UNIVERSITY OF NAIROBI
SCHOOL OF ENGINEERING

MASTER OF SCIENCE IN CIVIL ENGINEERING
(ENVIRONMENTAL HEALTH ENGINEERING)

ASSESSMENT OF FACTORS WHICH CONTRIBUTE TO NON-REVENUE WATER IN KENYA AND THEIR MITIGATION: CASE OF MERU WATER SUPPLY

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A thesis submitted in partial fulfilment for the award of the degree Master of Science in Civil Engineering in the department of Civil and Construction Engineering in the University of Nairobi

August 2020

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DEDICATION

I wish to dedicate this work to God for granting me the ability to undertake Master degree in Civil Engineering. I also dedicate it to all members of my family, my wife Pam, our sons Ted, Emmanuel and Shem, for the many days I could not be with them during the period of writing this thesis. Finally, to my late parents Kiliopa and Nyamondi who inculcated in me the culture of hard work and service to humanity. I will not forget to mention my late brothers Andericus and Peter, whom we grew up with tendering our Dad's cows and goats.

ACKNOWLEDGEMENT

My sincere thanks go to my supervisors Eng. Prof. P.M.A. Odira and Eng. Prof. E.N. Nyangeri for their advice, guidance and patience while preparing the research proposal and during the preparation of the thesis. My gratitude also goes to all the lecturers at the Department of Civil & Construction Engineering of the University of Nairobi.

I would not forget to thank Prof Ronnie Mckenzie and Prof Malcolm Farley who are renowned Professors in Civil Engineering and have undertaken many publications in the subject area of Non - Revenue Water particularly for the International Water Association for providing to a lot of reference materials on Non - Revenue Water Management.

At the place of work, I was given an opportunity despite the busy schedules to have time in the evening to attend classes, prepare my proposal and eventually the thesis. In this regards I recognize the role my past and current immediate supervisors, Eng. L.N Simitu and Mr. Joseph W. Irungu respectively, played during my studies and I thank them so much for their words of encouragement and understanding. Special acknowledgement to my secretary Jacinta Ncooro for typing part of the Thesis during correction period. To the team at Meru Water and Sewerage Company Limited, thank you so much for your assistance towards data collection.

To my family members, thank you so much for your intellectual and emotional support throughout my education and working career. Thanks to Pam, Ted, Emmanuel and Shem, I love you all. May God bless all those who assisted me in one way or another.

Thank you and I wish you God’s abundant blessings.

ABSTRACT

The availability of water resources has been undergoing reduction with time as a result of rising water demand from rapid growth in population, environmental degradation, and irrigated agriculture in the rural areas and industries in the cities and major towns. This has strained the available water sources leading to failure by water supplies to meet the current water demand resulting into water rationing as a way of managing the supply. In addition, there has been low funding resulting into low coverage presently standing at around 56% while the population growth is ever increasing. The sector also experiences large quantities in Non-Revenue Water and insufficient tariff to cater for maintenance and operations (O&M) costs.

The study aimed at assessing the factors which cause Non-Revenue Water in Kenya based on case study of Meru Water Supply Scheme, being one of the best managed Non- Revenue in the country. In addition, the study aimed at evaluating the water balance by establishing the levels of all components of Non-Revenue Water and Revenue Water in the scheme based on the International Water Association standards and water balance table. It also assessed the relationship between pressure and leakages and lastly analysed the economic level of leakage for Meru water supply scheme and strategies to mitigate against Non-Revenue Water. The specific objectives of the study were to Assess the factors that cause Non-Revenue Water, Evaluate the water balance for Meru water scheme, Assess the relationship between pressure and leakages and analyse the leakages' economic level and the strategies to control Non-Revenue Water.

The research findings revealed that high Non-Revenue depends on the organizational practices like operation and maintenance techniques, methodology of repair works, connection and disconnection practices, lack of as built drawings, illegal connections and organizational culture. The results of evaluation of the water balance, the Revenue Water Volume was 83% of which billed metered consumption was about 83% and billed unmetered consumption was 0%. The Non-Revenue Water Volume was 17% consisting of leakage on water mains, overflow from tanks, and leakages on service pipes, apparent losses 2.3% and metering inaccuracies 1.5%.

The study found that there is an empirical relationship between leakage and pressure. High operating pressures result into high leakage volumes whenever leaks occur. The analysis of economic level of leakage reveals that the cost of reducing Non – Revenue Water depends on the intensity of the exercise. Asset and pressure management, the speed and quality of repairs and active control of leakage are important factors to reduce Non – Revenue Water.

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

DFB	Design, Fund and Build
DMA	District Monitoring Area
COK	Constitution of Kenya
COR	Customer Relations Officer
GFS	Geographical Information System
IWA	International Water Association
JICA	Japanese International Corporation Agency
KS	Kenya Standards
MCM/yr.	Million Cubic Metres per year
MENR	Ministry of Environment and Natural Resources
MEWASS	Meru Water and Sewerage Services
MEWNR	Ministry of Environment, Water and Natural Resources
MWD	Ministry of Water Development
MWI	Ministry of Water and Irrigation
MWR	Ministry of Water Resources
MWRMD	Ministry of Water Resources Management and Development
MS	Microsoft
NWMP	National Water Master Plan
NWSS	National Water Services Strategy
MGD	Million Gallons per day
NRW	Non-Revenue Water
PPP	Public, Private Partnership
PRV	Pressure Reducing Valve
SCADA	Supervisory Control and Data Acquisition
O&M	Operation and Maintenance
WAB	Water Appeal Board
WASREB	Water Services Regulatory Board
WRMA	Water Resources Management Authority

WSBs	Water Services Boards
WSPs	Water Service Providers
WSS	Water Supply and Sanitation
WSTF	Water Services Trust Fund

CHAPTER ONE: INTRODUCTION

1.1 Background

Non-Revenue Water refers to the components of the water system input which are not billed and do not earn revenue. Like the rest of the world, Kenya is becoming gradually more water scarce with deterioration of water sources attributed mainly to population explosion and global warming. Currently safe water coverage in the country is about 56% of which 65% is in urban areas while sewerage coverage is **22%** only in urban areas. There are no sewerage facilities in rural areas **(MEWNR 2014).** This implies that at the moment about 17.6 million Kenyans are using water whose sources are not considered safe; hence the task of providing safe water is much heavier than 52 years ago at independence when there were only about 6 million Kenyans.

Creation of new water supplies schemes to address the ever increasing demand for water is expensive, comes with new challenges and needs more time. According to (MEWNR 2013) the budget provision required for universal sanitation and access to water by 2030 is Ksh 1.764 trillion which translates into an annual requirement Ksh 100 billion of which only about Kshs.40 billion is available. In this regard, the financing gap is still very wide and has to be bridged through innovative funding mechanisms including Public, Private Partnerships (PPP) and Design, Fund and Build (DFB) among others.

Reducing non-revenue water is one of the ways to manage costs in addressing water scarcity. It will improve coverage and at same time avail more funds for maintenance, operation and renewal of the system for water supply. The average non-revenue water in Kenya has remained high over time and is currently estimated at 42%. This means the country losses about Ksh 10 billion annually through losses caused by Non- Revenue Water. If this trend is not reversed, the country will lose more than Ksh 150 billion by the year 2030. Non-Revenue Water is therefore a big risk to sustainability of Kenya's water sector. Through the Ministry of Water and Irrigation, the Government plans to lower the Non-Revenue Water from 42% which is the current level to below 10% by the year 2030. Figure 1.1 shows the trend of NRW from 2007/2008 financial year to 2013/2014 financial year according to the impact report issued by the Water Services Regulatory Board, every year.

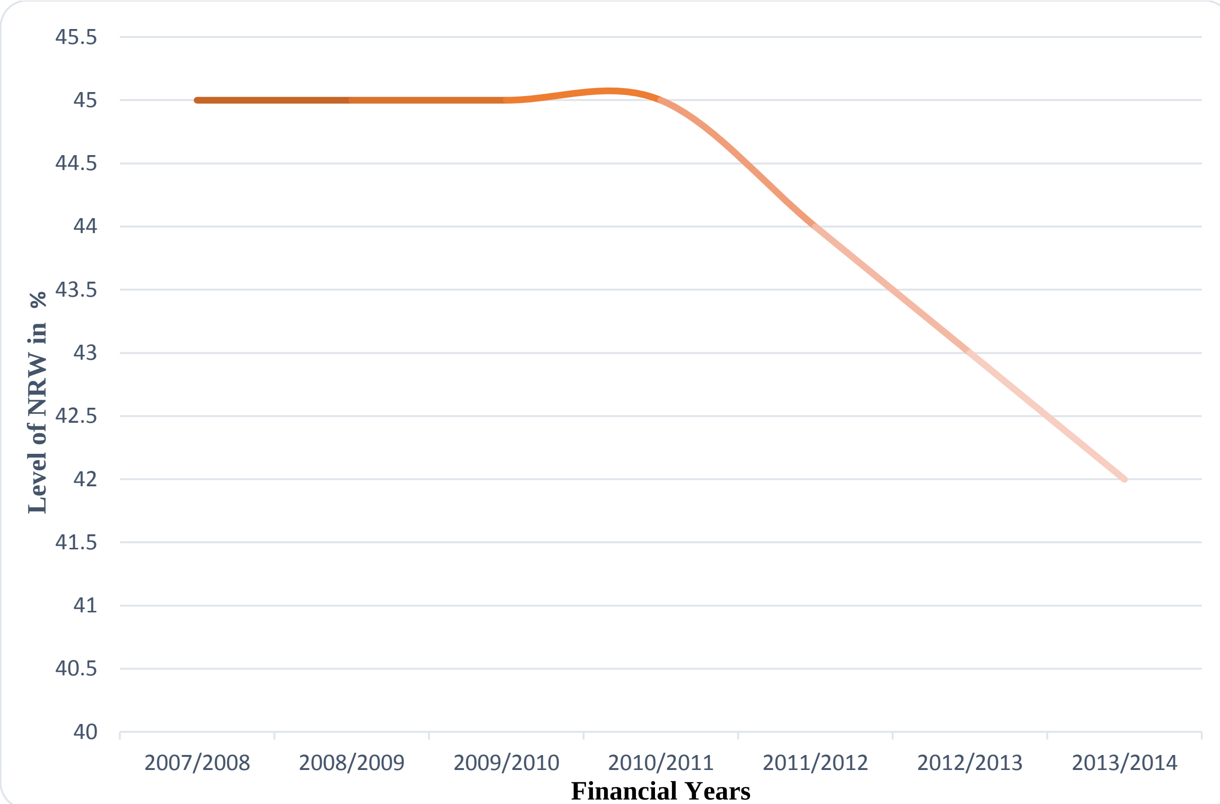

Figure 1.1: Trend of NRW from 2007 to 2014

According to the National Water Services Strategies (MWI 2009), the Non-Revenue Water in the country should have been about 15% by the year 2017. So far only three water utilities namely Meru, Nyeri and Malindi have attained NRW of below 30%. This is attributed to the fact; in Meru the system was upgraded through Japan Grant aid support in 2002 and immediately started Non-Revenue water reduction measures. While in Nyeri the system was rehabilitated in 1997 with funding from KfW and reduction of NRW was one of the funding conditions. Malindi benefited from the Private Sector Participation in a management contract between H.P Gauff K.G and the then Water supply operator NWCPC which focused on reduction of NRW (Barasa DK 2006). This is a study on assessment of factors that cause Non- Revenue Water in Kenya which was undertaken in Meru utility.

1.2 Historical Background of Meru Water Supply

Meru town is situated in Meru County and is approximately 90km North West of Embu town and about 300km north of Nairobi City. The town was established in 1929 as a regional Methodist Mission Centre and achieved municipality status in 1971 (MENR 2002). The municipality boundary occupies an area of $23km^2$ with the current population estimated at 240,900 people. The elevation within the town ranges from 1140m to 2240m above sea level. The town's main water source is Kathita River as it passes adjacent to the town. The town is served by Meru Water Supply currently being managed by Meru Water and Sewerage Services (MEWASS).

The water supply was first constructed in the year 1952 with a production capacity of $530m^3$/day to serve 14,000 people (MWD 1982). The first source of water at that time was Gatabora stream intake, which is still operational, from where raw water is transmitted to the treatment works located at Milimani area. The treatment works at the time consisted of two (2) composite treatment units with a combined capacity of $530m^3$/day and was supplying an area of $23km^2$ (MENR 2002).

A spring source at Gatabora with a capacity of $1,700m^3$/day and Kathita river intake with a capacity of $4,810m^3$/day were later developed. The main components of the water supply system have been improved over time and include:

i. Kathita river intake facilities
ii. Gatabora stream intake
iii. Gatabora springs
iv. Transmission mains
v. Two (2) composite treatment constructed in 1952
vi. One (1) direct filtration unit constructed in 1978
vii. One (1) backwash tank constructed in 1980 with a capacity of $77m^3$
viii. Two (2) composite filtration units constructed in 1995
ix. Three (3) clear water tanks and one (1) pump house
x. Two filtration units constructed in 2001
xi. Two (2) high level tanks and distribution system

The total installed capacity before the major rehabilitation that took place in 2002 was therefore around 7040m^3/day (MENR 2002). The system received major rehabilitation and expansion in the year 2002 through the Japanese grant aid costing Ksh 890 million targeted to assist a population of 51,000. The works aimed at improving the production from Kathita river intake, which at the time had effective capacity of 4, 489m^3/day to 6,730m^3/day. The project enhanced the total installed capacity to 8,960m^3/day. Figure 1.2 shows the distribution system of Meru Water network while Appendix II shows the location map of Meru Town.

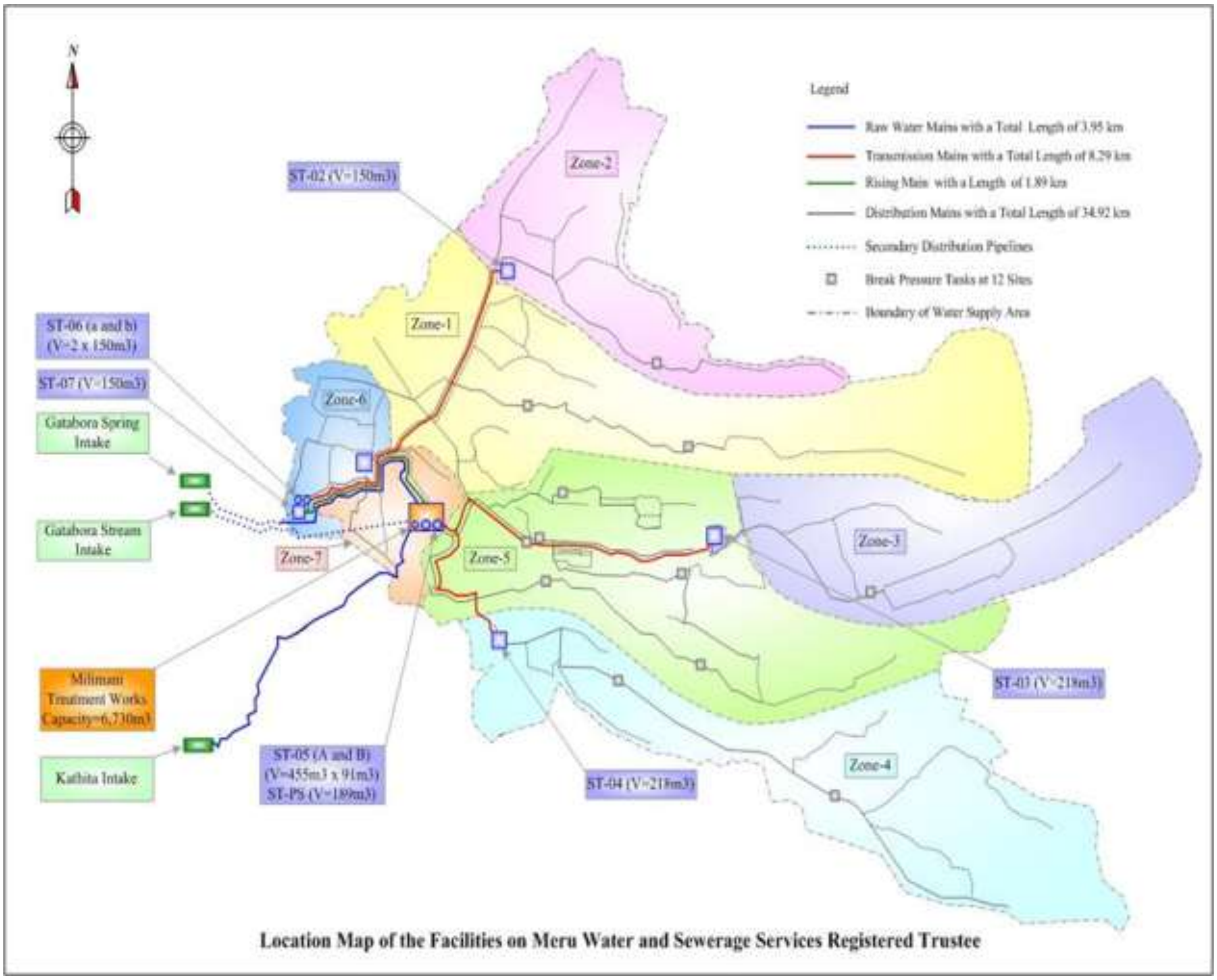

Figure 1.2: Distribution system of Meru Water Supply

Source: MEWNR 2014[c] NRW Case study

1.3 Non - Revenue Water in MEWASS

Kenya Government through 8th National and District Development Plan for the period 1997 – 2001 targeted the development and rehabilitation of the country's systems for water supply including improvement in Operation and Maintenance. A grant Aid from the Government of Japan was extended for extension and the rehabilitation of Meru Water Supply. The project aimed to increase the served population from 14,000 people in 2001 to 51,000 people in 2005. It also aimed at reducing Non-Revenue Water from more than 70% in 2001 to 30% in 2005 and lastly it targeted enhancing the health and sanitation situation of the residents located in area of supply through supply of treated water (MWRMD 2003).

The water project was therefore rehabilitated in 2002 through grant aid of Ksh 890 million from JICA. This improved the water production from 4,489m^3/day to 6,730m^3/day for Kathita Intake. The current Water Service Provider, Meru Water and Sanitation Services, MEWASS, took over the operation and maintenance of the supply of water and sewerage services on 1st July 2002. The Non-Revenue Water at that time was estimated at 70%. Which means only 30% of the production was available to the customers.

At the time of taking over the management and running of the water and sewerage services, the staff of MEWASS did not know anything about Non-Revenue Water so they did not collect any data on the same. Prior to the rehabilitation of the water supply, there were many leakages resulting into perpetual water shortage, water rationing, overloading of the treatment plant due to high water demand, many customer complaints and overworking of staff. At the same time, there were no master and zonal meters hence there was no data on water abstracted at the source, water produced and water supplied to the customers. Only about 100 out of the 2750 customer meters were operational. This resulted into most consumers being billed on average consumption based on past consumption records. There were no incentives for customers to conserve water and it was also impossible to determine the water demand with any degree of accuracy.

1.4 Problem Statement

Kenya has a territorial area of 582,646 km^2 of which water covers an area of 11,230 km^2 mainly L. Victoria and L. Turkana. Kenya also boarders the Indian ocean and has numerous small water bodies. According the National Water Master Plan, 2013, the renewable water resources available was estimated at 22.6 billion litres per year and is expected to rise to 26 billion litres by 2030, and to 28 billion litres by 2050 per year in both cases. The increase is due to the efforts of harvesting run off in dams being constructed in the country. However, by 2030 water demand is expected to reach 21 billion litres per year for the following sub-sectors: irrigation (84%), domestic (14%), industrial (1.3%), wildlife and fisheries (0.7%), (NWMP, 2013).

The availability of water resources has been reducing with time from degradation of environment, rise in water demand from population explosion and rural irrigated agriculture and industrial development in the cities and major towns. This has strained the available water sources to the extent that there are inadequate water supplies to cater for the current water demand resulting into water rationing as a way of managing the supply. Water resources management is carried out at catchment basin level. The country is divided into six catchment areas including; Lake Victoria South, Lake Victoria North, Athi River, Rift Valley, Tana River and Ewaso Nyiro North. The table 1.1 below shows average annual water availability in each basin in Kenya in million cubic metres per year (MCM/yr).

Table 1.1: Average annual water availability in Kenya

S/N^{O}.	Source	Area Km^2	Volume (MCM/yr) 2030
1.	Lake Victoria North	18,374	4,969
2.	Lake Victoria South	31,734	5,749
3.	Rift Valley Basin	130,452	3,045
4.	Athi River Basin	58,639	1,334
5.	Tana River Basin	126,026	7,261
6.	Ewaso Ng'iro North Basin	210,226	2,536
7.	Ground Water	-	600
	Total	575,451	25,494

Source: The National Water Master Plan, 2013

In 2010, Athi Catchment Area experienced a tight water balance due to a high water demand/resource ratio of more than 40%. Normally where the ratio is above 40% the situation is defined as under severe water stress. Thus, a need is present for effective water resources planning and, efficient water resources use to balance the availability and deficit. Under article 43 (1) (b) & (d) of the Constitution, every person has a right to reasonable standards of sanitation and to clean and safe water in adequate quantities, (COK 2010).

The realization of the constitutional requirement can be achieved progressively through interventions aimed at accelerating sanitation and access to water. In addition to conservation, preservation and management of available water resources, there must be concerted efforts to reduce loss of water in the water systems of supply so as to avail more water to the consumers and increased revenue which can be ploughed back for operation and maintenance.

1.5 Water Sector Reforms

The Water Sector in Kenya has been caught in a cycle of high financing gap resulting into low coverage which now stands at around 56% while the population growth is ever increasing. The sector also experiences high quantities of Non-Revenue Water and insufficient tariff to take care of costs in operations and maintenance (O&M) and under investment (MWI 2009).

It is against these challenges that the Government of Kenya rolled out extensive reforms in the water sector. The reforms were guided by the Water Act 2002 and the National Policy on Water Resources Management and Development. These two documents provided a framework for institutional and regulatory measures and mechanisms, which embraced broader principles of decentralization, participation, autonomy, sustainability and efficiency.

As part of the sector reforms, several institutions were established and assigned various roles and functions. The institutions established include the Water Services Regulatory Board (WASREB), the Water Resources Management Authority (WRMA), the Water Services Trust Fund (WSTF), the eight Regional Water Service Boards (WSBs), and the Water Appeals Board (WAB). The

Water Service Boards in turn operationalized several Water Service Providers (WSPs) to undertake the actual supply of water services in the areas of responsibility.

Despite all the efforts made by the Government and the relevant institutions, the average non-revenue water (NRW) in Kenya is currently estimated at 42%, which is very high compared to other countries (WASREB 2014). Consistent annual efforts to reduce the NRW levels have borne minimum results yielding only around 2% annually (WASREB 2014). In its endeavour to reduce NRW further and avail more water to the consumers the Government of Kenya has undertaken to reduce NRW ratio by 10% by 2020 in the whole nation (MWI 2010). This is in recognition that developing new sources is expensive and takes time, the quickest way to avail more water to the residents is by reducing NRW.

1.6 Justification and Importance of the Study

The expectations of the study include that the findings will generate knowledge and understanding on the area of Non-Revenue Water and its effects on the sustainability of the water sector in Kenya. It will assist the agencies in sector for water more so the providers for the water service to appreciate the factors that cause Non-Revenue Water plus methods that can be taken up for their mitigation.

Non-Revenue Water management reduces pressure on the scarce water resources, leads to increase in water coverage and high investment returns through revenue generated from water sales which can be used for developing more water sources to relieve the exchequer and donor funding. It will save the country from revenue loss caused by high losses of treated water.

Non-Revenue Water is therefore an enormous risk to water sector sustainability in Kenya as Ksh 10 billion is lost every year. The study will be of great value to the customer(s) as its intention is to seek ways of improving reliability of water supply and reduce losses. The study will also be beneficial to the academic world as it is expected to contribute current body of knowledge and understanding on Non-Revenue Water and how its reduction can be undertaken to improve on the operational performance of water supply systems. It will also form the basis for further study in the subject of Non-Revenue Water.

1.7 Objective of the Study

The purpose of the thesis included assessing factors which cause Non-Revenue Water in Kenya based on case study of Meru Water Supply Scheme. Additionally, the study is to evaluate the water balance by establishing the levels of all components of Non-Revenue Water and Revenue Water in the scheme. It will also assess the relationship between pressure and leakages and lastly analyse the economic level of leakage for Meru water supply scheme and strategies to mitigate against Non-Revenue Water. The specific objectives of the study include:

1. Assess factors causing Non-Revenue Water;
2. Evaluate the water balance for Meru water scheme;
3. Assess the relationship between pressure and leakages;
4. Analyse the economic level of leakage and the strategies to control Non-Revenue Water.

1.8 Limitation and Assumptions

Financial constraints and limited time led the study to be limited to selected water supply zones instead of the whole supply area. It assumed that the selected zones are true representatives of the whole supply area; this was gauged scientifically using statistics. The criteria for selecting the specific zones were developed during data collection.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

The literature review was undertaken under five themes namely: causes of Non-Revenue water, water balance, relationship between pressure and leakages, economic level of leakages and strategies for Non-Revenue Water control. A detailed review of the key legislation and policy documents guiding the operations in the sector of water in Kenya was undertaken to understand the direction the sector has taken with regard to Non-Revenue Water. These documents are the National Water Policy, the Water Act 2002, the National Water Services Strategy and the Non-Revenue Water Reduction standards.

2.1.1 National Water Policy

Preparation of the National Policy on Water Resources Management and Development started in early 1990's and was completed in 1999 after being passed by Parliament on 29th April 1999 as Sessional Paper No. 1 of 1999, (MWR, 1999). The Sessional Paper aimed to achieve management and sustainable development of the water sector through a framework whereby setting for desired targets is done, important strategies to guide actions are outlined and the entire range of related water activities and actors are synchronised. The policy underscores the principle and recognition that the potential of the private sector has not been fully utilised to be useful for the water sector's sustainable development. Basically, the policy touches on areas including management of water resources, supply of water and development of sewerage, arrangement of institutions and ensuring sustainability of the water sector through financing.

The policy has four objectives intended for improvement of the sector's performance and sustainability within the country.

i. Preserve, conserve and protect available water resources and allocate it in a sustainable, rational and economical way.
ii. Supply water of good quality and in sufficient quantities to meet various water needs, including poverty alleviation, while ensuring safe disposal of wastewater and environmental protection.

iii. Establish an efficient and effective institutional framework to achieve a systematic development and management of the water sector.

iv. Develop a sound and sustainable financing system for effective water resources management, water supply and sanitation development.

This policy therefore recognizes as a fact the scarcity of water resources and need to be preserved, conserved and protected. The preservation, protection and conservation of water resources include the proper use of treated water in water supply systems. The policy also gives a lot of emphasis to the sustainability of the sector through clear institutional framework, elimination of bad practices like high Non-Revenue Water and poor governance. The sector cannot achieve sustainability without addressing the challenges of large volumes of Non-Revenue Water. In essence the policy is recommending proper Non-Revenue Water management.

Estimates by the World Bank show that there is leakage of almost 45 million cubic metres per day by the developing countries (Kingdom, B., Liemberger, R. and Martin (December 2006). This is due to inappropriate policies, institutions which are weak and absence of incentives to curb water loss resulting into inadequate safe water supplies, poor sanitation and insufficient allocation of resources in the sector. The Kenyan, situation is not much different, however, there is clear policy direction guiding the sector, which has created an enabling environment for reforms and growth.

According to the Annual Water Sector Review of 2013 – 2014, the sector funding has grown with time since 2004 from total combined budget of recurrent and development of Ksh 6.6 billion in the 2004/2005 financial year to the highest point in 2012/2013 of Ksh 41.8 billion as shown in figure 2.1. The sector budget of Ksh 37.5 billion in the financial year 2014/2015 has also been included in the comparison.

Even though the sector budget has been increasing over time, the sector funding requirements are not being met as a huge funding gap exists as illustrated in figure 2.2. The only way to increase supply to the consumers is to make available a large proportion of treated water by reducing Non-

Revenue Water considerably and plough back the Ksh 10 billion which is being lost to asset development and renewal.

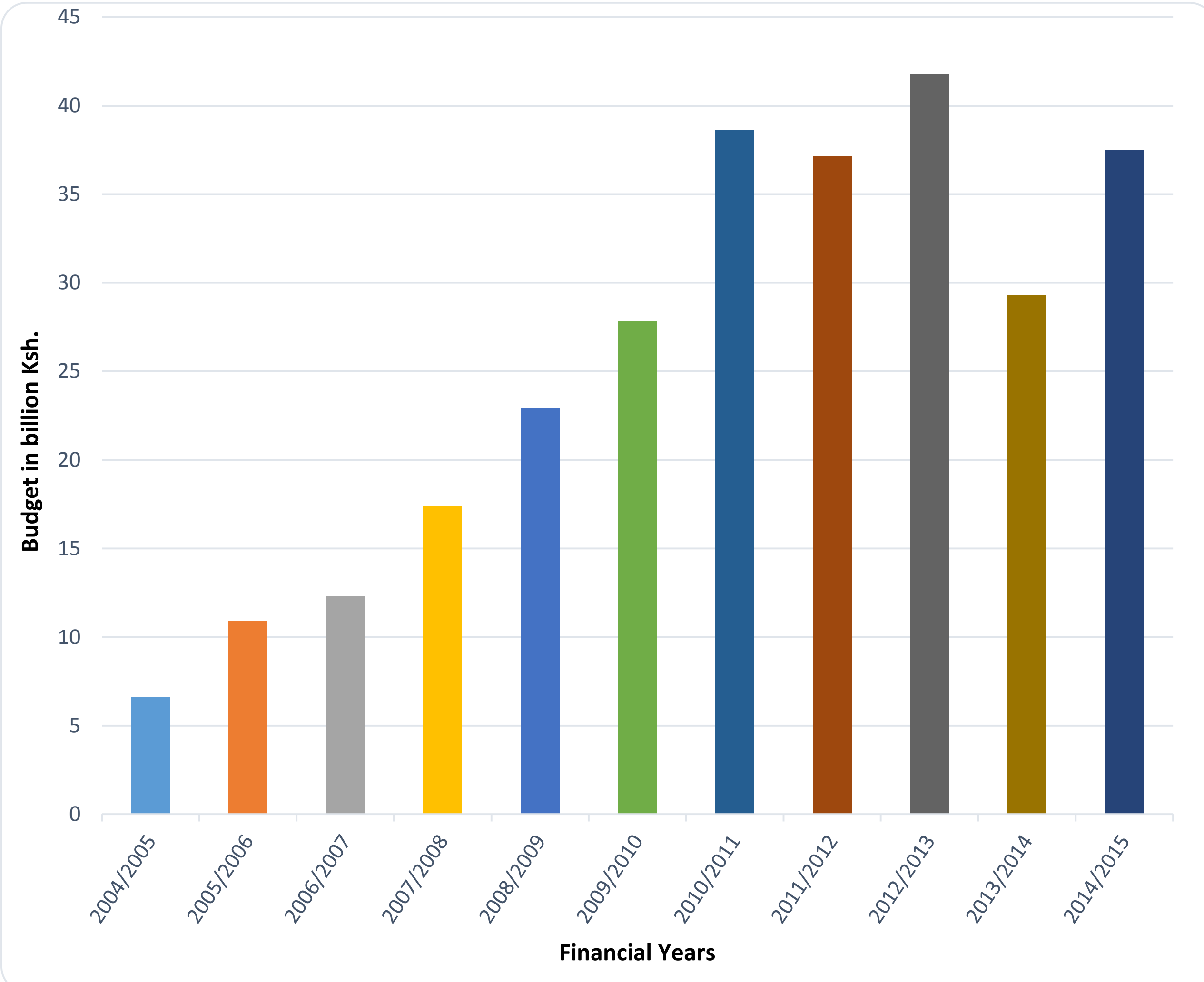

Figure 2.1: Growth in Water Sector Budget (Source: Annual Water Sector Review 2013 – 2014)

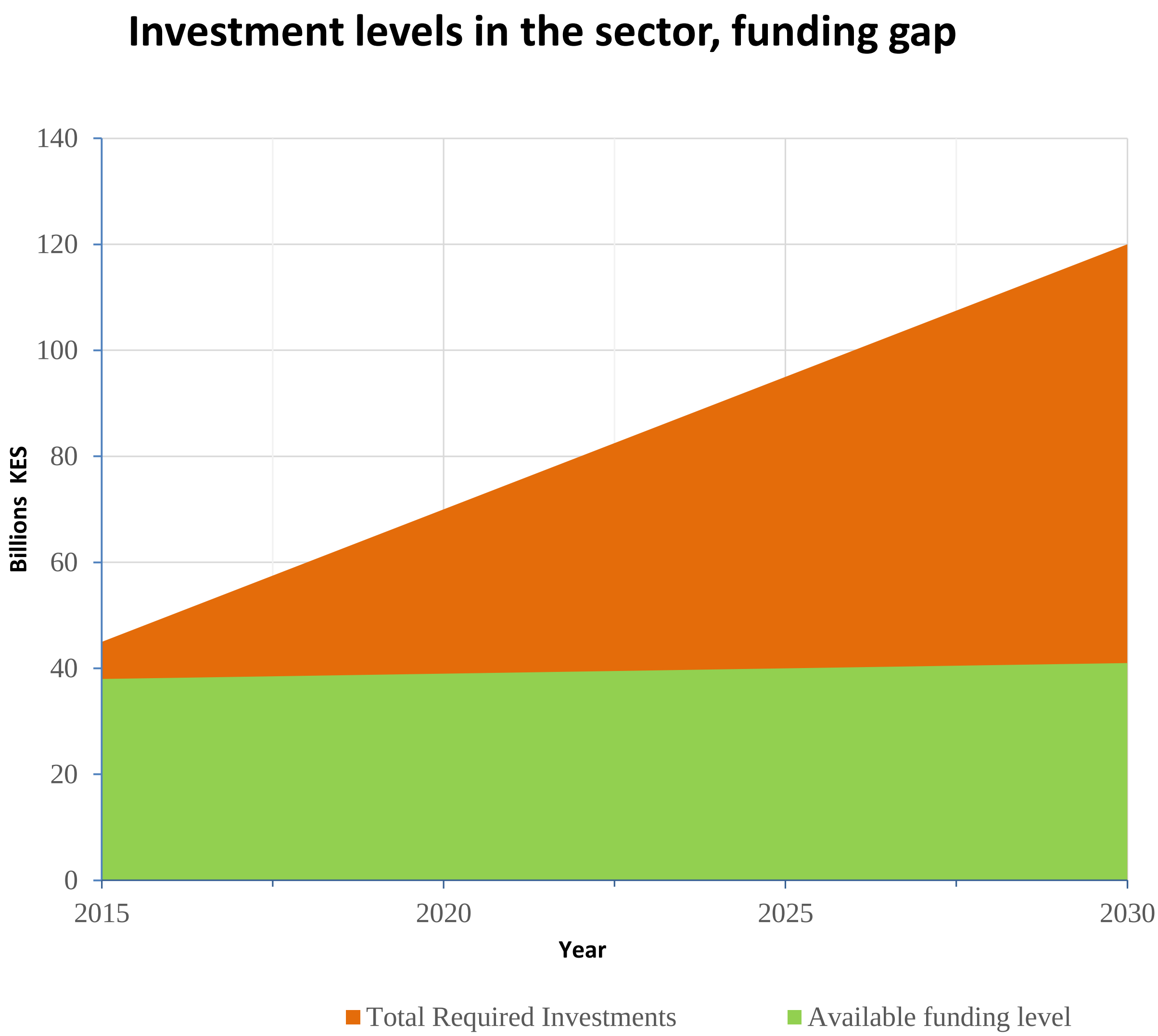

Figure 2.2: Funding gap in the water (*Source: Annual Water Review 2013- 2014)*

2.1.2 Water Act 2002

The Water Act 2002 became operational in March 2003 and provides the institutional and legal framework for the management, development and provision of water services in Kenya. From the Water Act 2002, several institutions were established and assigned various roles and functions. The institutions established include the Water Services Regulatory Board (WASREB), the Water Resources Management Authority (WRMA), the Water Services Trust Fund (WSTF), the eight Regional Water Service Boards (WSBs), and the Water Appeals Board (WAB). The Water Service Boards in turn operationalized several Water Service Providers (WSPs) to undertake the provision of water services within their areas of jurisdiction. The roles of these institutions are described in the table 2.1 below.

Table 2.1: Water institutions and their roles

Institution	Core responsibilities
Ministry of Water and Irrigation	i. Policy formulation, including NRW policy ii. Legislation iii. Development of Strategies
Water Resources Management Authority	i. Implementation of policies and strategies relating to management of water resources ii. Development of catchment level management strategies, including appointment of Catchment Area Advisory Committees and their facilitation.
Water Services Regulatory Board	i. Overseeing the implementation of policies and strategies relating to provision of water services. ii. Regulating the provision of water supply and sanitation services. iii. Licensing Water Service Boards and approving their appointed Water Service Providers. iv. Monitoring the performance of Water Service Boards and Water Service Providers. v. Non-Revenue Water is one of the performance indicator being monitored by WASREB
Water Service Boards	i. Planning for improvement in provision of water supply and sanitation services. ii. Appointment and contracting Water Service Providers. iii. Asset holder of central government facilities.
Water Services Trust Fund (WSTF)	i. Assist in financing of provision of water supplies in areas that are inadequately provided for.
Water Appeals Board (WAB)	i. Adjudicating disputes within the sector.

Source: WSRS, 2004

The major achievements realized in the sector following enactment of the Water Act 2002 are:

i) Separation of policy, regulation and service provision reduces conflict of interest, provides effective oversight and coordination.

ii) Improvement of performance in the Water Services and Water Resources after separation of management in the two sub-sectors.
iii) Establishment of sub-sector regulators (WRMA & WASREB) promotes customer protection, annual public reporting, consultation and enforcement.
iv) Ring-fencing revenue stream from fees/levies for the efficient operation and management of the institutions.
v) Framework allows for prudent water allocation planning and application of ‘polluter pays’ principle.

Institutional framework to allow for Non-Revenue Water management in Kenya exists at the Water Service Provider level with monitoring by the Water Services Regulatory Board. However, prior to the establishment of the current institutional set up, the sector was caught in a cycle of reduced investment, poor financial returns and low service quality characterized by:
i) unreliable service and low coverage;
ii) large unpaid bills and large levels of Non-Revenue Water;
iii) very dismal management of finances;
iv) a tariff insufficient to cover operations and maintenance (O&M) costs;
v) Inadequate commercial management.

Even though there has been improved funding and good governance in the current dispensation, the level of Non-Revenue Water still remains high at 42%, meaning almost half of the total water production in Kenya does not earn revenue and therefore does not contribute to the operation, maintenance and renewal of the water supply systems. However, there is clear institutional framework for the sector which is a good environment for the management of Non-Revenue Water.

2.1.3 National Water Services Strategy

According to section 49 of the Water Act 2002, the Cabinet Secretary in charge of Water Affairs is mandated to create by consulting with the public and publish in the Kenya Gazette the National Water Services Strategy (NWSS). The first strategy after the act’s enactment is for the period 2007 – 2015. It provided for a review in the sanitation and supply of water situation and recognized the unsatisfactory coverage of service and high Non-Revenue Water in the Sector. The strategy contributes towards the realization of Vision 2030 goals which the Kenya Government has on access to basic sanitation and affordable and safe water.

The Goals of the NWSS with base year being 2007 are:

i) To increase sustainable access to safe water complying with the Kenyan standards such as drinking water quality (formal service provision) from 60% to 80% in the urban setting by 2015 and to reduce the time taken to nearest public/communal outlet and back home to an average of 30 minutes.
ii) To increase sustainable access to water complying with the Kenyan standards such as drinking water quality (formal service provision) from 40% to 75% in the rural setting by 2015 and reduce the distance to the nearest public/communal outlet to 2 Km;
iii) To reduce Non-Revenue Water due to both economic and technical losses from the current average of 60% to 30% by 2015;
iv) To achieve Operation and Maintenance cost recovery of all WSS systems gradually by 2010 with the exception of targeted subsidies to the poor;
v) To increase access to waterborne sewage collection, treatment and disposal from 30% to 40% in the urban setting and from under 5% to 10% in the rural setting by 2015;
vi) Reach through sustainable waterborne sewage collection, treatment, and disposal systems 40% of the urban and 10% of the rural population by 2015 and total coverage in all urban centres by 2030;
vii) Increase access to safe and improved basic sanitation facilities particularly for the poor from 55% to 77.5% in the urban setting and from 45% to 72.5% in the rural setting by 2015

The target of reducing Non-Revenue Water due to both technical and economic losses from the current 60% to 30% by 2015 has not been achieved since Non-Revenue Water is still at 42%.

2.1.4 Non-Revenue Water Reduction Standards

The challenge of high Non-Revenue Water prompted the Government of Kenya to implement the Project for Management of NRW with JICA Technical Cooperation support. Phase one of the project started in 2010 and was completed in 2014. Phase two of the project will run from 2016 to 2020. The project aims at providing a structure for NRW reduction and at the same time improving technical competence of staff to ensure that water resources are effectively utilized by reducing NRW ratio by 10% by 2020 in the whole Nation.

Phase one of the project was implemented on pilot basis in Embu Water and Sanitation Company Ltd, Kapsabet Water and Sewerage Company and Narok Water and Sewerage Company within Tana Water Services Board, Lake Victoria North Water Services Board and Rift Valley Water Services Board respectively. The pilot project developed a manual, guidelines and handbook to be used by the Water Services Boards, Water Service Providers and water scheme operators respectively in the reduction of NRW in the country. Also NRW Reduction Plan was developed for Narok WSP and Kapsabet WSP with the aim of replicating and upscaling to the rest of the WSPs in the country. The manual recommends six stages in the reduction of Non-Revenue water as shown in the table 2.2.

Table 2.2 Stages in NRW control measures

Stage	Approximate NRW Ratio	Recommended NRW Reduction Measure
1st	More than 35%	Address surface leakage and commercial losses
2nd	35% - 25%	Detect and decrease underground leakages
3rd	30% - 25%	Stop occurrence of leakage and start replacement of aged pipes
4th	25% - 15%	Carry out leakage control work and accelerate pipe replacement
5th	15% - 10%	Wrap up the proactive leakage control work and complete pipe replacement
6th	Less than 5%	Keep minimum NRW ratio

Source: Non-Revenue Water Manual, MWI 2014

2.2 Causes of Non-Revenue Water

Non-Revenue Water refers to the components of water supply system input not billed and not earning revenue. It consists of authorised consumption which is unbilled, losses within commercial activities, which is also termed as apparent losses and physical losses often referred to as real losses (Farley M., Wyeth G., Ghazali Z., Istander, A. & Sher, S. 2008).

The causes of commercial losses according to Farley M, Wyoth G, Gazali Z, Istander A & Sher S. (2008) are meter reading errors, slow running meters, use of flat rates, illegal connections, tampering with meters, non functional meters, loss of records, data entry errors, delays in meter reading and administration errors. Water theft is another factor causing water losses in a in a utility Kingdom, B., Liemberger, R. and Martin (2006). Inaccurate master and consumer meters lead to substantial loss of water (MWRMD, 2003) because they take time to be noticed and given the fact that response time in Kenya is very poor.

Physical losses consist of leakages from overflows and the system from the tanks storing water. They result from poor maintenance and operations, absence of leakage control which is active and repair work, and underground assets of poor quality (Kingdom, B., Liemberger, R. and Martin, 2006). However, a study done in developing countries in (Farley M., Wyeth G., Ghazali Z., Istander, A. & Sher, S. 2008).

finds that the reasons for high Non-Revenue Water are:

i. Not understanding the problem: magnitude, sources and costs;
ii. Lack of capacity; insufficient trained staff
iii. Inadequate funding to replace the infrastructure, pipes and meters
iv. Lack of management commitment
v. Weak enabling environment and performance incentives

2.2.1 Impact Report 2014

According to the annual impact report (Impact, 2014) prepared by Water Services Regulatory Board, Non-Revenue Water is a measure of a utility's efficiency in delivering the water it produces to the customers. The report identifies causes of technical losses as leakages from the system while commercial losses are caused by theft of water, illegal connections, metering errors and authorised consumption which is unbilled. The report also identifies WSPs which have NRW less than 30% as Nyeri, Malindi and MEWASS at 24%, 29% and 26% respectively. MEWASS was chosen for this study in order to generate the best industry practice for benchmarking to other WSPs.

2.2.2 Benefits of Non-Revenue Water Reduction

The developing world looses through leakage about 45million cubic metres of water daily (Allan 2010). With basic per capita consumption of 100 litres each day, water lost through leakages can serve approximately half of the world population who are without safe water. In Kenya, the country loses almost half of the water produced; if the water loss is prevented then the water coverage can improve remarkably above the current level of 56%. Therefore the benefits of Non-Revenue Water Reduction include:

i. Increase in the quantity of water billed;
ii. Increase in net income to the Water Service Providers;
iii. Reduction of development costs by suppressing new water source development;
iv. Reduction of construction costs by reducing the number of new facilities
v. Elimination of secondary accidents like flooding and contamination caused by leakages

According to the First UFW/NRW Survey Report on Meru Water Supply undertaken by the Ministry of Water Resources Management and Development through a consultant in December 2003, the main causes of Non-Revenue in Kenya are:

i. Most water supply schemes in Kenya are old and dilapidated making it easy for bursts to occur. Maintainance and pipe replacement have not been given priority in the budgeting process;
ii. Weak pipe materials such as asbestos and cast iron pipes adopted in early 1970s are still in the systems. These pipe materials are susceptable to bursts;
iii. Pressure management in most WSPs is poorly done resulting in frequent bursts leading to water loss.

2.3 Water Balance

Step one in undertaking Non-Revenue Water management is to comprehend the magnitude of the lost water (Farley M., Wyeth G., Ghazali Z., Istander, A. & Sher, S. 2008) by establishing water balance or water audit. The process of water audit helps utilities to determine sources, magnitude and cost of Non-Revenue Water. A standard structure of international water balance has been developed by the International Water Association (IWA) (Farley M., Wyeth G., Ghazali Z., Istander, A. & Sher S. 2008). IWA methodology of determining the water balance traces water right from source through the system to consumption point (Charalambous et al; 2014).

The methodology has been standardized by IWA for uniformity and understanding of lost water, location of loss, reasons for loss and what strategies can be established for efficient and effective water loss control programme so as to improve potable water supply to the consumers (Charalambous, B. Foufeas, D. & Petroulias, N. 2014). To determine the water balance with accuracy and to avoid guess estimation requires (Charalambous, B. Foufeas, D. & Petroulias, N. 2014).

i. Master Meters to measure the production
ii. Consumer meters to determine the billed consumption
iii. Zonal meters to determine the amount of water flowing into each zone
iv. Strategic meters for measuring any authorized consumption

One of the challenge facing Non-Revenue Water reduction measures in the past was the use of many different definitions in different countries due to absence of standard tools, terminology, monitoring indicators (WB Module 3, 2006). IWA therefore developed one standardized set of definitions for Water Balance components to define common terminology and indicators to allow for comparison and benchmarking among utilities (Farley M., Wyeth G., Ghazali Z., Istander, A. & Sher, S. 2008). The standard IWA water balance is shown in table 2.3.

Table 2.3: International Water Association: Water Balance

<table>
<tr><td rowspan="9">System Input</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-Revenue Water (NRW)</td></tr>
<tr><td>Unbilled Unmetered Consumption (eg.hydrant)</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Commercial (Apparent) Losses</td><td>Unauthorized Consumption (eg. illegal connections)</td></tr>
<tr><td>Customer Metering Inaccuracies, Estimations and Data Handling Errors</td></tr>
<tr><td rowspan="3">Physical (Real) Losses</td><td>Leakage on Transmission and/or Distribution Pipes</td></tr>
<tr><td>Leakage and Overflows at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer Use</td></tr>
</table>

Source: IWA, Water Balance Table

Most utilities use the standard water balance table to calculate each component of the system input and determine points where the water losses occur. According the IWA the following definitions have been adopted:

1 **System Input Volume** refers to annual volume of the whole or part of the system for water supply. It is measured through metering using master meters or zonal meters when part of the system is considered (Farley and Liemberger, 2006). Accuracy of the system input has tremendous value in water balance accuracy. In case of unmetered connection, the flow can be measured through:

i) Temporary flow measurements using portable devices

ii) Reservoir drop tests

iii) Analysis of pump curves, pressure and average pumping hours

2 **Authorized Consumption** refers to volume of annual metered and non-metered water taken by the water supplier, registered customers and those who are authorized such as fire hydrants, government offices. It consists of unbilled metered and unmetered consumption, and billed metered and unmetered consumption.

3 **Non-Revenue Water** refers to difference between system input volume and billed authorized consumption. It consists of unbilled authorized consumption and water losses

4 **Water Losses** refers to the difference between authorized consumption and system input. It consists of physical losses and commercial losses.

5 **Commercial Losses** also called apparent losses consisting of consumption which is unauthorized and all types of inaccuracies in metering.

6 **Physical Losses** also termed as real losses or technical losses refer to the losses in annual volumes through all types of bursts, leaks, overflows on mains, reservoirs and service connections up to the customer metering point.

2.3.1 Determination of Water Balance

The water balance can be determined through a four step approach (WB Module 3, 2006) as detailed below:

Step 1 – Determine system input volume

The system input is determined through the use master meters and zonal meters, if only a section of the system is being considered. It is recommended that the input meters' accuracy is verified using measuring devices of portable flow (Farley and Liemberger, 2006). However, where production meters are not installed: temporary flow measurements using portable devices reservoir drop tests, analysis of pump curves, pressures and average pumping hours can be used to estimate the system input. It is important that the 95% confidence limit is adopted.

Step 2 – determine authorized consumption

To determine the authorized consumption with accuracy requires metering of the consumers, consumption data for consumers who are not metered, and metered and unmetered unbilled consumptions. In essence the following are required:

i. Billed metered consumption
ii. Billed unmetered consumption
iii. Unbilled metered consumption
iv. Unbilled unmetered consumption includes e.g. operational use and water for firefighting often seriously overestimated.

Step 3 – Estimate commercial losses

i. Fraud, water theft
ii. meter under-registration
iii. data handling errors

Step 4 – Calculate physical losses

Determination of physical losses involves calculation of customer service connections leakage, leakage on distribution mains, transmission mains, overflows and reservoirs (Farley *et al*, 2008). Once the billed authorized consumption volume is determined, Non-Revenue Water Ratio can thus be calculated as:

$$\text{NRW (\%)} = \frac{System\ \ Input\ \ Volume - Billed\ \ Authorized\ \ Consumption\ \ Volume}{System\ \ Input\ \ Volume} \text{ x } 100$$

Even though all the utilities in Kenya still use the NRW ratio, it has several limitations. In this regard several developed countries are now using:

i. Infrastructure Leakage index
ii. Losses per connection
iii. Losses per Km of service lines

Infrastructure Leakage Index may be the most appropriate for the developing countries.

2.3.2 Infrastructure Leakage Index

Water losses expressed as a percentage of the system input can only be suitable within a utility since data utilised and calculation methodology can be used consistently (Johnson M. K., Brandit J. N., Ratnayaka D.D., 2008). It is inappropriate for comparing between organizations that have differing operational and physical qualities that including system input volume. Percentage losses can misrepresent facts when a utility supplying large quantities of water through a small number of connections to industry consumers is in comparison with utilities that do not deliver large industrial supplies (Johnson M. K., Brandit J. N., Ratnayaka D.D., 2008).

The International Water Association Task Force on Water losses has therefore formulated the Infrastructure Leakage Index, *ILI* for comparing and reporting real losses (Johnson *et al,* 2008) within different utilities. ILI can be determined as follows:

$$ILI = {}^{CARL}/_{UARL},$$

Where CARL= Current annual real losses derived from the annual volume of real losses expressed either as litres/day or litres per connection per day or litres per kilometre of mains per day for the hours in the day when the system is pressurized

UARL=Is the system specific unavoidable annual real losses, or the technically achievable real water losses based on the pipe burst frequency, duration and flow rates

It is made up of background (unavoidable losses), reported bursts and Unreported bursts

$$UARL = (18L_m + 0.8\,N_c + 25L_p)\,P$$

Where, UARL is in litres per day

L_m =Total length of mains in Km

N_c = Number of service connections

L_p = Total length of underground supply pipe in km

P = Average zone operating pressures in metres

Table 2.4 shows the UARL coefficients from the study by Johnson M. K., Brandit J. N., Ratnayaka D.D., (2008).

Table 2.4: UARL coefficients

	Per Day/ Metre of pressure	Background losses	Reported Bursts	Unreported Bursts	UARL Total
Distribution Main	l/km	9.6	5.8	2.6	18
Service pipe to property boundary	l/connection	0.6	0.04	0.16	0.8
Service pipe to property boundary to meter	l/km	16	1.9[a]	7.1[a]	25

Source: (Johnson M. K., Brandit J. N., Ratnayaka D.D., 2008).

Note [a] assume 15m average length of underground service pipe with property boundary;

The accuracy of ILI does not depend on the accuracy of determination of UARL (Mackenzie and Liemberger, 2005) but on the accuracy of:

i. Annual volume of real losses
ii. Average pressure
iii. Distribution network data

A study undertaken in Philippines (Miya, 2014) through NRW reduction project under performance based contract, found that explaining water loss by using percentage of the system input and ILI gives completely different results as shown in figure 2.3. The study further found that the following are important for NRW reduction measures.

i. Water Audit/Water Balance
ii. District Metered Area Establishment
iii. Active Leakage Control
iv. Pipe Replacement
v. Commercial Loss Reduction
vi. Integrated Meter Management
vii. Pressure Management
viii. Hydraulic Modelling
ix. Data Collection and Management

x. NRW Training
xi. Holistic strategy – not only relying on pipe replacement
xii. Dedicated NRW team – more than 400 engineers
xiii. Significant transfer of know-how and technology
xiv. Best equipment and software systems
xv. Sufficient funding, year by year about USD 60 M
xvi. Most importantly: full support from top management

Figure 2.3 shows the comparison between Non – Revenue Water and Infrastructure Leakage Index from the study by Miya (2014).

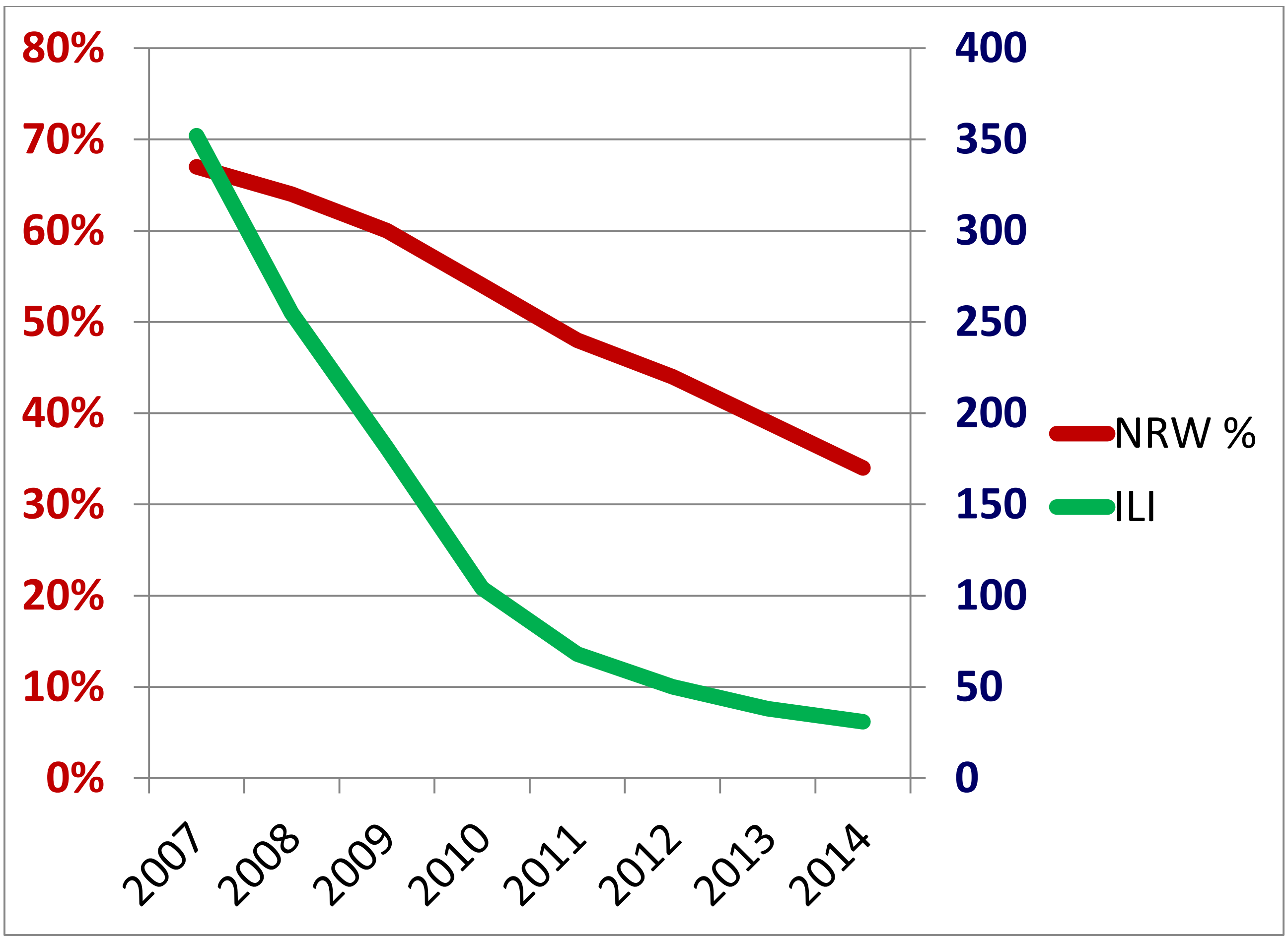

Figure 2.3: Comparisons of NRW & ILI, *Source: Miya (2014)*

2.3.3 Quantification of Leak Volume

There are six distinct methods of quantifying or measuring physical losses (MEWNR 2014[b]) as summarized in the following paragraphs.

1. Estimation method, by collecting leakage volume at the actual leakage point;

The measurement of actual leakage volume is determined at the leakage point using simple measuring devices to estimate the average flow rate. The total leakage volume within a target area is then found through multiplication of the average flow rate by the amount of leaks reported and the duration of the leaks (MEWNR 2014[b], Farley M., Wyeth G., Ghazali Z., Istander, A. & Sher S. 2008).

Total Annual Volume of leakage from mains = Number of Reported bursts x Average leak flow rate x Average leak Duration

The International Water Association, Water Loss Task Force, developed standard flow rates that can be adopted where data is not available (Farley M., Wyeth G., Ghazali Z., Istander, A. & Sher, S. 2008) as shown in table 2.5.

Table 2.5: Standard Flow Rates for bursts

Location of Burst	Flow rate for reported bursts (l/hr/m pressure)	Flow rate for unreported bursts (l/hr/m pressure)
Mains	240	120
Service Connection	32	32

Source: IWA Water Loss Task Force

The standard flow rates do not include background losses such as small leaks and weeping joints which cannot be detected through leak survey (MEWNR 2014[b]). Whenever the standard flow rates are adopted, adjustment must be made to cater for the background losses based on the standard background losses rate developed by the International Water Association, Water Loss Task Force (Farley et al 2008) as shown in table 2.6.

Table 2.6: Estimation of Background Losses

Location of bursts	Litres	Unit of measure
Mains	9.6	Litres per Km of mains per day per metre of pressure
Service connection: mains to property boundary	0.6	Litres per service connections per day per metre of pressure
Service connection: property boundary to customer meter	16	Litres per Km of service connection per day per metre of pressure

Source: IWA Water Loss Task Force

2. **Estimation method by calculation using the volume of distributed water and volume of water used;**

The existing leakage volume in a certain area can be approximated by calculating the distribution water volume minus the consumption billed water during a certain fixed period. However, the leakage calculated by this method includes water losses due to illegal connection, unbilled water for public use, water for institutional use and losses by metering error. So, the method advances only gives an approximate amount of volume of leakage. The simplest formula (MEWNR 2014[b]) is given by:

Leakage = Water Distributed – Water Used.

3. **Direct measurement method;**

The Direct Measurement Method is suitable in a system where there is zoning comprising of 3 to 5km of distribution network or 100 to 500 customer meters (MEWNR 2014[b]). The exercise is conducted mostly at night from 2.00am through to 4.00am when there is minimum usage of water and to avoid disruption of services to the consumers. The methodology is to close all peripheral and customer valves in the measuring zone. The flow rate in the measuring zone is determined at one point. The real losses represent the maximum flow rate. Figure 2.4 shows direct and Minimum Night Flow (MNF) measurements.

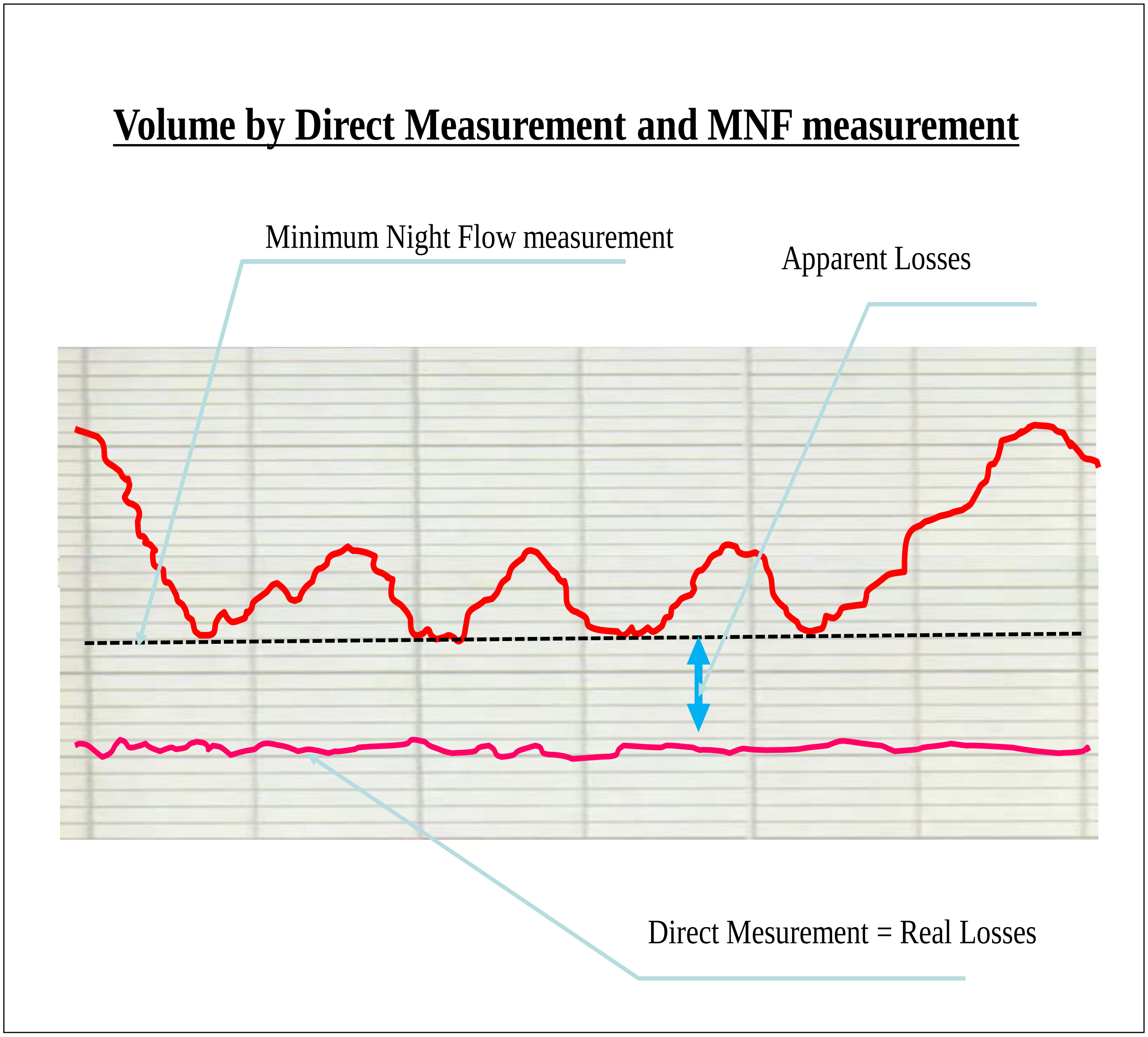

Figure 2.4: Direct and MNF Measurement, *Source: NRW Standard Manual*

4. Minimum Night Flow (MNF) measurement method

Figure 2.5 shows a typical water demand characteristic curve. By studying the curve for a particular zone, one can be able to approximate the leakage water volume. It can be explained by the information that water demand peaks occur in the morning, midday and early evening (MEWNR 2014[b]).

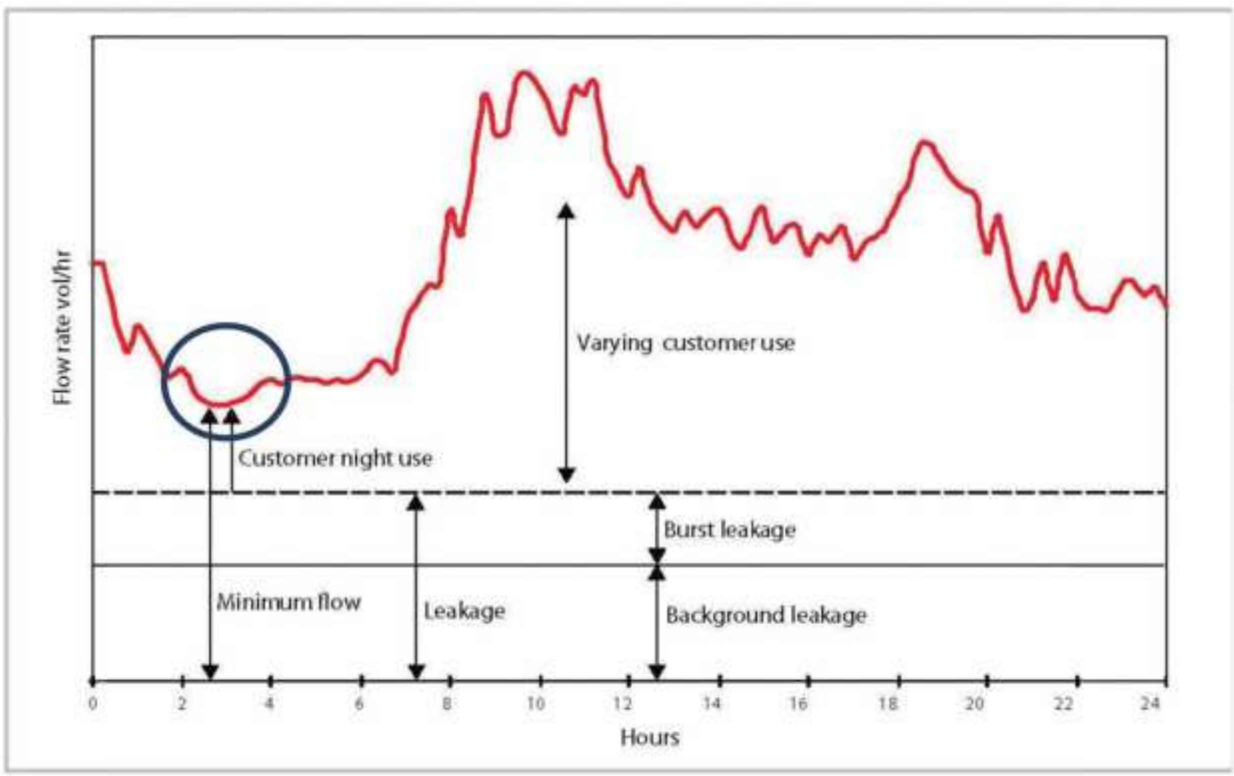

Figure 2.5: Typical Water Demand Characteristic Curve

Source: NRW Standard Manual

The method is suitable for zoned distribution network or within a pilot area. The minimum night flow occurs at 1.00am to 4.00am. Measuring the flow within a given zone using electro – magnetic meter or ultrasonic flow meter enhances the accuracy of the readings (MEWNR 2014[b]). The minimum flow measured by the MNF measurement method is governed by the equation:

Minimum flow = Leakage + Consumption

If the minimum flow is measured when there is no water use referred to as vacant Time, then the flow volume measured is only leakage volume.

5. Step Test Measurement;

This is the old measurement method, measuring the MNF of sub-blocks or divided pipelines. The measurement obtained is subsequently used for the leak detection work (MEWNR 2014[b]). It is a way that needs the gradual separation of parts of the pipe by shutting off line valves, starting at the point of pipe that is largest distance away from the meter and ending at the pipe that is closest to the meter. As the test progresses, observation of flow rate through the meter is made and the time when isolation of the separate sections of the pipe is recorded. A considerable amount of decrease noted in flow or "step," shows the presence of a leak in the just isolated pipe section.

6. Leak survey for areas with low water pressure

The method is applicable in water supply systems where water supply services are provided at very low pressures. Generally, leak occurring under the pressure of more than 0.1 MPa (10 m in water head) can easily be detected by sounding method while leaks occurring at less than 0.05MPa (5 m) can hardly be detected.

In such a case it is recommended to close all the peripheral valves and conduct the leak survey and measurement at night when the pressure builds up or use booster pump to enhance the pressure in the system.

2.4 Relationship between Pressure and Leakages

The leakage rate in a system of water supply is a function of the system's pressure (Charalambous, B. Foufeas, D. & Petroulias, N. 2014). The basic hydraulics formula based on Bernoulli principle, gives the flow through an orifice under pressure as:

$$Q = C_d \times V \times A = C_d \times (2g \times h)^{0.5} \times A$$

Where:

Q	=	volume of flow (per unit time)
C_d	=	discharge coefficient
A	=	Area (size) of the orifice
V	=	Velocity of flow through the orifice $(2g \times h)^{0.5}$
g	=	9.81 m/s^2 (acceleration, gravity)
h	=	meters water head above orifice (=pressure)

Pressure and leakage relationships in a network setting are complex and significantly different from the real pipe flow characteristics (WB Module 4, 2006). This has led to most utilities' technical/engineering staff not fully grasping the fact that pressure in the system affects leakage rate. The World Bank Institute Report in a study undertaken in Asia (WB Module 3, 2006) finds that the rate of leakage depends on:

i. Size, positioning and form of the opening
ii. Flow regime, laminar or turbulence flow; Reynolds number
iii. Pipe material

The study further finds that:

i. The occurrence of bursts increases with pressure
ii. Less pressure not only causes less leakage volume per day, but also a lower burst frequency
iii. Systems with direct pumping report higher frequency of new bursts than those fed by gravity from reservoir
iv. Where the system has intermittent supply, they may have between 10 and 20 times the amount of leaks than systems having steady pressure
v. A clear relationship has been established between leakage, pressure and frequency of bursts
vi. The higher the pressure the higher the leakage
vii. Higher pressures increase the occurrence of bursts
viii. Reducing pressure is a very cost effective leakage reduction method

Another World Bank Institute study (WB Module 4, 2006) conducted in Australia finds that:

i. Before installation of pressure reducing valves, there were some 20 bursts on service connections and a few bursts on mains per month.
ii. After the installation of a "Fixed Outlet PRV", burst frequency on service connection was reduced by more than 50% to below 10 per month. There were still a few leaks on mains.

iii. After installing a controller for the PRV ("Flow Modulated PRV"), that adjusts the pressure in accordance with the consumption in the zone, there were no further bursts on mains and only a few on service connections.

Two other studies undertaken by the International Water Association Task Force on Water Loss in South Africa and Sao Paulo found that reducing pressure through installation of pressure reducing valves saved upto 24 million litres per day and 260 million litres per day respectively, based on the intensity of the valves for reducing pressure (Thornton, 2008). Since the orifice area of splits (longitudinal) in plastic PVC and PE pipes varies with pressure (WB Module 4, 2006), the theoretical equation is much of a simplified form and does not work in the real network situation (WB Module 4, 2006). Empirical relationship between pressure and leakages is given by the equation:

$$Q_1/Q_0 = (P_1/P_0)^{N_1} \quad \text{or} \quad Q_1 = Q_0 \times (P_1/P_0)^{N_1}$$

Where Q_1 Final leakage at Pressure P_1

Q_0 Initial leakage at Pressure P_o

P_1 Final Pressure at Leakage Q_1

P_0 Initial Pressure at Leakage Q_0

N_1 Leakage exponent

In the above equation Q varies with P^{N_1} and $Q_1/Qo = (P_1/P_0)^{N_1}$. Analytical explorations show that N_1 tends 1.5 when the system pressure tends to infinity and 0.5 when system pressure tends to zero (Zyl and Cassa 2014). A higher N_1 value means the existing flow rates of leakage that are more sensitive change with pressure. The general equations are the most applicable in basic analysis and estimation of relationships between leakage and pressure. This can be for aggregate leakage from sectors of systems of distribution or laboratory tests on individual faults in pipes (WB Module 4, 2006).

Advanced pressure management is a popular technique in reducing leakages and burst frequency and most utilities avoid pressures above 25m (Mackenzie and Liemberger 2005). In Kenya residual pressure head of 10m is recommended at the consumer point (MWI 2005).

2.4.1 Variability of Area of Discharge

There are two types of discharge paths for leaks namely fixed area and variable area (Lambert 1992). Shape of holes which are irregular, hole patterns which are multiple and hole size change with pipe material and pressure under Fixed and Variable Area Discharges (FAVAD) Methodology. Examples of fixed area include holes and breaks in the walls of metal pipes and discharges from open ended plumbing, while examples of variable paths are splits in the walls of plastic pipes, leaks at joints and fittings (Lambert 1992).

The leakage-pressure relationship depends on the path of discharge. Losses from the fixed area leakage path vary according to the square root of the operating pressure in the system while discharges from variable area paths depend on the pressure raised to the power of 1.5 or 2.5. (Lambert, 1992). Because a mixture of variable and fixed discharge paths in a system exists in all instances, the leakage exponent lies in the limits of 0.5 to 2.5.

2.5 Economic Level of Leakages

The leakage economic level is that which costs would be incurred from any further reduction with no excess benefits derived from the savings (Pilcher R., Dizdar A., Toprak S, Angelis 2008) It is therefore the point at which the cost of saving 1m3 of water from being lost is more than the cost of production of the same 1m3 of water. It is important as an economic indication of the optimum level of leakage and depends on individual operating system pressures, network conditions, marginal cost of water, demands and their patterns and operating practices (Islam and Babel, 2013).

Marking out the Non-Revenue Water's economic level is necessary for creating a first NRW target, reviewing the progress made in NRW reduction measures and in deciding whether to undertake more measures or maintain the current level (Farley M., Wyeth G., Ghazali Z., Istander, A. & Sher, S. 2008). It comprises the cost of water lost and NRW reduction measures undertaking cost.

2.5.1 Cost of Water Lost

The water loss cost is equivalent to benefits of the lost water from both commercial and physical losses (Farley M., Wyeth G., Ghazali Z., Istander, A. & Sher, S. 2008). It includes the following operational costs

i. Manpower
ii. Chemical
iii. Electricity

The cost of commercial losses can be found based on the prevailing water tariff. Increase in NRW results to proportional increases to the lost water cost.

2.5.2 Cost of NRW Management

The cost of Non-Revenue Water Management is the cost of reducing NRW. It includes the following costs

i. Cost of maintenance: Staff and office maintenance costs
ii. Equipment and materials
iii. Cost of establishing District Metered Areas or Leakage Monitoring Blocks
iv. Transportation
v. Purchase of measuring devices
vi. Replacement of customer meters
vii. Leakage or water theft control
viii. Pipe replacements
ix. Pressure reducing devices

2.5.3 Graphical Presentation

The economic level of leakage can be explained through graphical presentation as illustrated in figure 2.6 (Farley M., Wyeth G., Ghazali Z., Istander, A. & Sher, S. 2008). The graph shows how cost of NRW management and cost of water lost are related. The leakage economic level is therefore the point place in which the sum of costs is minimum.

Once the Non-Revenue Water increases past the economic level, the cost of NRW management reduces while the cost of water lost and the total cost for the utility increases. Lowering the NRW below than the economic level of NRW will cost more than the potential saving since the cost of NRM management will be very high.

Utility managers are normally advised to maintain the NRW management cost at the economic level unless in a situation where the source of raw water is very limited or the strategy of the utility needs few loses (Farley M., Wyeth G., Ghazali Z., Istander, A. & Sher, S. 2008). This is more practicable in cases where there is subsidy from the government to cater for the shortfall between savings and the cost of NRW management.

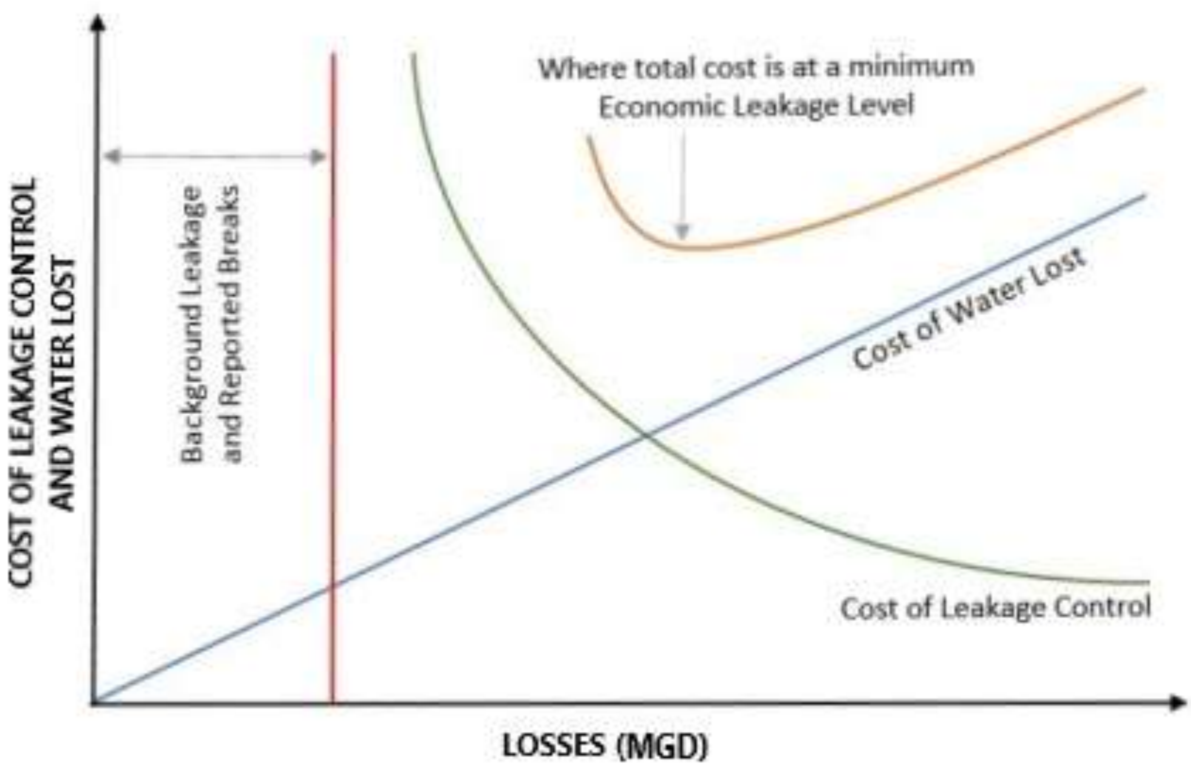

Figure 2.6: Economic Level of Leakage

Source; Adapted from Islam & Babel (2013) and Farley et al., (2008).

2.6 Strategies to Control NRW

The first step to creating a strategy to control Non-Revenue Water is to understand the reasons for Non-Revenue Water and the issues that cause NRW (Farley and Liemberger, 2007). Specific techniques, procedures and action plans with the necessary human and capital resources are then developed to address it. The utilities must first answer the following questions (Farley and Liemberger, 2007):

i. What is the amount of water being lost?
ii. At what point is the loss taking place?
iii. What are the reasons for the loss?
iv. What methods can be used to lower losses and build performance?
v. How can the methods be maintained and the achievements that have been gained sustained?

Utilities must therefore gain understanding as a matter of priority of the existing management policy, practices in operations, characteristics of the network, existing technology, cultural, social and skill influences in order to effectively develop and effect strategies for NRW (Farley and Liemberger, 2007). The first two questions of where loss of water occurs and the quantity of water lost are estimated by undertaking water balance and network audit.

The question of why water is lost is answered by undertaking a reassessment of practices for network operations. The main thing here is to understand regional characteristics, the network's state, current practices and methods utilised in running and supervising the network which includes infrastructure for observing flows, reservoirs and pressures, equipment, skills and expertise, physical data and estimates of authorized and unauthorized consumption (Farley and Liemberger, 2007). The table 2.7 shows the tools and tasks for creation of Non-Revenue Water Reduction Strategies.

Table 2.7: Tasks and tools for developing a NRW Reduction Strategy

	QUESTION	TASK
1	**How much water is lost?** i. Measure components	**Water Balance** i. Improve on measurement and estimation techniques ii. Meter calibration policy iii. Meter checks iv. Improve recording procedures
2	**Where is it being lost from?** i. Quantify leakage ii. Quantify apparent losses	**Network Audit** i. leakage studies distribution network reservoirs, mains, transmission ii. Operational/customer investigation
3	**Why is it being lost?** i. Conduct network audit ii. Conduct operational audit	Review of Network and Operating Practices Investigate i. Historical reasons ii. Poor practices iii. Procedures for Quality Management iv. Poor Materials/Infrastructure v. Political/Local influence vi. Cultural/Political/ Financial issues
4	**How to improve Performance?**	Upgrading and Strategy Development i. Upgrade records systems ii. Introduction of zoning iii. Introduction of leakage monitoring iv. Solve the causes of water losses v. Initiate leakage repair/detection policy vi. Create short, medium and long term action plans
5	**How to Maintain the Strategy** i. Design Strategy and action plans	O&M, Training & Policy Change **Training** i. Improve awareness ii. Increase motivation iii. Transfer skills iv. Introduce best practices **Operation and Maintenance** i. Community involvement ii. Water conservation and demand iii. Management programs iv. Recommendations from Action Plan v. Operation and Maintenance Procedures

Source: Farley and Liemberger, 2007

2.6.1 NRW Control Factors

The IWA Task Force on Water Loss has proposed the following four Non-Revenue Water Control factors to lower real losses from distribution of water and service systems (Charalambous *et al*, 2014, Pilcher R., Dizdar A., Toprak S, Angelis 2008)

i. Active control of leakage
ii. Asset or Infrastructure Management
iii. Quality Repairs done with Speed
iv. Pressure Management

The four factors must be balanced so as to achieve leakages levels that are economically, environmentally and socially acceptable (Thornton and Lambert 2008 and Lambert, 2000) as illustrated in figure 2.7. It is important the water supply network is divided into zones or District Meter Areas for ease of implementation of the four factors (Charalambous et al 2014)

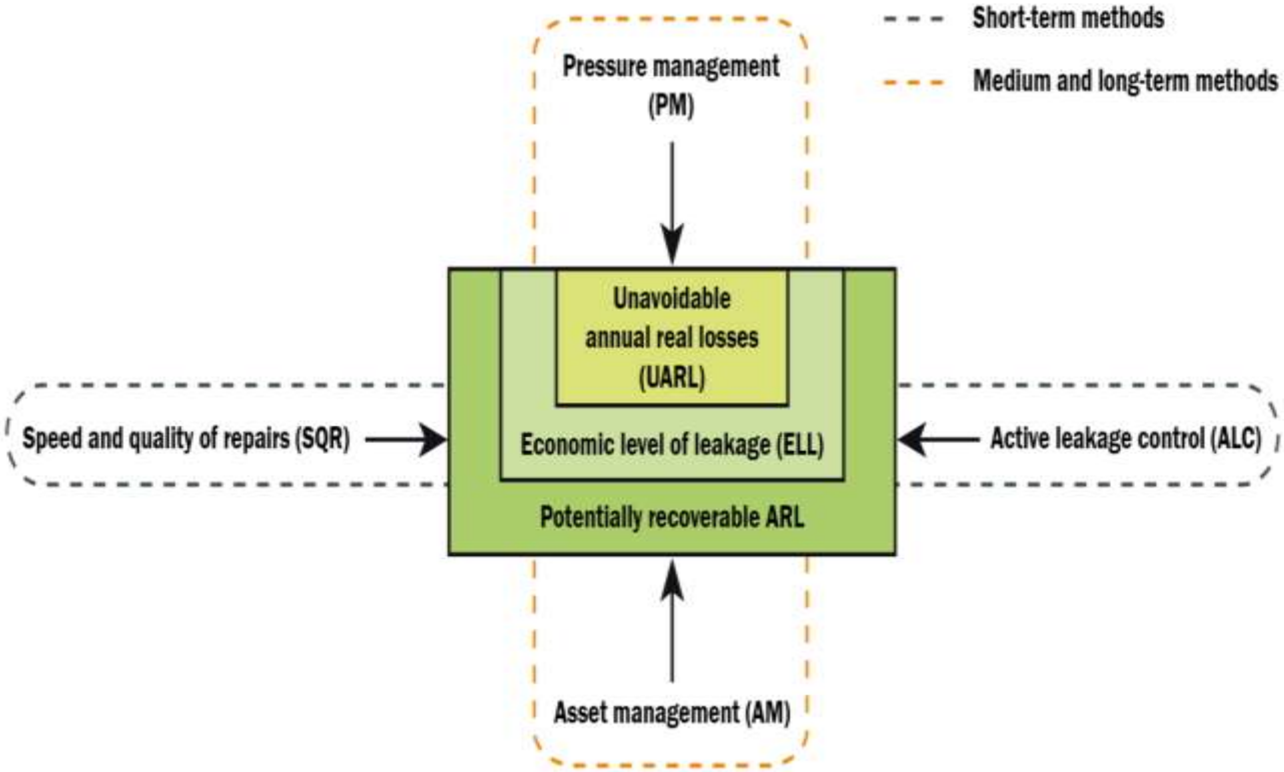

Figure 2.7: Leakage Control Strategies

Source: IWA

Active Leakage Control: It involves quantifying after identifying existing leakages continuously (Charalambous et al 2014) through the use of leak detection and surveys at regular intervals. The leak detection is carried out to identify invisible leaks based on data and information from each zone or district meter area (DMA) after which the leaks are repaired.

The active leakage control works is meant to cover all components of the system including transmission, distribution, reservoir overflows and service connections. Monitoring of flows into zones or DMA is conducted so as to detect burst and leaks that are not reported. In a study undertaken in Czech Republic, it was found that active leakage control could result into reducing the level of NRW by 30% (Bojkov et al 2011). The study therefore recommended Active Leakage Control as the more important principal in maintaining water balance to the required level.

The of active leakage control effectiveness depends on the design of the network, condition of the pipelines, zoning of the entire system and availability of updated as built drawings to assist identification of pipeline route (Charalambous, B. Foufeas, D. & Petroulias, N. 2014). Zoning the water supply network into DMAs is the most effective approach that is long term to reducing leakage but success is dependent on proper sizing, necessary data collection approach, evaluation, validation, interpretation and usage of results obtained (Bojkov et al 2011). Most utilities in the developed world have adopted the use of leakage monitor data collection, leakage evaluation, technical and economical optimization. SCADA is the commonly used leak monitor (Bojkov et al 2011).

Asset Management: Every asset namely, transmission mains, reservoirs, meters, pumping equipment, intakes, distribution pipelines, valves and service pipelines have economic useful life after which they should either be replaced or rehabilitated in a timely and programmed manner (MWI 2005). Management of Assets is therefore a good practice of engineering since as the asset deteriorates the burst frequency increases. However, priority setting is required whether to replace, rehabilitate, repair or maintain status quo of the assets (Charalambous, B. Foufeas, D. & Petroulias, N. 2014). The important factors in asset management are: awareness of asset performance, data collection and processing it to information that is useful for planning and adopting an information system that is good.

Infrastructure rehabilitation or replacement plans and their effective implementation are necessary in controlling NRW. The plans have basis on evaluation of the parameters which are technical like age, material, failure rate and burst frequency or leakage. Detailed assessment of water quality conditions and hydraulic normally give indication of operational problems (Bojkov et al 2011).

Speed and Quality of Repairs: The period of time a leakage is left to run affects volume of water lost as real losses. Repair works need to be finished fast enough after detection of a leak. Quality of repair determines the sustainability of the repair works (Charalambous, B. Foufeas, D. & Petroulias, N. 2014). Utilities are meant to develop and implement repair policy and in doing so the following factors need to be considered.

i. Efficient organization and steps from the time an alert is noted to the completion of works for repair;
ii. Adequate budget
iii. The right standards for workmanship and materials
iv. Availability of equipment and materials
v. Availability of mapping linked to GIS
vi. Committed management and utility staff
vii. High quality connections

Pressure Management: Leakage is proportional to the operating pressure. The goal of pressure management is to minimize unnecessary and excess system pressure but not to very low levels that would negatively affect distribution of water in the system. It can be done through pressure zoning and DMA management. Methods of the systems' pressure reduction in the system include break pressure tanks and variable speed pump controllers. The most cost effective and common way of reducing pressure is through automatic pressure reducing valves which can be installed at strategic points within a DMA downstream of water meter (Charalambous, B. Foufeas, D. & Petroulias, N. 2014).

2.6.2 Support Framework for NRW Reduction

The support framework necessary for the reduction of NRW (World Bank Institute Module 9 2006) is shown in figure 2.8.

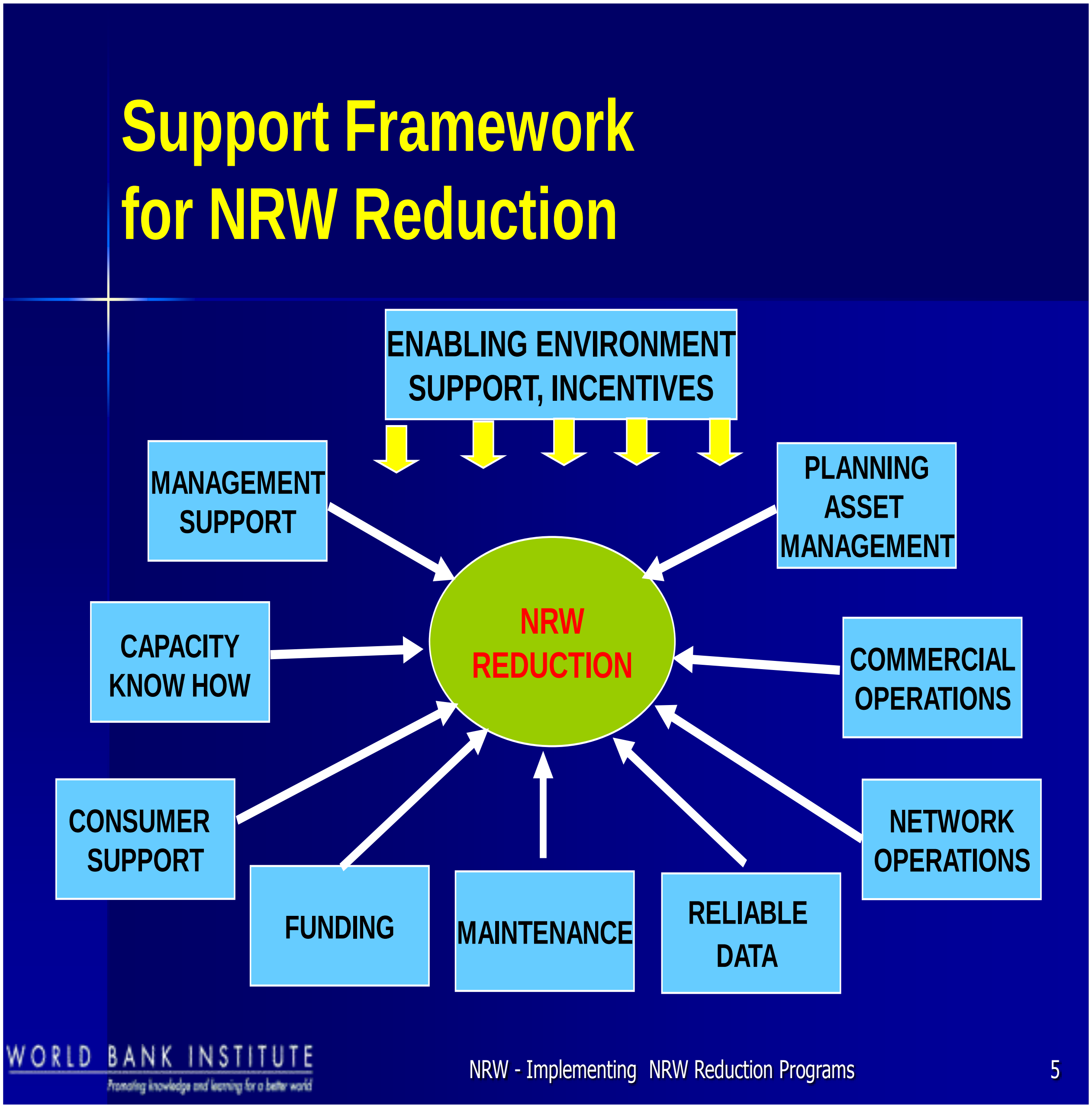

Figure 2.8: NRW Support Frameworks

Source: World Bank Institute 2006

2.7 Summary of Literature Review

The summary of literature reviewed is indicated in table 2.8.

Table 2.8: Summary of literature reviewed

Specific Objective	Literature Reviewed	Findings
Background	Policy documents, i. Water policy, ii. Water Act 2002, iii. National Water Strategy, iv. Impact Report	i. Huge funding gap for water development, ii. Clear institutional framework, iii. technical capacity exists
Causes of Non-Revenue Water	i. Farley et 2008, ii. Kingdom, et al 2006, iii. MWRMD, 2003 iv. Impact 2014 v. Allan S.W. 2010.	i. Dilapidated system ii. Operational procedures iii. Tank overflow iv. Poor construction v. Poor Designs
Water Balance	i. Farley et al 2008 ii. Charalambous et al 2014 iii. WB Module 3, 2006. iv. Farley and Liemberger, 2006 v. Johnson et al 2008 vi. Mackenzie & Liemberger 2005 vii. MIYA 2014 viii. MEWNR 2014[b]	First step to amount lost • How much water is lost? • Where is it being lost? • Why is it being lost? • What strategies to reduce losses
Relationship between pressure and leakage	i. Lambert 1992 ii. Charalambous et al 2014 iii. WB Module 4, 2006 iv. WB Module 3, 2006 v. Julian Thornton, 2008 vi. Zyl and Cassa 2014 vii. Mackenzie & Liemberger 2005 viii. MWI 2005	i. High Pressures high leakages
Economic Level of leakage	i. Pilcher et al 2008 ii. Islam and Babel, 2013 iii. Farley et al 2008	i. Each scheme has its own economic level of leakage
Strategies to Control NRW	i. Farley and Liemberger, 2007 ii. Charalambous et al 2014, iii. Pilcher et al 2008) iv. Allan Lambert, 2000) v. Charalambous et al 2014 vi. Bojkov et al 2011	i. Pressure management ii. Asset Management iii. Speed and Quality of repairs iv. Active leakage control

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the research design, population, sample design, collection and analysis of data. It describes the steps that were used to collect and conduct analysis for data from the field in order to determine causes of NRW, water balance, relationship between pressure and leakage, economic level of leakage and strategies to control NRW in Kenya's water sector based on case study of the operations of Meru Water and Sewerage Services.

3.2 Research Design

Since there were a number of factors to be determined in this study more than one research design was adopted so as to achieve the overall and specific objectives of the study.

3.2.1 Causes of NRW

The Non-Revenue Water causes in MEWASS were determined through an exploratory study to determine in depth the likely factors that leads to NRW. This method is suitable since it allows in depth analysis to be undertaken (Sekaran 2010). It was also done partly through a cross sectional survey through self-administered questionnaire. The cross sectional surveys allows the objective of finding the causes of Non-Revenue Water in Kenya based on the operations of Meru Water and Sewerage Services to be determined at a fixed point in time and can be generalized for the entire country. It also allows part of the members of the population to be studied in order to make generalization about the phenomenon (Sekaran 2010).

3.2.2 Water Balance

Water balance was determined through exploratory study of the existing data and information. It also involved a cross sectional survey through field measurements by actual reading of master meters, zonal meters and consumer meters. Exploratory study allows detailed and in depth investigation to be undertaken and results achieved retain the meaningful and holistic real life events characteristics (Ngechu, 2006)

3.2.3 Relationship between Pressure and Leakages

The link between leakage and pressure was assessed through analysis of existing data at Meru Water Supply Scheme involving several zones or DMA within the supply area. Data on pressure maps for the whole supply area exists. Through a program supported by JICA leakage volumes were being determined at given level of pressures. For each leak detected, the size of the orifice was also determined and pressure measured through several pressures that have been installed in the system. The available data was therefore used to study how pressure relates to leakages.

3.2.4 Economic Level of Leakage

The leakages' economic level was determined by evaluating the secondary data of the various cost centres at MEWASS. The cost of the lost water was determined through the analysis of the following operational costs:

i. Manpower
ii. Chemical
iii. Electricity
iv. The cost of commercial losses was found as per the prevailing water tariff.

The cost of reducing Non-Revenue Water was determined through the analysis of following costs:

i. Cost of maintenance: Staff and office maintenance costs
ii. Equipment and materials
iii. Cost of establishing District Metered Areas or Leakage Monitoring Blocks
iv. Transportation
v. Purchase of measuring devices
vi. Replacement of customer meters
vii. Leakage or water theft control
viii. Pipe replacements
ix. Pressure reducing devices

3.2.5 Strategies to Control NRW

The strategies to control NRW was determined through exploratory and cross sectional studies. The aim was to determine how active asset management, leakage control, quality and speed of pressure management and repairs have been employed at Meru Water and Sewerage Services. This was through analysis of historical data, observations and discussion with stakeholders including consumers.

3.3 Population

The unit of analysis was the staff of Meru Water and Sewerage Services and the consumers. The water company had 72 staff and 11600 consumers. A suitable sample was determined to represent the population depending on the specific objective under consideration. The aim was for data collection with a view of establishing the relationship between pressure and leakage, causes of Non-Revenue Water, Water balance and strategies to control Non-Revenue Water.

3.4 Sample Design

A sample size was determined so as to achieve data handling accuracy, minimize research cost and finalize the research within the limited stipulated time frame. Picking a sample provided reliable and speedy collection of data with more accuracy in analysis of data and processing. The sample size was computed based on Zikmund formula (Sekaran 2010) described below and a correction factor applied. The accuracy level and confidence were taken as 5 per cent and 95 per cent respectively on a five point Likert scale and adopting one sixth range in five- point as standard deviation. Zikmund formula states,

$$n = (Z^2S^2)/E^2$$

Where n = sample size

Z = Z score, for 95 per cent, Z = 1.96

S = estimated standard deviation, for the range of 1 to 5, S = 4/6

E = the accuracy

N = Population

If the calculated sample was more than 5 per cent of the population, a finite correction factor $\sqrt{(N-n)/(N-1)}$ would have to be applied to get to the size of sample. However, a sample size obtained based on this formula was compared with the recommendations of other authors like

Mugenda (2003) which recommends that 10% is a sufficient sample size for a study. All samples were drawn using systematic sampling method.

3.5 Data Collection

The research utilised secondary and primary data which were gathered by means of data mining, observations, both structured and unstructured questionnaires and from existing historical records. The questionnaires were issued to respondents through self-administration. The respondents of the research were managing director, top management, middle level managers, engineers, technicians and operation and maintenance staffs from the company and consumers. The respondents included staff from all sections of the company including finance, procurement and human resource and were not just limited to the technical personnel.

The information and data obtained is what led to determination of the causes of NRW, water balance, relationship between pressure and leakage, economic level of leakage and strategies to control NRW.

3.6 Data Analysis

The collected data was examined and checked for completeness and comprehensibility. Once the data was received it was edited and checked for consistency and completeness. Coding was then done then data was categorized and keyed in for analysis. The aim of the analysis was to get a feel of the data and to test its consistency and reliability. Measures of central tendency were determined; these included the median, mean and mode. These show how data cluster together around a central point while measures of dispersion such as the range and standard deviation were used to show if the scores in a given condition have similarities to each other or if they are spread out. Factor analysis was undertaken to test the validity of data while reliability and consistency were also tested by measuring the Cronbach's alpha coefficient.

CHAPTER FOUR: RESULTS

4.1 Introduction

The findings and analysis of the collected data were processed with a view to respond to the research objectives presented in Chapter one. The first objective of the study was to assess the factors that cause Non – Revenue Water. The second objective was to evaluate the water balance for Meru Water Scheme. The third objective was to assess the relationship between pressure and leakages while the fourth objective was to analyse the economic level of leakages and strategies to control Non – Revenue Water.

The chapter presents the background information of the respondents which assists in understanding how their contribution assists in explaining the causes of NRW, water balance, relationship between pressure and leakage, economic level of leakage and strategies to control NRW. In this way, the respondents are able to offer information related to the study topic, assessment of factors which contribute to non-revenue water in Kenya and their mitigation in Meru Water Supply.

4.2 Causes of Non- Revenue Water

Analysis of secondary data was undertaken to assess the factors which cause Non – Revenue Water in Meru Water Scheme. A structured questionnaire was also administered to 26 out of 72 employees for collection and analysis of primary data to assess the causes of Non-Revenue Water. The primary data was coded into the statistical package for Social Sciences (SPSS) and utilised for analysis. SPSS was considered more appropriate than excel since it gives more factors of analysis.

4.2.1 Results Based on Secondary Data

The first Non-Revenue Water baseline survey undertaken in MEWASS (MWRMD, 2003) outlined the major factors that could cause high Non-Revenue Water in MEWASS. The factors identified in the baseline survey were:

1 Operation and Maintenance Techniques

In most instances meter box covers were left open during meter reading activities leading to the customers operating stop cocks; some customers were found to have removed the meter and used water illegally leading to high Non-Revenue Water. Majority of the customers were also charged on flat rate basis hence did not have incentive to conserve water. In such cases treated water could even be used for irrigation at night.

2 Methodology of repair work

The survey found that in most cases where leak was detected, rubber band was used to stop leakage. The method did not work since the band became loose with time and continued to release water. The use of weak fittings and pipes in relation to the working pressures was common leading to frequent bursts. Solvent cement was commonly used in joining the UPVC pipes during repair and installation. It is generally recommended that water is allowed to flow in the pipe after 8 hours from the time the joints are connected using solvent cement. However, in MEWASS, the water is allowed to flow immediately once the joints are made which leads to erosion of the solvent cement hence causing water loss.

3 Connection and disconnection practices

It is good practice to have individual consumers served by individual service lines, however in MEWASS, the survey found that several consumers were connected to one service line leading to low pressure in the system hence consumers did not get adequate and steady supply.

The survey also found out that new connections were being undertaken by the use of tees instead of saddle clamps. The use of saddle clamp is to make sure that the affected area during any repair work is kept minimum, which is not possible when tees are used. The use of tees also allows air entry into the system causing household meters to register air passing through it.

4 Meter Reading

The survey found out that in some instances, meters were not read and only estimate consumptions were included in the bills. It was also discovered that there were cases where duplicate meter numbers existed. In addition, misreading of meters was found to be common

5 As built drawings

It was discovered during the survey that MEWASS never kept updated as-built drawings which made locating pipeline routes very difficult. Whenever leaks were reported it could take long response time for location and repair of the leaks. It was found that extension of pipelines, service lines, location of consumer meters and route maintenance were done haphazardly and maps were never updated once these activities were carried out.

Moreover, the service connections or pipeline constructions were undertaken by different plumbers using different methods. Construction details were never standardised.

6 Organizational culture

The working culture at the utility was found to be aiding high Non-Revenue Water since in the technical department, planning and design section which deals with designing new pipeline extension is not linked up with operation and maintenance section that deals with Non-Revenue Water management. The planning and design section does not know the challenges faced by operation and maintenance section in Non-Revenue Water Management.In the same manner, finance department that did budgeting and allocation of financial resources was not conversant with requirement of operation and maintenance section regarding the management of Non-Revenue Water.

4.2.2 Results Based on Primary Data

The primary data that was collected was based on a research questionnaire which was completed by 26 staff out of the total 72 staff. This represented 36% of the population. According (Mugenda

& Mugenda 2003} a sample of 10% is adequate to represent the population. The charateristics of the primary data were as follows:

1 Duration of Work at MEWASS

Majority of the respondents (50%) had worked at Meru Water and Sewerage Company Limited for the duration of between 10.5 to 15 years followed by durations of 5.5-10 Years and 1.5-5 years (19.2%) each. These results show that majority of the employees at MEWASS have worked for relatively longer periods and have knowledge on causes of NRW, water balance, relationship between pressure and leakage, economic level of leakage and strategies to control NRW. They were therefore able to respond satisfactorily to questions in the study. The distribution of workers experience are illustrated in Table 4.1 below:

Table 4.1: Duration of work at MEWASS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 1 Year	3	11.5	11.5	11.5
	1.5-5Years	5	19.2	19.2	30.8
	5.5-10 Years	5	19.2	19.2	50.0
	10.5-15 Years	13	50.0	50.0	100.0
	Total	26	100.0	100.0	

2 Grade of Workers at MEWASS

The study also revealed that most of the respondents (61.5%) were technicians or technical assistants followed by 30.8% who were their supervisors. These categories of staff at MEWASS were valuable to the study due to their work in the field where data for the study could be found. Their contribution assisted in collection of data related to causes of NRW, water balance, relationship between pressure and leakage, economic level of leakage and strategies to control NRW in the water sector in Meru Water and Sewerage Services. Table 4.2 shows the level of work at MEWASS.

Table 4.2: Work Level at MEWASS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Management	1	3.8	3.8	3.8
	Supervisor	8	30.8	30.8	34.6
	Technician	16	61.5	61.5	96.2
	CRO	1	3.8	3.8	100.0
	Total	26	100.0	100.0	

3 Department at MEWASS

Most of the respondents (80%) indicated that they worked in the technical department which is made up of technicians or technical assistants. This department deals with water supply including operation and maintenance and therefore central in providing data related to causes of NRW, water balance, relationship between pressure and leakage, economic level of leakage and strategies to control NRW in the water sector in Meru Water and Sewerage Services. Table 4.3 shows the respondents department at MEWASS.

Table 4.3: Department at MEWASS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Technical	21	80.8	80.8	80.8
	Finance	5	19.2	19.2	100.0
	Total	26	100.0	100.0	

4 Sections at MEWASS

The respondents were drawn from different sections within MEWASS with a significant number from Distribution and NRW (19.2% each) followed by Production and Meter Reading (15.4% each). The rest of the respondents were drawn from a wide range of sections in order to collect rich data related to causes of NRW, water balance, relationship between pressure and leakage, economic level of leakage and strategies to control NRW in the water sector in Meru Water and Sewerage Services. Table 4.4 shows respondent sections at MEWASS.

Table 4.4: Section at MEWASS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Distribution	5	19.2	19.2	19.2
	Technical	1	3.8	3.8	23.1
	Sewerage Works	2	7.7	7.7	30.8
	NRW	5	19.2	19.2	50.0
	Planning and Eng.	1	3.8	3.8	53.8
	Production	4	15.4	15.4	69.2
	Water Quality	1	3.8	3.8	73.1
	Customer Relations	1	3.8	3.8	76.9
	Meter Reading (MRS)	4	15.4	15.4	92.3
	Customer Connection	2	7.7	7.7	100.0
	Total	26	100.0	100.0	

5 Validity of the Data on Causes of Non-Revenue Water

The study used factor analysis for reducing the indicator numbers or factors corresponding to the research variable and retain those able to explain factors which lead to non-revenue water in MEWASS. All questions correlate fairly well and none of the correlation coefficients are particularly large (greater than 0.9).

The retained factors had factor loading values of above 0.5 as shown in Table 4.5 and were used for further analysis. In Table 4.5a, there were four (4) factors that had Eigenvalues that were greater than 1. The percentage (%) of variance shows how much of the variability total is explained for by each one of the factors. The first factor (1) is explained by 25.782%, factor 2 accounts for 44.832%, factor 3 accounts for 58.379% while the fourth factor (4) is explained by 69.059% which represents all of the 12 variables' variability.

The four factors correspond to the statements in the questionnaire which entail: There are high leaks at the old sections of the pipelines, storage tanks are always overflowing, the utility regularly checks for illegal connections and disconnect them, and utility uses standard fittings and pipes. All the remaining factors namely sharing of information by the technical department to other departments, meter reading errors, flat rate connections, master and zonal meters, maintenance of consumers are not significant.

The results in table 4.5a below show that the validity of the data for the questions falling under the Causes of Non-Revenue Water is satisfactory.

Table 4.5a: Validity of Data Causes of Non-Revenue Water

Component	Initial Eigen values		
	Total	% of Variance	Cumulative %
1	3.860	32.165	32.165
2	2.027	16.889	49.053
3	1.291	10.760	59.813
4	1.110	9.247	69.059
5	.963	8.021	77.080
6	.786	6.552	83.633
7	.600	5.002	88.634
8	.525	4.373	93.007
9	.336	2.798	95.806
10	.278	2.315	98.120
11	.127	1.056	99.176
12	.099	.824	100.000

The components referred to in Table 4.5a above, correspond to the elements on causes for non-revenue water as detailed in Table 4.5b below. The Eigen values indicates the extend of validity of the factors under consideration

Table 4.5b: Components of Elements of Causes for Non-Revenue Water

Component	Elements of Causes for Non-Revenue Water
1.	We have high leaks at the old sections of the pipelines
2.	Our storage tanks are always over flowing
3.	We regularly check for illegal connections and disconnect them
4.	We use standard fittings and pipes
5.	Technical departments are always linked up and share information on NRW
6.	In our organization meter reading errors are common
7.	In our organization we have substantial number of flat rate connection
8.	In our system, we have installed master meters, zonal meters and consumer meters
9.	In our organization there is frequent loss of consumer records
10.	We undertake meter reading regularly
11.	The cases of consumers tempering with meters are common
12.	In our system, there are many Nonfunctional meters

4.3 Water Balance

The Meru Water Scheme is zoned into eight (8) District Monitoring Areas (DMAs). Zonal meters are installed to take measurements for the volume of water that enters and is leaving each DMA. The water balance was evaluated based on secondary data which are available for the period October 2004 to March 2016. The data indicates the amount of water supplied to each DMA, consumption and Non-Revenue Water. The water balance was evaluated by determining monthly production, authorized consumption and system input. All the other components were then determined. The results show that the Non - Revenue Water for Meru water scheme was 17% as at March 2016. From the study, billed unmetered consumption, unbilled metered consumption and unbilled unmetered consumption were found to be negligible meaning the level of commercial losses are very low.

4.3.1 Water Balance in the Zones

The water balance analysis was undertaken from each zone and the results were as summarized in the figures that follow.

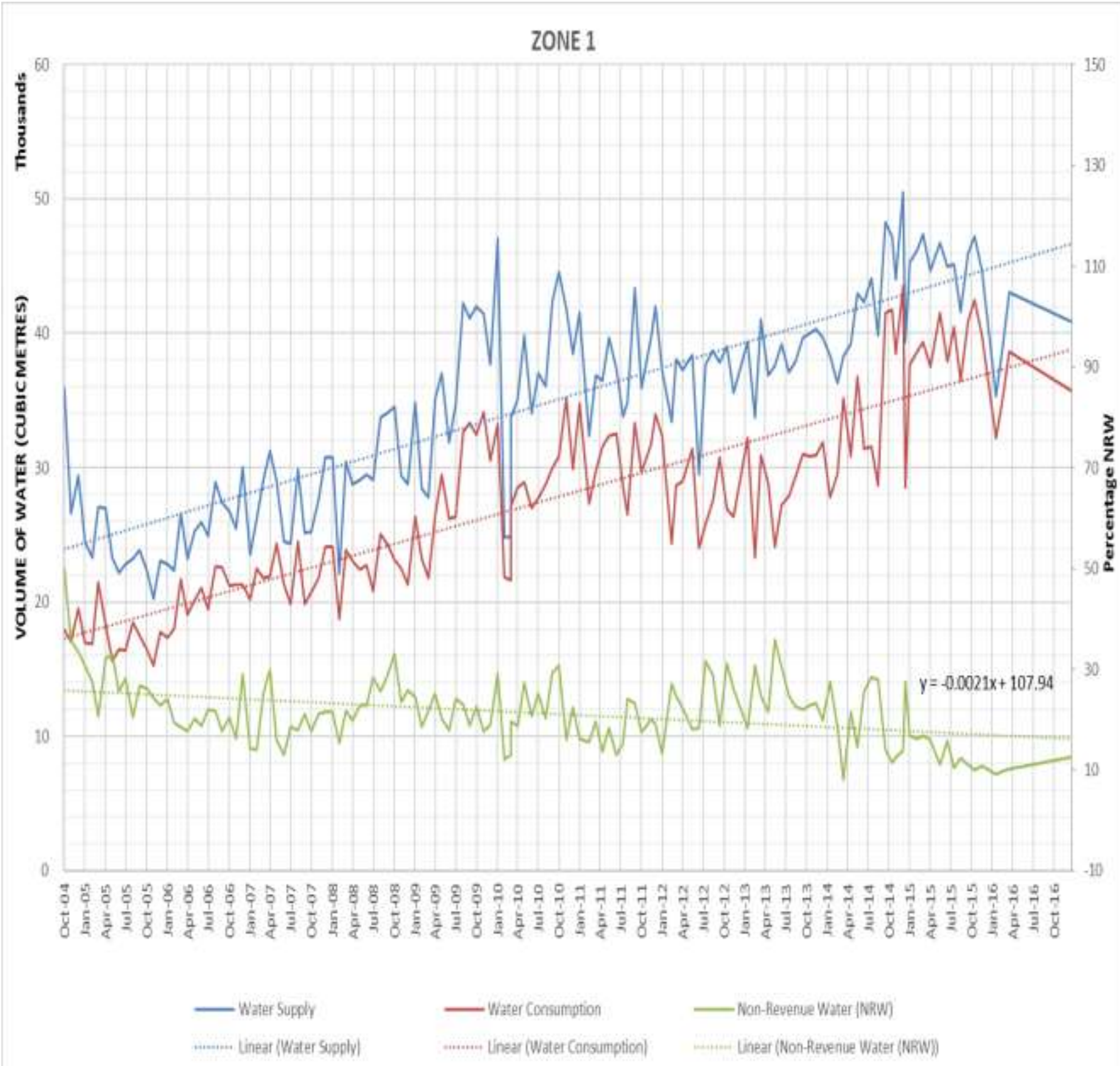

Figure 4.1: Analysis of water balance in Zone 1

The data indicates a consistent improvement in service levels i.e. increase in water supplied and consumed and also reduction in Non-Revenue Water (NRW) – as indicated in the linear trend lines. Pattern of supply and consumption is similar; thereby it is suggested that commercial water losses are consistent over the period. Between Jan to Apr 2010, there was a drop in water supplied which resulted in a sharp decline in NRW. This was not a good strategy as although reduction in NRW was noted it was as a result of decline in service levels. This scenario is contrasted to the period Aug 14 – Jan 15 as shown in figure 4.1 above, where improvement in service levels that is increase in water supplied and consumed resulted into a notable decrease in NRW.

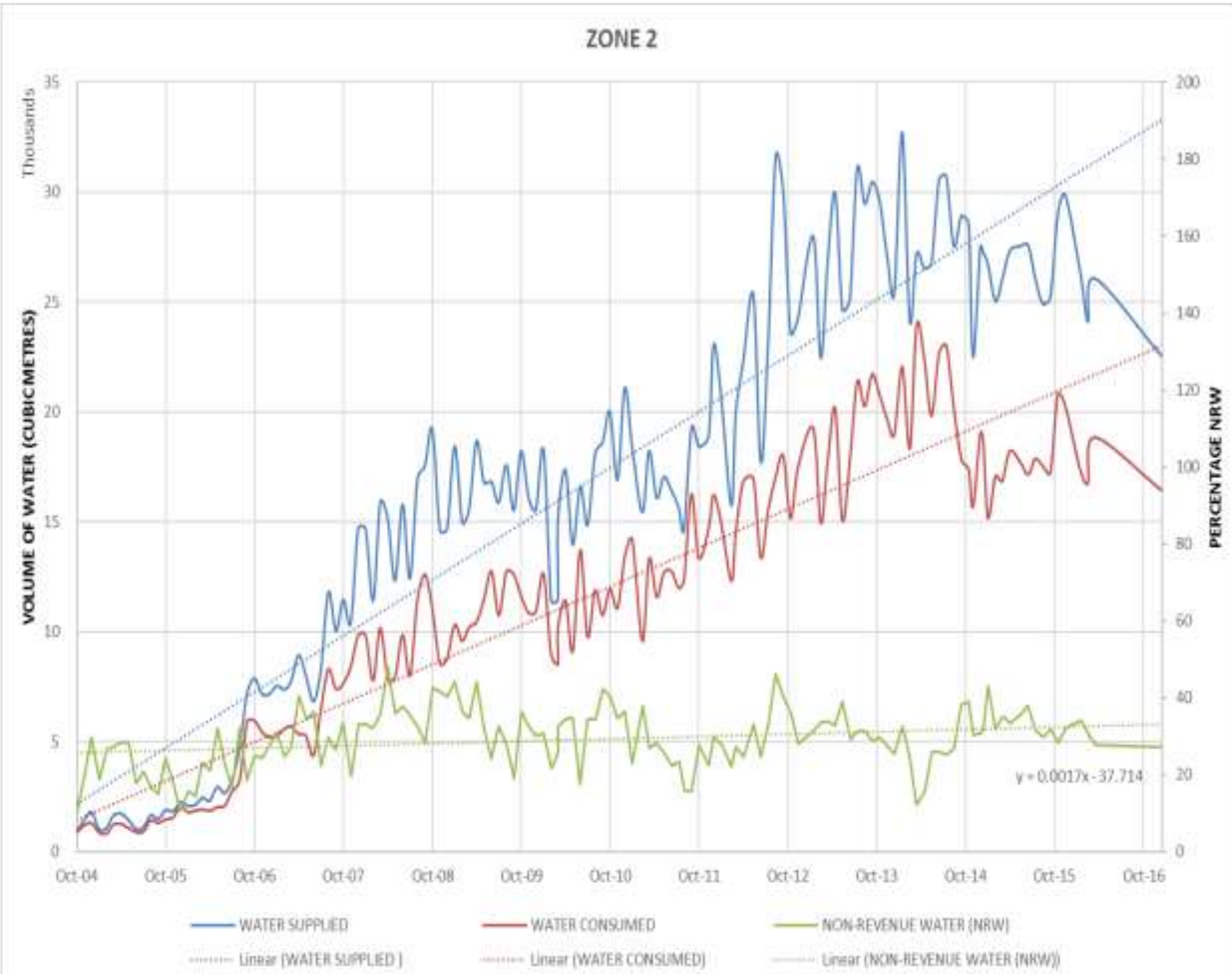

Figure 4.2: Analysis of water balance in Zone 2

There was generally an increase in water supplied and water consumption in the zone. Improvement in service levels was achieved without increase or decrease in NRW levels which remained relatively constant in the zone. Strategies in improving Service Levels and containing NRW were successful. Records showed there were no investments to improve distribution in this zone within the period under analysis as shown in figure 4.2 above. It could therefore mean that increasing water supply without distribution network improvement results in more physical water losses.

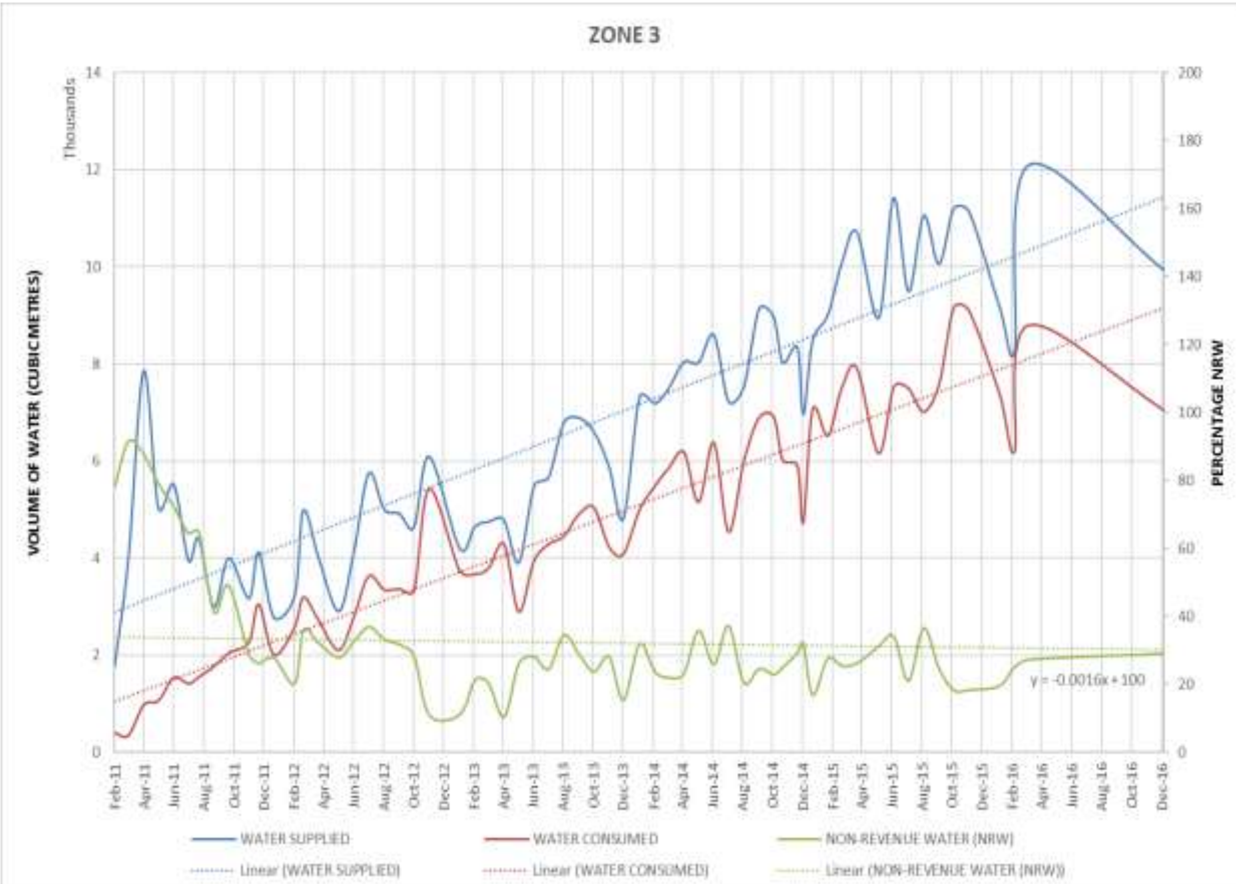

Figure 4.3: Analysis of water balance in Zone 3

The trend in water supplied and water consumed was generally similar to Zone 2 – Improvement in service levels was achieved without increase in NRW levels. Over the period analysed there was minimum decrease in NRW levels. Strategies in improving service levels and containing NRW were successful. The records at the utility showed that the utility did not invest in the distribution network in the zone for the period under review. It could therefore mean that increasing water supply without distribution network improvement results in more physical water losses. Over the period, the NRW levels in the zone decreased from around 40% to roughly 25% as shown in figure 4.3 above. This is an indication that strategies to reduce NRW levels which include speed and quality of repair works, pressure management, pipe replacement, rehabilitation works, leak detection, improvement in quality of construction materials and putting in place measures to reduce commercial losses is working fairly well in this zone. This led to overall reduction of NRW for the entire scheme.

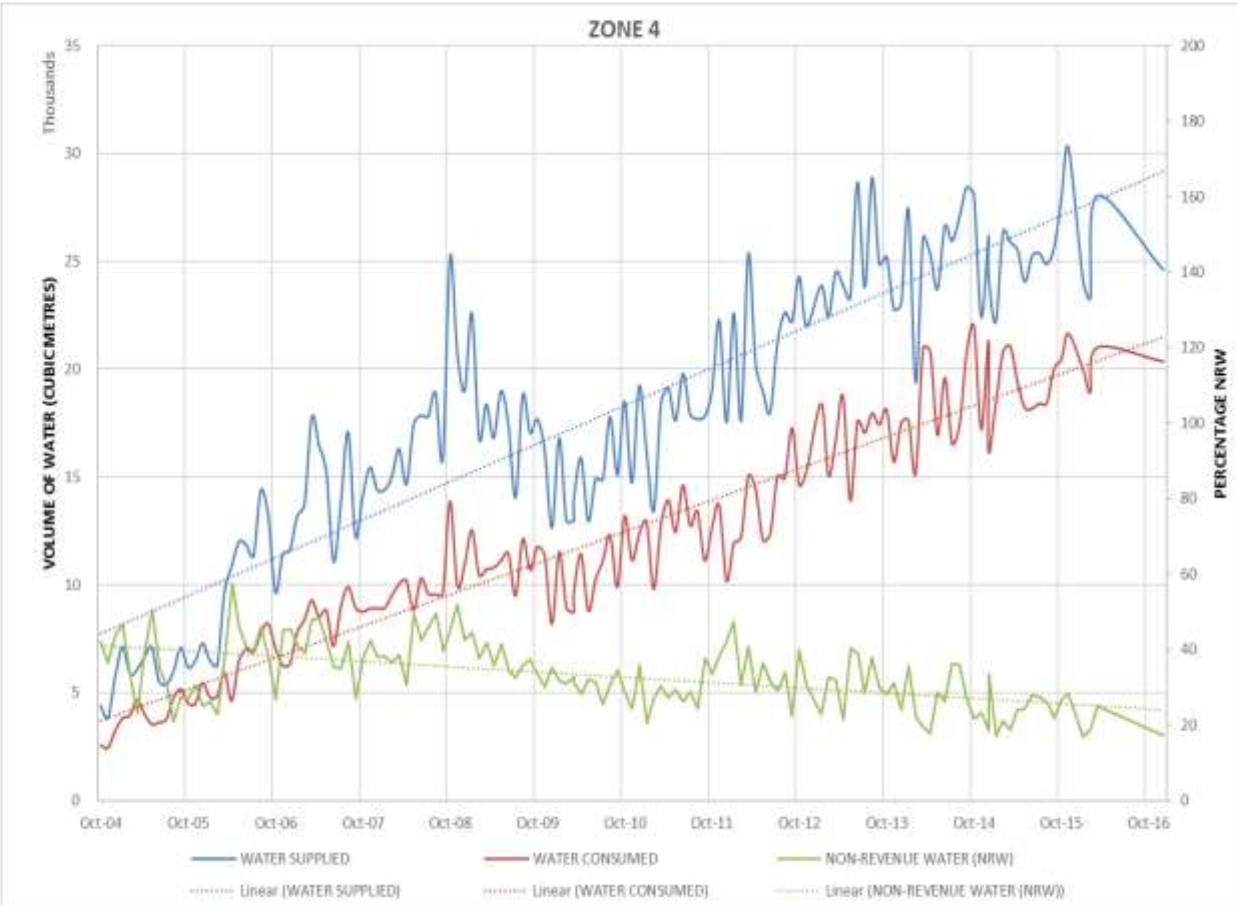

Figure 4.4: Analysis of water balance in Zone 4

There was increased trend in water supplied and water consumed in the zone. Improvement in service levels was achieved with reduction in NRW levels. Strategies in improving service levels as well as NRW reduction were successful. The utility did not invest the distribution network within the period of analysis, therefore increasing water supply without distribution network improvement could have resulted in corresponding increase in physical water losses as shown in figure 4.4 above.

However, the NRW decreased marginally from around 50% to 40%. This is an indication that strategies to reduce NRW levels which include pressure management, pipe replacement, speed and quality of repair works, rehabilitation works, leak detection, improvement in quality of construction materials and putting in place measures to reduce commercial losses was not very effective in the zone. The overall reduction of NRW for the entire scheme could still be substantial.

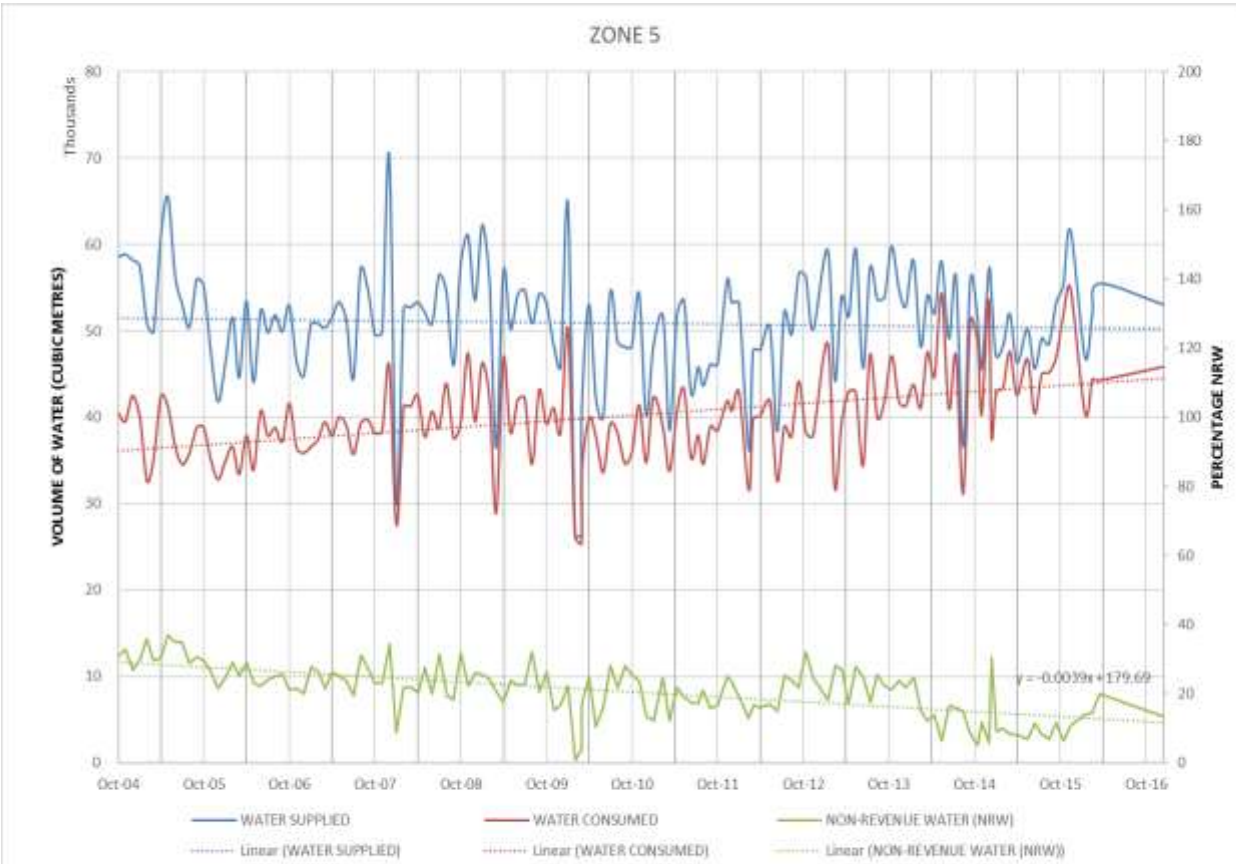

Figure 4.5: Analysis of water balance in Zone 5

The water supplied into the zone remained fairly constant with a marginal decrease over a long period of time. This means therefore that improved service levels were realized without substantial increase in water supplied. The water consumption increased marginally while NRW decreased over the period, this could mean that saving water that could otherwise be lost as NRW overtime resulted in more water consumptions.

The equation for the reduction of NRW shows a steep downward trend, y= -0.121x + 29.32 as indicated in figure 4.5. This means that strategies to reduce NRW levels which include leak detection, pressure management, pipe replacement, speed and quality of repair works, rehabilitation works, improvement in quality of construction materials and putting in place measures to reduce commercial losses could have been extremely effective in the zone. The reduction with the zone had greater impact for the overall reduction of NRW for the entire scheme.

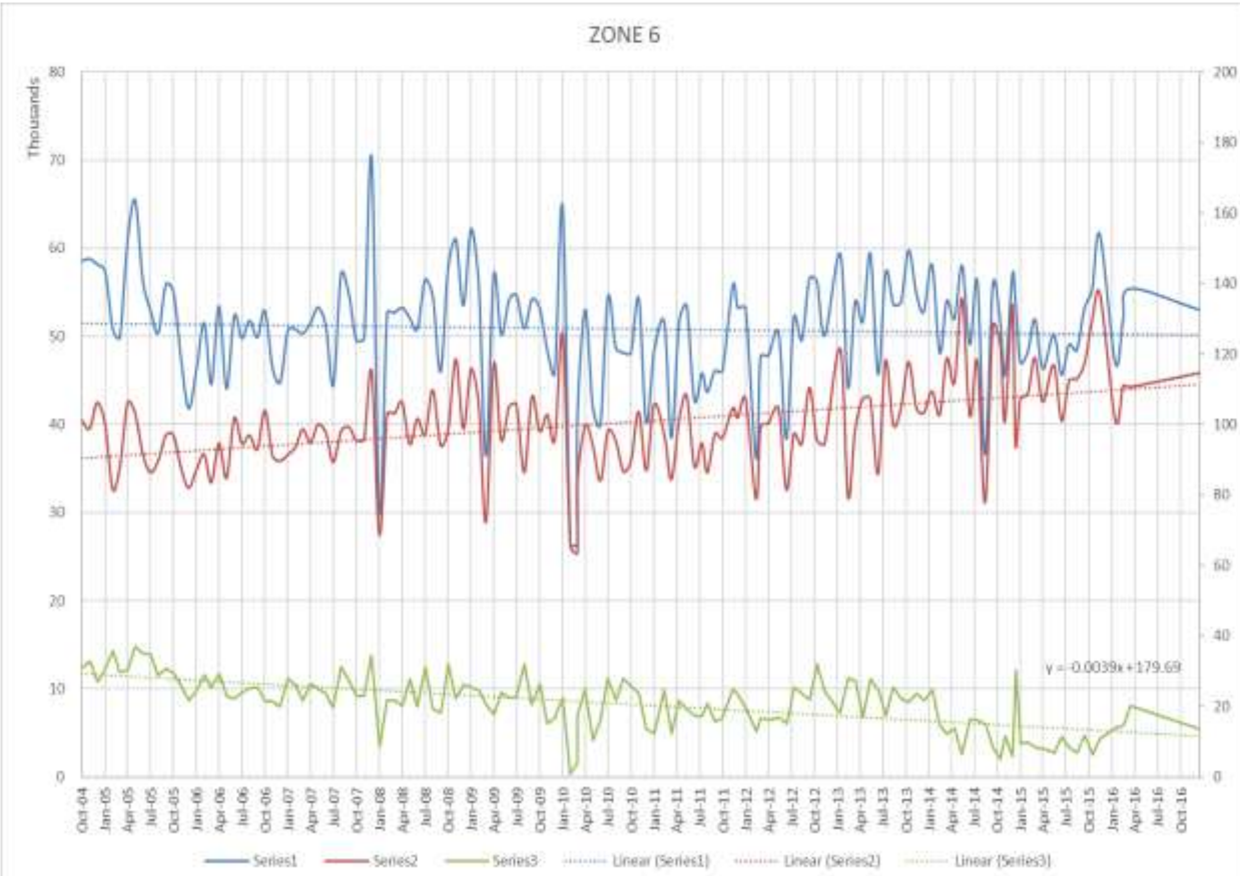

Figure 4.6: Analysis of water balance in Zone 6

While the trend in the water supplied and water consumed remained fairly constant during the period under review, there was a steep reduction in the NRW within the zone. This zone appears similar to Zone 5. Improvement in service levels were realized without substantial increase in water supplied. Reduction NRW overtime resulted in more water consumptions as shown in figure 4.6.

This is an indication that strategies to reduce NRW levels which include speed and quality of repair works, rehabilitation works, pressure management, pipe replacement, leak detection, improvement in quality of construction materials and putting in place measures to reduce commercial losses may have been very effective. The reduction within the zone might greatly contribute to the overall reduction of NRW for the entire scheme.

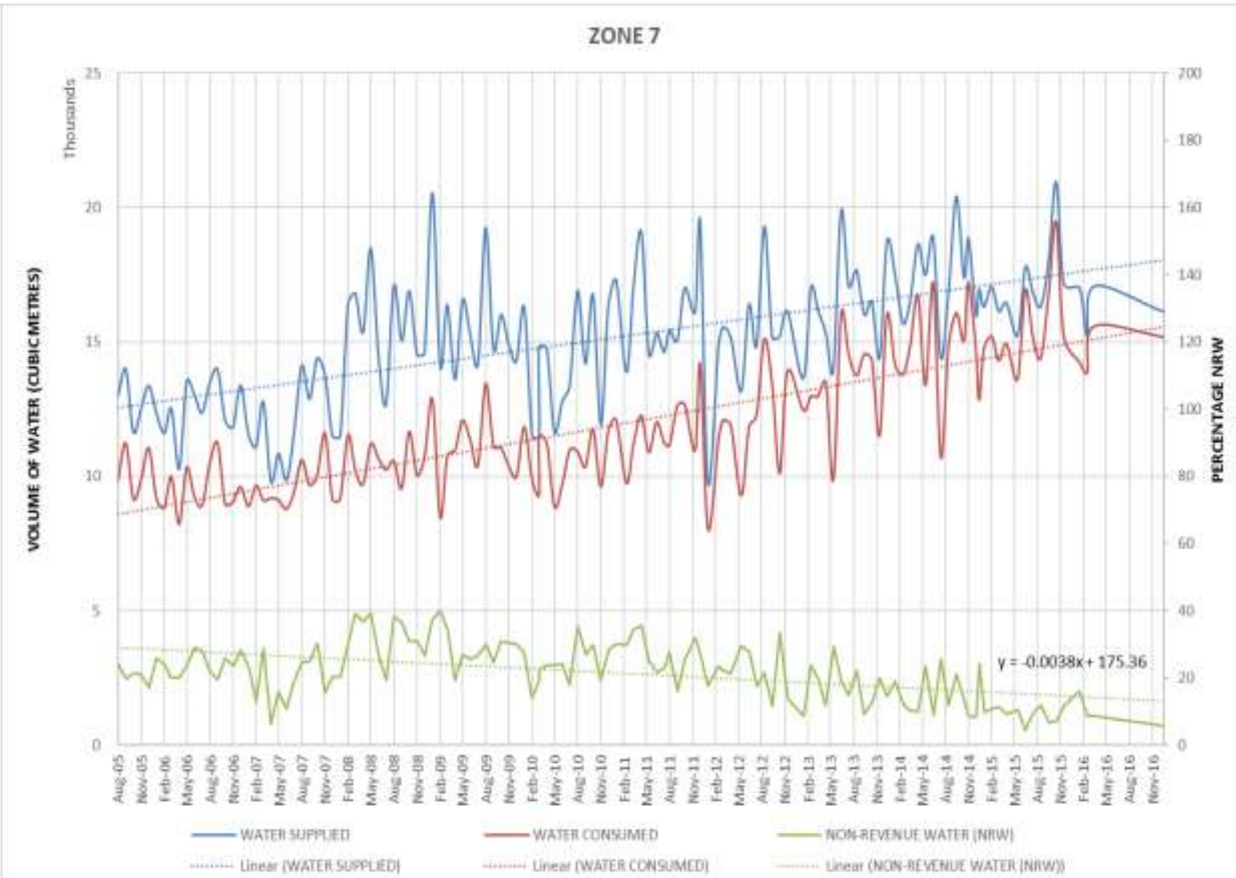

Figure 4.7: Analysis of water balance in Zone 7

There was general increase in the trend for water supplied and water consumption within the zone. The trend was similar to Zone 4. This means improvement in service levels was achieved with reduction in NRW levels. Strategies in improving service levels as well as NRW reduction were successful. The NRW levels decreased from around 35% to 15% in the zone as indicated in figure 4.7. However, since there were no investments in the pipeline it could mean that increasing water supply without distribution network improvement could have resulted in corresponding increase in physical water losses.

It is an indication that strategies to reduce NRW levels which include improvement in quality of construction materials, speed and quality of repair works, pressure management, pipe replacement, rehabilitation works, leak detection and putting in place measures to reduce commercial losses were effective in the zone and contributed to overall reduction of NRW for the entire scheme.

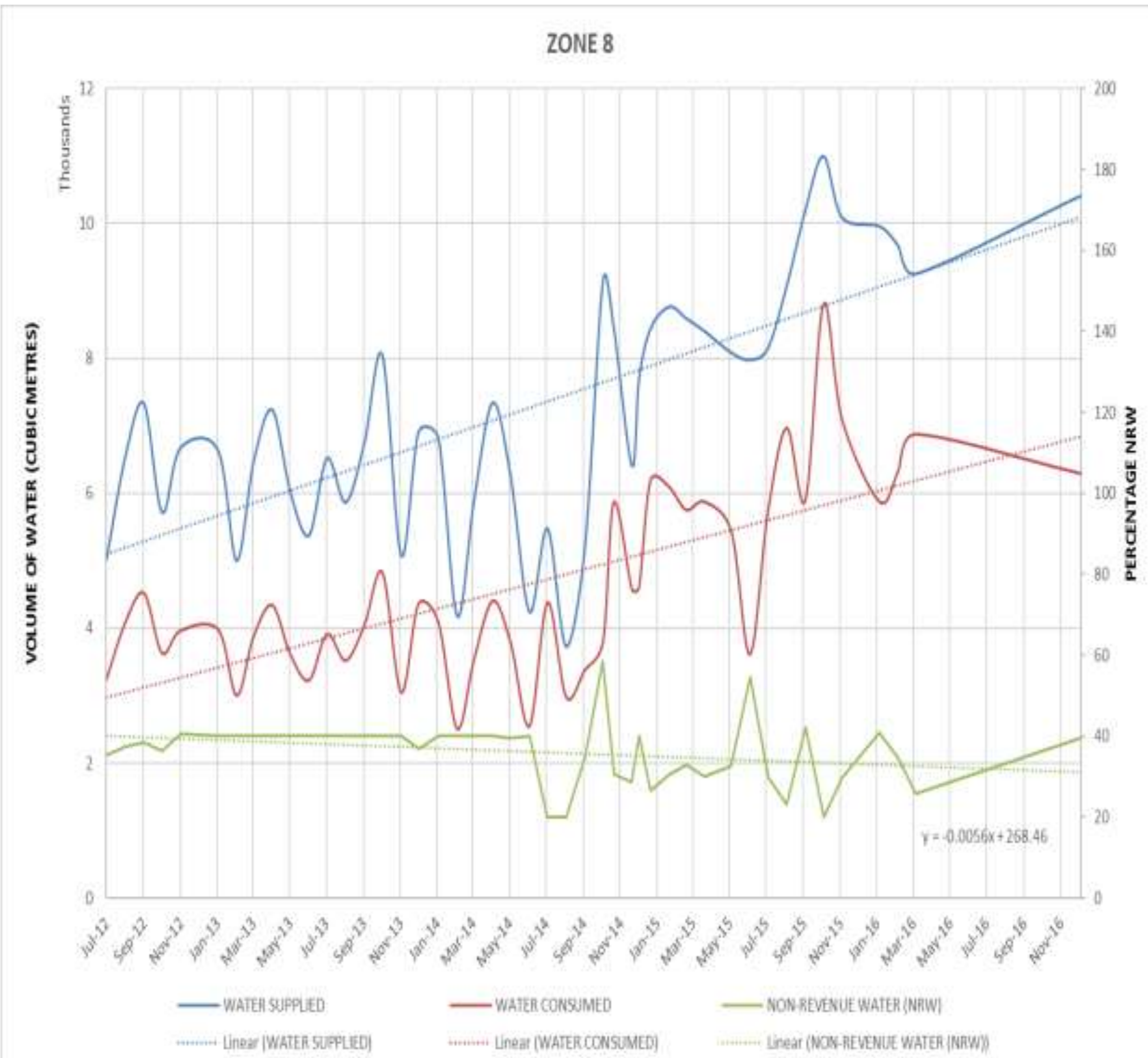

Figure 4.8: Analysis of water balance in Zone 8

The existing data for the zone had a lot of gaps. The period analysed shows consistent improvement in water supplied and consumed in the zone. NRW levels are relatively decreased at the same levels over the same period as shown in figure 4.8 above.

This was an indication that strategies to reduce NRW levels which include speed and quality of repair works, rehabilitation works, pressure management, pipe replacement, leak detection, improvement in quality of construction materials and putting in place measures to reduce commercial losses was not very effective in the zone. The marginal decrease contributed overall reduction of NRW for the entire scheme.

4.3.2 Overall Water Balance

The trend for NRW levels shows a decrease from about 45% to 17%. It could have been an indication that the overarching strategies to reduce NRW levels were very successful over the period under review. The country desires to have the overall and/or average NRW below 10%. This can be achieved by consistently implementing NRW reduction plans and interventions for a sustained period of time. From figure 4.9, Economic Level of Leakage (ELL) for the water scheme could be above 10% (say 14%) which was still fairly high. NRW reduction plan could still be implemented to reduce ELL further down.

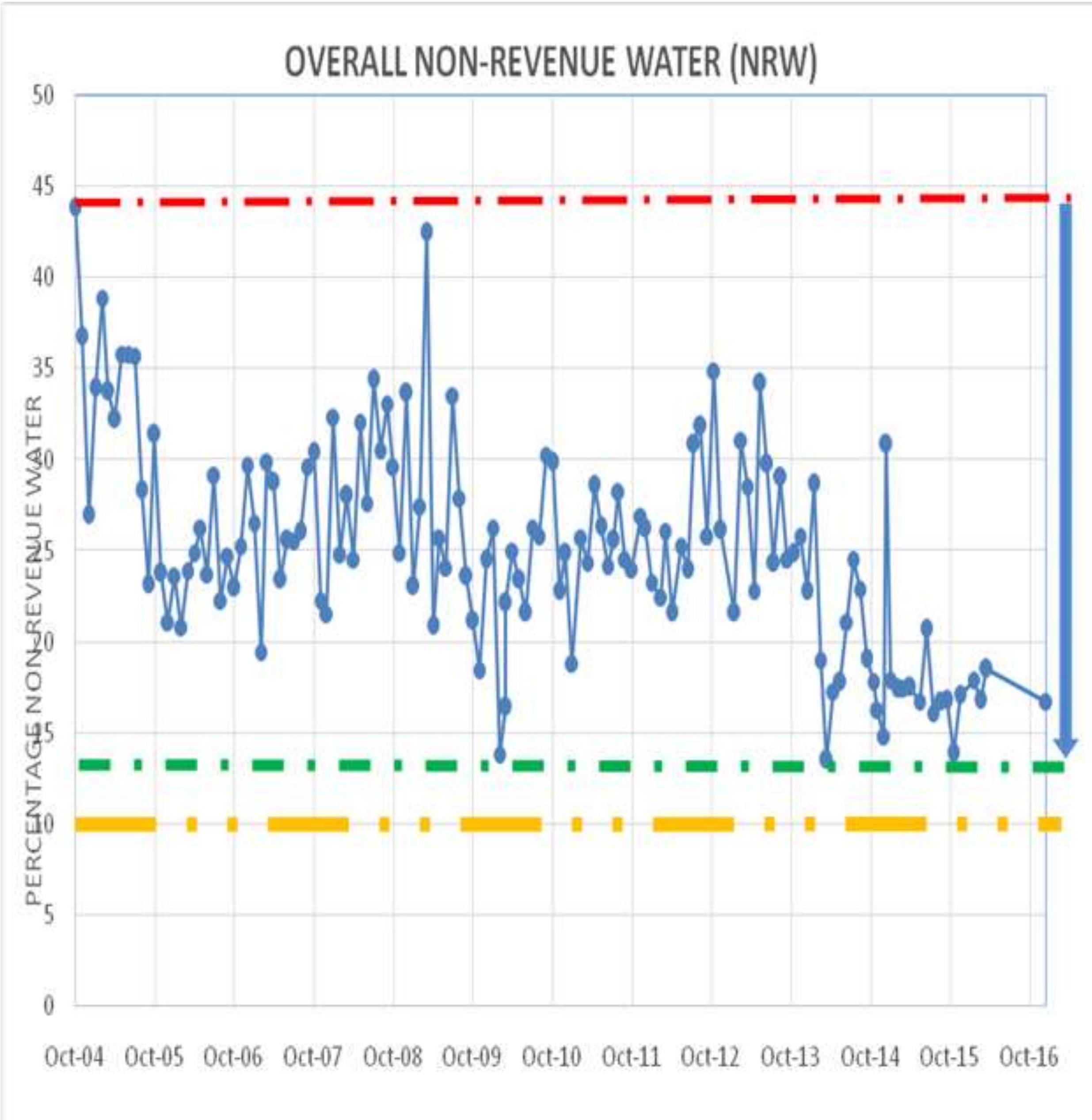

Figure 4.9: Analysis of overall water balance, Source: Data in appendix 3a and 3b

4.3.3Water Balance Table

The water balance data indicates that Meru Water Scheme produces 2,418,360 m^3/year of which 2,355,730m^3/year is the system in put volume. The results of evaluation of the water balance indicate that the Revenue Water Volume was 83% of which billed metered consumption was about 83% and billed unmetered consumption was 0%. The Non-Revenue Water Volume was 17%

consisting of leakage on water mains, overflow from tanks, and leakages on service pipes, apparent losses 2.3% and metering inaccuracies 1.5%. Table 4.6 and figure 4.10 show the analysis of leakages as evaluated in the Meru Water Scheme.

Table 4.6: Types of Water Losses

Type of losses	magnitude %
Leakage on Mains	4.7
Overflow from Tanks	1.9
Leakage from Service Pipes	6.6
Apparent Losses	2.3
Metering inaccuracies	1.5

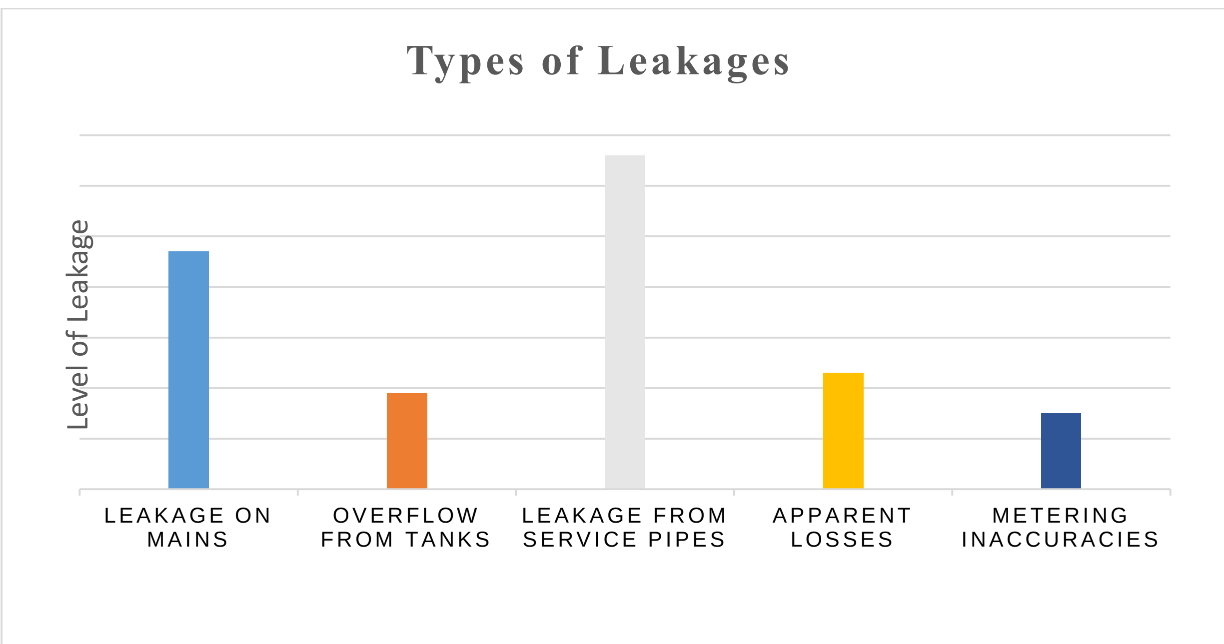

Figure 4.10: Types of leakages identified

The highest level of Non – Revenue Water occurs on the service pipelines estimated at 6.6% followed by leakages on water mains at 4.7%, apparent losses at 2.3%, overflow from tanks at 1.9% and metering inaccuracies at 1.5%. The overall physical losses were found to be 13.2% against commercial losses of 3.8%. The water balance table is shown on table 4.7

Table 4.7: Water Balance

				Annual Volume m^3/year	Rate %
Total Production				2,418,360	
System Input Volume				2,355,730	100
Authorized Consumption				1,954,968	83.0
	Billed Consumption	Billed Metered Consumption	Revenue Water **83%**	1,954,968	83.0
		Billed Unmetered Consumption		0	0
	Unbilled authorized Consumption	Unbilled metered Consumption	Non-Revenue **17%**	0	0.0
		Unbilled unmetered Consumption		0	0.0
	Real Losses	Leakage on Water Mains		110,462	4.7
		Overflow from tanks		45,000	1.9
		Leakage on Service pipes		150,538	6.6
	Apparent Losses	Unauthorized Consumption		55,545	2.3
		Metering in accuracies		39,217	1.5
					100

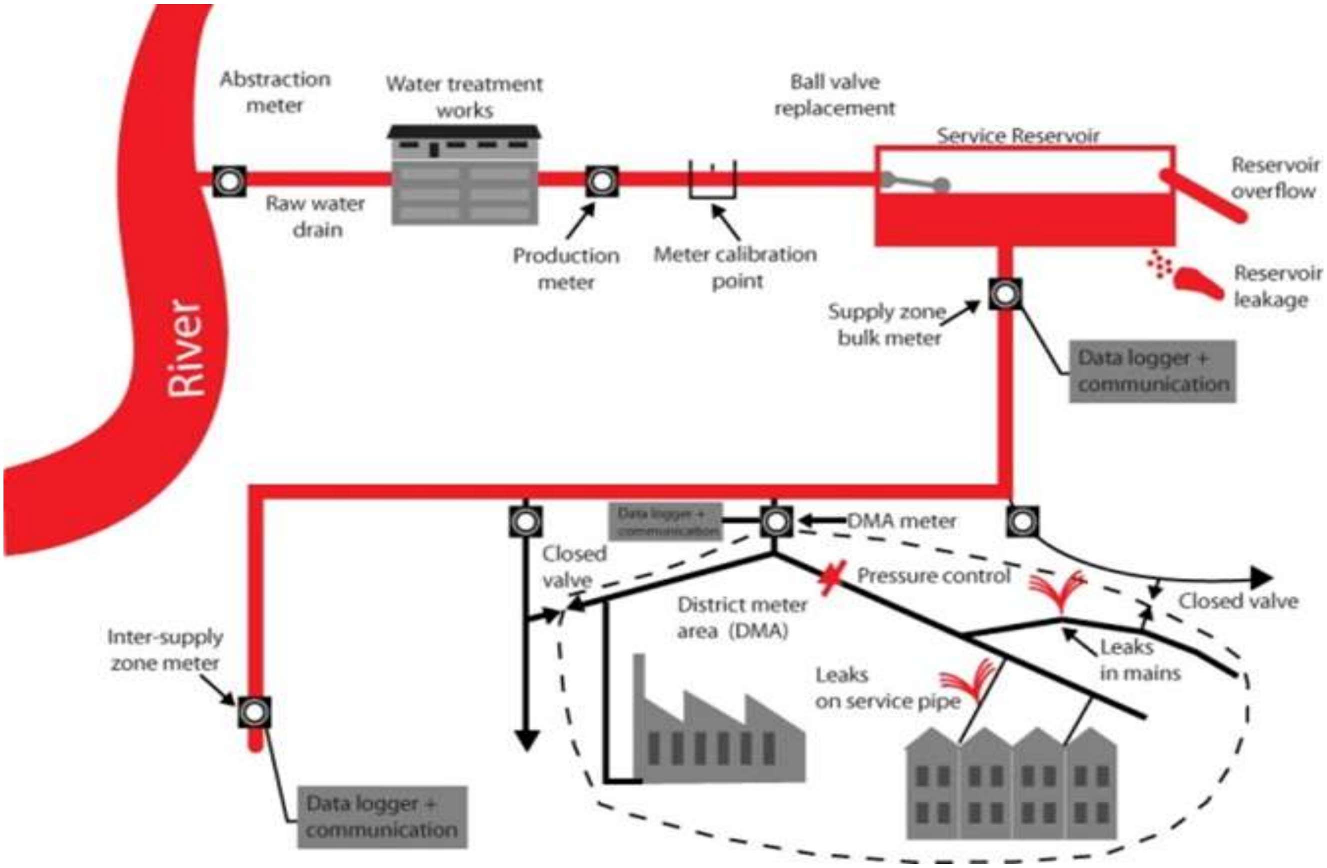

Figure 4.10a: Schematic Water Supply System showing areas where Leakage occur

Source: *World Bank Institute 2006*

Validity of the Data on Water Balance

In Table 4.8a, six factors had Eigen values more than 1. The variance percentage (%) shows how much of the variability total can be explained by every factor. The first factor (1) accounts for 26.800%, factor 2 accounts for 14.413%, factor 3 accounts for 13.022%, factor 4 accounts for 11.149%, factor 5 accounts for 8.894% while factor 6 accounts for 7.927% of the variability in all the 13 variables. All the remaining factors are not significant. The results in Table 4.8a below show that the validity of the data for the water balance is satisfactory.

Table 4.8a*: Validity of Data for Water Balance*

Component	Initial Eigen values		
	Total	% of Variance	Cumulative %
1	3.484	26.800	26.800
2	1.874	14.413	41.213
3	1.693	13.022	54.234
4	1.449	11.149	65.383
5	1.156	8.894	74.277
6	1.030	7.927	82.204
7	.805	6.194	88.398
8	.561	4.319	92.717
9	.418	3.214	95.931
10	.280	2.153	98.084
11	.182	1.402	99.486
12	.045	.343	99.828
13	.022	.172	100.000

The components referred to in Table 4.8a above, correspond to the elements on water balance as detailed in Table 4.8b below. It therefore important that utilities need to undertake regular water balance, install bulk and zonal meters to determine how much water is lost, where it is lost and why it is lost

Table 4.8b: Components of Elements of Water Balance

Component	Elements of Water Balance
1.	We undertake water balance regularly
2.	The system in put is measured through bulk meter
3.	We have installed zonal meters in all the zones
4.	We know how much water is lost
5.	We know where water is lost
6.	We know why water is lost
7.	We measure un billed authorized consumption
8.	We know the amount of unbilled un metered consumption
9.	We measure un authorized consumption
10.	We measure overflow in tanks
11.	We measure leakage in service connection
12.	We measure leakage in transmission mains
13.	We measure customer inaccuracies

4.3.4 Historical Data Analysis

The historical data on water balance was analysed from 2003 to 2016 and shows a reduction trend in the levels of Non – Revenue Water from 68% in the year 2003 to about 17% in the year 2016. The historical analysis of the balance data is shown in table 4.9 and figures 4.11 below. It is evident from the table that the Non- Revenue Water in the utility responded very well the reduction measures instituted in the year 2003 when a new water supply system was constructed in Meru.

Table 4.9: Historical Water Non – Revenue Water

YEAR	2003	04	05	06	07	08	09	10	2011	12	13	14	15	16
NRW %	68	51	29	25	26	29	26	24	25	24	29	21	19	17

The Non- Revenue Water reduction measures introduced in MEWASS in 2003 included the following:

1 Improved Operation and Maintenance Techniques

The company improved on the metering and flat rate charges were gradually eliminated and customers were encouraged to install meters only by the company qualified and registered plumbers. The open meter box covers were closed and locked after each meter reading activities. This eliminated any form of interference with the meters including the customers.

2 Water Balance

The company introduced monthly water balance determination in 2003. This was to identified How much water was being lost, where it was being lost, why it was being lost and strategies to repair to the system so as to prevent further loss of water.

3 Better Methodology of repair work

The method of repair work was improved by *eliminating* the use of rubber bands. The use of weak fittings and pipes in relation to the working pressures was also eliminated leading to reduction of bursts.

3 Good Connection and disconnection practices

The company enhanced good connection and disconnection practices by having individual consumers served by individual service lines. MEWASS introduced the practice that connections were through saddle clamps and not tees. The use of saddle clamp is to make sure that the affected area during any repair work is kept minimum, which is not possible when tees are used.

4 Meter Reading

The company introduced a system of reading meters a twice daily. This reduced the errors in metering readings. The meters were also scrutinized to ensure that duplication of meter numbers were eliminated.

5 As built drawings

MEWASS embarked on the updating of the as built drawings in 2003 and connections in the field were incorporated in the main drawings kept in the office. This made it easy to know the exact pipeline route for the success of leak detection survey. This also improved the speed of repair works.

6 Organizational culture

The company adopted a whole organization approach where planning and design section developed standardized design criteria to minimize leaks and bursts in the system. The fittings for operation and maintenance were standardized.

The above measures led to the decrease of Non – Revenue Water from 68% in 2003 to 17% in 2016 as shown in figure 4.11 below.

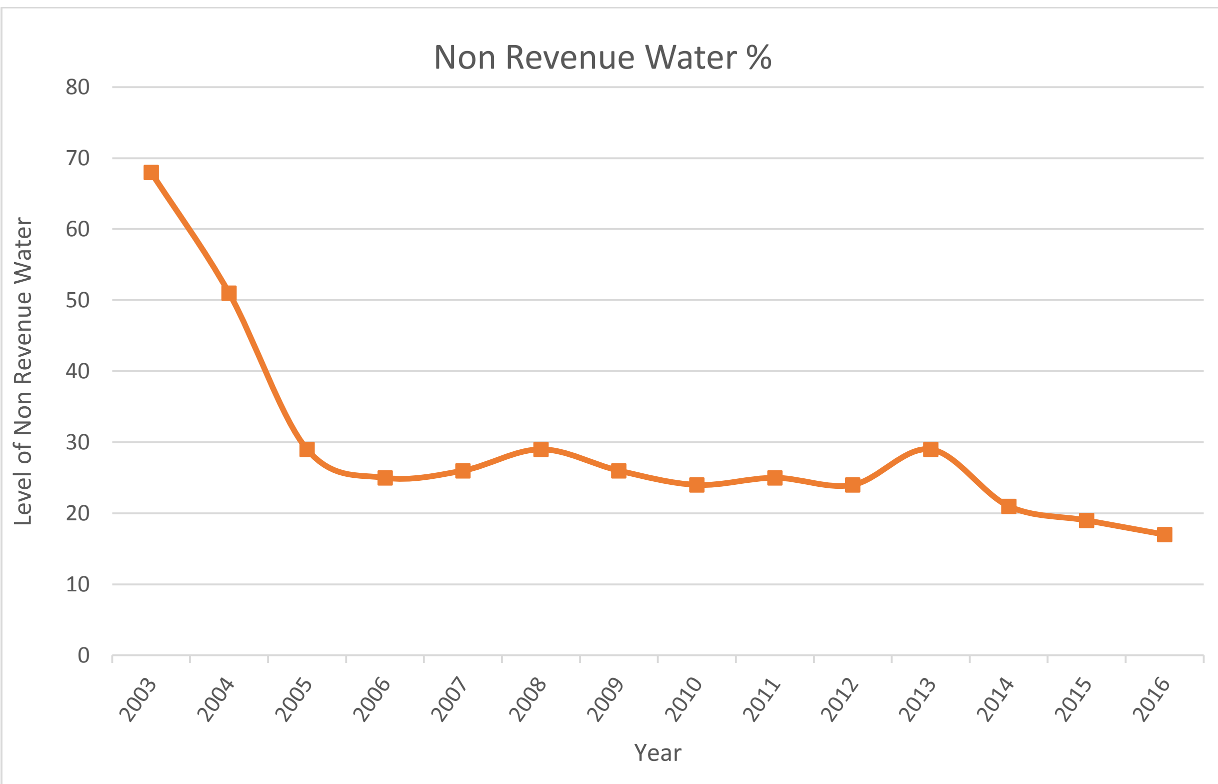

Figure 4.11: Historical data on Non-Revenue Water

4.4 Relationship between Pressure and Leakages

4.4.1 Introduction

The link between leakage volume and pressure was assessed for the existing data at Meru Water Scheme. The existing data shows leakage volume from various sizes of orifices at different levels of pressure, the data was built over a long period with assistance from JICA experts. The data is shown in table 4.10 below.

Table 4.10: Existing data on Pressure and leakage volume

	Pressure Kgf/cm²			
	3.00	4.00	5.00	6.00
Orifice size cm²				
1.00	75.90	87.90	98.10	106.80
0.60	53.60	62.50	68.90	75.30
0.50	51.60	59.80	66.00	72.00
0.40	49.00	56.00	63.00	68.00
0.30	34.00	39.00	44.00	48.00
0.20	26.90	30.30	34.60	38.20
0.10	16.70	18.90	21.00	23.00
0.08	15.40	17.80	20.10	22.20
0.06	11.50	13.30	14.90	16.30
0.04	7.80	8.80	9.90	11.20
0.02	3.80	4.40	4.90	5.40
0.01	1.40	1.70	1.90	2.10

4.4.2 Pressure Maps

There are a number of installed valves that reduce pressure in the system from which operating pressure can be measured. The pressure gauge network in the system is shown in the figure 4.12 below. The figure 4.12 shows the network of air valves, break pressure tanks, master meters, zonal meters, storage tanks. From this system the flow rate in each zone, the operating pressure was measured and could easily be monitored. Areas with high pressures could be identified and mapped out for installation of break pressure tanks or the pressure reducing valves

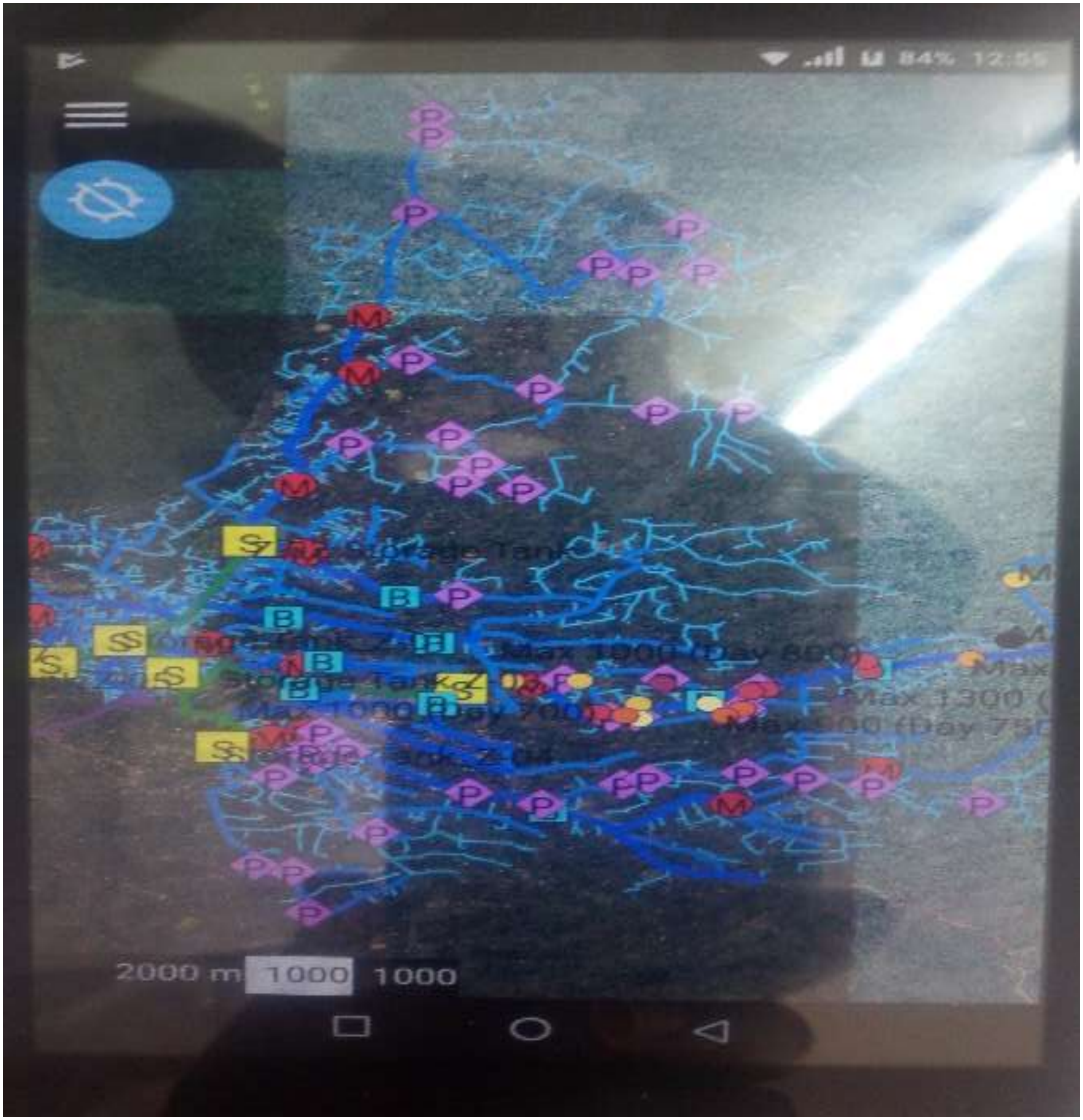

Figure 4.12: Distribution of PRV in the Scheme

Key to figure 4.12:

A Air Valves

B Break Pressure tanks

Dark Blue lines	Main Water Pipelines
Dots	Customers based on consumption category
Light Blue lines	Service lines
P	Pressure points where pressure is to be measured
M	Master meters
S	Storage tanks
SS	Sub Zonal
SZ	Sub zonal Valves

4.4.3 Assessment of Pressure and Leakage

Raw data was analysed to obtain an explanation for the link between pressure and volume of leakage. The World Bank Institute demonstrated that leakage rate in distribution networks of water is a function of gravity or the pressure from pumps. This proves a physical link between leakage rate of flow and pressure, and the frequency for new bursts' is also a pressure function. Therefore, the lower or higher the pressure, the higher or lower the leakage. Investigations point at complexity of the relationship, which is however assumed initially as a linear relationship i.e. 10% less pressure = 10% less leakage. Pressure fluctuation and pressure level has been found to influence strongly frequency of burst. The empirical relationship between pressure and leakages is given by the equation:

$Q_1/Q_0 = (P_1/P_0)^{N1}$ or $Q_1 = Q_0 \times (P_1/P_0)^{N1}$, where

Q_1	Final leakage at Pressure P_1
Q_0	Initial leakage at Pressure P_o
P_1	Final Pressure at Leakage Q_1
P_0	Initial Pressure at Leakage Q_0
N_1	Leakage exponent

In the above equation L varies with P^{N1} and $L1/Lo = (P1/P0)^{N1}$. Analytical explorations show that N_1 tends to 0.5 when system pressure tends to zero and 1.5 when the system pressure tends to infinity (Zyl and Cassa 2014). The higher the N_1 value, the more sensitive existing leakage flow rates changes with pressure. The figure 4.13 below shows graphical presentation of the relationship between pressure and leakage volume.

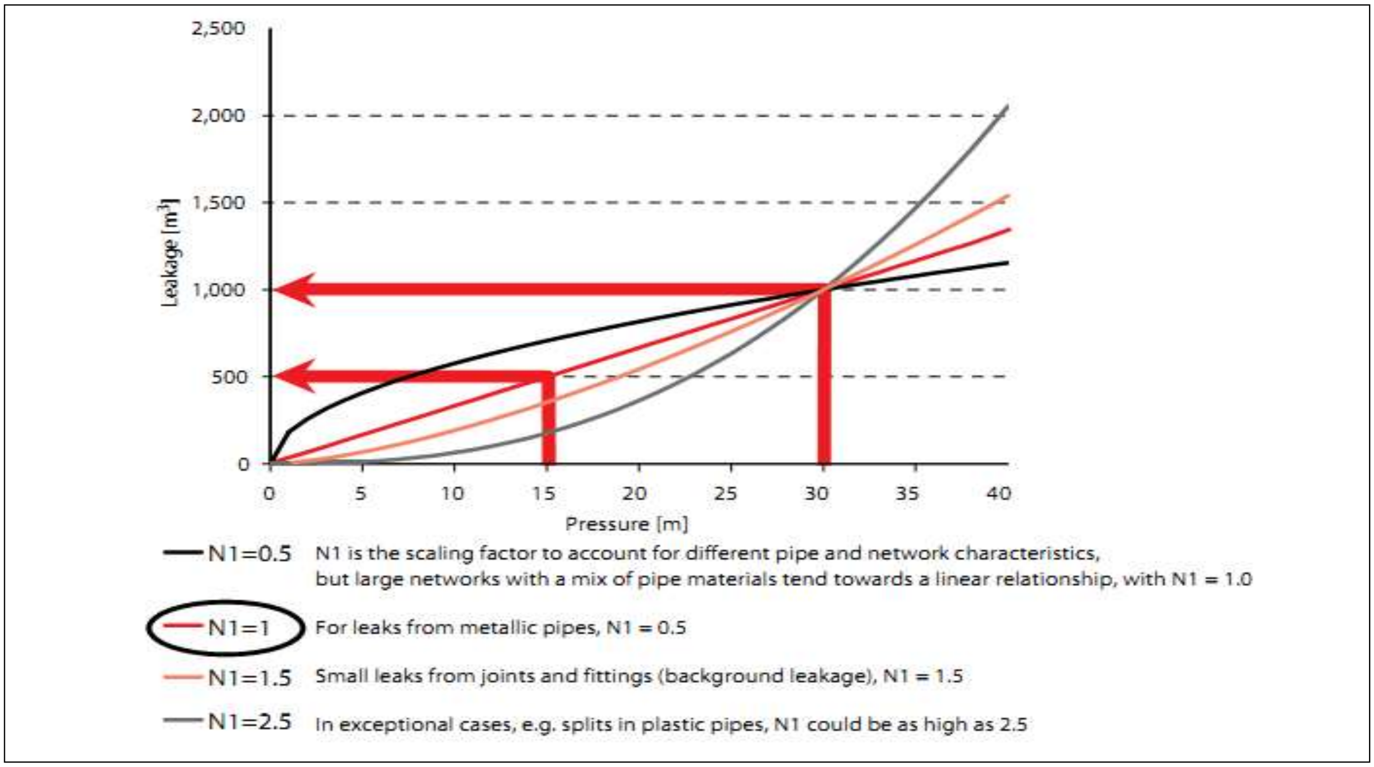

Figure 4.13 Pressure Leakage Relationship Source; World Bank Institute

The numerous measurements from the field by Thornton (2005) show that the relationship between pressure and leakage can be explained by the equation below also called the Power Law Formula.

Equation 1

$$\frac{Q_1}{Q_o} = \left(\frac{p_1}{p_o}\right)^{N1}$$

Where:-

Q_1 - is leakage under water pressure p_1 inside pipe,

Q_o - is leakage under water pressure p_o inside the pipe.

N_1 - is determined by field measurements of minimal night flows and real losses in the DMA depending on operating conditions, type of pipe damages, the pipe material and other factors.

The "N" Coefficient is different for each DMA, and is established from several experiments in the laboratory and from actual trials conducted on site. Thornton (2005) established that from investigations, N_1 normally ranges between 0.5 to 1.5, but may rise to 2.5. For Manila Water Company, the "N" coefficient was estimated as an average of "1". This led to the conclusion that the method used to calculate Real Losses using the relationship of Pressure-Leakage Rate and Apparent Losses in a DMA utilising comparisons in total NRW is efficient and reliable in calculating the NRW components (Macaluta and Pineda, 2012). Raw data was analysed and tabulated as shown in table 4.11.

Table 4.11: Tabulated raw data

Dia (cm^2)	**Pressure (kgf/cm^2)**				
	P_i=0	**P_0=3**	**P_1=4**	**P_2=5**	**P_3=6**
1.00	0.0	75.9	87.9	98.1	106.8
0.60	0.0	53.6	62.5	68.9	75.3
0.50	0.0	51.6	59.8	66.0	72.0
0.40	0.0	49.0	56.0	63.0	68.0
0.30	0.0	34.0	39.0	44.0	48.0
0.20	0.0	26.9	30.3	34.6	38.2
0.10	0.0	16.7	18.9	21.0	23.0
0.08	0.0	15.4	17.8	20.1	22.2
0.06	0.0	11.5	13.3	14.9	16.3
0.04	0.0	7.8	8.8	9.9	11.2
0.02	0.0	3.8	4.4	4.9	5.4
0.01	0.0	1.4	1.7	1.9	2.1

The computed of Q1/Q0 and P1/P0 were also plotted as shown in table 4.12 below

Table 4.12: Computed data Q_1/Q_0 and P_1/P_0

Q_1/Q_0	P_1/P_0	Q_2/Q_1	P_2/P_1	Q_3/Q_2	P_3/P_2
1.16	1.33	1.12	1.12	1.09	1.20
1.17	1.33	1.10	1.12	1.09	1.20
1.16	1.33	1.10	1.12	1.09	1.20
1.14	1.33	1.13	1.12	1.08	1.20
1.15	1.33	1.13	1.12	1.09	1.20
1.13	1.33	1.14	1.12	1.10	1.20
1.13	1.33	1.11	1.12	1.10	1.20
1.16	1.33	1.13	1.12	1.10	1.20
1.16	1.33	1.12	1.12	1.09	1.20
1.13	1.33	1.13	1.12	1.13	1.20
1.16	1.33	1.11	1.12	1.10	1.20
1.21	1.33	1.12	1.12	1.11	1.20
AVERAGES					
1.15	**1.33**	**1.12**	**1.12**	**1.10**	**1.20**

A graph of leakage volume against pressure was drawn as shown below in figure 4.14. It yields a pressure – leakage power relationship in the form:

$$\mathbf{P} = K.\,(\mathbf{Q})^{x} \quad \text{where k and x are constants} \;\ldots\ldots\ldots\ldots\; \text{(i)}$$

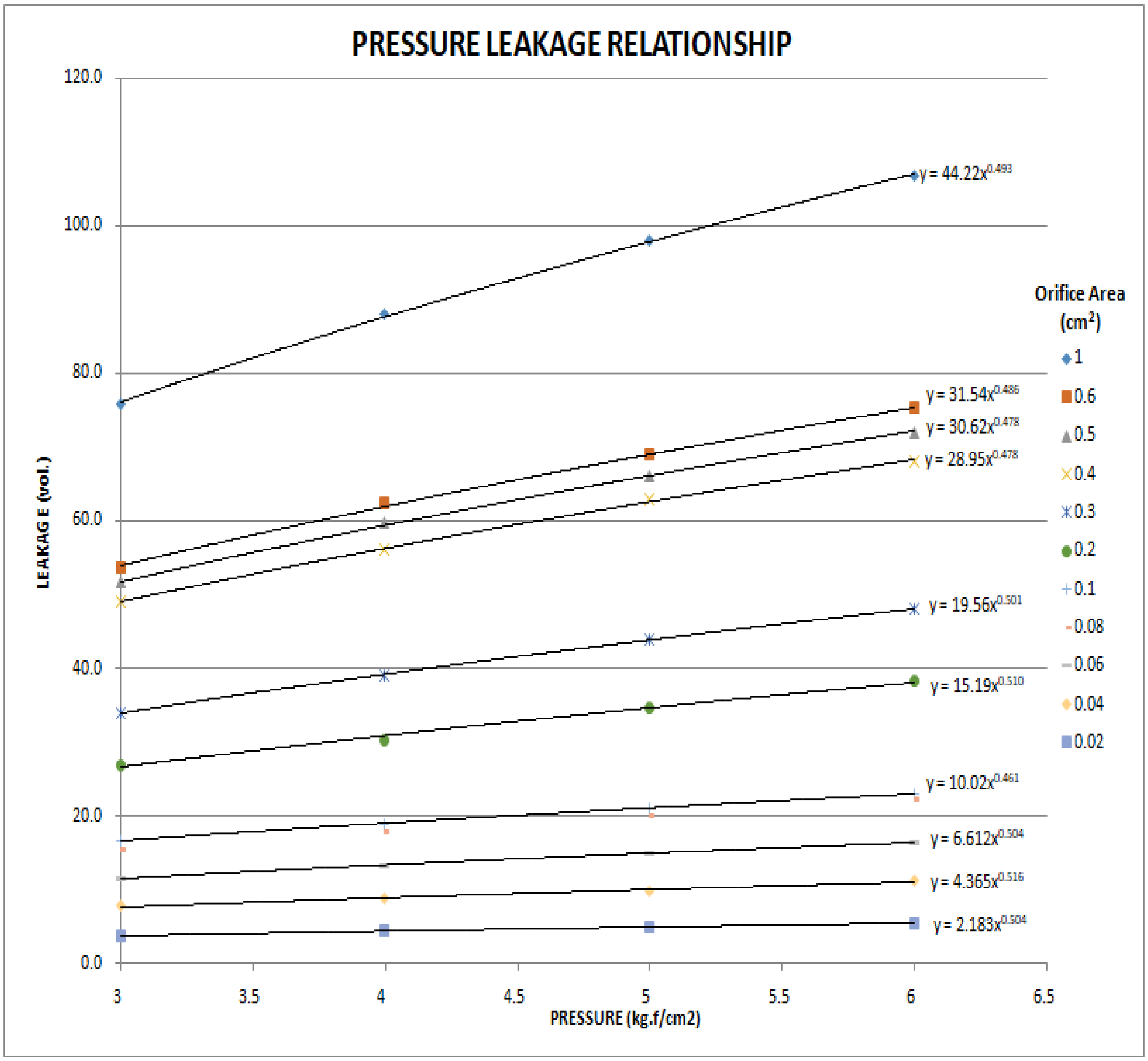

Figure 4.14: Graphical presentation of Pressure – Leakage

From the graphical presentation it can be deduced that:

- Experimental values applied are for orifice area (cm^2)
- There was a general trend Y = constant X^n, where Y is the pressure and X is the leakage volume
- For diameter 0.02, Y = $2.183X^{0.504}$
- Power relationship observed therefore ranges from: **P** = (44.22 – 2.183) **Q** $^{(0.461 - 0.516)}$
- Constant increases with increase in orifice area

- Power factor is approximately 0.5 for all values of orifice area; thereby specific to characteristics of orifice
- Expected N_1 value in Eqn. 1 to corresponds to $N_1 = 0.5$ as discussed in Figure 4.13 and is expected to range from 0.0 – 1.0.

Investigating further, the Pressure Leakage Relationship was found as shown in equation 1 on page 76 with average computed data as tabulated in Table 4.12 yields Figure 4.15 below.

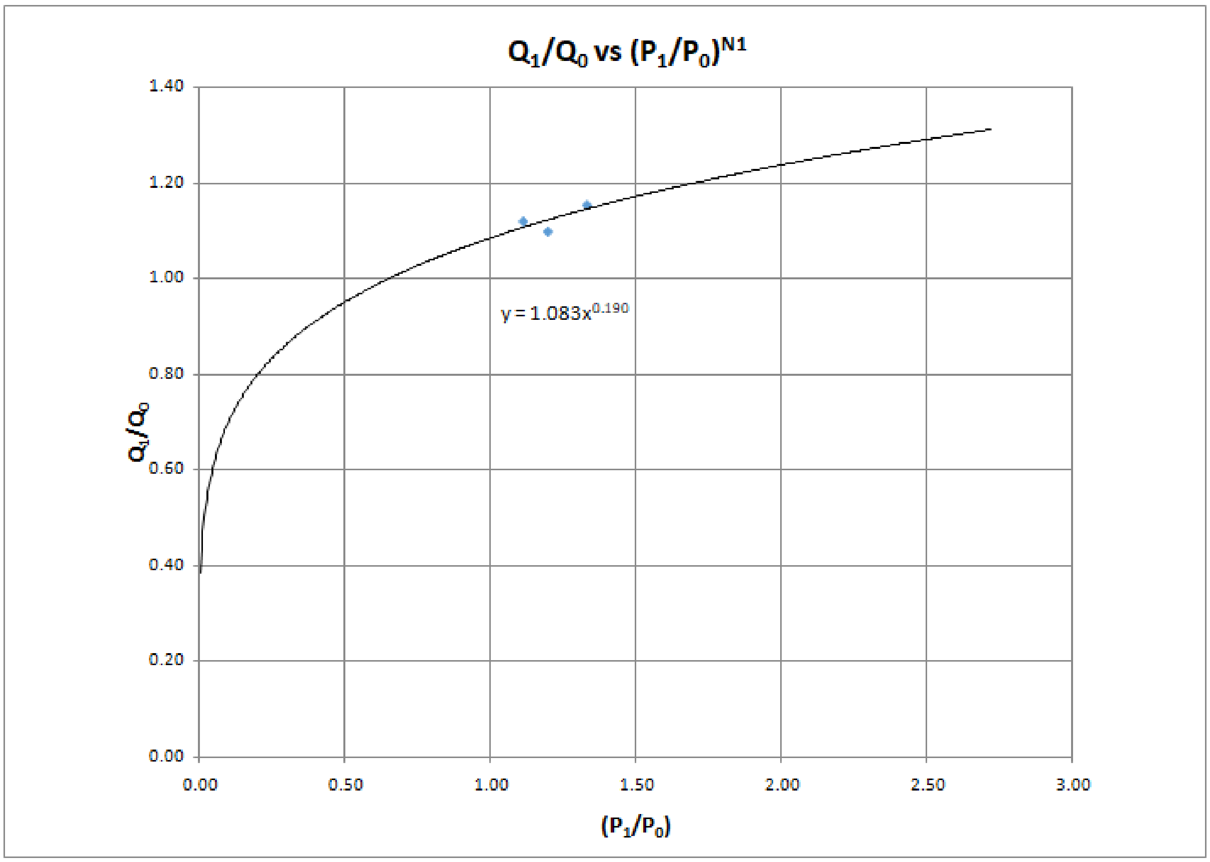

Figure 4.15: Approximation of N1 from experimental Data

4.4.4 Results of Analysis

- There exists a power relationship between pressure and leakage volume as follows: -

  $(Q_1/Q_0) = 1.083(P_1/P_0)^{(0.19)}$

- From the experimental data obtained, N_1 for Eqn. (1) is 0.19.

- Although within the expected range, approximated N_1 value can be improved with more data over a wider range of pressure conditions.

Validity of the Data on Pressure Management

In Table 4.12, three factors had Eigenvalues of more than 1. The variance percentage (%) indicated how much of the variability total can be explained by every factor. The first factor (1) explains 37.846%, factor 2 accounts for 20.235% while factor 3 accounts for 12.257% of the variability in all the 9 variables. All the remaining factors are not significant. The results in Table 4.13a below show that the validity of the data for the questions falling under pressure management is satisfactory. The analysis shows that there are high leakage volumes in the zones with high operating pressure and it is significant to zone the water supply schemes into the pressure zones and install pressure reducing valves.

Table 4.13a*:* Validity of Data for Pressure Management

Component	Initial Eigen values		
	Total	% of Variance	Cumulative %
1	3.406	37.846	37.846
2	1.821	20.235	58.081
3	1.103	12.257	70.339
4	.911	10.121	80.460
5	.611	6.784	87.244
6	.507	5.639	92.883
7	.339	3.770	96.653
8	.245	2.722	99.375
9	.056	.625	100.000

Extraction Method: Principal Component Analysis

The components referred to in Table 4.13a above, correspond to the elements on Pressure Management as detailed in Table 4.13b below.

Table 4.13b: Components of Elements of Pressure Management

Components	Elements of Pressure Management
1.	There are high leakage in pipelines with high pressure
2.	We have zoned the water scheme into pressure zones
3.	We frequently install pressure reducing valves in the system
4.	We avoid a high pressures in the system in order to avoid frequent bursts
5.	Working pressures are determined at design stage
6.	Pipe selection take care of anticipated pressures in the system
7.	We develop pressure maps in the system
8.	The pressures in the system is closely monitored
9.	Low pressures affect water supply to the consumers negatively

4.5 Analysis of Economic Level of Leakages

4.5.1 Introduction

The determination of economic level of leakage at Meru Water Scheme was undertaken based on the existing data. It was expected that MEWASS would have collected and stored historical data on costs for NRW management at every level of NRW. The cost on NRW management is expected to be collected with each water balance activity. However, this had not been done and can only be estimated at the present time.

The analysis involved comparing the cost of reducing water from being lost and cost of water lost. The cost of water lost refers to water value lost from physical and business related losses. With the current NRW level at 17% and with the overall system input of 2,355,730m^3/year, the amount of water lost per year is about 400,762m^3/year. The cost of water lost consists of various costs namely staff cost, chemical cost and electricity cost which is computed from the system operations as Ksh 46,095,372 per year.

4.5. Cost of Water Lost

Table 4.14 shows the cost of water lost per month.

Table 4.14*: Cost of water lost*

	Description	Input/Month(Kshs)	Lost revenue/Month(Kshs)
i	Salaries/Wages	2,000,000	344,100
ii	Chemicals	743,990	130,200
iii	Electricity	1,092,291	186,000
	Total	**3,841,281**	**660,300**

4.5.3 Cost of NRW Management

The cost of Non - Revenue Management is the cost of reducing NRW. It consists of maintenance cost, equipment cost, cost of establishing DMAs, transportation cost among others as shown in the table 4.15 below.

Table 4.15*: Cost of NRW management*

		Description	**Cost/Month (Kshs)**
i	Maintenance cost	Staff and office maintenance cost	925,338
ii	Equipment and tools		26,000
iii	Cost of establishing DMAs	MEWASS has 8 DMAs	4,588,200
iv	Transportation	Four motor bikes and one pickup.	3,039,400
v	Purchase of measuring devices and equipment.	Ultrasonic flow meter	1,260,000
		Insertion Flow Meter	1,200,000
		Pipe Locators	123,000
		Sounding Rods	300,000
		Correlator	1,400,000
	Total		**12,861,938**

From the analysis of the two costs, the cost of water lost per m^3 is approximately Ksh 115 while cost of NRW management per m^3 is about Ksh 385. The economic level of leakage being the level of leakage at which it would cost more to make further reduction than producing water from other sources, is driven by the cost of establishing DMAs and cost of transport. The major cost drivers for the cost of Non – Revenue Water management in MEWASS are therefore the cost of setting DMA, cost of transport and cost of leak detection equipment as shown in table 4.14 above. These costs are normally high at the beginning when a utility sets out to undertake leak detection measures for the first time. Efficiency of operation is required to bring down the cost of Non-Revenue Water Management.

MEWASS case would mean that the utility uses more funds for NRW management than the water cost for the water being saved from loss. It could also be an indication that the NRW management cost is beyond the optimal cost hence the utility may contain cost by cutting down necessary activities such transportation cost. This would also minimize the total cost to the customers as the utility is required to operate efficiently. From the water balance analysis, the economic level of leakage could be about 10% – 14%. The utility therefore needs to explore ways of reducing the cost of NRW management.

4.6 Strategies to Control Non – Revenue Water

The strategies to control Non - Revenue Water in MEWASS was analysed through observation, oral interviews and structured questionnaire administered to twenty-six (26) staff out of 72 staff. The utility has adopted a strategy that includes every employee involvement through Non – Revenue control units. The Non- Revenue Water Unit sets out targets for every DMA which are then discussed with all members of staff in staff general meetings. The strategy involves continuous leak detection process, pressure management, updating of as built drawings, speed and quality of repair and quick repair works. The creation of the strategy is based on the idea of Awareness, Location and Repair, (ALR).

Any loss occurring from overflows, faulty customer meters, leaks, or other sources has three stages namely

i. Awareness time; time needed for the Water Service Provider to be aware of the leaks
ii. Location time; time needed by the Water Service Provider to allocate the leak
iii. Repair time; time required by the Water Service Provider to conduct repairs on the leak.

The volume of water lost is therefore a function of the Awareness time, Location time and Repair time. For efficient operations the total time must be kept to minimum. Figure 4.16 shows the ALR model.

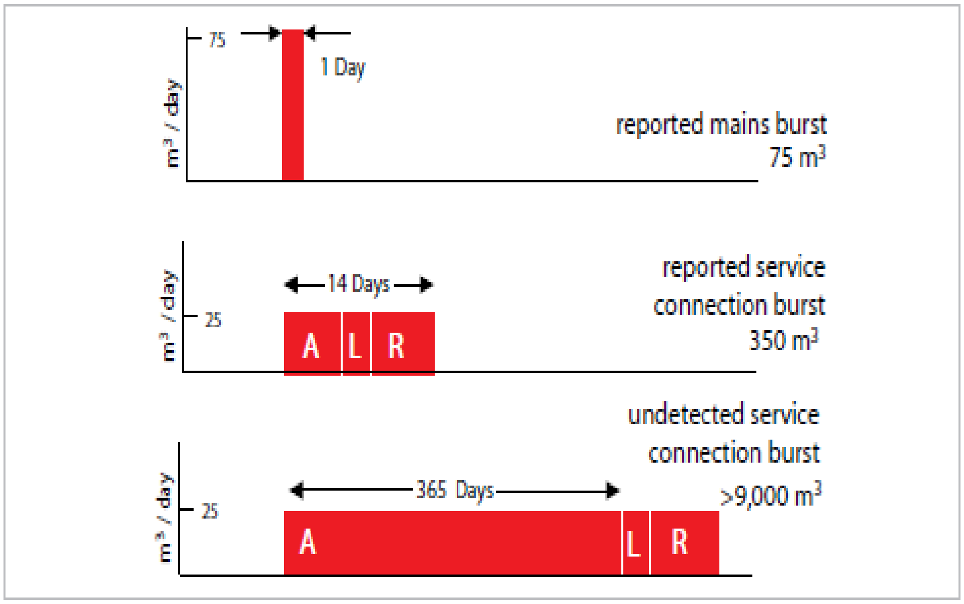

Figure 4.16: ALR Model

The utility periodically identifies and replaces aged pipelines in the system which are prone to bursts. The system has also been divided into various pressure zones in order to monitor the operating pressure in the system at any given time.

Leak detection and repair is vigorously undertaken after leak detection equipment were procured. Leaks are repaired immediately they are identified. The use of rubber bands to stop leakage where they are identified has been eliminated. The use of weak fittings and pipes in relation to the working pressures has been stopped.

The study found out that initially solvent cement was commonly used in joining the UPVC pipes during repair and installation and that water was being allowed to flow in the pipe immediately the joints were connected instead of the required 8 hours. This could lead to erosion of the solvent cement hence causing water loss. This practice has since been stopped. Asset management, pressure management, active leakage control, speed and quality of repairs are the key strategies adopted by the utility, hence reduced Non – Revenue Water levels over time which is now 17% compared with the national average of 42%.

Validity of the Data on Strategies to Reduce Non-Revenue Water

In Table 4.16a, four factors have Eigen values of more than 1. Percentage (%) variance shows the level that total variability can be explained for by each of the factors. Factor 1 accounts for 33.924%, factor 2 accounts for 18.236%, factor 3 accounts for 15.846% while factor 4 accounts for 10.463% of the variability in all the 13 variables. All the remaining factors are not significant. The results in Table 4.16a below show that the validity of the data for the questions falling under the Strategies to Reduce Non-Revenue Water is satisfactory.

Table 4.16a: Validity of Data for Strategies to Reduce Non-Revenue Water

Component	Initial Eigen values		
	Total	% of Variance	Cumulative %
1	3.392	33.924	33.924
2	1.824	18.236	52.160
3	1.585	15.846	68.006
4	1.046	10.463	78.469
5	.736	7.362	85.832
6	.587	5.868	91.700
7	.484	4.837	96.537
8	.204	2.037	98.574
9	.083	.825	99.399
10	.060	.601	100.000

Extraction Method: Principal Component Analysis

The components referred to in Table 4.16a above, correspond to the elements on Strategies to Reduce NRW as detailed in Table 4.16b below.

Table 4.16b: Components of Elements of Strategies to Reduce Non-Revenue Water

Components	Elements of Strategies for reduction of NRW
1.	We identify and quantify leakages on continuous basis
2.	As built drawings are regularly updated
3.	We emphasis on speed and quality of repair works
4.	We have rehabilitation and renewal program
5.	We have continuous pressure management program
6.	Leaks are detected and repaired as soon as they occur
7.	In repair works standardized fittings and pipes are always used
8.	There is always a budget for Non- Revenue Water activities
9.	All the pipeline mappings are linked to GIS
10.	The top management is committed to Non- Revenue Water Reduction

4.7 Suggested Ways of NRW Management

The respondents were asked to suggest ways through which Non-Revenue Water Management could be improved. They gave suggestions which included allocation of more revenue for acquisition of modern equipment such as leakage sensor equipment, ultrasonic sounding rods, replacement of zonal meters older than 5 years and training for computation of commercial losses at greater levels of accuracy.

The respondents indicated that efforts should be made to calibrate bulk or consumer meters regularly, link all accounts to GIS mapping, maintain correct pressure in the pipeline network and regularly monitor zonal and master meters in addition to placing other measures to monitor leakages and losses in various zones. Additionally, it was suggested that there should be commitment by top management, team work and attitude change, coordination of roles and optimal participation of all employees regardless of their departments.

The suggestions of the staff are in line with the findings of Farley *et al.* (2008) that insufficient trained staff, inadequate funding to replace the infrastructure, lack of management commitment and weak enabling environment and performance incentives contribute to Non-Revenue Water. By meeting these requirements and others such as water balance and network audit, utilities can reduce the magnitude of Non-Revenue Water.

Utilities must gain understanding of network characteristics, the existing management policy, operational practices, existing technology, skills, social and cultural influences in order to effectively develop and implement NRW strategies (Farley and Liemberger, 2007). The four Non-Revenue Water control factors to reduce real losses from water distribution and service systems include asset or infrastructure management, speed and Quality Repairs and pressure Management (Charalambous, B. Foufeas, D. & Petroulias, N. 2014.; Pilcher R., Dizdar A., Toprak S, Angelis 2008)

CHAPTER FIVE: DISCUSSIONS

5.1 Introduction

The study sought to assess the factors that cause Non-Revenue Water, evaluate the water balance for Meru water scheme, assess the relationship between pressure and leakages and analyse the economic level of leakage and the strategies to control Non-Revenue Water. This chapter presents a summary of the findings, implications from the findings and conclusions. It also presents the recommendations and areas for further research.

5.1.1 Causes of Non- Revenue Water

The research findings reveal that causes or factors which contribute to Non-Revenue Water in Meru Water Scheme and which can be generalized for the entire country are related to operation and maintenance techniques, methodology of repair works, connection and disconnection practices, meter reading errors, lack of as built drawings, organizational culture, age of pipelines, standard of manufacture of pipe materials and fittings and system operating pressure. These findings agree with those of Farley *et al.*(2008) who indicated that Non-Revenue Water is caused by non functional meters or faulty meters, water theft, lack of active leakage control and repair work and lack of capacity to undertake leak detection and repair among other countermeasures.

5. 1.2 Water Balance

The findings on the evaluation of the water balance indicate that the Revenue Water Volume was 83% of which billed metered consumptions was 83% and unmetered consumption that is billed was 0%. The Non-Revenue Water Volume was 17% consisting of leakage on water mains, overflow from tanks and leakages from the service pipes and metering inaccuracies and apparent losses.

The process of water balance helps utilities to determine the magnitude of water lost, where it is lost, reasons for loss and strategies to prevent the loss. The International Water Association (IWA) has come up with a structure for standard international water balance (Farley et al; 2008). IWA methodology of determining the water balance traces water right from source through the system to consumption point (Charalambous et al; 2014). The IWA methodology was used to evaluate the water balance in Meru Water Scheme.

Through evaluation of the water balance, it was found that it was possible to achieve Non – Revenue Water of 10% or less by eliminating commercial losses which stood at 4.1% and managing the supply and demand to reduce overflow from tanks which was found to be 1.9%. Leakage on service pipelines found at 7.7% and on water mains found at 4.7% can be reduced through renewal of the pipe network and through leak detection and repair work. The economic level of leakage could easily be achieved at the level of 10% to 14%.

5.1.3 Relationship between Pressure and Leakage

The study assessed the relationship between pressure in the system and leakage volume. It could be deduced from the analysis that

- A relationship is present for pressure and leakage volume of the form:

  $P = K. (Q)^{x}$

- Power relationship observed ranges from: $\mathbf{P} = (44.22 - 2.183)\ \mathbf{Q}^{(0.461 - 0.516)}$
- Constant increases with increase in orifice area
- Power factor is approximately 0.5 for all values of orifice area. Thereby specific to characteristics of orifice
- Expected N_1 is approximately $N_1 = 0.5$ is expected to range from 0.0 – 1.0.
- There exists a power relationship between pressure and leakage volume as follows: - $(Q_1/Q_0) = 1.083(P_1/P_0)^{(0.19)}$
- From the experimental data obtained, N_1 is 0.19.
- Although within the expected range, approximated N_1 value can be improved with more data over a wider range of pressure conditions.

5.1.4 Economic Level of Leakage

Analysis of the economic level of leakage was undertaken by comparing the cost of water lost and the cost of NRW management. The analysis revealed that the cost of water lost was Ksh 115 per m^3 while the cost of NRW management was Ksh 385 per m^3. This is an indication that the company is spending more money in NRW management than the cost of water lost. Therefore, subsidy may be required to support the scheme in the management of Non-Revenue Water initially. It is expected that the cost of major items like setting out DMAs, cost of leak detection equipment will come down once all the required fittings at DMAs and equipment for leak detection measures are procured and installed.

The factors affecting the economic level of leakage include; the condition of water distribution system, NRW levels, water demand, water price, the economy of the county, water cost and operating practices (Kanakoudis and Gonelas, 2015). It is for this reason that the cost of Non – Revenue Water Management is very high. The cost of setting DMAs and installation of leak detection equipment is very high. With time it is expected the cost of Non – Revenue Water Management will comprise only the maintenance cost of the system. Therefore, in the long term, the cost of Non – Revenue Water Management and the cost of water lost may achieve some balance.

5.1.5 Strategies to Reduce Non – Revenue Water

Analysis of the strategies to control Non-Revenue Water revealed that active leakage control, speed and quality of repairs, pressure management and asset management are important factors to reduce Non – Revenue Water. These findings are consistent with the recommendations of IWA Task Force on Water Loss to reduce real losses from water distribution and service systems (Charalambus et al 2014, Pilcher et al 2008).

It was also realized that the four factors must be balanced so as to achieve leakage levels that are economically, environmentally and socially acceptable as recommended by Thornton and Lambert (2008) and Lambert, (2000). It is also important that the water supply network is divided into zones or District Meter Areas for ease of implementation of the four factors (Charalambous et al 2014).

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This study has brought transformation in engineering by outlining the importance of undertaking water system audit, proactive pressure management as part of demand management and importance of performing cost benefit analysis of Non-Revenue Water reduction measures. These key elements of Non-Revenue Water reduction measures are not performed in this country and majority of the third world countries. The results of the study will be disseminated to the sector institutions as part of knowledge sharing to assist in solving Non – Revenue Water Problems.

6.1.1 Causes of Non- Revenue Water

The research findings reveal that causes of Non-Revenue Water in Meru Water Scheme are connected to organizational practices like operation and maintenance techniques, methodology of repair works, connection and disconnection practices, lack of built drawings, illegal connections and organizational culture. There are also other factors related to the technical integrity of the system like age of the pipelines, meter reading errors, aged meters, overflowing reservoirs, and standard of manufacture of pipe materials and fittings and system operating pressure.

These findings agree with those of Farley *et al.*(2008) who indicated that Non-Revenue Water is caused by non functional meters or faulty meters, water theft, lack of active leakage control and repair work and lack of capacity to undertake leak detection and repair among other countermeasures. From the survey, it was found that:

- There are high leaks at the old sections of pipelines;
- There are serious overflows from the storage tanks;
- Illegal connections are regularly checked and disconnected;
- Standard pipes and fittings are used
- Technical departments always share information on NRW with other departments. NRW reduction measures are therefore organization based not left to the technical department alone;
- Flat rate connections are discouraged and all consumers are metered;

- Master meters, zonal meters and consumer meters are installed for measurement of system input, system flow in the various DMAs and consumption. The meter errors, mistakes in records are avoided to reduce commercial losses.

6.1.2 Water Balance

Through evaluation of water balance, it was found that the level of Non- Revenue Water in Meru Water Scheme was approximately 17% as at March 2016. The importance of frequently undertaking water balance was to enable utilities to identify the amount of water lost, place of loss, why it is lost and strategies that would be instituted to prevent the loss.

Figure 4.17 shows the Non – Revenue trend in MEWASS. Analysis of the trend of water supplied in the zones and water consumed showed there would be a rapid reduction of Non- Revenue Water levels in zones where the water supplied and consumed showed an increase in trend over time than in zones where the water supplied and consumed remained fairly constant. This means additional demand within the zones could be served from water which would otherwise be lost as Non-Revenue Water. Further it was found that:

- In MEWASS the water balance is undertaken monthly; the system input is measured through a bulk meter whereas the zonal inputs are measured by zonal meters;
- The amount of water lost is measured, where it is lost is identified and why it is lost is also identified;
- Unbilled consumptions and illegal connections are eliminated in MEWASS
- The levels of NRW since 2003 to 2016 was evaluated as shown in figure 4.17 below

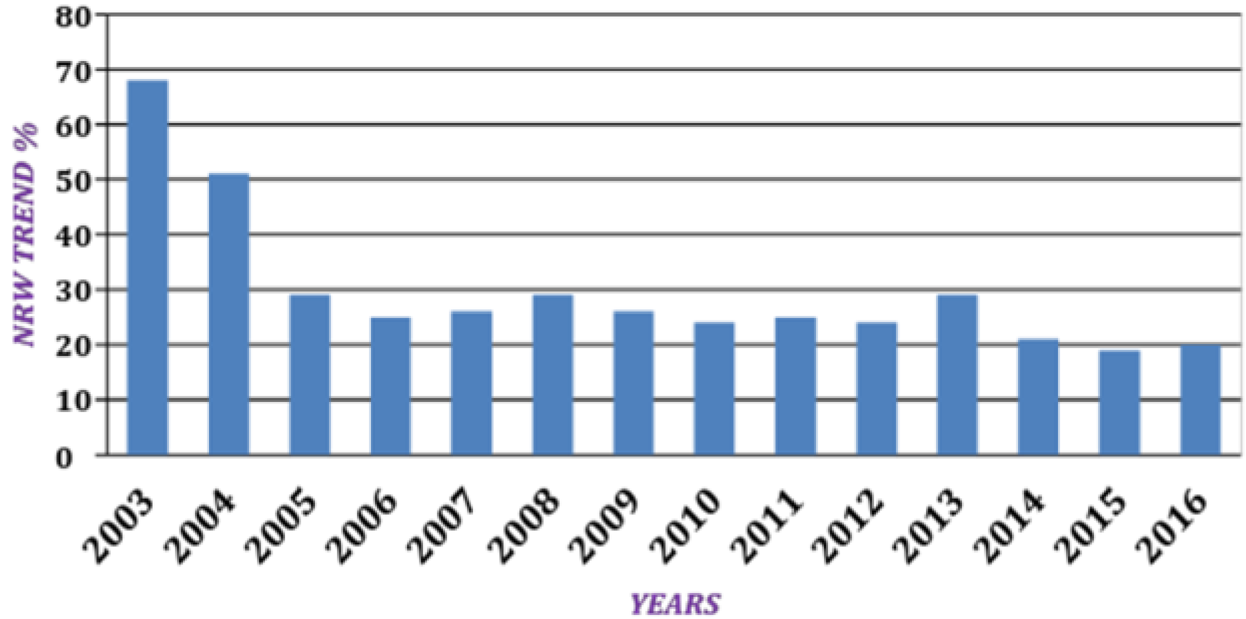

Figure 4.17 Non – Revenue Trend in MEWASS

6.1.3 Relationship between Pressure and Leakage

The study found that there is an empirical relationship between pressure and leakage in the form: $P = K. (Q)^{x}$ where k and x are constants. The constant K is a function of the size of the orifice. It increases as the size of the orifice is increased. The exponent x is a function of the pressure. The higher the pressure the higher the exponent, meaning high operating pressures result into high leakage volumes whenever leaks occur.

The findings agree with those of (Charalambous et al; 2014) which found that the leakage rate in a water system is a function of the pressure in the system. From the study it was found that:

- There are high leakages in pipelines with high operating pressures. The MEWASS system is zoned into eight (8) DMAs and pressure reducing valves are installed for pressure management. The pressure maps and developed to aide in pressure management;
- High pressure in the system is avoided at the design stage and the classes of pipelines and fittings are selected based on the expected operating pressures;
- Low pressure also affects water supply to the consumers negatively.

6.1.4 Economic Level of Leakage

The analysis of economic level of leakage reveals that the cost of Non – Revenue Water Management does not accrue any benefit to the utility in the short term. The cost of leak control and the cost of production are not at minimum i.e. nearly equal. This is because, the cost of Non – Revenue Water Management is higher than the cost of water lost. However, in the long term, the marginal cost of water will be equal to the marginal cost of leakage detection activity.

The utility should therefore undertake NRW control measures in the long term and must ensure the system is operated efficiently as much as possible. The cost of establishing DMAs and purchase of leak detection equipment are considered as fixed costs and will not be incurred in the long run.

6.1.5 Strategies to Reduce Non – Revenue Water

The asset management, speed and quality of repairs, pressure management and active leakage control are important factors to reduce Non – Revenue Water (Charalambus et al 2014, Pilcher et al 2008). Further from the survey it was shown that:

- Identification and quantification of leakages should be on a continuous basis for any utility to reduce NRW to acceptable levels;
- Updating of built drawings is important for leakage reduction strategies as it makes the work of identifying the pipeline routes simple. It is even more useful if it is linked to a GIS;
- Utilities should have a rehabilitation and renewal program for the system. It is imperative that pipelines, fittings and other system facilities are replaced or renewed once they achieve their economic lifespan;
- Emphasis should be given to the speed and quality of repair work to ensure the strategy is successful. The speed factor is to ensure leaks are identified immediately they occur. Currently there is computer software that can assist utilities to identify leakages immediately they occur. The longer the leaks remain unrepaired, the higher the quantity of water lost;
- Pressure management is important for any strategy meant to reduce Non-Revenue Water. The study found that the higher the pressure the higher the quantity of leaks and that frequency of leaks increases when the pressure is high;

- It is useful for any strategy that standards for construction, design, maintenance and operation including standards for manufacture of pipe and fitting are followed;

6.2 Recommendations

6.2.1 Introduction

Based on this study the following general recommendations are made:

1.0 Utilities can achieve NRW reduction measures by constituting NRW unit which can draw up and implement NRW reduction plans. Apart from undertaking NRW reduction through leak detection and repairs, the other activities include posting public notices encouraging customers to pay arrears by instalments and to avoid giving bribes to meter readers and billing personnel and also requesting the customers to report water leakages and bursts to the office for prompt repairs.

2.0 The utilities to undertake monthly reading of customer meters, monthly billing using a MS Access macro program or any other suitable program, intensify installation of customer meters, institute systematic data collection and analysis, update mapping of the water and sewerage system, train staff on meter reading, install and repair meters, repair pipe bursts and institute culture change to reduce commercial losses

3.0 The Water Services Regulatory Authority should formulate standards for design, operation, construction and maintenance for the sector. In MEWAS, even after the initial measures were undertaken, the Non-Revenue Water levels did not improve much as uPVC pipes and fittings used in the system were being procured in various classes making it difficult to manage repairs and pipe extensions. Specifications of pipes and fittings were never given resulting into mixed standards of materials e.g. uPVC pipes supplied to KS 06 – 149 and inches series ISO 4422 were being supplied at the same time.

4.0 There is need for mechanisms to certify quality of materials and that proper fittings are procured otherwise it would result into the use of fire coupling, rubber bands and plastic papers to repair the leaks and the use of tees instead of the use of saddle clamps in the customer service lines.

5.0 Despite the efforts already undertaken at MEWASS, Non- Revenue Water is still high at around 17%; the utility should therefore intensify leak detection and repair works.

6.1.2 Cause of Non-Revenue Water

In order to reduce Non – Revenue Water, it is recommended that utilities should:

- Prioritize asset renewal, rehabilitation and replacement. The budget to undertake these activities should be provided annually. Utilities should formulate policies on asset renewal;
- Meter reading errors and mistakes due to record taking should be minimized to reduce the level of commercial losses;
- Utilities should eliminate all forms of illegal connections and encourage metering consumption; flat rate billing should be discouraged;
- Updating as built drawings should be priority to the utilities, leak detection work is simplified if the pipeline routes can be identified;
- Provide storage facilities that are economically and adequately sized to avoid frequent overflows.

6.2.3 Water Balance

Water balance is an important component in leak reduction measures and from the study, it is recommended that:

- Utilities undertake monthly audit of the water balance to identify how much water is lost, where it is lost, why it is lost and factors that can be considered to reduce leakage;
- The water balance data can be built over time to assist in analysis for decision making;
- The water balance exercise can only be successful if the master meters, zone meters and consumer meters are installed; as a matter of priority, utilities should embrace full metering;
- The meters should also be frequently tested to keep them in good working status;
- Utilities should embrace midnight leak survey, as it is successfully adopted at MEWASS

6.2.4 Pressure Management

The study found that the leakage volume increases with increase in operating pressure, it is recommended that:

- Utilities should divide the water supply network into manageable DMAs, the DMAs should be based on pressure zones;
- Utilities should install pressure reducing valves in the entire system to assist in pressure management;
- The pipe and fittings selection at design stage should be based on the available operating pressure in order to reduce frequency of bursts;

6.2.5 Economic Level of Leakage

In MEWASS, it was found that historical data which can assist in the analysis of the economic level of leakage was not available. Through analysis of economic level of leakage utilities get to know whether continuing with Non- Revenue Water Management results into reduction of NRW and brings benefits to the utility. It is therefore recommended that:

- Utilities prepare and store data for the cost of NRW management for each value of NRW;
- Every time the water balance is undertaken, analysis of economic level of leakage is also done;
- Water supply systems must be managed very effectively and efficiently so that the analysis of the cost of Non – Revenue Water management can be useful.

6.2.6 Strategies to Reduce NRW

The strategies are important for NRW reduction as employed in MEWASS and which all utilities should embrace. It is recommended that:

- Utilities should embrace speed and quality of repair;
- Pressure management should be practiced by all utilities;
- Asset management is an important strategy to reduce NRW levels which utilities should adopt;
- Leak detection survey should also have adopted by utilities.

6.3 Suggestions for Further Study

The following areas are identified as potential for further studies

- The factors that affect economic level of leakages need to be researched on so that utilities do not undertake measures that are not adding value;
- The relationship between volume and the pipe material needs to be researched on as utilities mix pipe material in the water supply systems

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APPENDICES

APPENDIX 1: RESEARCH QUESTIONNAIRE

Introduction

This questionnaire is designed for the sole purpose of gathering information on the causes on Non-Revenue Water, Water Balance, the relationship between pressure and leakage, economic level of leakage and strategies to control Non-Revenue Water. The responses will remain anonymous and that the information that is provided will be treated as confidential at all times. Your name will not be identified as only summaries will be used.

SECTION A

Please answer the following questions by crossing with (x) or tick (√) the relevant box or filling in the blank spaces as appropriate.

1. Are you an employee of MEWASS? (a) Yes. ☐ (b). ☐
2. For how long have you worked with MEWASS..
3. At what level are you working at MEWASS...
4. In which department.. Section...

SECTION B

The following statements describe what may or may NOT be happening in your organization regarding causes of Non-Revenue Water. Please tick appropriate column to indicate your opinion as regards each statement.

	Extremely Agree	**Somewhat agree**	**Neither agree nor disagree**	**Somewhat Disagree**	**Strongly Disagree**
13. We have high leaks at the old sections of the pipelines					
14. Our storage tanks are always over flowing					
15. We regular check for illegal connections and disconnect them					
16. We use standard fittings and pipes					

17. Technical departments are always linked up and share information on Non-Revenue Water					
18. In our organization meter reading errors are common					
19. In our organization we have substantial number of flat rate connection					
20. In our system, we have installed master meters, zonal meters and consumer meters					
21. In our organization there is frequent loss of consumer records					
22. We undertake meter reading regularly					
23. The cases of consumers tempering with meters are common					
24. In our system, there are many Non-functional meters					

□

SECTION C

The following statements describe what may or may NOT be happening in your organization regarding water balance. Please tick appropriate column to indicate your opinion as regards each statement.

	Extremely Agree	**Somewhat agree**	**Neither agree nor disagree**	**Somewhat Disagree**	**Strongly Disagree**
25. We undertake water balance regularly					
26. The system in put is measured through bulk meter					
27. We have installed zonal meters in all the zones					
28. We know how much water is lost					

29. We know where water is lost					
30. We know why water is lost					
31. We measure un billed authorized consumption					
32. We know the amount of unbilled un metered consumption					
33. We measure un authorized consumption					
34. We measure overflow in tanks					
35. We measure leakage in service connection					
36. We measure leakage in transmission mains					
37. We measure customer inaccuracies					

SECTION D

The following statements describe what may or may NOT be happening in your organization regarding pressure management. Please tick appropriate column to indicate your opinion as regards each statement.

	Extremely Agree	**Somewhat agree**	**Neither agree nor disagree**	**Somewhat Disagree**	**Strongly Disagree**
38. There are high leakage in pipelines with high pressure					
39. We have zoned the water scheme into pressure zones					
40. We frequently install pressure reducing valves in the system					
41. We avoid a high pressures in the system in order to avoid frequent bursts					

42. Working pressures are determined at design stage					
43. Pipe selection take of care of anticipated pressures in the system					
44. We develop pressures maps in the system					
45. The pressures in the system is closely monitored					
46. Low pressures affect water supply to the consumers negatively					

SECTION E

The following statements describe what may or may NOT be happening in your organization regarding strategies to reduce Non – Revenue Water. Please tick appropriate column to indicate your opinion as regards each statement.

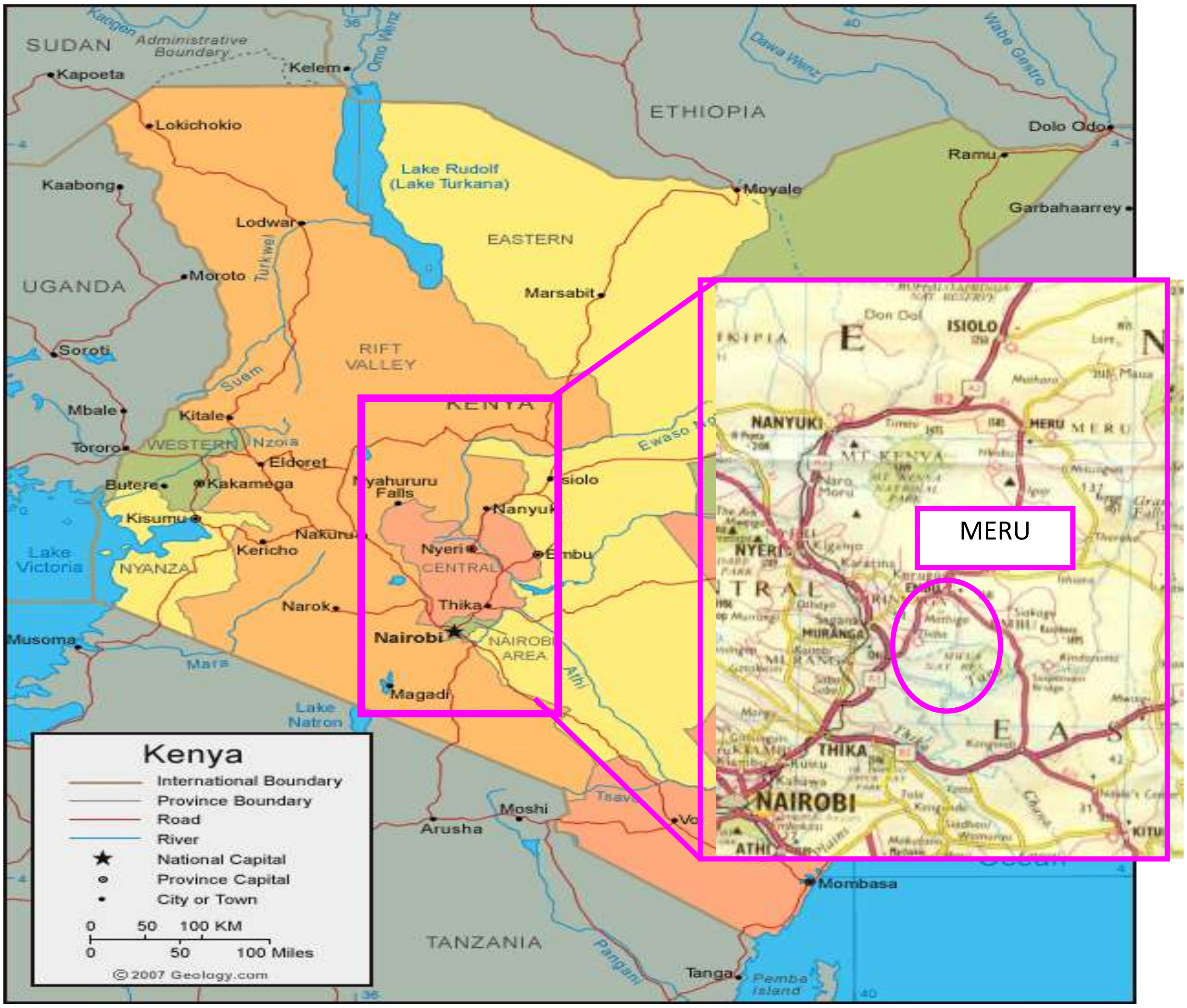
	Extremely Agree	**Somewhat agree**	**Neither agree nor disagree**	**Somewhat Disagree**	**Strongly Disagree**
47. We identify and quantify leakages on continuous basis					
48. As built drawings are regularly updated					
49. We emphasis on speed and quality of repair works					
50. We have rehabilitation and renewal program					
51. We have continuous pressure management program					
52. Leaks are detected and repaired as soon as they occur					
53. In repair works standardized fittings and pipes are always used					
54. There is always a budget for Non-					

Revenue Water activities					
55. All the pipeline mappings are linked to GIS					
56. The top management is committed to Non- Revenue Water Reduction					

What suggestion would you give for the improvement of Non - Revenue Water management in your organization? ………………………………………………………….…………………….

Thank you for your participation

APPENDIX 2: Location Map of Meru Town



APPENDIX 3a: NRW FIGURES FEBRUARY 2016 ZONE 1

ZONE	ZONE 1										
	Supply	Consumption	N.R.W	Monthly production including zone 8	Total consumption	Total distributed	BACK WASH	Transmitted Water Losses	Distributed to zone 5	OVERALL N.R.W. (Total production @ Wtp & HLT)	DISTRIBUTION NRW
Oct-04	35,934	17,954	50	136,351	76,625	123,699				44	38
Nov-04	26,557	17,060	36	117,532	74,373	114,156				37	35
Dec-04	29,407	19,553	34	114,847	83,907	120,487				27	30
Jan-05	24,497	16,951	31	116,040	76,672	112,090				34	32
Feb-05	23,288	16,882	28	112,848	68,961	102,425				39	33
Mar-05	27,077	21,477	21	122,389	81,103	108,892				34	26
Apr-05	26,970	18,341	32	122,389	83,003	120,355				32	31
May-05	23,325	15,615	33	121,660	78,117	120,789	5,523	67,035		36	35
Jun-05	22,195	16,495	26	114,311	73,386	106,169	4,582	57,321		36	31
Jul-05	22,847	16,409	28	110,202	70,886	103,993	3,440	54,872		36	32
Aug-05	23,222	18,457	21	108,588	77,871	103,585	3,038	55,501		28	25
Sep-05	23,891	17,528	27	105,805	81,363	113,109	4,582	54,039		23	28
Oct-05	22,350	16,461	26	111,432	76,457	105,782				31	28
Nov-05	20,254	15,316	24	99,021	72,620	97,305	3,775	53,301		27	25
Dec-05	23,023	17,766	23	101,195	76,150	96,245	3,729	56,212		25	21
Jan-06	22,851	17,332	24	103,045	75,442	99,211	3,275	56,060	46,985	27	24
Feb-06	22,333	17,989	19	101,738	77,246	102,828	3,303	55,772	45,966	24	25

Mar-06	26,593	21,689	18	110,414	80,660	105,706	3,394	61,339	49,075	27	24
Apr-06	23,208	19,088	18	110,645	77,639	107,614	5,488	65,122	45,523	30	28
May-06	25,280	20,148	20	115,957	80,758	107,584	4,749	69,537	46,420	30	25
Jun-06	25,919	21,031	19	119,616	87,443	115,398	3,831	69,886	52,345	27	24
Jul-06	24,897	19,418	22	123,285	83,423	111,018	3,930	71,526	51,759	32	25
Aug-06	28,939	22,626	22	123,198	91,834	124,085	3,913	73,468	51,792	25	26
Sep-06	27,408	22,549	18	128,918	93,190	121,263	3,900	77,239	49,896	28	23
Oct-06	26,732	21,244	21	126,516	91,721	118,049	5,755	79,111	52,921	28	22
Nov-06	25,441	21,303	16	121,418	85,316	111,786	5,472	73,462	46,337	30	24
Dec-06	30,070	21,326	29	128,505	85,630	115,797	4,678	73,462	44,765	33	26
Jan-07	23,543	20,194	14	124,448	86,701	116,592	4,707	74,518	50,725	30	26
Feb-07	26,209	22,529	14	119,214	91,747	119,057	4,274	74,518	50,811	23	23
Mar-07	29,043	21,755	25	137,892	92,123	126,746	4,548		50,338	33	27
Apr-07	31,271	21,923	30	134,263	90,924	127,700	4,721		51,541	32	29
May-07	29,028	24,372	16	128,098	95,429	125,882	2,726		53,326	26	24
Jun-07	24,522	21,333	13	122,230	88,474	112,616	2,479		51,219	28	21
Jul-07	24,339	19,845	18	122,520	88,869	111,840	2,383		44,425	27	21
Aug-07	29,854	24,533	18	141,797	101,428	140,683	3,451		57,075	28	28
Sep-07	25,168	19,873	21	137,555	94,402	125,733	2,418		54,773	31	25
Oct-07	25,204	20,773	18	139,310	94,058	125,474	2,943		49,552	32	25
Nov-07	27,601	21,757	21	128,477	96,946	126,792	2,938		49,805	25	24
Dec-07	30,789	24,129	22	138,396	105,730	151,812	2,904		70,270	24	30
Jan-08	30,789	24,130	22	133,317	87,171	111,621	3,021		30,079	35	22
Feb-08	22,131	18,719	15	130,667	96,339	127,201	1,957		52,667	26	24
Mar-08	30,461	23,856	22	144,842	101,550	138,958	2,722		52,667	30	27
Apr-08	28,740	23,069	20	133,512	99,121	133,895	1,655		53,277	26	26
May-08	29,050	22,441	23	144,735	94,670	137,193	3,663		52,125	35	31
Jun-08	29,499	22,746	23	142,696	100,516	135,920	2,798		50,842	30	26

Jul-08	29,094	20,809	28	146,461	93,497	136,064	2,622		56,464	36	31
Aug-08	33,703	25,084	26	157,988	106,637	148,354	3,157		54,576	33	28
Sep-08	34,056	24,330	29	155,567	99,666	136,115	4,431		45,980	36	27
Oct-08	34,542	23,107	33	158,307	107,327	163,149	4,120		57,736	32	34
Nov-08	29,403	22,513	23	144,220	104,573	147,591	3,766		61,049	27	29
Dec-08	28,753	21,306	26	154,486	97,795	138,239	4,696		53,498	37	29
Jan-09	34,882	26,362	24	155,550	116,788	169,170	2,929		62,237	25	31
Feb-09	28,454	23,183	19	139,500	98,303	135,373	2,913		55,653	30	27
Mar-09	27,830	21,778	22	159,777	88,541	121,858	3,413		36,426	45	27
Apr-09	35,140	26,326	25	145,241	112,252	148,872	2,695		56,909	23	25
May-09	37,028	29,510	20	149,560	108,340	147,271	2,783		50,201	28	26
Jun-09	31,911	26,176	18	148,349	110,105	142,685	2,558		54,141	26	23
Jul-09	34,711	26,360	24	162,295	105,178	140,066	2,683		54,665	35	25
Aug-09	42,271	32,576	23	161,126	113,283	157,833	2,917		50,865	30	28
Sep-09	41,083	33,367	19	157,181	117,731	149,983	2,392		54,263	25	22
Oct-09	41,998	32,477	23	147,146	113,600	156,299	2,471		53,253	23	27
Nov-09	41,443	34,149	18	142,078	113,695	143,848	2,211		48,459	20	21
Dec-09	37,685	30,543	19	141,046	104,268	133,621	2,258		45,860	26	22
Jan-10	47,021	33,239	29	140,164	125,265	170,000	2,123	2,746	64,725	11	26
Feb-10	24,824	21,833	12	133,044	81,357	93,305	1,654	1,064	26,405	39	13
Mar-10	24,824	21,578	13	133,044	78,879	93,305	1,654	1,064	26,405	41	15
Mar-10	33,740	27,158	20	143,758	98,591	125,302	2,075	1,289	40,484	31	21
Apr-10	35,107	28,554	19	148,431	109,061	143,231	2,073	2,143	53,059	27	24
May-10	39,837	28,919	27	142,514	98,551	126,285	1,979	2,350	42,067	31	22
Jun-10	34,042	26,975	21	147,944	100,644	125,650	1,782	2,673	40,008	32	20
Jul-10	37,044	27,718	25	144,110	104,704	141,804	1,785	120	54,504	27	26
Aug-10	36,058	28,784	20	151,994	107,964	144,415	1,662	1,128	48,751	29	25
Sep-10	42,291	29,931	29	158,819	102,194	145,955	1,882	520	48,132	36	30

Oct-10	44,574	30,835	31	164,416	110,165	155,619	1,996	1,405	48,189	33	29
Nov-10	41,836	35,178	16	150,016	114,432	146,365	1,987	1,812	54,311	24	22
Dec-10	38,490	29,910	22	155,383	109,301	143,947	1,578	1,518	40,204	30	24
Jan-11	41,510	34,818	16	154,271	122,926	150,836	2,154	610	48,198	20	19
Feb-11	32,337	27,338	15	146,630	101,542	136,419	1,764	271	51,593	31	26
Mar-11	36,899	29,702	20	169,240	107,867	141,235	2,514	1,384	46,808	36	24
Apr-11	36,482	31,541	14	162,148	118,573	160,374	2,532	5,648	51,693	27	26
May-11	39,707	32,397	18	162,178	119,816	156,110	2,558	6,461	53,513	26	23
Jun-11	37,326	32,517	13	154,636	115,648	145,448	1,976	7,006	44,271	25	20
Jul-11	33,810	28,629	15	173,308	110,729	139,728	1,808	9,064	45,797	36	21
Aug-11	34,888	26,480	24	173,083	106,016	138,741	2,092	9,064	43,682	39	24
Sep-11	43,394	33,332	23	160,070	121,206	152,878	2,522	7,745	46,129	24	21
Oct-11	35,888	29,632	17	165,952	116,636	151,030	2,551	2,380	46,116	30	23
Nov-11	39,692	31,724	20	160,568	122,432	165,886	2,368	1,538	55,801	24	26
Dec-11	42,008	33,956	19	167,250	127,009	170,546	3,222	1,595	53,231	24	26
Jan-12	37,290	32,383	13	170,536	117,873	152,640	2,137	969	53,195	31	23
Feb-12	33,392	24,359	27	163,038	101,435	130,145	2,101	649	36,168	38	22
Mar-12	38,110	28,662	25	179,390	120,573	159,912	2,211	3,200	47,691	33	25
Apr-12	37,292	29,000	22	167,654	122,615	155,553	2,342	829	47,782	27	21
May-12	38,390	31,412	18	175,449	119,516	155,833	2,641	4,066	50,399	32	23
Jun-12	29,469	24,043	18	177,430	103,578	131,621	2,601	4,572	38,324	42	21
Jul-12	37,642	25,781	32	169,905	118,024	163,069	2,409	7,293	48,141	31	28
Aug-12	38,698	27,574	29	178,466	124,203	177,454	2,040	4,190	44,543	30	30
12-Sep	37,840	30,728	19	177,485	134,633	175,163	3,131	5,030	55,572	24	23
12-Oct	39,055	26,892	31	175,614	121,293	171,124	2,767	4,404	47,202	31	29
12-Nov	35,556	26,314	26	164,492	129,771	168,123	2,568	3,219	48,120	21	23
12-Dec	39,716	31,854	20	175,442	126,996	172,715	2,592	3,449	48,789	28	26
13-Jan	39,392	32,181	18	178,621	133,122	170,870	2,359	3,054	59,363	25	22

13-Feb	33,736	23,341	31	165,882	124,151	166,169	2,037	3,100	38,190	25	25
13-Mar	41,071	30,946	25	186,867	136,646	176,967	2,364	2,828	48,900	27	23
13-Apr	36,837	28,877	22	178,570	124,143	166,743	2,628	3,591	51,677	30	26
13-May	37,594	24,099	36	185,746	116,272	169,590	2,745	2,552	49,429	37	31
13-Jun	39,229	27,231	31	178,249	131,060	174,780	2,314	3,055	40,659	26	25
13-Jul	37,098	27,880	25	1,877,489	129,055	178,954	3,148	2,668	54,282	93	28
13-Aug	37,947	29,337	23	188,711	130,434	178,668	2,211	2,903	50,639	31	27
13-Sep	39,675	30,987	22	186,914	144,850	185,758	3,145	2,896	48,939	23	22
13-Oct	39,994	30,829	23	194,646	136,312	182,733	4,129	3,396	55,765	30	25
13-Nov	40,321	30,910	23	182,908	136,092	176,112	3,969	1,259	51,606	26	23
13-Dec	39,374	28,516	28	190,704	138,200	184,176	3,148	2,169	42,579	28	25
14-Jan	38,336	27,818	27	198,022	133,419	184,654	3,634	1,815	56,157	33	28
14-Feb	36,297	29,589	18	161,855	126,980	168,832	2,807	1,172	45,137	22	25
14-Mar	38,305	35,219	8	186,510	153,255	186,295	3,618	743	54,374	18	18
14-Apr	39,231	30,815	21	189,588	143,731	172,778	3,816	579	52,036	24	17
14-May	42,961	36,753	14	192,771	150,482	182,293	3,125	472	58,036	22	17
14-Jun	42,292	31,444	26	194,217	151,367	189,561	3,227	229	49,067	22	20
14-Jul	44,061	31,579	28	196,227	151,792	192,530	3,736	76	54,262	23	21
14-Aug	39,808	28,713	28	172,483	140,715	180,884	3,280	11	36,586	18	22
14-Sep	48,304	41,487	14	212,115	151,923	193,485	4,082	10	54,018	28	21
14-Oct	47,231	41,767	12	205,415	144,343	177,637	4,641	53	51,595	30	19
Nov-14	44,001	38,442	13	187,985	155,446	184,980	5,214	34	45,609	17	16
Dec-14	50,534	43,535	14	205,889	162,954	191,349	4,222	27	57,025	21	15
Jan-15	45,323	37,697	17	191,212	148,170	180,049	4,719	25	47,139	23	18
Feb-15	46,178	38,660	16	196,354	160,525	189,310	3,890	12	48,318	18	15
Mar-15	47,365	39,350	17	202,158	153,356	184,660	5,157	20	51,953	24	17
Apr-15	44,616	37,513	16	196,444	152,914	185,236	5,041	28	46,306	22	17
15-May	46,758	41,559	11	196,004	155,791	186,368	4,645	21	50,206	21	16

15-Jun	45,013	37,878	16	196,867	149,758	184,101	4,374	19	45,618	24	19
15-Jul	45,153	40,461	10	197,571	154,526	182,044	5,808	20	49,090	22	15
15-Aug	41,582	36,436	12	191,238	147,747	177,638	4,400	30	48,455	23	17
15-Sep	45,926	40,881	11	207,915	156,845	184,511	4,827	42	53,244	25	15
15-Oct	47,253	42,496	10	223,942	162,209	190,605	5,729	27	55,275	28	15
15-Nov	44,613	39,818	11	224,564	167,637	201,100	6,449	23	61,570	25	17
15-Dec	40,895	35,760	13	194,091	165,253	189,158	4,506	20	53,033	15	13
16-Jan	35,369	32,176	9	187,473	159,338	186,422	4,817	30	46,943	15	15
16-Feb	38,950	35,141	10	188,522	148,364	175,030	4,349	62	51,938	21	15

APPENDIX 3b: NRW FIGURES FEBRUARY 2016 ZONE 2-7

ZONE	ZONE 2			ZONE 3			ZONE 4			ZONE 5			ZONE 6			ZONE 7		
	Supply	Consumption	N.R.W	Supply	Consumption	N.R.W	Supply	Consumption	N.R.W	Supply	Consumption	N.R.W	Supply	Consumption	N.R.W	Supply	Consumption	N.R.W
Oct-04	957	862	10	1,674	966	42	4,369	2,537	42	58,561	40,453	31	6,598	4,558	31	15,606	9,295	40
Nov-04	1,465	1187	19	1,495	957	36	3,834	2437	36	58,802	39,538	33	6,299	4409	30	15,705	8785	44
Dec-04	1,826	1281	30	2,239	1132	49	5,764	3227	44	58,176	42514	27	6,757	4820	29	16,318	11380	30
Jan-05	1,053	854	19	2,292	1222	47	7,118	3802	47	57,477	40104	30	6,507	4549	30	13,147	9190	30
Feb-05	1,113	816	27	1,809	1169	35	5,861	3921	33	50,823	32590	36	6,950	5048	27	12,580	8535	32
Mar-05	1,674	1217	27	3,087	1897	39	6,067	4664	23	49,914	35138	30	7,588	6078	20	13,484	10632	21
Apr-05	1,753	1253	29	2,392	1481	38	6,636	3997	40	60,869	42436	30	6,159	5221	15	15,577	10274	34
May-05	1,485	1066	28	3,230	1329	59	7,102	3521	50	65,480	41253	37	7,069	5440	23	13,098	9893	24

Jun-05	1,073	882	18	2,123	1295	39	5,541	3597	35	56,322	36653	35	6,544	5243	20	12,370	9221	25
Jul-05	1,119	887	21	1,847	1389	25	5,355	3744	30	53,030	34551	35	6,131	5095	17	13,664	8811	36
Aug-05	1,682	1396	17	2,262	1862	18	5,987	4738	21	50,386	35865	29	7,088	5730	19	12,958	9823	24
Sep-05	1,523	1294	15	3,287	1858	43	7,071	5138	27	55,952	38758	31	7,404	5554	25	13,981	11233	20
Oct-05	1,922	1455	24	2,728	1523	44	6,162	4502	27	55,127	38819	30	5,862	4544	22	11,631	9153	21
Nov-05	1,865	1,537	18	2,607	1,459	44	6,463	4486	31	47,317	35006	26	6,298	4955	21	12,501	9861	21
Dec-05	2,285	2042	11	1,795	1589	11	7,275	5447	25	41,802	32797	22	6,709	5456	19	13,357	11053	17
Jan-06	2,103	1775	16	2,091	1646	21	6,471	4769	26	46,208	34875	25	7,148	5896	18	12,339	9149	26
Feb-06	2,166	1852	14	2,294	1828	20	6,257	4825	23	51,548	36607	29	6,641	5333	20	11,589	8812	24
Mar-06	2,478	1907	23	2,743	2149	22	9,631	5921	39	44,557	33385	25	7,199	5618	22	12,506	9991	20
Apr-06	2,343	1849	21	2,355	1475	37	10,861	4603	58	53,439	37881	29	5,153	4536	12	10,257	8207	20
May-06	2,969	2012	32	2,511	1925	23	11,992	6472	46	44,044	33896	23	7,265	5983	18	13,524	10322	24
Jun-06	2,688	2,080	23	3,289	2,010	39	11,837	7,001	41	52,345	40,733	22	6,309	5,368	15	13,010	9,220	29
Jul-06	3,284	2,730	17	2,968	1,984	33	11,339	6,865	39	49,761	37,845	24	6,421	5,680	12	12,348	8,901	28

Aug-06	4,709	3,199	32	3,158	2,354	25	14,383	7,746	46	51,792	38,799	25	7,634	6,618	13	13,470	10,492	22
Sep-06	7,237	5,889	19	2,988	2,214	26	13,255	8,186	38	49,896	37,171	26	6,537	5,951	9	13,942	11,230	19
Oct-06	7,919	5,948	25	2,638	1,636	38	9,635	7,052	27	52,921	41,616	21	6,133	5,270	14	12,072	8,955	26
Nov-06	7,199	5,434	25	3,298	1,666	49	11,389	6,247	45	46,337	36,404	21	6,304	5,230	17	11,818	9,032	24
Dec-06	7,187	5,199	28	2,468	1,820	26	11,618	6,331	46	44,765	35,868	20	6,320	5,482	13	13,370	9,604	28
Jan-07	7,574	5,236	31	2,739	1,948	29	13,179	7,769	41	50,725	36,572	28	7,279	6,112	16	11,553	8,870	23
Feb-07	7,401	5,566	25	3,054	2,034	33	13,728	8,368	39	50,811	37,456	26	6,761	6,138	9	11,093	9,656	13
Mar-07	7,778	5,681	27	3,021	1,768	41	17,762	9,280	48	50,338	39,465	22	6,041	5,078	16	12,763	9,096	29
Apr-07	8,959	5,333	40	2,837	2,013	29	16,462	8,514	48	51,541	37,944	26	6,846	6,016	12	9,784	9,181	6
May-07	8,019	5,257	34	2,705	2,141	21	15,235	8,801	42	53,326	40,009	25	6,740	5,741	15	10,829	9,108	16
Jun-07	6,855	4,355	36	2,733	2,113	23	11,067	7,139	35	51,219	39,077	24	6,391	5,686	11	9,829	8,771	11
Jul-07	8,275	6,425	22	2,814	2,336	17	13,802	8,982	35	44,425	35,712	20	6,626	6,185	7	11,559	9,384	19
Aug-07	11,821	8,285	30	3,187	2,514	21	17,081	9,899	42	57,075	39,254	31	7,560	6,338	16	14,105	10,605	25
Sep-07	10,065	7,396	27	3,269	2,629	20	12,239	8,942	27	54,773	39,706	28	7,359	6,188	16	12,860	9,668	25

Oct-07	11,489	7,635	34	3,493	2,691	23	14,094	8,747	38	49,552	38,183	23	7,267	6,033	17	14,375	9,996	30
Nov-07	10,434	8,385	20	3,474	2,366	32	15,442	8,880	42	49,805	38,395	23	6,267	5,546	12	13,769	11,617	16
Dec-07	14,700	9,812	33	3,888	2,467	37	14,397	8,909	38	70,270	46,029	34	6,276	5,227	17	11,492	9,157	20
Jan-08	14,700	9,813	33	3,888	2,468	37	14,397	8,910	38	30,079	27,464	9	6,276	5,228	17	11,492	9,158	20
Feb-08	11,440	7,753	32	1,936	976	50	15,005	9,489	37	52,667	41,221	22	7,615	6,649	13	16,407	11,532	30
Mar-08	15,888	10,164	36	-	0	N/A	16,296	10024	38	52,667	41,221	22	6,850	6,067	11	16,796	10218	39
Apr-08	15,152	7873	48	-	0	N/A	14,653	10173	31	53,277	42523	20	6,728	5,791	14	15,345	9692	37
May-08	12,344	7912	36	-	0	N/A	17,423	8810	49	52,125	37735	28	7,774	6,577	15	18,477	11195	39
Jun-08	15812	9840	38	-	0	N/A	17858	10277	42	50842	40672	20	7,445	6329	15	14464	10652	26
Jul-08	12438	7989	36	-	0	N/A	17807	9581	46	56464	38802	31	7,592	6078	20	12669	10238	19
Aug-08	16966	11459	32	-	0	N/A	18901	9559	49	54576	43942	19	7,118	6026	15	17090	10567	38
Sep-08	17558	12609	28	-	0	N/A	15855	9562	40	45980	37609	18	7,633	6019	21	15033	9537	37
Oct-08	19237	11042	43	-	0	N/A	25208	13857	45	57736	39294	32	9,545	8365	12	16881	11662	31
Nov-08	14654	8558	42	-	0	N/A	20732	9,955	52	61049	47442	22	7,246	6071	16	14507	10034	31

Dec-08	14705	8780	40	-	0	N/A	18981	10,899	43	53498	39502	26	7,709	6598	14	14593	10710	27
Jan-09	18459	10301	44	-	0	N/A	22588	12,532	45	62237	46337	26	10,479	8385	20	20525	12871	37
Feb-09	15010	9571	36	-	0	N/A	16768	10441	38	55653	42119	24	5,409	4530	16	14079	8459	40
Mar-09	15581	10192	35	-	0	N/A	18368	10698	42	36426	28872	21	7,280	6261	14	16373	10740	34
Apr-09	18698	10456	44	-	0	N/A	16798	10786	36	56909	46928	18	7,741	6789	12	13586	10967	19
May-09	16820	11424	32			N/A	18982	11099	42	50201	38222	24	7,688	6009	22	16552	12076	27
Jun-09	16845	12753	24			N/A	17497	11452	35	54141	41995	22	7,084	6407	10	15207	11322	26
Jul-09	15898	10728	33			N/A	14039	9485	32	54665	42237	23	6,584	5974	9	14169	10394	27
Aug-09	17607	12706	28			N/A	18797	12109	36	50865	34552	32	9,060	7898	13	19233	13442	30
Sep-09	15540	12,593	19			N/A	17036	10677	37	54263	43185	20	7,351	6800	7	14710	11109	24
Oct-09	18241	11602	36			N/A	17672	11751	34	53253	39219	26	9,129	7495	18	16006	11056	31
Nov-09	16116	10849	33			N/A	16258	11345	30	48459	41100	15	6,707	5896	12	14865	10356	30
Dec-09	15586	10912	30			N/A	12632	8176	35	45860	38233	17	7,580	6420	15	14278	9984	30
Jan-10	18291	12629	31			N/A	16797	11512	31	64725	50244	22	6,887	5808	16	16279	11833	27

Feb-10	11453	8970	22			N/A	12976	8939	31	26405	26188	1	6,157	5529	10	11490	9898	14
Mar-10	11453	8508	26			N/A	12976	8725	33	26405	25337	4	6,157	5445	12	11490	9286	19
Mar-10	15041	10114	33			N/A	13885	9581	31	40484	33484	17	7,377	6783	8	14775	11471	22
Apr-10	17395	11400	34			N/A	15891	11425	28	53059	39877	25	7,084	6585	7	14695	11220	24
May-10	13975	9094	35			N/A	12946	8786	32	42067	37720	10	5,824	5170	11	11636	8862	24
Jun-10	16635	13708	18			N/A	14915	10235	31	40008	33603	16	7,267	6436	11	12783	9687	24
Jul-10	14871	9759	34			N/A	14889	11096	25	54504	39233	28	7,116	5921	17	13380	10977	18
Aug-10	18121	11874	34			N/A	17789	12298	31	48751	38151	22	6,800	5950	13	16896	10907	35
Sep-10	18632	10742	42			N/A	15097	9880	35	48132	34628	28	7,629	6672	13	14174	10341	27
Oct-10	20033	11946	40			N/A	18508	13184	29	48189	35854	26	7,568	6583	13	16747	11763	30
Nov-10	16927	11066	35			N/A	14721	11142	24	54311	41442	24	6,667	6004	10	11903	9600	19
Dec-10	21116	13405	37			N/A	19226	12329	36	40204	34761	14	8,608	7234	16	16303	11662	28
Jan-11	18352	14145	23	864	0	100	16229	12912	20	48198	42299	12	8,406	6662	21	17277	12090	30
Feb-11	15455	9561	38	1,789	394	78	13416	9788	27	51593	38809	25	7,962	5916	26	13867	9736	30

Mar-11	18243	13327	27	4,016	345	91	18421	12810	30	38480	33767	12	8,165	6725	18	17011	11191	34
Apr-11	16109	11569	28	7,854	971	88	19130	13917	27	51693	40502	22	10,026	7817	22	19080	12256	36
May-11	17066	12687	26	5,036	1060	79	17608	12447	29	53513	43306	19	8,652	7035	19	14528	10884	25
Jun-11	16436	12741	22	5,529	1533	72	19787	14606	26	42732	35251	18	8,326	6990	16	15312	12010	22
Jul-11	15641	11964	24	3,958	1411	64	17905	12743	29	45797	37912	17	8,009	6833	15	14608	11237	23
Aug-11	14655	12301	16	4,400	1549	65	17681	13404	24	43682	34532	21	8,009	6596	18	15426	11154	28
Sep-11	19299	16260	16	2,999	1764	41	17793	11114	38	46129	38943	16	8,232	7182	13	15032	12611	16
Oct-11	18433	13337	28	4,007	2042	49	18984	12635	33	46116	38448	17	10,608	7884	26	16994	12658	26
Nov-11	18955	14734	22	3,175	2261	29	22264	13678	39	55801	41870	25	9,884	7204	27	16115	10961	32
Dec-11	23087	16211	30	4,126	3046	26	17527	10181	42	53231	40769	23	11,138	8670	22	19429	14176	27
Jan-12	20688	14943	28	2,779	2009	28	22589	11916	47	53195	42936	19	6,370	5672	11	9729	8014	18
Feb-12	15763	12293	22	3,219	2572	20	17612	12203	31	36168	31541	13	9,105	7080	22	14886	11387	24
Mar-12	19930	14487	27	4,980	3193	36	25357	15042	41	47691	39728	17	8,298	7379	11	15546	12082	22
Apr-12	22349	16817	25	4,002	2716	32	20241	14423	29	47782	40133	16	8,745	7638	13	15142	11888	21

May-12	25338	16958	33	2,909	2098	28	18965	12070	36	50399	41835	17	6,681	5870	12	13151	9273	29
Jun-12	17733	13349	25	4,160	2804	33	18003	12347	31	38324	32575	15	7,550	6628	12	16382	11832	28
Jul-12	23146	15506	33	5,751	3630	37	21212	15026	29	52141	38902	25	8,340	6918	17	14837	12261	17
Aug-12	31624	17034	46	5,012	3350	33	22612	14940	34	49543	37788	24	10,685	8413	21	19280	15104	22
12-Sep	30019	17990	40	4,921	3362	32	22211	17262	22	56572	44190	22	8,438	7686	9	15162	13415	12
12-Oct	23632	15145	46	4,643	3330	28	24286	14621	40	56202	38202	24	8,360	6314	24	15187	10096	34
12-Nov	24297	17476	40	6,095	5429	11	22003	15261	31	50120	37873	22	9,157	7746	15	16118	13920	14
12-Dec	25413	18962	36	4,818	4084	15	23019	17484	24	52789	41299	32	11,398	9812	14	18729	16030	14
13-Jan	28009	19255	28	4,202	3738	11	23872	18409	23	59363	48619	24	6,909	6486	6	13630	12459	9
13-Feb	22471	14936	25	4,653	3667	21	22393	15066	33	44190	31785	22	10,053	7301	27	16988	12967	24
13-Mar	26753	17669	31	4,752	3794	20	24489	16673	32	53900	39278	18	10,041	8081	20	16167	12966	20
13-Apr	29995	20157	34	4,781	4288	10	23899	18768	21	51677	42965	28	9,246	8063	13	15311	13489	12
13-May	24669	15055	34	3,909	2893	26	23310	13900	40	59429	42917	27	7,965	5734	28	13936	9844	29
13-Jun	25167	17805	33	5,481	3941	28	28669	17566	39	45659	34374	17	10,051	8055	20	19865	16027	19

13-Jul	31077	21366	39	5,668	4284	24	23781	17030	28	57282	47270	28	9,490	8018	16	17072	14537	15
13-Aug	29480	20241	29	6,796	4455	34	28870	17945	38	53639	39946	25	10,008	7889	21	17650	13741	22
13-Sep	30471	21710	31	6,887	4908	29	24881	17420	30	53939	41930	17	10,114	9116	10	16007	14551	9
13-Oct	29,620	20762	31	6,601	5041	24	25,221	18104	28	59,765	47120	26	9,971	8641	13	16460	14322	13
13-Nov	27,084	19662	29	5,876	4226	28	22,771	15697	31	54,818	41833	22	9,648	7598	21	14395	11501	20
13-Dec	27263	18679	30	6,960	4734	32	24383	16188	34	54079	37717	21	10,788	7889	27	16940	12827	24
14-Jan	32724	22046	27	7,327	4998	32	27406	17625	36	58157	43784	24	11,631	9386	19	17446	14119	19
14-Feb	24165	18316	31	7,185	5484	24	19378	15158	22	48137	41094	30	9,808	8533	13	15670	13787	12
14-Mar	27207	23925	33	7,492	5850	22	26057	20972	20	54044	47539	25	10,271	9468	8	16503	14829	10
14-Apr	26560	22474	24	8,039	6184	23	25333	20844	18	52019	44769	15	10,866	9796	10	18623	16751	10
14-May	26776	19805	12	8,027	5154	36	23711	16934	29	58036	54349	12	9,077	8374	8	17477	13387	23
14-Jun	30558	22631	15	8,597	6378	26	26606	19598	26	49067	40990	14	11,038	10325	6	18861	17201	9
14-Jul	30722	23011	26	7,222	4541	37	25935	16551	36	56262	47218	6	8,032	7042	12	14377	10685	26
14-Aug	27559	20173	26	7,526	5994	20	27025	17319	36	36586	31102	16	11,397	10314	10	16875	14890	12

14-Sep	28938	17838	25	9,128	6892	24	28444	20761	27	55898	51251	16	11,725	10776	8	20402	16076	21
14-Oct	28536	17380	27	8,953	6909	23	28059	21981	22	51595	49035	15	9,822	9102	7	17380	15023	14
Nov-14	22499	15676	38	8,029	6025	25	22426	17200	23	45609	40323	8	12,895	12307	5	18830	17214	9
Dec-14	27557	19057	39	8,331	5897	29	26130	21305	18	57025	53680	5	9,664	9141	5	15992	14656	8
Jan-15	26747	15175	30	8,474	7056	17	22171	18398	17	47139	42793	12	11,888	11083	7	16291	14727	10
Feb-15	25054	17059	31	9,005	6521	28	26392	20808	21	48318	43539	6	11,720	11142	5	17038	15202	11
Mar-15	26036	16840	43	10,062	7500	25	25879	21063	19	51953	47617	9	10,995	10256	7	16122	14305	11
Apr-15	27331	18215	32	10,713	7916	26	25500	19387	24	46306	42582	10	12,086	11529	5	16429	14931	9
15-May	27554	17692	35	8,939	6160	31	24047	18202	24	50206	46790	8	10,533	9904	6	15220	13611	11
15-Jun	27600	17141	33	11,415	7523	34	25252	18174	28	45618	40422	8	11,833	10986	7	17770	16962	5
15-Jul	26078	17857	36	9,492	7497	21	25362	18406	27	49090	44947	7	11,785	11041	6	16814	15166	10
15-Aug	24915	17516	38	11,048	7012	37	24872	18413	26	48455	45178	11	10,562	9792	7	16307	14390	12
15-Sep	25251	17222	32	10,056	7568	25	25589	20020	22	53244	46979	8	14,033	13084	7	17969	16744	7
15-Oct	28977	20762	30	11,197	9153	18	27854	20438	27	55273	51819	7	14,931	14354	4	20939	19479	7

15-Nov	29871	20266	32	11,134	9098	18	30236	21648	28	61570	54892	12	12,735	12396	3	17151	15182	11
15-Dec	22567	16427	28	9,938	7057	29	24615	20357	17	53033	45859	6	11,261	10322	8	16105	15182	6
16-Jan	26320	17317	32	9,183	7391	20	24094	19984	17	46943	40453	11	13,165	12049	8	16997	14254	16
16-Feb	24116	16725	27	8,277	6202	25	23288	18933	19	51938	44413	14	11,824	10921	8	15186	13880	9