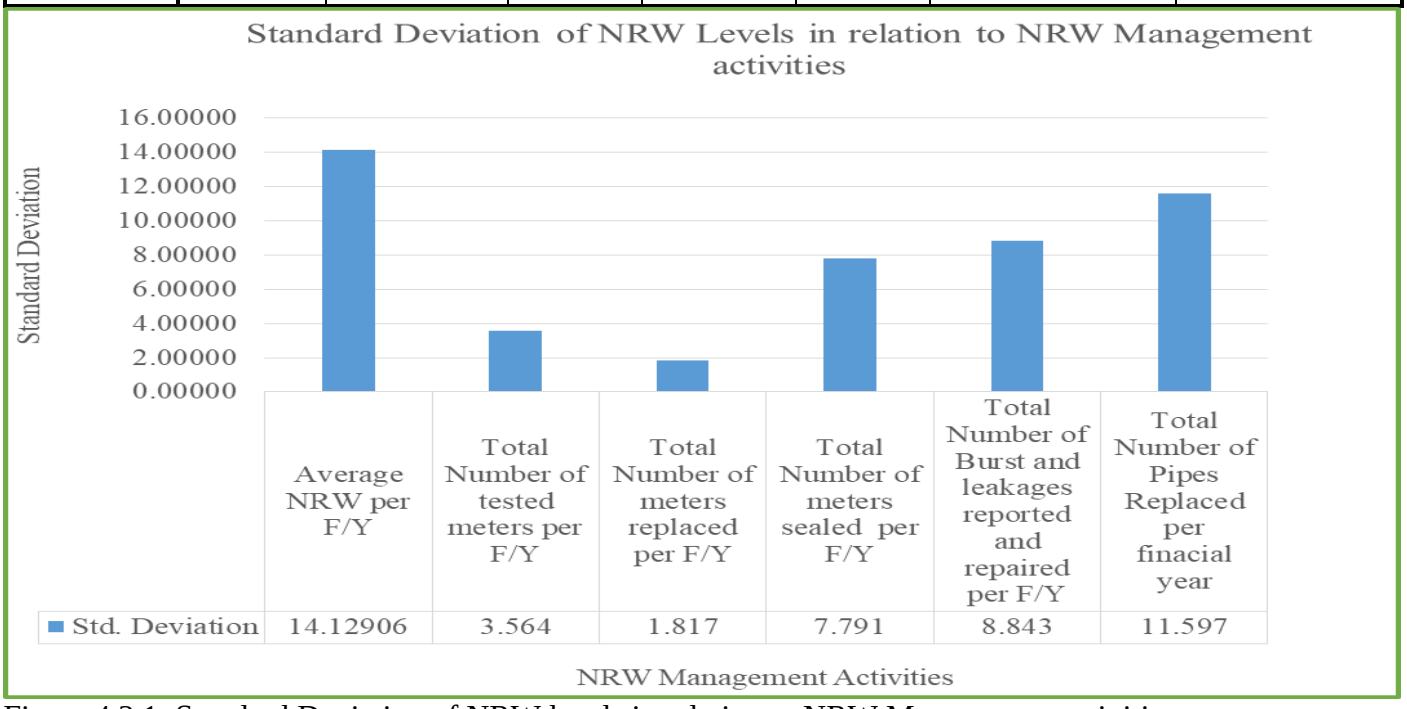

Figure 4.2.1: Standard Deviation of NRW levels in relation to NRW Management activities

Table 4.2.2: NRW levels Standard deviation before and after implementation of GIS technology

	Average NRW levels before Implementation of GIS 2013/2014 and 2014/2015	Average NRW levels After Implementation of GIS (2015/2016 to 2017/2018)
Std. Deviation	0.49	12.02
Range of maximum and minimum	0.70	23.75

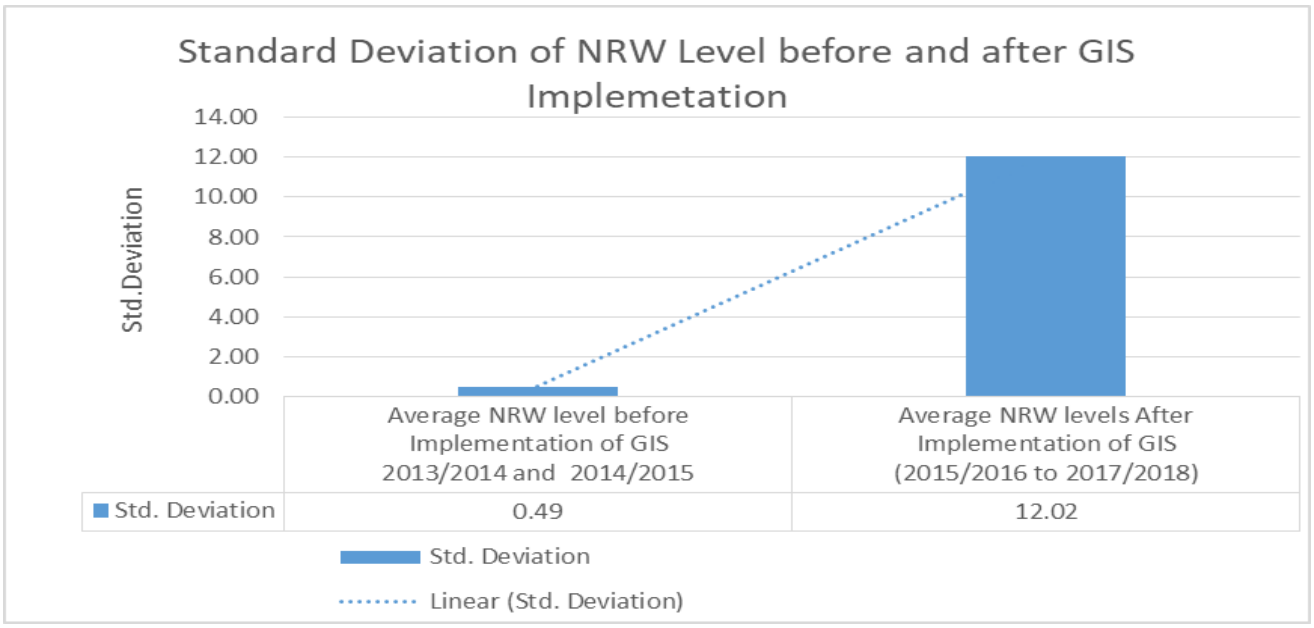

Figure 4.2.2: The NRW levels standard deviation before and after GIS implementation

4.3 Discussions.

The active connections from Figure 4.2.1 show a big standard deviation which can be linked to the reduction in the number of active connections in the financial year 2017/2018 which showed a very sharp drop. On the other hand, there is a large standard deviation for the NRW levels for financial years 2013/2014 to 2017/2018 depicting a big change, in that the NRW level in the financial year 2017/2018 is 25.08% as compared to Financial 2013/2014 which was 56.84% hence the change is positive.

The total number of dilapidated pipes replaced shows a larger standard deviations value which depicts a bigger change than other activities, this is shown by any numbers of dilapidated pipes replaced in the financial year 2015/2016 which is the year the GIS technology started to be implemented. The Table in appendix D2 shows that the use of the exact location of pipes to record burst and leakages using the printed maps from the Web GIS started in this year(2015/2016) and is presumed to have contributed to this improvement. Figure 4.3.8 also shows a sharp rise in this activity in that financial year.

As shown in Figure 4.2.2 the bigger margin of standard deviation before and after the implementation of GIS technology shows that there was a high intensity of change in the NRW levels after the GIS implementation. Figure 4.3.3 shows a sharp drop in the NRW level in the financial year 2015/2016 the year GIS was implemented hence the big difference in standard deviation before and after GIS implementation depicts a positive change.

As shown in the Appendix C: Appendix C1, Figures, on monthly NRW Level trends, its is shown that the trendlines for financial years 2013/2014 and 2014/2015 is almost a straight line depicting almost constant NRW Levels and as also shown by a small standard deviation in Table 4.2.1 while for the rest of financial years (2015/2016 to 2017/2018) the trendlines show a sharp slopping which depicts a positive improvement on the NRW Levels. However the big margin in NRW levels for the financial year 2016/2017 and 2017/2018 might have resulted due to other factors of which according to the figure on monthly NRW levels trends for the financial year 2017/2018 it shows a sharp drop in the number of active connection from the month of December 2017 which was 103 and the NRW level of 42.19% and for the next month of January 2018 the NRW percentage dropped to 24.88% as well as active connections dropping to only 11 which remained constant for the rest of the months. This in relations to the NRW levels shows that the fewer the number of connections the easier the management of NRW levels.

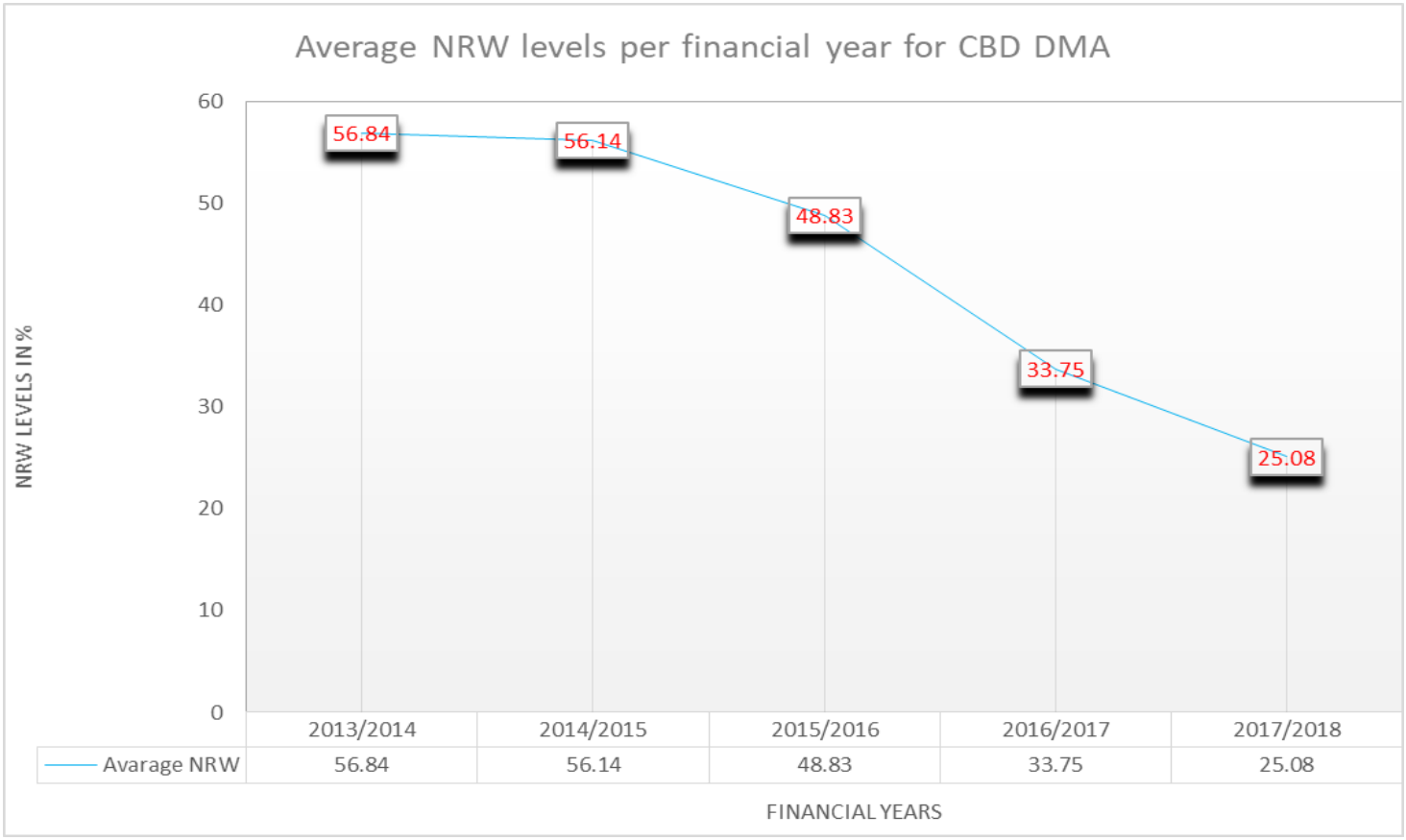

Figure 4.3.3: Average NRW Levels per financial year for CBD DMA

In the Figure 4.3.3, the GIS technology was implemented in the financial year 2015/2016 a point where there was a significant drop in NRW level from the previously 56.14% to 48.83% which is a positive drop

of 7.31% as compared to the previous year which dropped only for 0.7%. This is presumed to have been because of the improvement of NRW Management activities by the use of GIS technology as shown in Table 4.3.1. It was noted that the NRW Levels started improving by big margins since the GIS technology was implemented of which by the financial year 2017/2018 it had improved to 25.08%.

It was also noted that some of the NRW management activities improved since 2015/2016, for example, the number of dilapidated pipes replaced increased to 35 while the number of burst and leakages reported and repaired started reducing in financial year 2015/2016 which is a sign of reduced loss of water. This is presumed to be mainly because of improvement in burst and leakages recorded which included locational values and also the record of the age of pipes as one of the attributes in pipe network data.

In terms of the NRW Management activities, the intensity of change was not so much as compared to NRW levels as shown by their standard deviations in Table 4.2.1 and as also shown in the Figure 4.3.4 to Figure 4.3.8 showing the trends of the changes in values of each NRW management activity in relation to the NRW levels.

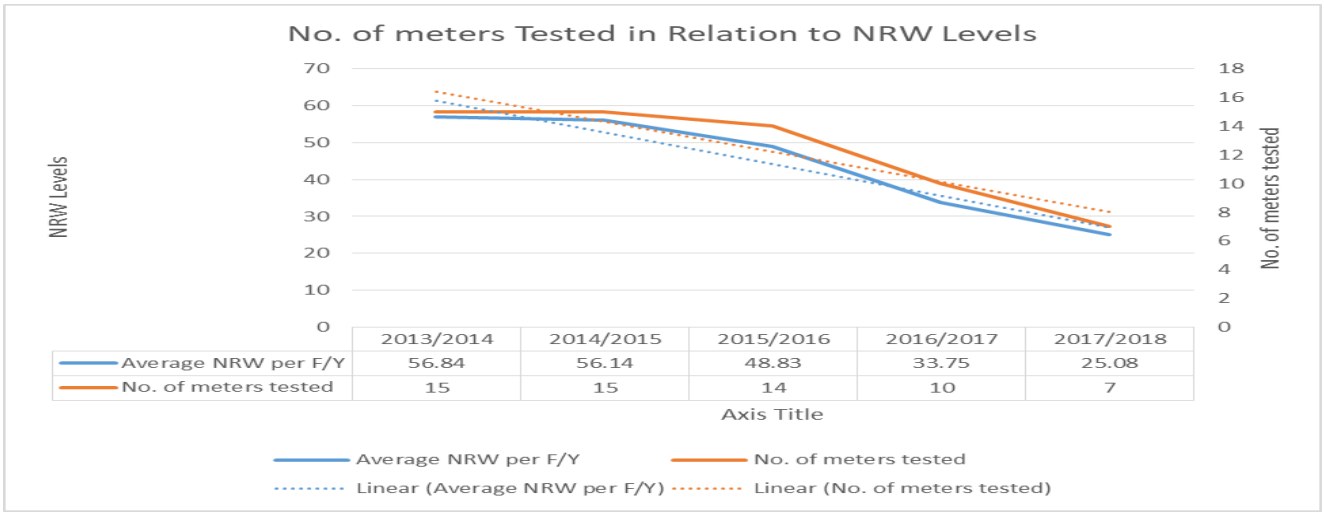

Figure 4.3.4: The number of meters tested in relation to NRW levels

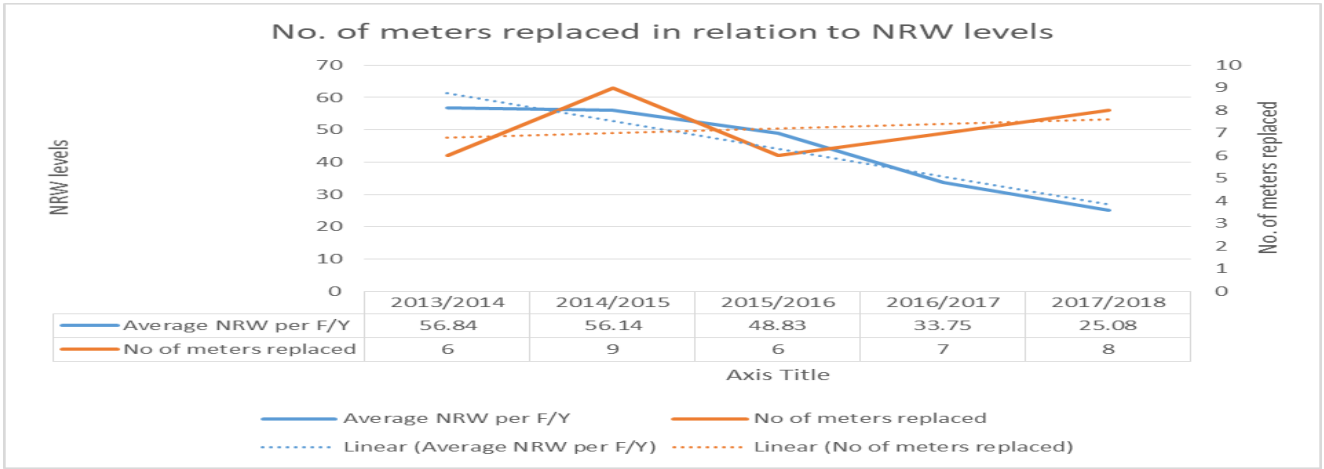

Figure 4.3.5: The number of meters replaced in relation to NRW levels

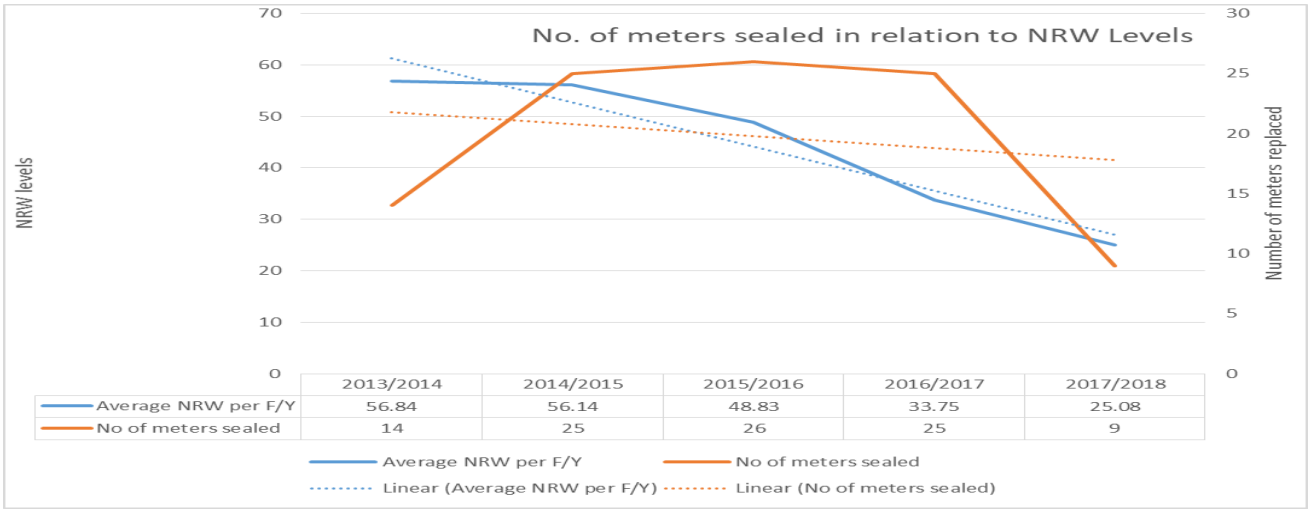

Figure 4.3.6: The number of meters sealed in relation to NRW levels

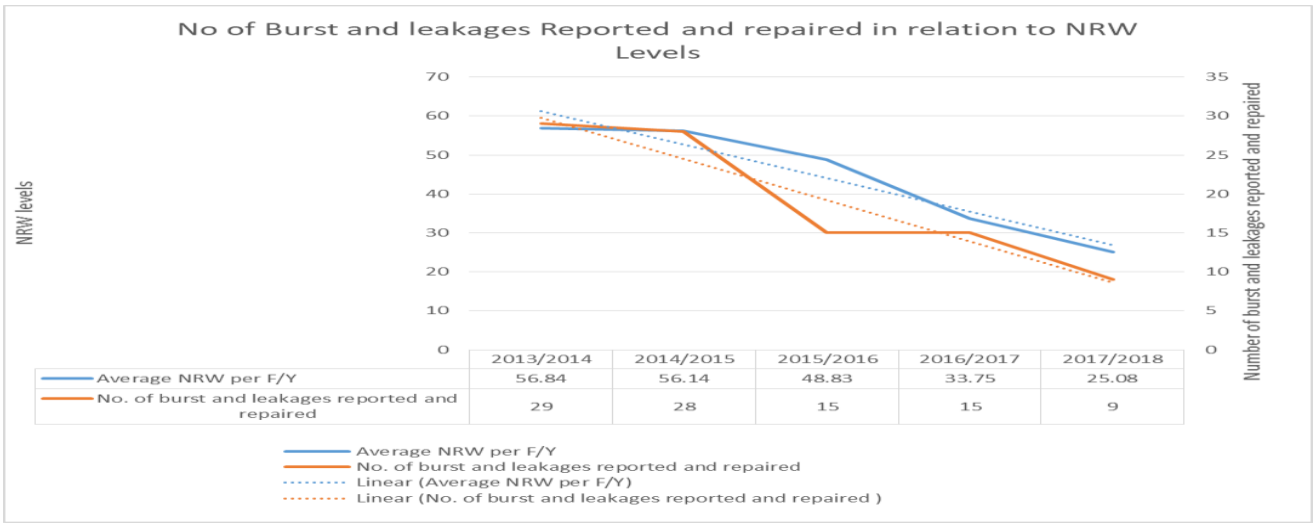

Figure 4.3.7: The number of Burst and leakages reported and repaired in relation to NRW levels

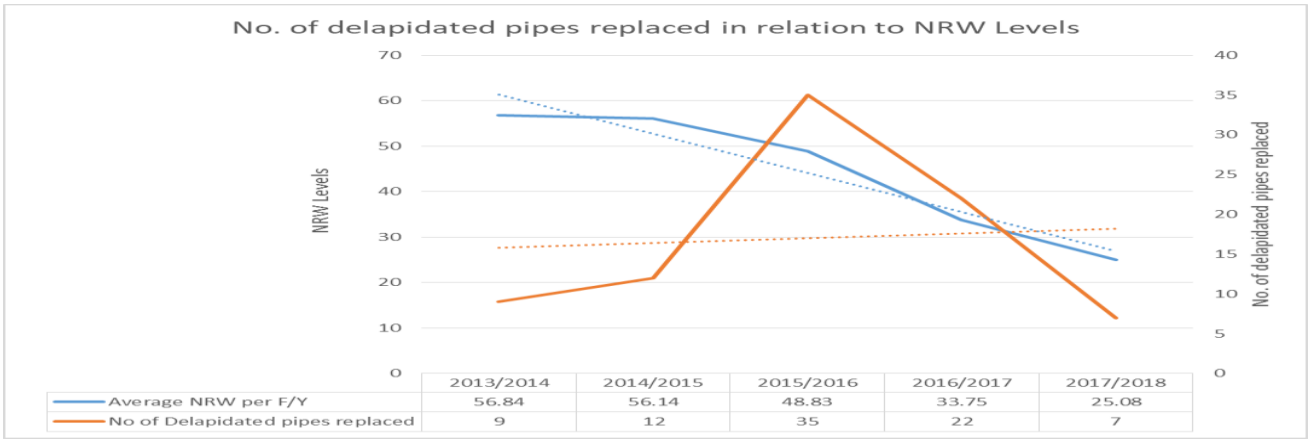

Figure 4.3.8: The number of dilapidated pipes replaced and repaired in relation to NRW levels

The NRW management activities affect the NRW levels differently and the results for five financial years were as follows

Table 4.3.1: NRW management activities effects on NRW levels

Item No.	NRW management Activity	Effects on NRW Level	The intensity of change for five financial years (2013/2014 to 2017/2018)
1	Number of meters tested per F/Y	When the number of meters tested is high, it means there will be reduced malfunctioned meters and hence less loss of water through commercial losses.	As shown by the Standard deviation(3.564), the tested meters did not show a big change as compared to others
2	Number of meters replaced per F/Y	The higher the number of meters replaced the less water lost through inaccurate meters (Commercial losses)	The smaller standard deviation of 1.817 shows a positive change as shown in Figure 4.3.5, even though there was no much change as compared to others.
3	Number of meters sealed per F/Y	The higher the number of meters sealed the lesser the possibility of water theft which reduces the commercial losses.	For the five financial years, there was not much change as shown by the trendline in Figure 4.3.6
4	Number of Burst and leakages reported and repaired per F/Y	The lower number of burst and leakage reported and repaired will mean less water lost was lost through physical losses.	The standard deviation shows a positive change of 8.843 which shows reducing trend as shown in Figure 4.3.7
5	Number of Dilapidated Pipes Replaced per financial year	The higher the number of dilapidated pipes replaced the lesser the burst and leakages will occur hence less loss of water through physical losses.	This showed the highest change among the NRW management activities with a standard deviation of 11.597. The highest change was positive as shown by the increasing trend in Figure 4.3.8

The high standard deviation of NRW levels as compared to NRW management activities can be directly linked to the improvement made on the management of the NRW levels by use of GIS technology which depicts a positive improvement.

4.4. Improvement made in NRW management activities by use of GIS technology

Table 4.4.1 shows some of the improvements that were made by NARWASSCO on some of the NRW management activities after the implementation of GIS technology and their advantages.

Table 4.4.1: Improvements in some of the NRW management activities by the application of GIS technology in NARWASSCO.

Management Activity	**Before the implementation of GIS**	**After Implementation of GIS**	**Advantages of the use of GIS technology**
Locating a Water Meter/customer	Depending on the meter reader or the person who knows to locate	Use of Web GIS system to locate	Any staff locate a customer or a water meter
Pipe replacement	Replaced only during repair	Replaced depending on the age and when there are regular bursts of a pipe in a given area	Reduced bursts and leakages since the pipes are replaced before it burst or leak
Recording of Burst and leakages	Recorded on an excel sheet with no locational values	Recorded on a printed maps/O &M worksheet with locational values downloaded from GIS web system (Appendix B1: GIS web system)	Easy to locate the regular points where the burst and leakage occur which can be rectified to reduce more loss of water
Getting the total water consumed in a given DMA	Selecting the connections from a given DMA and getting the meter reading from meter reading sheets and subtracting it from the previous meter reading and getting the consumption for all connections manually	Use of SQL and get the consumption from the Postgres/PostGIS database since it is integrated with the billing system database	Save time and reduce the errors that might occur during calculations.
Information on the infrastructure	Use of hand-drawn maps which have only a few attributes (i.e for pipes it had Size and material only)	Use of digital maps (shapefiles) which have so many attributes which included the date of installations, sizes, the material used and many others which could be obtained very easily by querying the database using SQL	There were additional information that guided in the management of the NRW and even the exact locations of the infrastructure and obtaining the data was made easy and accurate.

Table 4.4.1 shows a big improvement on a day to day NRW Management activities which have really made feasible to reduce the NRW Levels to the set benchmark of 25% for example locations of customers/meters using the GIS Web System has contributed to improvement in meter replacement, meter sealing, meter reading, meter disconnections and regular surveillance which has shorten the time and reduce cost of looking for the locations of this customer meters.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

There are many changes that occurred on the NRW management activities due to the use of GIS technology, for example, recording of burst and leakages using printed maps that show the exact location has really helped in the management of the leakages and burst. NARWASSCO can now manage the burst and leakages very easily by replacing pipes and other fittings that leak or where burst occur regularly thus reducing further loss of water. Generally, GIS technology has brought about many changes in the way things are done in terms of management of NRW. All the NRW management activities were affected by the technology positively hence directly contributing to the reduction of NRW level, this is depicted by the standard deviations of every NRW management activity which showed a change.

The big changes in the NRW levels before and after the implementation of GIS in NARWASSCO clearly shows that technology has played a big role in NRW management. This can be linked directly to the impact of the technology on NRW management activities which showed positive improvement.

5.2 Recommendations

It is therefore clear that GIS technology is the best alternative for the management of NRW which has shown a positive impact on NRW level. Water Service Provider(s) can, therefore, adopt the use of the technology to manage their NRW levels to acceptable levels of 25%. The technology can make the management of NRW cost-effective in that most of the things can be done easily and without any much cost, for example, some of the things can be done in-office instead of going to the field by the help of GIS.

Mapping of a distribution system by any Water Service Provider, that is geared to using the system for management of NRW management, should, however, ensure some specific attributes as shown in the Table in appendix D1 are included in their network.

5.3 Recommendations for further studies

The study only focused on the impact of GIS technology on NRW levels, however, studies can be further made on other capabilities of GIS technology in the management of NRW for example management of pressures in a distribution system to avoid burst and leakages.

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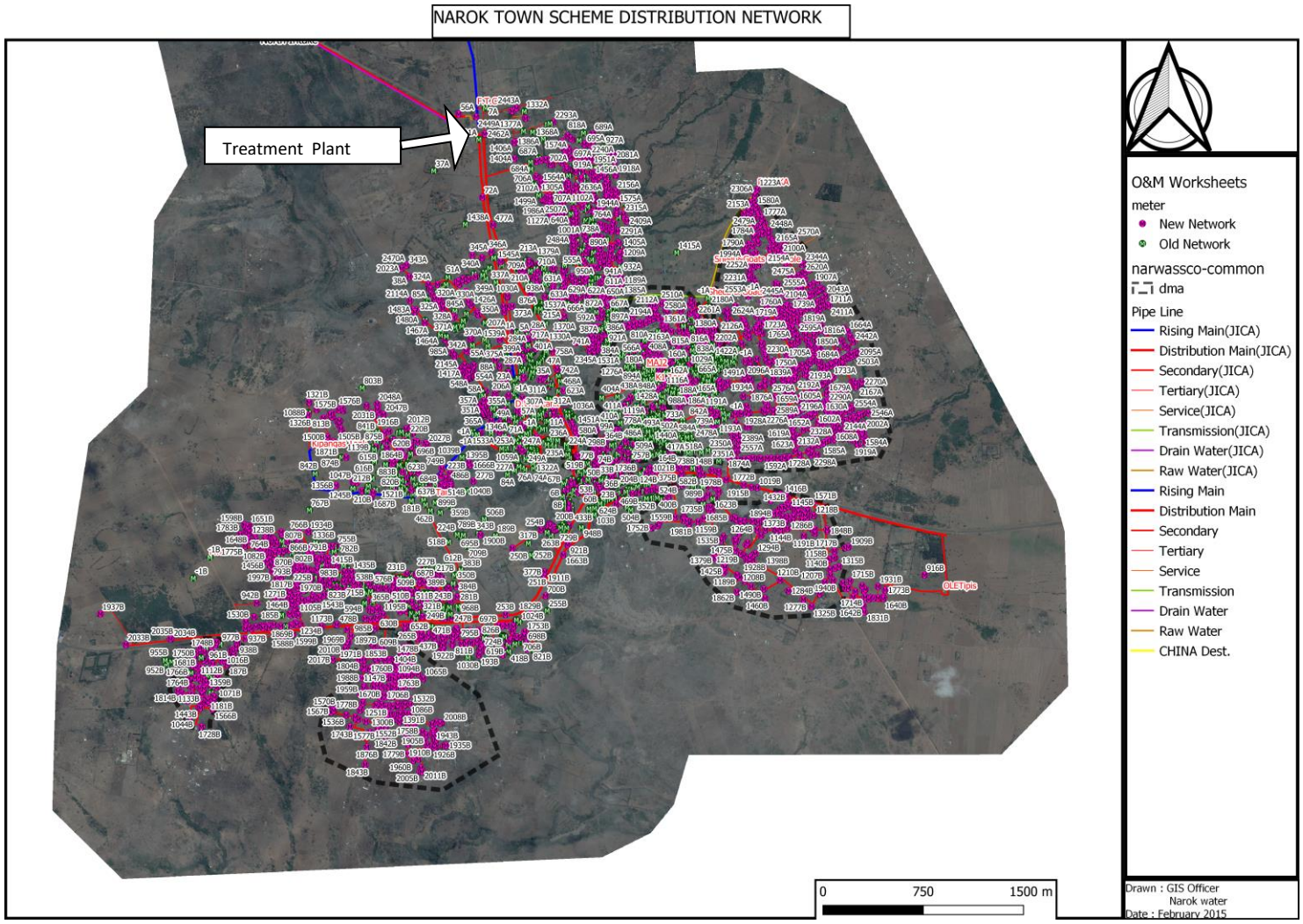
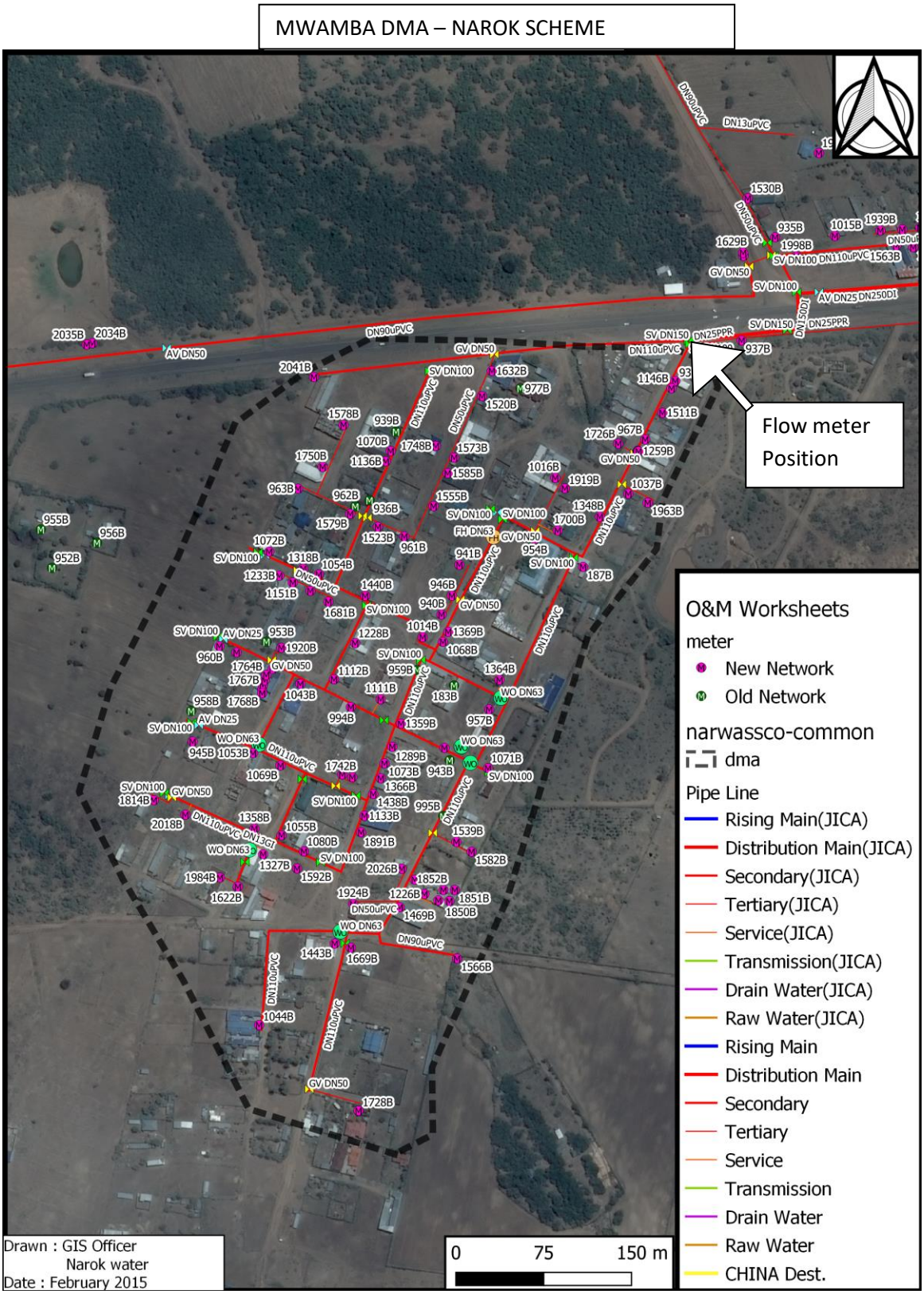
APPENDICES

Appendix A: maps

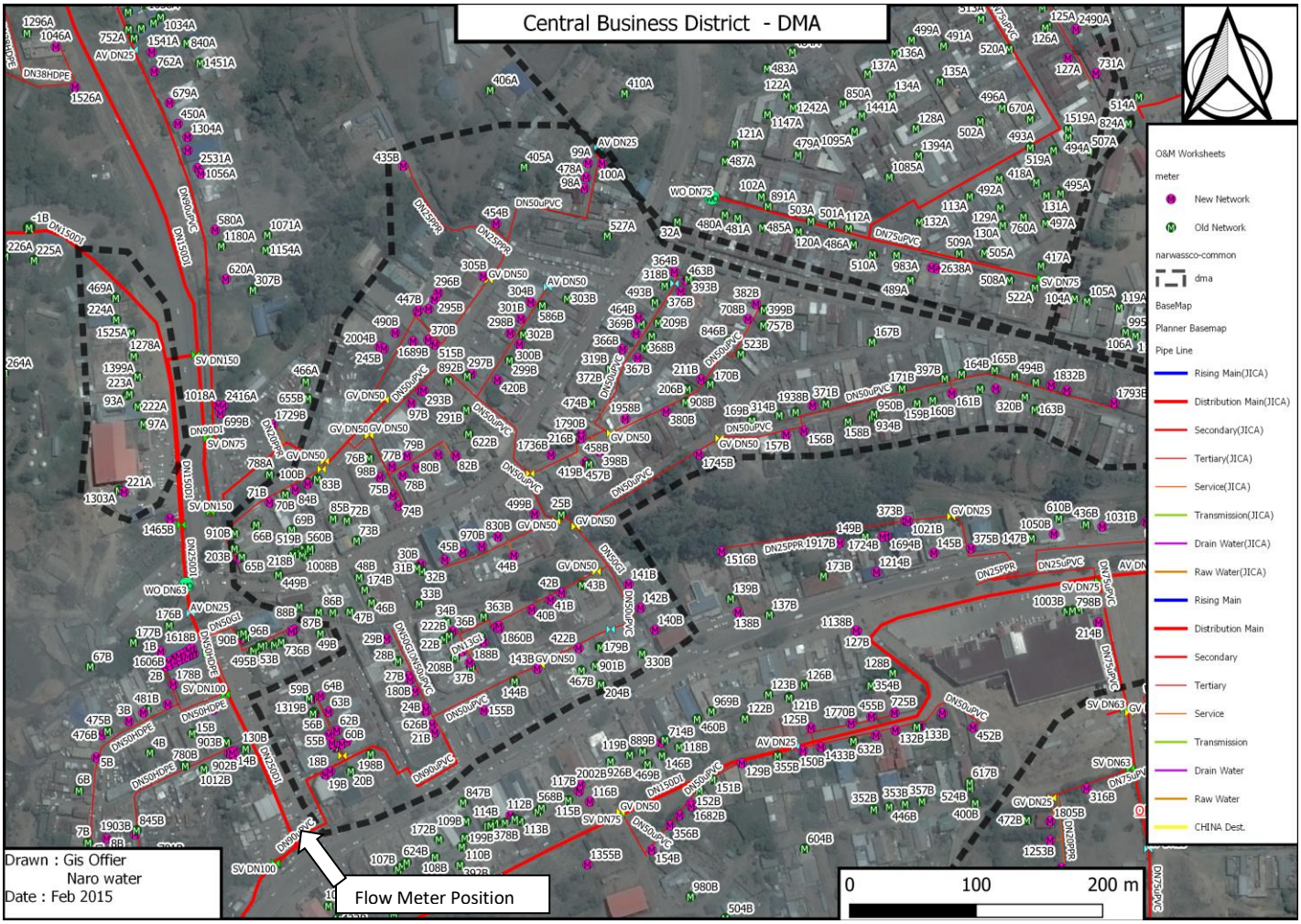
Appendix A1: Narok Water Current Distribution System (Narok Town Scheme)



Appendix A2: Example of a good DMA

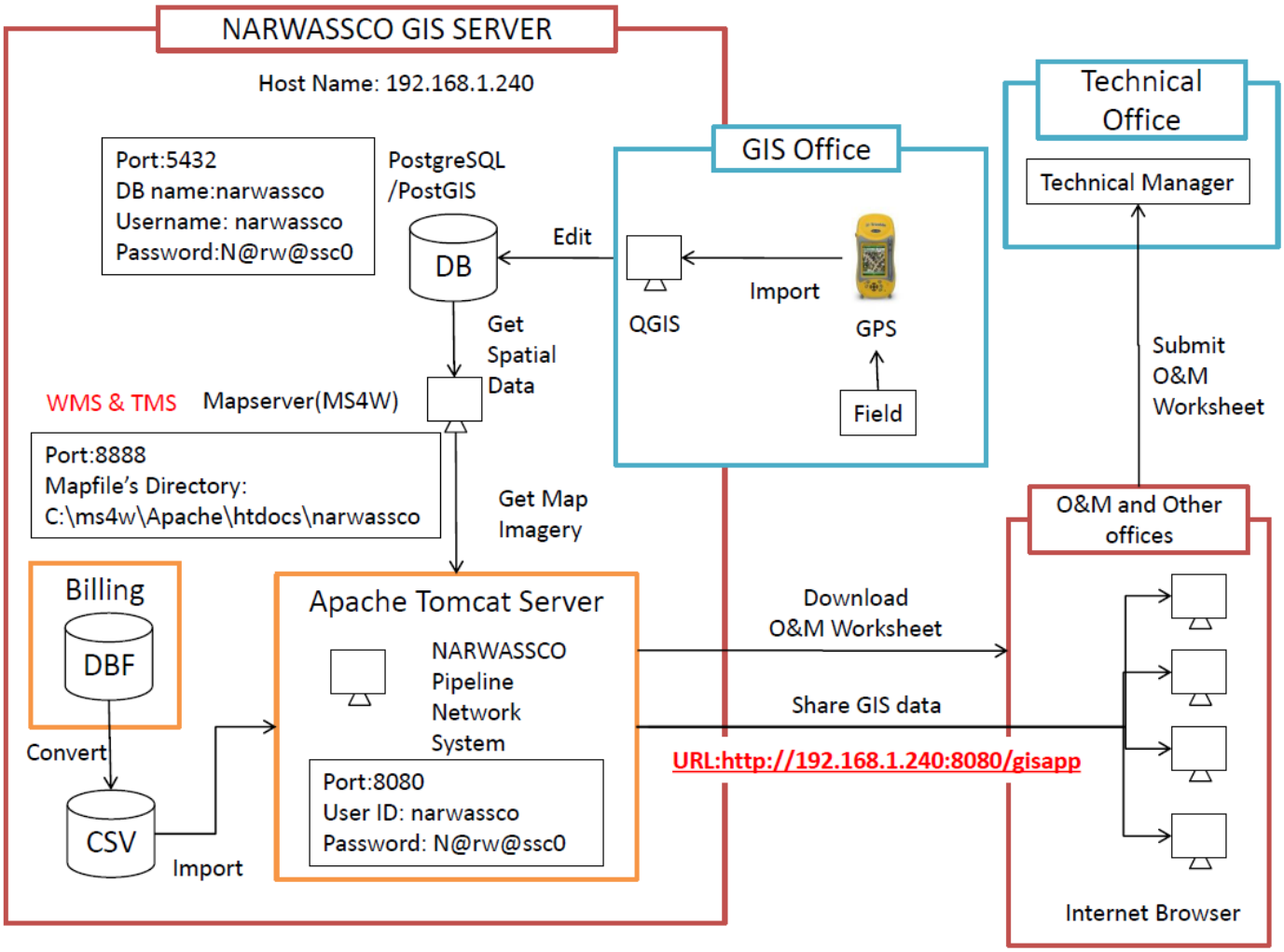


Appendix A3: Central Business District DMA



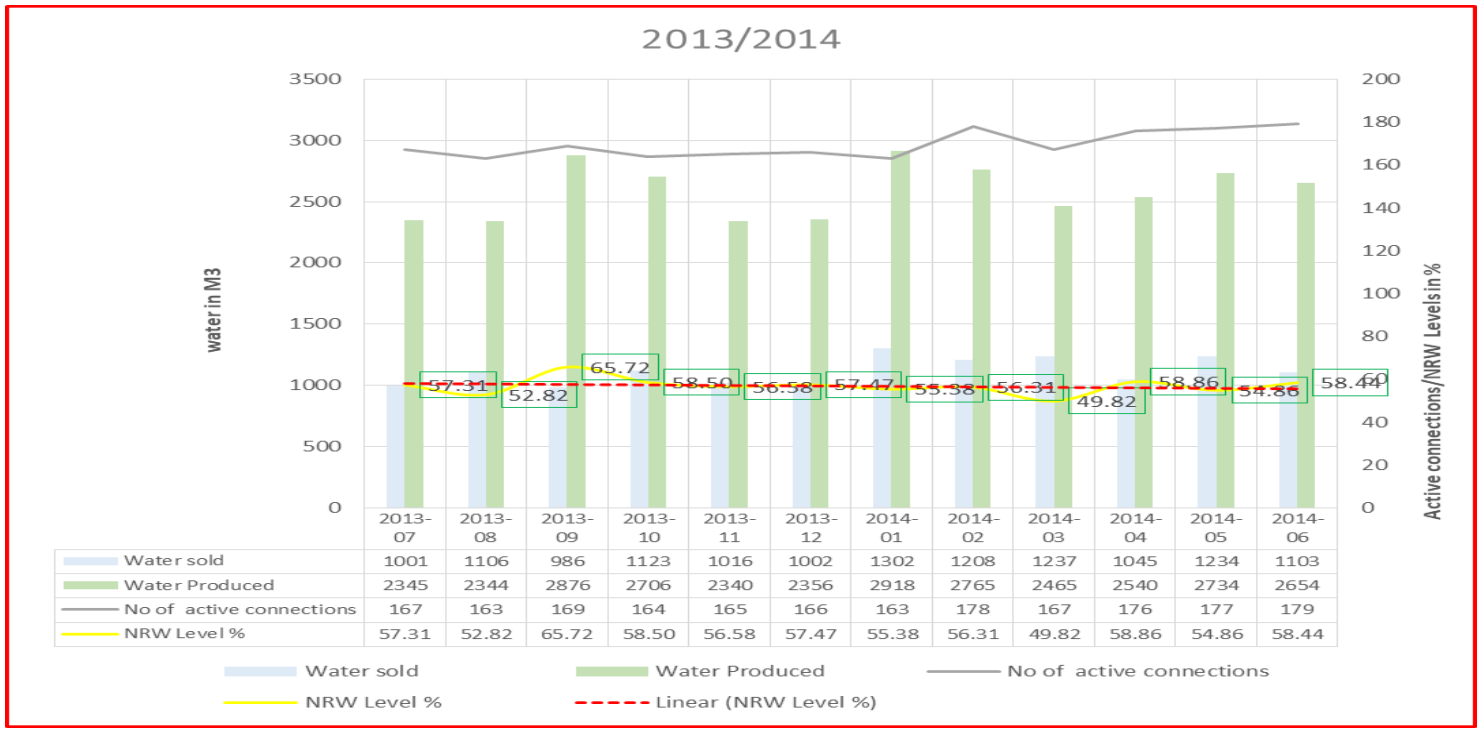
Appendix B: Charts

Appendix B1: A flow chart showing the existing GIS Web system in NARWASSCO

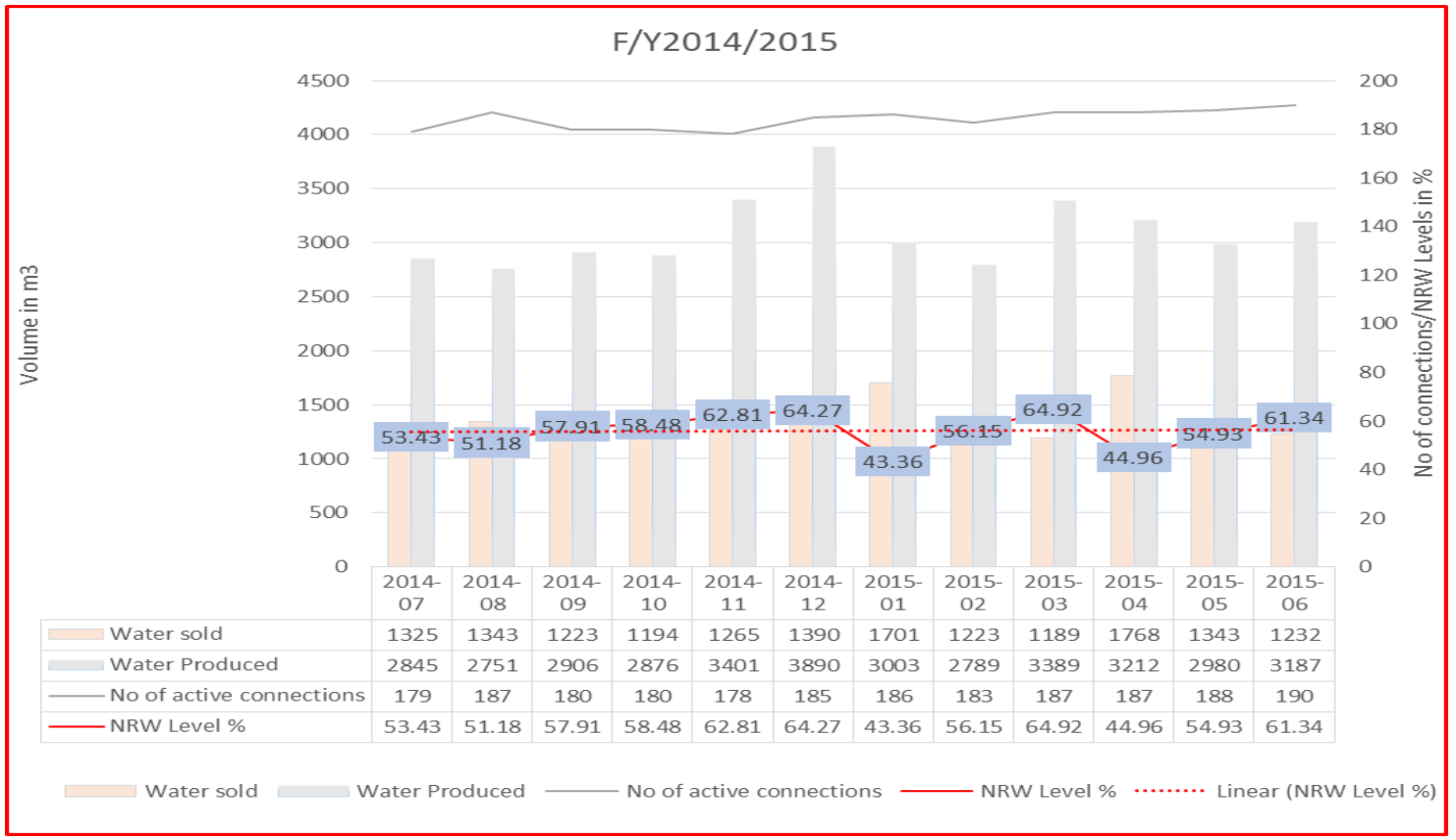


Appendix C: Figures

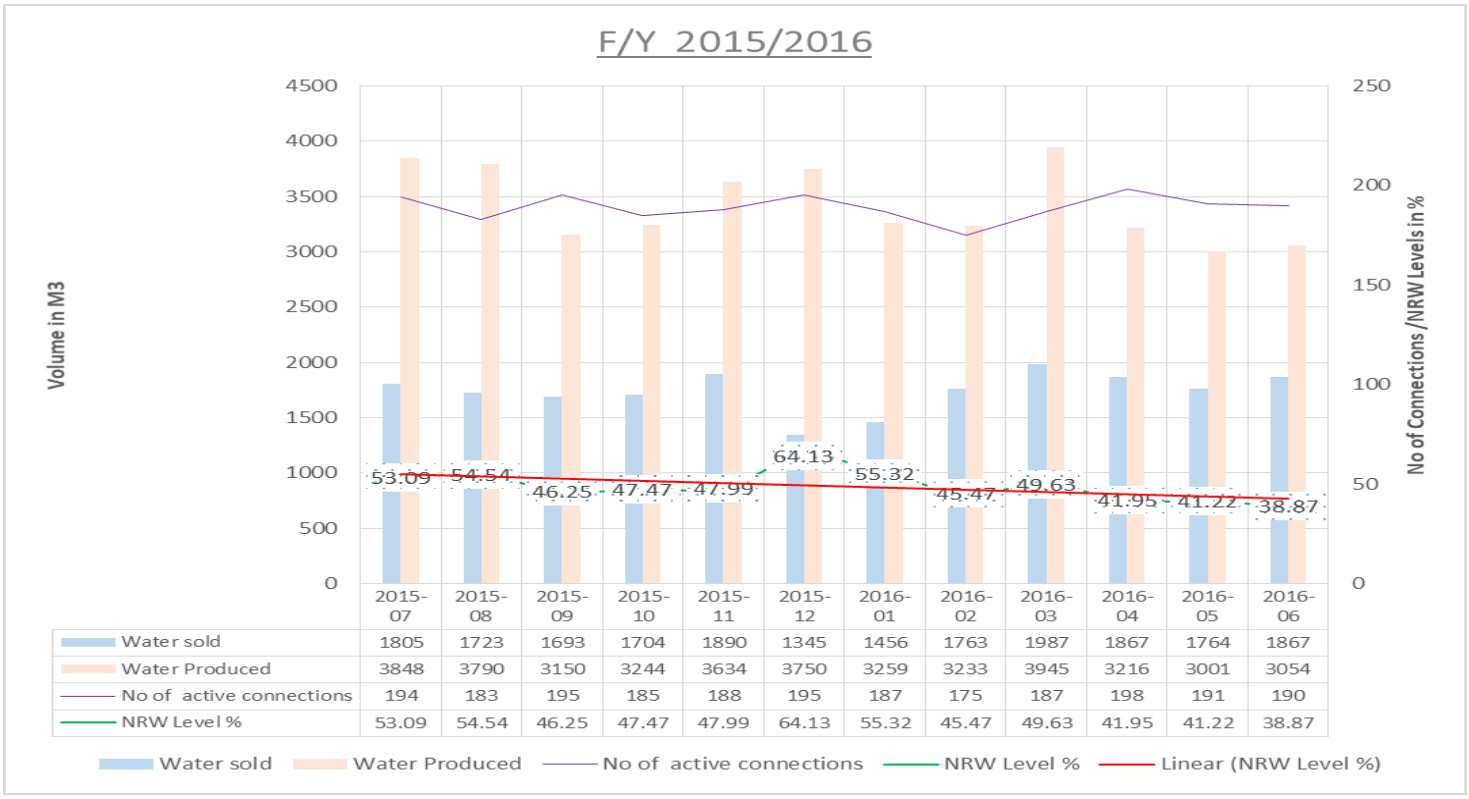
Appendix C1: Figures showing monthly NRW levels trends per financial year since 2013/2014 to 2017/2018

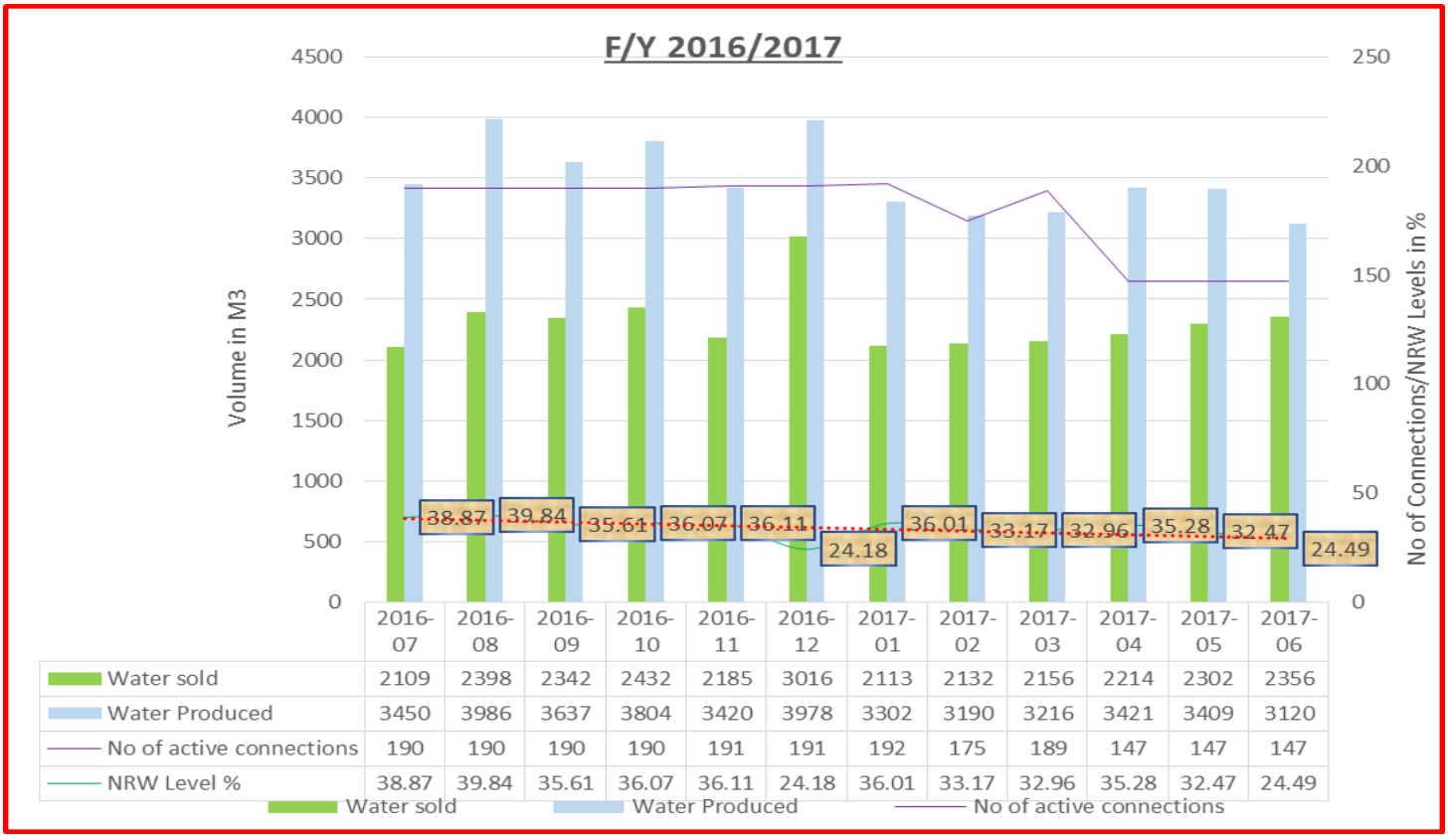


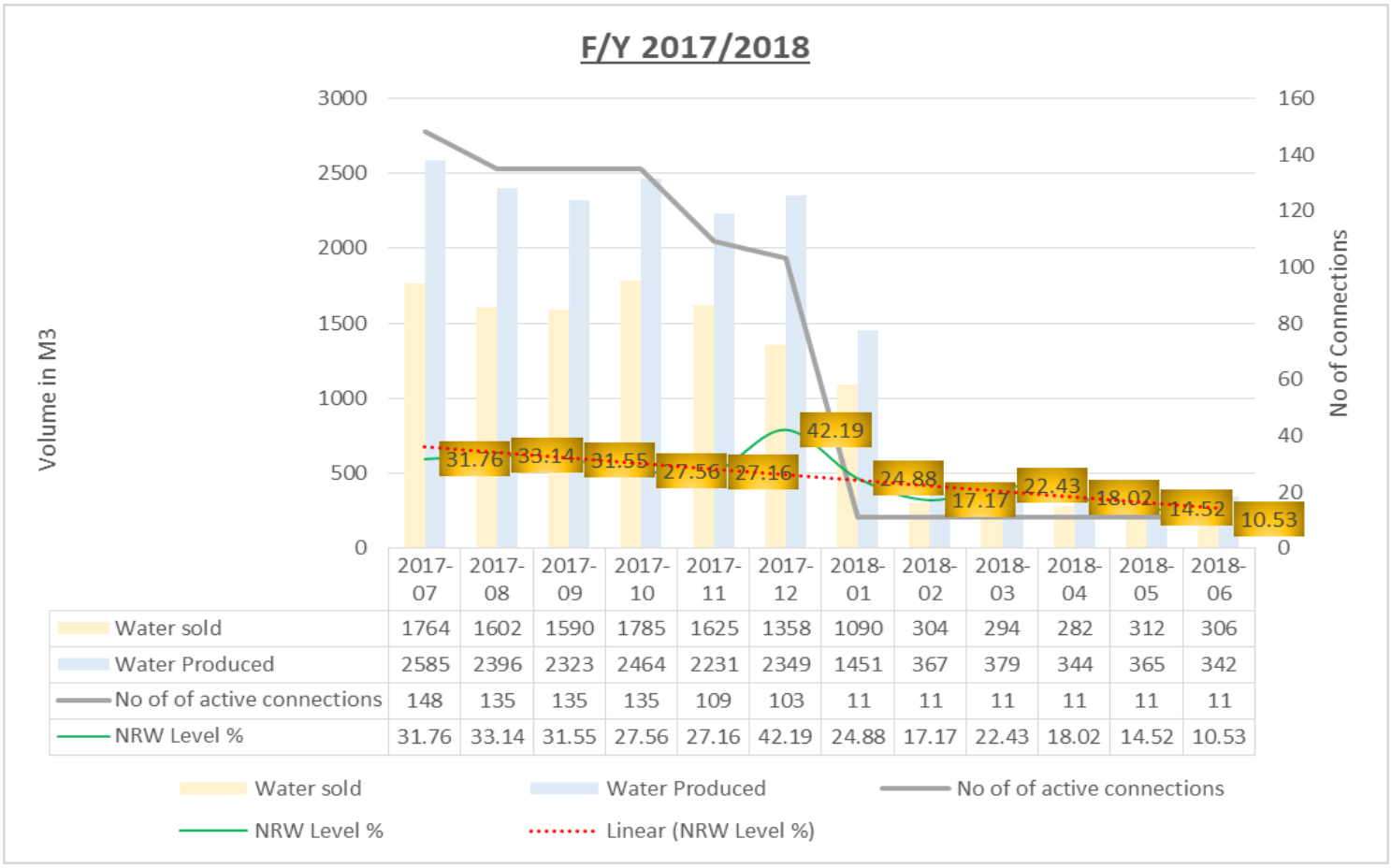
	2013-07	2013-08	2013-09	2013-10	2013-11	2013-12	2014-01	2014-02	2014-03	2014-04	2014-05	2014-06
Water sold	1001	1106	986	1123	1016	1002	1302	1208	1237	1045	1234	1103
Water Produced	2345	2344	2876	2706	2340	2356	2918	2765	2465	2540	2734	2654
No of active connections	167	163	169	164	165	166	163	178	167	176	177	179
NRW Level %	57.31	52.82	65.72	58.50	56.58	57.47	55.38	56.31	49.82	58.86	54.86	58.44



	2014-07	2014-08	2014-09	2014-10	2014-11	2014-12	2015-01	2015-02	2015-03	2015-04	2015-05	2015-06
Water sold	1325	1343	1223	1194	1265	1390	1701	1223	1189	1768	1343	1232
Water Produced	2845	2751	2906	2876	3401	3890	3003	2789	3389	3212	2980	3187
No of active connections	179	187	180	180	178	185	186	183	187	187	188	190
NRW Level %	53.43	51.18	57.91	58.48	62.81	64.27	43.36	56.15	64.92	44.96	54.93	61.34


F/Y 2015/2016
Volume in M3
No of Connections /NRW Levels in %
4500
4000
3500
3000
2500
2000
1500
1000
500
0
250
200
150
100
50
0
53.09
54.54
46.25
47.47
47.99
64.13
55.32
45.47
49.63
41.95
41.22
38.87
2015-07 2015-08 2015-09 2015-10 2015-11 2015-12 2016-01 2016-02 2016-03 2016-04 2016-05 2016-06
Water sold 1805 1723 1693 1704 1890 1345 1456 1763 1987 1867 1764 1867
Water Produced 3848 3790 3150 3244 3634 3750 3259 3233 3945 3216 3001 3054
No of active connections 194 183 195 185 188 195 187 175 187 198 191 190
NRW Level % 53.09 54.54 46.25 47.47 47.99 64.13 55.32 45.47 49.63 41.95 41.22 38.87
Water sold
Water Produced
No of active connections
NRW Level %
Linear (NRW Level %)


F/Y 2016/2017
Volume in M3
No of Connections/NRW Levels in %
4500
4000
3500
3000
2500
2000
1500
1000
500
0
250
200
150
100
50
0
38.87
39.84
35.61
36.07
36.11
24.18
36.01
33.17
32.96
35.28
32.47
24.49
2016-07 2016-08 2016-09 2016-10 2016-11 2016-12 2017-01 2017-02 2017-03 2017-04 2017-05 2017-06
Water sold 2109 2398 2342 2432 2185 3016 2113 2132 2156 2214 2302 2356
Water Produced 3450 3986 3637 3804 3420 3978 3302 3190 3216 3421 3409 3120
No of active connections 190 190 190 190 191 191 192 175 189 147 147 147
NRW Level % 38.87 39.84 35.61 36.07 36.11 24.18 36.01 33.17 32.96 35.28 32.47 24.49
Water sold
Water Produced
No of active connections



	2017-07	2017-08	2017-09	2017-10	2017-11	2017-12	2018-01	2018-02	2018-03	2018-04	2018-05	2018-06
Water sold	1764	1602	1590	1785	1625	1358	1090	304	294	282	312	306
Water Produced	2585	2396	2323	2464	2231	2349	1451	367	379	344	365	342
No of of active connections	148	135	135	135	109	103	11	11	11	11	11	11
NRW Level %	31.76	33.14	31.55	27.56	27.16	42.19	24.88	17.17	22.43	18.02	14.52	10.53

Appendix D: Tables

Appendix D1: The important attributes to be considered while mapping of some of the water infrastructure in connection to NRW management

Infrastructure	Attributes	Reason
Pipes	Material	Enable to get the same type of pipe when repairing or replacing and also fittings
	sizes	Enable to get the same type of pipe when repairing or replacing and fittings to be used
	Date of Installation	Enable to get the dates of replacement
	Pressure (PN)	Enable to get the same type of pipe that can maintain pressure when repairing or replacing and fittings to be used
Meters	Size	To enable to know the type of fittings to be used
	Date of installation	Enable to get the dates of replacement if any
	Type	To enable gaging its functionality in terms of locations
Appurtenances	Sizes	Enable to get the same size when repairing or replacing
	Material	Enable to get the same type when repairing or replacing
	Pressure	Enable to get the same type of appurtenances that can maintain pressure when repairing or replacing

Appendix D2: Monthly NRW levels in relation to NRW Management Activities and the improvements in NRW Management activities for five financial years

Financial Years (F/Y)	Months	NRW levels in %	Average NRW level per F/Y		NRW management Activities					
				No of Active Connections	No. of meters tested	No. of meters replaced	No of meters sealed	No. of burst and leakages reported and repaired	No. of Dilapidated pipes replaced	Improvements in NRW Management Activities
2013/2014	Jul-13	57.31	**56.84**	167	1	0	0	1	1	-Use of drafted hand-drawn hard copy maps to locate the customers and pipes -Generally recording of Burst and leakages using excel sheets within the DMA and repairing them - Regular Meter testing to the suspected malfunctioning meters Reduction of water theft by sealing of customer meters of the suspected customers
	Aug-13	52.82		163	2	1	0	4	0	
	Sept-13	65.72		169	0	0	0	5	2	
	Oct-13	58.5		164	3	2	0	3	0	
	Nov-13	56.58		165	1	0	0	4	1	
	Dec-13	57.47		166	3	1	0	1	3	
	Jan-14	55.38		163	0	0	0	0	0	
	Feb-14	56.31		178	1	0	0	4	0	
	March-14	49.82		167	2	1	5	3	0	
	Apr-14	58.86		176	1	0	3	1	1	
	May-14	54.86		177	0	0	2	1	1	
	Jun-14	58.44		179	1	1	4	2	0	
Totals				**169.5**	**15**	**6**	**14**	**29**	**9**	

Financial Years (F/Y)	Months	NRW levels in %	Average NRW level per F/Y		NRW management Activities					
				No of Active Connections	No. of meters tested	No. of meters replaced	No of meters sealed	No. of burst and leakages reported and repaired	No. of Dilapidated pipes replaced	Improvements in NRW Management Activities
2014/2015	Jul-14	53.43	56.14	179	2	1	3	1	2	- Use of drafted hand-drawn hard copy maps to locate the customers and pipes -Generally recording of Burst and leakages using excel sheets within the DMA and repairing them - Regular Meter testing to the suspected malfunctioning meters - Reduction of water theft by sealing of customer meters of the suspected customers
	Aug-14	51.18		187	3	2	2	3	1	
	Sept-14	57.91		180	0	0	0	1	3	
	Oct-14	58.48		180	1	1	0	2	1	
	Nov-14	62.81		178	0	0	0	4	1	
	Dec-14	64.27		185	1	1	4	3	0	
	Jan-15	43.36		186	1	1	2	2	1	
	Feb-15	56.15		183	1	0	2	1	0	
	March-15	64.92		187	0	1	3	6	0	
	Apr-15	44.96		187	1	0	4	2	1	
	Mei-15	54.93		188	0	0	1	1	0	
	Jun-15	61.34		190	3	2	4	2	2	
	Totals			**169.5**	**13**	**9**	**25**	**28**	**12**	

Financial Years (F/Y)	Months	NRW levels in %	Average NRW level per F/Y		NRW management Activities					
				No of Active Connections	No. of meters tested	No. of meters replaced	No of meters sealed	No. of burst and leakages reported and repaired	No. of Dilapidated pipes replaced	Improvements in NRW Management Activities
2015/2016	Jul-15	53.09	48.83	194	3	2	3	2	2	- Started mapping of the distribution network in the whole scheme area - Development of Postgres database and loading of all the shapefiles i.e Customer meters, pipe network, Valves, washouts, and all other pipe fittings - Zoning of the DMA's and loading the Boundary shapefiles to the database - Development and use of GIS web system -Use of exact location of pipes to record burst and leakages using the printed maps from the web GIS
	Aug-15	54.54		183	1	1	4	2	1	
	Sep-15	46.25		195	1	0	1	1	0	
	Okt-15	47.47		185	0	0	0	2	3	
	Nov-15	47.99		188	1	0	1	0	4	
	Dec-15	64.13		195	1	0	3	1	1	
	Jan-16	55.32		187	2	1	3	2	4	
	Feb-16	45.47		175	0	0	2	0	2	
	March-16	49.63		187	1	1	3	1	4	

Financial Years (F/Y)	Months	NRW levels in %	Average NRW level per F/Y		NRW management Activities					
				No of Active Connections	No. of meters tested	No. of meters replaced	No of meters sealed	No. of burst and leakages reported and repaired	No. of Dilapidated pipes replaced	Improvements in NRW Management Activities
	Apr-16	41.95		198	2	0	1	1	1	
	May-16	41.22		191	0	0	1	2	7	
	Jun-16	38.87		190	2	1	4	1	6	
Totals				**189**	**14**	**6**	**26**	**15**	**35**	

Financial Years (F/Y)	Months	NRW levels in %	Average NRW level per F/Y		NRW management Activities					
				No of Active Connections	No. of meters tested	No. of meters replaced	No of meters sealed	No. of burst and leakages reported and repaired	No. of Dilapidated pipes replaced	Improvements in NRW Management Activities
2016/2017	Jul-16	38.87	33.75	190	0	1	3	3	1	- Integration of GIS database with the billing database - Use of SQL to obtain the water sold/Consumed within the DMA and number of connections - Use of the GIS web system to locate the customers within the DMA and access of customer ledger - Use of exact location of pipes to record burst and leakages using the printed maps using the GIS Web system
	Aug-16	39.84		190	2	1	1	0	0	
	Sep-16	35.61		190	1	0	2	0	4	
	Oct-16	36.07		190	1	1	1	1	1	
	Nov-16	36.11		191	0	0	0	3	4	
	Dec-16	24.18		191	0	0	2	2	2	
	Jan-17	36.01		192	1	1	2	2	3	
	Feb-17	33.17		175	0	0	1	0	0	
	March-17	32.96		189	2	1	2	0	1	
	April-17	35.28		147	2	1	2	1	1	
	May-17	32.47		147	0	0	4	1	3	
	Jun-17	24.49		147	1	1	5	2	2	
Totals				**178.25**	**10**	**7**	**25**	**15**	**22**	

Financial Years (F/Y)	Months	NRW levels in %	Average NRW level per F/Y		NRW management Activities					
				No of Active Connections	No. of meters tested	No. of meters replaced	No of meters sealed	No. of burst and leakages reported and repaired	No. of Dilapidated pipes replaced	Improvements in NRW Management Activities
2017/2018	Jul-17	31.76	25.08	148	1	2	2	3	2	- Use of the GIS web system to locate the customers within the DMA and access of customer ledger - Use of SQL to obtain any information regarding the DMA, for example, age, materials, and sizes of pipes and their locations and e.t.c
	Aug-17	33.14		135	0	0	1	0	1	
	Sept-17	31.55		135	0	0	0	0	0	
	Oct-17	27.56		135	1	1	1	1	1	
	Nov-17	27.16		109	1	1	0	1	1	
	Dec-17	42.19		103	1	0	2	1	0	
	Jan-18	24.88		11	0	0	0	2	0	
	Feb-18	17.17		11	1	0	1	0	0	
	March-18	22.43		11	0	0	0	0	0	
	Apri-18	18.02		11	1	0	1	1	0	
	May-18	14.52		11	0	0	1	0	1	
	Jun-18	10.53		11	1	0	0	0	1	
Totals				**69.25**	**7**	**4**	**9**	**9**	**7**	