［付属資料編］

資料 1)　無収水削減年次報告書

1) -1　NON-REVENUE WATER MANAGEMENT Annual Report 2017 – 2018

MINISTRY OF WATER AND SANITATION

NON-REVENUE WATER MANAGEMENT

ANNUAL REPORT 2017/2018

FOREWORD

Water is the most important natural resource, indispensable for life and also the backbone of growth and prosperity of our country. The past performance of the water sector in Kenya has been characterized by low investment as compared to the other sectors of the economy, poor utilization of existing infrastructure coupled with bad governance and inadequate capacity in the responsible sector institutions, which resulted in inadequate access to clean portable water for all citizens of Kenya. However, there has been tremendous sector growth in the last 16 years due to the implementation of water sector reforms occasioned by Water Act 2002. The sector has put in place plans, mechanisms and projects to achieve universal access to water by the year 2030 as envisaged by the constitution, vision 2030 and Sustainable Development Goals (SDGs) number 6.

Though the implementation of the sessional paper No. 1 of 1999 on national policy in Water Resources Management and development and of the Water Act 2002, the water sector has seen improved investments and funding towards rehabilitation, augmentation and new infrastructure as well as support service provision improvements. This has necessitated interventions to ensure optimization of financing to better water services coverage which includes among other interventions, the reduction of Non-Revenue Water (NRW) to economically sustainable levels with the target being reduced from the current national average NRW ratio of 42% to 20% by 2030. This will also lead to affordable and cost-effective water tariffs that can be extended towards financing of improvements of sector efficiency as contained in provisions of the Water Act 2016.

As a sector, we are at the final stages of formulation of a new National Water policy to address the challenges the sector is still facing in the management of water resources, water harvesting and storage, water and sanitation services, training, innovation and technology, financing and investment and institutional framework among others while safeguarding the gains the sector has made so far.

Still, NRW remains a challenge that the new policy will address as the sector loses up to 8 billion annually; enough to undertake a major investment. Therefore, it is my sincere hope that this *Non-Revenue Water Management Annual Report* shall raise awareness of all stakeholders on the importance of Water Service Providers to put in place the mechanisms to reduce NRW for their sustainability and contribute to the attainment of universal access to water in Kenya by the year 2030.

Simon K. Chelugui
Cabinet Secretary
Ministry of Water & Sanitation

NON-REVENUE WATER OUTLOOK

One critical area in water service provision is the management of Non-Revenue Water (NRW) Reduction. The national level of NRW in Kenya currently stands at 42%. The sustainability and economic viability of the water utilities with high NRW levels are therefore at stake.

The water sector reforms which were initiated in 2003 after the enactment of Water Act 2002 brought a lot of improvements to the sector, however, Non-Revenue Water levels has continued to remain a big challenge against the achievement of universal access by 2030 as per Vision 2030 and Sustainable Development Goals of United Nations No. 6. A lot of revenue which could be used for investment continues to be lost annually in form of Non-Revenue Water.

This first publication of *NRW Management Annual Report* intends to provide Kenyans with brief introduction of NRW, its challenges, benefits of reducing NRW, and an overview of ongoing NRW reduction activities which are implemented by various stakeholders of Kenya's water sector.

The preliminary pages of the report highlight the current water situation in the country, the general definition of Non-Revenue Water and the national trend of Non-Revenue Water ratio in Kenya.
The publication shows the need of WSPs Managers and operational staff for commitment to manage NRW as a long-term process that incorporates numerous aspects of water operations. Addressing NRW is the responsibility of managers across the water utility, including finance and administration, production, distribution, customer service, and other departments. There is a need to understand and accurately quantify NRW as an indicator of a water utility's operating efficiency. The International Water Association (IWA) water balance is an excellent method for utility managers to break down and identify the key components of NRW.

Water Service Providers should establish NRW management teams to develop strategies is to ensure that all components of NRW are addressed, and verify that the proposed strategy is feasible and practicable in terms of the workload and budget. Choosing the right team members promotes ownership among the various utility departments involved in the strategy's implementation, and also facilitates consensus at the senior management level including the county government that are managing the devolved water services.

The publication also emphasises the need of creating awareness at all level from top decision-makers to the end consumer as critical for a successful NRW reduction programme. Support from the programme's top-level management, and the budget required, promotes the financial sustainability of the strategy. Middle level management and staff must understand their roles and responsibilities in reducing NRW, since it requires a long-term combined effort from all departments in the utility.

NRW is in general defined as **the amount of water produced for distribution but which is not accounted for as revenue.** Therefore, reducing NRW ratio benefits WSPs, customers and the society at large.

- For WSPs: utilities can increase revenue, which can enhance their financial sustainability. With more revenue, the WSPs can invest in infrastructure to improve water services.

- For customers: reduction of NRW means more water is available for distribution. WSPs can expand their service areas to more customers or hours of water supply to existing customers can be increased.
- For the society at large: Reduction of NRW means precious water resources are preserved. Industries can also benefit if the water supply is reliable and tariffs are low. Therefore, each water utility needs to ensure that NRW ratio is kept low.

Water Losses have two components:

1. **Commercial Losses (or Apparent Losses)** which are non-physical losses of water due to illegal connections (or water thefts), metering errors, meter reading inaccuracies and unmetered connections.
2. **Physical Losses (or Real Losses)** are the losses of water through leakages and/or bursts of distribution and/or services pipes, and overflows from water reservoirs.

The Ministry of Water and Sanitation (MWS) has initiated measures to address and tackle the problems of water losses and develop NRW management strategies in order to overcome the current challenges. Some of these measures are the development of National Policy on the management of Non-Revenue Water to guide the sector and the establishment of a Non-Revenue Water Unit at the national level to coordinate the implementation of the policy. The Ministry in collaboration with WASREB and JICA has also developed, issued and disseminated NRW Management Standards to be used by WSPs in addressing water losses.

Since NRW reduction requires the involvement of stakeholders at every level, the Ministry of Water and Sanitation has sensitization on NRW as one of the crucial activities of NRW Unit.

The Ministry in collaboration with KEWI has introduced NRW short courses and On Job Training (OJT) to address skill limitation in NRW reduction professionals and also capacity building of the WSPs staff.

The enthusiastic support Japanese International Cooperation Agency **(JICA)** has been giving to the Water Sector on NRW reduction is highly appreciated is also a strong indication of their commitment to partner with us to resolving the challenge conclusively.

Winnie Guchu
Chief Administrative Secretary
Ministry of Water & Sanitation

PREFACE

The water sector reforms which started in 2003 with the enactment of the Water Act of 2002 introduced great and positive fundamental transformation in the water sector. Implementation of these reforms substantially improved access to water and sanitation services in the country. It is estimated that 60% of the Kenyan people now have access to safe and reliable water.

The national goal, as envisaged in Vision 2030, is that universal access to water and sanitation should be realized by 2030 as well as the objective of the internationally accepted Sustainable Development Goal No.6. However, Non-Revenue Water (NRW) level which is currently estimated at 42% as national average remains a big challenge against the achievement of universal access for water. Revenues of Water Service Providers (WSPs) which could be used for investment continue to be lost annually due to high NRW ratio. The Water Services Regulatory Board (WASREB) estimates that the sector is losing about Kshs 7.8 billion annually because of NRW (Impact Report No. 10).

This *NRW Management Annual Report* intends to highlight the performance of the water services sector in the management of NRW reduction for the financial year 2017/2018. The report will enlighten the stakeholders and the public in general on benefit of reducing NRW ratio and the downside of high NRW levels, efforts and good practices of WSPs to reduce NRW levels.

Ministry of Water and Sanitation (MWS) has been putting measures in place to deal with the challenges of NRW. Among these measures are the development of the National Policy on Management of NRW to guide the sector and the establishment of a Non-Revenue Water Unit in the MWS to coordinate the implementation NRW reduction measures of WSPs. The implementation of the policy will require support from county governments, water sector institutions, Water Service Providers, private sector, civil society organizations and water consumers. The role of consumers is as important as the role of other actors in the water sector. If consumers say no to illegal practices like illegal connections, water thefts, doctoring of water bills, etc., the sector could achieve much progress in reducing NRW levels in a short time.

To support WSPs to address the issues of NRW, the MWS is working in collaboration with water sector institutions such as WASREB, Kenya Water Institute (KEWI), Water Service Providers Association (WASPA) and Japan International Cooperation Agency (JICA). In the specific legal context, NRW reduction can also mean reducing legal liability and complaints from the stakeholders and the public in general. I would like to reaffirm our readiness to continuously support all NRW reduction efforts at the national level to ensure that the average NRW level in Kenya will drop below the 20% benchmark.

Joseph W. Irungu, CBS
Principal Secretary
Ministry of Water & Sanitation

ACKNOWLEDGEMENTS

The completion of this report could not have been possible without the kind support and help of many individuals and organizations. I would therefore like to extend my sincere gratitude to all of them, particularly the following organizations: Water Services Regulatory Board (WASREB), Gesellschaft fur Internationale Zusammenarbeit (GIZ), Kenya Water Institute (KEWI), Water Service Providers Association (WASPA), Japanese International Co-operation Agency (JICA), Netherlands Development Organization (SNV), Vitens Evides International (VEI) for their co-operation and contribution of the information that is related with their NRW activities;

Nyeri Water & Sewerage Company (NYEWASCO) for sharing the best practices of the Non-Revenue Water reduction activities. It will provide a learning platform for the other water service providers. The nine WSPs we have been piloting with namely: Meru, Embu, Kisumu, Eldoret, Nyahururu, Mavoko, Nakuru Kilifi-Mariakani and Ruiru-Juja for their total commitment to reduce Non-Revenue Water and share their experiences with other WSPs.

Embu Water & Sanitation Company (EWASCO) and students from Kiamuringa and Iveche primary schools for providing their voices on the importance of water conservation. Our special thanks go to JICA Experts Team, “Project for Strengthening Capacity in Non- Revenue Water Reduction”, for their guidance and expertise in planning, execution and completion of this report. Surely, your support has been very essential.

Finally, not forgetting my colleagues in the Ministry (Non-Revenue Water Unit) who have devoted their time and knowledge in ensuring the successful completion of the report. The Non-Revenue Water Unit team include Eng. SAO Alima, David N. Mabonga, Anderson M. Kioi and Ms. Patricia M. Mutua who are very committed professionals.

The war on Non-Revenue Water is won by commitment, knowledge and everyone in the organization combining efforts. I urge all the Water Service Providers in the country to sustain the efforts by undertaking monthly water balance, pressure management, improve speed and quality of repair works and formulating sound strategies to reduce NRW.

God bless you all.

Eng. SAO Alima
Water Secretary
Ministry of Water & Sanitation

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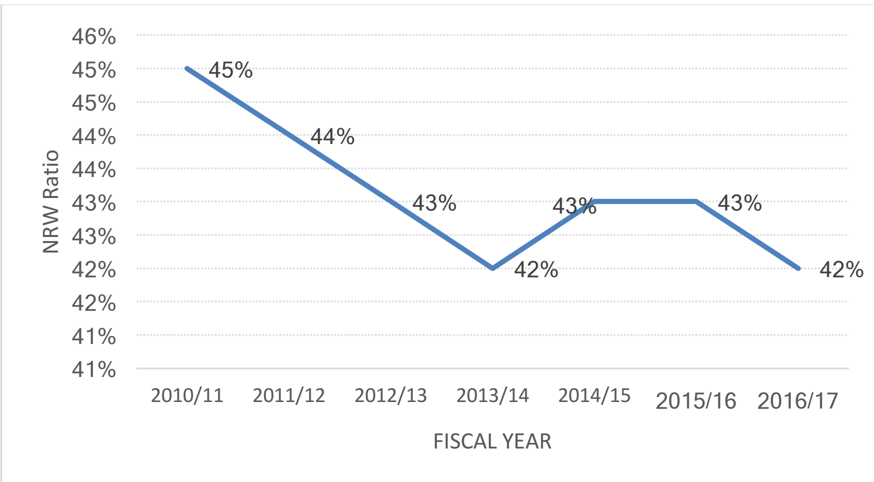
Abbreviation	**Name**
CIS	Customer Identification Survey
CoG	Council of Governors
CREWS	Climate Resilient Water Services
DMAs	District Meter Areas
EWASCO	Embu Water and Sanitation Company
GIS	Geographic Information System
GIZ	Gesellschaft für Internationale Zusammenarbeit
GoK	Government of Kenya
HDPE	High Density Polyethylene Pipe
IWA	Iinternational Water Association
JICA	Japan International Cooperation Agency
KMT	Kenya Markets Trust
KEWASCO	Kericho Water and Sewerage Company
KEWI	Kenya Water Institute
KPIs	Key Performance Indicators
MEWASS	Meru Water and Sewerage Services Company
MOWASCO	Mombasa Water Supply and Sanitation Company
NAIVAWASS	Naivasha Water and Sanitation Company
NARUWASCO	Nakuru Rural Water and Sanitation Services Company
NAWASCCO	Nakuru Water and Sanitation Services Company
NYEWASCO	Nyeri Water and Sewerage Company
MWS	Ministry of Water and Sanitation
NRW	Non-Revenue Water
ODK	Open Data Kit
PEWAK	Performance Enhancement of Water Utilities in Kenya
SDGs	Sustainable Development Goals
SNV	Netherland Development Organization
VEI	Vitens Evides International
WASH	Water, Sanitation and Hygiene
WASPA	Water Service Providers Association
WASREB	Water Services Regulatory Board

WRA	Water Resources Authority
WSB	Water Services Boards
WSP	Water Service Provider
WSTF	Water Sector Trust Fund

1 Introduction

Kenya, like the rest of the world, is becoming more water stressed. This is because of diminishing water resources as a result of population growth which is leading to the destruction of catchment areas for settlement and increased farming and industrial activities. Also, lack of efficient and effective management of water service provision can lead to scarcity of water. One critical area in water service provision is the management of Non-Revenue Water (NRW) which is in general the water loss which cannot be accounted for by the water services provider. NRW has become a major concern to the water sector in Kenya.

According to Water Services Regulatory Board (WASREB), the current Kenya's national average NRW ratio is 42%. Historically, this average NRW ratio has been declining since 2010 as shown in Figure 1. However, in recent years, the decline has stopped. Therefore, Government of Kenya (GoK) set a national target that the national average NRW ratio should be less than 20% by 2030. It is a huge challenge ahead for Kenya to reduce NRW ratio to achieve this target.



Source: WASREB, Impact Report 10

Figure 1 National Trend of NRW Ratio in Kenya

In monetary terms, considering the year 2016/17, the water service providers had a total turnover of Kshs. 20.57 billion with an average NRW loss of 42%. If the NRW ratio drops to a sector benchmark of 20%, an additional Kshs. 7.8 billion as revenue will be available for water service providers. The amount of money lost in a year due to NRW is enough to construct one

"Northern Collector Tunnel Project[1]" which costs Kshs. 6.8 billion. This should serve as a wakeup call for all the sector players. In this context the Ministry of Water and Sanitation (MWS) has initiated some measures to address and tackle the problems of water losses and develop NRW management strategies in order to overcome the current challenges.

This first *NRW Management Annual Report* intends to provide Kenyans with brief introduction of NRW, its challenges, benefits of reducing NRW, and an overview of ongoing NRW reduction activities which are implemented by various stakeholders of Kenya's water sector.

2 What is NRW?

NRW is in general defined as **the amount of water produced for distribution but which is not accounted for as revenue.**

2.1 NRW Ratio

The level of NRW is expressed as ratio (percentage). The formula for NRW ratio is defined as follows[2]:

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

Higher NRW ratio means less revenue for WSPs and less water is available for distribution to the customers. Kenya's average national NRW ratio is 42% (2016/2017). **This means WSPs only get 58% of revenue from the water they produced (100%).**

Reducing NRW ratio benefits WSPs, customers and the society at large.

- For WSPs: utilities can increase revenue, which can enhance financial sustainability of WSPs. With more revenue, the WSPs can invest in infrastructure to improve water services.
- For customers: reduction of NRW means more water is available for distribution. WSPs can expand their service areas to more customers or hours of water supply to existing customers can be increased.
- For the society at large: Reduction of NRW means precious water resources are preserved. Industries can also benefit if the water supply is reliable and tariffs are low.

[1] The Northern Collector Tunnel Phase-I is part of a master plan development strategy for new water sources for Nairobi and 13 satellite towns up to the year 2035. The project, financed by World Bank (Kshs.6.8 billion), includes construction of a 12 km long water transfer tunnel which will intercept three rivers to the north of Nairobi and transfer the intercepted water to the existing Thika Dam, the main water source for Nairobi.

[2] IN WASREB's Impact Report, System Input Volume is expressed as Total Water Production.

On the other hand, high NRW ratio adversely affects the WSPs' sustainability and economic viability. It is detrimental to the commercial viability of the WSPs as well as the safety of the water they supply. Therefore, each water utility needs to ensure that NRW ratio is kept low.

2.2 Component of NRW

The International Water Association (IWA) describes the components of NRW in Water Balance in Table 1. **System Input Volume** is the overall amount of water produced which is composed of **Authorized Consumption** and **Water Losses**.

Authorized Consumption has two components: 1. **Billed Authorized Consumption** (issued water bills); and 2. **Unbilled Authorized Consumption** (e.g. firefighting, public fountains, etc.)

Water Losses have two components: 1. **Commercial Losses (or Apparent Losses)** which are non-physical losses of water due to illegal connections (or water thefts), metering errors, meter reading inaccuracies and unmetered connections. 2. **Physical Losses (or Real Losses)** are the losses of water through leakages and/or bursts of distribution and/or services pipes, and overflows from water reservoirs. **NRW is described as**;

NRW = System Input Volume – Billed Authorized Consumption

Or

NRW = Commercial Losses + Physical Looses + Unbilled Authorised Consumption

Table 1 Components of NRW

<table>
<tr><th colspan="5">Components of NRW (Water Balance Table)</th></tr>
<tr><td rowspan="5">System Input Volume</td><td rowspan="2">Authorized Consumption</td><td colspan="2">Billed Authorized Consumption</td><td>Revenue Water</td></tr>
<tr><td colspan="2">Unbilled Authorized Consumption
(e.g. firefighting, public fountains)</td><td rowspan="4">Non-Revenue Water (NRW)</td></tr>
<tr><td rowspan="3">Water Losses</td><td rowspan="2">Commercial (Apparent)Losses</td><td>Unauthorized Consumption (e.g. Illegal connections)</td></tr>
<tr><td>Metering Inaccuracies</td></tr>
<tr><td colspan="2">Physical (Real) Losses</td></tr>
</table>

Source: IWA

IWA defines the water that are not **Authorized Consumptions** as **Water Losses.** There are two types of **Water Losses: Commercial (Apparent) Losses** and **Physical (Real) Losses.**

Commercial (Apparent) Losses are:

- **Unauthorized Consumption** such as water thefts through illegal connections and meter tampering.
- **Metering Inaccuracies** are caused by meter reading errors, failure to take meter readings, faulty or inaccurate meters, and data acquisition errors. The above inaccuracies can be caused by corrupt employees (e.g. meter readers, technicians etc.) or system errors.

Example of water theft with modified pipe to bypass the meter

Real (Physical) Losses are the losses by leakages. Leakages are caused due to:

- Aged pipes
- Using sub-standard pipes and low-quality fittings
- Destruction of water services infrastructure such as pipes due to the construction and maintenance of roads, buildings, cables and storm water drainage systems

Leakages at connections are very common

In developing countries including Kenya, the high percentage of water losses is due to **Commercial Losses** such as water thefts and inaccurate meter readings, while the majority of water losses in developed countries is **Physical Losses**. It is estimated that, on average, **Commercial Losses** in particular thefts through illegal connections account for about 40% [3] of NRW in WSPs in Kenya and around the world. Therefore, NRW reduction measures in Kenya should take serious consideration in **Commercial Losses** besides leakages.

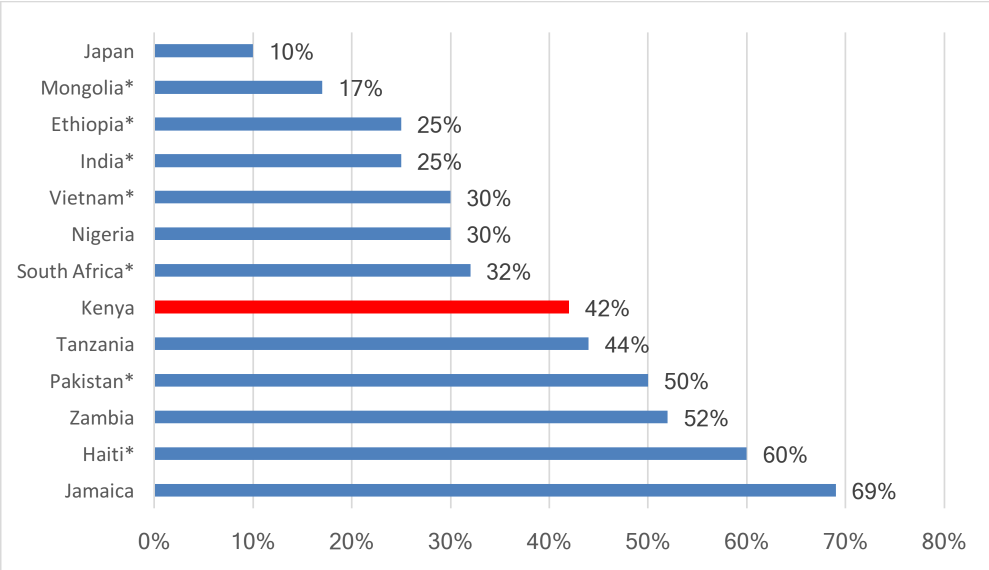
Kenya loses almost half of its drinkable water to leaks

Lost water could be used to improve access to 42 per cent of Kenyans

Source: Nation Newspaper Mar. 18, 2018

[3] The World Bank, *The Challenge of Reducing Non-Revenue Water (NRW) in Developing Countries*, Dec. 2006

Figure 2 shows the NRW ratio of selected countries. Many developed countries such as Japan have low NRW ratio.



Sources: JICA and UN GLAAS[4] 2016/2017 Survey

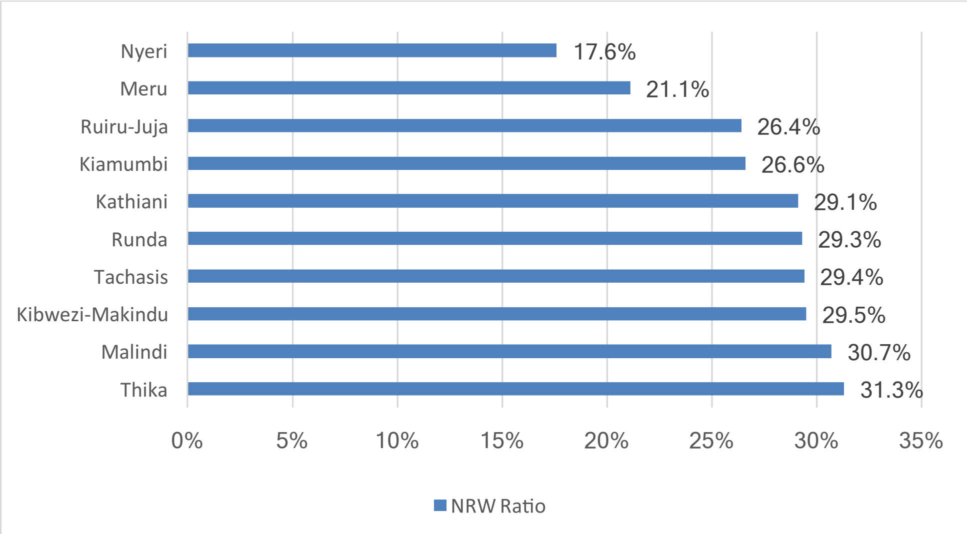
[5]*Figure 2 NRW Ratio of Selected Countries*

2.3 Monitoring of NRW Ratio

WASREB regularly monitors NRW ratio of WSPs which is included among the nine (9) Key Performance Indicators (KPIs) of WASREB's annual Impact Report. In the past few years, Nyeri Water and Sewage Company (NYEWASCO) has been showing the lowest NRW ratio. In the year 2016/2017, NYEWASCO only lost 17.6% of revenue from the produced water, while Eldama Ravine Water Company lost 74% of revenue as shown in Figure 3 and Figure 4 respectively.

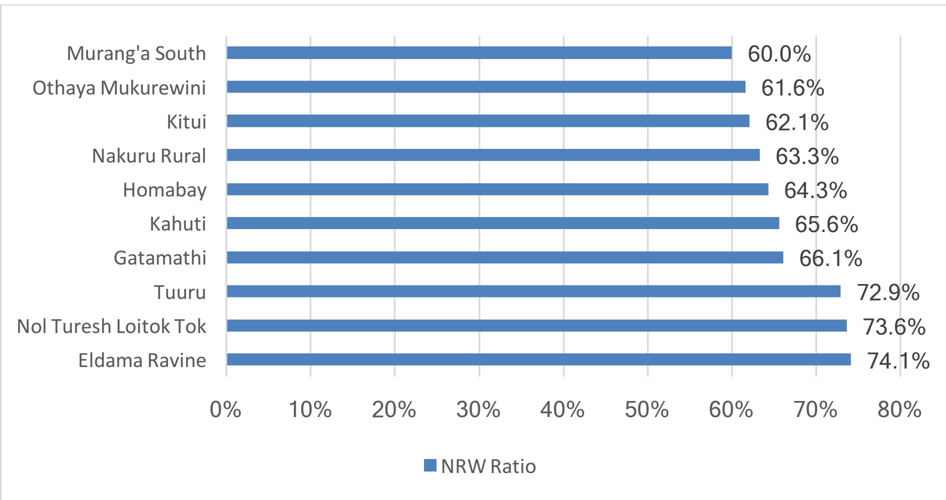
[4] UN GLAAS: United Nations Global Analysis and Assessment of Sanitation and Drinking Water

[5] Average for the most recent year (mostly 2014, 2015) with an average for 3 largest water suppliers are indicated with an asterisk*



Source: WASREB, Impact Report 10

Figure 3 Top 10 WSPs in Kenya with the Lowest NRW Ratio



Source: WASREB, Impact Report 10

Figure 4 Bottom 10 WSPs in Kenya with the Highest NRW Ratio

3 Stakeholders in NRW Reduction and Their Activities

3.1 Stakeholders in NRW Reduction

Kenya set the national target to reduce NRW ratio below 20% by year 2030. To achieve this target, various stakeholders are involved with and/or support for WSPs' NRW reduction activities. Figure 5 describes the stakeholders in NRW reduction in Kenya and their roles and ongoing activities.

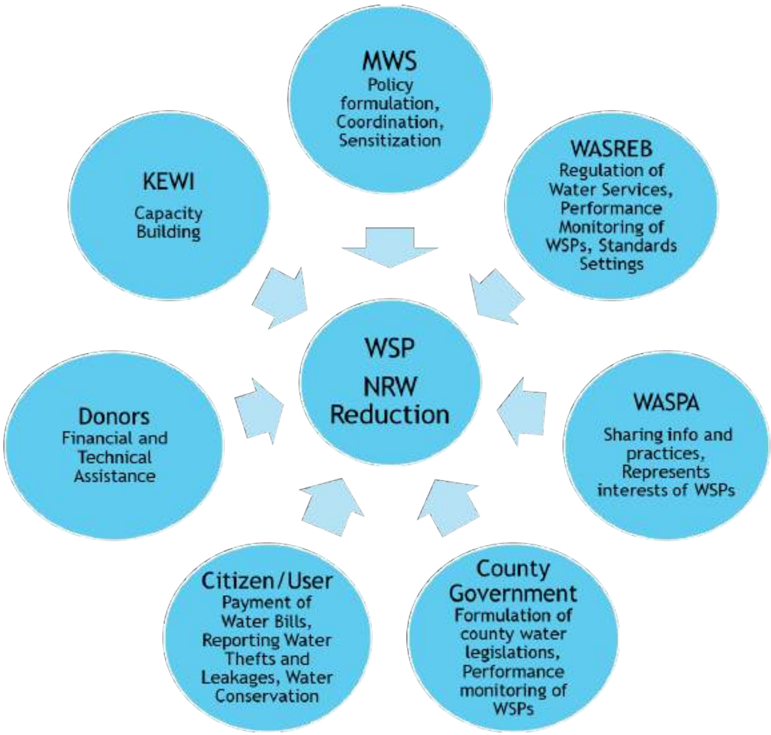


Figure 5 Stakeholders and their functions in NRW Reduction

3.2 Ministry of Water and Sanitation

At a glance:
- *Dedicated NRW Management Unit was established*
- *Formulation of National NRW Management Policy (draft)*
- *Sensitization of various stakeholders on NRW reduction*

3.2.1 NRW Unit

To accelerate nation-wide efforts to reduce NRW, MWS established Non-Revenue Water Management Unit (NRW Unit) in 2016. The mandates and responsibilities of NRW Unit are followings:

- Formulation of national policies and strategies for NRW reduction;
- Coordination of NRW reduction activities of related organizations;
- Promotion of NRW reduction activities including sensitization of County governments;
- Ensure dissemination of NRW Standards to all WSPs;
- Compile a report on the resources and other requirements needed to achieve reduction of NRW;
- Monitor levels of NRW and implement the recommendations;
- Prepare a report on NRW levels;
- Provide policy direction on NRW reduction.

3.2.2 National NRW Management Policy

MWS is formulating National NRW Management Policy to provide a policy guidance of NRW reduction at national level. As of March 2018, drafting of the Policy was at the final stage.

3.2.3 Sensitization of Various Stakeholders on NRW Reduction

Since NRW reduction requires the involvement of stakeholders at every level, sensitization on NRW is one of the crucial activities of NRW Unit. During the first Kenya Water Summit on March 1st and 2nd 2018, Eng. S.A.O Alima, Director of Water, Sewerage and Sanitation Development department of MWS gave a presentation on NRW to the representatives of County governments, WSPs, and other governmental organizations. Also, the NRW Unit organized an exhibition during World Water Day held in Taita Taveta County on March 22nd, 2018.

NRW presentation by Eng. Alima at the first Kenya Water Summit

NRW Unit staff explaining about NRW during the World Water Day in March 2018

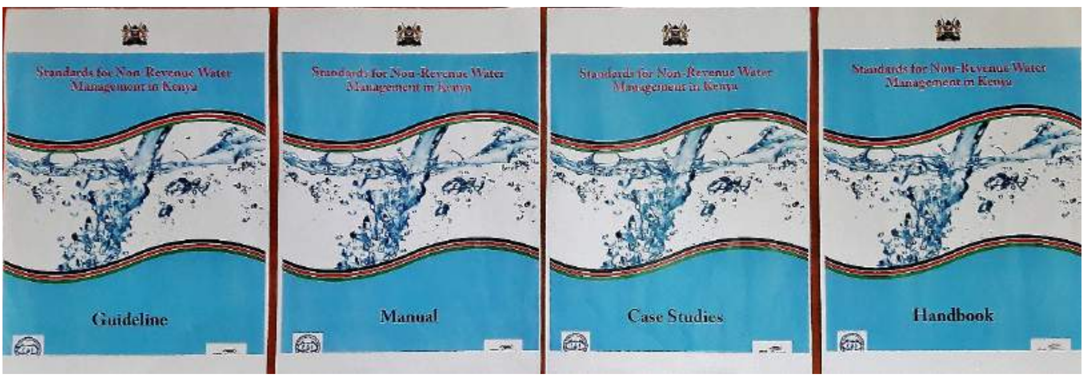
3.3 The Water Services Regulatory Board (WASREB)

At a glance:
- *Formulation of NRW Standards*
- *Monitoring of NRW ratio of WSPs*
- *Development of **Maji Voice***

The Water Services Regulatory Board (WASREB) was established in 2003 as a regulator to oversee the implementation of policies and strategies relating to the provision of water and sanitation services. To fulfil its mandates, WASREB determines, prescribes and enforces standards that guide the sector towards ensuring that consumers are protected and have access to efficient, adequate, affordable and sustainable water services.

3.3.1 NRW Reduction Framework

WASREB recognizes that the most effective means of consistently addressing water losses is through the use of a systematic NRW reduction framework that comprises of NRW self-assessment, development of NRW reduction plan and implementation of the well-defined NRW reduction strategies in the plan. Towards progressive realization of the right to water, WASREB has therefore developed, issued and disseminated NRW Management Standards to be used by WSPs in addressing water losses. If these losses are not contained, then it is a pipe dream for the consumers to have an access of their rights to water as enshrined in the Constitution of Kenya and also as demanded by Sustainable Development Goals (SDGs) of universal access to water services by 2030.



NRW Management Standards 2014

3.3.2 Engagement of County Governments in NRW Reduction

As a regulator, WASREB continuously monitors implementation of the NRW reduction activities by WSPs over time and guides those facing challenges in their implementation. To complement this effort, WASREB calls upon the County governments to pay special attentions to water losses in their respective WSPs. In addition, the County governments can assist their WSPs a great deal by passing County water legislations that explicitly incriminate all possible illegal water malpractices for prosecution of any involvement by anybody, staff and customers.

3.3.3 Licensing and Tariff Approvals Linked to NRW Activities of WSPs

WASREB considers NRW reduction management as a priority area in WSPs therefore it imposes stringent conditions and targets in both the licensing and tariff approvals to the WSPs. Specifically, in the tariff approval, WASREB allows for justified and acceptable resources directly meant to address NRW reduction activities.

3.3.4 Customer Sensitization and Communication through *Maji Voice*

WASREB also advocates for sensitization of all customers across the respective WSPs to be aware of existence of such laws that criminalize illegal water activities. It is the duty of all customers to assist the direct water players in containing the water losses. Failure to do this means the likelihoods of lacking access for water services become frequent, thus bring negative impacts on the standards of dignified living. WASREB is therefore encouraging all customers to always report any illegal water activities that they encounter to their respective WSPs for immediate action. To facilitate this, the customers are encouraged to obtain customer care contacts of their respective WSPs either from the website, during open day clinics or other publicities of the same.

To improve communication between customers and WSPs, WASREB developed ***Maji Voice***, an IT based platform that enables two-way communication between the customers and WSPs via text messages (SMS) and/or via the internet.

By using ***Maji Voice***, consumers of participating WSPs can provide feedback their respective WSPs on related to service delivery including issues of access, tariffs, service provider performance, responsiveness, quality of service, resolution of complaints, and others. It uses affordable, accessible and user-friendly technologies as an alternative to other tedious and often time-consuming processes of lodging complaints with service providers. It also strengthens the capacity of consumers and Water Action Groups to participate in improving the performance of their WSPs.

Table 2 List of Water Service Providers Participating to Maji Voice

Water Service Provider	Contact
Embu Water & Sanitation Company Limited	0729126908
Eldoret Water & Sewerage Company Limited	0724255538
Kisumu Water & Sewerage Company	0572024100
Mathira Water & Sanitation Company Ltd	0716802664/0773855003
Murang'a Water and Sanitation Company	0716645345
Mombasa Water and Sanitation Company	0714906091
Nairobi City Water & Sewerage Company	07425382/0702206328/0702206459/0702 205964

Nakuru Water	0774389372/0791389372
Nanyuki Water and Sewerage Company	0800721101/0716136559/0734810463
Nyahururu Water & Sanitation Company Ltd	065-2032774/0728348312
Nyeri Water & Sewerage Company	0734732481
Othaya Mukurweini Water Services Company Limited	0702598602/0791574554
Thika Water and Sewerage Company	0720418444

Source: WASREB

How to use *Maji Voice*

1. **SMS to 15444**. **WATERCOMPANY#your message**
2. Go to www.majivoice.com. Click on the first link titled 'Your Feedback/Complaint' and follow the simple instructions.

3.3.5 Conclusion

WASREB has established the NRW Management Standards in 2014. However, the uptake and implementation of NRW Management Standards have been significantly low. Some basic fundamentals like establishing a dedicated team for NRW reduction activities, resourcing them consistently with competent skills, equipment, facilitation and management goodwill among others, have not been undertaken in many WSPs.
The use of the appropriate meters, pipes and fittings materials remains a thorny issue. Functionality of the meters is also a major issue to be resolved, instead of using estimated water volumes that lack empirical data. Water service providers must ensure that procurements of meters, pipes and fittings is based on the correct specification and they must confirm their quality at the time of delivery.
Further WSPs must improve on workmanship during installation of the meters, pipes and fittings by ensuring that only competent artisans are allowed to undertake such works. Practical training is therefore imperative as one measure of overcoming this endemic challenge. Therefore, WSPs are encouraged to get into partnership with Kenya Water Institute (KEWI) for building their capacity to manage NRW.

As the Regulator, WASREB is convinced that the solution to the NRW challenge lies with the direct players in the sector and more so in its governance. To support WSPs on its management, WASREB has developed *Corporate Governance Guidelines for the Water Service Sector.*

3.4 Kenya Water Institute (KEWI)

At a glance:

- Offers tailor-made short course on NRW to including theoretical trainings and On-the-Job field trainings

KEWI was established by an Act of Parliament, KEWI Act 2001, with the mandate to provide directly or in collaboration with other institutions of higher learning services, trainings, consultancy, research and development, seminars and workshops in the water sector on a commercial basis and awards diplomas and certificates to successful candidates. KEWI's vision is to become "A World Class Centre of Excellence in Training, Research and Consultancy in the Water Sector". Its mission is to offer competency-based training, research, consultancy and outreach services in the water sector for Sustainable Development.

3.4.1 KEWI's NRW Courses

One of the KEWI's efforts towards achieving its mission is to build capacity of personnel of WSPs in NRW reduction. As a higher learning institution, KEWI offers the following courses that are related with NRW management.

Regular Courses

- Diploma and Certificate in Water Engineering
- Water Operator's Course in Meter Readings

Short Courses

- Non-Revenue Water Reduction
- Flow Measurements
- GIS for Water facilities
- Leak Detection and Use of NRW Investigation Equipment
- Plumbing and Pipe Fitting
- Meter Installation Servicing and Service Connections
- Meter Reading and Billing
- Operation and Maintenance of Water Reticulation Systems
- Customer Care and Public Relations

3.4.2 Collaboration with JICA

KEWI is a counterpart institution implementing Japan International Cooperation Agency **(JICA)**'s 'Project for Strengthening capacity in Non-Revenue Water reduction in Kenya'. Through the Project, KEWI, in collaboration with Embu Water and Sanitation Company (EWASCO) and Meru Water and Sewerage Services Company (MEWASS), has reviewed its short course on NRW reduction to include On-the-Job field trainings to increase the practical skills and technologies necessary for the NRW reduction. The field trainings include the use of NRW investigation equipment, flow measurements, pressure management and data collection. After the pilot trainings, KEWI had conducted tracer studies of NRW reduction course participants and the findings from the tracer studies will be incorporated in the revised NRW course contents.

KEWI through assistance of development partners mainly French Development Cooperation, Gesellschaft für Internationale Zusammenarbeit (GIZ) and Japan International Cooperation Agency **(JICA)** has invested in a water distribution training platform that can be used to simulate NRW reduction activities including pipe tracing, flow measurements, water meter testing, leak detection and pressure logging.

3.5 Water Service Providers Association (WASPA)

At a glance:

- Advocating for stiffer penalties for water theft
- Developing technical guidelines for critical equipment
- Peer-to-peer Learning Program in place (WASPA benchmark program)

Water Service Providers Association (WASPA) was established in 2002 to support WSPs to achieve their mandate under the Water Act 2002. The Association is registered under the Societies Act (Cap 108) of the Laws of Kenya. With the mandate being to provide a platform for members to advocate for issues pertaining to their development and sustainability, the membership continues to grow and stands at 76 organizations and individuals, with 67 of them being WSPs.

3.5.1 Penalty Program against Water Theft

NRW largely occurs due to water theft, pipe bursts along the network among others. The Association is currently advocating for stiffer penalties for water theft especially through illegal connections, non-payment of bills and ordinary wastages. Consumers must champion water conservation in the wake of enduring water scarcity. Water consumed and not paid for is a major challenge to the sustainability of WSPs since WSPs do not recover its operational costs.

3.5.2 Lifting up the Technical Levels of NRW Reduction

Several measures are being undertaken to address the challenges of NRW. The Association, in conjunction with WASREB, have developed standards for critical equipment in use in water and sewerage supply. Developed guidelines such as ***Technical Guidelines for Water Meter (Management) in Kenya*** inform purchase, installation, maintenance and disposal of meters, pumps, valves and pipes. These standards are continuously revised to adapt to the changing international best practices.

In addition, the Association has acquired modern equipment that WSPs can affordably hire for certain periods to conduct tests and measurements to determine NRW levels. These include portable ultrasonic flow meters, portable meter testing devices, portable pressure loggers, leak noise correlators and ground microphone, metallic & non-metallic pipe locators, ultrasonic thickness gauge among others. Technical personnel are also available to work with utilities where necessary.

Field demonstrations and trainings are regularly conducted: bringing together WSP operators such as plumbers, artisans and other field staff to learn about modern techniques to combat water losses. In these trainings, the Association ensures suppliers (and manufacturers) of such equipment build capacity of operators of WSPs.

A technician testing the accuracy of consumer meters

3.5.3 Peer-to-peer Learning Program

The Association also anchors WSPs led peer-to-peer learning (commonly referred to as WASPA benchmark program) that enables WSPs to assess their performances on a set of Key Performance Indicators (KPIs). Observed trends in the KPIs assist WSPs to interrogate peers on the emerging leading practices which are then translated into yearly performance improvement plans of each WSP. The benchmark program also awards innovative and best improved WSPs through criteria geared to inspire competition in service delivery as well as reduced wastages.

3.6 Gesellschaft für Internationale Zusammenarbeit (GIZ)

At a glance:

- Multilevel NRW approach from national to WSP level
- Separation of service areas in order to reduce the problems to a manageable size (creation of DMAs)
- Identification of types and causes of water losses
- Introducing advanced IT management systems to manage NRW

GIZ Water Sector Reform Programme (WSRP) in Kenya provides technical assistance to the Kenyan water sector institutions as part of the German Development Cooperation to Kenya. The objective of WSRP is to improve pro-poor governance of urban drinking water supply and sanitation, including water resources management. The lead executing agency is the MWS. The partners comprise managers and experts from MWS, WASREB, Water Sector Trust Fund (WSTF), Water Resources Authority (WRA), the County of Kericho, and selected water service providers as Kericho Water and Sewerage Company (KEWASCO) and Oloolaiser Water and Sewerage Company.

3.6.1 GIZ Support to Reduce Water Losses

The high level of NRW in the Kenyan water sector is a threat for sustainable service delivery thus for the progressive realization of the human right to water. With a multilevel approach, GIZ seeks to support its partners in the field of policy formulation, regulations, financing and service provision to contribute to the sectors key target which is universal access of water. Specific support to each partner organization is:

- MWS to develop policy guidelines on management and reduction of NRW
- WASREB to monitor compliance to standards including NRW and to report to the public
- WASPA to share NRW related best practices and knowledge within the sector
- KEWASCO and Oloolaiser to develop structures and processes in order to manage NRW.

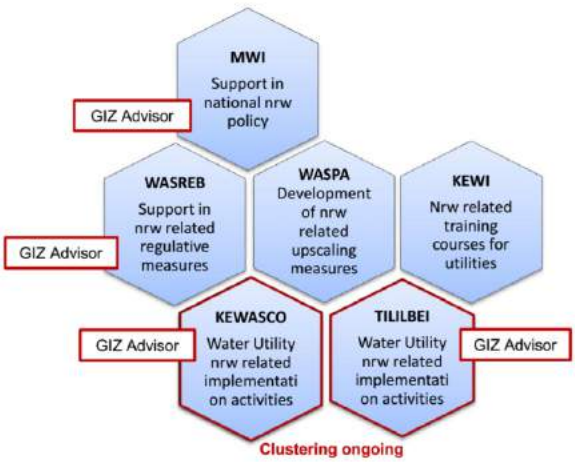


Figure 6 GIZ multilevel NRW approach and staff input of fiscal year 2016/17

3.6.2 Roadmap to Reduce Water Losses in Kericho County

Since 2011, GIZ has been supporting KEWASCO in improving its effective and efficient service delivery. In 2015, GIZ entered into a new cooperation with Kericho County to support its new mandate under the Water Act 2016 and to merge the two water companies in Kericho County. The guiding principle of the GIZ intervention in NRW related activities on WSP level is ***"A service area of a WSP is separated into areas in order to reduce the problems to a size which is manageable".***

The main focus of GIZ's support to reduce NRW in Kericho therefore comprises:

- Improve availability of data for decision making and implementation of IT-based management systems (new billing system etc.)
- Geo-referencing of the service area and the infrastructure by using Geographic Information System (GIS)
- Development of a strategy to reduce NRW and implementation of roadmap
- Alignment of organizational structure and processes
- Creation of District Meter Areas (DMAs)
- Identification of key mitigation measures per DMA

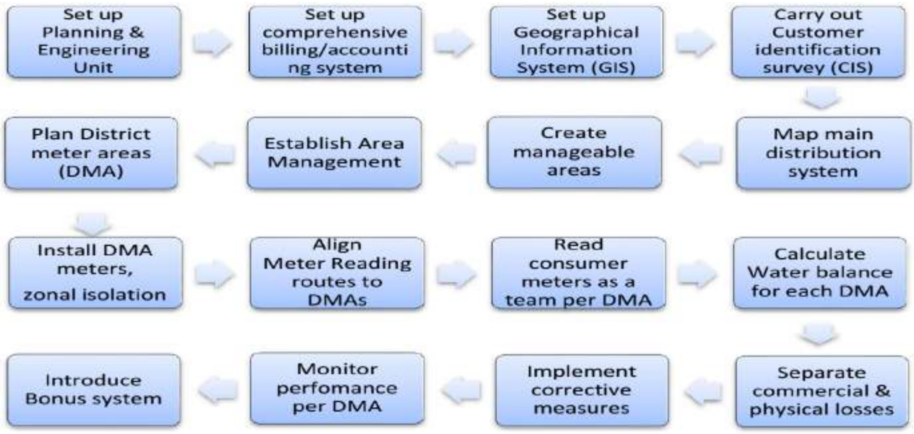


Figure 7 NRW roadmap of GIZ applied at KEWASCO

3.6.3 DMA to Manage NRW at KEWASCO

In the last fiscal year, KEWASCO and GIZ have focused on setting up a pilot area with 4,045 connections. This is approximately quarter (1/4) of the total customers' records of KEWASCO. The pilot area has been further divided into 7 DMAs.

The DMAs have been equipped with master meters to monitor the in- and outflow of each isolated DMA. The customer meter reading sheets were aligned to the DMAs. NRW is identified on a monthly basis after each meter reading cycle. All meters within one DMA are read in the same day.

Table 3: Snapshot of NRW ratio for Pilot Area C at KEWASCO for May & June 2017

MONTHLY READINGS		**May-17**	**Jun-17**	**Jul-17**	**Aug-17**	**Sept-17**
ID	**DMA**	**in m3**	**In m3**	**in m3**	**in m3**	**in m3**
C1.3	Kaptebeswe	517650	528884	546455	564837	580770
	Kakiptui	57860	66239	79833	94384	107669
Date of reading:		16/05/17	13/06/17	14/07/17	15/08/17	
No of customers readings		380	382	380	385	
Total Water supplied in		5125	11234	17571	18382	15933
Total Water supplied out		1372	8379	13594	14551	13285
Water Available for sale		3753	2855	3977	3831	2648
Total Water Billed (m3)		738	1,084	1533	1673	1509
Volume losses in (m3)		4,387	1,771	2,444	2,158.00	1,139.00
NRW (%)		**85.60%**	**62.03%**	**61.45%**	**56.33%**	**43.01%**

The monthly NRW monitoring shows that the WSP is still working on stabilizing its activities. It also indicates the complexity of dividing the supply networks into manageable areas. The most time consuming sub-activities of figure 7 are hereby:

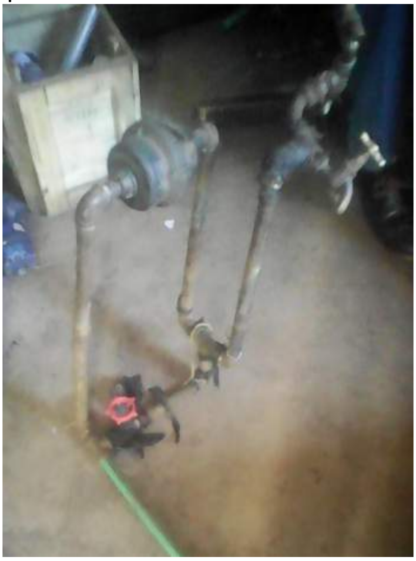
- Mapping of main distribution system
- Installation of DMA meters
- Alignment of old meter reading routes in the billing system to the required DMA meter reading routes in the field
- Separation of commercial and physical losses
- Implementation of mitigation measures such as leak detection, meter calibration, identification of customers not billed, cut off exercises etc.

3.6.4 Separation of Commercial and Physical Losses

Physical: The pilot team is focusing on identifying the minimum night flows to estimate the physical losses per DMA. In addition to the daily use of mobile ultrasonic flow measuring devices, KEWASCO is supported by GIZ, Performance Enhancement of WSPs in Kenya (PEWAK) and UPANDE in the setup of permanently installed flow sensors at all master meter locations which shall report the daily flows into the DMAs to a dashboard for further analysis and action.

Left - typical flow sensor and data logger installation at KEWASCO, right- set up of ultrasonic flow measurement device

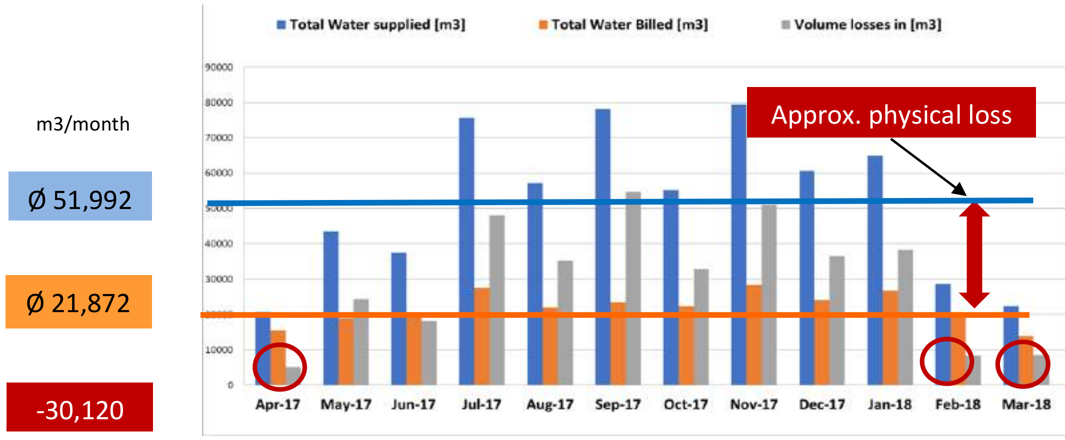
Commercial: A monthly anomaly report of the pilot area C supports KEWASCO to follow up on all types of anomalies and specifically on illegal connections which are mostly found at disconnected customers. The Managing Director of KEWASCO has established a special process for dealing with defaulters in all supply areas. Through this process, Illegal connections are documented and immediately processed.



Illegally bypassed meter discovered by KEWASCO

3.6.5 Results of Pilot Area

The results of one year operation of the DMAs in the pilot area at KEWASCO show that the physical losses are the driving factor of a high NRW rate at KEWASCO, specifically in the pilot area. After the customer database had been cleaned up through a Customer Identification Survey (CIS) and the use of a new meter reading team, the billed water volume has been stable for the pilot area throughout the year. Rationing of water during the dry season leads to a dramatic drop down of the NRW rate and the high night flows into the area during rainy season lead to the conclusion that mostly the physical losses contribute to the high NRW rate. The separation of the pilot area allows the KEWASCO team to focus on the hotspots. Various bottlenecks have been identified where the entire network has to be replaced. The preferred mitigation measure is the replacement of old pipes with the use of High Density Polyethylene Pipe (HDPD) pipes of PN 16 and the installation of pressure reducing valves. The intervention requires substantial investments which cannot be raised by the company alone. KEWASCO is therefore including the replacement exercises in the strategic plan to sort for external funding.



Area C	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18
Total Volume of water billed (m3)	15,519	19,028	19,380	27,598	21,974	23,421	22,359	28,273	24,098	26,663	20,222	13,929
Total Volume of waterproduced (m3)	20,648.00	43470	37463	75758	57139	78193	55282	79352	60554	65013	28637	22389
Volume losses in (m3)	5,129.00	24,442	18,083	48,160	35,165	54,772	32,923	51,079	36,456	38,350	8,415	8,460
NRW (%)	**24.84%**	**56.23%**	**48.27%**	**63.57%**	**61.54%**	**70.05%**	**59.55%**	**64.37%**	**60.20%**	**58.99%**	**29.39%**	**37.79%**

Figure 8 Overview Water Balance of Pilot Area C in KEWASCO

3.6.6 Conclusion

The positive impact of NRW strategies cannot be expected within a very short period due to the complexity of the task. The efforts of GIZ and other partners is preliminary focusing on breaking down the problem to a manageable size and identify the appropriate mitigation measures. The NRW roadmap developed by GIZ in Kericho 2012 needs further fine-tuning and a strong national support for upscaling.

3.7 Japan International Cooperation Agency (JICA)

At a glance:

- Work flow approach to establish effective NRW reduction activities in the entire service area of WSP
- Creating enabling environment for NRW reduction at national level
- Developing NRW training program that caters the needs of WSPs

Japan International Cooperation Agency (JICA) is Japan's development agency that aims to promote international cooperation through growth and development in the world by using Japan's experience and expertise. JICA has been supporting Kenya's water sector since the 1970s. Through "The Project for Management of Non-Revenue Water in Kenya" (2010-2014), JICA supported a creation of **NRW Management Standards** through WASREB and established NRW short courses at KEWI.

3.7.1 Project for Strengthening Capacity in Non-Revenue Water Reduction

Since October 2016, JICA has been implementing five-year project called "Project for Strengthening Capacity in Non-Revenue Water Reduction". The Project aims at enhancing NRW reduction activities among WSPs by establishing the NRW reduction support mechanism and technical standards in Kenya. In this Project, JICA works with the MWS, WASREB, KEWI, WASPA, and nine (9) pilot WSPs [6](Embu, Meru, Eldoret, Kisumu, Nakuru, Nyahururu, Mavoko, Ruiru-Juja, Kilifi-Mariakani) to achieve the following Project Purpose and Outputs.

Table 4 Strengthening Capacity of NRW Reduction Project Framework

Item	Description
Project Purpose	An NRW reduction support mechanism is established for WSPs to implement NRW reduction activities.
Project Outputs	1: Promotion and coordination of NRW reduction activities by MWI NRW Unit are strengthened.
	2: Use of NRW reduction standards by WSPs is promoted by WASREB.
	3: NRW related training capacity of KEWI is strengthened.
	4: NRW planning and/or implementation capacity of pilot WSPs is enhanced.
	5: Experience and knowledge of NRW reduction activities are shared among WSPs.

Source: JICA

At the inception stage of the Project, a baseline survey was conducted to assess the capacity and current situation of the counterpart organizations. Based on the results of baseline survey, 9 Pilot WSPs were selected from each area within the jurisdiction the seven Water Service Boards (WSBs) countrywide.

3.7.2 Introduction of Work Flow Approach to NRW Reduction

The JICA Experts are assisting pilot WSPs to formulate annual NRW reduction plans and to enhance technical and managerial skills for NRW reduction. Based on the existing data and information, and through consultation with the JICA Experts, Embu Water and Sanitation Company (EWASCO) and Meru Water and Sewerage Services Company (MEWASS) formulated their NRW reduction plans. To increase the efficiency of NRW management, the work flow approach was introduced. With this approach, pilot WSPs prioritized to implement easy and highly effective NRW reduction activities and avoid activities that may cause delay such as large infrastructure construction. Multiple NRW reduction activities are carried out simultaneously and these activities cover the entire service area rather than selected DMAs only. The information and data collected from the activities were stored by using Open Data Kit (ODK), an online-based application. By using ODK, data in the field are updated in real time and shared among the officers and technicians involved in NRW reduction. The results of activities will be analysed and reflected on the following year's NRW reduction plan to increase the effectiveness of the NRW reduction activities. The experiences and lessons learnt from the pilot WSPs will be shared among other WSPs.

[6] Among 9 pilot WSPs selected, Embu WSP (EWASCO) and Meru WSP (MEWASS) are positioned as leading WSPs.

3.7.3 Building Enabling Environment for NRW Reduction

The Project also supports the newly established NRW Unit of MWS to fulfil their mandates such as coordination of NRW reduction activities at national level; promotion and sensitization on NRW reduction activities; preparation of NRW Annual Management Report, etc. During the first Kenya Water Summit held on 1st and 2nd March 2018, NRW was presented as one of the urgent issues of Kenya's water service sector. In addition, the NRW Unit has been assisting WSPs with the implementation of NRW sensitization activities.

NRW Management Standards, issued by WASREB in 2014, are consisting of a Guidelines, Manual, Handbook and Case Studies, and aimed at providing a practical approach for NRW reduction to WSPs. These documents were disseminated to the water sector stakeholders. In this Project, WASREB will be reviewing the states of usage of NRW Standards by WSPs. Based on the review, WASREB may revise the NRW Standards to make them more effective and user friendly.

JICA is supporting KEWI to improve their NRW short courses. At the initial stage, the NRW courses and teaching materials were reviewed. Based on the review, KEWI organized a NRW joint training course in conjunction with EWASCO and MEWASS. The joint training consists of a 5-day theoretical training and a 5-day field-based practical training. Many participants of the joint training expressed their appreciations for the training contents and materials provided. KEWI will continue tracing the participants in order to monitor the progress that they are making in NRW reduction at their work places. KEWI will continue conducting joint trainings and the evaluation of each training will be reflected upon their course contents to make their trainings more effective to NRW reduction of WSPs.

KEWI's NRW Joint Trainings

3.8 Netherlands Development Organization (SNV)

At a glance:

- Climate Resilient Water Services (CREWS) supports 9 WSPs to reduce their NRW and improve operational efficiencies.
- Addressing NRW related issues by using a participatory approach, benchmarking best practices, integration of GIS in management that can reduce the NRW within identified DMAs.

Netherlands Development Organization (SNV) is an international development organization that delivers capacity development advisory services to over 2,000 clients in developing countries of Africa, Asia, Latin America and the Balkans. SNV's current focus is in 3 key sectors namely Water, Sanitation and Hygiene (WASH); Agriculture; and Renewable Energy. In WASH, SNV aims to impact the lives of under-served communities in rural, peri-urban, and small towns to improve their health and well-being through our contribution to (1) adequate and sustainable access to safe, sufficient, and reliable drinking water; (2) access to improved sanitation and; (3) sustained hygiene behaviour change as part of their daily lives.

In 2014, WASREB developed NRW Reduction Management Standards, consist of a Manual, Guideline, Handbook and Case study that provides WSPs with a practical approach to reduction of NRW in Kenya. However, WSPs are still faced with significant challenges related to investment, infrastructure and operation management that hamper efficient service delivery. In one of the 9 Key Performance Indicators (KPIs), WASREB monitors WSPs' performance of NRW loss levels and estimates the annual average NRW at 43%, which is equivalent to an annual revenue loss in excess of USD 100 Million. WSPs are still faced with challenges on issues around infrastructure management, accurate customer metering, consumer engagement and downward accountability, technology utilisation and staff awareness on contributors of NRW and its implications on the overall performance.

3.8.1 Climate Resilient Water Services (CREWS)

One of SNV's programmes - Climate Resilient Water Services (CREWS) in partnership with Kenya Markets Trust (KMT) has an intervention that focuses on addressing NRW management in urban water service providers. This intervention is geared towards transformational change in the Kenyan water sector by contributing to the reduction of NRW from 44% to 38% within 3 years. CREWS supports selected water service providers to reduce their NRW and improve operational efficiencies and subsequently increase their revenues. SNV supports 9 WSPs – (Tavevo, Nakuru-Rural, Isiolo, Nanyuki, Malindi, Homabay, Kakamega, Thika and Gatamathi) to develop NRW strategies in line with WASREB - NRW Standards, identify DMAs and implement the NRW strategies through conventional approaches.

In CREWS, SNV focuses on the physical losses – pipe bursts and leaks, and commercial losses associated with billing, illegal connections and poor data management within these 9 WSPs. WSPs across the country sometimes lack the technical expertise: issues to do with procurement of quality equipment and proper installation of various infrastructure. Low quality meters, pipes, fittings and poor installation with disregard to system pressures and other implementation factors resulting in physical losses of entire system. Majority of WSPs currently have advanced software for dealing with their data but these same software results in losses in revenue if data is not well managed. SNV assists these 9 WSPs to address those issues by using a participatory approach of actively involving their staff in benchmarking best practices, including integration of GIS in management, that reduce NRW within identified DMAs. SNV's main objective is to build on the successes of these 9 WSPs and replicate best practices of NRW management to the remaining Kenyan water sector.

Installation of leakage detection equipment

3.9 Vitens Evides International (VEI)

At a glance:

- *Supporting water companies to expand their service capability and to professionalise their operations to reduce NRW*
- *Focuses on peer-to-peer learning and sharing of best practices on NRW reduction, cost recovery, service levels and pro-poor services*
- *PEWAK project includes NRW investments at 10 WSPs*

Vitens Evides International (VEI) is an international water operator from the Netherlands, supporting water companies to expand their service capability and to professionalise their operations, amongst other things by improving NRW management and water supply operations. VEI currently works with 12 WSPs in Kenya through Water Operator Partnerships (WOPs). There are four projects ongoing: PEWAK, WOP in Naivasha, WOP in Mombasa, and Nakuru County Sanitation Program (NCSP) which is focused on demonstrating and upscaling an innovative sanitation value chain for the peri-urban low-income areas in Nakuru County. The other three projects have a main focus on improving the performance of the WSPs through NRW reduction.

3.9.1 Performance Enhancement of Water utilities in Kenya (PEWAK)

"Performance Enhancement of Water utilities in Kenya" project, in short PEWAK, is a five-year project co-funded by the Dutch Sustainable Water Fund (2015-2019). It includes technical assistance of Aquanet, VEI, SNV and UNESCO-IHE on the benchmark of WSPs hosted by WASPA. This benchmark facilitates peer-to-peer learning and sharing of best practices on NRW reduction, cost recovery, service levels and pro-poor services. The PEWAK project includes NRW investments at 10 WSPs where the best practices in NRW reduction are demonstrated. The 10 WSPs are: Bomet, Kakamega, Kericho, Kikuyu, Kisumu, Malindi, Mathira, Murang'a, Nakuru, Nakuru Rural. The target is to bring NRW ratio down to the national benchmark of 25%. This is achieved through the introduction of blended (commercial) finance for NRW investments and implementation of WASPA's NRW Roadmap. VEI further supports the above WSPs on the development of strategies for pro-poor water supply in low income areas and increased access to water for an additional 100,000 people.

3.9.2 Water Operators Partnership in Naivasha

VEI has a Water Operator Partnership with Naivasha Water and Sanitation Company (NAIVAWASS) to improve the provision of water and sanitation services to all residents of Naivasha sub-county, funded by the Netherland Embassy (2012-2018). With support of SNV and VEI, the company has increased the access to sustainable water supply services, through: increased consumer dialogue to develop and implement a consumer communication plan; a consumer feedback mechanism, and a complaints register; development and implementation of a water production improvement plan; establishment of new connections; increased revenue by improving billing, revenue collection and dis/re-connection; and reduced NRW by implementing caretaker approach for NRW reduction.

3.9.3 Water Operators Partnership in Mombasa

The overall objective of VEI's WOP with MOWASSCO is to improve the provision of water services to the residents of Mombasa County. The partnership has a special focus on reduction of the level of NRW experienced by MOWASSCO through activities that will improve the water absorptive capacity of its water supply distribution system, and strengthen its institutional capacity, in view of the anticipated increase in water availability upon completion of the Mwache Dam scheme. The project (2012-2018) has been funded primarily by the Netherlands Embassy in Nairobi and VEI's own resources. Efforts are given to enhance water sales by reduction of NRW through management turnaround, regular monitoring of performance indicators, introduction of DMAs, and optimization of the application by MOWASSCO of GIS software to map information provided by the MFA meter reading and EDAMS billing systems in order to identify and prioritize measures aimed at minimization of commercial losses.

3.9.4 Water WorX

In the second half of 2018, the Nakuru County WaterWorX project will commence. This project aims to further increase sustainable access to water and sanitation in Nakuru County by strengthening the three WSPs: Nakuru Water and Sanitation Services Company (NAWASSCO), Nakuru Rural Water and Sanitation Services Company (NARUWASCO) and NAIVAWASS.

NRW field training in Nakuru County

4 Interview with a NRW Management Champion

Mr. Peter Gichaga, Managing Director of NYEWASCO

While NRW is a challenge to the sustainability of water services in Kenya, some organizations and companies are demonstrating success in NRW reduction. In this corner, we highlight the success of such an organization or company by interviewing the key person of the organization.

Nyeri Water and Sewage Company Limited (NYEWASCO) has been successfully reducing NRW since late 90s. The NRW ratio of NYEWASCO marked 17.6% in 2016/2017 (Impact Report No. 10, WASREB), the lowest in the county and one of the only two WSPs that achieved the national benchmark of 25% set by WASREB. Not only NRW ratio, NYEWASCO has maintained the number one position in overall for Key Performance Indicators of WASREB since 3rd Impact Report (2008/2009). The interviewer asked Mr. Peter Gichaga, Managing Director of NYEWASCO, about the company's key ingredients for success in lowering the NRW ratio.

Interviewer: *Currently what is your NRW ratio and when was it the highest?*

MD. Gichaga: *It is now at 14.84%. In 1997 when it was the highest, the NRW ratio was 50%. It then dropped to 43.5 % between 2006 to 2007 after the completion of the Nyeri water extension project, which focused on improving the capacity of the distribution systems.*

Interviewer: *It is a general belief that there is a lot of water in Nyeri, do you actually tell people to save water?*

MD. Gichaga*: Nyeri itself doesn't have a lot of water as it is perceived, so we do lots of sensitization to the customers on the water savings. We have put in place public sensitization programs / forums like sensitization on NRW in our vernacular radio stations. We organize an Open Day on every 22nd of March (World Water Day), when all our customers can visit our company, our water and sewerage treatment works and talk on water conservation issues with our staff. We usually hold an Annual Stakeholders' Forum and report our performances every year. Also, we participate in Central Kenya Agricultural Shows where we exhibit our best practices.*

Interviewer: *How do you deal with your commercial and physical losses?*

MD. Gichaga*: On commercial losses, we put efforts on customer sensitizations. We regularly check and calibrate meters. Once there is a complaint from the customer, we test meters so the customer get satisfaction in case of doubt. We conduct regular staff refresher courses and use of Android technology. Our Customer Care Unit upgraded the system of customer complain. Now we use Maji Voice. Customers can file complains through Maji Voice so they can track the process of complaints. We try that information to the public is transparent.*

On Technical losses, we have a NRW Unit with qualified technicians to detect leaks. We compare the records of meter readers with that of customers' readings. We conduct minimum night flow measurement in all of 41 DMAs.

Interviewer: *How do you deal with your water pressures?*

MD. Gichaga: *Across DMAs, we check the high-pressure areas and put pressure reducing valves. We are also replacing aged water pipes, 70% of pipes were replaced now with HDPE pipes.*

Interviewer: *After the reduction of NRW ratio, what are the benefit of the reduction?*

MD. Gichaga: *The main benefit of reducing NRW is that we are able to supply water to more customers with no additional water production required. We serve more customers now than before.*

Now we have new water treatment plant and the capacity of water production has improved from 6000m^3 to 27000m^3. We have extended our services to more customers in the rural areas. Our production capacity is enough to meet the demand.

Interviewer: What challenges do you face while implementing the NRW reduction activities?

MD. Gichaga: *Cost of maintaining low NRW ratio is a challenge. We have 15 NRW Unit staff employed only to reduce NRW which is an additional cost on staff remuneration.*

The operation cost for the Unit is enormous because acquisition of modern equipment such as ultrasonic flow meters and leak detection equipment. We have vehicles and motorcycles only for the NRW Unit, so the cost of maintaining these are not small. To sustain the current level of NRW, we need to monitor all the distribution systems of 41 DMAs.

Interviewer: Are there some external opportunities or factors which favour the implementation of low NRW?

MD. Gichaga*: We work very closely with our customers and suppliers, and sensitize them on their roles. This can enhance their ownerships of the company. In Nyeri, everybody feels they own the water company so it does not take long time to find leakages because our customers report leakages and we respond to it. We must be working together with the stakeholders. The customer satisfaction is no. 1 goal. We provide our customers a 24/7 quality service of clean, safe and affordable water. Assurance of clean water is very important for us.*

Interviewer: *Now how do you undertake your stakeholder sensitization?*

MD. Gichaga*: We use different media to sensitize the public. Apart from the Open Day which is at every 22nd March, we normally have an Annual Stakeholders' Forums last Monday in March. There, we report our performances every year such as our achievements, challenges and our future plans and discuss the support we required from the stakeholders. We also participate in Central Kenya's Agricultural Shows. In 2016, we participated in Africa Water Network and Kenya Water Network in Nairobi.*

As our corporate social responsibility, we partner with Kenya Red Cross, Nyeri Hospice and County Hospital during Christmas period. We participate in half marathon organized by Mater Hospital. Also, we support primary schools within our areas by providing them water tanks for rain harvesting.

Interviewer: *I am grateful. Thank you very much for your time talking to us.*

---

[7] This interview was conducted in March 2018.

5 Children’s Voice

In March 2018, students from Kiamuringa Primary School and Iveche Primary School in Embu visited EWASCO’s Mukangu Water Treatment Plant. Through the visits, the students learned how EWASCO’s water is treated and tested before it is distributed to their consumers. They also learned the importance of conserving water. Here are what students said about their visits.

Students wrote about the treatment processes they learned…

First, we entered into the control room. We saw how water comes from the source. Its source is in river Rupingazi. First, they put Aluminium Sulphate. It is used to purify water and you let it to stay for 30 minutes. After that they put Soda Ash. Soda Ash is used to neutralize the water. The third is Chlorine. It is used to kill germs. The dangerous bacteria is called E.coli. There was a machine called turbidity meter. This was used to test turbidity of the water. (Kennedy, Kiamuringa Primary School)

The second part, we were taken to the laboratory to see how water is treated and how the chemicals are added to the water. We also saw the stages of water which is treated. We were shown the chemicals, they use like Aluminium Sulphate, Chlorine and Soda Ash. We were also shown machines like chlorine meter which was used to test the Chlorine residue. We were shown how to test the colour of water with a colour meter and other machines. (Yvon, Iveche PS)

There is the intake where the water got from the river to the treatment plant. They get their water from river Rupingazi. They use a lot of chemicals in the water treatment plant. We were told EWASCO uses three types of chemicals namely: Aluminium Sulphate (Alum), Chlorine and Soda Ash. They put ten bags of Alum in the water treatment in one day, and each bag is 50 kilograms. They use one drum of Chlorine per day. They use Soda Ash to stabilize the water. There are six major stages of water treatment. There is the coagulation, rapid mixing, flocculation, sedimentation, filtration and disinfecting. They wait for four hours so that the water may settle on its own and after that the dirt falls into the sludge lagoon. (Caleb, Iveche PS)

Students wrote about what they discussed with their family ....

I told them this water is meant for animals and human beings and not for plants. When you see someone trying to make a hole on the pipe of water from EWASCO, first you should warn him or her, when he/her refuse you go and say him/her to the nearest police station. (Charles, Kiamuringa PS)

I discussed everything I had learned with my parents and neighbours. I advised them not to leave the taps running and to fix the broken pipes. I advised them to report the illegal people who steal water to the police officers. Not to misuse water and to start practicing reusing of the water you have used to clean the house. You can use it to wash your shoes.

In conclusion, I will help EWASCO company by reporting the ones who illegally connect by stealing water and will store water for future use to help them preserve the water because they use a lot of money for buying all the chemicals to make the water clean and the customers should also pay them in order to buy the chemicals. I will advise everyone not to misuse and will inform them if I see a broken pipe and a pipe which is pouring some water. (Diana, Iveche PS)

When I went home I found my brother irrigating crops with EWASCO water. I quickly ran and switched off the water and warned him that EWASCO water is not meant for irrigation. (Karela, Kiamuringa PS)

Students also thanked the water company for their work…….

The Water company, I am advising you to keep your hard work and continue to give us safe and clean water. We will not pollute water any more. Thank you very much. I know God will bless you for your great work. (Stacy, Iveche PS)

We thank so much the EWASCO people for the water they provide is very clean and with high quality. (Abigail, Iveche PS)

I will help EWASCO when I see water dripping down, I will go and close. When I see somebody beating the pipe of EWASCO, I will go and tell him don't beat the pipe because we will drink water with germs and I will go and report to the Police officer and EWASCO. (Eric, Kiamuringa PS)

To all people that if you see a leaking pipe anywhere, report the matter as quick as possible. I would also like to warn you on using too much fertilizer because it will be washed away to the river once it rains. Never ever leave the tap running because you waste a lot of money. Do not use treated water for irrigation because it can kill plants. I would also like to encourage you to pay the EWASCO water bill because they use that money to buy the water supplies like chemicals and pipes. I would also like to thank the people who work there. They do a good job with much effort to ensure the water is safer for domestic use. (Carlos, Iveche PS)

6 Events and Activities

6.1 The First Kenya Water Summit

On March 1ST and 2nd 2018, the First Kenya Water Summit was held in Naivasha, Nakuru County. The Summit, organized jointly by MWS, Council of Governors (CoG) and WASPA, was attended by over 400 representatives from governmental organizations, county governments, WSPs and development partners. The key topics of the Summit were: the Water Act 2016, Sustainable Water Service Provision, Management and Financing of NRW, and Financing Alternatives for Water Sector. Eng. S.A.O. Alima, Director of Water, Sewerage and Sanitation Development of MWS presented about the cost of high NRW and benefits of reducing NRW ratio, and the challenges of reducing NRW at WSPs. It was clear from the CS Hon. Chelugui's speech that high NRW is an obstacle for Kenya to achieve Universal Access to Water by 2030 and MWS is taking the reduction of NRW seriously.

CS Hon. Chelugui and Vihiga County Governor Hon. W. Ottichero. with signed Framework

During the Summit, Intergovernmental Framework for the cooperation between MWS and county governments in waters sector development have been signed by CS. Hon. Chelugui and Vihiga County Governor Hon. W. Otichilo.

6.2 World Water Day

CS Hon. Chelugui and Taita Taveta County Governor Hon. Samboja visiting MWS exhibition on NRW

The World Water Day is internationally celebrated on 22nd March of every year. This year's event was held in Mwasere Girls High School, Taita Taveta County which drew participants from all over the country including governmental departments, parastatals, county goverments, WSPs and general public. The event was officiated by the MWS Cabinet Secretary.

The MWS NRW Unit carried an exhibition on NRW reduction. The exhibition majored on NRW as a setback for the water sector if Kenya as a country is to attain a universal access to water by 2030. The partispants to the event were informed about NRW, the causes of NRW in the water supply system, how it affects consumers, and what the consumers can do to help water companies to reduce NRW. The participants also learned that NRW reduction measures have to be applied in all the WSPs if Kenya is to attain our goal of universal access, and that the reduction strategies are a collective responsibility touching on various levels of governance, water service providers, consumers and the general public.

7 You Can Help!

Reducing NRW means more water become available to all of us. The following actions by the each of us as water consumer can help water service providers of your area to reduce the NRW.

Report Water Leakages and Water Thefts to Water Service Provider

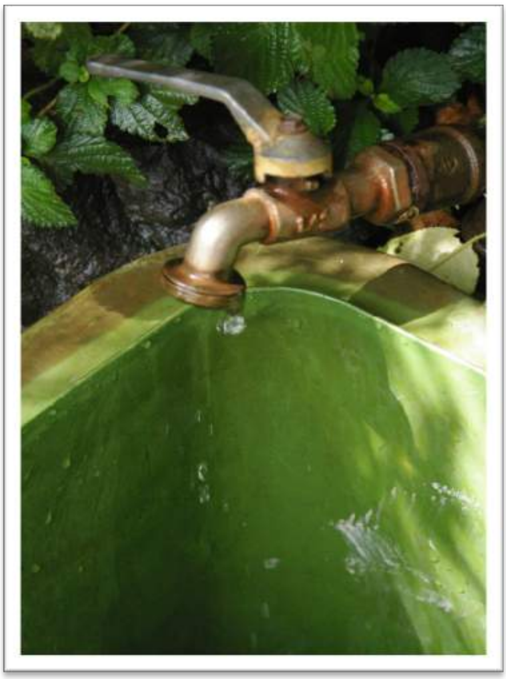
Water service providers have telephone number for reporting. If WSP has *Maji Voice*, use *Maji Voice* for tracking the reporting.

Check for Leaks in Your House

Check for leaks regularly by turning off all taps and checking the water meter. If the water meter dial is still running, it means there is a leak. Fix immediately.

Pay Water Bill on Time

Know your water consumption, read the meter, take a photo and report to the water service provider of your area.



Make sure your tap is closed all the time

Ministry of Water and Sanitation, Maji House,
Upper hill, Off Ngong road,
P.O BOX 49720 – 00100, Nairobi
Tel: +254 020 2716103, 4900000 | **Fax:** +254 020 2727622
Email: ps@water.go.ke | **Web:** www.water.go.ke

1) -2 NON-REVENUE WATER MANAGEMENT
Annual Report 2018 – 2019

MINISTRY OF WATER, SANITATION AND IRRIGATION

NON-REVENUE WATER MANAGEMENT
ANNUAL REPORT – 2018/2019

FOREWORD

The Kenya Vision 2030 envisions Kenya to be a middle-income country and its citizens enjoying high quality of life, with universal and equitable access to clean, safe and affordable drinking water. Water is recognised as a key enabler to many other activities as contained in the development blueprint. The Big Four Agenda also has water as an important component facilitating in realisation of the Agenda's goals.

However, water resources in Kenya are limited. With the national population rapidly increasing, there is an increase in water demand exerting a lot of pressure on available freshwater resources.

The balancing act between competing water uses and scarcity of water resources is not only a delicate but also a major challenge facing this country. As part of demand-supply management, the Ministry of Water, Sanitation and Irrigation (MWSI) promotes water conservation measures such as reduction of water losses and encouraging efficient usage of water at both the domestic and industrial levels.

In relation to addressing water losses, the ministerial policy objective is to develop and implement Non-Revenue Water (NRW) reduction strategies for all categories of Water Service Providers (WSPs) across the country. It intends to gradually bring NRW levels to the globally acceptable levels. Since Kenya is still recording high NRW levels of above 40%, the Ministry is focusing on NRW reduction to justify the capital outlay on water infrastructure.

This report highlights some of the activities that the Ministry, in conjunction with other sector players, has undertaken towards NRW reduction. I wish also to extend an invitation all sector players to join this concerted initiative and implement water loss reduction measures at each of their respective level so that we can optimise on the value from this scarce, vital natural resource.

As a Ministry, we acknowledge and appreciate the efforts made by JICA in training nine of our WSPs on strategies of how to reduce NRW in their areas. We believe that through implementation of the proposed strategies, the WSPs general performance will improve and more Kenyans will have access to adequate, clean and affordable water.

Sicily K. Kariuki (Mrs), EGH
Cabinet Secretary
Ministry of Water, Sanitation and Irrigation

PROJECT FOR STRENGTHENING CAPACITY IN NON-REVENUE WATER REDUCTION IN KENYA

The water sector has been losing funds in form of Non-Revenue Water (NRW) that would have otherwise been used to improve the sector infrastructure and increase access to water. NRW is all about integrity and proper governance of our water institutions, particularly the Water Service Providers (WSPs). As an intervention to end this massive water loss, the government of Kenya entered into an agreement with JICA in "The Project for Strengthening Capacity in NRW Reduction in Kenya".

This project, which started in October 2016 to run for a period of 5 years, aims at establishing support systems for sustainable NRW reduction in the country as well as enhance the capacity of the WSPs in NRW reduction strategies. In order to sustain the NRW reduction gains made in this project, the ministry has been using a collaborative approach with full involvement of both levels of Government (Ministry of Water, Sanitation and Irrigation and the CoG), WASREB, KEWI, JICA, WASPA and the WSPs in planning and implementation of the project.

This project is being implemented in nine pilot WSPs distributed evenly in the eight water works development agencies namely: Embu, Meru, Nakuru, Ruiru-Juja, Nyahururu, Kisumu, Mavoko, Eldoret and Kilifi-Mariakani. The project has so far achieved the following:

1. Formulation of National Policy on NRW Management to give direction on management and reduction of NRW in the country.
2. County sensitisations on NRW reduction has been rolled out in all counties aimed at stepping up access to water in the counties by enhancing their understanding on NRW reduction and their role in NRW reduction. This activity is still ongoing having so far hosted 10 Counties and 19 WSPs.
3. The Ministry has been supporting NRW reduction sensitisation campaigns through production of NRW Management Annual reports, undertaking water use education in primary schools in liaison with WSPs, carrying out NRW campaigns during WSPs' open-day and public events. The campaigns aimed at enlightening the community on the benefits of reducing NRW, recommending good practices they can embrace to reduce NRW and bringing about a lasting culture change on NRW reduction.
4. JICA's technological support to WSPs that enhanced their capacity to handle NRW reduction through: -leak management, pressure management, data management including data analysis and interpretation, formulation of annual reduction plans, implementation and review of the plans.
5. Through this project, the Ministry has donated leak detection equipment to some pilot WSPs to support the use of modern appropriate technologies to ensure sustainability of NRW reduction initiatives.
6. Revision of the NRW Standards is currently being undertaken to make it user friendly as a way of promoting its use.

7. Review of KEWI courses to incorporate NRW reduction in the main course syllabus, introduction of NRW short courses and on-the-Job training alongside classroom training.

8. The Project has had thematic and benchmarking workshops organised through WASPA platform where WSPs met and shared experiences, best practices and technologies on NRW reduction.

Henceforth, the Ministry will be working on upscaling of the project activities to cover the rest of the WSPs in the country starting 2020/2021 financial year.

Implementation of this project was however challenging as most counties did not prioritise NRW as an issue that required urgent attention. Likewise, we have seen management of some WSPs not taking NRW reduction commitment with the seriousness it deserves.

But that notwithstanding, and as stakeholders in the water sector, it is important to know that we all have a duty to create awareness within our community and promote behaviours and practices that enhance NRW reduction.

Dr. Andrew Tuimur, CBS
Chief Administrative Secretary
Ministry of Water, Sanitation and Irrigation

PREFACE

Every year, Water Service Providers (WSPs) in Kenya lose large amount of safe and treated water. Non-Revenue Water (NRW) is the water which does not earn revenue to WSPs. NRW jeopardises sustainability of water supply operations and limits availability of water in the taps, meaning low quality of water services to the consumers. Water can be lost through leakages from pipes and taps. It can also be lost through water theft and inaccurate metering and billing management. If water losses or NRW is reduced to manageable level, WSPs can generate more revenue without additional investment. We witnessed examples from the Project for Strengthening Capacity in NRW Reduction in Kenya supported by the Japan International Cooperation Agency (JICA) that some of the WSPs could increase their revenues by billing actual consumption by the customers based on accurate meter readings. Water losses are not only occasioned from dilapidated or poorly fixed pipes but also from human aspects which must be addressed to reduce NRW.

The Ministry is keen to see that provision of water services in the county remains sustainable for a long term through generation of enough revenues that make WSPs break even. The Ministry is aware that the reducing NRW is a deal-breaker in this quest. For example, some of the WSPs which have managed to bring down NRW levels to the lowest in the country are also the best performing, going by the ratings by Water Services Regulatory Board (WASREB).

In light of this, the Ministry has set up a NRW Unit in its establishment to monitor NRW levels, promote and coordinate NRW reduction activities, develop and promote NRW standards, and implement ministry policies and strategies on NRW reduction. The Ministry's national institutions like WASREB and Kenya Water Institute (KEWI) are also on board in the NRW reduction strategy: WASREB promotes the observance of NRW reduction by WSPs, while KEWI develops and rolls out curriculum for strengthening NRW reduction capacity amongst staff in the main institutions dealing with NRW reduction.

This report is the 2nd volume documenting information of NRW reduction during the 2018/19 Financial Year. In cognisance of the chain of interconnectivity between various parties in NRW activities, the report aims at sensitizing players in the water sector in a bid to create a collaborative effort towards achieving NRW short-term target of 35% by 2022.

I wish to acknowledge the contribution of the Water Secretary Eng. SAO Alima under whose able leadership and guidance the report was produced. For all those individuals and organisations that in very diverse way made the production of this 2nd New Management Report successful, but I could not mention by name, I say thank you.

Joseph W. Irungu, CBS
Principal Secretary
Ministry of Water, Sanitation & Irrigation

ACKNOWLEDGMENT

The Constitution of Kenya obliges the state to facilitate provision of information to the citizens. It is in keeping this constitutional provision that the Ministry of Water, Sanitation and Irrigation produced this 2nd Annual NRW Management Report.

Invaluable effort and commitment has gone into ensuring that Kenyans are provided with accurate, objective and timely information on the progress and implementation of the Ministry's NRW activities. I therefore wish to take this early opportunity to express my personal and institutional gratitude to all our counterpart organisations e.g. Water Service Regulatory Board (WASREB), Kenya Water Institute (KEWI), Water Service Providers Association (WASPA), Japanese International Cooperation Agency (JICA), interviewees and all those provided for their effective participation and commitment in developing this 2nd Annual NRW Management report.

I wish to particularly recognise and acknowledge the technical officers from Non-Revenue Water Unit that worked tirelessly in the collection and compilation of the data that went into production of this report. Not forgetting the nine pilot WSPs for actively participating in the Project for Strengthening Capacity in Non-Revenue Water Reduction namely: Meru, Embu, Kisumu, Eldoret, Nyahururu, Mavoko, Nakuru, Kilifi-Mariakani and Ruiru- Juja for providing extremely useful comments and feedback on initial drafts of this report, I thank them most sincerely for their time and good will.

I would like to express sincere appreciation to Murang'a Water and Sanitation Company (MUWASCO) for inviting pupils of Ndikwe and Kiawambeu Primary Schools to visit the water treatment facility in Embu. Our special thanks to JICA Expert Team from the project for their guidance and expertise in planning, execution and completion of planned Non-Revenue Water activities. With this level of commitment, I know it is just a matter of time for Non-Revenue Water to start going down from the current level of 41%.

Lastly, I thank the Ministry's top leadership for timely direction given to the sector.

Eng. SAO Alima
WATER SECRETARY

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ACRONYMS

Abbreviation	Name
AWWA	American Water Works Association
CECM	County Executive Committees
CEO	Chief Executive Officer
CIS	Customer Identification Survey
CoG	Council of Governors
DMAs	District Meter Areas
ELDOWAS	Eldoret Water and Sanitation Company
EWASCO	Embu Water and Sanitation Company
GIS	Geographic Information System
GoK	Government of Kenya
HDPE	High Density Polyethylene
IWA	International Water Association
JICA	Japan International Cooperation Agency
KACUWASCO	Kakamega County Urban Water and Sanitation Corporation
KEWI	Kenya Water Institute
KES	Kenyan Shilling
KIWASCO	Kisumu Water and Sewage Company
KPIs	Key Performance Indicators
MEWASS	Meru Water and Sewage Services
MNF	Minimum Night Flow
MUWASCO	Murang'a Water and Sanitation Company Ltd.
MWS&I	Ministry of Water, Sanitation and Irrigation
NAWASCCO	Nakuru Water and Sanitation Services Company
NPBF	National Performance Based Financing
NYAHUWASCO	Nyahururu Water and Sanitation Company
NRW	Non-Revenue Water
PBC	Performance Based Contract
PEWAK	Performance Enhancement of Water Utilities in Kenya
SDG	Sustainable Development Goal
SWC	State Water Company
UFM	Ultrasonic Flow Meter
VEI	Vitens Evides International
WASAC	Water &Sanitation Corporation
WASPA	Water Service Providers Association
WASREB	Water Services Regulatory Board
WRA	Water Resource Authority
WSP	Water Service Provider

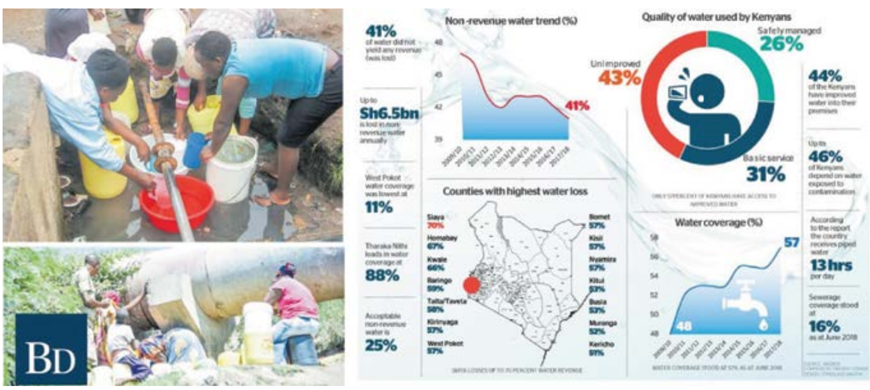
1. WHAT IS NRW?

1.1 Introduction

Access to safe water and improved sanitation services are the backbone of well-being of Kenyans. Country's Constitution 2010 links access to clean drinking water and reasonable standards of sanitation as the rights of every citizen. It is a key pillar for Kenya's development goal which is in tandem with the United Nations' Sustainable Development Goals (SDGs) No. 6 and Kenya's Vision 2030.

Kenya is a water scarce nation. Per capita available water has been declining over the years. Nevertheless, chronic water losses have beleaguered Water Service Providers (WSPs) throughout the country. The Government of Kenya (GoK) has recognized the reduction of water losses as a priority issue to be addressed for efficient use of available water resources. The difference between the amount of water in the distribution system and the amount of water billed to the customers is called Non-Revenue Water (NRW). The estimated Kenya's average of NRW ratio was 41% (2017-2018). The challenges remain to achieve the national NRW target ratio of 25% by 2030. A high level of water losses is due to leaks and thefts from the system; as well as losses due to inaccurate or non-meter readings and billings because of poor management of customer records.

Water Secretary explaining to the President on the country's NRW status.



High water losses dim Kenya's hope of universal access reported by Business Daily August 28, 2019(digital)

1.2 Definition of NRW

Non-Revenue Water (NRW) is the difference between the total amount of water produced for distribution and the amount of total water billed to the customers. NRW is generally expressed as a ratio, the percentage (%) of amount of water not billed against the total amount of water produced for distribution.

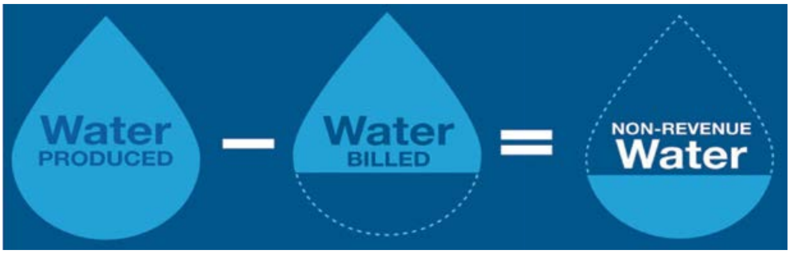
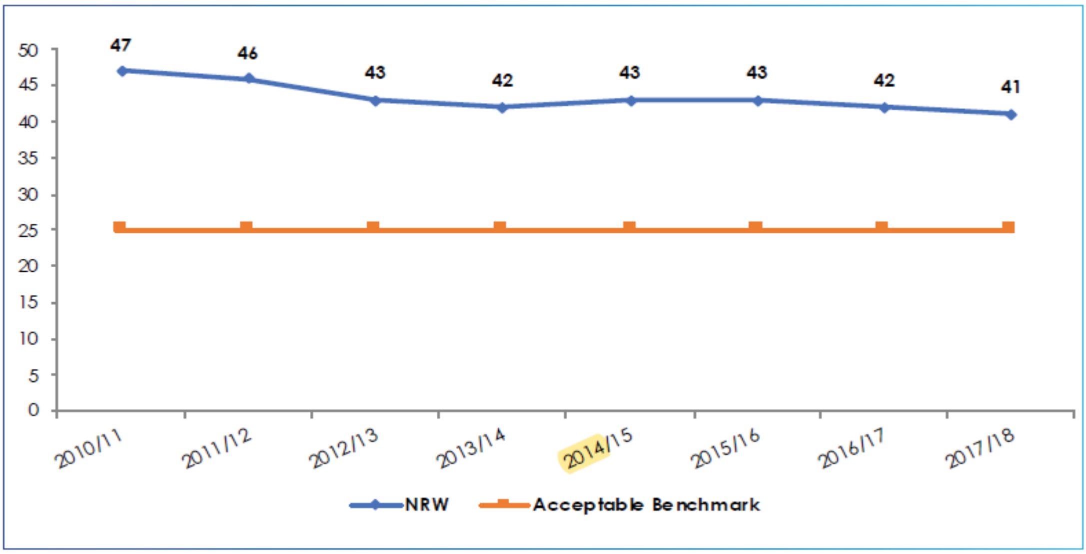


Figure 1: NRW at a glance

Despite the efforts by water utilities or WSPs to contain water losses, levels of NRW have remained relatively stagnant between 41% and 47% for the last 10 years. Reducing NRW to the sector target of 25% can help close the supply and demand gap without the need to build costly infrastructure or exploit new water sources (which are dwindling). Additionally, reducing water losses increases revenue for WSPs while reducing operating costs linked to producing and pumping water, thus unlocking savings that can be used to expand access and improve service delivery.



Source: WASREB, Impact Report 11

Figure 2: National Trend of NRW Ratio in Kenya

1.3 Components of NRW

When studying NRW, Water Balance Table by the International Water Association (IWA) is a good reference tool. The data in the table is based on the measurement or estimation of water produced, imported, exported, consumed or lost. In Kenya, most WSPs are able to estimate water volumes produced, exported, imported and consumed but are not able to safely and reliably estimate the remaining components.

Table 1: Water Balance Table

<table>
<tr><th colspan="5">Components of NRW (Water Balance Table)</th></tr>
<tr><td rowspan="5">System Input Volume</td><td rowspan="3">Authorised Consumption</td><td colspan="2">Billed Authorised Consumption</td><td>Revenue Water</td></tr>
<tr><td colspan="2">Unbilled Authorised Consumption (e.g. firefighting, public fountains)</td><td></td></tr>
<tr><td rowspan="2">Apparent (Commercial) Losses</td><td>Unauthorised Consumption (e.g. Illegal connections)</td><td rowspan="3">Non-Revenue Water (NRW)</td></tr>
<tr><td>Water Losses</td><td>Metering Inaccuracies</td></tr>
<tr><td colspan="3">Real (Physical) Losses</td></tr>
</table>

Source: International Water Association

From the table, NRW ratio can be calculated.

$$\text{NRW ratio (\%)} = \frac{\text{System Input Volume} - \text{Billed Authorised Consumption Volume}}{\text{System Input Volume}} \times 100$$

Three components of NRW are: **real/physical losses, apparent/commercial losses** and **unbilled authorised Consumption** in which water is taken by registered customers for public and institutional uses and is not paid for. This includes water for firefighting, backwash and public fountains. In many countries, water losses are the main cause of NRW.

Table 2: Causes of water losses

Type of losses	Main causes
Real (Physical) losses	Physical losses are caused by leakages and bursts of the water supply network such as pipes and tank overflows due to: • Aged pipes and fittings • Sub-standard pipes and fittings and/or poor workmanship • Unmanaged high pressures • Destruction of water infrastructure such as pipes during construction or repair of roads, underground cable, storm water or water drainage systems • Vandalism of pipes

	  Left: Pipe joints are prone to the leakages. Right: Water leakages caused by road construction in Nairobi
Commercial (Apparent) losses	Commercial losses are caused by mainly human such as corrupt employees and water users through: • Unauthorised consumption: Illegal connections, water thefts, meter tampering • Meter inaccuracies: unmetered connections, faulty or inaccurate meters, meter reading errors or non-reading meters and data recording errors.   Left: Illegally modified pipe to bypass meter. Right: To prevent meter modification, some WSPs are using plastic seals

1.4 Importance of reducing NRW

What is Acceptable level of NRW?

Water Services Regulatory Board (WASREB) sets sector benchmarks; NRW level of under 20% is regarded as **good**, 20-25% is regarded as **acceptable**, while over 25% is **not acceptable**. Internationally, the acceptable level of NRW is 10%.

Table 3: NRW performance of WSPs

Performance boundaries	NRW Ratio	No of WSPs in the category
GOOD	<20	2
ACCEPTABLE	20-25	4
NOT ACCEPTABLE	>25	73
TOTAL		79

Source: WASREB Impact Report 11

In Kenya, only handful of utilities reached 'Good' or 'Acceptable' levels in the reported period of 2017-18. NRW has a serious effect on the financial viability of water utilities through loss of revenue and water resources, and increase of operational costs. High level of NRW reduces a WSP's capacity to fund necessary expansions of services, especially to low-income consumers. It is now widely acknowledged that NRW is a key indicator of a WSP's operational and financial performance. A high level of NRW normally indicates a WSP that lacks good governance, autonomy, accountability, and the technical and managerial skills necessary to provide a reliable service.

WASREB's Impact Report points out that the current NRW average of 41% and the sector turnover of KES 19.70 billion, against a sector benchmark of 20%, the sector is losing about seven billion shillings. In terms of volume, the amount lost annually after allowing for the 20% acceptable level of loses is 90 million cubic metres. This is adequate amount to serve Nairobi City County with a daily demand of 750,000m³/day for four months. Therefore, concerted effort from all stakeholders is required to reduce the high levels of NRW.

In his report for the financial year 2016-2017, the Auditor General warned that high levels of NRW poses a big threat to the financial sustainability of the water sector. Such losses are also a significant risk to the nation's water security. Given current levels of NRW, the sector would need to increase water production to two and a half times the current level to meet existing demand. To invest in water production and the creation of new assets without solving the issues at the heart of NRW could jeopardise water access for future generations.

What are the benefits of reducing NRW?

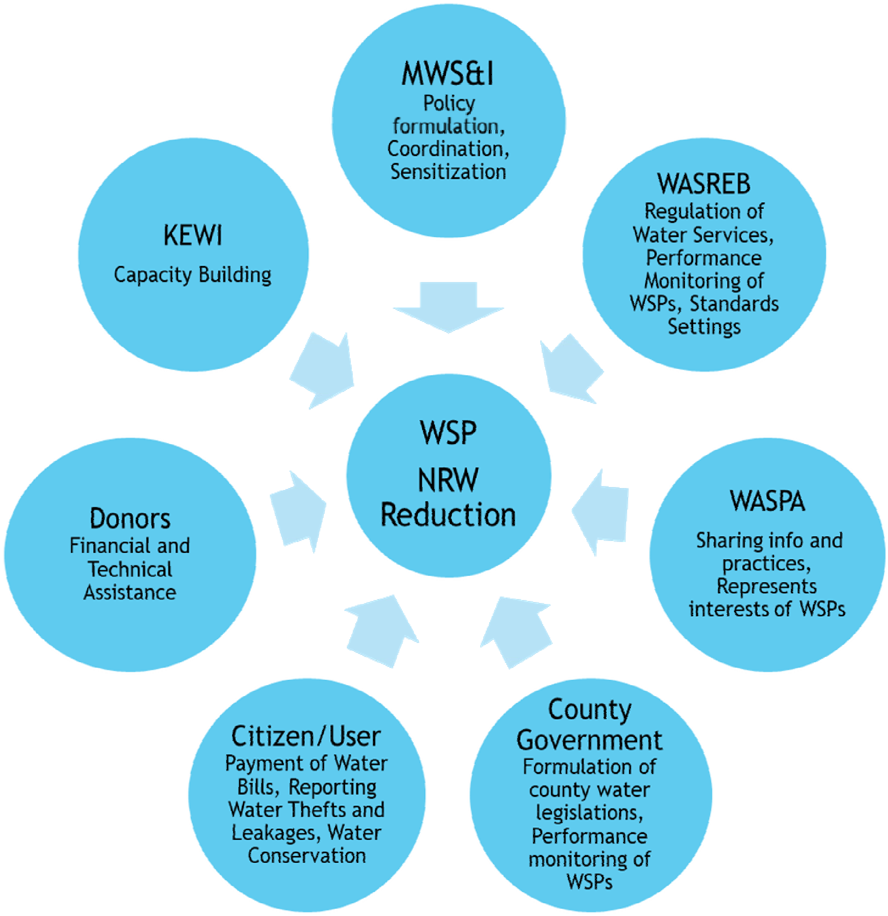
Reducing NRW ratio benefits water utilities, customers and society at large.

- For water utilities, utilities can increase revenue, which can enhance financial sustainability of their operations. With more revenue, the utilities can invest in infrastructure to improve water services.
- For customers, reduction of NRW means more water is available for distribution. Utilities can expand their service areas to more customers or more hours of water supply to existing customers, hence improving their customer services.
- For county and national government, by lowering NRW, county water utilities become financially healthy, the county government can then allocate their financial resources to rural water development or other socio-economic activities. As for the national government, availability of more water by lowering NRW means less money can be spent on water resources development.
- For the society at large, reduction of NRW means precious water resources are preserved. Industries can also benefit if the water supply is reliable and tariffs are low. Reducing illegal connections supports greater fairness among water consumers. Conflict due to the shortage of water can be reduced when more water becomes available.

Technician is fixing leakages of pipe at night (MUWASCO)

2. STAKEHOLDERS IN NRW REDUCTION

Kenya set the national target to reduce NRW ratio below 20% by year 2030. To achieve this target, various stakeholders are involved with and/or support for water utilities' NRW reduction activities. The following figure describes the stakeholders in NRW reduction in Kenya and their roles and ongoing activities.



2.1 Ministry of Water, Sanitation and Irrigation

At a glance:

The NRW Unit has been actively campaigning on NRW reduction to county governments and the general public

NRW annual management report intends to educate about NRW and its benefit of reduction and activities by stakeholders.

More water utilities are conducting NRW sensitisation campaigns targeting schools children, nurturing the habit of water conservation at young age.

The NRW Unit in the Ministry is responsible for co-ordinating the NRW reduction activities across the country. Promotion of NRW sensitisations and campaigns has made the following progress in this reporting period:-

2.1.1 County sensitisations

The NRW Unit organised workshops for sensitising county governments on NRW issues. The first county sensitisation workshop was held in Nakuru on 28th March 2019 hosted by Nakuru County and attended by representatives of surrounding 5 counties.

During the one day workshop, stakeholders presented NRW's effects on water access in the county population, financial health of WSPs and measures taken to manage NRW by national institutions and WSPs in the area. In the afternoon session, participants from county governments and WSPs discussed actions that support WSPs in the reduction of NRW. Further regional county sensitisation workshops were planned targeting county government, water executives and WSPs' top management.

Left: County Executive Committee Member of Nakuru giving his welcoming remarks. Right: Group discussions during the workshop

2.1.2 NRW sensitisations to the public

The NRW Unit actively campaigned NRW reduction to the general public through public events to drive changes of citizen's behaviours on water use. The Unit co-organised NRW sensitisation event with Kakamega County Urban Water and Sanitation Corporation (KACUWASCO) during the World Water Day of March 22, 2019.

School campaigns

The Unit believes creating awareness among school-going children on the benefits of reducing water losses and nurturing the habit of water conservation is a powerful way of transmitting messages on the importance of water conservation for short and long-term. The NRW Unit continues to encourage and support WSPs to organise NRW related campaigns targeting school children. The campaigns targeting schools were conducted in Embu, Meru, Murang'a and Nyahururu WSPs. Other utilities are planning to do similar activities in the coming years.


Left: Students learning about water treatment processes at Embu Right: Children pledged their water conservation activities at the Nairobi Show.

The Nairobi Agricultural Trade Fair Show

The NRW Unit and Nairobi Water & Sewerage Company co-organised NRW sensitisation events during the Nairobi Agricultural Trade Fair on September 31st to – October 3rd, 2019. Visitors to the stand were shown NRW posters; youth and children, often with their guardians took NRW quiz to test their knowledge. Young children did colouring and pledged on water saving activities. More than 400 people visited and participated in these events during the trade shows. This is an effective way of raising awareness on NRW issues, and how high NRW impacts on them.

2.1.3 Production of NRW Management Annual Report

The 2017/2018 NRW Annual management report was launched on 20th August, 2019. The former Water Cabinet Secretary, Hon. Simon Chelugui, officially released the report to Kenyan citizens. The report aimed at enlightening the readers on mechanism of NRW reduction, the impact of high NRW and benefits of reducing NRW. The report also introduced ongoing reduction efforts by various institutions and the voices from children and good practices the citizens can embrace to reduce NRW.


Left: Cabinet Secretary Chelugui launching the 1st Edition of the Annual Report (2017/2018) Right: KACUWASCO staff taking a client through the NRW presentations during the World Water day 2019

2.2 The Water Services Regulatory Board (WASREB)

At a glance:

WASREB considers NRW management as a governance issue

Various measures are placed for WSPs to reduce NRW such as tariff identification, reporting, the performance-based contracts

WASREB is currently reviewing NRW Management Standard

Innovative approaches such as performance based contract and National Performance Based Financing have been introduced to support WSPs in their efficient NRW reduction

2.2.1 Background

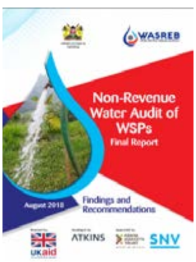
Kenyans will face a 30% gap between the available water supply and the anticipated demand by the year 2030 if the NRW levels continue to remain relatively high and almost stagnant as has been experienced over the last ten years (47% to 41%). During FY2017/18, the national average NRW level was 41%. Considering the sector turnover is KES 19.7 billion and the sector benchmark of 20%, then conservatively the sector lost slightly more than KES 7 billion. Continued investment in water production and affiliated infrastructure without addressing underlying issues of NRW could be strategies and efforts in futility. This is the reason why WASREB is spearheading and championing interventions intended to enhance sustainability of utilities as outlined below. Besides, NRW is a significant measure facilitating evaluation of operational efficiency of the utilities.

2.2.2 Deepening governance

Despite continuous efforts by water utilities to contain the water losses, success has been very low. For this reason, WASREB has established that NRW management is largely a governance issue which needs to be addressed using the sector governance guideline frame-work. WASREB is keen to enforce good governance principles in the sector that allow appointment of directors and utility managers that possess both competences and capacities to drive, adopt and provide leadership on innovations around NRW management and ultimately demonstrate accountability to the stakeholders. The regulator has now developed a governance indicator whose objective is to institutionalise implementation of governance ethos.

2.2.3 NRW Management Guidelines

WASREB has previously developed NRW Management Standards in 2014 to systematically address NRW issues. Overtime, the uptake and implementation of these standards has been fairly low. WASREB has come to a conclusion that utilities failed to prioritise and institutionalise NRW management and thus capacity growth meant to address NRW challenges was not realised.



NRW Audit Report
Source: WASREB

WASREB is now revising the existing NRW Management Standards. The objective of its revision is to propose new approach to NRW management which include institutional approach with the governance agenda, taking the lead role to turn around NRW. To better inform the revision, the regulator conducted an audit of NRW management in nine utilities across the country whose output was launched by the Cabinet Secretary for MWS&I. Subsequently, a supplementary survey on usage of the NRW Standards was conducted on about 50 percent of all the regulated utilities.

In addition, WASREB, through its licensing mandate, is enforcing creation of NRW management functions at strategic levels to the proximity of utility leadership. It aims to establish a facilitative environment in which capacity and requisite resources for effective NRW management coupled with responsibilities for targets are nurtured and thriven within water utilities.

2.2.4 Monitoring and National reporting

WASREB conducts regular monitoring of utilities through inspections using both internal capacity as well as outsourcing as appropriate. A key element of these inspections entails reviewing implementation of outlined NRW reduction activities. Continuous engagement of utilities on this subject matter will lead to progressive attendance to NRW as core issue of the utilities.

WASREB is mandated to collect, process and maintain data as well as report on all issues of water services to the citizens. An analysis of NRW levels and their issues of concern are reported annually by WASREB's Impact reports, outlining the best and the worst performers on NRW management for purposes of encouraging benchmarking and adaption of good practices. Through Impact report, WASREB sends a wake-up call to the poor performers to rethink and review their NRW strategies.

2.2.5 Tariff indexation

WASREB introduced NRW management as tariff condition. This is in order to conditionally cushion utilities against vagaries of inflationary costs. While the regulator will enforce utilities to meet NRW management for its tariff condition, failure is automatically denied the opportunity to adjust its tariff rates until such a time that the NRW targets are met. Though this is in its initial implementation in a few WSPs, it shall be rolled out to other potential utilities whose tariff adjustments become due.

2.2.6 Promoting innovations and incentives

WASREB believes that specific innovations like the Performance-Based Contracts (PBCs) in NRW management, a form of sub-contracting in which the remuneration of the contractor is tied to realisation of outcomes, could be option for utilities to access capacity in form of skills, equipment and resources that they may lack currently.

To broaden the diversity of mechanisms to help address NRW challenges, WASREB has partnered with the World Bank and the MWS&I and designed the programme "National Performance Based Financing (NPBF)". It will provide for WSPs, through a competitive framework, to be eligible for receiving concessionary credit financing from the World Bank that is specifically targeted to address NRW reduction activities provided the initially set targets and outcomes are realised within the framework of regulation coupled with project execution strategy.

The initial phase is underway and expected to draw lessons learnt from which NPBF's financing mechanism entailing a scale up strategy and guidelines shall be generated to inform a framework of sustained drive of addressing NRW in the country.

2.2.7 Collaboration with the Counties

WASREB's collaboration with the county government is through a county engagement strategy centred on three key areas: awareness, governance and performance. Counties own the water utilities but oversight them at arm's length for clear accountabilities. This collaboration with the counties is therefore central to the success of NRW activities countrywide and eventual reduction of inefficiencies in the utilities.

2.3 Kenya Water Institute (KEWI)

At a glance:

KEWI's new NRW training course has theoretical sessions and field training at WSP.

So far, 141 staff from 20 WSPs were trained in the new course

KEWI continues to improve their course materials and modules incorporating evaluation results

2.3.1 Review and revised NRW training course

KEWI has been continuously reviewing its NRW training materials from 2017 to date. Restructured course now have two sessions:

- Classroom sessions with theoretical and demonstrations
- On-Job Training which entails NRW field practical trainings and the use of NRW equipment

On-Job Training is normally conducted in conjunction with water utilities like Embu Water and Sanitation Company (EWASCO). KEWI conducted six NRW joint trainings between 2017 –2019 as a part of JICA's project activities. Summary of trainings are in the table below.

Table 4: List of trainings conducted

Classroom	On-Job Training	No of participants
6th – 10th June 2017	19th -24th June 2017	20
23rd - 27th April 2018	4th – 29th June 2018	41
14th – 18th August 2018	27thAugust – 1st September 2018	13
4th – 8th March 2019	18th – 23rd March 2019	16
3rd – 8th June 2019	17th – 22nd June 2019	20

Source: KEWI

KEWI continuously reviews the training materials and mode of training reflecting the feedback of third party evaluation whose evaluators are invited to the training sessions. Joint training evaluation scores of participants indicates the improvement of the courses provided.

So far, KEWI trained 141 staff from more than 20 WSPs (Embu, Meru, Nyahururu, Nakuru, Eldoret, Ruiru-Juja, Mavoko, Mathira, Kericho, Malindi, Kilifi-Mariakani, Kisumu, Thika, Machakos, Narok, Kiambu, Kapsabet, Nanyuki, Naivasha)and other relevant institutions. Lately, Nyahururu, Eldoret and Thika WSPs were trained in their premises. More WSPs are considering inviting KEWI to conduct the trainings.

KEWI representative is part of the review team for WASREB's NRW Management Standard.

KEWI has some challenges for NRW trainings such as: training platform which is yet to be modified to accommodate all NRW activities, delay in budget disbursement, inadequate equipment and low turn-up of participants. Nevertheless, KEWI sees way forward to improve NRW trainings:

- From the feedback of third party evaluators and participants, KEWI uses the comments in reviewing the next course content and course delivery;
- Improve practical demonstration during classroom trainings;
- Continue to pursue for budget disbursement to support establishment of the course;
- Formulate short course calendar that includes NRW course of the new structure and advertise using brochure;
- In talks with Nairobi City Water and Sewerage Company for using their networks near KEWI in conducting On-Job Training in future activities;
- Formulated industrial attachment programme to share technologies and ideas.

Participants of KEWI's trainings had ample opportunities to experience practical activities of NRW reduction

2.4 Water Services Providers Association (WASPA)

At a glance:

WASPA is strengthening the capacity of WSPs to implement performance improvements through benchmarking and collective learning.

WASPA's bi-monthly meetings has provided members opportunity to meet and share knowledge. NRW is always one of the agenda to be discussed.

WASPA annually awards WSPs with good practices for improved performances

2.4.1 Facilitating capacity development of member utilities

Through several projects and donor support, including the Partnership for "Performance Enhancement of Water and Sanitation Utilities in Kenya' (PEWAK), WASPA is strengthening the capacity of WSPs to implement performance improvements through benchmarking and collective learning. WASPA aims to trigger performance improvement through peer to peer learning and adoption of good practices among members.

Publication of the Good Practices for Improved Performance

WASPA has been maintaining the benchmark programme since 2012 which advocates for peer to peer learning and implementation of the identified good practices for water services provision. Benchmarking and peer to peer learning is the best forum for knowledge sharing as it brings together more utilities with diverse mitigation measures and solutions to NRW management.

Left: Publication of the Good Practices for Improved Performance Right: Benchmarking workshop

Knowledge Sharing

There has been knowledge sharing in WASPA's bi-monthly meetings. The platform has provided members opportunity to come and share knowledge. An agenda on NRW is included in the bi-monthly meetings where members discuss the challenges facing them and the measures to be taken.

Under this forum, environmental conservation has become one of the core initiatives through tree-planting to conserve our water towers. Continued sensitisation has seen introduction of the Children's corner who are introduced to water issues at their tender ages to understand more about water extraction and treatment hence appreciating good water use and maximum utilisation.

The 3rd WASPA International Conference (8th-10th May 2019)

Theme: Unlocking potentials for a water secure world


Left: Deputy President visits WASPA's booth during International conference. Right: annual field trainings

Annual field practical skills trainings

Field practical skills is being carried out annually (2018 in Embu & 2019 in Nyeri).

Highlight of training in Embu (2018)

- Meter testing using EWASCO's fixed meter test bench calibrated meter installed in series, portable meter testing kit and the calibrated bucket.
- Through JICA's support, all utilities in attendance were issued with the calibrated bucket to enhance the exercise back at their utilities.
- Minimum Night Flow measurement was carried out, demonstrating how to calculate physical losses in a District Metered Area (DMA).

Highlight of training in Nyeri, November 2019

Theme: Addressing Water Loss in the 21st Century using Culture Change & Technology

- The billing and meter reading analysis done on pilot WSPs under the JICA project showed a positive trend. Participants who weren't actively carrying out the exercise saw the essence.
- The in-depth analysis is to be escalated in the benchmark forum to enable utilities to carry the exercise more effectively.
- Sealing of meters to avoid meter tampering was demonstrated by MEWASS.

2.5 Japan International Cooperation Agency (JICA)

At a glance:

JICA's project targets 9 utilities and supports them to reduce NRW

Identification of unbilled customers, monitoring of large customer meters, scouting visible leaks, and standardising service connections were effective to reduce NRW

Strengthening organisational structure for NRW management and encouraging the involvement of entire WSP to the activities are the key to effective NRW reduction

The Government of Kenya with support by JICA is implementing the Project for Strengthening Capacity in NRW Reduction with the overall goal of developing support mechanism for NRW reduction and enhancing NRW reduction activities of WSPs. The project started in October 2016 for a period of five (5) years and currently it is in 2018/2019 of implementation.

2.5.1 Targets

The project targets nine pilot WSPs (Eldoret, Embu, Kilifi-Mariakani, Kisumu, Mavoko, Meru, Nakuru, Nyahururu and Ruiru-Juja) covering the entire Kenya as well as MWS&I, KEWI and WASREB to enhance their roles in reduction of NRW nationwide.

2.5.2 Key activities of pilot WSPs and achievement

Through the baseline survey, challenges related to NRW reduction were identified for each pilot WSP. The following approaches of project have been recognised as effective for NRW reduction so far.

(i) NRW reduction activities targeting entire service areas and pilot areas

To accelerate large-scale NRW reduction, activities that are relatively easy to expand have been prioritised with a view of covering the entire service areas. Activities such as identification of the unbilled customers, monitoring of large customers' meters, scouting visible leaks, and standardising service connections were effective in reducing NRW. Five pilot WSPs (Kisumu, Nakuru, Nyahururu, Ruiru-Juja, and Eldoret) have reduced NRW levels significantly.

Meanwhile, leak detection and pressure reduction in distribution network can be done more effectively in hydraulically isolated areas. Those activities were done at the distribution zones or DMAs selected as pilot areas before expanding these activities to other areas.

(ii) Strengthening organisational structure for NRW management

Each pilot WSP has been encouraged to strengthen their organisational structures for NRW reduction. This included engaging the commercial department in NRW reduction activities and increasing the staff of NRW Section/Unit. Analysis of billing and NRW planning activities required whole WSP or across multiple departments to get involved. Four WSPs (Embu, Kisumu, Nakuru & Eldoret) have strengthened their organisational structures to tackle NRW reduction while two WSPs (Ruiru-Juja and Kilifi-Mariakani) are currently building them.

(iii) Tackling commercial losses through billing and meter reading analysis

To tackle commercial losses, the project focused on its activities around customer meters. The project conducted billing and meter reading analysis for all nine (9) WSPs. The results indicated that all the WSPs billed around 50% or more of their customers based on the estimation of consumption at least one month in a year: In one WSP, the ratio of billings based on actual meter readings throughout a year was only 9% of the total number of active customers. It was apparent that those WSPs had not managed the accuracy of the billings, even to the large consumers who may have potentially high consumption.

- The results of the analysis were presented to managements of WSPs. It was an eye opener and led to realisation that NRW is not only the matter of NRW section but also commercial and administrative sections.
- Many pilot WSPs started to check the accuracy of large consumer meters and replaced faulty meters. This led to the increase of billing amounts, for some customers the billing amounts were doubled or tripled.

NRW Unit of MWS&I conducted sensitisation activities to increase the awareness of NRW among county governments, the general public and supported WSPs to do the same. The NRW Management Standard issued by WASREB in 2014 has been reviewed and a revised version will be presented in 2020. The project supported KEWI to improve their NRW short courses. The new course includes class room sessions and field sessions which is conducted at WSPs.

2.5.3 Lessons learnt and way forward

Installing Ultrasonic Flow Meters for measurement (ELDOWAS)

Based on the experiences with pilot WSPs, the project is working with WASREB to develop formats for NRW planning which will be shared among WSPs nationwide. The project is currently developing recommended NRW reduction measures to be taken at each stage of NRW ratio. Draft recommendations are shown in the table below.

Table 5: Recommended NRW activities at each NRW ratio

Stage	Approx. Range of NRW %	Recommended NRW Reduction Measures
1	40% and above	• Determine the accuracy of production meters by testing, calibrating, and replacing them if they are faulty or inaccurate. • Eliminate major commercial losses by servicing, testing (replacing if faulty) customer meters and, identifying illegal uses (starting with large then to medium customers). • Install meters for unmetered customers and identify unbilled customers through Customer Identification Survey (CIS) then start billing. • Reduce the time taken to repair bursts, surface leaks and overflows
2	30 to 40%	• Intensify Stage1 measures by establishing routine activities. • Isolate distribution zones & DMAs with accurate bulk meters and monitoring of NRW. • Reduce underground leaks by step testing, acoustic survey & pressure reduction from high priority areas • Map bursts & leaks and monitor their recurrences • Introduce better quality pipe and fittings for new pipelines and service connections • Minimize commercial losses (including at small customers & data handling errors) by improving meter reading & billing system, and their uses
3	24% to 30%	• Intensify Stage-2 measures listed above • Reduce underground leaks • Start replacing pipes which are prone to bursts & leaks
4.	20% to 24%	• Intensify Stage-3 measures listed above • Accelerate and complete pipe replacement
5.	Below 20%	• Maintain the facilities and skills to sustain the achieved low NRW ratio

Source: JICA project

*(**Note:** Table is based on results of activities of WSPs. GIS development and NRW monitoring are not listed here, but they are required as support for NRW reduction measures)*

2.6 Vitens Evides International (VEI)

VEi Dutch Water Operators	At a glance: PEWAK's benchmarking facilitates peer-to-peer learning of best practices among WSP on NRW reduction have participated. Some of the successful DMAs showed that a return on investment is possible within one year. WASPA has published the first "Good Practices Report" which contains eight good practices from the Kenyan WSPs

Performance Enhancement of Water Utilities in Kenya project

"Performance Enhancement of Water utilities in Kenya" project (PEWAK), is a five-year project co-funded by the Dutch Sustainable Water Fund (2015-2019).

2.6.1 Targets

The PEWAK partners VEI, SNV and IHE Delft provide technical assistance on the benchmark of WSPs hosted by WASPA. This benchmark facilitates peer-to-peer learning and sharing of best practices between WSPs on: NRW reduction, Cost recovery, Service levels and Pro poor services.

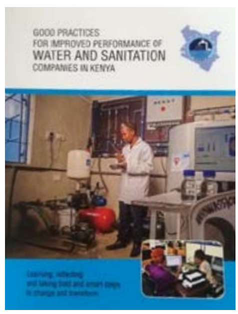
The best practices on NRW reduction are implemented at 10 WSPs through small but smart investments. The target is to reduce NRW to the national acceptable level of 25%. This is achieved through the introduction of blended (commercial) finance for NRW investments and implementation of WASPA's NRW Road-map. This Road-map guides the WSPs in the creation of DMAs. These are physically and administratively isolated parts of the company's network in which all water use is measured both on the distribution lines and at the consumer. This allows the company to measure and address their losses area by area.

2.6.2 Results

33 WSPs participated in the WASPA benchmark that allowed the companies to learn from each other's experiences, successes and lessons learnt.

The annual NRW field training is a successful way of disseminating the practical knowledge on NRW management. Over 60 participants attend each training to get hands-on experience with NRW assessment and use of equipment in the field for 4 days.

WASPA published the first "Good Practices Report" which contains eight good practices from the Kenyan WSPs. This report is publicly available on the WASPA website.



The first Good practice report by WASPA

2.6.3 NRW investments under PEWAK project

About KES 145million has been invested in NRW reduction measures in 10 WSPs between 2016 and 2019.

25 DMAs have been created. The areas with the highest water losses have been addressed first and served as pilot areas for the NRW teams.

The NRW reduction trend is positive for eight (8) of the 10 WSPs:

- Five (5) DMAs have reduced the NRW to levels lower than 25%.
- Four (4) DMAs have reached levels below 30% NRW.
- In all DMAs NRW measures continue to be implemented further to reduce the losses.
- The three most successful DMAs showed that a return on investment is possible within one year.

Bomet case: The graphs below show the NRW trend for Bomet Scheme from June 2016 to September 2019. The first graph shows the NRW percentage, the second graph shows the trend of water in cubic metres produced, billed and lost versus the revenue from the same area. Thanks to the NRW reduction, the revenue from Bomet Scheme has doubled (green line). This allows the company to invest more in further reduction of the losses and improved services to their consumers.

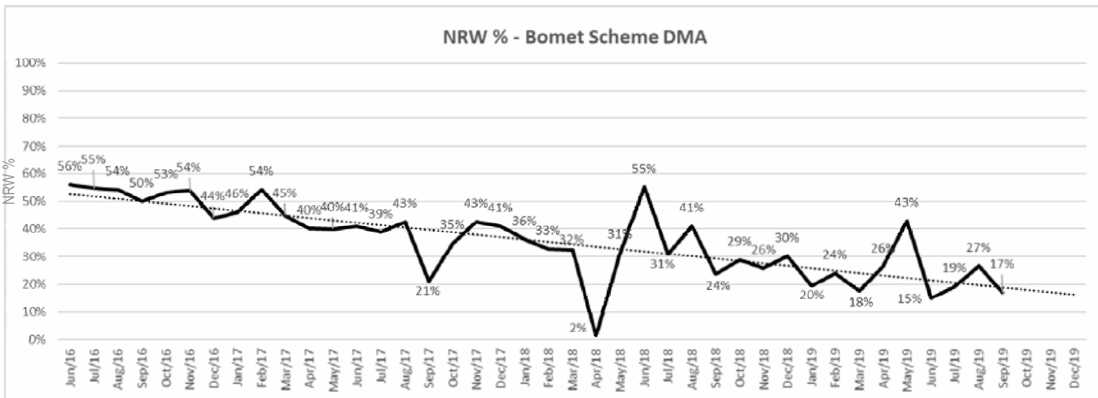


Figure 3: NRW % Bomet Scheme DMA

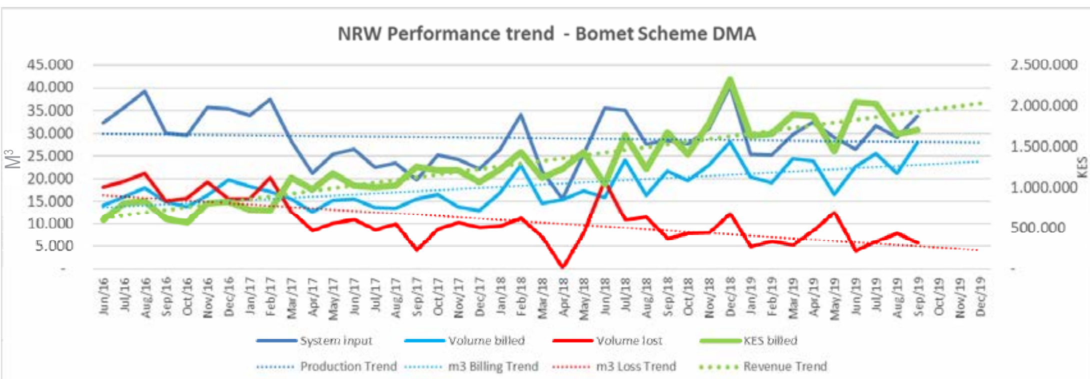


Figure 4: NRW performance trend of Bomet Scheme DMA

2.6.4 Lessons learnt and way forward

The most important factor in NRW reduction is people. It is the governance of the company and the behaviour of management, staff and consumers that determine the level of NRW and the pace of the progress. To improve the performance of the WSP, it requires a change in behaviour of all involved. Best results are witnessed at the WSPs that have managed to change the way they work.

The activities in the 25 DMAs have been prioritised from the area with the highest losses to the area with the lowest losses. In each area, the measures have been taken based on the assessment of the NRW causes. This assessment is pivotal to identify the main causes of NRW in each area and address those first, making the measure cost efficient.

The NRW teams of the 10 WSPs have been trained and equipped to continue the NRW assessment and implementation of measures. The PEWAK project ended on the 31st of December 2019, but the processes established will continue.

3. REPORT FROM WATER SERVICE PROVIDERS

3.1 Kisumu Water and Sanitation Company (KIWASCO)

KIWASCO
Refresh Life

At a glance:

KIWASCO conducted customer billing analysis and accuracy testing of customer meters

Replacing multi-jet meters in some service areas could help reduce NRW ratio by 5%

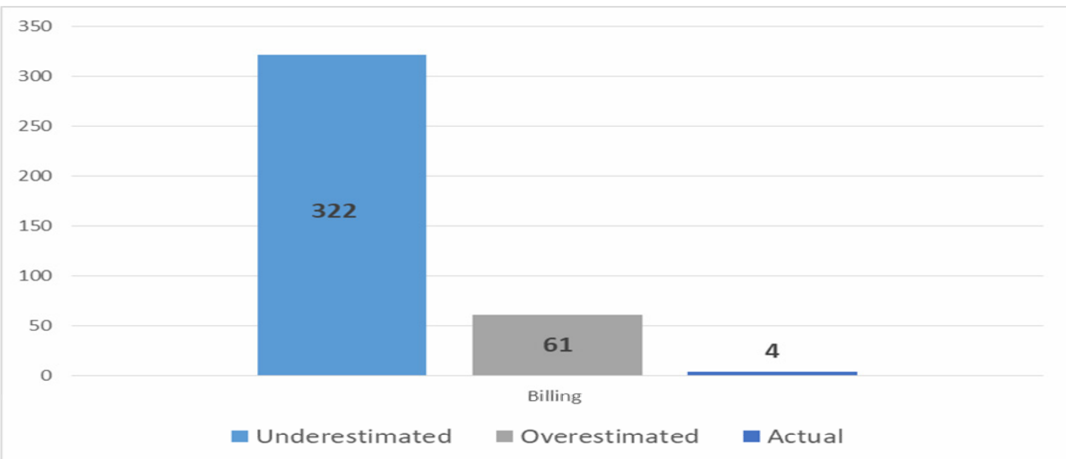
Sensitisation on meter thefts and illegal connections helped to reduce meter thefts by 20%

KIWASCO's approach to NRW is focusing on the management of water losses due to water bills issued on estimation or averages not by actual readings.

The company aims at billing all the customers based on their actual consumption. But due to various reasons such as meters that cannot be read, some customers were billed on average consumption. KIWASCO set a target that 95% of customers will be billed on actual consumption, remaining 5% of customers will be billed on average.

This article focuses about customers' accounts billed based on average consumption in the financial year 2018/2019.

To start with, KIWASCO started to examine 387 out of a total 3,889 customer accounts which were billed on average in May 2019, representing 9.95% of total accounts. In May 2019, the total amount of consumption by 387 accounts that were billed on average was 15,439m^3. The total average consumption for 6 months for the same 387 accounts which were billed based on actual readings was 41,867m^3/month. This means that 26,428m^3 of water was lost by billing on average amounts (Figure 5).



Source: KIWASCO

Figure 5: Results of metering and billing analysis

Out of 387 accounts, the analysis results shows that customer billing for 322 accounts was underestimated while 61 accounts were overestimated. Only 4 accounts were being billed the same as their actual consumption.

Further, KIWASCO took the following steps to reduce NRW.

(i) Installation of multi-jet meters

In November 2018, KIWASCO installed multi-jet meters for their customers in Kenya-Re/Kajulu area. The area is prone to silt which affects the accuracy of standard piston meters. The installation of multi-jet meters has led to the reduction of accounts billed on average by an average of 73%.

The company conducted mass meter mapping to help eradicate accounts being billed on average as a result of unknown location. Those accounts with anomalies such as buried, disconnected, damaged and stuck meters were visited to ascertain the reason for the anomalies. The NRW section is performing meter testing and servicing of stuck meters monthly analysis of average accounts and advising the relevant authorities to act on the anomalies identified.

(ii) Sensitisation of meter theft and Illegal connection

Public awareness notice for meter theft and Illegal connections

KIWASCO has stepped up public awareness and sensitisation campaign in public gatherings such as barazas (public meetings), churches, schools etc. This has helped to reduce meter theft by 20%. The Company is implementing an incentive programme for reporting illegal connections. The staff can receive 20% of fines paid by those found with the malpractices. As shown in the photo, any incident reported to KIWASCO officers or the nearest police station leading to arrest will be awarded Kshs 10,000.

In conclusion, KIWASCO realised that the installation of multi-jet meters can contribute to the reduction of commercial NRW by 5%.

3.2 Nyahururu Water and Sanitation Company (NYAHUWASCO)

At a glance:

NYAHUWASCO staff have been gaining skills necessary for NRW reduction which helped to reduce their NRW ratio.

GIS system is now operational and they can map customer and infrastructure data and information

"TO A THIRSTY MAN, A DROP OF WATER IS WORTH MORE THAN GOLD" - NYAHUWASCO

NYAHUWASCO welcomed the JICA project. The project's main goal is to reduce our overall NRW ratio from a high of 49% in 2016 to the National Water Services Strategy goal of below 30%, and the Vision 2030 goal of below 25%. The project provided NYAHUWASCO with experts support in the following areas:

(i) *Commercial loss management:* Simple but effective means of NRW reduction through billing analysis and measurement of customer meter accuracy on site through calibrated buckets and jerricans was introduced.

(ii) *Physical loss reduction:* Staff were trained on how to use leak detection equipment such as listening sticks, electronic leak detectors etc.

(iii) *Pressure management:* NYAHUWASCO staff were trained on how to manage pressure with pressure monitoring equipment, pressure loggers and pressure gauges. They were also trained on flow measurement techniques using Ultrasonic Flow Meters, Minimum Night Flow measurements and step tests.

At NYAHUWASCO, the Geographic Information System (GIS)was operationalised and they are now able to map customers, infrastructure, leaks etc.

These activities coupled with management support have enabled NYAHUWASCO to achieve NRW of as low as 34%. To date all the staff working for NYAHUWASCO have been sensitised on the importance of NRW and its impact to both the customers and sustainability of the company.

NYAHUWASCO remains true to its mission "To offer our customers high quality water and sanitation services in the most efficient and cost-effective manner".

Left: NYAHUWASCO officers visiting schools for water education. Right: demonstration of water leak

3.3 Nakuru Water and Sanitation Service Company (NAWASSCO)

At a glance:

Through Minimum Night Flow measurement and step test, NAWASSCO could identify leakages, which led to the reduction of NRW ratio

Testing accuracy of meter and meter readings helped NAWASSCO to bill customers. It also helped to identify illegal water use.

NAWASSCO is tackling the NRW in two ways: first by reducing the water loss (physical loss) and second by reducing the commercial losses.

(i) Reduction of physical water loses

Nakuru's soil is composed of mostly volcanic soil which is highly permeable. This calls for intensive leak detection activities. Therefore as the kick-start of activities, NAWASSCO started physical reduction activities in piloting areas of Manyani Estate, Kanyon Estate and Bondeni Estate and unsurveyed area.

In those pilot areas, NAWASSCO first conducted Minimum Night Flow (MNF) measurements: water flow was measured during night time when the amount of water used was assumed to be the lowest. Based on the results of MNF measurement, NAWASSCO conducted step test to identify the gaps of water flow. Step test showed potential water leakages or burst points, and those identified leakage points were repaired. As a result, NAWASSCO achieved NRW reduction of 14% from 42% to 28%.

This was the part of activities of JICA's NRW project. Through those activities, NAWASSCO staff could gain insight on how to conduct leak detection activities introduced by the JICA expert.

(ii) Reduction commercial of water loss

Based on billing analysis carried out under the JICA project, it was evident that most customer meters were being billed on estimate at some point. NAWASSCO decided to put emphasis on meters consuming over 300m^3 in a month. To tackle inaccuracy of meters, NAWASSCO replaced all of the 105 meters of larger consumers (category of over 300m^3/mo.) who were billed on estimate for more than 4 times in last 21 months. Accuracy of meters was tested and non-functional meters were replaced. The activities helped to identify illegal water users as well. As a result of these activities, the company was able to bill customers accurate water consumption which led to increase in billing amount as shown in the billing sample table below. NAWASSCO acknowledges that the billing analysis should be a common practice as this will address most of the commercial losses. Another lesson NAWASSCO learnt was that the reduction of NRW involves teamwork and participation of general public.

Table 6: Sample meters replaced and billing impact

METER REPLACEMENT FOR LARGE CONSUMERS					
ACCOUNT	CONSUMPTION	JULY BILLING	AVG. CONSUMPTION	AUGUST BILLING	IMPROVEMENT (KSHS.)
400550	934	126,370	1202	144,245	17,875
701140	1148	315,150	1492	414,910	99,760
1500370	585	75,765	702	92,150	16,385
3100560	881	208,411	1978	486,775	278,364
3100090	1257	303,821	2842	706,015	402,194
2000221	569	110,300	438	148,290	37,990
6802100	1717	239,855	1864	261,170	21,315
1500490	1567	436,260	1596	444,690	8,430
4902180	368	44,500	409	50,445	5,945
42451780	442	110,010	558	143,650	33,640

Source: NAWASSCO

4. ASK THE EXPERT

Mr. Takahashi is one of the Japanese experts of JICA's the Project for Strengthening the Capacity of NRW Management. We asked him about his experiences of working with WSPs and the challenges of NRW reduction in Kenya.

Question: *What do you do in this project?*

Eng. Takahashi: *I support pilot WSPs on management of distribution networks through transferring skills of water flow and pressure management and leakage management. I support for WSPs to be able to identify practical NRW reduction skills. For example, in-flow management, WSPs want to determine the accurate volume of NRW (water losses). So, the question is what the causes of those losses are, and what kind of effective activities to be introduced to prevent the losses. I work with WSPs to plan NRW reduction considering the above factors.*

Question: *Can you explain about your activities?*

Eng. Takahashi: *My activities in the project are physical losses. It is important for WSPs to know the composition of physical losses. To know the losses, first WSPs need to determine an accurate amount of water (water flow) and water pressure. The collection of data is crucial to make effective diagnosis. Water flow data is collected by using Ultrasonic Flow Meter (UFM) to identify where (which points) of the network have the most (or frequent) water losses from the leakages or thefts. To do this, the Minimum Night Flow measurements are conducted. Because customers use less water at night. After the measurements are acquired, we conduct the step test which can show us approximate areas where leakages are located. So, the maintenance team can prioritize to work on the areas with high potential of leakages.*

Question: *What do you see as the challenges of NRW in Kenya?*

Eng. Takahashi: *One of the challenges in Kenya for reduction of NRW is weak organisations. Even though many WSPs have NRW units or teams, there are not enough technical staff who are specialised for NRW reduction. Often, those staff are responsible for multiple tasks. Lack of equipment is another challenge. If WSPs do not have leakage detection equipment, it is not possible for them to detect leakages. Road construction destroys pipes in Kenya, In Japan, it is a law that the road construction companies must conduct research where the water pipes and electricity cables are before starting the construction. This kind of law does not exist in Kenya.*

Question: *What are the advantages of Kenya in terms of reducing NRW?*

Eng. Takahashi: *In my experience with other countries, Kenya has much less water thefts compared with Latin American countries. Also, there are not many pipes that are buried under the road. In Kenya, the pipes are between roads and houses, and the challenge is the locations of pipes are not known, as no accurate maps exist to locate them.*

5. INTERVIEW WITH AN NRW CHAMPION

Mr. Fredrick Atwa – Managing Director Kakamega County Urban Water & Sanitation Corporation

Having laws to govern water service provision within the water utilities has remained a dream to many but there are those who have made great strides to have a county Water Act formulated. Here, we are going to highlight the success of Managing Director of Kakamega County Urban Water & Sewerage Corporation who worked with the County to develop the Act to ensure concerns of the water corporation are incorporated into the Act. Mr. Frederick Atwa, welcome to the NRW Champion.

Interviewer: *The Kenyan Constitution 2010 devolved water service provision into the county governments. It is the primary duty of the counties to oversee the reduction of NRW in their water utilities through formulation of bylaws to govern. We understand that Kakamega County is preparing County Water Act and your organization, Kakamega County Urban Water and Sanitation Company is working together with the county government in the formulation of the Act. Is this the correct understanding of the situation?*

MD Kakamega: *Thanks, I take this opportunity to welcome you and appreciate your concerns and support. Yes, it is true we have already finished working on the county water Act which was ascended into law and signed by H. E Governor in May this year (2019). It is now in operation.*

Interviewer: *How did you get involved in the formulation of the Act?*

MD Kakamega: *The Company played a big role in the sense that our Board were already in place by that time that the Act was being formulated. In the Act, we really wanted the issues that pertained to the company being licensed by WASREB to come out clearly in which to separate the urban areas from rural areas. Because initially the Act was about the entire operation of water within Kakamega county. But we came strongly to say that we need to address/separate issues of urban areas alone, then we look into rural areas separately in which the Act to guide rural areas will be formulated on its own. Now as we are talking, the rural water Act is in the County Assembly for public participation. There are a lot of gains made under urban company which the company felt it should not be brought down due to normalizing the operations at rural areas that require huge funding management conflict and sustainability issues. So, we played a very big role.*

Interviewer: *Were there any external factors that favoured the formulation of the Water Act?*

MD Kakamega: *There was not much external factors that favoured the process since the entire process had a blessing of the Governor. So, we had a full discussion, very serious ones with his excellency, the Governor was chairing the meeting. Present were the County Government operation lead by the County Attorney and the Company's Board of Directors lead by the chairperson, to harmonize before it goes to the other stakeholders. So we got involved from the beginning.*

Interviewer: *Is the NRW reduction included in the Water Act? (If yes), can you elaborate the section of NRW reduction in the Act?*

MD Kakamega: *It is included and it comes out as regulations. The County Ministry of water in conjunction with the Company to come up with regulations how to regulate this Act, so that regulations can guide the operationalization of the Act. In the Act, part of it talks about the water and sewerages services provision Section 30 sub section I and 2. Just to mention a few highlights,*

Section 30 sub section 1

a) Tempering of water infrastructures including water meters
b) Installation of illegal/unauthorized water connections
c) Use of substandard material which have not been approved. e.g. pipes, meters etc.

Sub section 11, talks about the punishments including fines. It talks about the area of operation of the Company. If I may narrow it down on that.

Interviewer: *Do you think the County Water Act will help your Company's efforts to reduce NRW?*

MD Kakamega: *The County has been, and is still helping the Company in terms of NRW reduction. For example,*

They procured almost 1000 meters for the schemes in Mumias, simply because NRW in Mumias is more than 52%. They have procured meters to enable us to have NRW reduced because the most of meters have not been operational.

They are also changing our pipelines replacing most of them by HDPEs pipes. They have procured some pipes and done rehabilitation using HDPE pipes to ensure water wastage is not really encountered within the Company.

County has set aside good amount of money KES 87million to support the headquarters, Kakamega area so that more people can get water in a more organized way. The money will facilitate construction of water storage tank of 5 million litres within the Kakamega town.

Interviewer: *What challenges do you foresee (or experienced) in implementing the County Water Act?*

MD Kakamega: *First pronounced challenge is the areas touching on National and County Cooperation and how to harmonize the two. Remember, now the County Act talks about water cooperation and while the National one talks about Water Company. So, this is a grey area we need to harmonize with the support of WASREB and our County attorney's office so that there is no conflict of information and interest.*

Second, the regulation of the Act. We need to move with the speed so that regulation addresses needy gritty issues which will enable this Act to operate. For example, storm water within urban areas is the function of the County Government under general 4 of the Act. But you will find the other acts addressing about the town management is also talking about storm water. So, we need to decide who is going to be responsible. For an example, when the storm water once enters our sewerage system, we have problems of blockage and overflow when it is raining. We need to have this Act within the County harmonized. Those are the two challenges we might experience as we implement.

Interviewer: *Is the formulation of the County Water Act the way to go for the WSPs in NRW reduction? What do you think?*

MD Kakamega: *That is very true. I have shared with other utility colleagues our Act as a sample, so that they can also develop theirs. The development of the act should be in line with devolution or constitution and guided by the national government through WASREB or the Ministry. On issues about NRW and clearly indicating how we are going to handle it. Since water service provision is the mandate of the county government, the county* *government should come up with the act to safeguard those areas that have already been done. Because all Governors and county executives Members are not the same but once the act is there for future, it will protect the water utilities.*

Interviewer: *Are there alternative ways you can advise on NRW reduction to other WSPs apart from the county to formulate Water Act?*

MD Kakamega: *Yes it is true. We are working on NRW reduction strategies of performance-based contract (PBC) with the support of PEWAK. This is an organization that has been supporting us in reduction of NRW tackling both commercial and physical NRW activities. We have given a contractor one year with specific targets which is supposed to end in next two and half month or three to reduce NRW in that given areas. They look for things like:*

- *efficiency or effectiveness of meter readings;*
- *how are our meters operating;*
- *how many people are within that area;*
- *who have been disconnected and likely to be back in the system without our knowledge;*
- *Identification of illegal connection which we cannot 100% rule out in our water supply.*

The arrangement has seen us increase our operations and decrease our NRW from 57-44% in that specific areas of the contract for a period of 8months. It is simply identifying the commercial and physical NRW then we narrow down. If it is commercial which I know it takes a lot of parentage.

We sat down and did analyse to determine proportion of commercial and technical losses. For commercial losses we realized that we didn't need a lot of money to fix the issues. We looked at:

- *Our billing systems*
- *What is the mode of reading our meters?*
- *How are our people getting meter operated?*
- *Do we have meter testing machine on the ground?*
- *How are our meters being read? By use of our smart phones which I know most of the companies have adapted*

We do SMS billing. We went 100% cashless and I will advise others if you to go cashless, remain cashless 100%. Initially Kakamega – Busia was billing and collecting between KES13-15 million a month. We are now cloaking around ksh20-22 millions.

Interviewer: *Lastly, what advice can you give to other WSPs who are struggling to have their Counties to formulate Water Act?*

MD Kakamega: *During WASPA's bimonthly meetings, we can share and see the advantages and disadvantages and how we can approach these areas. There are counties that are fast learners and there are others that are slow depending on county leaderships so after the MD's getting the information, they can drive it through the CECM water successfully and ensure the gains made can remain in that county. Through the Act, if it is supported then WSPs can benefit in terms of*

- *Funding from the county*
- *Address issues of destructed/destroyed pipelines during upgrading of roads within the county*
- *Harmony in working relationship etc.*

Interviewer: *Mr. Atwa, thank you very much for your time.*

Note: Kakamega County Water Act is available from Kakamega County Government Website.

Interview took place in March 2020.

6. CHILDREN'S VOICE

On February 2020, Murang'a Water and Sanitation Company Limited (MUWASCO) embarked on an NRW reduction sensitization activity by inviting pupils from Kiawambeu Primary School and Ndikwe Primary school to MUWASCO's water treatment facility. Students learnt about water treatment processes, the cost of producing safe drinking water using chemicals, and the efforts by MUWASCO which operate the plants 24 hours/365days towards ensuring adequate and reliable supply of clean water to the consumers. We asked students about the visits. Here are some of their voices.

It was on Monday when we visited MUWASCO. We discovered very many things there. I was very surprised to know how the water is processed there. That day, I went home to tell my father to connect that water to our home. Water from MUWASCO is very sweet and clean. When you take water from MUWASCO, you can't get a dangerous disease. MUWASCO's clean water is safe for drinking. (Rita, Class 7)

Then I think about how water is stolen and I imagined those processes that water's chemicals caused very much money. I imagined when people steal water, what did they help with it? And I asked myself what did they see they are? Then I imagined how they steal. Those people who steal water, their heads are not good. Because they steal water to do what? (Sabina, Class 7)

Many homes were supported by water from MUWASCO. We use water from MUWASCO. Because the water from MUWASCO was very sweet. (Josphat, Class 7)

When I grow up, I will be an engineer. (Phillip, Class 7)

They were dirty water and when we were being shown it was clean water. I was shocked and surprised because they are dirty water and when I go to another place that water was very clean as a pin. That water was colorless. That water had no particles and was free from microorganisms. (Derrick, Class 7)

The chemicals are so expensive like chlorine is five thousand and they buy everyday ten. If you can see someone is stealing, you can report. (Jacinta, Class 7)

After a short tour, we then gathered and one of the engineers asked us how the water is misused. We gave the answers. Water is stolen in many ways. One is connected pipes from the meter to any other place. The other one is cutting the pipe and left the pipe leaking the water. Because he or she does not care about the water. People remove their original meters and put fake meters and then use water. When the bill comes, he seems that they did not use water. (Grace, Class 7)

We also learned how to keep water safe for drinking. We can boil water for drinking but the safe water is the one that is treated. (Levis, Class 7)

That day we were very happy. Thank you, teacher and other officers, for the lesson. God bless you. I will not forget that visit to the Murang'a Water and Sanitation Company. (Kelvin, Class 7)

The people were given the cup to drink water from the tap. In that MUWASCO, their water was best water and fresh. (Simon, Class 7)

7. EVENTS AND ACTIVITIES

7.1. The 3rd WASPA's International Water Conference & Expo

Left: Panellists discussions at the conference hall Right: NRW Unit officer briefing on NRW to Deputy President of Kenya

The 3rd WASPA's International Conference & Expo were held from 8th to 10th May, 2019 at KICC, organised jointly by MWS&I, WASPA and development partners. The conference was attended by government agencies, WSPs, international stakeholders, private sectors, and Kenyan citizens.

The events theme was" Unlocking the potential for a water secure world". Water scarcity is one of the environmental challenges of Kenya is facing. The conference intended to look at the strategies that can be put in place to make Kenya's water secure by exploring the technologies that can be adapted at utilities and even at household level. International exhibitors gave the conference participants opportunities to share experiences, best practices and the emerging technologies on water use, water conservation and even reduction of NRW.

7.2 Thematic workshop on illegal water use

A one-day thematic workshop on 'Illegal Water Use' was held on 5th August, 2019 as a part of JICA's project undertaken by the Ministry. The forum brought together over 70 senior managers, NRW managers and technical staff of WSPs all over the county to share their challenges, best practices, experiences and ideas on illegal water use. Ideas and suggestions to tackle the malpractice were discussed and their own home-grown solutions were proposed.

Overwhelming participation showed strong interests on the topic

The participants successfully shared their experiences on ways to find illegal connections, preventing illegal water use, safety of the employees when looking for illegal connections, the needs for legal backup, increasing customer ownership while building the corporate culture to discourage illegal water use. The formulation of the County Water Act for enforcement, which is a collaborative activity between the County Governments and the WSPs emerged to be the urgent issue for many WPSs.

7.3 Forum for Enhancing Sustainability of Urban Water Services in Sub-Saharan Africa

JICA conducted an “Executive Forum for Enhancing Sustainability of Urban Water Services in Sub-Saharan Africa” in Kigali, Rwanda on 13th and 14th November, 2019. It was the first forum of its kind to be conducted in African continent by JICA. The forum aimed at establishing a network among water service entities in the sub-Saharan countries and strengthening their water service activities by sharing the knowledge and experiences. It was attended by at least 60 participants from eight (8) countries among them 15 Water & Sanitation utilities, represented by Managing Directors or CEOs or their supporting staff as shown in the table below.

Table 7: Countries and Participating Utilities to the Forum

	Country	Name of Entities
1	Kenya	Embu Water& Sanitation Co., Nakuru Water & Sewage Services Co., Kisumu Water & Sewage Co.
2	Rwanda	Water &Sanitation Corporation (WASAC)
3	Malawi	Lilongwe Water Board
4	Nigeria	Federal Capital Territory Water Board
5	Tanzania	Zanzibar Water Authority
6	Zambia	Lusaka,Western,Luapula,Kafubu water utilities
7	Sudan	Gesira State Water Company (SWC),White Nile SWC, North Kordofan WSC
8	South Africa	Ekurhuleni WSD

Keynote speech was given by Dr. Shigeyuki Matsumoto, Deputy Director General, Global Environment Department, JICA, on “Improvement of Water Supply Management of Water Utilities in Asia – to Utilize Asian’s Experience in Africa”, in which he introduced Asian successful experiences and emphasized for their application into African contexts. Kenya was represented by 3 WPSs whose Managing Directors presented the following topics:

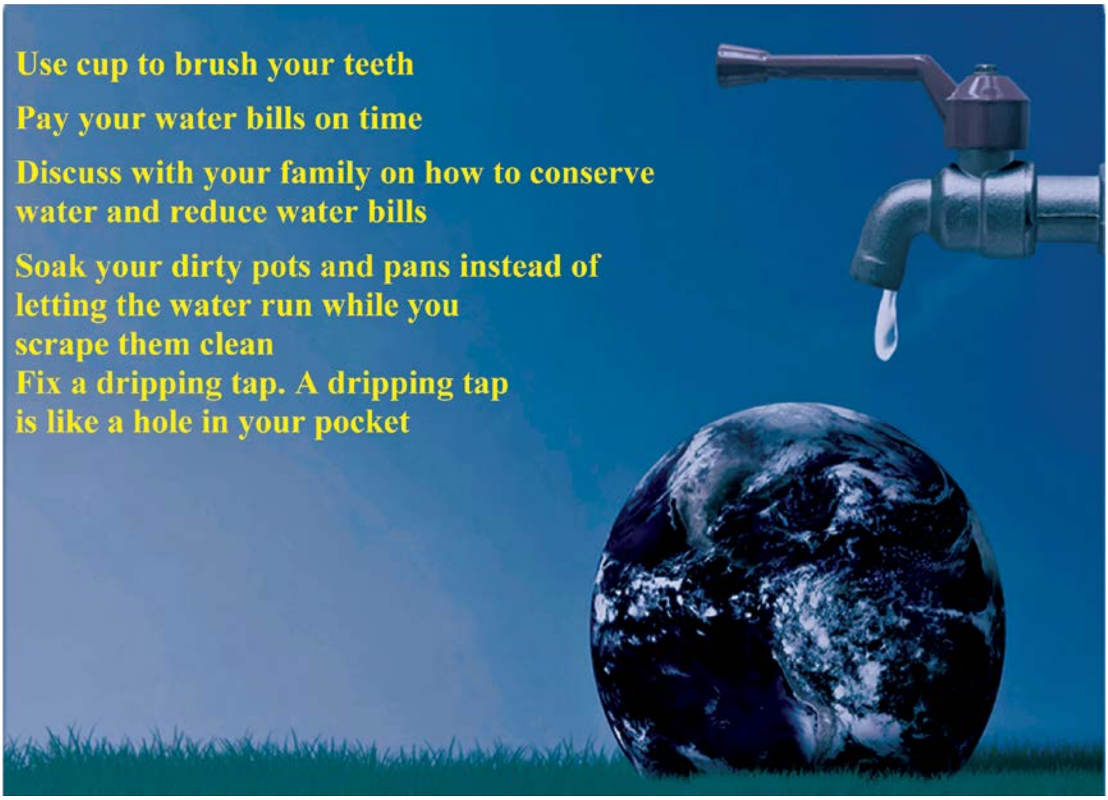
(i) Eng. Karugendo (EWASCO); sensitization on effective water use through the visits by primary school pupils to water treatment plant
(ii) Mr Gehathi (NAWASSCO); increasing revenue by improving meter readings and billing data focusing on large customers.
(iii) Mr Odongo (KIWASCO); success in decreasing NRW in a low income residential area.

All the participants. Ms. Yuko Hotta, Japanese Ambassadress to Rwanda (front centre). Dr. Shigeyuki Matsumoto, Deputy Director General, Global Environment Department, JICA (front left).

Left: Representatives from Kenya. Eng. Karugendo, Mr. Gehathi, and Mr. Odongo. Right: Participants enjoyed dancing with local dancers at the welcome reception

8. CITIZEN'S ACTION CORNER

The small actions you do at home to save water can lead to big changes. By taking following actions, you will be helping your water company to access adequate and reliable water to you and your neighbours.



Non-Revenue Water Reduction Management Short Course

Overview

With a total turnover of KES 20.6 billion for the water supply sector, NRW ratio stands at 41% against a sector benchmark of 20% which implies that the sector is losing KES 7.8 billion due to NRW. Despite the rolling out of NRW Management Standards, the uptake and implementation of Standards are not effectively used. The selection of quality water meters, accurate water balance analysis, identifying leakage points and causes of leaks among others remain as challenges. KEWI in collaboration with the Ministry of Water, Sanitation &Irrigation, Japan International Cooperation Agency (JICA) and Water Service Providers (EWASCO & MEWASS) have restructured NRW Reduction Management Course. Six courses already conducted under the programme, 150 personnel from the 16 WSPs have benefited from the training: Those WPSs are: Embu, Meru, Nyahururu, Nakuru, Eldoret, Ruiru-Juja, Mavoko, Kilifi-Mariakani, Kisumu, Thika, Machakos, Kiambu, Narok, Kapsabet, Nanyuki, Naivasha, MWS&I and other institutions.

Feedback from participants

Feedback of participants from the trainings are positive. They gained knowledge of; procedures and strategies for NRW reduction, elimination of major commercial losses, necessary intra-organizational linkages, operation of NRW equipment, meter accuracy test, analyse NRW related data.

Benefits to Employer

The course is aimed at benefiting the WSPs in reducing and managing NRW and increasing revenue collection. Reports from the pilot WSPs in the JICA's project are encouraging with some of WSPs could reduce their NRW ratios an average of 25% from 40%.

Target Group

The course is designed for personnel involved in metering, O&M of distribution networks, billing and leak detection as NRW activities

Learning Objectives

At the end of the course, participants will be able to:

1. Conduct water balance calculation
2. Cultivate good work ethics
3. Manage water distribution networks, distribution reservoirs and hydraulic concept
4. Work Ethics and Compliance
5. Manage system pressure
6. Control physical, commercial losses and billing
7. Manage leak survey and prevention methods
8. Undertake workflow approach to NRW Reduction
9. Identify leaks through water quality assessment
10. Interpret and use NRW water standards
11. Plan and implement NRW reduction activities
12. Formulate NRW action plan reduction
13. Use and apply NRW equipment

Course Sessions:

1st Session (Classroom training at KEWI)

Participants will undertake theoretical classes and demonstrations

2nd Session Field On-the-Job training (OJT) in Embu EWASCO

Participants will engage in field and practical activities by collecting data using NRW management equipment and interpreting it.

Course Dates: Available on our website: www.kewi.or.ke short course calendar

Course Fees: The training costs are as follows:

Session 1. Classroom (Nairobi, KEWI) for 5 Days:
KES. 30,000.00 Residential
or
KES. 22,500.00 Non-Residential

Session 2. On-Job Training (Embu, EWASCO) for 6 Days: KES. 24,700.00 Non-Residential

For more information on the course kindly email info@kewi.or.ke or wmoseti@gmail.com, or Mobile: 0700-413901

KEWI: Mission Statement:

"To offer competency-based Training, Research, Consultancy and Outreach Services in the Water Sector for Sustainable development"

This report was produced as part of JICA project "The Project Strengthening Capacity in Non-Revenue Water Reduction in Kenya".

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1) -3 NON-REVENUE WATER MANAGEMENT
Annual Report 2019 – 2020

MINISTRY OF WATER, SANITATION AND IRRIGATION

NON-REVENUE WATER MANAGEMENT

DRAFT ANNUAL REPORT – 2019/2020

FOREWORD

The year 2019/2020 was a period of immense challenges to all facets of humanity and the water sector was not spared. The entire world was going through an extraordinary emergency due to the COVID-19 pandemic. As a countermeasure against the coronavirus (COVID 19) in Kenya, the Ministry issued a circular to all water institutions directing them to ensure that adequate handwashing points were installed within all urban areas including market centers, bus stations, and shopping malls. In addition, all the Water Works Development Agencies were directed to ensure all public water points within their respective towns/city centers were fully operational for effective hand washing services.

As I reflect on 2019/2020, we have been reminded on the significance of water. Reliable supplies of clean water have been fundamental to keeping us safe during COVID-19.

Our Ministerial policy objective in relation to water losses remains to develop and implement Non-Revenue Water (NRW) reduction strategies for all categories of Water Service Providers (WSPs) across the nation. Kenya is still recording high levels of NRW, currently standing at 47%. Our focus still is to bring NRW level to the globally acceptable level.

This third report on NRW management highlights some of the activities that the Ministry, in conjunction with other sector players, have undertaken towards NRW reduction. It also illustrates the impact of COVID-19 on Water Service Providers and responses undertaken.

As a Ministry we continue to partner and acknowledge JICA with much appreciation for their efforts in training nine of our water service providers (WSPs) on NRW reduction strategies. We acknowledge their support in form of water treatment chemicals to cushion the nine water service providers (WSPs) against the impact of the COVID-19 pandemic.

We believe as a Ministry that the implementation of the proposed NRW strategies will be a step forward to sustaining the nine pilot water utilities and will be replicated to other water utilities across the country.

James .W. Macharia, E.G.H
Ag. Cabinet Secretary
Ministry of Water, Sanitation and Irrigation

PROJECT FOR STRENGTHENING CAPACITY IN NON-REVENUE WATER REDUCTION IN KENYA

The national NRW ratio for 2019/2020 was reported at 47% against an acceptable sector benchmark of 20%. This figure means that WSPs only get 53% of the revenue from the water they produced and the remaining water produced is not accounted for as revenue. During this financial year, we were challenged by COVID-19 pandemic which reminded us that sustainable services provided by WSPs are key in public health emergency.

This Annual Report for 2019/2020 intends to provide Kenyans with the strides achieved while executing NRW reduction activities which are implemented by the Ministry and our counterparts in the water service sector. “The Project for Strengthening Capacity in NRW Reduction in Kenya” started in October 2016 by the government of Kenya in collaboration with JICA has so far made significance impact in the reduction of NRW of nine WSPs; Embu, Meru, Nakuru, Ruiru-Juja, Nyahururu, Kisumu, Mavoko, Eldoret and Kilifi-Mariakani.

The project aims at establishing support systems for sustainable NRW reduction in the country as well as enhance the capacity of the WSPs in NRW reduction.

Implementation of this project has been challenging during this financial year of 2019/2020 as deployment of some JICA experts from Japan was hindered by the COVID-19 outbreak, limiting communication through e-mail and telephone.

NRW reduction continues to be achieved in the project with concerted efforts of both national and county governments, WASREB, KEWI, JICA, WASPA and the pilot WSPs. All the 9 pilot WSPs have been formulating NRW reduction annual plans every year by using a template created by the project. The template aids them to review their performance and recognize their challenges.

This report explains some of the approaches that the project has so far identified as effective for NRW reduction.

In summary the approaches are as follows:

- Strengthening WSPs organizational structures that will enhance NRW management through NRW reduction activities to ensure improvement of coordination between NRW staff, commercial and operations and maintenance staff.

- Enhancing the supporting mechanism for WSPs by for instance equipping the NRW unit with equipment such as leak detectors will ensure effective NRW activities.
- Conducting various activities targeting the WSPs entire service areas, executing leak reduction and pressure reduction in hydraulically isolated areas within their distribution networks.

We all have a duty as stakeholders in the water sector, to promote activities and ensure best practices that enhance NRW reduction are embraced in our community.

Dr. Andrew.K.Tuimur, CBS
Chief Administrative Secretary
Ministry of Water, Sanitation and Irrigation

PREFACE

In the year 2019/2020, the Water Service Providers (WSPs) in Kenya lost approximately 151 million cubic meter of safe and treated water. In monetary terms, this is equivalent to Kshs.11.61Billion. NRW endangers sustainability of water distribution operations implying that quality water service provision to the consumers remains low.
Going by the findings of WASREB, a majority of the regulated utilities have the potential to finance their operations sustainably with internal resources by embracing greater respect for standards and endeavor for performance and efficiency. We have witnessed examples of WSPs who have undergone financial transformation in the Project for Strengthening Capacity in NRW Reduction in Kenya, in partnership with Japan International Cooperation Agency (JICA).

The Ministry remains steadfast in ensuring sustainable water services provision in the country through the WSPs. The Ministry through the NRW Unit in collaboration with our counterpart organizations like Water Service Regulatory Board (WASREB), Kenya Water Institute (KEWI), Water Service Providers Association (WASPA), Japanese International Cooperation Agency (JICA), are also on board in development of the new NRW standards. WASREB regulates utilities to ensure that there is fairness and non-discrimination in the provision of services and also to empower consumers on their rights and obligations. WASREB will also develop new license regulations that centers on the NRW Standards.

This report is the 3rd volume that details information on NRW reduction during the 2019/2020 Financial Year. The report aims to sensitize players in the water sector in a bid to create a joint effort towards realizing reduction of NRW to acceptable levels 20%.

I wish to acknowledge the contribution of the Water Secretary Eng. SAO Alima under whose able guidance and leadership the report was produced. Similarly, to all who contributed directly or indirectly towards production of this 3rd NRW Report, I say thank you.

Dr. (Eng.) Joseph K. Njoroge, CBS
Ag. Principal Secretary
Ministry of Water, Sanitation & Irrigation

ACKNOWLEDGEMENTS

Reducing water losses is critical to efficient resource utilization, efficient utility management and heightened consumer satisfaction. The cost of improved service delivery are much lower when undertaken through investments in non-revenue water reduction rather than through investments in capital projects to augment supply capacities.

Immense effort and invaluable commitment has gone into use to ensure that Kenyans are provided with objective information on the progress and implementation of the Ministry`s NRW activities. I take this opportunity to express my official gratitude to all our project counterpart institutions: Water Service Regulatory Board (WASREB), Kenya Water Institute (KEWI),Japanese International Cooperation Agency (JICA). Nakuru Water & Sanitation Services Company (NAWASSCO) is also recognized in a special for making great strides in NRW reduction and in particular the Managing Director for spearheading the achievements made by the institution in terms of NRW reduction.

I also wish to particularly recognize and acknowledge Ministry of Water, Sanitation and Irrigation technical officers from Non-Revenue Water Unit that worked diligently in the collection and compilation of the articles that went into production of this report. The Pilot WSPs who have been instrumental in providing extremely useful comments and feedback on initial drafts of this report, I thank them most sincerely for their time and goodwill.

I would like to express our sincere appreciation and special thanks to JICA Expert Team from the project for their guidance, dedication and expertise in planning strategies and execution of NRW activities. With this level of commitment, I know it is just a matter of time for NRW to start going down from the current level of 47%.

I urge all the Water Service Providers in the country to sustain the war on NRW by combining their efforts through commitment, knowledge sharing and embracing sound strategies.

God bless you all.

Eng. SAO Alima
WATER SECRETARY

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ACRONYMS

Abbreviation	**Name**
AWWA	American Water Works Association
CAPEX	Capital Expenditure CECM County Executive Committee Member
CEO	Chief Executive Officer
CIS	Customer Identification Survey
CoG	Council of Governors
DMAs	District Meter Areas
ELDOWAS	Eldoret Water and Sanitation Company
EWASCO	Embu Water and Sanitation Company
GIS	Geographic Information System
GoK	Government of Kenya
HDPE	High Density Polyethylene
IWA	International Water Association
JICA	Japan International Cooperation Agency
KEWI	Kenya Water Institute
KES	Kenyan Shilling
KIWASCO	Kisumu Water and Sewage Company
KPIs	Key Performance Indicators
LIAs	Low Income Areas
MEWASS	Meru Water and Sewage Services
MNF	Minimum Night Flow
MUWASCO	Murang'a Water and Sanitation Company Ltd.
MWS&I	Ministry of Water, Sanitation and Irrigation
NAWASCCO	Nakuru Water and Sanitation Services Company
NPBF	National Performance Based Financing
NYAHUWASCO	Nyahururu Water and Sanitation Company
NYEWASCO	Nyeri Water and Sewerage Company
NRW	Non-Revenue Water
OPEX	Operating expenditure
PBC	Performance Based Contract
PEWAK	Performance Enhancement of Water Utilities in Kenya
PI	Performance Indicator
SDGs	Sustainable Development Goals
SWC	State Water Company
UFM	Ultrasonic Flow Meter
USAID	United States Agency for International Development
VEI	Vitens Evides International
WASPA	Water Service Providers Association
WASREB	Water Services Regulatory Board
WRA	Water Resource Authority
WSB	Water Service Boards
WSP	Water Service Provider

1 INTRODUCTION

As we reflect on 2019/2020, we have been reminded that access to safe water for all remains the backbone of well-being of Kenyans. Reliable supplies of clean water have been fundamental in keeping us safe during COVID-19 pandemic. The Government of Kenya (GoK) put in place the following measures but not limited to the same for instance: adequate handwashing points were installed within all urban areas including market centers, bus stations, and shopping malls. In addition, all the Water Works Development Agencies were directed to ensure all public water points within their respective towns/city centers are fully operational for effective hand washing services.

According to Water Services Regulatory Board (WASREB), the Kenya's national average Non-Revenue Water ratio for the year 2019/2020 was 47%. This is far from the target set in the National Water Services Strategy (NWSS) of less than 30% and Vision 2030 goal of less than 25%.

A high level of water losses is due to leaks and thefts from the system; as well as losses due to inaccurate or non-meter readings and billings because of poor management of customer records.

Source: WASREB Impact Report

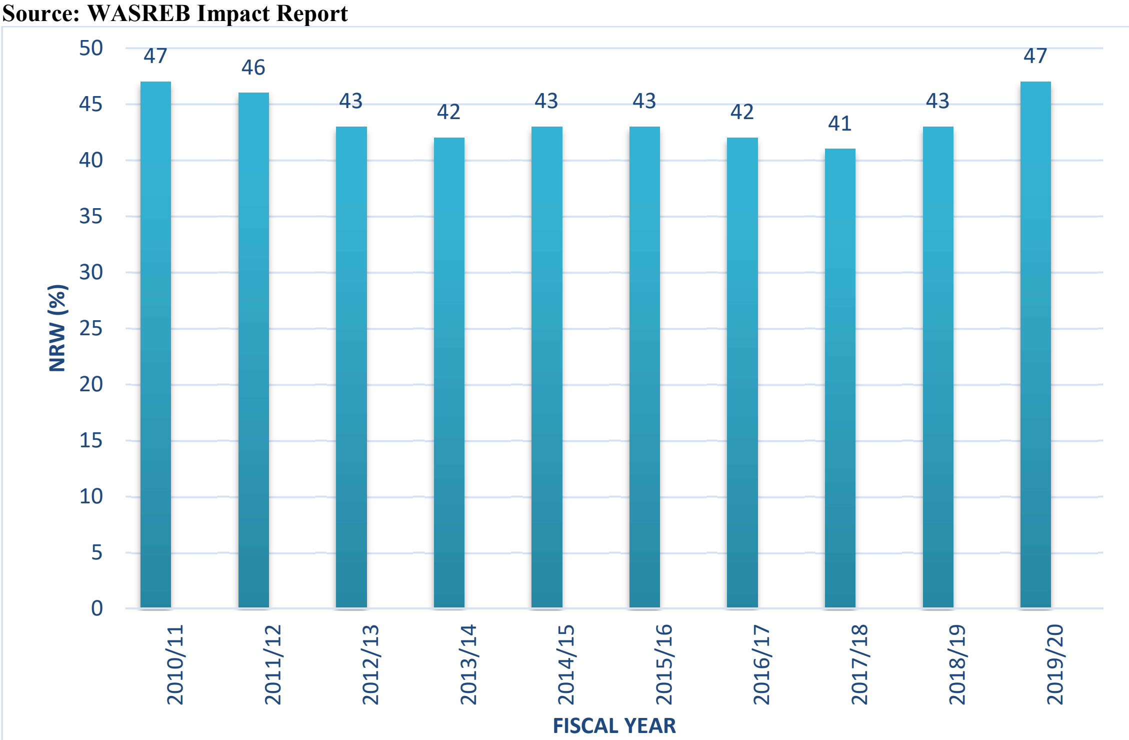


Figure 1: National Trend of NRW Ratio in Kenya

1.1 What is NRW?

NRW is in general defined as the amount of water produced for distribution but which is not accounted for as revenue.

1.1.1 NRW Ratio

The level of NRW is expressed as ratio (percentage). The formula for NRW ratio is defined as follows

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

In monetary terms, for the year 2019/2020 Water Service Providers (WSPs) had a total turnover of **Kshs.22.80 billion** with an average NRW of 47% against an acceptable sector benchmark of 20%. This means WSPs only got 53% of revenue from the water they produced (100%). The financial implication is that the sector is losing slightly more than Kshs. 11.61 Billion and a volume of **151 million cubic meters.** This is adequate to serve Nairobi County with a daily demand of **750,000M3/day** for approximately **six and a half months.**

The impact of water loss in Kenya is substantial. A collaboration of all water counterparts and equal partners is required to combine efforts to deal with this challenge.

In this context the Ministry of Water, Sanitation and Irrigation initiated measures to address and tackle issues of water losses and develop NRW management standards in order to mitigate the current challenges.

Figure 2 shows a comparison NRW levels of various countries including Kenya. Our national target is NRW levels of below 20%.

Source: Global Water Intelligence- water data 2019

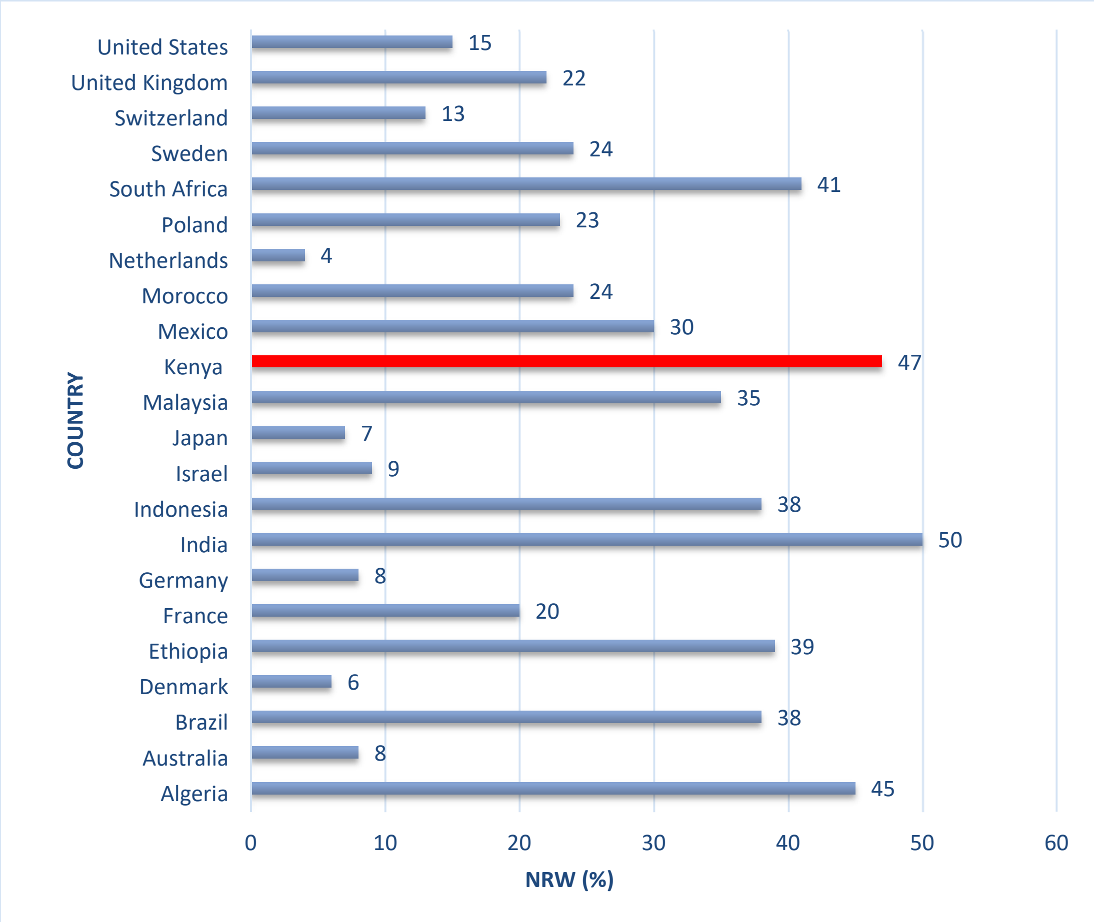


Figure 2: NRW ratios of selected countries

1.2 Addressing Non-Revenue Water

Physical losses and commercial losses have negative impacts on the overall performances of the WSPs. Physical losses cause an increase in the operating costs whereas the commercial losses reduce the revenues. This is clearly illustrated through the vicious and virtuous circles (Figure 3 and 4). The vicious circle shows that an increase in NRW level would result in higher production costs and eventually less revenues. The water utilities are challenged to transform the vicious circle to the virtuous one. Once this transformation is achieved there is a more likelihood of water utilities to earn more revenue.

1.3 Impacts of NRW: the Vicious and Virtuous Circles

The 'Vicious Circle' of NRW (Figure 3) depicts one of the key reasons for poor performance of a water utility that results in both physical and commercial losses. Physical losses, such as leakages, reduces the volume of water required to serve customers and increases operating costs. In return, the end user or customer is unsatisfied with the services of the water utility. Physical losses results in larger investments than necessary to augment the network capacity. Commercial losses, caused by inaccuracies of customer meter, poor data handling and illegal connections, reduces water utilities` income .

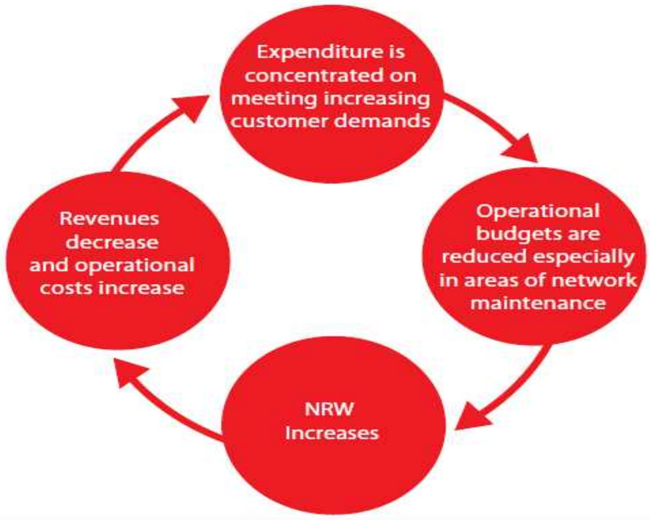


Figure 3: Vicious NRW cycle

Figure 4: Virtuous NRW cycle

The task for the water utility managers is to transform 'the vicious circle' (Figure 3). into 'the virtuous circle' (Figure 4). Reducing NRW creates new sources of both water and finances. Reducing excessive physical losses results in a greater amount of water available for consumption and lowers the operating costs. Similarly, reducing commercial losses generates more revenue.

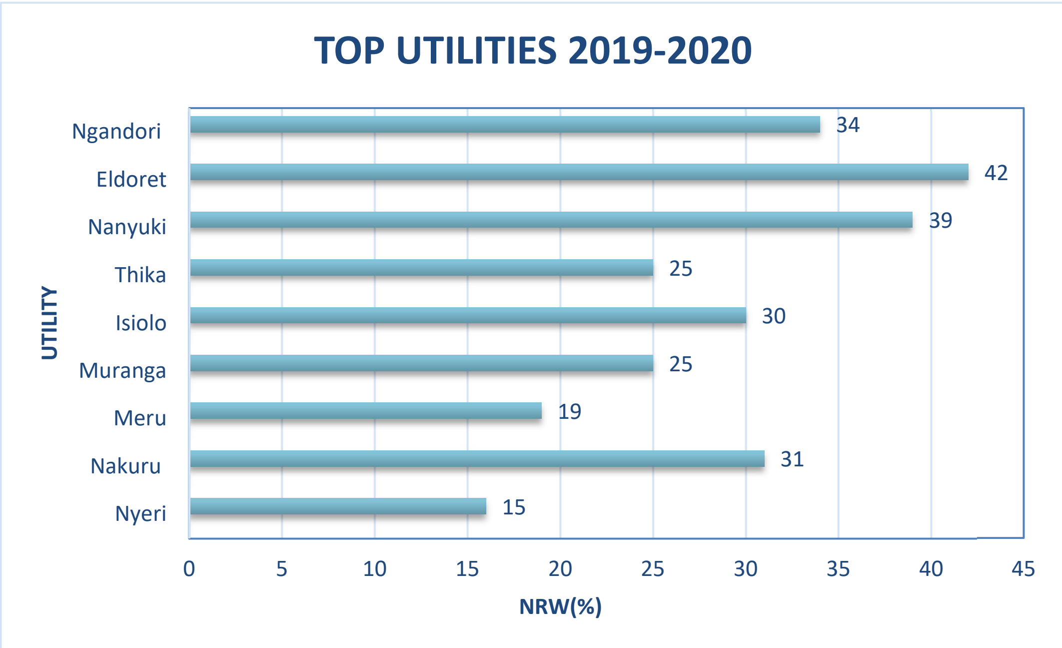
Studies have reported the following key points that lead to failure in NRW management in water utilities:

- NRW management is not approached as a long term commitment with involvement of all the departments of water utility.
- There is a lack of awareness on the complexity and magnitude of NRW or the potential benefits of reducing NRW.
- Utilities would rather invest in `visible' new projects than invest in leakage reductions.
- Successful NRW reduction is not an isolated technical problem, but it is linked to overall operations, asset management, customer support, financial allocations among other factors.

1.4 Monitoring of NRW ratio

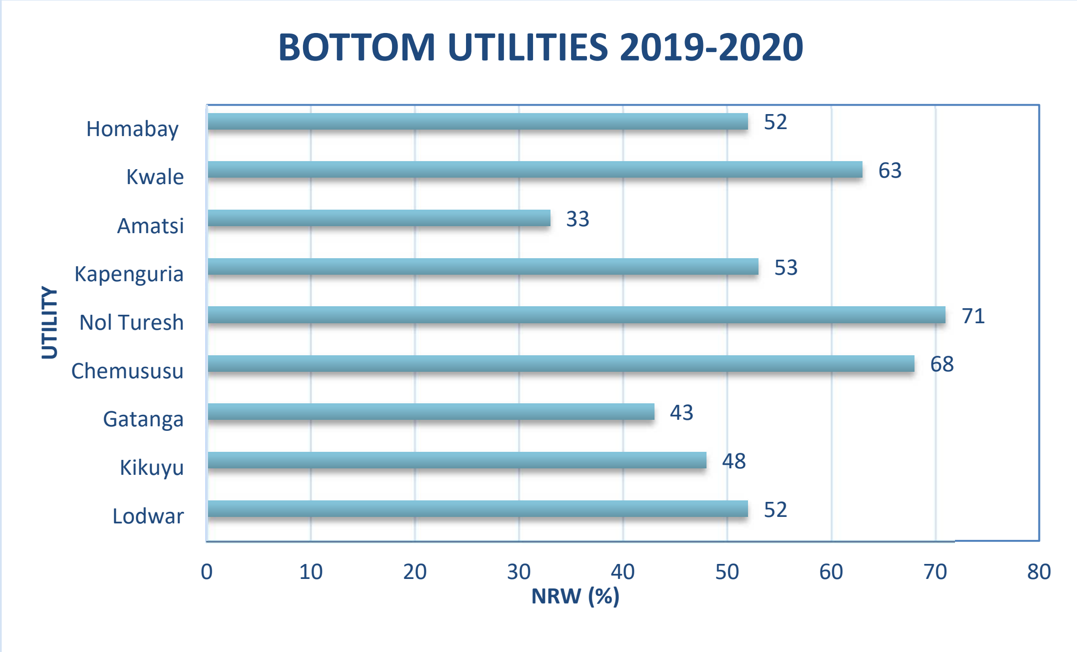
WASREB regularly monitors NRW ratio of WSPs and reports in its Impact Report annually. Figure 4 shows the top 9 ranked water utilities with low NRW ratio. In the year 2019/2020, Nyeri Water and Sewerage Company (NYEWASCO) was listed as the best performing WSP with the lowest NRW ratio of **15%.**

Similarly, figure 5 shows the bottom 9 ranked water utilities with high NRW ratio. Nol-Turesh WSP has the highest NRW ratio of **71%.**



Source: WASREB, Impact report 13

Figure 5: Top 9 utilities in NRW ratio 2019-2020



Source: WASREB, Impact report 13

Figure 6: Bottom 9 utilities in NRW ratio 2019-2020

1.5 Knowing water losses

1.5.1 The water balance

Most water utilities use the level of NRW as a key performance indicator of efficiency. However some water utilities may tend to underestimate NRW because of institutional and political pressures. Inaccurate levels of NRW, whether due to deliberate misinformation or, more likely, a lack of accurate information, will not help the water utility to reduce its costs or increase revenue. Instead, it will mask the real problems affecting the water utility's operating efficiency.

Water utilities need to properly understand their NRW situations. This can only be properly understood by them and the required actions taken by quantifying NRW and its components, calculating appropriate performance indicators, and turning volumes of lost water into monetary values.

The first step WSPs can take to reduce NRW is to establish current levels of water losses through a water audit. The water audit leads to a water balance. This process helps utility managers to understand the magnitude, sources and cost of NRW.

The calculation of a water balance is very important because:

- It is the basis of assessing the level of water loss for any utility.
- A first time calculation reveals the availability and reliability of data and level of understanding.
- It is a mechanism for benchmarking.
- Comprehending the water balance is essential for water utilities to prioritize actions and investments
- Provides a first step towards improvement.

This first step is critical, yet it is often overlooked. The International Water Association (IWA) developed a standard international water balance structure and terminology that has been adopted by national associations in many countries across the world, as shown in table 1.

Table 1: Water Balance

<table>
<tr><td rowspan="9">System Input Volume</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Metered Consumption</td><td rowspan="4">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Commercial Losses</td><td>Unauthorized Consumption</td><td rowspan="5">Non-Revenue Water</td></tr>
<tr><td>Metering Inaccuracies and Data Handling Errors</td></tr>
<tr><td rowspan="3">Physical Losses</td><td>Leakage on Transmission and/or Distribution Mains</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 Metering</td></tr>
</table>

Source: International Water Association

- **System Input Volume** is the annual volume input to that part of the water supply system.
- **Authorized Consumption** is the annual volume of metered and non-metered water taken by registered customers, the water supplier, and others who are implicitly or explicitly authorized to do so (e.g. water used in government offices or fire hydrants). It includes exported water and the leaks and overflows after the point of customer metering.

- **Non-Revenue Water (NRW)** is the difference between System Input Volume and Billed Authorized Consumption. NRW consists of Unbilled Authorized Consumption (usually a minor component of the water balance) and Water Losses.
- **Water Losses** is the difference between System Input Volume and Authorized Consumption. It consists of Commercial Losses and Physical Losses
- **Commercial Losses,** sometimes referred to as **'apparent losses',** consist of Unauthorized Consumption and all types of metering inaccuracies
- **Physical Losses**, sometimes referred to as **'real losses'**, are the annual volumes lost through all types of leaks, bursts and overflows on mains, service reservoirs and service connections, up to the point of customer metering.

Apparent losses can be calculated as follows:

AL = NRW – (RL+ UAL)

Where: **AL** = Apparent Losses: unauthorized consumption, metering inaccuracies and data handling errors;

NRW = Non-Revenue Water: the difference between system input volume and billed authorized consumption;

RL = Real Losses: leaks, overflows;

UAL = Unbilled Authorized Losses: volume of unmetered water taken by registered customers, the water supplier and others who are authorized to do so.

1.5.2 Calculating a Water Balance

For the water balance to be calculated the constituent pieces of data need to be measured or estimated. Whereas some of the key components can be measured others may have to be estimated. In most cases there is likely to be a mix of data accuracy and it will be necessary to estimate the exactness of each of these components.

There are four steps to calculating a water balance:

- **Step 1** – determine system input volume by identifying all sources and quantities of water entering the network.
- **Step 2** – determine authorized consumption through analysis of billing records and identifying authorized use that is either unbilled or unmeasured.
- **Step 3** – estimate apparent (commercial) losses by assessing the level of customer meter under-registration and estimates of illegal connections and theft.
- **Step 4** - calculate physical (leakage) losses by adding the volumes from steps 2 and 3 and subtracting from step 1

Source: (Alegre H, Hirner W, Baptista J.M, Parena R, Performance Indicators for Water Supply Services. IWA Manual of Best Practice, July 2000. ISBN 900222272.)

Although it is always worth trying to establish a water balance (at least the calculation of accurate NRW ratio), the percentage of each commercial loss component (i.e. meter accuracy error, data handling error, and illegal water uses) is quite difficult to estimate with a reasonable accuracy especially in a country like Kenya where the estimation of billed consumption due to faulty meters and illegal water uses are quite common but not well recorded nor analyzed. The commercial losses are usually underestimated significantly in such countries due to the difficulties of estimating their volumes, which often results in the serious negligence of commercial loss reduction at WSPs while disproportionally blaming their technical departments and/or aging pipe networks for their high NRW ratio. Nevertheless, for advanced utilities with the NRW ratio is less than 25% where the commercial losses are limited and accurate losses are easily estimated, the reliable volumetric estimation of each commercial loss component may be possible to some extent. By doing the trial establishment of a water balance table, it would be possible for them to produce a catalogue of required actions that are needed to improve the accuracy of the water balance.

2 ROLE OF PERFORMANCE INDICATORS IN NRW REDUCTION

2.1.1 Monitoring Performance of NRW Management

NRW is one of the measure of a water utility's efficiency in terms of its financial and operational performance. Managers, policymakers, regulatory agencies, and financing institutions use NRW as one of the performance indicators (PIs) to rank the utility's performances against industry standards and other water utilities.

2.1.2 Characteristics of performance indicators

Using NRW as a performance indicator helps a water utility to:

- Understand water losses better
- Monitor compliance
- Prioritize investments
- Define and set targets for improvement
- Measure and compare performance

A good NRW PI should be clear and easy to comprehend and have a rational basis. Similarly, it should also be easy to calculate by using data that the utility gathers regularly. Finally, utilities should include standard performance indicators to measure performance and facilitate comparisons with other utilities.

PIs are categorized by function, level and defined as follows:

• **Level 1 (basic):** Is a first layer of indicators that provides a general management overview of the efficiency and effectiveness of the water undertaking.

• **Level 2 (intermediate):** Additional indicators that provide a better insight than the Level 1 indicators; for users who need to go further in depth.

• **Level 3 (detailed):** Indicators that provide the greatest amount of specific detail, but are still relevant at the top management level.

Table 2: Recommended indicators for physical losses and NRW

Function	Level	Performance indicator	Comments
Financial: NRW by Volume	1 (Basic)	Volume of NRW [% of System Input Volume]	Can be calculated from simple water balance not too meaningful
Operational: Physical Losses	1 (Basic)	[Litres/service connection/day or [Litres/km of mains/day] (only if service connection density is < 20/km)	Best of the simple 'traditional' performance indicators, useful for target setting, limited use for comparisons between systems
Operational: Physical Losses	2 (Intermediate)	Litres/service connection/day/m pressure] or [Litres/km of mains/day/m pressure] [only if service connection density is < 20/km)	Easy to calculate indicator if the ILI is not known yet, useful for comparisons between systems
Financial: NRW by cost	3 (Detailed)	Value of NRW [% of annual cost of running system]	Allows different unit costs for NRW component, good financial indicator
Operational: Physical Losses	3 (Detailed)	Infrastructure Leakage Index (ILI)	Ratio of current annual Physical losses to unavoidable annual real losses, most powerful indicator for comparisons between systems

Source : Alegre H., Hirner W. Baptista J. M. and Parena .R. (2000) Performance Indicators for Water Supply Services: IWA Manual of Best Practice. ISBN 90022227

3 STAKEHOLDERS IN NRW REDUCTION AND THEIR ACTIVITIES

3.1 Ministry of Water, Sanitation and Irrigation

At a glance:

The NRW Unit has been actively campaigning on NRW reduction to county governments and the general public.
NRW annual management report intends to educate the public on NRW, benefits of reducing NRW and activities done by stakeholders in the water sector towards reduction of NRW.
More water utilities are conducting NRW sensitization campaigns targeting schools children in order to nurture the habit of water conservation at a young age.

The NRW Unit in the Ministry is responsible for promoting and coordinating the NRW reduction activities across the country. The Ministry has been promoting NRW reduction through NRW sensitizations and awareness campaigns to schools and the public and the following is the progress made in this reporting period:-

3.1.1 County sensitizations

The Ministry organized the 2nd Regional County sensitization workshop in Nanyuki Laikipia County in November 2019. The workshop was part of the ministry's strategy to reduce NRW by sensitizing the water managers and County decision makers on NRW reduction issues. It involved sharing knowledge on NRW reduction, the good practices in NRW reduction the challenges faced in the NRW reduction as well as coming up with sustainable strategies to reduce NRW.

The workshop was attended by Laikipia County Executive Committee Member (CECM) and County water directors from Laikipia, Meru, Isiolo, Nyeri counties and Managing Directors of: Nanyuki, Nyahururu, Isiolo, Meru, Imetha,Nyeri, Othaya-Mukurweini, Tetu-Abandare and Mathira Water and representatives from WASPA, WASREB and JICA.

Welcoming remarks from the CEC of Laikipia county

Group photo of the workshop participants

3.1.2 Thematic workshops with WSPs

Due to COVID-19 pandemic and ban on public gatherings a virtual workshop was organized theme being, *'Sharing the best practices on use of smart metering and use of Ultrasonic flow meters'*. Targeted invitees included Technical Managers and other WSPs officers.

3.1.3 School campaigns

The NRW Unit believes creating awareness among school-going children on the benefits of reducing water losses and nurturing the habit of water conservation is a powerful way of conveying messages on the importance of water conservation for in both the short and long-term. The NRW Unit continues to encourage and support WSPs to organize NRW related campaigns targeting school children. The COVID-19 pandemic prevented WSPs to interact with school children in person. The Unit is producing educational videos for the students to learn about water processing and water services. A series of four videos will be produced and be posted online so that schools and other learning institutions can use to sensitize students. The videos are on the following themes.

- Water Treatment Processes
- Water Quality Management
- Water Supply process
- Water Conservation

3.2 The Water Services Regulatory Board (WASREB)

At a glance:
WASREB considers NRW management as a governance issue. Measures to reduce NRW such as tariff identification, regular reporting, and the performance-based contracts are in place. NRW Management Standard has been reviewed.
Innovative approaches such as performance based contract and National Performance Based Financing have been introduced to support WSPs to improved NRW reduction

3.2.1 Background

Water losses continue to be the biggest challenge to a majority of counties. It is worrying that 21 counties up from the previous year's 14, lost more than 50% of the water they produce. During FY2019/20, the country's annual average NRW has increased from 43% to 47% when compared to 2018/19. In monetary terms, for the year 2019/2020 Water Service Providers (WSPs) had a total turnover of Kshs.22.80 billion with an average NRW of 47% against an acceptable sector benchmark of 20%. The financial implication is that the sector is losing slightly more than Kshs. 11.61 Billion. The volume of water lost annually after allowing for the 20% acceptable level of losses is 151 million cubic meters. This is adequate to serve Nairobi County with a daily demand of 750,000M^3/day for approximately six and a half months. The impact of this loss is substantial. Concerted efforts are therefore required from all actors to deal with this challenge.

To deal with this challenge, WASREB as the regulator is reviewing the NRW management standards to incorporate experiences from the last six years of implementation. The licensing process also provides an avenue to entrench some of the practises proposed in the standards.

3.2.2 Deepening governance

Despite continuous efforts by water utilities to contain the water loss, success has been limited. For this reason, WASREB has established that NRW using sector governance guideline frame-work. WASREB is keen to enforce good governance principles in the sector that allow appointment of directors and utility mangers that possess both competences and capacities to drive, adopt and provide leadership on innovations around NRW management and ultimately demonstrate accountability to the stakeholders. The regulator has now developed a governance indicator whose objective is to institutionalize implementation of governance ethos.

3.2.3 NRW Management Guidelines

In 2014, WASREB issued the NRW Management Standards which composed of 4 publications: Guidelines, Manual, Handbook, and Case Studies) and distributed them to WSPs. The results of the study on the usage of the Standards indicated that many activities recommended in the Standards required major investments. For medium and small WSPs who often struggle with operation and maintenance costs, the activities in the Standards may not be easy to implement. The study found that the uptake and implementation of the Standards have been fairly low. WASREB concluded that utilities failed to prioritize and institutionalize NRW management and thus capacity growth meant to address NRW challenges have not been realized.

WASREB is now revising the existing NRW Management Standards. The objective of the revision is to propose new approach to NRW management which include institutional approach with governance agenda, taking the lead role to turn around NRW.

The revision of the NRW guidelines is at the final stage with the draft guidelines has been finalized. Two validation workshops were held to collect stakeholder comments on the draft: first held in Nakuru town on the 27th -28th of May 2021 and the second held on the 29th -30th July 2021. The comments collected from the two workshops were integrated into the standards. A national validation conference was held on 25th November 2021 in Nakuru town. The guidelines are currently being finalized before being launching and dissemination.

3.2.4 Licensing of WSPs

The Water Act 2016 under Section 72 (c), gives WASREB the mandate of setting license conditions and accrediting Water Service Providers. The License is therefore a statutory requirement which gives the WSPs the power to provide water services in the Counties. As a tool for regulating the sector, the License sets out the conditions and targets of performance to be observed by WSPs to ensure quality in service provision.

Through this mandate, WASREB has been setting performance improvement targets for all licensed WSPs for all the 9 KPIs including NRW. With this, WASREB tasks the WSPs to constantly reduce the NRW within their utilities and achieve the negotiated performance targets. Failure to perform the set targets would lead to a surcharge of their performance guarantee.

As part of the license conditions, WASREB requires that all WSPs establish an NRW unit in their organizations. The NRW unit should be embedded in the approved organization chart and approved by the Board of Directors. The head of the NRW unit should placed at level 3 (management) as outlined in the model NRW organization chart developed as part of the NRW management guidelines.

3.2.5 Monitoring and National Reporting

WASREB conducts regular monitoring of utilities through inspections using both internal capacity as well as outsourcing as appropriate. A key element of these inspections' entails reviewing implementation of outlined NRW reduction activities. Continuous engagement of utilities on this subject matter will lead to progressive attendance to NRW as a core issue to the utilities.

WASREB is mandated to collect, process and maintain data as well as report on all issues of water services to the citizens. An analysis of NRW levels and their issues of concern are reported annually by WASREB IMPACT reports, outlining the best and worst performers on NRW management for the purposes of encouraging benchmarking and adoption of good practices. Through IMPACT report, WASREB sends a wake-up call to the poor performers to think and review their strategies.

3.2.6 NRW Performance as Per Impact 13 Report

The increasing level of losses currently at 47%, coupled with the decreased production and an increasing population, negatively impacts on the progressive realization of the right to water. At the current NRW level of 47% and sector turnover of Kshs. 22.796 billion, the sector is losing approximately Kshs. 11.61 billion after factoring in the acceptable level of losses of 20%.

Water loses continues to be the biggest challenge to a majority of counties. It is worrying that 21 counties up from the previous year's 14, lose more than 50% of the water they produce. Migori county has the highest losses at 77%. Looking at the current period and comparing with the previous period, the unit cost of water produced remained fairly constant. However, the foregoing situation has contributed to the significant change in unit cost of water billed from Kshs. 87 per cubic metre to Kshs. 93 per cubic metre. If this state of affairs is not mitigated, there is going to be a very great risk, which will undermine the progressive realization of the right to water as is enshrined in the constitution. In addition, the achievement of operational sustainability by the respective water utilities based on the principle of social commercialization, may not be realized. The issue of concern is that the reasons contributing to the very high levels of NRW are not technical, but largely commercial and governance (corruption and illegal practices). This means that with minimal resources and strict enforcement of guidelines/rules, these losses can be reduced to acceptable levels. This call for goodwill from all the actors such as staff members, Boards of Directors of utilities, National and County Governments, political leaders, community leaders, consumers, judiciary, law enforcement personnel and development partners.

The regulator will continue to enforce a number of interventions to deal with this challenge. These include:

a) Incorporating in the license condition a requirement for a strategy to deal with NRW including having the requisite structure and staff

b) Revision of the NRW management standards to incorporate the lessons learnt in the last six years of implementation

c) Having NRW as a key component in assessing the potential of a utility to turn around.

3.2.7 Tariff Indexation

WASREB introduced NRW management as a tariff condition. This is in order to conditionally cushion utilities against vagaries of inflation costs. While the regulator will enforce utilities to meet NRW management for its tariff conditions, failure to achieve will lead to the WSP being automatically denied the opportunity to adjust its tariff rates unit such a time that the NRW targets are met. This has been done for all WSPs applying for a tariff renewal.

3.2.8 Alternative/ Innovative Approached to Tackling NRW

Non-revenue water (NRW) management can deliver significant financial and economic benefits, and to a large extent, NRW programs can be self-financing with rapid revenue gains from commercial loss reduction. For example, revenue gained can provide funds required for operating expenditure (OPEX) and capital expenditure (CAPEX) needed to reduce the NRW.

But these benefits often remain unrealized, because water service providers face many political, financial and technical hurdles. NRW PBCs (performance-based contracts) provide an opportunity to invite a third party to overcome some of these hurdles, with the incentive to do so as rapidly and cost-effectively as possible. WASREB believes that specific innovations like PBC in NRW management could be an option for utilities to access capacity in terms of skills, equipment and resources that they may lack. In this regard, WASREB has been championing the use of PBC as an alternative approach to tackling the NRW problem in Kenya.

In addition to PBC, WASREB has partnered with the world bank and the MWS&I and designed the programme "National performance-based finance (NPBF) "It will provide WSPs, through a competitive framework, to be eligible for receiving concessionary credit financing from the world bank that is specifically targeted to address NRW reduction activities provided the initially set targets and outcomes are realized within the framework of regulation coupled with project execution strategy.

The initial stage is underway and expected to draw lessons learnt from NPBF's financing mechanism entailing a scale up strategy and guidelines shall be generated to inform a framework of sustained drive of addressing NRW in the country.

3.2.9 Collaboration with the Counties

WASREB has been collaborating with the county governments through a county engagement strategy centered on three key areas: awareness, governance and performance. Counties own water utilities but oversight them at arm's length for clear accountabilities. This collaboration with the counties is therefore central to the success of NRW activities countrywide and eventual reduction of inefficiencies in the utilities.

Counties are encouraged to support their utilities to implement the required interventions to deal with the NRW challenge. These interventions include close oversight of the utilities and strengthening of enforcement mechanisms within the county water legal framework. The county legal framework should help in discouraging the offenders by putting necessary penalties in place. The regulator on its part, will continue to intensify efforts to deal with the challenge. This will be done by enforcing the regulatory standards through imposing conditions in both licenses and tariffs, as one means of institutionalizing NRW management function at respective utilities.

3.3 Kenya Water Institute (KEWI)

At a glance:

- KEWI's new NRW training course has theoretical sessions and field training at WSP.
- From inception of the project for Strengthening Capacity in Non-Revenue Water reduction, 179 staff members from 22 WSPs have undertaken the new NRW course
- KEWI continue to improve their course materials and modules incorporating evaluation results

3.3.1 Review and Revised NRW Training Course

KEWI has been continuously reviewing its NRW training materials from 2017 to 2020 and restructured the course now have two sessions

- Classroom sessions with theory and demonstrations
- On-Job Training which entails NRW field practical trainings and the use of NRW equipment

On-Job Training is normally conducted in conjunction with water utilities. In Embu Water and Sanitation Company (EWASCO) KEWI has conducted NRW joint trainings between 2017 –2020 as a part of JICA project activities. Summary of trainings are in the table below.

Table 3: List of trainings conducted

Classroom	On-Job Training	No of participants
6th – 10th June 2017	19th -24th June 2017	20
23rd - 27th April 2018	4th – 29th June 2018	41
14th – 18th August 2018	27th August – 1st September 2018	13
4th – 8th March 2019	18th – 23rd March 2019	16
3rd – 8th June 2019	17th – 22nd June 2019	20
19th -23rd August, 2019	26th – 31st August, 2019	6
11th – 15th November, 2019	25th – 30th November, 2019	26
9th – 13th March, 2020	23rd – 28th March, 2020	15
9th – 13th November, 2020	23rd – 28th November, 2020	22

Source: KEWI

continuously reviews the training materials and mode of training reflecting the feedback of third party evaluation whose evaluators are invited to the training sessions. Joint training evaluation scores of participants indicates the improvement of the courses provided.



Classroom Training

Since inception of the project for **Strengthening Capacity in Non-Revenue Water reduction**, KEWI trained 179 staff from more than 22 WSPs (Embu, Meru, Nyahururu, Nakuru, Eldoret, Ruiru-Juja, Mavoko, Mathira, Kericho, Malindi, Kilifi-Mariakani, Kisumu, Thika, Machakos, Kiambu, Narok, Kiambu, Kapsabet, Nanyuki, Naivasha, Lodwar, Iten and Nairobi) and other relevant institutions.

KEWI representative is a part of reviewing team of the WASREB's NRW Management Standard and Working Team to disseminate the revised Standards.



Participants on Joint On-Job trainings in the field, had opportunities to experience practical activities of NRW reduction and the use of NRW Investigation Equipment

3.4 Japan International Cooperation Agency (JICA)

At a glance:

- JICA's pilot project targets 9 water utilities and organizations supporting them to reduce NRW.
- Identification of the unbilled customers, monitoring of large customers' meters, scouting visible leaks, and standardizing service connections are effective ways to reduce NRW.
- Strengthening organizational structure for NRW management and encouraging the involvement of entire WSP are the keys to effective NRW reduction.

The Government of Kenya and JICA entered into partnership under the Project for Strengthening the Capacity of NRW Management with the overall goal of developing support mechanism for NRW reduction in the country and enhancing NRW reduction activities in WSPs. The project started in October 2016 for five years and later extended until May 2022 due to the COVID-19 pandemic

The project targets nine pilot WSPs (Eldoret, Embu, Kilifi-Mariakani, Kisumu, Mavoko, Meru, Nakuru, Nyahururu and Ruiru-Juja) covering the entire Kenya as well as MWS&I, KEWI and WASREB to enhance their roles in reduction of NRW nationwide.

3.4.1 Targets

The project targets nine pilot WSPs (Eldoret, Embu, Kilifi-Mariakani, Kisumu, Mavoko, Meru, Nakuru, Nyahururu, Ruiru-Juja) covering the entire Kenya as well as the MWS&I, KEWI, and WASREB to enhance their roles in the nationwide efforts for NRW reduction.

3.4.2 Key Activities of the Pilot WSPs and their Achievement

Through the baseline survey, challenges related to NRW reduction were identified for each pilot WSP. Their progress and relevant capacity have been self-reviewed annually before preparing their annual NRW reduction plans and updating their medium-term NRW reduction plans. The following approaches of this project have been recognized as effective for NRW reduction.

1. Various Activities Targeting Entire Service Areas and Leak Reduction in Isolated Areas

To accelerate large-scale of NRW reduction, the NRW reduction activities that are relatively easy to expand have been prioritized in a view of covering the entire service areas. Activities such as identification of the unbilled customers, monitoring of large customers' meters, scouting visible leaks, and standardizing service connections were effective to reduce NRW. The majority of pilot WSPs were successful at reducing NRW ratio significantly through the project although the pandemic reversed their progress by hindering their activities and causing large revenue losses.

Meanwhile, the pilot WSPs have been carrying out leak detection and pressure reduction in hydraulically isolated areas within their distribution networks, which are effective especially under continuous water supply condition. The gradual separation of entire service areas into distribution zones and then into smaller DMAs for detailed NRW monitoring has also been supported at the pilot WSPs while a higher priority is given to the improvement of their universal NRW monitoring targeting the entire service areas.

2. Strengthening Organizational Structure for NRW Management

Each pilot WSP has been encouraged to strengthen their organizational structures for NRW reduction. This includes the engagement of commercial department in NRW reduction activities and the improvement of coordination between NRW staff and O&M staff. Addressing the problems found through meter reading, and planning various NRW reduction activities are good opportunities to involve a wide range of staff across multiple departments and sections in NRW reduction. It was found in several pilot WSPs such as Eldoret & Embu that the organizational restructure is one of the most effective measures for NRW reduction.

3. Enhancing the Supporting Mechanism for WSPs

NRW Unit of the MWS&I have been conducting sensitization activities to increase the awareness of NRW among county governments and the general public while supporting the pilot WSPs through the procurement of equipment required for NRW reduction. The NRW Management Standard issued by WASREB in 2014 has been reviewed and a revised version will be presented in 2021. The project also supported KEWI to improve their NRW short courses partly by adding practical field sessions.

Photos of the flagging-off ceremony

3.4.3 Donation of Chemical during the COVID-19 Pandemic

In response to the Covid -19 pandemic, JICA donated water treatment chemicals through this project. The chemicals were given to the 9 pilot WSPs through the MWS&I in a colorful event that was flagged-off by JICA Kenya Office's Chief Representative Mr.

Katsutoshi Komori together with the Water Secretary Eng. S.A.O Alima, Irrigation Secretary Mr. Aboud Moeva and Secretary Administration Mr. Joseph Keter on 9th July 2020 at Maji House.

The donated chemical was comprised of 50, 535 kg of chlorine, 728,085 kg of alum and 92,400 kg of soda ash at a total cost of Ksh 40 million. This donation was meant to cushion the negative financial influences of the pandemic on the WSPs for a period of 3 months. Kenyan WSPs were not supposed to compromise on the quality of treated water while being directed not to disconnect the overdue customers to fight the virus with hand washing.

Mr. Komori in his speech reiterated the role of JICA assisting the MWS&I as well as WASREB, KEWI and WSPs for NRW reduction. He hoped that the chemicals will contribute to maintaining safe water supply to the people in Kenya.

Eng. Alima who read the speech on behalf of the Principal Secretary Mr. Joshua Irungu extended his appreciation to the government and people of Japan for the continuous support including the fast response to the pandemic.

3.4.4 Lessons Learnt and Way Forward

Based on the experiences with the pilot WSPs, the project has developed a template for each WSP to plan various NRW reduction activities based on a thorough self-assessment of their current situation. WASREB is expected to share the template with WSPs nationwide when publishing their revised NRW management guideline. Besides, the revised guideline recommends key measures for each stage of NRW reduction as shown in table 4 below.

Table 4:The Five Stages of Non-Revenue Water Reduction Measures

Stage	Approx. Range of NRW %	Recommended NRW Reduction Measures (Note: GIS development and NRW monitoring are not listed here, but they are required as support for NRW reduction measures)
Stage-1	**NRW ratio ≧ 40%** (or unknown or unreliable)	◆ Determine the accuracy of production meters by testing and calibrating, and replacing if faulty or inaccurate. ◆ Eliminate major commercial losses by servicing and testing (and replacing faulty) customer meters and, identifying illegal uses (starting with large and then medium customers). ◆ Install meters for unmetered customers and identify unbilled customers through Customer Identification Survey (CIS) and issue them with bills. ◆ Reduce the time taken to repair bursts, surface leaks and overflows.

Stage-2	**30% < NRW ratio < 40%**	◆ Intensify Stage-1 measures by e.g. establishing routines, etc. ◆ Isolate distribution zones and district metered areas (DMAs) with accurate bulk meters and do NRW monitoring. ◆ Reduce underground leaks by step testing, acoustic survey and pressure reduction in priority areas (this leak reduction can be carried out as a pilot project). ◆ Map bursts and leaks and monitor their recurrences. ◆ Introduce better pipe materials and fittings for new pipelines and service connections (e.g. HDPE or uPVC-D/E). ◆ Minimize commercial losses (including at small customers and data handling errors) by improving meter reading and billing systems, and their uses.
Stage-3	**24%< NRW ratio 30%**	◆ Intensify Stage-2 measures listed above. ◆ Reduce underground leaks in other areas. ◆ Start replacing pipes which are prone to bursts and leaks.
Stage-4	**20%< NRW ratio ≦ 24%**	◆ Intensify Stage-3 measures listed above. ◆ Accelerate and complete pipe replacement.
Stage-5	**≦ 20%**	◆ Intensify Stage-4 measures listed above. ◆ Maintain the facilities and skills to sustain the achieved low NRW ratio.

Note 1: This table is prepared based on experiences of project in Kenya.
Note 2: The approx. percentage range of NRW ratio for each stage corresponds to that of commercial viability criteria for each level included in WASREB Guideline on Clustering of WSPs (August 2018).

4 REPORT FROM WATER SERVICE PROVIDERS

4.1 Nyahururu Water and Sanitation Company Ltd (NYAHUWASCO)

At a glance:

NYAHUWASCO has been conducting sensitization campaigns in schools in order to enlighten students on various issues concerning but not limited to:

- Water treatment.
- Payment of water bills.
- Wastewater management.
- Water conservation and pollution.
- Non-revenue water.
- Hygiene

4.1.1 School sensitization campaign

On 3rd September 2020, a team of staff visited Starehe Primary School in Nyahururu town environs. The team drawn from Production, Technical and Commercial departments held an interactive discourse with the pupils from class six to eight, the number being limited due to COVID-19 protocols which were being observed to the letter.

The first to take the floor was the production officer who began with water abstraction from the Ngare Naro river just before the famed Thompson Falls. He took them through the process of pumping the water to the water treatment unit, explained how the brown looking water is eventually turned to clean water and then to the main supply lines.

He exited the floor and gave the mantle to the technical officer, who explained to the attentive pupils how water distribution up to the customer's meter is done. Not only that, but he brought to their attention of losses of water through: bursts, leaks, and theft which contributes to the non-revenue water. He also enumerated several mitigation measures and the pupil’s part to play in curbing the losses.

‘’Clean water has a cost!!’’, the accountant almost shouted, after rising up to replace the now exiting technical officer. He explained to the pupils, whose curiosity had been further aroused by the statement, about the costs involved from the production of water up to when it reached the consumer's meter. He explained to them the need to pay water on time and took them through the different payment modes introduced by the company to ease payment.

The presentation was brought to an end by an explanation of how waste from households and businesses is treated in the sewerage plant. The pupils were amazed by the process and wondered how the waste would end up as clean water, which later rejoined the water cycle. Proper hygiene was also insisted upon and waterborne diseases highlighted

The pupils were given a chance to shoot their questions, which they did in quick succession. The officers were at hand to answer them to their satisfaction. The session was brought to an end by the moderator requesting the pupils to do a composition of what they had learned. The best pupils to be given a tour of the company’s installations.

"Every child you encounter is a divine appointment." – Wess Stafford


Nyahururu water and sanitation company LTD staff and students of Starehe Primary School during the sensitization campaigns.

5 EFFECT OF COVID-19 PANDEMIC ON WATER SERVICE PROVISION

5.1 Effect of COVID -19 on the Water Sector in Africa

This is based on a report done by the United States Agency for International Development (USAID) that assessed the effects of the novel Coronavirus Disease 2019 (COVID-19) on access to water, sanitation, and hygiene (WASH) services and products. The report encompassed studies done in seven countries that is: the Democratic Republic of the Congo [DRC], Ghana, Kenya, Mozambique, Nepal, Rwanda, and Senegal). The mission of the study was to illustrate the current state of affairs and to forecast near-term trends that could assist governments, donors, and other implementers prepare an informed response to the WASH-related impacts of the pandemic.

In summary, the synthesis of that work, carried out between June and October 2020 detailed the following findings in as far as water supply is concerned:

- The pandemic made water access more difficult for consumers, there were declines in water access linked not only to economic shocks borne by consumers but also to financial pressures endured by water service providers (WSPs) as they suffered revenue shortfalls, due to both government directives for free water provision and tariff collection difficulties.
- Water access difficulties driven by COVID-19 were reported across the urban-to-rural spectrum. It was reported that across the six countries in which the team conducted SMS surveys, that roughly one-third of both urban and rural respondents reported that the pandemic had made access to drinking water more difficult. In Kenya and Rwanda for instance, the proportions of urban respondents reporting COVID-linked water access difficulties were 5 and 15 percentage points higher than that of rural respondents, respectively.
- Water suppliers also faced major financial challenges, and some operational obstacles related to supply chain disruptions and price increases for chemicals. International donors and other lenders have offered some assistance that has been essential to service providers. In some countries, the assistance had been significant and sufficient for the immediate term. In selected countries, there were service disruptions particularly for smaller operators who had exhausted cash reserves and were unable to cover electricity costs to operate pumps.

5.2 Effect of COVID -19 on the Water Sector in Kenya

COVID-19 has adversely affected the global community and like most countries, Kenya has not been spared. The economic shock as a result of COVID-19 varies widely across countries. The first case of COVID-19 in Kenya was reported on March 13th, 2020.

It is reported that countries such as Kenya that rely heavily on tourism and remittances suffered comparatively more. Similarly, there was a huge negative economic effect in countries where the government`s response resulted in more extensive or longer-duration movement restrictions.

In Kenya, the government instituted COVID-19 control measures which resulted in cessation of movement across some counties, as a result there were significant economic losses. The Kenyan economy suffered from major pandemic-related declines in both tourism and remittances. According to the report on ``***assessing the effects of covid-19 on access to water, sanitation, and hygiene in USAID high priority and strategy-aligned countries – USAID’’*** Kenyan water service providers (WSPs) were required by the government to provide tariff-free water to low-income areas (LIAs), including previously unserved areas, and to reconnect disconnected customers. This intervention caused considerable financial pressure on WSPs.

Both large and small water service providers suffered major losses due to tariff holidays and elevated production associated with both free provision and emergency water provision measures. Smaller providers were particularly vulnerable, making clear the need for efficient distribution of rescue funds to operators other than the largest urban utilities.

Kenyan water service providers (WSPs) also were subject to government directives, including:

- free water service provision to low-income areas (LIAs), including previously unserved areas
- no disconnection of non-paying customers
- reconnection of disconnected customers
- establishment of additional water points in LIAs (via tanker delivery)
- installation of handwashing stations in public areas.

(Source: Assessing the effects of COVID-19 on access to water, sanitation, and hygiene in USAID high priority and strategy-aligned countries – USAID)

5.3 Effect of COVID -19 on the Water Sector – International Situation

In USA, the report titled *‘The Financial Impact of the COVID-19 Crisis on U.S Drinking Water Utilities’* released in April 2020 by American Water Works Association and Association of Metropolitan Water Agencies revealed the colossal financial impact of COVID - 19 on water utilities.

Drinking water utilities across U.S.A experienced revenue and cost impacts associated with the national, state, and local response to the COVID-19 crisis.

The report states that water utilities across the nation were expected to experience an estimated revenue shortfall of $7.4 billion (annualized) due to declines in revenue from non-residential customers (i.e. commercial, industrial, and institutional) in terms of water consumption due to the COVID-19 crisis. Other effects included:

- **Changes in utility policies** to not shut off water service to customers with delinquent accounts and providing forgiveness of late penalty fees. This included preparing estimates of the anticipated rise in delinquencies due to the policy change, as well as due to anticipated rising unemployment rates.

- **Losses in revenue from non-residential** (i.e., commercial, industrial, and institutional) customers, net of residential revenue increases, as a result of national and state directives for the temporary shutdown of non-essential businesses and "stay at home "orders.
- **Operational actions** taken, or anticipated to be taken, by water utilities to ensure safe and reliable water service, such as sequestering water operators and other key staff.
- **Reducing, deferring or eliminating capital expenditures** to preserve cash and help maintain financial sustainability.
- **Reduction in system development charges** and user charges from new growth due to slowing of economic growth and development.

6 INTERVIEW WITH A NRW MANAGEMENT CHAMPION

Eng. James Gachathi: Managing Director Nakuru Water & Sanitation Services Company (NAWASSCO)

So many WSPs have stumbled on their journey to reduce NRW in their water utilities, but there are those who seem to have mastered the art of reducing NRW. NAWASSCO has exhibited great success in reducing NRW and we are glad to present our interview with the MD who is the key person at the institution.

Interviewer: Thank you for the opportunity you have given me to ask you about your approach to NRW reduction. I would like to ask you about Nakuru's approach to NRW reduction, I am interested to learn about the approaches you are putting in place and the effectiveness of the changes to reduction of NRW ratio.

The current Impact Report positions NAWASSCO among the top as the most improved and best performing after Nyeri water, how did you navigate your way to the top?

MD NAWASSCO: WASREB uses 9 indicators to rate the regulated WSPs in the country and those indicators are further clustered into 3 as follows:

- Quality of service
- Financial stability
- Operations

So we work on the 9 indicators in total as a team. And because those 9 indicators cut across. It means that everyone in the organization is involved and as we do that we also carry our customers with us.

Interviewer: So minimizing NRW is a priority for each staff in your organization?

MD NAWASSCO: Yes, we have actually sold out that message to all our staff. We have done this by simplifying it in monetary terms (Kenya shillings). All our staff now understand that if you reduce NRW by 1% that translates to 1 million shillings revenue equivalent. So like in the month of October our NRW water ratio was 29%. So if you rate that against the green color when WASREB rates you, green color is when you are 20% and below meaning NAWASSCO loses 9 million from the water it sells to the customers during the month. This is equivalent to an annual loss of 108 million which can do a lot of things when it is put in to operation. So when you sell that message in

Kenyan shillings every staff comprehends the impact of the water losses.

Interviewer: How do you manage to coordinate these departments to work on one goal?

MD NAWASSCO: First you need to identify the lead people or the lead champion departments. In this particular case in this organization it is understood the two big departments that are the center of NRW are the technical and the commercial departments. All staff involved in these two departments meet every month together with the MD and all other managers in the other departments because that is the only way the message can spread to all staff in other departments. The point here is teamwork as the quote says *"if you want to go faster move alone, but if you want to go far walk as a team"*. So it's the issue of teamwork that makes the issue of NRW to become a priority to all of us.

Interviewer: What are some of these activities that you are focused on to bring your NRW down?

MD NAWASSCO: For us the first thing was to unpack the International Water Association (IWA) water balance into its constituent elements in order to understand the elements in the water balance causing them to lose water. Are they physical losses e.g. leaks, bursts, tank overflows or are they commercial losses i.e. water theft and billed consumption and once we unpack that, we are able to gather our energies and deal with areas we are losing water and that way, we were in a short term able to bring down NRW and when it came down, we started seeing money flowing in our bank.

We also work as a team in the organization selling the idea that NRW is a problem for us all. We also engage our customers in reporting of physical losses. We have over 30 WhatsApp groups that keep on posting/ reporting when they come across a leak or vandalism of infrastructure.

Interviewer: Did you coordinate the formation of the WhatsApp groups through your institution or how did they come about?

MD NAWASSCO: The institution has only two WhatsApp groups only which tries to bring our customers on board. Our customers went ahead and created another extra twenty eight and added our field staff. The beauty is that an issue can be raised in the group and we are able to address. I believe that a customer who is complaining is trying to tell us something than a customer who is quiet. A customer who raises his voice over certain services that are not working, is a good customer who is trying to make you improve the way you serve them or you do your job.

Interviewer: While making these changes, what did you find most challenging?

MD NAWASSCO: One is selling the idea that NRW is a challenge to all of us. When the staff come across a leak while executing their activities out there, they never bothered to report as it did not look their work but when you make them understand that what happens in technical department affects even the ICT in terms of money collected by NAWASSCO and reducing NRW in terms of Kenya shillings instead of volumes that has helped to refocus our staff towards addressing NRW as a team.

Interviewer: Now that other WSPs see you highly placed on the top, how do you plan to sustain those performance gains you have already attained?

MD NAWASSCO: We are not going to rest on the success we have already achieved because from where I sit it's not where we want to go as our aim is to attain a single digit in NRW levels. So we still have to proceed with `preaching the gospel' of reducing NRW to our staff and carrying our customers on board and the battle of NRW is not won yet until we achieve a single digit.

Interviewer: Will you carry it to the staff only or you will still sensitise the customers on the same as well?

MD NAWASSCO: For you to win NRW battle, it can't be done by staff only who are 178 in number and serving 530,000 customers in this town. The majority of people who will help us solve these issues are our customers whom we need to carry on board. One way is to use the social media groups we have created. If there is a message we have to pass to them or through targeted SMS with that it will help address physical losses.

Interviewer: That can be one way of tackling physical losses, do you find it a challenge tackling commercial losses because this is where most of the utilities lose their water?

MD NAWASSCO: I agree with you our statistics show that if our NRW is 30%, 20% is due to commercial losses in the sense that perhaps there are meter bypasses, removal of meters at night or maybe some meter reading errors by my staff. We normally do spot checks to address physical losses. For example when we get into a compound we ask children where they get their water from, children don't lie, they will tell you the truth. To address commercial losses, we need to think outside the box and be a bit creative and craft a message that resonates with our customers and that will help us further reduce our NRW from the current 29%.

Interviewer: Commercially, is there an approach you would like to use that you find a bit challenging to address this NRW issue?

MD NAWASSCO: The biggest challenge in addressing NRW in the commercial aspect is not internally because my staff understand what it is. The challenge is out there to get the customers understand this and craft a message that will not cause social unrest. Like for instance, when one neighbour A reports another neighbour B for stealing water. This is the part where we as NAWASSCO need to find a way to craft a message that resonates well with our customers. One of the ways we are thinking of is to tell neighbour A if neighbour B is stealing water he will end up paying for the increase in cost of service provision because the tariff will be reviewed upwards. It is not an easy aspect so we need to look for a good way of doing it.

Interviewer: Do the customers know why they have to support you in your service to them?

MD NAWASSCO: It is important for customers to understand that we don't sell water, it's the service we sell and that the water belongs to them. It's not a business like any normal business where a customer approaches my shop and wants to buy all the sugar and I sell to them. Water is not the same even if you have all the money in this town we cannot sell to you all the water because water is a social right for all of us. Once that message is out there, we might see them reporting much of the commercial losses just like they have done with the physical losses.

Interviewer: Do you really feel there is something you still need to do to be well armed in dealing with any emerging issues on NRW?

MD NAWASSCO: We are still not where we want to be on a single digit and one of the ways we can easily get there is through embracing technology e.g. currently we are piloting 300 smart meters that are read by meter readers on motorcycles or a in a vehicle and I think if that pilot works, it will benefit us in meter reading and ensure we get accurate meter readings which will also reduce customer complaints for example where a meter is misread and once a bill is correct, they tend to honour it. The other one is improving the infrastructure using better quality pipes. We still have a large percentage of our water pipes being Asbestos Cement and these ones other than the health challenge associated with dust coming from the asbestos cement, we tend to lose a bit of water physically from these pipes given the nature of soils in Nakuru. These soils are porous and it becomes difficult to detect some of the leaks as they don't appear on the surface.

Interviewer: How do you coordinate these complaints coming together from different areas from these customers?

MD NAWASSCO: We have tried to embrace technology and one of our latest thing we did is to own a new enterprise resource planning system. In this particular system it does not only have billing but also customer complaints module, they can raise their complaints through their phones or emails and that gets to us and we are able to address it. That is the formal system. The other one is the WhatsApp groups that has been created by the customers and they raise issues there and we quickly try to address those issues and that way we gain their confidence and they become loyal customers and we have seen dividends out of that as we used to disconnect an average of 5000 customers every month. These days we hardly go beyond 200 customer disconnections every month meaning we get that revenue and we are able to plan our NRW activities well.

Interviewer: What are the lessons learnt or success stories that you can share with

other WSPs?

MD NAWASSCO: One of the lessons learnt in this reduction of NRW is that it requires teamwork and `preaching' that message daily to your staff as they need to believe and sell it for you to get results. At the same time you need to carry yourself forward with your customers because if you leave your customers behind and they are the majority out there they will not be able to get information about why you are losing water. But again, it's double edged because if your customers don't trust you they will not respond to you as you should also seem to be doing the right thing. In this particular case because our water is rationed and we don't have a 24 hr water supply when we tell them that you will get water on this specific day, you have to make sure that water is available on that specific day. We also have to make sure that their bills are correct and that when they make complaints, they are addressed within the shortest time possible with that we can then create loyal customers out there because when people are loyal to you, they will work with you and they will report issues that they think are going to affect their water supply.

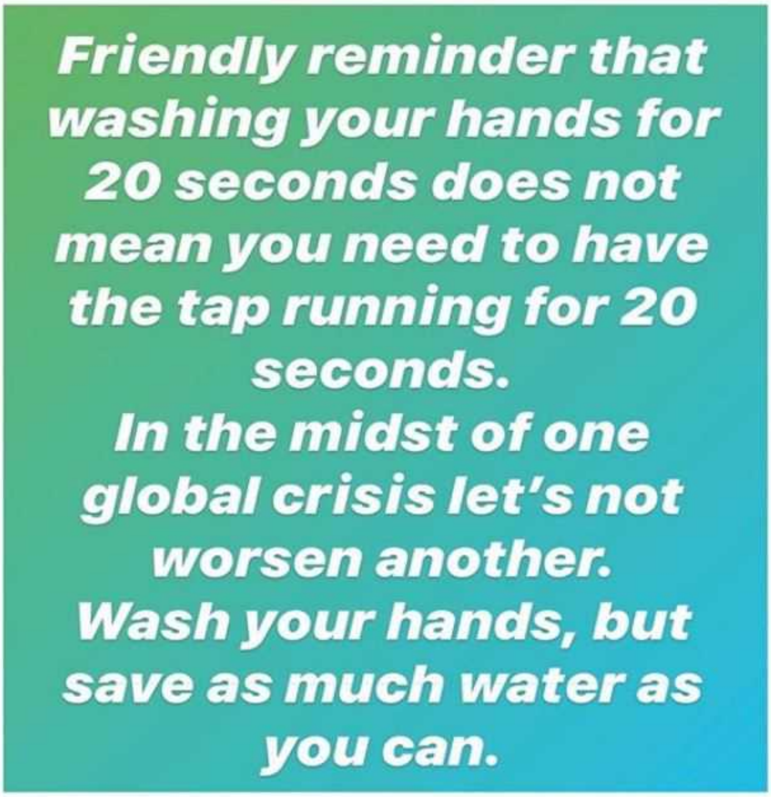
Interviewer: Mr MD, it has been a pleasure for you to give me this opportunity to interview you on behalf of the institution. I am very grateful for the information you have shared with us and I wish NAWASSCO and you well including your customers. I am sure with all these activities you are implementing you are going to uplift the standards of the institution.

Thank you so much.

MD NAWASSCO: Thank you very much, We appreciate our partners JICA, KEWI , UNICEF and Vitens Evides International (VEI). We have quite a number of developing partners working with us and I think it's because we seem to be doing something.

7 CITIZEN'S ACTION CORNER

As the world fights the COVID-19 pandemic, we are advised to ensure that we wash our hands frequently to limit the spread of the virus. Whilst we fight the disease we are not to turn a blind eye on the pre-existing global water crisis.



Source: Alia Bhatt

Non-Revenue Water Reduction Management Short Course

Overview

With a total turnover of KES 22.80 billion for the water supply sector, NRW ratio stands at 47% against a sector benchmark of 20% which implies that the sector is losing over KES 11 billion due to NRW. Despite the rolling out of NRW Management Standards, the uptake and implementation of Standards are not effectively used. The selection of quality water meters, accurate water balance analysis, identifying leakage points and causes of leaks among others remain a challenges.

KEWI in collaboration with the Ministry of Water, Sanitation &Irrigation, Japan International Cooperation Agency (JICA) and Water Service Providers (EWASCO & MEWASS) have restructured NRW Reduction Management Course. Six courses already conducted under the programme, 179 personnel from the 22 WSPs have benefited from the training: Those Embu, Meru, Nyahururu, Nakuru, Eldoret, Ruiru-Juja, Mavoko, Mathira, Kericho, Malindi, Kilifi-Mariakani, Kisumu, Thika, Machakos, Kiambu, Narok, Kiambu, Kapsabet, Nanyuki, Naivasha, Lodwar, Iten and NairobiI and other institutions.

Feedback from participants

Feedback of participants from the trainings are positive. They gained knowledge of; procedures and strategies for NRW reduction, elimination of major commercial losses, essential inter-organizational linkages, skills to operate NRW equipment, how to conduct meter accuracy test and analyze NRW related data.

Learning Objectives

At the end of the course, participants will be able to:

1. Conduct water balance calculation
2. Cultivate good work ethics
3. Manage water distribution networks, distribution reservoirs and hydraulic concept
4. Work Ethics and Compliance
5. Manage system pressure
6. Control physical, commercial losses and billing
7. Manage leak survey and prevention methods
8. Undertake workflow approach to NRW Reduction
9. Identify leaks through water quality assessment
10. Interpret and use NRW water standards
11. Plan and implement NRW reduction activities
12. Formulate NRW action plan reduction
13. Use and apply NRW equipment

Course Sessions:

1st Session (Classroom training at KEWI)
Participants will undertake theoretical classes and demonstrations

2nd Session Field On-the-Job training (OJT) in Embu EWASCO

Participants will engage in field and practical activities by collecting data using NRW management equipment and interpreting it.

Course Dates: Available on our website:www.kewi.or.ke short course calendar

Course Fees: The training costs are as follows:
Session 1. Classroom (Nairobi, KEWI) for 5 Days:

KES. 30,000.00 Residential
or
KES. 22,500.00 Non-Residential

Session 2. On-Job Training (Embu, EWASCO) for 6Days: KES. 24,700.00 Non-Residential

Benefits to Employer

The course is aimed at benefiting the WSPs in reducing and managing NRW and increasing revenue collection. Reports from the pilot WSPs in the JICA's project are encouraging with some of WSPs reducing their NRW ratios by 10% – 20%.

Target Group

The course is designed for personnel involved in metering, Operations and Maintenance of distribution networks, billing and leak detection as NRW activities


For more information on the course kindly email info@kewi.or.ke or wmoseti@gmail.com, or Mobile: 0700-413901

KEWI: Mission Statement:

"To offer competency-based Training, Research, Consultancy and Outreach Services in the Water Sector for Sustainable development''

This report was produced as part of JICA project

"The Project Strengthening Capacity in Non-Revenue WaterReduction in Kenya".

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資料 2)　無収水管理基準（改定版）

2) -1　Non-Revenue Water Management in Kenya
VOLUME1 Guidelines

MINISTRY OF WATER, SANITATION AND IRRIGATION

Non-Revenue Water Management in Kenya

VOLUME 1

Guidelines

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FOREWORD

Water is an important natural resource to all forms of life and for mankind. It is the backbone of economic growth and a nation's prosperity. Kenya as the rest of the world is becoming more and more water scarce due to deterioration of water sources resulting mainly from global warming and population explosion. Construction of new water schemes to meet the growing demand for water services is expensive, requires more time to develop and comes with new challenges. Alternative sources of water are water re-use, desalination and rain water harvesting. However, reduction of Non-Revenue water is the cheapest way to alleviate the water stress.

The Government of Kenya is committed to ensuring the sustainability of Water Service delivery universally and the right to water and sanitation as envisaged under the bill of rights in the constitution. However, among the challenges to achieving the Kenyan dream includes a high level of Non-Revenue Water (NRW) which is estimated at an average of 47% of the total water production in the country. The water services provision has been developed in the County Government and therefore, it is timely to ensure an elaborate mechanism is put in place for the proper management of Non-Revenue Water in the country.

Kenya Vision 2030 recognizes that Kenya is a water scarce country and therefore emphasizes water conservation and prudent use for the limited available portable water. In this regard, the Government of Kenya has instituted specific strategies to raise the standards of the country's overall water supply and resource management among others. The National Water Resources Management Strategy and the National Water Services Strategy aim at ensuring the water resources are conserved and maintained and Non-Revenue Water at all developed water supply and sanitation systems is reduced to acceptable levels. Accordingly the Ministry of Water , Sanitation and Irrigation in conjunction with Japanese International Cooperation Agency (JICA) has developed standards for Non-Revenue Water Management in order to cut down on Operation and Maintenance (O&M) costs and avail more water that could otherwise be lost to consumers.

The Non- Revenue Water reduction management standards consisting of the Guidelines and Handbook are meant to provide a practical approach to reduction of NRW in Kenya. The effective utilization of the standards will result in significant education of NRW and all the Water Service Providers are encouraged to use them.

Cabinet Secretary
Ministry of Water, Sanitation and Irrigation

PREFACE

Previously, a lot of myth surrounded the full understanding of what the non-revenue water really is. In some instances, management of NRW was not viewed with importance and hence there were no foreseeable benefits and need for investing in it. In other cases, NRW management was viewed as a very expensive undertaking whose management required sophisticated equipment and large capital overlays. This position is still held by many water utilities. However,the truth of the matter is that NRW is manageable as has already been demonstrated in some local and international water utilities.

The difference between the amount of water put into the distribution system and the amount of water billed to consumers is what is known as Non Revenue Water(NRW).

NRWisakeyindicatorofautility'soperationalandfinancialperformance.AhighlevelofNRW normally indicates a water utility that lacks good governance,autonomy,accountability, and the technical and managerial skills necessary to provide a reliable service.

In 2010, the International Water Association (IWA) published 'The Manager's Non-Revenue Water Handbook for Africa: A Guide to Understanding Water Losses'. Later on in 2014, the Ministry of Water, Sanitation and Irrigation also published the 'Standards for Non- Revenue Water Management in Kenya'. These two publications have been used nationally by most water companies as a guide towards the management of non-revenue water.

Since their inception in 2014, the Ministry has been monitoring the use of its standards especially with regard to their application and impact to the management of NRW. To date one important finding was that the NRW ratio only reduced marginally with no prospects for substantial positive improvement. Furthermore, there was poor use of the standards guideline by water utilities with some not being aware of their existent at all. These findings tally very well with the prevailing conditions whereby the knowledge of non-revenue water is still very limited in most water service providers country wide. The same scenario-subsists in majority of the county governments who are the main stakeholders in these companies. With the prevalence of this scenario good performance in NRW management continues to be a mirage for most water utilities.

The purpose of this book therefore is to provide guidance in the management of non–revenue water in Kenya. This is are viewed version of the initial ministry's NRW management standards launched in 2014 and incorporates experiences gained from its use during the last seven years since its inception It also draws many experiences gained from the 'GoK/JICA project for strengthening capacity in non-revenue water reduction' where nine(9) WSPs were involved during the piloting phase (Meru, Embu, Ruiru Juja, Mavoko, Kilifi Mariakani, Kisumu, Nyahururu and Nakuru).

The book is designed for all categories of WSPs irrespective of their level of competency in the subject. Most importantly, the book will not only be very vital for beginners who have no prior knowledge about non-revenue water but also to those who have already started the journey to manage it. It is designed for use by all county governments and water utilities charged with responsibility for water provision at any level. The book is applicable to both the urban and rural water service providers.

Incoming up with this book the authors were inspired by the need to reduce escalating water losses in the country. With the prevailing levels of NRW remaining unsustainably high against a large solution gap about it management within water utilities, the need for proper guidance on the matter was inevitable.

The review of these standards was successfully accomplished by an experienced team comprising of WASREB, JICA Expert Team, KEWI, WASPA and the Ministry's NRW Unit.

Every effort was made to eliminate errors in the book, but should the reader discover some, the author would appreciate having these brought to his attention. Suggestions from the readers for improvement in the book will be most gratefully acknowledged.

PRINCIPAL SECRETARY
Ministry of Water, Sanitation and Irrigation

ACKNOWLEDGMENT

The completion of these guidelines could not have been possible without the support of several individuals and organizations whose invaluable support and input the development of this guidelines would not have been possible.

I therefore would like to extend my sincere gratitude to the following organizations in particular: Water Services Regulatory Board(WASREB),Kenya Water Institute (KEWI),Water Service Providers Association (WASPA),Japanese International Cooperation (JICA) and the JICA expert team,Netherlands Development Organization (SNV), Vitens Evides International (VEI) for their co-operation and contribution of information related to Non Revenue Water activities.

Nyeri Water&Sewerage Company (NYEWASCO) for their readiness to share best practices of the Non Revenue Water Reduction activities which has provided a learning platform to other water services providers

I wish to thank the nine WSPs we have been piloting with namely; Meru, Embu, Kisumu, Eldoret, Nyahururu, Mavoko, Kilifi-Mariakani, Mombasa, and Ruiru-Juja for their commitments in reducing Non-Revenue Water.

Finally,I would like to thank my colleagues in the Ministry particularly Non-Revenue Water Unit who have tirelessly devoted their time,energies and knowledge in ensuring successful publication of these guidelines and handbook.

The war on Non-Revenue Water cannot be won by a single person,it requires concerted efforts by all stakeholders and calls for commitments by everyone in the organization. I therefore, urge all the Water Service Providers in the country to make maximum use o both the guidelines and handbook to sustain the war on Non-Revenue Water reduction to attain acceptable levels of below twenty per cent.

God bless you all.

Eng. SAO Alima
Water Secretary

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ABBREVIATIONS

AP	-	Annual Plan
Aspect	-	A primary activity in the Non-Revenue Reduction Planning Template
Baraza	-	local community meeting
CIS	-	Customer Identification Survey
CM/FM	-	Commercial Manager/Finance Manager
Co-	-	Commercial Loss Reduction Activity
Co-1	-	1st Commercial Loss Reduction Activity
Co-2	-	2nd Commercial Loss Reduction Activity
Co-3	-	3rd Commercial Loss Reduction Activity
Co-4	-	4th Commercial Loss Reduction Activity
DMA	-	District Metered Area
DZ	-	Distribution Zone
EU	-	European Union
GIS	-	Geographical Information System
GOM Player	-	Gretech Online Movie Player
HDPE	-	High-density polyethylene
HRM	-	Human Resources Manager
ICT	-	Information and Communication Technology
I&AC	-	Inspection and Acceptance Committee
JICA	-	Japan International Cooperation Agency
KEBS	-	Kenya Bureau of Standards
KEWI	-	Kenya Water Institute
KShs	-	Kenya Shilling
LMB	-	Leakage Monitoring Block
M3	-	Cubic meter
Ma-	-	Mapping/GIS Activity
Ma-1	-	1st Mapping/GIS Activity
Ma-2	-	2nd Mapping/GIS Activity
Ma-3	-	3rd Mapping/GIS Activity
Ma-4	-	4th Mapping/GIS Activity
MajiVoice	-	an innovative accountability mechanism software in the Kenyan water and sanitation sector
MD	-	Managing Director
Mo-	-	Monitoring Activity
Mo-1	-	1st Monitoring Activity
Mo-2	-	2nd Monitoring Activity
Mo-3	-	3rd Monitoring Activity
MP	-	Medium-term Plan
NRW	-	Non-Revenue Water
NRW Unit	-	May also be NRW Department or Section

OJT	-	on-the-job training
O&M	-	Operation and Maintenance
PEWAK	-	Performance Enhancement of Water and Sanitation Utilities in Kenya through Benchmarking & Collective Learning – a programme funded by the Netherlands Enterprise Agency
PDCA	-	Plan-Do-Check-Adjust
Ph-	-	Physical Loss Reduction Activity
Ph-1	-	1st Physical Loss Reduction Activity
Ph-2	-	2nd Physical Loss Reduction Activity
Ph-3	-	3rd Physical Loss Reduction Activity
SA	-	Service Area
Sht	-	Sheet
SMS	-	short message service
SNV	-	Netherlands Development Organization
SOPs	-	Standard Operating Procedures
TM	-	Technical Manager
TV	-	Television
uPVC	-	unplasticized polyvinyl chloride
uPVC-D/E	-	unplasticized polyvinyl chloride class D or E
VEI	-	Vitens Evides International, a Dutch company
WARIS	-	Water Regulation Information System
WASPA	-	Water Services Providers Association
WASREB	-	Water Services Regulatory Board
WB	-	World Bank
WSP	-	Water Services Provider
WSPs	-	Water Services Providers
yr	-	year

EXECUTIVE SUMMARY

One of the major challenges facing water utilities is the high level of water loss in distribution networks. If a large proportion of water that is supplied is lost, meeting consumer demands is much more difficult. Since this water yields no revenue, heavy losses also make it harder to keep water tariffs at a reasonable and affordable level. This situation is defined as Non-Revenue Water. NRW is a good indicator for water utility performance; high levels of NRW typically indicate a poorly managed water utility.

The main objective of this manual is to provide the basis for a substantive dialogue on NRW reduction and management of water utilities. It aims to raise awareness on key issues surrounding NRW, including the magnitude of the NRW problem, NRW management practices in the country, international terminologies and methodologies for improving NRW management and the importance of using appropriate performance indicators. The following is a brief outline of the guideline.

Chapter 1 examines the basic concept of NRW management and the overall picture of NRW reduction is explained.

Chapter 2 explains on how to coordinate the activities for mapping, commercial and physical loss reduction and NRW monitoring in a strategic way.

Chapter 3 It explains the organization structure of an NRW unit and explains the importance of capacity development and sensitization of staff, annual NRW reduction plans and self-assessment of water utilities.

Chapter 4 This Chapter talks on GIS and how to use it in NRW reduction

Chapter 5 The Chapter explains how to monitor NRW monthly and also how zoning of distribution networks into Distribution Zones and DMAs is to be done so as to closely manage NRW

Chapter 6 It explains the significance of Commercial Losses in NRW and the causes and methods for reducing this type of loss.

Chapter 7 It explains the mechanism of meters and the importance of maintaining customer meters in order to maintain accuracy and efficiency of meters.

Chapter 8 The Chapter explains the causes of Physical Water Losses and the reduction measures for this type of loss.

Chapter 9 It explains methods of underground leak detection and replacement of pipes gradually in service water connections.

Chapter 10 This Chapter provides an explanation on how to manage water pressure as it is one of the most effective methods of NRW management.

Chapter 11 It talks on the importance of water utilities conducting Cost-Benefit Analysis when trying to determine the scope of NRW reduction measures that should be implemented. Cost-Benefit Analysis will show the effects of the invested cost by comparing the benefit obtained with the cost invested.

Chapter 12 This Chapter explains what needs to be done to effectively manage NRW reduction. NRW reduction activities implemented in a Pilot area are explained and the most suitable measures for the entire service area are provided.

Chapter 13 It provides a summary of the experiences of the project for strengthening capacity in NRW reduction in Kenya from Output 4. It tries to answer the question 'How is it possible with our limited resources to achieve the nation-wide reduction of NRW under the difficult conditions in developing countries?'

Chapter 1

Basic Concept of Non-Revenue Water Management

1.1 Definition of Non-Revenue Water

Non-Revenue Water (NRW) is defined as the amount of water which is not billed and does not earn revenue. This is the difference between the system input volume and billed authorized consumption volume in m^3.

NRW = System Input Volume – Billed Authorised Consumption Volume

Where:

System input volume = the amount of water produced for distribution,

Billed authorized consumption = amount of water billed to consumers.

NRW ratio is the percentage of the amount of water not billed against the total amount of water produced for distribution.

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

1.2 Components of Non- Revenue Water

The volume of treated water that does not earn revenue is NRW.

Components of NRW are described below:

- Real Losses: these are Physical Losses of water through leakages and bursts in distribution pipes and service pipes; and overflows/leakages from water reservoirs;
- Apparent Losses: these are called “non-physical losses” or “Commercial Losses” of water due to illegal connections (or water theft), meter errors, meter reading inaccuracies and unmetered connections.

Unbilled authorized consumption: This is water taken by registered customers for public and institutional uses and is not paid for. This includes water for firefighting, backwash and public fountains. Figure 1.1 shows the component of NRW.

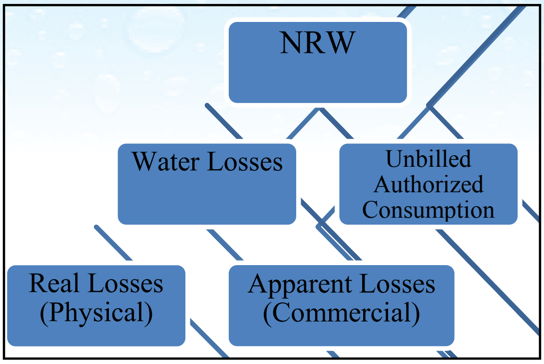


Figure 1.1: Components of NRW

1.3 Benefits of Non-Revenue Water Reduction

NRW Management consists of knowing what is happening to water supplied and taking corrective measures to reduce the loss of water or revenue.

NRW management offers the following benefits:

- Increased connectivity and revenue: By reducing causes of NRW such as water theft, meter inaccuracies and leakages, water that was previously unbilled will be earning revenue.
- Improved level of service (water pressure and hours of service) hence reduced customer complaints
- Sustains water supply and increases protection of potable water supply.
- Reduces unauthorized usage.
- Reduces potential claim due to water damage.
- Defers capital expenditure with respect to new water sources, treatment plants and distribution facilities.
- Reduces cost of energy associated with water treatment and pumping; and thus, contributes to reducing global warming.
- The precious water resources are preserved
- Improves public awareness of water value.
- Improves the company’s image

1.4 Current Status of Non-Revenue Water in Kenya

Water supply systems in Kenya differ depending on social, financial and geographical conditions, but the following issues are common:

1. Dilapidated facilities
2. Weak and substandard distribution pipe materials (e.g., asbestos cement, and cast-iron, low-class uPVC) are still in use in some water supplies leading to leakages.
3. Inadequate water distribution due to lack of water resources and/or limited water facilities.
4. In general, water pressure is low with the exception of Water Services Providers (WSPs) around the foot of Mt. Kenya. However, there are significant pressure variations depending on the WSP's service area.
5. Inadequate staff with capacity to implement NRW Management programs.
6. Lack of adequate equipment to address NRW issues.
7. Lack of flow Meters in appropriate locations.
8. Low quality meters.
9. Lack of uniformity in pipe standard.
10. Poor workmanship and construction methods.
11. Inadequate (and often outdated) mapping of pipe network in most WSPs.
12. Customer meters are sometimes not read accurately.
13. Illegal connections and failure to pay for water consumed are common.
14. Lack of policies and enough budget for NRW reduction and control.
15. Lack of management's goodwill and support to fight NRW.
16. Absence of institutionalized NRW Unit and ad hoc staff appointments when required.
17. Often ignored as an essential service on the road reserve and is readily damaged by other actor like road contractors.

1.5 Non-Revenue Water Reduction Measures

In developed countries, a large part of NRW is due to real losses (physical losses). However, in developing countries including Kenya, a high percentage of water is lost through apparent losses (commercial losses) such as water theft, meter error, meter reading error and unbilled authorized consumption. Therefore, NRW reduction measures should take into consideration all these additional factors besides leakage.

Details of reduction measures are explained in Chapters 3 and 4.

1.6 Stages and Overall Procedure for Non-Revenue Water Reduction

(This section is further explained in Chapter 3)

1.6.1 Stages of NRW Reduction

Effective NRW reduction measures vary depending on the current technical and non-technical capacities of each WSP. NRW reduction measures implemented in developed countries may not necessarily be suitable for WSPs in Kenya. Hence, each WSP must assess and understand well its current NRW status so as to plan and successfully implement appropriate NRW reduction measures.

Table 1.1 broadly recommends NRW reduction measures necessary to reduce NRW from one stage to the next. The table is intended to generally orient and motivate WSP staff to discuss their conditions and prepare detailed NRW reduction plans even before carrying out a full assessment of the NRW status.

Table 1.1: The Five Stages of NRW and Recommended Reduction Measures

Stage	Approx. Range of NRW %	**Recommended NRW Reduction Measures** (Note: GIS development and NRW monitoring are not listed here, but they are required as support for NRW reduction measures)
1	**Red** NRW ratio ≥ 40% (or unknown or unreliable)	● Determine the accuracy of production meters by testing and calibrating, and replacing if faulty or inaccurate (Mo-1). ● Eliminate major commercial losses by servicing and testing (and replacing faulty) customer meters and, identifying illegal uses (starting with large and then medium customers) (Co-1, Ma-1). ● Install meters for unmetered customers and identify unbilled customers through Customer Identification Survey (CIS) and issue them with bills. (Co-2, Ma-1, Ma-2). ● Reduce the time taken to repair bursts, surface leaks and overflows (Ph-1).

Stage	Approx. Range of NRW %	**Recommended NRW Reduction Measures** (Note: GIS development and NRW monitoring are not listed here, but they are required as support for NRW reduction measures)
2	**Yellow** 30% < NRW ratio < 40%	● Intensify Stage-1 measures by e.g., establishing routines, etc. ● Isolate distribution zones and district metered areas (DMAs) with accurate bulk meters and do NRW monitoring (Mo-2). ● Reduce underground leaks by step testing, acoustic survey and pressure reduction in priority areas (this leak reduction can be carried out as a pilot project) (Ph-2). ● Map bursts and leaks and monitor their recurrences (Ma-3, Ma-4). ● Introduce better pipe materials and fittings for new pipelines and service connections (e.g., HDPE or uPVC-D/E). ● Minimize commercial losses (including at small customers and data handling errors) by improving meter reading and billing systems, and their uses (Co-3, Co-4).
3	**Green** 24% < NRW ratio ≤ 30%	● Intensify Stage-2 measures listed above. ● Reduce underground leaks in other areas (Ph-3, Mo-3). ● Start replacing pipes which are prone to bursts and leaks (Ph-3).
4	**Blue** 20% < NRW ratio ≤ 24%	● Intensify Stage-3 measures listed above. ● Accelerate and complete pipe replacement (Ph-3).
5	**Purple** NRW ratio ≤ 20%	● Intensify Stage-4 measures listed above. ● Maintain the facilities and skills to sustain the achieved low NRW ratio (Ph-3).

Note-1: This table is based on experiences in Kenya.
Note-2: The approx. percentage range of NRW for each stage corresponds to that of commercial viability criteria for each level included in WASREB Guideline on Clustering of WSPs (August 2018).

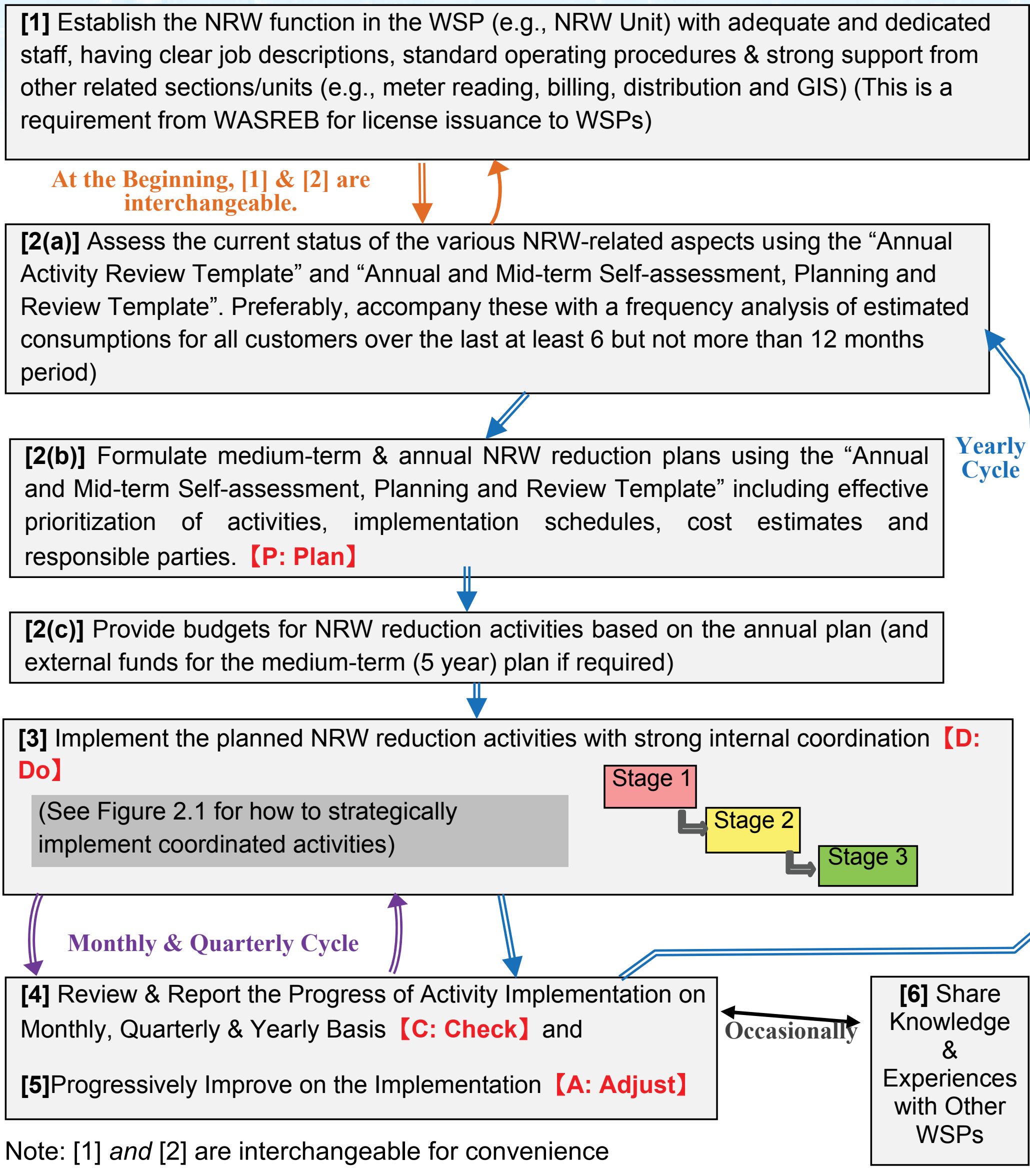
1.6.2 Organizational Set-up, Assessment of Current Status and Plan-Do-Check-Adjust Cycle

Plan-Do-Check-Adjust (PDCA) Cycle is an iterative design and management method used in business for the control and continuous improvement of processes and products.

The meaning of PDCA cycle is explained below:

- **Plan:** During this phase, the objectives and processes required to deliver the desired results are established.
- **Do:** The objectives of the **Plan** are carried out or implement in this phase.
- **Check:** During this phase, the data and results gathered from the **Do** phase are evaluated. Data is compared to the expected outcomes to see any similarities and differences. The testing process is also evaluated to see if there were any changes from the original test created during the **Plan**ning phase. If the PDCA cycle is conducted multiple times, any trends can be seen easily by plotting the data in a chart. This helps to see which changes on "**Do**phase" give better results than others, and if the said changes can be improved.
- **Adjust:** This is where a process is improved. Records from the "**Do**" and "**Check**" phases help identify issues with the process. These issues may include problems, non-conformities, opportunities for improvement, inefficiencies and other issues that result in outcomes that are evidently less-than-optimal. The root causes of such issues are investigated, found and eliminated by modifying the process. The risk is also re-evaluated. At the end of the actions in this phase, the process has better instructions, standards or goals. Planning for the next cycle can now proceed with a better base-line. Work in the next Do phase should not create recurrence of the identified issues If it does, then the action was not effective.

Figure 1.2 shows the overall procedure for NRW reduction and its proposed **PDCA** cycle based on recent WSPs' experiences in Kenya. The monthly, quarterly and yearly PDCA cycle is important to sustain improvement of NRW-related conditions and progressively achieve lower and lower NRW levels.



Note: [1] *and* [2] are interchangeable for convenience

Figure 1.2: Overall Procedure for NRW Reduction & PDCA Cycle

[1] Organizational Set-up

As seen in Figure 1.2, the overall procedure for NRW reduction starts with {**[1]** *Establishing NRW function with adequate and dedicated staff…}*. This function should be permanently established and institutionalized in the organization chart of each WSP. Any temporarily appointed NRW team/unit which is not institutionalized in the organization chart is liable to fail miserably (see **Sec. 3.1** for further explanation).

To ensure an NRW Unit reduces NRW significantly, it must have the following characteristics:

- adequate and competent staff <u>dedicated</u> to NRW reduction,
- <u>strong support</u> from the management, and
- <u>strong coordination</u> with other relevant sections in both technical and commercial departments

The level of the NRW function is discretional (can be departmental level for the very large WSP; to sectional or unit level for other lower sized WSPs).

[2(a)] (P: Plan)→ Assess the Existing Conditions

Before commencing NRW reduction, it is necessary to self-assess the current conditions and capacity. These conditions and capacity are divided into four categories as follows:

[A] Organizational Structure, Sensitization, PDCA Cycles and Procurement,

[B] GIS, NRW Monitoring, Zoning and Water Balance Analysis,

[C] Reduction of Commercial (Apparent) Water Losses, and

[D] Reduction of Physical (Real) Water Losses.

A template containing 33 NRW-related aspects to assist in self-assessment of a WSP's current conditions and capacity is provided in these guidelines **[Appendix-1: Sht(2)].**

The template is also used to periodically Plan (set future targets) **[Sht(4)]** and review the status and capacity of a WSP **[Sht(1)** and **Sht(5)]** as the NRW reduction activities continue to be implemented (Figure 1.2 Item **[2(a)-(c)]).**

When data is typed into the template, the results of the self-assessment (or review) are automatically displayed as a single bar chart **[Sht(3)]** showing the current achievement levels of the 33 aspects (see **Section 3.5** for further explanation).

Most WSPs often estimate water consumption, including for large consumers, due to stalled meters, unreadable meter counters, locked gates, etc. They also often fail to send bills to existing active customers and, newly connected and reconnected customers. These failures cause a large volume of NRW.

These guidelines include a computer programme (MS Excel) **(Appendix-2)** for analysing meter readings and billing trends over a number of months to determine the status of commercial water losses in WSPs. Through this analysis at the initial stage and later as the NRW reduction activities continue to be implemented, the current conditions and periodical reviews can be assessed for planning.

[2(b)] (P: Plan)→ Formulate medium-term and annual Non-Revenue Water reduction plans

Once self-assessment is complete, it is necessary to formulate plans on how the NRW reduction will be implemented. The planning part of the "Annual and Mid-term Self-assessment, Planning and Review Template" **[Appendix-1 Sht(4)]** is useful to assist WSPs in formulating the plans including prioritization of activities from the 33 NRW-related aspects, implementation scheduling, cost estimation and allocation of responsible persons. Activity prioritization then yields the annual, quarterly and medium-term plans and budgets.

[2(c)] (P: Plan)→Provide budgets for Non-Revenue Water reduction activities

After prioritization of activities and cost estimation, it's time to allocate funds through budgeting and obtaining the necessary approvals from the WSP's senior management and the board. This process should also include approval for external funding such as grants/loans for medium term plans.

[3] (D: Do)→Implement the planned Non-Revenue Water reduction activities with strong internal coordination

Once the funding is available, NRW reduction activities should be implemented with effective coordination between the various sections/units while keeping recordsat the same time. These records will later be analysed **(C: Check)** to review the achievements and to come up with corrective measures **(A: Adjust)** going forward for more efficient and effective outcomes.

In summary, for Item [2(b)] in Figure 1.2, a template (Appendix-1) containing <u>medium-term plans, annual plans</u> **[Appendix-1 Sht(4)]** and <u>capacity assessment</u> procedure[Sht(2)] is included in these guidelines for ease of planning based on the assessment results (see Sec. 3.6 for further explanation). Item [2(c)]is explained in Sec. 3.7. Item [3]is explained in Chapter 2 with a flow chart example (Figure 2.1) of how to strategically implement coordinated activities.

Reviewing and reporting (Item [4])should be on monthly basis to facilitate internal discussions; quarterly for progress monitoring; and yearly for updating the medium-term and annual plans.

Quarterly review can be done by filling the additional columns in the planning template **[Appendix-1 Sht(5)]** while the yearly review can be done by filling the Annual Activity Review Template **[Sht(1)]** (see Sec. 3.8 for further explanation).

Every annual review should include updating (Item [5]) of each year of the medium-term NRW reduction plan based on the results of the yearly activity review, re-assessment of improved conditions including skills, availability of funds, etc.

For Item [6] (Figure 1.2), occasional internal and external sharing of knowledge and experiences (e.g., at Water Services Providers Association's (WASPA) benchmarking workshops) and participation in trainings are vital for development of country-wide capacity (see Sec. 3.2 for further explanation).

Chapter 2

Strategic Implementation of Coordinated Activities

2.1 Understanding the Necessary Skills and Interactions

Planning and implementation of NRW reduction activities require a wide range of skills such as:

- GIS maps development,
- design work to modify the existing distribution facilities,
- pressure management, etc.

These skills usually belong to different sections/units (e.g., GIS mapping development – GIS/mapping Unit; Design – Design Section; etc).

One of the most difficult aspects of NRW reduction is how to coordinate the various actors in a strategic way such that the effectiveness and efficiency of their activities is maximized for successful NRW reduction.

It is crucial that the head of NRW Unit and his/her manager/supervisor gradually develop enough capacity to properly coordinate the activities. Further, other staff/sections need to understand the interactions and skills necessary to interlink them in order to ease the coordination. These interactions should be discussed in monthly meetings for improvement.

Figure 2.1(a) explains how to coordinate the activities for commercial and physical loss reduction in a strategic way.

(Note: The activities are from Table 1.1 and are coloured correspondingly; e.g., Stage 1 activities are coloured red in both Table 1.1 and Figure 2.1(a), and so on.)

Since majority of WSPs in Kenya are still in Stage 1 (i.e., NRW ≧ 40% or unreliable), Figure 2.1 begins by elaborating priority activities for Stage 1 (red).

The figure is developed based on recent experiences in WSPs in Kenya.

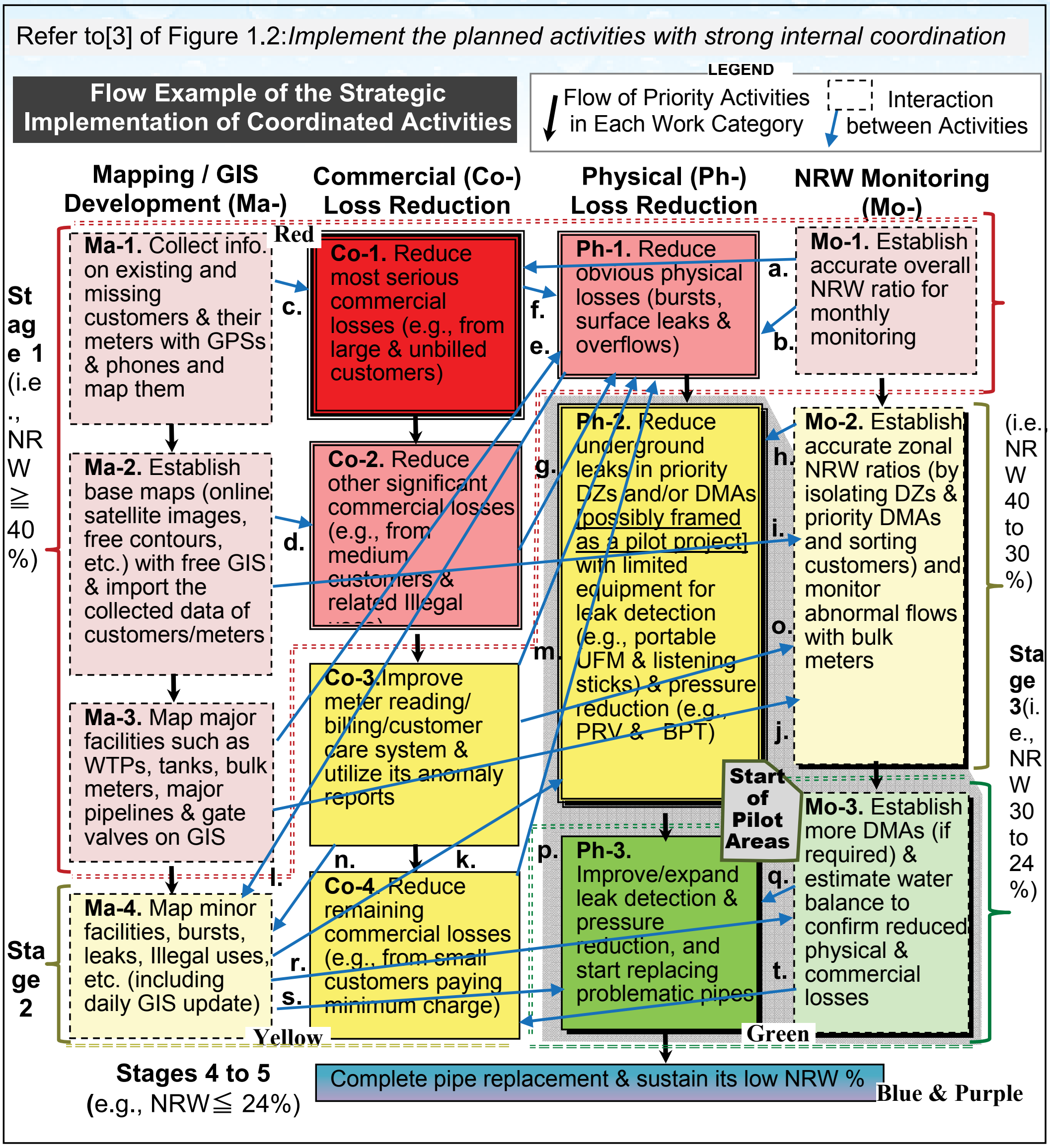


Figure 2.1 Example of Strategic Implementation of Coordinated Activities

Table 2.1: Legend to Figure 2.1

Symbol	Meaning
Ma	Mapping/GIS development activities: - Ma-1 is 1st activity to be undertaken, Ma-2 is 2nd, etc
Co	Commercial Loss Reduction activities: - Co-1 is 1st activity to be undertaken, Co-2 is 2nd, etc
Ph	Physical Loss Reduction activities: - Ph-1 is 1st activity to be undertaken, Co-2 is 2nd, etc
Mo	NRW Monitoring activities: - Mo-1 is 1st activity to be undertaken, Mo-2 is 2nd, etc
Black Arrow	The activities in the textbox behind the arrow are of higher priority than those in the textbox ahead of the arrow
Red and light-red box	Activities to be undertaken when WSP is in Stage 1
Yellow and light-yellow textbox	Activities to be undertaken when WSP is in Stage 2
Green and light-green textbox	Activities to be undertaken when WSP is in Stage 3
Blue-toped and purple-bottomed rectangle textbox	Activities to be undertaken when WSP is in Stages 4 and 5
Bright coloured textbox	Activities in the box are of higher priority than light coloured box
Light coloured textbox	Activities in the box are of lower priority than bright coloured box
Coloured double dash borderline	Borderline between Stages (e.g., Stage 1 and Stage 2)
Grey coloured textbox Pilot Areas	Symbol indicates the 4 activities (i.e., Ph-2, Ph-3, Mo-3 and partly Mo-2) to be undertaken in pilot areasbefore expanding them to other areas.
Interaction arrow(blue)	• Implementing the activity behind the arrow will assist while implementing the activity ahead of the arrow; OR, • The activity behind the arrow can be implemented together with the activity ahead of the arrow

Table 2.2: How to Read Figure 2.1

Arrow	Explanation
Blue arrow: a.	• Implementing Mo-1 will assist to implement Co-1; or, • Mo-1 can be implemented together with Co-1
Blue arrow: b.	• Implementing Mo-1 will assist to implement Ph-1; or, • Mo-1 can be implemented together with Ph-1
Blue arrow: c.	• Implementing Ma-1 will assist to implement Co-1; or, • Ma-1 can be implemented together with Co-1
Blue arrow: d.	• Implementing Ma-2 will assist to implement Co-2; or, • Ma-2 can be implemented together with Co-2
Blue arrow: e.	• Implementing Ma-3 will assist to implement Ph-1; or, • Ma-3 can be implemented together with Ph-1

Arrow	Explanation
Blue arrow: f.	• Implementing Co-1 will assist to implement Ph-1; or, • Co-2 can be implemented together with Ph-1
Blue arrow: g.	• Implementing Co-2 will assist to implement Ph-1; or, • Co-2 can be implemented together with Ph-1
Blue arrow: h.	• Implementing Mo-2 will assist to implement Ph-2; or, • Mo-2 can be implemented together with Ph-2
Blue arrow: i.	• Implementing Ma-2 will assist to implement Mo-2; or, • Ma-2 can be implemented together with Mo-2
Blue arrow: j.	• Implementing Ma-3 will assist to implement Mo-2; or, • Ma-3 can be implemented together with Mo-2
Blue arrow: k.	• Implementing Ma-4 will assist to implement Ph-2; or, • Ma-4 can be implemented together with Ph-2
Blue arrow: l.	• Implementing Ph-1 will assist to implement Ma-4; or, • Ph-1 can be implemented together with Ma-4
Blue arrow: m.	• Implementing Co-3 will assist to implement Ph-1; or, • Co-3 can be implemented together with Ph-1
Blue arrow: n.	• Implementing Co-3 will assist to implement Ma-4; or, • Co-3 can be implemented together with Ma-4
Blue arrow: o.	• Implementing Co-3 will assist to implement Mo-2; or, • Co-3 can be implemented together with Mo-2
Blue arrow: p.	• Implementing Co-4 will assist to implement Ph-1; or, • Co-4 can be implemented together with Ph-1
Blue arrow: q.	• Implementing Mo-3 will assist to implement Ph-3; or, • Mo-3 can be implemented together with Ph-3
Blue arrow: r.	• Implementing Ma-4 will assist to implement Mo-3; or, • Ma-4 can be implemented together with Mo-3
Blue arrow: s.	• Implementing Ma-4 will assist to implement Ph-3; or, • Ma-4 can be implemented together with Ph-3
Blue arrow: t.	• Implementing Mo-3 will assist to implement Co-4; or, • Mo-3 can be implemented together with Co-4

2.2 Coordination of Stage 1 Activities

Stage 1 activities involve production and large customer meters, CIS and visible leaks.

As illustrated by the coloured textboxes (Figure 2.1(a) and (b)), the most important activity among the activities highlighted in red (Stage 1) are Co-1(Reduce most serious commercial losses, starting with the large and unbilled customers. It is relatively easy and cost effective to focus on those customers consuming large volumes of water (e.g.,> 100m3/month) because they are few and their locations are well-known. Eliminate their under-registering meters and under-estimated consumption (caused by stalled or unreadable meters, gate locks, etc.) through meter accuracy testing, meter replacement, meter relocation and resizing; and investigation of illegal connections and leaks around their meters.

Through conducting the targeted activities of consumers with large meters described above, a huge volume of NRW can be reduced and the revenue increased drastically since the higher water tariff (Ksh/m3)is applied to the same large consumers. The revenue increase from addressing large customers should support and encourage other NRW reduction activities to follow.

Therefore, the management should adequately support procurement of prioritized large customer meters to replace faulty ones. This activity on large customers, as well as other activities for commercial loss reduction, should be carried out over the entireservice area of the WSP to maximize its impact (see Sec. 5.2, 5.6 and Chapter 6 for further explanation).

In order to monitor NRW reduction from the activity on larger customers and other basic activities (e.g., Ph-1), accurate calculation of monthly overall NRW ratio should be established and institutionalized as soon as possible (as illustrated by interaction arrows ↙a. and ↙b.), based on reliably accurate production meters and total billed consumption (see Sec. 5.2 for further explanation).

Some customers may have been connected by WSP staff but, for some reason, not captured in the billing system. These are unauthorized unbilled consumers and sources of most serious commercial losses (Co-1). Customers previously disconnected due to non-payment, vacated premises, etc but reconnected later (by staff or self illegally) without being billed for the consumed water also cause significant NRW. These hidden unbilled customers should be identified immediately by conducting CIS and mapping (Ma-1); and billed to reduce NRW. It is recommended that mapping (Ma-1) of the water supply should be done using, e.g., handheld GPSs and smartphone-based data-collection software with cloud mapping functions. Kobo Toolbox is free (or open source) and a good example of such a software and can be easily be downloaded and used with the help of mapping/GIS staff (arrow ↘c.) (see Sec. 4.3 and 6.7 for further explanation).

The next priority in Stage 1 is Co-2 and Ph-1.

This should target the large number of medium customers such as multi-dweller buildings (e.g.,>20m3/month) and their potential illegal connections in the entire service area (e.g., irrigated agricultural areas that have limited irrigation systems of their own, informal/slum areas, houses with large gardens, car wash services). The WSP should introduce own GIS mapping database with a customer meter layer. Use of free (open source) GIS software (e.g., QGIS) as indicated in Ma-2 and (↘d.) is recommended and is quite helpful.

Arrow (↘e.) recommends digitization of the major facilities in the entire service area on GIS maps (Ma-3) and sharing the maps,accessible from smartphones, with field staff through PDF format, mobile GIS or web-publishing. This would significantly help to reduce time spent to locate and repair obvious physical losses (bursts, surface leaks and overflows – Ph-1). This digitization can be done mainly on-screen in a relatively short period using online or offline high-resolution satellite images as the GIS base map (see Sec. 4.2 for further explanation). As illustrated by Arrow (↘f.) and (↗g.), surface leaks found while reducing most serious and other significant commercial losses at large and medium customers (Co-1 and Co-2) should be repaired together with obvious physical losses {Phy-1.}. This should include the noises detected with listening sticks from customer meters/meter stands hinting at potential underground leaks.

2.3 Coordination of Stage 2 Activities

Stage 2 activities involvezoning, invisible leaks, pipe materials and commercial loss minimization.

Even for WSPs considered to be in Stage 2 or Stage 3, Stage 1 activities should be completed while proceeding to Stage 2 and 3 activities.

Among commercial and physical loss reduction activities of Stage 2 (yellow textboxes), WSPs may start with Ph-2. As illustrated by arrow (↘h.), reduction of underground leaks should start from the priority areas (priority DZ(s) and/or priority DMA(s)). The priority areas should be identified through planning and gradual implementation of zoning over the entire service area for better NRW monitoring, (Mo-2). This can be achieved by understanding the existing structures, network pipe materials, terrains, areas having water shortage, etc; (see Sec. 5.3 and 5.4 for further explanation).

Referring to arrow (↗i.) and (↗j.), development of GIS layers for customer meters and major facilities (Ma-2 and Ma-3) is essential for planning the separation of DZs (and DMAs in large DZs – Mo-2). <u>These advanced physical loss reduction activities within a few priority DZs and/or priority DMAs may be recognized as pilot activities. They may then be framed as a pilot project after combining with the necessary basic activities in the same areas. This is a good tool for further motivation, engagement and training of staff (see Chapter 12).</u>

Arrow (↗k.) introduces mapping of tertiary distribution pipes, past bursts and leaks, pressure measurements, etc (Ma-4) which is useful for Ph-2 through leak detection and pressure reduction. Arrow (↙l.) recommends mapping (Ma-4) of bursts and leaks detected through Ph-1. In addition to underground leak detection and pressure reduction, better pipe materials and fittings can be introduced for new pipelines and service connections in this stage in order to reduce bursts and leaks.

Alternatively, in Stage 2, the WSP may start with Co-3 if a software for meter reading, billing, customer care, etc. is available. Full utilization of monthly abnormalities reports (on bursts, surface leaks, unreadable dials, stalled meters, tampered meters, gate locks, significant consumption reduction, illegal connection hints, underground leaks from service connections, etc.) from the system is recommended in order to effectively and efficiently address recurrence of serious commercial losses at large and medium customers (Co-1 and Co-2), and the un-investigated commercial losses at the many small customers (Co-4).Customers billed on fixed minimum charge (e.g. ≦ 6m3/month – residential and ≦10m^3/month – other customers) may not have a high impact on NRW reduction, hence Co-4 is given lower priority than Co-3 in this example.

Arrows (↗m.), (↙n.) and (↗o.) imply the need for system improvement to better handle notification of bursts and leaks from the public to assist Ph-1 and Ma-4 while accurate zonal/DMA total billed consumption is essential for Mo-2. Arrow (↗p.) recommends that surface leaks and underground leak noise hints found during Co-4 be communicated to staff repairing Phy-1.

2.4 Coordination for Stage 3 Activities

This involves expansion of leak detection and beginning of large-scale pipe replacement.

The priority activities in Stage 3 are shown in green text-boxes (Figure 2.1). Enhancement of leak detection and pressure reduction (possibly with more equipment) are part of Ph-3. Ph-3 also includes area-by-area expansion of underground leak detection and pressure reduction over other areas outside the pilot area.

Arrow (↙q.) and (↗r.) means implementing Mo-3 for better NRW monitoring may be required to expand the target areas of leak detection and pressure reduction while Ma-4 may assist in selection of priority areas to create additional DMAs (Mo-3).The start of replacement of problematic pipes (having frequent and recurrent bursts, leaks and illegal connections) in the priority areas previously targeted for underground leak detection is also part of Ph-3.

Arrow (↙s.), means implementing Ma-4 on GIS can assist in selection of pipelines or service connections to be replaced with better pipes.

Underground leak detection is labour-intensive and pipe replacement is expensive. However, commercial losses are relatively easy to reduce. Therefore, as indicated with arrow (↗t.), estimation of overall water balance as part of Mo-3 is recommended. The purpose is to check whether commercial loss components have been adequately reduced in the entire service area before starting leak detection in DMAs pipe replacement (Ph-3) (see Sec. 5.6 for further explanation).

As shown in Table 1.1 and Figure 2.1, Stage 4 involves further improvement of physical loss reduction including acceleration and completion of pipe replacement, while Stage 5 is for maintaining the achieved low NRW ratio.

Chapter 3

Organization Structure and Plan-Do-Check-Adjust Cycle

3.1 Establishment of NRW Unit and Coordination with other Units

1) NRW Unit should be established and permanently embedded in the organization chart.

2) NRW Unit should be fully operational with adequate dedicated staff (e.g., technical officers, leak surveyors, etc).

3) NRW Unit should have adequate support from:

    i) the top managers (e.g., MD, TM, CM/FM and HRM)

    ii) other relevant commercial and technical staff (e.g., billing, meter reading, meters servicing, GIS mapping, distribution, connections installation, procurement, customer care, etc).

4) NRW Unit should have suitable:

    i) job descriptions,

    ii) standard operating procedures (SOPs), and

5) The other staff should:

    i) Be sensitized on their jobs' contribution to NRW reduction,

    ii) Have SOPs in order to ensure effective workflows for NRW reduction including interaction among them and with NRW Unit.

6) Incentives for NRW reduction (e.g., allowance for night-time activities, performance-based incentives for individuals and/or groups in charge of different areas, etc.) should be established to motivate NRW Unit and other staff.

7) An inter-departmental committee on NRW management should be established comprising representatives (preferably the heads) of all departments/sections/units that have a stake in NRW management. The committee should hold monthly meetings to review the previous month's NRW reduction activities and give guidance on the way forward. The MD strive to chair this committee to understand the challenges and give support where needed.

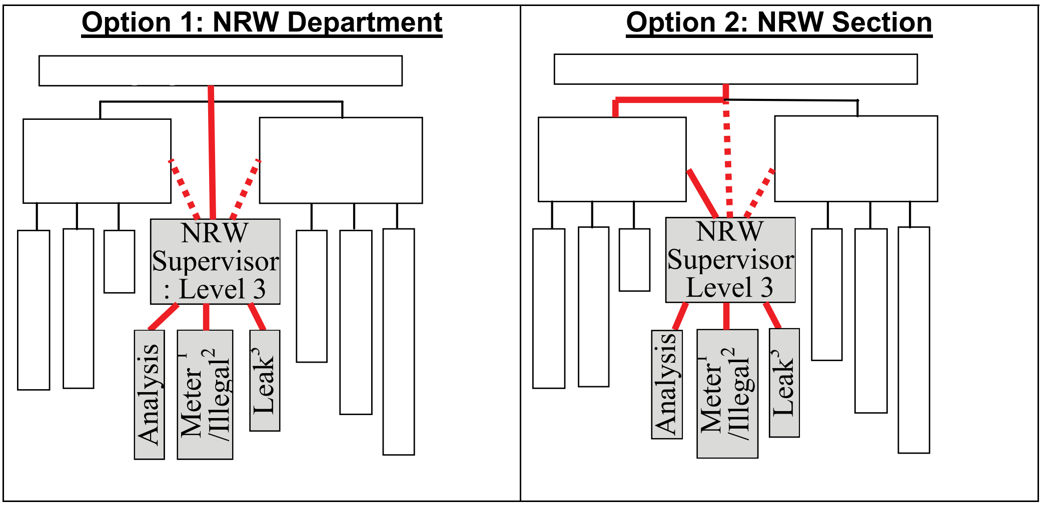
8) Each WSP should come up with a NRW policy to guide in management.

3.2 Organization Structure for NRW Reduction

The organizational structure of a WSP should be optimized for NRW reduction based on the most prevalent types of NRW (e.g., metering errors), etc. The Managing Director and board of directors should clearly understand that organizational optimization is a basic requirement for successful NRW reduction. The two basic organizational options shown in Figure 3.1 can be considered for different conditions. The supervisor of NRW-related tasks should be at least Level 3.

NRW can be reduced by all the staff understanding that NRW activities have to be shared among all the staff.

Since NRW reduction activities need various quick coordination between departments and sections, the NRW Supervisor needs to have direct access to and support from both the Technical and Commercial Manager and even the Managing Director if necessary (e.g., for funding).



Responsibility for/to   Coordinating between

Notes 1: Reduction of inaccurate meters, 2: Reduction of illegal water use,

3: Reduction of physical water losses

Figure 3.1: Organizational Options for Coordinating NRW Reduction Activities

Option 1 may be suitable where:

a. A WSP is very largeand the NRW Department consisting of many staff,

b. The Technical Manager is already overloaded,

c. The Managing Director wishes to get involved in NRW reduction directly, and

d. More commercial staff should be involved in NRW reduction than technical staff.

Option 2 is suitable for other WSPs but

a) The Technical Manager should ensure effective coordination between the Distribution Section and the NRW Section to effectively deal with bursts and leaks repair, pipe replacement, zoning of distribution systems, etc.

Option 1 is ideally the most recommended while Option 2 is more balanced. Regardless of the option, the NRW head should have direct access to the Managing Director, Commercial Manager as the Technical Manager.

In each case, the NRW head, should put a strong initiative in coordinating with the departments, sections and units, as well as head office and zonal offices, to reduce NRW effectively. It is crucial for the MD to give full support to the NRW head to enable him effectively execute the NRW reduction. The NRW Unit may have zonal NRW teams administratively under Zone Heads.

3.3 Main Tasks of NRW Unit

The staff of NRW Unit may be divided into three teams:
Team 1 for management, analysis and coordination,
Team 2 mainly for reducing commercial water losses on site, and
Team 3 mainly for reducing physical water losses on site.
Below are the main tasks of each team in order of priority:

Team 1

Members: NRW Supervisor

NRW Unit Head and Analysist

1) Establishing a robust yearly and quarterly PDCA cycles (annual activity review, self-capacity assessment, annual planning and update of medium-term plan, implementation, monitoring, adjustment, reporting, etc.) for NRW reduction in coordination with Team 2 and 3 and relevant departments/sections.

2) Discuss with Team 2 and 3 and relevant departments/sections (monthly) and report the progress and effects of NRW reduction activities based on the results of Universal NRW Monitoring (i.e., analysing NRW ratio fluctuations, total billed consumption, average tariff, etc.).

3) Analyse monthly meter reading and billing data of all the customers (including the ratio of estimated billed consumption) by consumption categories based on water tariff (e.g., Category 1: 300 m3/month and above, Category 2: 100 – 299 m3/month, ….) in liaison with Commercial Department and prioritize the NRW reduction activities.

4) Liaise with Commercial Department, Team 2 and GIS staff to:

   a) conduct customer identification survey (CIS) including mapping of all customer meters, and

   b) focus on large customers (e.g.,> 100m3/month) to reduce metering errors and illegal water use (Managing Director, Commercial Manager and Technical Manager should be involved).

5) Liaise with Distribution Section, Team 3 and GISstaff to conduct:

   a) daily abnormal flow monitoring of mains,

   b) bursts and leaks data collection and mapping, and

   c) planning and implementation of priority pipe replacement to reduce pipe bursts and leaks (Technical Manager should be involved).

6) Develop:

   a) relevant policies,

   b) internal standards and materials specifications (pipes, fittings, meters, etc.), and

   c) better workmanship to prevent leakage, meter errors and tampering in liaison with relevant technical and procurement sections (Technical Manager should be involved).

7) Work with Distribution Section and GIS staff to:

   a) establish hydraulic distribution zones and DMAs with bulk meters for zonal/ DMA based NRW reduction activities, and

   b) optimize water pressure using pressure regulating valves and/or break-pressure tanks (Technical Manager should be involved).

8) Liaise with Team 2 and 3 and Zonal Heads on their zonal based NRW reduction activities (zonal NRW teams may be necessary).

9) Once distribution zones and DMAs are established to some extent, discuss monthly (and report) the progress and effects of zonal NRW reduction activities with Team 2 and 3; and Zonal Heads based on monthly zonal NRW monitoring results in order to target the most problematic areas the following month, and create competition among zones.

10) If water supply is continuously, work with Team 2 and 3 and conduct minimum night flow measurement and step test to identify areas with large leaks and night water theft.

Team 2

(Staff dealing mainly with customer meters and illegal water use on site to reduce commercial water losses)

1) Contribute to the annual and quarterly review; and planning of NRW reduction activities.

2) Contribute to the monthly discussions on improving NRW reduction activities

3) Work with Commercial Department and GIS staff to:

   a) conduct CIS, and

   b) focus on large customers (plus possible large illegal water users) to reduce meter errors and water theft

4) Test and ensure bulk meters are accurate; and read them monthly (maybe with Team 3's help) synchronous with customer meter reading for universal and zonal NRW monitoring.

5) Deal with medium customers (e.g., 20 to 100m3/month) and potential medium illegal water users (e.g., farmers) with help of Zonal Heads to reduce metering errors and water theft (small customers can be dealt with later selectively with help of meter readers and Team 3 by checking service connections with listening sticks).

Team 3

(Staff mainly dealing with bursts and leaks on site to reduce physical water losses)

1) Contribute to the annual and quarterly review; and planning of NRW reduction activities.

2) Contribute to the monthly discussions on improving NRW reduction activities.

3) Work with Distribution Section and GIS staff to conduct:

   a. daily abnormal flow monitoring (e.g., reading bulk meters preferably by 9 am to determine 24 hours flows and prioritizing the day's patrol areas),

   b. bursts and leaks data collection and mapping, and

   c. planning and implementing priority pipe replacement to reduce pipe bursts and leaks.

4) Check leaks on service connections and near-by distribution pipes with listening sticks (e.g., 20% of service connections per year starting from prioritized areas) possibly in liaison with meter readers and distribution staff; and replacing spaghetti connections.

5) If water supply is continuously, work under Team 1 (maybe with help of Team 2) to:

   a. conduct minimum night flow measurement and step test in prioritized zones, and

   b. carry out follow-up leak detection survey with listening sticks and other equipment in areas having high night flow rates (Team 2 may need to conduct follow-up illegal water use survey).

6) If water supply is intermittently,

   a. track down leaks with potable ultrasonic flow meter from upstream to downstream in areas expected to have large leaks and,

   b. narrow down leak location with other equipment.

3.4 Capacity Development through Training and Benchmarking

1) Adequate relevant staff (e.g., NRW Unit staff, zone managers, plumbers, meter readers etc) should be sent to KEWI's training course on NRW management.

2) Adequate relevant plumbers and other field staff should be sent to KEWI's other training courses relevant to NRW reduction (e.g., plumbing, metering, connection installation, O&M of distribution system, etc).

3) Adequate relevant ICT and GIS staff and other technical officers should be sent for GIS-related training courses at KEWI, Kenya Institute of Mapping and Surveying and/or Kericho WSP.

4) Adequate relevant staff should be sent for WASPA's benchmarking workshops/ forums for collective learning.

5) Adequate staff should have opportunities of trainings held by donor organizations (e.g., JICA, VEI, SNV, WB, EU, etc.) and other Kenyan institutions (e.g., WASREB, other prominent WSPs, etc.).

6) Adequate in-house and tailor-made training (including on-the-job training (OJT)) for various NRW activities should be conducted at the WSP.

7) Adequate training on culture change should be impacted on all staff to improve the attitude of the staff.

8) WSPs should institutionalize writing and sharing of training reports by training participants with other staff members; benchmarking tours, etc.

3.5 Sensitization of Staff and Board of Directors on NRW Management

1) Ethics and the spirit of cooperation of all WSP staff should be effectively enhanced through sensitization activities for NRW reduction (e.g. through speeches from managers, warning against being involved in water theft, collusion with customers and water wastage, requests for thorough internal information-sharing and whistle blowing on any hints of surface (visible) leakage and water theft, and request for cooperation in relevant data collection for calculation of performance indicators, etc).

2) Recent operational financial losses (KSh/yr or /month) due to NRW should be:

    a) calculated (by multiplying the total of authorized unbilled and commercial losses with the average tariff (i.e. (total revenue–grant revenue)/ (annual billed consumption, KSh/m3) and the total of physical losses with the unit production cost (i.e., total O&M cost / annual production, KSh/m3) based on their roughly-estimated or assumed balance (e.g., authorized unbilled + commercial losses: 60% and physical losses: 40%)) and converted to financial loss per staff.

    b) explained to a wide range of staff and board members of WSP

3) Other parameters such as revenue loss per staff, capital investment from saved revenue loss, etc can also be calculated to sensitize staff and board on the need to reduce NRW.

4) Potential reduction in further capital investment (KSh) for water resource development (e.g., additional intakes, water treatment plants, pipeline facilities etc) through NRW reduction should also be roughly estimated (KSh) based on the volume of expected or assumed physical losses reduction (e.g., 40% → 20%).

5) The overall scale of justifiable investment for NRW reduction should be discussed among the managers and board members (e.g., based on the rough financial estimations described above).

3.6 Enhancement of Customer Compliance and Support

1) Printed or electronic water bills, SMS, etc. carrying messages requesting customers for cooperation, such as notification of visible leaks and illegal water uses, to reduce NRW and excessive water uses should be extensively used.

2) Toll free telephone number, low-cost SMS number, etc. should be established to encourage the public to notify problems to the WSP.

3) Customer care section should be enhanced with a software system (e.g., WASREB's Maji Voice and a customized internal customer management system) for receiving and managing complaints and problem notifications (e.g., bursts, leaks and water theft).

4) Awareness campaigns for NRW reduction and saving water (e.g., overflow from customers' ground/underground/rooftop reservoirs/tanks and excessive consumption) in the following forms should be adequately conducted:

    a) Public forums/open clinics (e.g., baraza, water action group, etc) for community sensitization (especially in areas with many illegal water users)

    b) Activity-based sensitization such as inviting school to learn about the water facilities

    c) Media campaigns (e.g., TV, radio and social media)

    d) Participating in events and trade shows (e.g., World Water Day, trade fairs and exhibitions, etc)

3.7 Self-Assessment of Existing Conditions

3.7.1 NRW Self-Assessment Matrix

At the start of NRW activities, WSPs are required through their NRW functions or otherwise to conduct a self-assessment on diverse NRW issues/variables herein called aspects. The WSPs are required to carry out the Self-Assessment as teams as per the template in **Appendix-1Sht(2)**.

Currently identified NRW challenges fall into four main categories with affiliated sub-categories. Within these categories, 33No aspects of NRW are identified and outlined for action in a bid to facilitate a better understanding of the challenges and hence identification of potential NRW management aspects for positive results.

For self-assessment, each NRW aspect is assigned points on a scale of 5 (5 levels) depending on perception of status. WSPs must therefore objectively assess their own levels to establish their NRW baseline conditions.

Level 1 is the most advanced status and corresponds to a state where nearly all good practices of NRW measures have been taken and the WSP is at cutting edge of NRW management and can only sustain the status at the lowest NRW expectation. Level 5 is the lowest and most basic status which corresponds to a situation where operations in relation to that aspect are either non-existent or still very low and therefore requires much improvement.

After assessing the NRW status level using the standard Self-Assessment template, WSPs can then strategically plan for NRW reduction specifically along those distinct

NRW aspects. They should follow the steps outlined in the Template for Annual Review, Assessment, Planning and Monitoring [Appendix-1Sht(4)] where there are provisions to identify required resources and investments as appropriate in order to improve NRW management in the short, and medium terms.

The four main categories of NRW reduction and management are as follows:

a) Organizational Structure

In the past, addressing NRW challenge were dampened by inadequate commitment from the management. It is therefore proposed that WSPs shall institutionalize the NRW function in their organizational structures. This shall be followed by staffing this function with the required competent staff, resources and other necessary capacities and facilitation. Just like other functions, NRW unit shall be assigned responsibilities with expected targets.

b) GIS, NRW Monitoring, Zoning and Water Balance Analysis

Mapping of water supply facilities including customer meters and sharing GIS data and maps (using free software) are critical essentials to addressing NRW. In addition, daily NRW monitoring by zones and DMAs plus monthly water balance analysis assist in detecting abnormal flows, bursts, leakages and illegal water use; and addressing them early enough, hence mitigating the potential losses.

c) Reduction of Commercial (Apparent) Water Losses

Water service provision is supposed to be run on business principles where potential losses should be at the bare minimum if any. Each WSP management shall therefore pay special attention to large customers through analysis of their meter reading and billing data including conditions of these customer meters. In addition, the WSP shall aim to reduce unbilled, unmetered and illegal water uses by frequently undertaking CIS as well as targeting suspicious customers.

d) Reduction of Physical (Real) Water Losses

This entails reduction of physical losses through proactive patrolling for leaks, quick quality repairs, daily detection of illegal water use including illegal connections, use of better-quality pipe materials, underground leak detection and pressure management among many others.

Beyond the assessment of all the NRW aspects, sub-categories and main categories with each being allocated points as appropriate, there shall be the weighted scores which then give rise to the level of assessment as per the template(Appendix-1).

3.7.2 NRW Reduction Planning

After successfully conducting NRW self-assessment, the next step is the planning phase. The achievement level of the self-assessment is taken as the baseline. The maximum achievable point in every NRW aspect is noted. Priority for improvement in every NRW aspect, with 1 being the highest and 5 the lowest, is determined. Subsequently, the target achievement for the short term (1 year) and the medium term (5 years) are determined which then become the basis for execution of the required activities and their corresponding monitoring and evaluation over time (monthly, quarterly or annually).

Appendix-1Sht(2) shows the Capacity Self-Assessment Template on current conditions for NRW Reduction.

3.7.3 Analysis of the Self-Assessment Matrix

Based on the Self-Assessment Matrix developed by the WSP, the management must analyse the priority activities to be implemented by the NRW function directly or through coordination with other pertinent functions of the WSP.

Table 3.1 shows the "Issues and Questions" that are raised in the Self-Assessment Matrix and describes the priority of each issue in column 2. Column 3 describes the activities that need to be implemented by the management in order to accomplish the priority issue in column 2.

Table 3.1: Issues and Questions Raised in Self-Assessment Matrix and their Priorities

Issues and questions	Priority of each issue	Activities by Management
1. Organizational Structure, Sensitization, PDCA Cycle and Procurement		
1.(a) Staffing with Essential Support and Training	-Establishment of a permanent NRW unit with requisite skills and competencies plus explicit job descriptions and SOPs and its Strong Coordination with other units. -Capacity Development through Trainings and Benchmarking	Management support through facilitation with resources as appropriate

Issues and questions	Priority of each issue	Activities by Management
1.(b)Sensitization and Awareness raising for wider support	Sensitization of staff and Board on Ethical, Cooperative, Financial and Water resource aspects of NRW - Enhancement of existing and potential customers compliance and support	Reaching out to both staff and current and potential customers and other people of affiliated interest to be part and parcel of NRW reduction initiatives either directly or indirectly
1.(c) PDCA Cycle	-Yearly PDCA Cycle: Participatory Review and Planning, and Budget and Funds for NRW Reduction Activities -Monthly and Quarterly PDCA Cycles: Performance Indicators, Monthly Report, Data-based Discussions and Progress Monitoring	-Management support through self- involvement in the planning and review activities, Monthly Reports, Data-based Discussions and Progress Monitoring -Facilitation with resources as appropriate
1.(d) Suitable, Sufficient and Timely Procurement	-Internal Standardization of Pipes, Fittings, Customer Meters, etc. and Quality Control -Procurement of Sufficient Materials, Equipment, Means of Transportation, etc.	- Management support through facilitation with resources as appropriate
2. GIS, NRW Monitoring, Zoning and Water Balance and Analysis		
2.(a) Mapping/GIS Development, and Utilization of Free Mapping Soft-wares	-GIS Establishment and Mapping of Water Supply Facilities -Mapping of Customer Meters, Various Problems at Customer Points, and Bursts and Leaks -Backup, Update and Enhanced Sharing of GIS Data/Maps using Free Software	- To ensure there are updated pipe network drawings of the infrastructure

Issues and questions	Priority of each issue	Activities by Management
2.(b) Monthly NRW Monitoring and Zoning	-Monthly Monitoring of Total Billing, Universal NRW Ratio, etc. for entire Service Areas (SA) - Zoning of the Existing Distribution Networks into DZs and DMAs -Monthly Calculation of NRW Volume and Ratio for Each DZ and DMA	- Ensuring there are accurate production and customer meters as a mandatory priority for reconciliation to make sense - Management support through facilitation with resources as appropriate
2.(c) Abnormal Flow Monitoring and Water Balance	-Abnormal Flow Monitoring for Quick Detection of Bursts, Leaks and Illegal Water Uses -Universal Water Balance Table 1/2 (Confirmation of the Reduced/Remaining Commercial Losses) - Universal Water Balance Table 2/2 (Separation of Physical Losses) and Additional Zonal Analysis	-Management support through facilitation with resources as appropriate -Penalties must be imposed as stipulated by the law, and water theft must be punished in liaison with the enforcement arm of the county government. -All Illegal connections must be legalized or removed.
3. Reduction of Commercial (Apparent) Water losses (i.e., Data Handling and Meter Accuracy Errors and Illegal Uses) etc.		
3.(a) Starting from Large Customers (e.g., by NRW Section)	-Analysis of Meter Reading and Billing Data to Understand the Conditions of Existing Customer Meters, etc -Straight-forward Reduction of Various Commercial Losses starting from Large Customers -Additional Focused Management of Large and Medium Customers	-Management support through facilitation with resources as appropriate

Issues and questions	Priority of each issue	Activities by Management
3.(b) Activities for New and Problematic Customers (e.g., by the section installing Service connections and Customer meters)	-Reduction of Unbilled, Unmetered and Illegal Water Uses based on CIS and Targeting of Suspicious Customers -Preventive Measures at the Installation of Service Connections and Customer Meters	-Management support through facilitation with resources as appropriate -Information Management System such as the GIS should be introduced -Training must be conducted for GIS.
3.(c) System-Related and Procedural Internal Improvements (e.g., by the section in charge of Meter Reading and Billing)	-System-related and Procedural/ Internal Improvements for Meter Reading and Billing -Procedural/Internal Improvements against Illegal Water Uses	-Management support through facilitation with resources as appropriate -Information Management System such as the GIS should be introduced. -Training must be conducted for GIS. -Penalties must be implemented as stipulated by law, and water theft must be punished in liaison with enforcement arm of the county government. -All Illegal connections must be legalized or removed.
4. Reduction of Physical (Real) Water Losses i.e. (Bursts, leaks and Overflows)		

Issues and questions	Priority of each issue	Activities by Management
4.(a) Physical Loss Reduction Measures applicable without isolating DZs and /or DMAs	- Reduction of Visible Physical Losses by Active Patrolling and Quick Quality Repairs -Daily Usage of Low-Cost Listening sticks and Hand Pumps for Detecting Leaks (and Illegal Water Uses) -Sufficient Valves, Introduction of Better Pipe Materials and Small-scale Replacement of Most Problematic Pipes	-Management providing: - -Institutionalized and operational NRW function -Appropriate equipment -Training for use of these equipment -Budget provision for implementation of prioritized NRW reduction-based activities - Management support the implementation of efficient and effective leakage control measures - Adoption of geographical information system (GIS) for management of leak repair records to facilitate decision-making
4.(b) Underground Leak Detection in a priority DZ(s) and /or DMA(s) and its expansion over other areas	-Strategic Approaches for Underground Leak Detection varying from Place to Place -Improvements for Underground Leak Detection	-Management providing: - -Institutionalized and operational NRW function -Appropriate equipment -Training for use of these equipment -Budget provision for implementation of prioritized NRW reduction-based activities - Management support the implementation of efficient and effective leakage control measures - Adoption of GIS for management of leak repair records to facilitate decision-making

Issues and questions	Priority of each issue	Activities by Management
4.(c) If REQUIRED Pressure Measurement and Pressure Reduction / Management without large investments (e.g., PRV and BPT)	-Zone Prioritization for Pressure Reduction and Identification of Problematic Pipelines with Pressure Measurements -Pressure Reduction/ Management with Relatively Small Investments (e.g., PRV, BPT, etc.)	-Management providing: - -Institutionalized and operational NRW function -Appropriate equipment -Training for use of these equipment -Budget provision for implementation of prioritized NRW reduction-based activities - Management support the implementation of efficient and effective leakage control measures - Adoption of GIS for management of leak repair records to facilitate decision-making -Creation of Water pressure map(s) by use of water pressure gauge. -Installation of Pressure Reducing Valves as appropriate
4.(d) If REQUIRED Leak Reduction with large Investments (e.g., Pressure reduction with Reservoirs and Replacement of Many pipes).	-Pressure Reduction/ Management with Relatively Large Investments (e.g., Zoning with Reservoirs, Pump Replacement, etc.) -Large-scale Replacement of Deteriorated Pipelines and/or Service Connections	-Budget provision for implementation of prioritized NRW reduction-based activities - Management support the implementation of efficient and effective leakage control measures - Adoption of GIS for management of leak repair records to facilitate decision-making -Creation of Water pressure map(s) by use of water pressure gauge. -Installation of Reservoirs and Pipe replacement with the correct pipe material as appropriate

3.8 Preparation of Medium-term and Annual NRW Reduction Plans

3.8.1 Developing and Implementing a NRW Reduction Plan

Water is a fundamental resource for human and economic development. Many water utilities in Kenya are not able to account for large portions of water they deliver. In some cases, the NRW is above 50%. This is a major cause of concern in terms of inefficient use of the scarce water resources. It also affects a utility's ability to earn revenue to support its financial sustainability and thereby offer efficient services. A utility which has a high NRW means it has lower revenue hence it does not have funding to fix the problem that causes NRW and NRW increases.

In order to address the situation of high NRW and achieve the required efficiency, a utility needs to operate in an environment in which NRW declines, revenue increases, the utility has funding to invest in system improvement, and network expansion resulting to further decline in NRW.

Developing and implementing a successful NRW reduction plan entails the following steps:

Step 1: Seek support for a Non-Revenue Water Reduction Programme

NRW programmes require resources and time which are scarce. Therefore, the first step should be to outline a NRW programme. The programme should show the anticipated benefits in order to gain support of the utility's leadership and customers.

Step 2: Establish a Non-Revenue Water management team

The team performs the analysis and develops a strategy, recommends intervention and oversees implementation. The team must include members from all of the utility's departments; i.e., Administration, Technical (Production, Distribution) and incorporate customer service, communication, etc. this is crucial in order to promote ownership and build consensus by the utility's senior management.

Step 3: Calculate the Non-Revenue Water Ratio

The NRW ratio will show the magnitude of the losses and the areas where NRW is present. This enables decision-making in use of the limited utility resources in areas of high return in revenue and cost cutting.

Step 4: Set Non-Revenue Water reduction targets

The utility should set realistic targets for NRW reduction taking into consideration the utility's goals, policies and resources and any targets established by the National Water Policy and the regulator. The National Water Services Strategy (NWSS: 2019-2030) for NRW is 25% by 2030 while the benchmark by WASREB is 20%.

Sep 5: Identify Non-Revenue Water reduction projects

Undertaking a pilot project to demonstrate the effectiveness of NRW reduction is a useful way to start because it will generate lessons and it will show the value of NRW reduction strategy. A pilot project covers a small area that is still large enough to test the NRW reduction strategy.

The type of pilot project can vary from improved metering to better customer accounting to full-scale repair and rehabilitation of the network and customer service connections.

Step 6: Prioritize Non-Revenue Water projects

Most utilities face scarce resources in staffing, equipment or funding. The potential projects will have different levels of payback, impacts on service, timing, etc. Prioritizing is the way to select the projects that will have the greatest overall benefit and to decide on the timing of when projects are accomplished.

Some projects may reduce NRW significantly but will have a high cost. Others may have a lower cost and lower reduction but can be accomplished more readily because resources are available. Gains from doing these projects may generate additional revenues which can then be used to accomplish the more expensive projects.

Step 7: Planning and approvals

In order to obtain resources. The team needs a budget that is approved by the utility leadership. Therefore, when developing an NRW plan, remember that reducing NRW is not a short-term process. Some activities may span years rather than months. Timeframe between four and seven years are reasonable. Anything shorter is ambitious and anything longer will not be cost effective.

In preparing the budget, the team must identify costs that may include:

i) Staffing for both direct NRW works (e.g., leakage technicians) and direct support (e.g., procurement staff).

ii) Equipment installed permanently (e.g., DMA meters) and those used on a day-to-day basis e.g., leak detection equipment)

iii) Vehicle and equipment to maximize the productivity of staff.

Step 8: Implementation, monitoring and evaluation

As the project takes place, it is a good idea to monitor both the costs and benefits and compare them to budgets and NRW targets. This will demonstrate the benefits of NRW reduction and build support for the strategy. It will also allow the team to take action to improve performance as needed.

Step 9: Sustain the gains of a Non-Revenue Water reduction project

NRW management is a continuous process. Even after the initial gains are made, NRW must continue to be managed. This requires vigilance and attention to make sure that leaks are eliminated when they occur, that all customers are legally connected and billed and, all water uses are tracked.

3.8.2 Contents and Layout of Non-Revenue Water Reduction Plan

There are many activities that constitute NRW reduction measures. The purpose of an NRW Reduction Plan is to determine the most suitable measures for adoption and use the available budget effectively.

An NRW Reduction Plan must include the following components:

a) Introduction

This covers the WSP's background, rational for the reduction of plan, assumptions in developing the plan, methodology of developing the plan, and organization of the plan.

As geographical and social conditions are unique to each WSP, any existing problems related to these conditions must be identified. Hence, the overall management, financial status and funds available are all important factors in the planning for NRW reduction.

b) Current status of Non-Revenue Water

It is important to first understand the current situation that is causing high NRW. Therefore, the analysis of the current status should be based on a self-assessment carried out by the WSP using the SELF ASSESSMENT MATRIX.

As a first step it is important to understand what happens to water when it enters the network. Therefore, NRW must be calculated by using volume of distributed water (system input volume) and billed authorized consumption volume.

In cases where the volume of distributed water and/or volume of consumption cannot be correctly established, then priority should be placed on the installation of flow/water meters.

c) Objective (target Non-Revenue Water ratio and target area)

A company-wide target for NRW reduction, taking into account the utility's other goals or policies that will either complement or conflict with NRW reduction should first be established. This target should be guided by the National Water Services Strategy and the sector benchmark as issued by the regulator. Often, many utilities choose the NRW target arbitrarily, without any real consideration of cost implications or whether it is achievable.

Identifying the economic level of NRW is essential to setting the initial NRW targets and requires a comparison of the cost of water being lost versus the cost of undertaking NRW reduction activities.

For utilities with more than 40% NRW ratio, commercial loss reduction and visible leakage reduction measures must be given priority. For those utilities with NRW ratio of between 40% and 30%, invisible leak detection and repair are necessary. Between 30% and 24% ratio, it is necessary to replace aging pipes. Significant amount of funds will be required to replace all aging pipes and therefore, it is necessary to prioritize areas and also activities.

Generally, leakage occurrence record must be plotted onto a map, which will show areas with high occurrences of leakages. Areas with high water pressures and also large pressure variations should be given priority. Furthermore, if there are any asbestos cement pipes, replacement of those must be prioritized.

d) Non-Revenue Water Reduction Implementation Plan

It presents the implementation matrix, which covers for each of the strategies, proposed actions, bill of quantities, and cost estimates, implementation schedules, expected outputs and output indicators.

e) Monitoring and Evaluation

It is essential for the success of the NRW management programme. It enables managers to track progress against plans, budgets and expected results in the form of performance indicators. It also enables managers take action when performance is lagging behind expectations or exceeding budgets. To achieve the desired results from the plan, MONITORING through regular observation and recording of activities taking place is important.

3.8.3 Prioritizing Implementation Plan of Non-Revenue Water Reduction

Once the utility's NRW target is set, utility managers should calculate the proposed volume of water saved by comparing the NRW baseline with the target level. The volume components, as detailed in the implementation plan for NRW reduction Table 3.2 are then prioritized according to how the required total reduction can be most cost-effectively achieved. That is, some components may comprise a significant volume, but would not be targeted because of the high cost to achieve reduction in that component. On the other hand, focusing on another component may cost less while reducing the same volume. Therefore, the scope of implementation will depend on the financial capability of each utility and be guided by the action plan in Table 3.3 (also refer to Appendix-1Sht(5).

In general, if a physical loss is detected and repaired then the savings will be in terms of a reduction in variable operational costs. When a commercial loss is detected and resolved, then the savings will be an immediate revenue increase, and this is based on the water sales tariff.

The water sales tariff is higher than the variable production cost for all profitable water utilities. Therefore, a smaller volume of commercial loss may have a higher financial value, so if increasing financial resources is the objective, then commercial losses should be prioritized.

Similarly, where a water utility has a shortage of treated water, and some customers receive less than a 24-hour supply or the supply coverage is less than 100%, then reduction in physical losses would effectively create additional water supply. Hence if increasing water supply is the objective, then prioritizing physical losses reduction could enable customers to receive water 24 hours a day, or new customers to be connected to the supply system.

Table 3.2: Non-Revenue Water Reduction Implementation Plan

Issues	**Activities**	**Description of Activities**	**Concept and Quantified Aim**
Fundamental Measures: Water Balance/ Flow/ Pressure Monitoring/ Mapping, Procurement & Zoning	Consumption Metering	Customer meter installation	Installation of customer meters at every household to aid in the determination of consumption and billing process and also to assist in the determination of the NRW volume in the system is therefore paramount
	Pressure Monitoring	Pressure gauge installation	To determine current water pressure at select points in the distribution system
		Water pressure map	Water pressure map must be developed using data from water pressure gauge measurements
	Maps/GIS	Pipeline map	Pipe network maps and drawings are absolutely necessary for WSPs to implement efficient and effective NRW reduction measures. In the absence of drawings, the WSP should start to build up the drawings of distribution mains and major distribution facilities. Coming up with pipeline map which contains types of pipes, size, age, length, valves, etc.
		Digitize the mapping data	Comprehensive map of the pipelines by computer aided design ensures ease in retrieval, updating, amendment, storage, etc.

Issues	Activities	Description of Activities	Concept and Quantified Aim
	Leak Repair Records	Check for any leakage. Recording the leakage promptly. Checking and recording meter tampering	It is necessary to provide repair records, such as pipe diameter, material, location, etc
	Provision of basic equipment necessary for NRW reduction		Procurement of equipment related to NRW reduction. To carry out the leakage control work at least the following equipment are necessary: Hearing bar, electronic leak detector, Pipe locator (for metallic and non-metallic pipes). Necessary number of basic equipment depends on the size of the WSP
	Separating into distribution zones and DMAs gradually while getting trained in a pilot DMA		Establishment of small DMAs requires a lot of resources. It is therefore recommended to begin by establishing a pilot DMA to conduct training of NRW reduction measures for relevant WSP's staff while gradually separating the entire service areas into large distribution zones and then into DMAs.
Reduce Commercial Losses	Customer metering	Inspection of all customer meters	- Inspection of stuck meters, non-active and/or aged customer meters
		Ensure 100% metered connections	- Improving the customer meter ration
	Customer meter replacement based on age and accuracy	Replacement of stopped/ inaccurate and/or aged customer meters	- Investigating all customer meter tampering suspects - Repairing and/or replacement of customer meters

Issues	Activities	Description of Activities	Concept and Quantified Aim
	Customer meter class	Ensuring purchase of meters that meet required standards	- Replacement of existing meters not meeting required specifications
	Customer database	Customer database and billing	- Update and maintain the database with specific times of update. - Purchase of software to make work easier to manage database
	Customer meter reading	Reading all meters monthly	Develop a schedule on the meter readers rotation
		Billing all customers on monthly basis	- Preparation and Printing of meter reading books. - Capturing of all the meter readings. - Bill adjustments. - Processing the bills
		Less errors in meter reading. Less corruption cases	- Correct reading of meters. - Rotating meter readers in the company. - Sub-contract meter reading. - Ensuring proper routing
	Illegal connection, meter tampering, bypasses	Illegal and dormant connection inspection	- Identifying illegal accounts - Disconnecting/legalizing illegal accounts - Management to take stern, stiff and legal action on corrupt staff manipulating meter readings, meters, etc.
		Forming inspection team, taking legal action on the illegal cases, random monthly inspection by top management	- Management to be swift, steady, fearless and persistent in dealing with corrupt cases like meter interference, illegal connections.

Issues	Activities	Description of Activities	Concept and Quantified Aim
Reduce Physical losses	Active leakage control	Leakage detection	Conduct continuous non-visual leakage detection activities
		Leakage repair works	In principle, detected leakages must be repaired immediately
		Replacement of service pipes	When leakage occurs in the service pipes, the fundamentals are to replace rather than repair.
		Replacement of distribution pipes	Plans for distribution pipes replacement are affected by the availability of financial resources. However, replacement is preferred option
	Reduce repair time in distribution pipes	Record time taken to repair leakages. Analyse the data to determine time taken	Reduced response time of pipe repair to 6hrs irrespective of size.
	Water pressure management	The most common and cost effective is the use of pressure reducing valve - PRV	Water pressure of around 1 MPa must be maintained as much as possible throughout the distribution system.
Capacity Building	Training on NRW management	Taking the relevant staff for training on NRW management. Field visitation. On-Job-Training (OJT)	To improve technical skills and capacity

Issues	Activities	Description of Activities	Concept and Quantified Aim
Public Aware-ness	Aware-ness of stake-holders on NRW management	NRW public campaigns	Create stakeholder awareness for proper water use and disseminate benefit of NRW management.

The action plan would be summarized as shown in Table 3.3.

Table 3.3: Non-Revenue Water Reduction Action Plan

Issues/Questions		Desired Status / Target	Short Term Measure
1	**Water Balance, Flow and Pressure Monitoring, Mapping**		
1.1	Water Balance		
1.2	System Input Metering		
1.3	Pressure Monitoring		
1.4	Mapping/GIS		
2	**Leak Repair Records**		
2.1	Leak Repair Records		
3	Performance Indicators		
3.1	Performance Indicators		
4	**Active Leakage Control**		
4.1	Active Leakage Control		
4.2	District Metered Areas (DMAs)		
4.3	Leak Repair - Distribution Pipes (Repair Time)		
4.4	Leak Repair - House Connections (Repair Time)		
5	**Customer Metering**		
5.1	Customer Metering		
5.2	Customer Meter Replacement and Age		
5.3	Customer Meter Class		
5.4	Customer Database		
5.5	Customer Meter Reading		

Issues/Questions		Desired Status / Target	Short Term Measure
5.6	Illegal Connections, Meter Tampering, Bypasses		
6	**Other Interventions**		
6.1	Capacity Building on NRW Management		
6.2	Stakeholder awareness on NRW Management		

3.9 Budgeting, External Funds and Public Private Partnership

3.9.1 General

a) Sound strategies and/or main activities to reduce NRW should be well stated in the WSP's latest 5-year strategic plan.

b) The following documents should be developed in a fully participatory way among relevant staff:

i) yearly self-assessment of current conditions (i.e., Self-Assessment Template and its visualized results) – Appendix-1 Sht(2).

ii) yearly update of medium-term NRW reduction plan (MP) with activity prioritization (i.e., MP - Appendix-1 Sht(4)Template <2-1>)

iii) annual NRW reduction plan (AP) with cost estimation (i.e., AP - Appendix-1 Sht(4)Template <2-2>)

iv) yearly review sheet (i.e.,Appendix-1 Sht(1) and/or report of NRW reduction activities

c) Submission of the four documents listed above (e.g., to managers, board of WSP and/or WASREB)

d) The budget required for implementing the annual NRW reduction plan should be approved (e.g., by the managers and/or the board of WSP)

e) Possibility of receiving external funds required for capital investment included in the medium-term plan (e.g., for replacing degraded pipes) should be discussed well.

3.9.2 Caution

Private sector participation can take many forms, and the best approach in the short term is probably a low-key gradualism whilst preparing the ground for larger scale private sector participation.

a) If a loan/grant is involved, ensure relevant constitutional requirements are followed in formulation of the loan/grant agreement

b) Develop adequate legal, institutional and regulatory setting to promotePublic Private Partnership (PPP)

c) Ensure financial proposal is adopted and approved by the legislative arm of the government and has gained enough social and political support

d) Create internal and external accountability, prioritizing investments within financial availability

e) Overcome institutional rigidities, particularly regarding manpower and investment planning and implementation

3.9.3 Performance Based Contracts

a) Under Performance Based Contracts (PBC), a private firm is contracted to implement an NRW-reduction programme, and contract payments are linked to achievements.

b) Contract models and the level of performance-based payments can vary widely from one utility to another.

c) It is important that contract period should be Realistic and in proportion to the project network area. Not too short and not long period.

Note: The principal advantages of NRW PBCs over conventional projects that are directly implemented by a utility is that the utility can benefit more rapidly from NRW reduction and faces a lower risk of the project not achieving its targets.

3.9.4 Drivers for implementing Non-Revenue Water Performance Based Contracts

a) Major constraints on water resource availability, currently or expected in future

b) Utility is not recommended to increase staff to reduce NRW and then scale back staff to maintain low NRW

c) Limited or low utility expertise in NRW planning and reduction

d) High water production costs, such as through the use of desalination or high energy cost.

3.9.5 Characteristics of Performance Based Contracts

It is output-based: design, build, operate contract with strong performance element.

a) Both the client and contractor must understand the contract before signing.
b) Payment - Small fixed fee - 'Priced Activity Schedule'
c) DMA establishment - lump sum price per DMA established
d) Performance indicator fee per m3/day leakage reduction
e) BoQ (supply and installation) for unforeseen works
f) Works to connect new customers
g) Leak Repair
h) Network Pipes Replacement and Extension
i) Pressure Control Implementation and Optimisation
j) Improving water customer services (customer satisfaction)

3.10 Periodic Discussions, Progress Monitoring and Review Reports

1) Prioritization of data collection (daily, monthly, quarterly and annually) for calculating performance indicators (should be carefully done. The indicators can also be used for WASPA's benchmarking activities and WASREB's Impact Report.

2) Systematic and simplified data collection and analysis methods should be formulated and operationalized.

3) The NRW Unit should:

    i) prepare quantitative monthly progress report using selected PI's

    ii) submit the report to the supervisor/manager

4) The NRW Unit and other relevant staff including managers should have monthly NRW reduction coordination meetings and discuss concreate improvement of the PI's

5) Progress in implementing the planned NRW activities should be monitored

3.11 Internal Standardization and Procurement

1) The types of problematic existing pipes, fittings, valves, etc (causing bursts and leaks frequently) and bulk and customer meters (with defects and being tampered with) should be discussed adequately (and analysed based on collected data) to identify the need for changing their procurement.

2) Suitable types of pipes, fittings, valves, etc of different sizes and suitable pressure rating (e.g., HDPE pipes to reduce leaks from joints) should be selected for procurement with adequate internal standardization (based on performance, availability and price)

3) Suitable specifications of bulk and customer meters such as ISO Class and/or OIML R, type (e.g., copolymer piston), availability of spare parts, etc should be decided for each size

4) The procurement of pipes, fittings, valves, bulk and customer meters, etc should be done in accordance with suitable types and specifications (including those provided by WSB, County, etc)

5) The WSP should appoint adhoc but competent staff for different inspection and acceptance committees based on the various procurement categories (e.g., pipes and fittings, motors and pumps, meters, etc). The committees should be strengthened well to reject faulty and unmatched materials and services

6) Some portion (e.g., 5%) of each batch of new customer meters should be sent to a credited meter testing institution (i.e., KEBS and Nyeri WSP) and sub-standard ones rejected (WSP with own meter test bench may test all or some of the new meters)

7) Trace survey should be conducted to evaluate durability and actual lifespan of newly procured meters (results showing a significantly limited durability may be used to reject the products from the same manufacture)

8) Enough pipes, fittings, valves and other common appurtenances should be procured and stored for quick repair of bursts and leaks.

9) Enough bulk and customer meters of different sizes (including spare parts if available) should be procured and stored for quick replacement and repair of faulty and degraded meters

10) Enough number of NRW survey equipment (e.g., listening sticks, calibrated buckets, portable ultrasonic flow meter, electric leak detector, noise correlator, pipe locator, pressure gauges with maximum pressure pointer/ pressure loggers, hand pumps, etc) should be acquired

11) Enough office appliances and specialized hardware required for establishing or improving GIS database, e.g. A3- inkjet printer with scanner (or plotter), spare inks, desktop PC or laptop, hand-held GPSs, large PC monitor, etc should be procured and well maintained (Note: Free GIS software programmes and free base maps such as QGIS and online satellite images are available for PCs)

12) Enough official-use smartphones/tablets should be procured for improving NRW activities at site (Free mobile GIS and interactive data collection software programs, etc can be installed in the procured smart-phones/tablets)

13) Reliable internet connections with reasonable speed in WSP offices (i.e., WIFI) and in official-use smartphones/tablets (i.e., data connection) should be provided to the staff involved in NRW-related activities

14) Enough transportation means should be secured for NRW reduction activities

Chapter 4

Mapping and Use of Free Software

4.1 Necessity for Geographical Information System

4.1.1 What is Geographical Information System?

Geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface. GIS can show many different kinds of data on one map, such as streets, buildings, vegetation etc. It is therefore ideal for viewing and managing water facilities (e.g., pipelines, storage tanks, etc.) compared to paper maps that have been in use in the past.

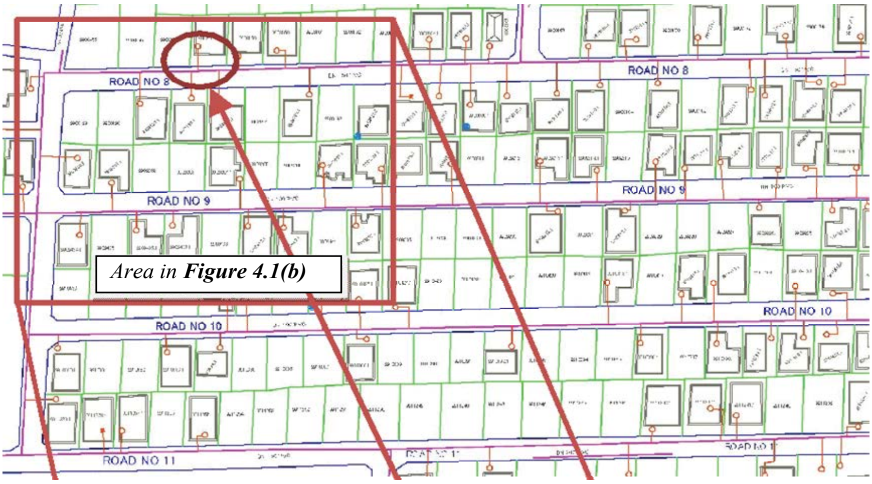


Figure 4.1(a): Advanced GIS map showing water supply network

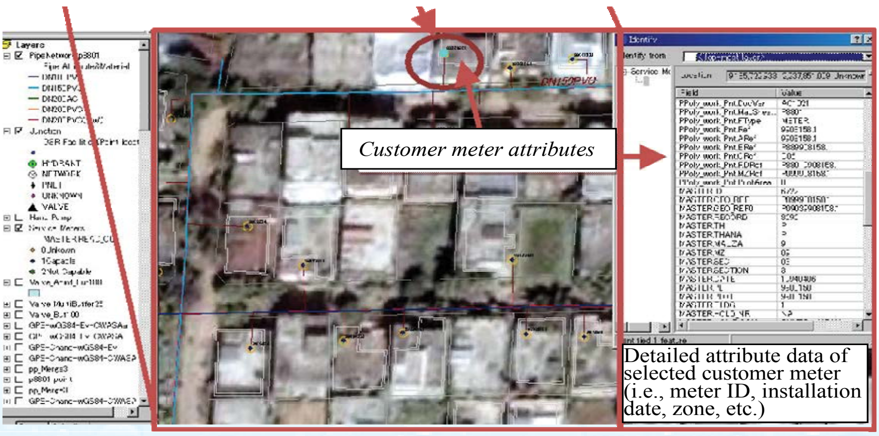


Figure 4.1(b): Satellite imagery used as base map of GIS

GIS can be used for storing and updating the geographical locations of water supply facilities such as customer meters, area boundaries, etc. and their attributes (including records of problems - bursts, leaks, water thefts etc.). Figure 4.1(a) is an example of advanced GIS database of water supply (customer meters, service and distribution pipes) showing supplementary layers (plots and buildings). Figure 4.1(b) is the satellite image showing part of the area covered by Figure 4.1(a).

4.1.2 Free GIS Software

In order to effectively reduce NRW, it is essential to utilize data from multiple information systems such as:

- Customer management systems for data on meter readings, billing, revenue collection, complaints handling, etc.
- Statistical data calculation sheet/processing system relating to NRW management (e.g., spreadsheets to calculate NRW ratio in each area)
- GIS and other mapping systems for collecting, identifying and analysing information on water supply facilities and their problems including locations of bursts, leaks, water thefts, etc.

Most of these systems are already installed as stand-alone systems by WSPs in Kenya. However, some of the large and/or advanced WSPs try integrating the systems using local software developers.

For mapping, highly-functional software programs (e.g., Kobo Toolbox/Collect, QGIS, QField) are now widely available online free of cost. WSPs just need to acquire the basic skills on handling these information systems. They can then use the systems in combination for more effective NRW reduction by exporting and importing data from one system to another.

4.1.3 Advantages of GIS over Other Mapping Software

Use of GIS by WSPs has been low in Kenya due to the high cost of software. However, there is no more excuse for not using GIS for NRW reduction since highly-functional GIS software and online base maps are available for everybody at no cost.

Other mapping software are Computer-Aided Design (CAD) and Google Earth.

1) GIS has significant advantages in operation and maintenance of water supply facilities (e.g.,searching facilities having certain conditions, analysing problems, etc.) over CAD systems such as AutoCAD, online-mapping software such as Google Earth, etc., GIS can also be integrated with smartphone based free software applications and the billing software thereby further easing management of the water facilities.

2) CAD system is quite useful for detailed design but has also been widely used for mapping by WSPs (and WSPs should safely keep all the as-built CAD and paper-based drawings of existing water supply facilities for occasional reference). These CAD files can be used to develop GIS layers to some extent but it is very difficult to convert CAD data (e.g.,dxf files) to GIS data (e.g., shapefiles) because their data structures are quite different. Therefore, if a WSP wishes to have a useful geographical database of water supply facilities in future, it should start the preparations by using a GIS software from the beginning without temporarily resorting to the familiar CAD system.

3) Google Earth is another free software program which is often used at WSPs to create geographical data sets of their existing water supply facilities. Google Earth allows mapping of water supply facilities and also updating high-resolution satellite images. However, when converting the digitized data on Google Earth (i.e.,kml or kmz files) into GIS data (e.g., shapefiles) later to develop a fully-fledged GIS database, there may be difficulties in transferring the attribute data of each mapped facility due to the differences in their data structure. Therefore, a GIS software such as QGIS should be used from the beginning without detouring to Google Earth.

4.2 Establishment of GIS

4.2.1 Characteristics of GIS Establishment and Utilization

Since GIS field is a very wide and relatively complicated technology, competent IT specialists are needed to apply the technology in the actual work. WSPs are therefore advised to deploy IT specialists toset up GIS database and coordinate its full utilization among the WSP staff. Where necessary, the specialists can undergo further training in KEWI or other institutions.

The tasks for establishing and using GIS fall under three categories:

a) Initial establishment of GIS and mapping of water supply facilities (see 4.3)

b) Mapping of customer meters, problems at customer points, and bursts and leaks (see 4.2.2 and 4.4)

c) Updating and wider use of GIS data/maps (see 4.5)

4.2.2 Activities Prior to Establishment of GIS Skills

Development of a GIS layer for customer meters is time consuming but very important for effective NRW reduction. If there are no staff with basic GIS skills, the WSP may need to recruit or wait until its designated staff to acquire the skills or send them for a training course such as QGIS in KEWI.

While waiting for the GIS skills acquisition, the WSP may commence collection of data which will later be required to build the GIS layer of customer meters. This data collection can be done using smartphones installed with an easy data collection software with map view functions (e.g., Kobo Toolbox/Collect – refer to YouTube on how to create kobocllect forms) to record the locations and conditions of all the existing customer meters at site. It is advisable to include handheld GPSs to confirm the accuracy of the smartphones during the data collection. The collected customer meter data can then be exported (refer to YouTube on how to export data)from Kobo Toolbox into a text-based data table (i.e., CSV legacy file) which can be imported later into GIS database.

4.2.3 GIS Layers Necessary for NRW Reduction

Table 4.1 gives the typical GIS layers to be considered for inclusion in a WSP's GIS database for NRW reduction activities.

The recommended combination of geographic coordinate systems to use for easy GIS operation is the World Geodetic System 1984, WGS84 (i.e., longitude and latitude) and Universal Transverse Mercator, UTM (Zone 36N, 36S, 37N, 37S depending on location in Kenya) for metric/x,y coordinates.

After creating the base map (e.g., satellite image) and general layers for the WSP's GIS database with these coordinate systems, the digitization of the major facilities such as distribution tanks, pipelines, etc. can be done initially by plumbers confirming on the screen and then through field surveys using GPSs.

Table 4.1: Typical GIS Layers for O&M, Planning and NRW Reduction Activities

Category	Example of GIS Layers
1. Base Map and General Layers (from external sources)	**[First Priority]** ● **Base Map:** Recent high-resolution satellite imagery with a geographical coordinate system called WGS84 (which is used for GPS and Google Earth) is recommended. [Note: This could be an online satellite image layer of free GIS software (e.g.,Open Layers Plugin - an experimental plugin of QGIS), satellite imagery downloaded by using low-cost software (e.g.,geotiff images created by using Google Satellite Maps Downloader) or satellite imagery purchased/shared by the country]. Otherwise, online street maps, which is much lighter than satellite imagery, can be used (e.g.,OpenLayers Plugin or Quick Map Services of QGIS)

Category	Example of GIS Layers
	[Second Priority] ● **Elevation Contours:** For example, standard GIS files (i.e., shapefiles) of the contours with 25m interval are available at http://www.opendem.info/opendem_client.html [Note: the contours probably need clipping with a boundary such as country boundary to reduce the heaviness of the GIS layer]. ● Other General Layers such as Administration Boundaries (e.g., county, sub-county, etc.), Roads, Water Bodies including Rivers, Landmarks, etc.: These general layers can usually be found on the Internet (e.g., https://www.wri.org/resources/data-sets/kenya-gis-data) or extracted from Open Street Map (OSM).
	[Third Priority] ● Cadastral Maps with Land Plots: Paper cadastral maps, which carry an old geographical coordinate system (i.e., Arc 1960 but not WGS84), are usually purchasable by sections at a national government institution [Note: This means that scanning the paper maps, combining the images, georeferencing and digitization are required at the initial stage and occasional updates to use them as a GIS layer] ● **Current and Future Land Use Maps:** This may be required for the planning of water supply systems over a large area.
2. Layers for Water Supply Facilities and Area Boundaries (through conversion of existing data, on-screen confirmation and site surveys)	**[First Priority]** ● **Main Structures/Sites [Polygon or Point] (possibly multiple layers separated by type):** The required data fields are probably type (office site, intake site, well field, water treatment plan, distribution reservoir/tank, elevated tank, pump station, etc.), name, identification number, construction year, status (e.g., not in use), condition (e.g. leaking), remarks, label and other type-specific information such as capacity, dimensions, low and high water levels, target area, number of pumps, etc. ● **Main Pipes [Line]:** Type (raw water transmission, clear water transmission, primary distribution, secondary distribution, tertiary distribution, etc.), line name, diameter, material, pressure rating, installation year, status, condition, remarks, label, etc. [Note: When drawing pipe lines on GIS, it is better to reflect which side of road each pipe is laid, how pipes are connected at intersections and within main sites such as WTP to make the GIS more useful for various activities including leak line survey]

Category	Example of GIS Layers
	• **Customer Meters [Point]:** Connection/customer account number, meter serial number, type, product name, material, diameter, pressure rating, installation year, existence of meter box, orientation (horizontal or vertical), condition, etc. The digitization of customer meters can be done through CIS by using data collection software such as Kobo Toolbox/Collect. [Note: Connection/customer number or meter serial number can be used as a common data field to join other customer information such as each customer's name, account number, address, cadastral map number, type, connection status, etc. extracted from the customer database used for meter reading and billing] • **Service Areas [Polygon]:** Type (individual supply area, bulk supply area, etc.), name, etc.
	[Second Priority] • **Bulk Meters [Point]:** Type (raw water transmission/intake meter, back wash meter, clear water transmission meter, DZ meter, DMA meter, etc.), product name, meter ID, diameter, material, pressure rating, installation year, status, condition, remarks, label, etc. • **DZs and DMAs [Point] (possibly separated by type):** Type (DZ, DMA, pressure zone, etc.), name of bulk meters for inflow and outflow, number of customers, etc. • **Other Equipment and Appurtenances [Point] (possibly separated by type):** Type (well pump, intake pump, transmission pump, distribution pump, booster pump, pressure reducing valve, break-pressure tank, isolation valve, air valves, washouts, hydrants, pressure gauge, strainer, etc.), product name, ID, installation year, status, condition and other type-specific information such as size/diameter, capacity, pressure head, settings, etc.
	[Third Priority] • **Service Connections or Take-off Points [Line or Point]:** diameter, material, pressure rating, installation year, length, condition, type of take-off point (e.g., tee, saddle, etc.), etc. • **Meter Reading Sections and Routes [Polygon or Line]:** Section and/or route ID, etc. • **Other Pipe Fittings [Point]:** Type, diameter, installed year, etc. [Note: The digitization of minor fittings is probably not necessary in developing countries like Kenya]

Category	Example of GIS Layers
3. Layers showing NRW-related Problems	● **Perceptional Maps of Problematic Areas [Polygon]:** For example, problematic areas (e.g., old pipe networks, high pressure areas, and water-theft prone areas) can be encircled on a satellite image base map through participatory discussions based on participants' perception and/or limited available data) ● **Records of Bursts/Leaks, Water Theft, etc. [Point] (possibly separated by type):** Type (burst, leak, underground illegal connection, above-ground illegal connection, meter tampering, etc.), location (distribution pipe, distribution pipe fitting, service pipe, service pipe fitting, etc.), magnitude of water loss, repair method, remarks, etc. ● **Problematic Customer Meters [Point]:** After analysing the meter reading and billing data in spreadsheets or conducting CIS, identified problematic customer meters can be presented on GIS.

4.3 Initial GIS Establishment and Facilities Mapping

4.3.1 GIS Procedure 1

This subsection covers the points to be checked regarding the initial establishment of GIS in a WSP and the digitization of major water supply facilities (such as water treatment plant, distribution tanks, transmission pipes and distribution pipes) into GIS layers. The beginning of GIS establishment typically includes the set-up of a base map (e.g., georeferenced satellite image) and the development of general layers (e.g., contours, administration boundaries, rivers, etc.) (see Table 4.1), The following broad procedure is recommended:

1) Ensure that the need for developing and fully-utilizing a GIS database is well discussed between different departments/sections/units (including branch offices covering different areas) and prioritized.

2) Ensure enough number of GIS staff to support NRW reduction activities are employed.

3) Ensure free GIS-related software programs are used for mapping of existing water supply facilities with:

   i) PCs (e.g., QGIS with various plugins such as OpenLayers)

   ii) Android smartphones/tablets (e.g.,QField, Kobo Collect, etc.) and,

   iii) Cloud space/web site (e.g., Kobo Toolbox).

Note: Initiative by GIS staff may be required to shift from expensive commercial GIS software programs with familiar interface (e.g., ArcGIS) to free software programs so that more staff can use GIS without spending additional funds such as annual software license fees.

4) Ensure the following base maps and other general layers are added to the GIS map/project file being developed to establish the GIS database (Note: offline base maps/layers usable without internet connections are more reliable) as follows:

   i) online base maps such as satellite image, street and terrain maps (e.g., from OpenLayers plugin of QGIS) if the internet connection is reliable and fast.

   ii) offline high-resolution satellite image (e.g., offline satellite imagery) downloaded and automatically-georeferenced with low-cost commercial software such as Google Map Downloader.

   iii) offline street map (e.g., open street map - OSM) layers downloaded with OSM Downloader plugin of QGIS.

   iv) offline elevation contours (e.g., downloaded from http://www.opendem.info/opendem_client.html).

5) Ensure reliable GIS layers of major water supply facilities (e.g. intakes, WTPs, pumping stations, distribution reservoirs/tanks, transmission pipelines, major (primary and secondary) distribution pipelines with sluice valves, BPTs, PRVs, bulk meters, etc.) are developed well (e.g. through on-screen digitization with those staff who know the locations of these facilities, on-site digitization with mobile GIS such as QField, mapping with data collection software such as Kobo Toolbox/Collect, digitization from existing drawings, import/conversion of existing CAD data, etc.) (see 4.3.2).

6) Ensure reliable GIS layers of existing zone/area boundaries (e.g., boundaries of water supply service areas, schemes, customer meter reading zones, DZs, DMAs, etc.) are developed well (see Figure 4.2).

7) Ensure reliable GIS layers of minor water supply facilities other than customer meters (e.g., minor (tertiary) distribution pipelines with gate valves, service connections, air valves, hydrants, washouts, etc.) are developed well.

8) Ensure GIS layers of public sanitation facilities (e.g., wastewater treatment plants, public toilets, sewers, manholes, etc.) are developed well.

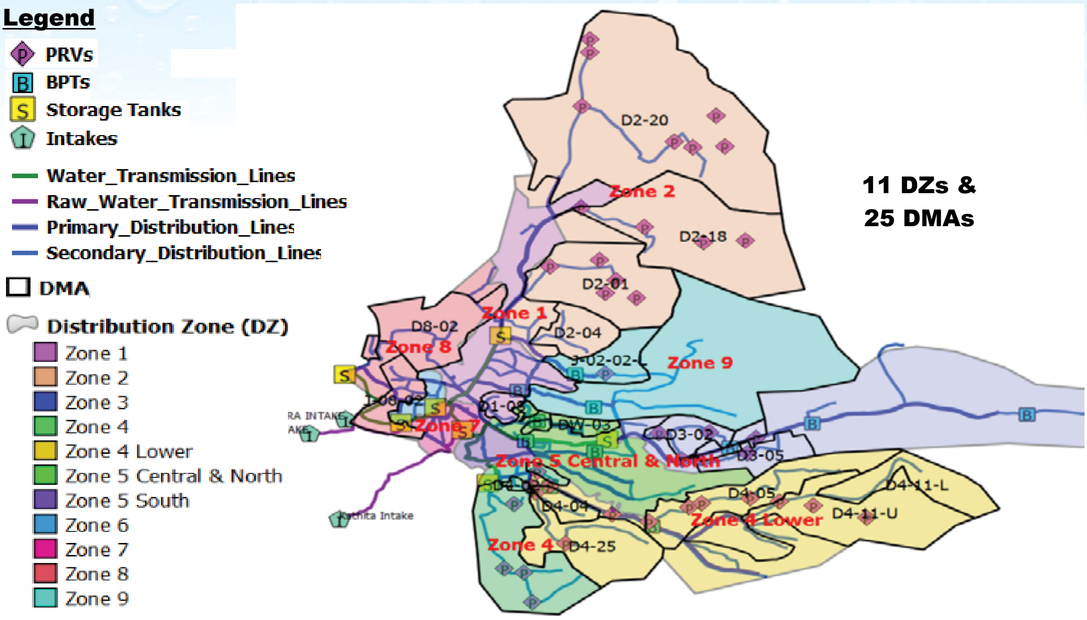


Figure 4.2: DZs and DMAs planned on GIS at Meru WSP

4.3.2 Use of Handheld GPS and Mobile GIS Software for Digitization

Digitization of water supply facilities into GIS layers can be done through a combination of following methods:

1) Scanning, geo-referencing and on-screen digitization of paper maps.

2) Data conversion from CAD files, KML/Z files, etc. into GIS files (Note: Manual re-entry of attribute data would probably be required [see 4.1.3(2)].

3) Direct on-screen digitization with technical staff who know the location of facilities such as plumbers (Note: at least 27-inch external screen or a projector is better for effectively communication between GIS operators and field staff in front of the screen).

4) Use of low-cost handheld GPSs (e.g., Garmin eTrex 10) and paper data collection forms/tables on site. (Note: the horizontal accuracy of a handheld GPS under clear sky is usually ±2→3m but its vertical accuracy error can often be more than ±10m).

5) On-site use of free mobile GIS software installed on smartphones (e.g.,QField which can open QGIS files) [Note: satellite images used as base map in QGIS may need to be compressed into suitable formats (e.g.,geotiff-RGB to geotiff–PCT or Mbtiles) to operate smoothly with smartphones].

6) Use of free cloud-based data collection software installed on smartphones and PCs on site and in the office (e.g., Kobo Collect/Kobo Toolbox), preferably in combination with handheld GPSs to confirm the accuracy of locations (see further explanation in Sec. 4.4.2).

4.4 Mapping of Customer Meters, Problems at Customer Points and Bursts/Leaks

4.4.1 GIS Procedure 2

While on site locating existing customer meters for GIS mapping, a large number of problems related to and around customer meters (e.g., stalled meters, water thefts, leaks, etc.) can be found. This is especially so if CIS is implemented effectively to locate existing and missing customer meters and identifying various problems.

Therefore, this section covers not only how to digitize customer meters but also how to identify and map the problems including those related to and around customer meters [see 4.4.2 for example of CIS and Table 4.1(3) for types of GIS layers and NRW-related problems]. It also covers the CIS issues that should be checked and,mapping of NRW-related problems for analysis and geographical representation.

1) In the beginning, ensure that the areas and pipelines with many problems related to NRW are mapped based on the knowledge of relevant staff through participatory mapping. Examples are areas with many stalled meters, illegal connections and high pressure; pipelines with many and frequent bursts and leaks.

2) Ensure that CIS is conducted to locate all the customers (registered and unregistered water and, kiosks) and collect data on their meters including existing problems. Examples of problems are unreadable and stalled meters, illegal connections, leakage from service connection, etc.

Note 1: CIS can be done using an electronic on a form of data collection software (e.g., Kobo Collect) installed in smartphones and cloud software for mapping and analysing the collected data (e.g., Kobo Toolbox).

Note 2: Handheld GPSs can be used (by entering waypoint number) in combination with smartphone-based data collection software to enhance the accuracy of the captured coordinates.

3) Ensure GIS layers of customer meters and kiosks are developed well. Example of GIS layer include collected attribute data of customers and their meters such as connection number, meter serial number, meter size, type, class, status, reading at during CIS, etc. Development is by importing the location and attribute data of customer and kiosk meters collected during CIS.They should then be represented with symbols for the different types of identified problems such as unregistered, tampered, stalled, unreadable meters; meters inside locked gates, leaking service connection, etc.

4) Ensure the results from meter reading and billing data analysis (e.g., for 12 months) are linked to the customer "account number" layer and presented with categorized symbols. The results include customer categorization by consumption level, frequency and continuity of estimating consumption due to stalled meters, locked gates, meter reading/billing status of customers registered as disconnected, etc.

5) Ensure the various problems at customer points listed in the monthly abnormalities/ complaints reports (e.g., for 12 months) from the billing/customer care system are linked to the customer account number layer and represented with categorized symbols. Examples of the problems are unreadable or stalled meters, locked gates, etc.

6) (i) Ensure bursts, leaks, illegal water uses, etc. are recorded with GPS coordinates by all staff (O&M, leaks detection, illegal connections, etc.) using data collection software on smartphones (e.g., Kobo Toolbox/Collect) or handheld GPSs with paper forms, and

   (ii) Ensure the collected data is mapped on GIS including enough attribute data (e.g., pipe material, size, probable leak cause, leakage scale, etc.).

4.4.2 Use of Data Collection Software for CIS

a) CIS can be done with handheld GPSs and printed survey forms. However, data collection software such as Kobo Toolbox/Collect can be used to collect the same data faster and more accurately.

Figure 4.3 is an example of Kobo Toolbox/Collect installed in smartphones of field staff and used for CIS at Nyahururu WSP. From the figure, the data is sent to the server (cloud space/website created with Kobo Toolbox) where it is consolidated and analysed (mapped, tabulated, sorted and graphed) to determine the best NRW reduction actions (e.g., leaks repair) and for export to other databases including GIS.

b) Additional Notes on Use of Handheld GPS and GIS for CIS:

Normally, the accuracy of a smartphone GPS depends on the quality of installed GPS sensor, weather (i.e., access to GPS satellites) and settings (e.g.,internet connection on or off). This accuracy can significantly deteriorate in rural areas. Therefore, at the beginning of CIS, it is recommended to compare the smartphones GPS accuracy and that of handheld GPSs (Figure 4.3). This can be done by entering the way point/ location number from the handheld GPS onto the printed form of Kobo Collect so that the two sets of GPS coordinates can be compared later.

The data after consolidation on the (Kobo Toolbox) website can then be exported into a CSV (legacy) file and further imported into the GIS to create a GIS layer of customer meters. This is achieved by adding the CSV file as a delimited text layer into the QGIS and saving the delimited text layer as a shape file for converting the data into an editable GIS layer.

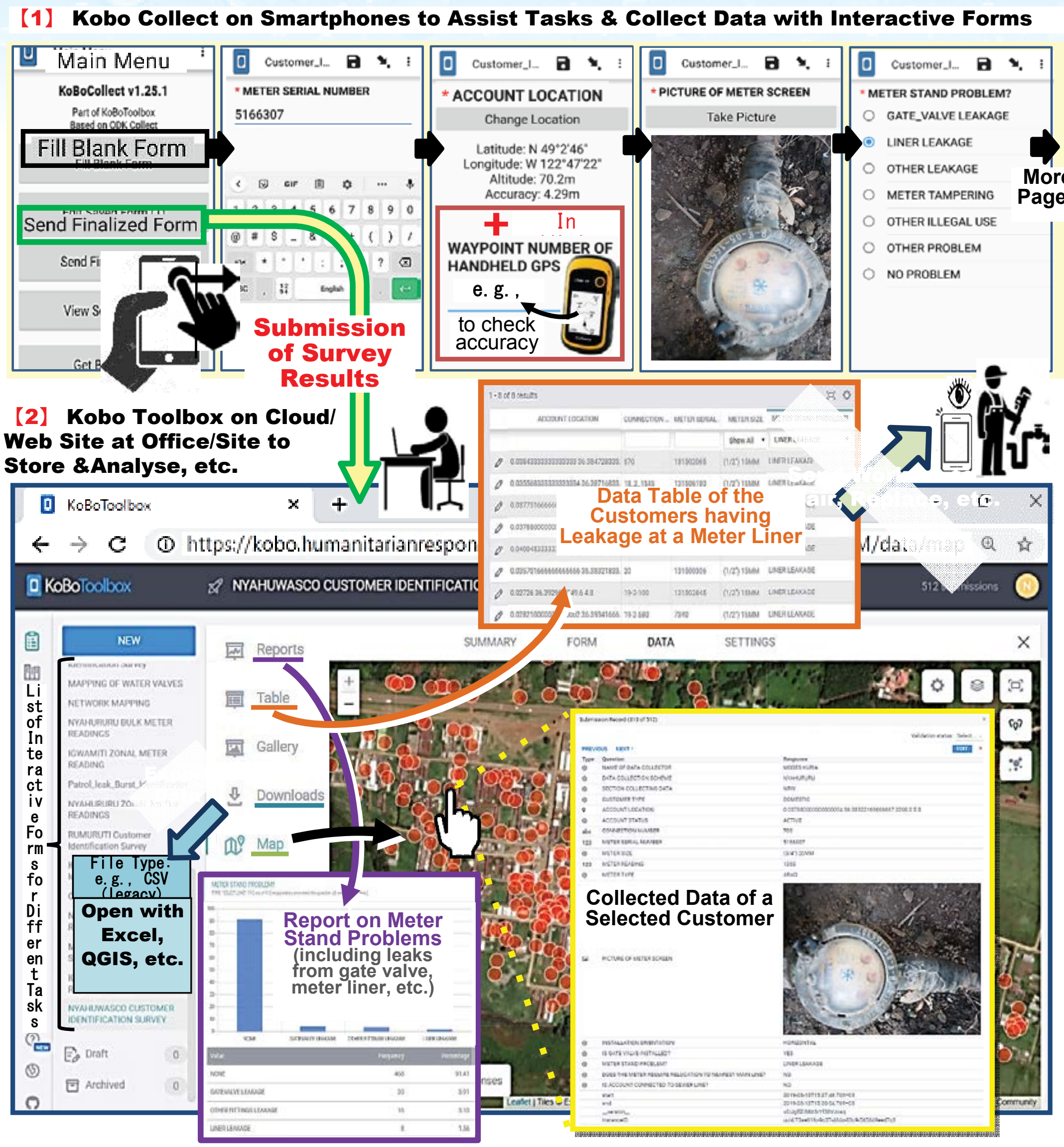


Figure 4.3: Use of Kobo Toolbox/Collect for CIS to Locate Existing & Missing Customer Meters and Collect Relevant Data Including Problems at Nyahururu WSP

c) Additional Notes on Using Kobo Toolbox/Collect for CIS

i) To download a sample CIS form developed at Nyahururu WSP:

1) open https://kf.kobotoolbox.org/accounts/login/?next=/#/

2) enter the username “nrwprojectinkenya” for both the username and its password and login

3) select “Customer_Identification_Survey_ver1”

4) select the tag “FORM” and click the icons of eye and three dots to view the sample form and download its XLS file.

   ii) Then, create your WSP’s own account on the cloud space/website and import the downloaded sample XLS form into Kobo Toolbox and Kobo Collect as follows:

1) Open the same login page shown above,

2) Create a new account for your WSP and long in,

3) Select the blue bottom “NEW” and upload the downloaded XLS form into the web page of Kobo Toolbox with a project name,

4) Click on the pen icon to edit the sample form to meet your WSP’s needs and deploy it,

5) Download and install Kobo Collect into your smartphones and set the server info under its general settings as “https://kc.kobotoolbox.org/” along with the same username and password created for your WSP, and

6) Get the edited form from your web page of Kobo toolbox wirelessly by clicking “Get Blank Form” under the main menu of Kobo Collect. To use your own satellite imagery as the offline base map of Kobo Collect, create the specific holders “Android/odk/layers/offline/” to save the imagery under the internal storage of your smartphone.

4.5 Updating and WiderUseof GIS Data/Maps

4.5.1 GIS Procedure 3

This subsection details the points to be checked during and after development of the GIS layers to sustain and enhance the impacts of using GIS by continuous update and extensive sharing of the GIS data among WSP staff for a wider GIS utilization:

1) Ensure that all the latest GIS data is frequently backed up into a secure data storage of the WSP.

2) Ensure GPS coordinates of customer meters (including service pipes take-off points from distribution pipes and their alignment) are captured on site and mapped with QGIS (e.g., Kobo Toolbox/Collect plus Smartphones or Handheld GPSs plus paper forms and GPS Tools of QGIS plugin) when:

   i) installing new service connections/customer meters, or

   ii) improving/replacing existing service connections/customer meters.

3) Ensure the newly installed and replaced facilities such as distribution pipelines, bulk meters, valves, etc. are continuously mapped on the GIS layers without delays.

4) Ensure that QGIS (free GIS software) is installed on every PC of relevant staff and is used to enhance sharing and use of GIS data (the latest GIS data may be shared through the WSP's internal network).

5) Ensure creation of high-resolution PDF maps (showing existing facilities with or without a raster base map such as a high-resolution satellite imagery) from the GIS data with QGIS's print composer and, viewing of the maps with Acrobat Reader (free PDF reader) installed on each PC and/or Smartphone of relevant staff.

6) Ensure printing of the high-resolution PDF maps on A3 or A4-size papers using Acrobat Reader to create large wall maps (without using an expensive plotter) for easy daily discussions among staff (a low cost A3-size inkjet printer with functions of flat head scanner is recommended as a low-cost alternative to a plotter).

7) Ensure publishing of GIS layers on QGIS Cloud (free online GIS platform) by using QGIS Cloud plugin (free plugin of QGIS) and viewing of the online map from web browsers on PCs and smartphones of staff.

8) Ensure use of QField (free mobile GIS software) installed on each smartphone of relevant staff.

Note:

- The GIS data needs to be copied into the location: -</Android/data/ch.opengis.qfield/files/share/> within the internal storage of smartphone for editing.
- A base map of satellite imagery may need to be compressed into PCT, MBTiles, etc. for quick display.

9) Conversion of GIS layers such as customer meters into kmz files (e.g., with Layer2kmz plugin that is free plugin of QGIS) for viewing with Google Earth (on PCs and smartphones) and/or MAPinr capable of searching and navigating (on smartphones).

Note:

- kmz files of multiple layers can be combined into a single kmz file with Google Earth on PC and saved into a shared holder of Google Drive for quick and easy downloading of the data into multiple smartphones) (see 4.5.2 for further explanation).

4.5.2 Locating and Visiting Customers Easily

Many WSPs have difficulties in locating customers on site although most of their customers are registered in the customer database used for meter reading and billing. Locating customers can be especially difficult if meter readers with knowledge of the system are not available or have left a WSP. This leads to failure in customer meter reading, delay in sending staff on site to solve problems, etc.

Therefore, full utilization of GIS' customer meter layer (developed from CIS results) is very important for making the visits to customers easier and faster in the day-to-day tasks without depending on meter readers.

Figure 4.4 shows a technic for locating and visiting a particular customer quickly using a mobile mapping software called MAPinr and Google Map which is capable of route search and real-time route navigation.

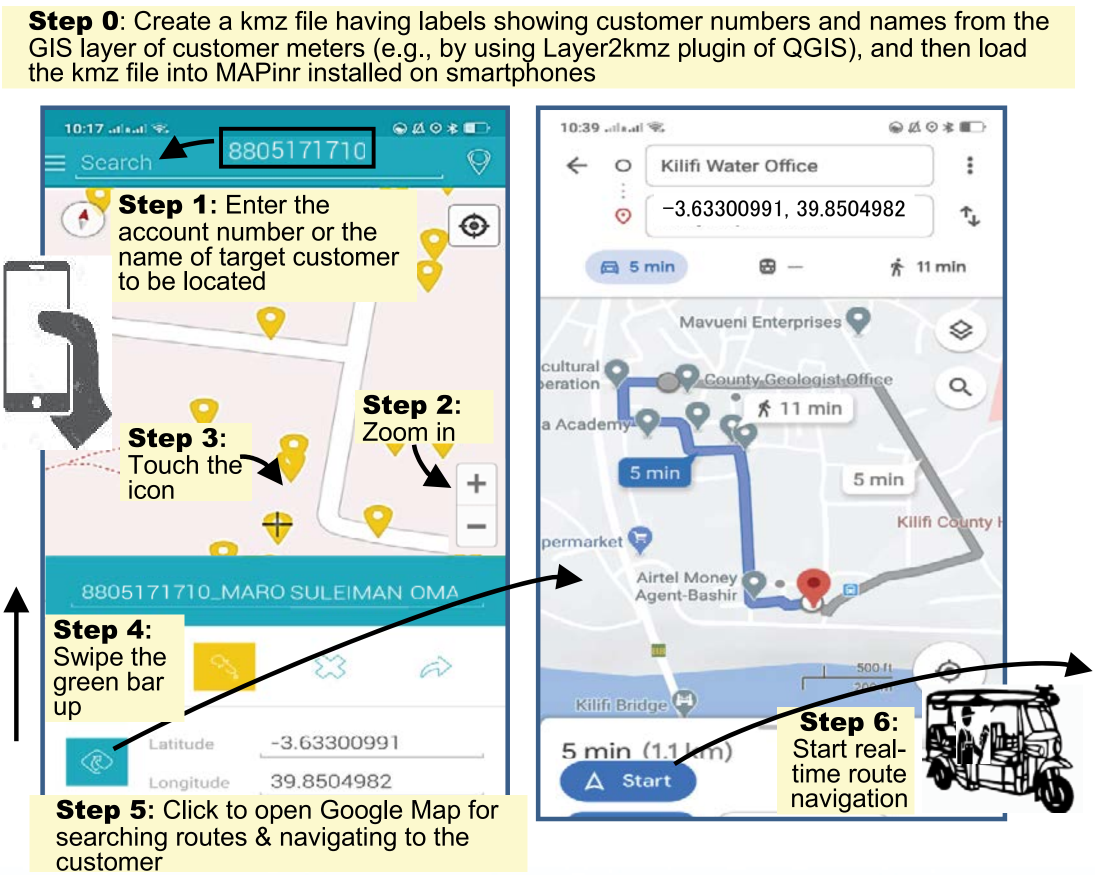


Figure 4.4: Locating a customer using MAPinr's search function on smartphone & visiting the customer using Google Map's navigation function

4.5.3 Updating Customer Connections on GIS

When an installation (e.g., of a new service connections) or a repair is done (e.g., of bursts and leaks) are done, the results must be recorded on site and updated in the GIS. When new materials such as pipes, valves, etc. are used in installation or repair works, it is important to record their type, diameter, location, etc. and submit the records to the office for updating GIS layers. Recording can be by handheld GPS or printed data-collection forms and sketches or; by smartphones and electronic interactive forms for easy data collection including taking of pictures.

Regarding service connections, the paper forms for new connection application,new connection installation record, relocation of existing meters, etc. should include connection numbers and GPS coordinates of customer meters among other data for updating the GIS layer of customer meters.

Recording GPS coordinates at the take-off locations of service pipes from the distribution pipes as well as sketching the service pipes routes from take-off points to customer meters on paper forms is also recommended for the purpose of NRW reduction. The coordinates and/or routes recorded on the paper forms can be used later to create additional GIS layers of take-off points and service pipes when the GIS development reaches an advance stage.

4.6 Integration of Free Desktop GIS, Mobile GIS, Data Collection and Billing Software

4.6.1 Integration of Desktop GIS & Field GIS

Integrated use of different software programs (e.g., meter reading software, billing software and GIS software) is essential for a successful implementation of NRW reduction activities which requires involvement ofboth office and field staff of several departments/sections. Free mobile GIS software and cloud-based data collection software have been evolving fast since the proliferation of smartphones all over the world. For example:

a) QGIS is the most popular free desktop GIS software. It has integrable free mobile GIS solutions called QField and Input; which can be installed into a smartphone:

   i) The GIS data updated on QField can then be easily synchronized into QGIS on PC using QGIS plugin called QField Sync although a data package file has to be copied from the smartphone into PC manually before synchronization. Currently, QField is being upgraded to adopt a cloud-based synchronization technology (i.e.,QField Cloud).

   ii) Input is a powerful free GIS-based data collection software, which can be installed in a smartphone and used on site. Input uses a QGIS plugin called Mergin to easily synchronize/transfer the field data into QGIS on a PC through a cloud space.

b) MAPinr may be used to view and search customer locations. Google Map can then be easily launched from MAPinr to have real-time route navigation to the target customer.

c) Web-based GIS publishing software (e.g., QGIS's plugins such as QGIS Cloud, qgis2web or GIS Cloud) is another solution for various staff to utilize GIS data efficiently for NRW reduction and other purposes.

4.6.2 Combined use of Software for Active Leak Reduction

A smooth coordination between NRW staff investigating leaks and O&M staff repairing leaks is the most important characteristic of a sustainable implementation of proactive leak detection.

Some commercial software developed for water utilities (e.g., ERP)are capable of collecting data (e.g., registering problems based on reports from staff and customers), assigning tasks to field staff and registering feedback reports, all remotely. This kind of advanced software can be used to improve the coordination between NRW staff and O&M staff foractive leak reduction. However,if a WSP does not have this kind of commercial software, creative combinational use of free software programs may be a solution to enhance the coordination.

For NRW staff, Kobo Toolbox/Collection can be quite helpful in investigating leaks, meter-related problems and illegal connections. However, it is often too complicated for O&M staff to use for reporting repairs remotely.

It is therefore recommended that O&M supervisors should use simple and common communication software such as WhatsApp to assign tasks to each plumber and receive feedback reports once the tasks are attended to. Example of the tasks are repair of leaks investigated and registered in Kobo Toolbox cloud server by NRW staff using Kobo Collect installed on their smartphones.

When assigning tasks using WhatsApp, the coordinates (e.g., -0.5354971, 37.4502462) of each issue recorded by the NRW staff with Kobo Collect can be used as the ID of each task and sent to a plumber with a pre-fix for creating a weblink to show its location on Google Map and a brief instruction on the issue (e.g. https://www.google.com/search?q=-0.5354971+37.4502462 Nicolas, please repair this leak this morning. Very Urgent!).

This way, plumbers can view the reported issue together with its coordinates by accessing the Kobo Toolbox cloud server while locating it on site using Google Map. This creative combined use of free software programs can contribute greatly in NRW reduction.

4.6.3 Smooth Data Transfer from Non-Spatial Database to GIS

Customer-related information from commercial meter reading and billing software (e.g.,Majics, ERP, etc.) or field data from free data collection software (e.g., Kobo Toolbox) can be transferred to free GIS software (e.g., QGIS) or web maps (e.g., by using a plugin of QGIS such as QGIS Cloud, GIS Cloud, qgis2web, Lizmap, etc.) in order to map issues related to customers or facilities if their coordinates are available. As already realized in Nanyuki and Nakuru WSPs, dynamic integration between meter reading & billing software and GIS can also be done by using free database management software (e.g., PostgreSQL and PostGIS). However, periodic update of customer and facility data to desktop GIS (e.g., by exporting the data into a CSV file and adding it as a delaminated text layer of QGIS) and upload of the layer onto a web map or potable GIS on smartphones may be enough for efficient NRW reduction.

More importantly, customer locations should be searchable with customer number or meter serial number(customer names can be excluded from GIS to protect customers' private information) to enable staff working on NRW reduction find customers having problems without the help of meter readers. The search can be achieved by using different types of free software such as MAPinr and QField on a smartphone and qgis2web (a plugin of QGIS for creating web maps) and Google Earth on a PC.

The anomalies found through monthly meter reading (e.g., stopped meters, buried meters, visible leaks from service connections, etc.) can also be mapped periodically on desktop GIS, mobile GIS and web GIS to effectively analyse the current situation and address the anomalies every month. However, WSPs may face difficulties in transferring the anomaly data to GIS because GIS software normally accepts upto only 10 characters for each data field name. For smooth data transfer to GIS(including the addition of recent data to existing GIS layers), data-field names used in data collection software, billing software, etc. should be no longer than 10 characters and should match those in the attribute tables of GIS.

Moreover, using the same drop-downlist of selections for existing facilities and problems (e.g., tampered meter, buried meter, stalled meter… as meter reading anomalies) in the different software (e.g., billing software and GIS) makes the data transfer to GIS and the combinational use of multiple softwareprograms easier.

For example, if leaking gate valves of different sizes are to be mapped in different colours, a drop-down list of valve sizes (e.g., 15mm, 20mm, 25mm…) can be used for easy data entry on QGIS (i.e., by setting Value Map as Widget Type) while using exactly the same list of selections on data collection software such as Kobo Collect (i.e., not ½ inch, ¾ inch, 1 inch…. but 15mm, 20mm, 25mm….) in order to update the GIS layer of leaking gate valves easily without having inconsistencies in data categorization. By using the same set of selections, muddling up the categorized symbology of GIS layers (e.g., symbol of valves in different coloursbased on size) can be avoided without editing data each time newly recorded data is imported into the GIS.

Chapter 5

Monthly NRW Monitoring and Zoning

5.1 Relationship Between Monthly NRW Monitoring and Zoning

When conducting trial NRW reduction activities within a limited area, it is normal to calculate NRW ratio of the area twice (before and after the activities) to determine by how much NRW has been reduced through the activities. Unfortunately, NRW ratio in Kenya often fluctuates seasonally, and the NRW ratio of a target area may rise again soon after NRW reduction activities end in the area. Therefore, measuring NRW ratio only twice is not enough to understand the effects of the implemented NRW activities and their sustainability over time. This is one of reasons monitoring of NRW-related performance indicators (Section 5.2) on monthly basis from the beginning of NRW reduction efforts is quite important. The monthly monitoring should be based on the monthly cycles of reading bulk meters and customer meters, billing and reporting of NRW-related activities. The results of the monthly NRW monitoring can also be used for the quarterly and annual NRW reduction monitoring.

Once a WSP has succeeded in establishing a reliable monthly monitoring of main performance indicators of the entire service area (e.g., total amount of supplied water/production, total billed consumption, universal NRW ratio, etc.), the WSP can also try to monitor similar NRW-related performance indicators for each hydraulically isolated area. However, if the distribution system is not properly separated into DZs, the zone-by-zone monitoring of the entire service area for more effective and efficient NRW reduction will never happen. This is one of the reasons zoning of the distribution system (Section 5.3) is very important for effective and efficient expansion of NRW reduction activities over the entire service area. WSPs may further sub-divide large DZs with NRW high level into DMAs to enable planning, implementation and review of NRW reduction activities area-by-area in detail.

Moreover, when dealing with reoccurring bursts on transmission and distribution pipelines and/or service connections due to deteriorated old pipes, high pressure, etc., monthly monitoring may be inadequate to identify and fix potentially large water losses from bursts in a timely manner. In such cases, setting up weekly, daily or even real-time abnormal flow monitoring using bulk meters on transmission and distribution pipelines, including those used for monthly monitoring may be necessary. As soon as abnormal flow at one of the monitored bulk meters is detected, a team is sent to fix the burst, large leak or illegal water use causing the abnormal flow.

In large WSPs in developed counties, filling a detailed water balance table(Section 5.4) once a year (e.g., Water Audit) may be a focal point of their NRW monitoring. However, it is quite difficult for most WSPs in Kenya to create a reliable water balance table consisting of various water loss components for their entire service area. Filling a detailed water balance table is especially difficult in WSPs where commercial losses (e.g., underestimated billed consumption due to faulty customer meters and water thefts) have not been actively reduced substantially and where minimum night flow cannot be measured to verify the balance table (say, due to intermittent water supply condition). Therefore, filling a water balance table (to be explained at the end of this chapter) is given less priority in this chapter compared to monthly monitoring of NRW-related performance indicators, zoning, and abnormal flow monitoring.

5.2 Monthly NRW Monitoring

5.2.1 Selection of Suitable Performance Indicators

There are many performance indicators (PIs) related to NRW reduction activities. If too much data for calculating an excessive amount of NRW-related performance indicators is repeatedly collected without realising enough benefits from monitoring of those indicators, the NRW reduction activities will be negatively affected. Excessive collection of data for PIs wastes the limited manpower available for NRW reduction activities and causes distrust among those providing the data when they realise the limited benefits of collecting the data. Therefore, it is very important for each WSP to carefully consider which data to collect and how often to realisethe expected benefit.

Of course, all WSPs in Kenya are required to submit PIs data to WASREB through WARIS. The comparative results of these PIs are published every year as the Impact Report for benchmarking among WSPs. Further, many WSPs are also involved in WASPA's comprehensive benchmarking fora for mutual learning.

Besides these benchmarking fora, each WSP should carefully monitor its own progress in NRW reduction over months and years based on its own select PIs based on its specific needs.

Table 5.1 shows examples of essential and basic PIs recommended for NRW reduction although the selected PIs depends on the conditions of each WSP.

The seven essential PIs (three raw data ([1] to [3]) to be collected, and four values ({4} to {7}) to be calculated from the raw data) are explained in details in Section 5.2.2.

The 12 basic PIs (eight raw data to be collected, and four to be calculated ([9], [12], [16] and [18]) are directly related to different types of NRW reduction activities.

The table also shows the break-down of data to be collected for some of the raw data (e.g., for [10] - Number of Bursts and Leaks Repaired, 3 break-downs for transmission pipes, distribution pipes, and service connections including tapping points). The raw data that requires broken-down data for analysis may be collected using a data collection software (e.g., Kobo Collect) installed on smartphones of field staff. One example of utilizing these basic PIs to analyse the effects of NRW reduction activities is explained in Section 5.2.4.

When calculating PIs related to estimated billed consumption due to faulty meters, etc (i.e. [14], [17] and [19]), the active connections should be categorized based on their billed consumption level (preferably in reference to their block tariff ranges such as 0-6m3/month). This is in order to obtain helpful broken-down data for analysis of the PIs. Further, more focus should be on larger customers to reduce NRW significantly within a limited time.

An example of customer categorization and analysis to evaluate the effects of replacing faculty meters at different groups of customers are explained in Section 5.2.5.

Table 5.1: Example of Essential and Basic Performance Indicators to Monitor NRW Reduction

Category	Data No. or Formula No.	PIs for the Entire (Universal) Service Area and Each Area (e.g., DZ or DMA)	Unit	Note
Essential PIs	[1]	Total Water Produced for Distribution (or Supplied as Inflow)	m^3/month and year	Related to Physical Losses
	[2]	Total Billed Consumption	m^3/month and year	Related to Commercial Losses
	[3]	Total Billing of Water Supply Services	Ksh/month and year	
	{4}=[3]/[2]	Average Tariff	Ksh/m^3 -monthly and yearly	
	[5]=[1]-[2]	Total NRW	m^3/month and year	Showing Overall Effects
	[6]=([1]-[2])x 100/[1]	NRW Ratio	% -monthly and yearly	
	{7}={1}x{2}	Potential Revenue Loss due to NRW (excluding Sewerage)	Ksh/month and year	
Basic PIs	[8]	Total Length of Transmission and Distribution Pipes*(make break-down of Transmission and Distribution pipes) ←* ***Thiscan becalculated on GIS.*** *Monthly pipeline replacements and extensions should be documented separately to avoid confusion*	km	Related to Physical Losses
	{9}=([1]-[2])x 100/[8]	NRW per km	m^3/km/month and year	
	[10]	Number of Bursts and Leaks Repaired *(e.g., Breakdown-1: Transmission, Distribution, and Service Connections including Tapping Points. Breakdown-2: Bursts, Visible Leaks and Underground Leaks) →* **To be mapped on GIS**	number/month and year	
	[11]	Total Number of Water Connections	number	Related to Commercial Losses
	{12}=([1]-[2])x 100/[11]	NRW per Connection	m^3/connection/ month and year	
	[13]	Number of Water Theft incidences identified*(e.g., Breakdown of Meter Reversed, Meter Tampering, Above-ground Illegal Connection including Meter Removal, Underground Illegal Connection including Meter Bypass, etc.)→* **To be mapped on GIS**	number/month and year	
	[14]	Total Number of **Active** Water Connections*(e.g., Break-down based on billed consumption level categorized by WSP's block tariff ranges)*	Number	
	[15]	Total Number of **Active Metered** Water Connections	Number	
	{16}=[15]x100/ [14]	Metering Ratio	%	
	[17]	Total Number of Estimated Billed Consumption (e.g., Broken down as in [14])	Number	
	{18}=[17]x100/ [14]	Ratio of Estimated Billed Consumption (e.g., Broken down as in [14])	%	
	[19]	Number of Customer Meters improved*(e.g., Breakdown 1: As same as in [14] // Broken down 2: Serviced, Replaced, Relocated, etc.)*	number/month and year	

Once the calculation of PIs become a routine and reliable for entire service area, then the same or similar sets of PIs may also be applied for each DZ and/or DMA for more detailed analyses. Two additional PIs for the amount of NRW (i.e. {9} NRW per km and {12} NRW per connection) can be helpful to use in addition to {5} Total NRW and {6} NRW Ratio especially for comparing different DZs and/or DMAs with different concentration levels of customers and/or distribution pipes.

5.2.2 Seasonal Fluctuations and Overall Effects of NRW Reduction Activities

Monthly meetings between departments are quite important to discuss the strategies and progress of NRW reduction activities based on the results. However, the effects of NRW reduction activities can be difficult to understand especially when only a limited data that indicate variation in NRW ratio over the last few months is presented in the meetings. This is because NRW ratio often fluctuates a lot seasonally especially under intermittent water supply conditions. Therefore, in order to isolate the effects of NRW reduction activities from seasonal fluctuations, WSPs should analyse the monthly values of the seven essential PIs (Table 5.1) over at least the previous 3 years on a single graph and thereafter update the graph every month. Figure 5.1 indicates the monthly changes of the 7 essential PIs over the previous 3 years in Nyahururu WSP. The figure helps to understand the difference between seasonal fluctuation of NRW ratio and the effects of NRW reduction activities.

In this example, the NRW ratio (Red line▲) decreased by about 10% within two years (July 2017 to July 2019) while fluctuating seasonally every few months. Regarding the seasonal fluctuations, it was revealed that there are shallow wells used by small customers (as alternative water sources) which dry up in the dry season, resulting in a corresponding increase in both total Supplied Water (Orange line ●) and total Billed Consumption (Purple line ●). Therefore, while the amount of NRW (Red line ●) (=Supplied Water - Billed Consumption) did not change much, the NRW Ratio (the amount of NRW / Supplied Water x 100) decreased for a few months in each dry season. The decrease in Average Tariff for water supply (Blue line ◆) (=Billing for Water (Green line ■) / Billed Consumption(Purple line ●)) in each dry season can be considered as resulting from the increase in piped-water consumption among small customers whose average water charge per m3 is relatively low due to the low charge block in the tariff. In WSPs, shortage of water sources and intermittent water supply conditions often significantly affect the total amount of supplied water while fluctuations in water demand significantly affect the total billed consumption. Therefore, these values fluctuate repeatedly due to the seasonal changes in temperature and rainfall. This phenomenon, that NRW ratio (Red line ▲) often goes up and down every few months was found to be common, as illustrated in this example.

The changes in the monthly amount of Supplied Water (Orange line ●) shown in Figure 5.1 is a useful indicator to understand the progress of physical water loss reduction. The total Billed Consumption (Purple line ●) and the total Revenue Billed (Green line

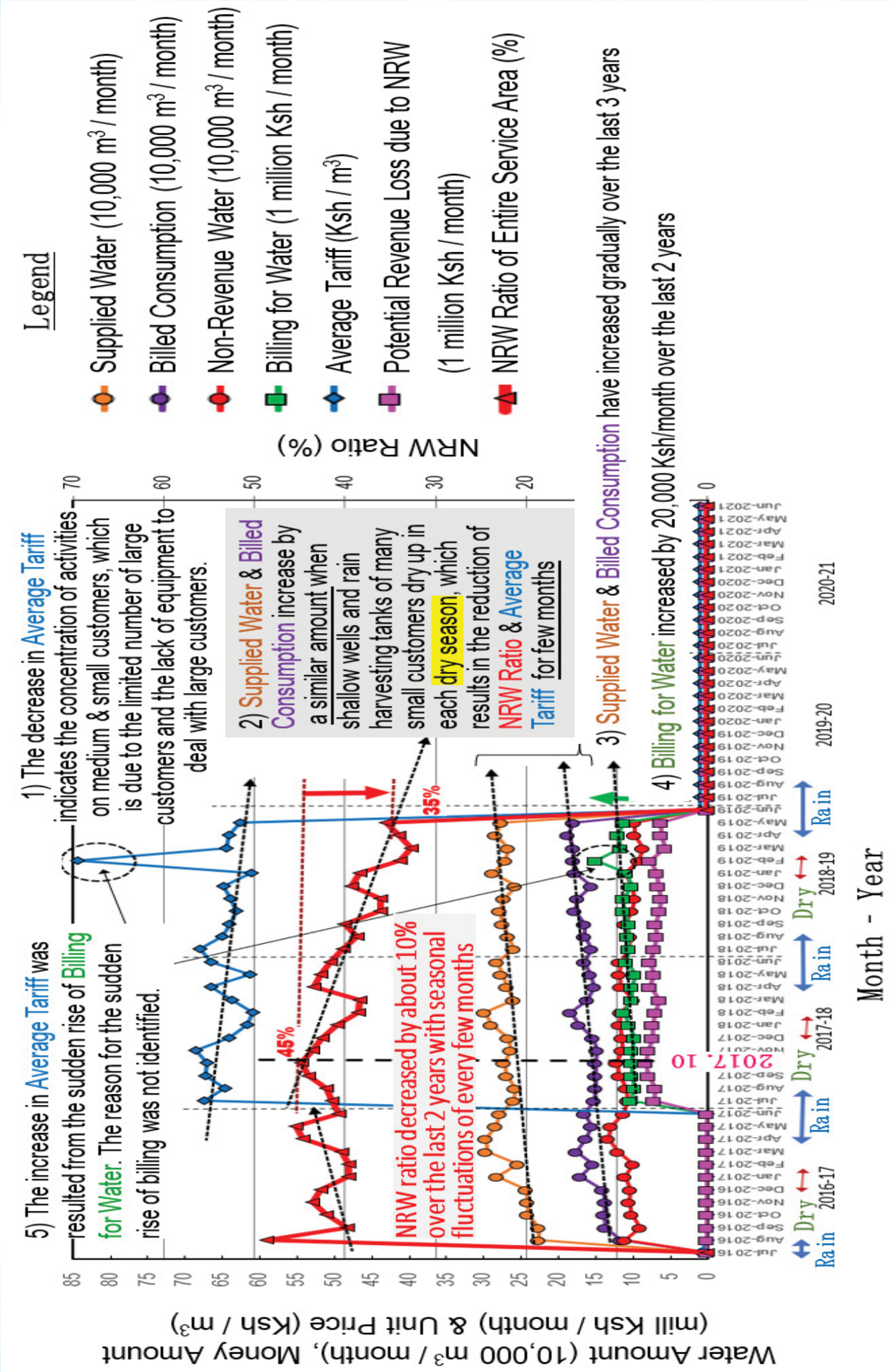


Figure 5.1: Seasonal Fluctuation of NRW Ratio & Effect of NRW Activities in Nyahururu WSP

■) are effective indicators for understanding the progress in reducing commercial losses resulting from low meter accuracy,meter reading and billing errors and water thefts. Moreover, the Average Tariff (total billing / total amount of billing consumption) (Blue line◆), which usually increases when billing of large customers improve, can be an indicator of how well large customers are targeted in the commercial loss reduction. The universal supplied amount (Red line ●), the ratio of NRW for the entire service area (Red line ▲) and the potential revenue loss due to NRW (Pink line ■) are useful indicators for evaluating the overall effects of NRW reduction activities quantitively. This analysis using a line graph is much easier and often more effective than filling annually a complicated water balance table for the entire service area.

5.2.3 Ensuring Credible Universal NRW Ratio at the Beginning

In Kenya, many WSPs use estimated monthly flow instead of measured monthly flow, due to inaccurate bulk meter readings (from faulty bulk meters) used for calculating the universal NRW ratio. In such cases, the universal NRW ratio most likely fluctuates a lot with seasons; much more than the usual seasonal fluctuations.

For example, during the dry season, the amount of supplied water usually increases as water demand increases. If during this season a WSP uses the average monthly flow of the previous year or the previous few months as the estimated flow of a bulk meter which has just become faulty, the NRW ratio during the dry season will probably,erroneously, drop drastically (Note: this is because the supplied flow of previous year or previous few months is likely to be smaller than the actual flow which the faulty meter has failed to measure). This drop in NRW ratio will not be due to NRW reduction activities but the underestimated inflow at the faulty bulk meter thereby causing a higher rate of underestimation to the total amount of NRW than to the total supplied volume (Note: NRW ratio = NRW amount / supplied volume x 100). Therefore, the abnormal fluctuations of NRW ratio caused by faulty bulk meters should be checked through analysis of the main performance indicators over the last few years. If a WSP ignores the problems of existing bulk meters that often make the universal NRW ratio deceptively low (with the purpose of conveniently reporting false figures to WASREB or BoDor out of negligence), then the WSP will remain in the dark and NRW will probably never,in reality, be effectively reduced. Therefore, any problems with production bulk meters or those used to calculate the total amount of supplied water should be resolved as soon as possible and as a matter of priority.

5.2.4 Additional Analysis to Evaluate Effects of NRW Reduction Activities

Figure 5.2 shows an example of monthly changes and the relationship between several additional monthly indicators. It shows the amount or results of certain NRW reduction activities in Kisumu WSP (i.e., 4 basic PIs – [10], [15], {16} and {18} – in addition to 3 essential PIs – [1], [2] and {6} – from Table 5.1). This graph was used to identify the factors that were significantly affecting the successful reduction of NRW.

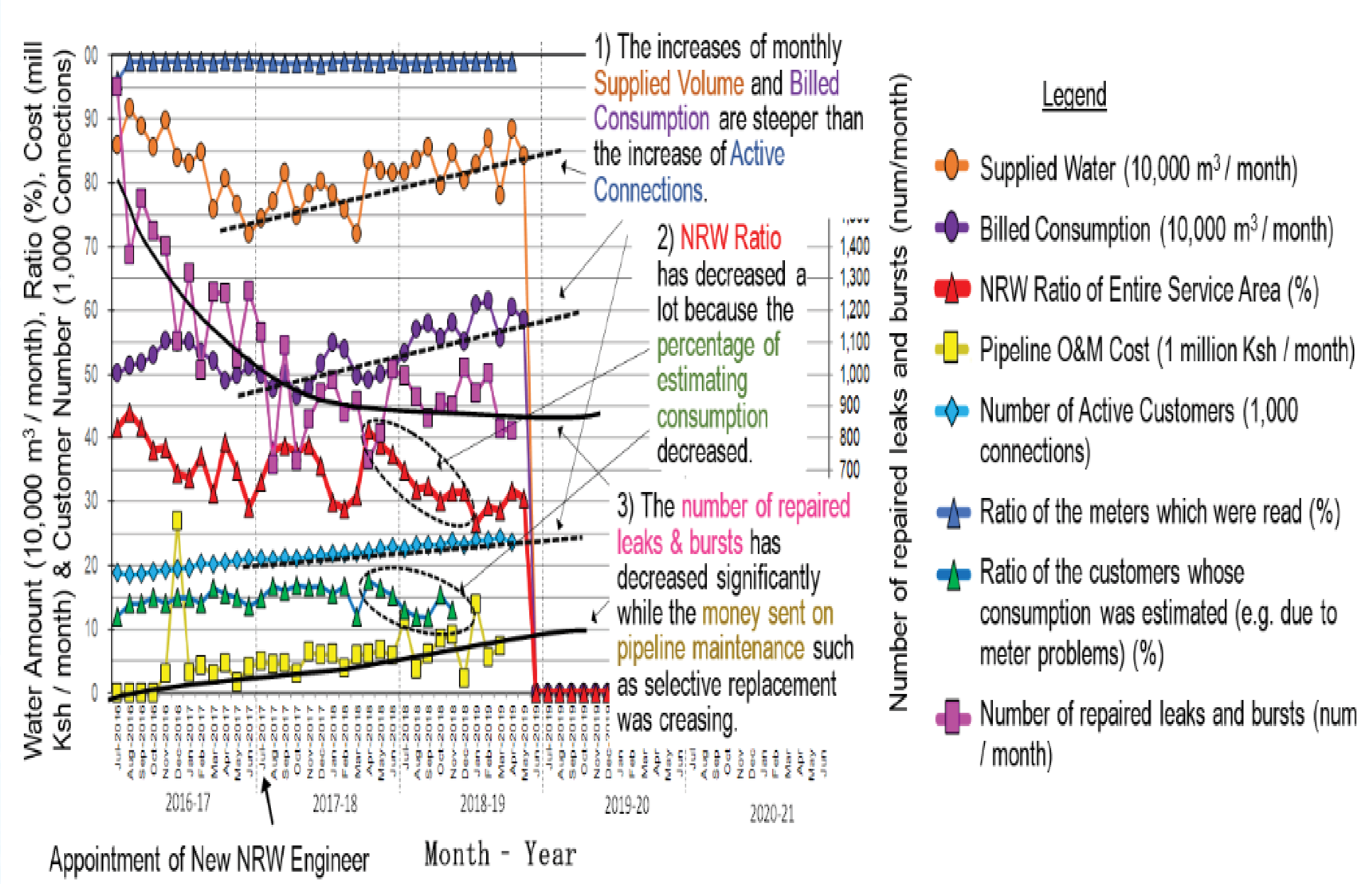


Figure 5.2: Analysis of NRW Reduction Factor based on the Changes of Additional Monthly Indicators in Kisumu WSP

The findings from this graph are that replacement of faulty customer meters to reduce estimated billed consumption (Greenline ▲) was quite effective in reducing their NRW ratio (Redline ▲) and; that the budget increase for pipeline maintenance such as selective replacement of aged pipes (Yellowline ■) could successfully reduce the number of leaks and bursts found and repaired per month (Pinkline ■).

5.2.5 Categorization of Customers and Reduction of Estimated Billed Consumption

Table 5.2 is a comparison of two months data (before reading and billing improvement and, after meter reading and billing improvement such as replacement of faulty meters). The table was drawn to evaluate the reduced use of estimated consumption for billing and its effects on the total billed revenue amount (see {18} and [3] of Table 5.1) in Nakuru WSP. In this analysis, the customers were categorized by their monthly billed consumption level based on their tariff block ranges. This example shows that active reduction of using estimated billed consumption (especially for large customers) successfully resulted in large increases of the total billed consumption and total billed revenue.

5.2.6 Performance Indicators for Monthly Monitoring

1) Prioritize data to be periodically collected (monthly, quarterly and annually) for calculating useful performance indicators (PIs).

2) Prioritize data such as NRW %; number of meters tested, replaced and/or relocated, etc (to enable targets setting in planning, progress monitoring and encouraging internal competition between zones, etc.). Prioritization should be carefully done taking into account the practical aspects of data collection. Note: the calculated indicator values can also be used for WASPA's benchmarking activities, WASREB's Impact Report and WARIS.

3) Ensure that a systematic and easy way to periodically collect and analyse the prioritized data from the different departments/sections/units and/or branch offices is fully operational to enable PIs calculation.

4) Ensure the NRW Unit (i) prepares its monthly report showing the progress in a quantitative manner using selected PIs and (ii) submits the report to its supervisor/ manager.

5) Ensure that the NRW Unit and other relevant staff including managers have (i) monthly coordination meetings for NRW reduction and (ii) concrete monthly discussions for improvements based on the PI values included in their monthly reports.

6) Ensure that the progress in implementation of the planned NRW activities is continuously monitored.

Table 5.2: Analysis of the Reduced Frequency of Estimated Billed Consumption for Each Customer Category based on the Billed Consumption Amount and Water Tariff Block in Nakuru WSP

Customer Category by Average Billed Consumption	Year - Month	Number of Connection		Billed Consumption			Customers whose Consumption is Estimated			Number of Customers for Each Type of the Consumption Estimation			
		[1] Num	Distribution %	[2] Total Volume (m³/month)	Distribution %	[3](=[2]/[1]) Average (m³/month/customer)	[4] Num	Distribution %	[5] (=[4]/[1]) Frequency %	Increase from no consumption 0↑X	Increase from other than no consumption +X	Change to no consumption X↓0	Decrease to other than no consumption -X
C1: > 300 m3/month	2017 - October	130	0.3%	115,732	18.1%	890.2	17	0.2%	13.1%	15	1	0	1
C2: 101-300 m3/month		465	1.2%	74,839	11.7%	160.9	64	0.8%	13.8%	36	18	0	10
C3: 51-100 m3/month		1,077	2.7%	73,597	11.5%	68.3	155	1.9%	14.4%	110	27	0	18
C4: 21-50 m3/month		4,664	11.6%	144,864	22.6%	31.1	891	10.9%	19.1%				
C5: 7-20 m3/month		15,330	38.0%	181,004	28.3%	11.8	4,800	58.6%	31.3%	4321			
C6: 0-6 m3/month		18,630	46.2%	49,882	7.8%	2.7	2,267	27.7%	12.2%	1989			
Total		40,296	100.0%	639,919	100.0%	15.9	8,194	100.0%	20.3%	7,464	437	9	284
C1: > 300 m3/month	2019 - May	114	0.3%	130,787	18.9%	1,147.3	4	0.1%	3.5%	2	0	0	2
C2: 101-300 m3/month		601	1.4%	94,577	13.7%	157.4	43	0.6%	7.2%	23	11	0	9
C3: 51-100 m3/month		1,375	3.3%	93,946	13.6%	68.3	127	[illegible]	9.2%	95	14	0	18
C4: 21-50 m3/month		5,769	13.7%	177,675	25.7%	30.8	[illegible]	11.1%	14.0%	726	44	0	35
C5: 7-20 m3/month		16,971	40.4%	199,200	28.8%	11.7	3,959	54.7%	23.3%	3702	192	0	65
C6: 0-6 m3/month		19,437	46.2%	50,480	7.3%	2.6	2,058	28.4%	10.6%	1767	163	14	114
Total		44,267	100.0%	746,666	100.0%	16.9	6,996	100.0%	15.8%	6,315	424	14	243

Effective focus on large & medium customers (reduction of about 10% to 5%)

Increase of customers by around 4,000 (10%)

Large increase of billed consumption by more than 100,000 m³/month (17%)

Reduction of the number of customers whose consumption is estimated by around 1,200

Reduction of the estimated consumption for billing by 4.5% on average

Mainly by replacing the faulty meters which are completely stalled.

5.2.7 Monthly Monitoring of Main Performance Indicators

1) Ensure bulk meters required to accurately calculate the total production of the entire service area (SA) (including imported water and excluding exported water over the boundary of the SA) are:

i) installed, and

  ii) Properly installed (including improvement of meter chambers, installation of strainers before bulk meters, etc if required).

  Note: Bulk meters should be installed in such a way that air does not enter the bulk meter during interruptions of water supply or water shortage. This is to prevent over-estimation by mechanical bulk meters (happened in Embu WSP- resolved by relocating the meter to a lower location) or under-estimation by ultrasonic or electromagnetic flow meters).

  Bulk meters where air intrusion is difficult to avoid may need to be relocated to a low-lying location where the pipe is always full of water even during water supply interruptions. If such a low-lying point is not available, a small section of the pipe on which the bulk meter is installed should be lowered so that the section remains full during water supply interruptions.

2) Ensure bulk meters required for measuring all the production are read on monthly basis without failure to accurately calculate monthly total production. It is recommended that the meters be read daily to enable daily flow monitoring and data flexibility during calculations of the monthly PIs.

3) Ensure the accuracy of each production bulk meter is monitored based on its monthly flow fluctuation; and tested periodically (e.g., semi-annually/quarterly) with portable clamp-on UFM for timely meter servicing and/or calibration; or replacement. Note: calibration is adjustment of measured volume by adding or reducing a certain percentage of the volume if found to be necessary.

4) Ensure monthly calculation of the total billed consumption volume for the entire SA is continuous and accurate. This should preferably be done by a computerized meter reading / billing system. Care should be taken not to misuse the upper consumption limit of the lowest tariff block. For example, if the lowest tariff block is fixed say at Kshs 200 for all consumptions from 0 to 6m3/month, some WSPs bill 6m3/month even when the consumption is 0 to 5m3/month. This implies that the consumption is 6m3/month thereby erroneously reducing the NRW volume.

5) Ensure monthly calculation of NRW volume and ratio and other prioritized PIs related to NRW volume, if any, for the entire SA is continuous and accurate based on synchronized bulk meter and customer meter readings.

6) Ensure that the:

i) fluctuations of monthly total production, total billed consumption, NRW volume and ratio for the entire SA for the last few years are tabulated and represented on a graph. They should be plotted on the same graph by factoring the volume in million m3/month (for example) and placing the volumes (mill m3/month) on the right Y-axis and the ratio (%) on the left Y-axis for easy analysis of the relationships, and

ii) the graph(s) are updated monthly and the causes of fluctuations and effects of NRW reduction activities analysed.

7) Ensure that increase in monthly total billing (Ksh/month) and monthly average tariff (KSh/m3) (i.e., monthly total billed revenue/monthly total billed consumption) are monitored to confirm that revenue is increasing because of tackling large customers first (i.e., the average tariff is expected to increase if more large customers are properly billed due to the high incremental block of the tariff structure.

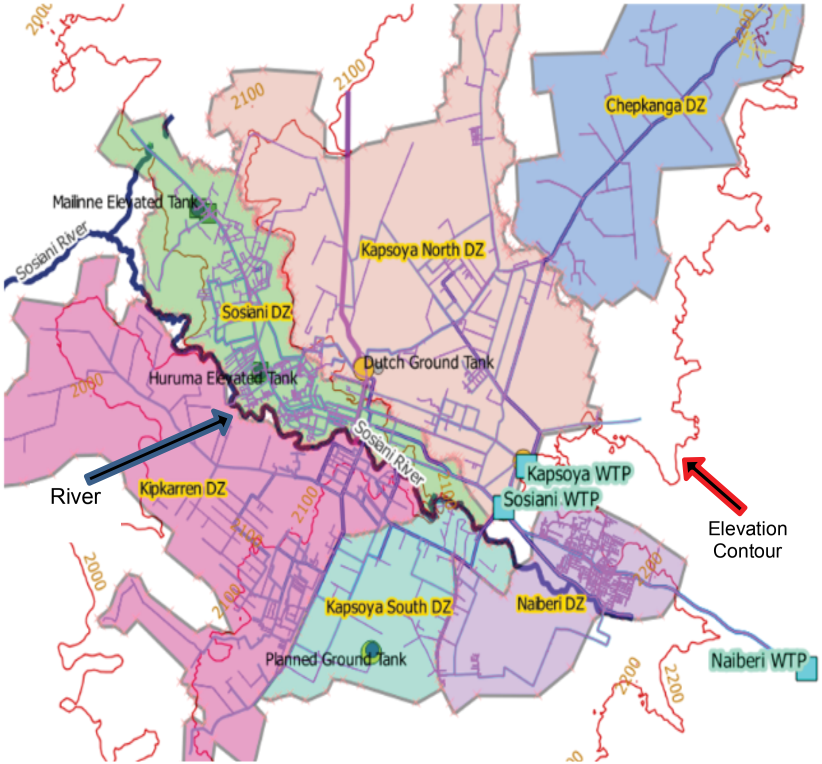
8) Ensure the tables and graphs are updated every month and used effectively in the monthly and other meetings held among relevant staff including manager(s) to improve NRW reduction activities.

5.3 Zoning of Distribution Networks

5.3.1 Zoning and NRW Monitoring at DZ Level

Figure 5.3 is an example of a plan for separating the existing distribution system into hydraulically isolated DZs in Eldoret WSP mainly to enable effective monitoring of monthly zonal NRW in addition to the universal one (refer Figure 5.1).

Figure 5.4 shows NRW monitoring at DZ level at Nyahururu WSP. In this example, two of the existing five DZs were selected as priority zones for NRW reduction as both had a relatively large share of the supplied water and one of the two had especially high NRW ratio although it had been falling over the previous three years.



Distribution Zone	Required Water in 2027 (m3/day)	Water Sources until 2027 (m3/day)	Water Sources beyond 2027 (m3/day)
Chepkanga DZ	8,016	Chebara WTP 22,000 + Kapsoya WTP 7,000 = 29,000	Chebara WTP + Kapsoya
Kapsoya North DZ	18,135		
Kapsoya South DZ	3,036		Kipkarren Dam WTP (use the elevated tank for Kapsaya South)
Kipkarren DZ	8,919	Kipkarren Dam WTP 24,000 (around 13,000 required)	
Sosiani DZ	15,659		
		Sosiani WTP 12,000	
Naiberi DZ	1,332	Naiberi WTP 2,000	
Zone 50	845	Kipkarren Dam WTP (2,000 allocated)	

<u>Note:</u> These distribution zones (DZs) were planned in 2019 based on the locations of existing WTPs & tanks, the terrain (elevation contours) of service areas, the balance between future water demand (including NRW & increase) & production capacity, etc. The required water supply calculated for 2027 includes reduced NRW ratio (40%→30%) and the annual demand increase of 6% over 8 years (from 2019 to 2027).

Figure. 5.3: Planned Zoning of the Distribution Networks into 7 DZs in Eldoret WSP

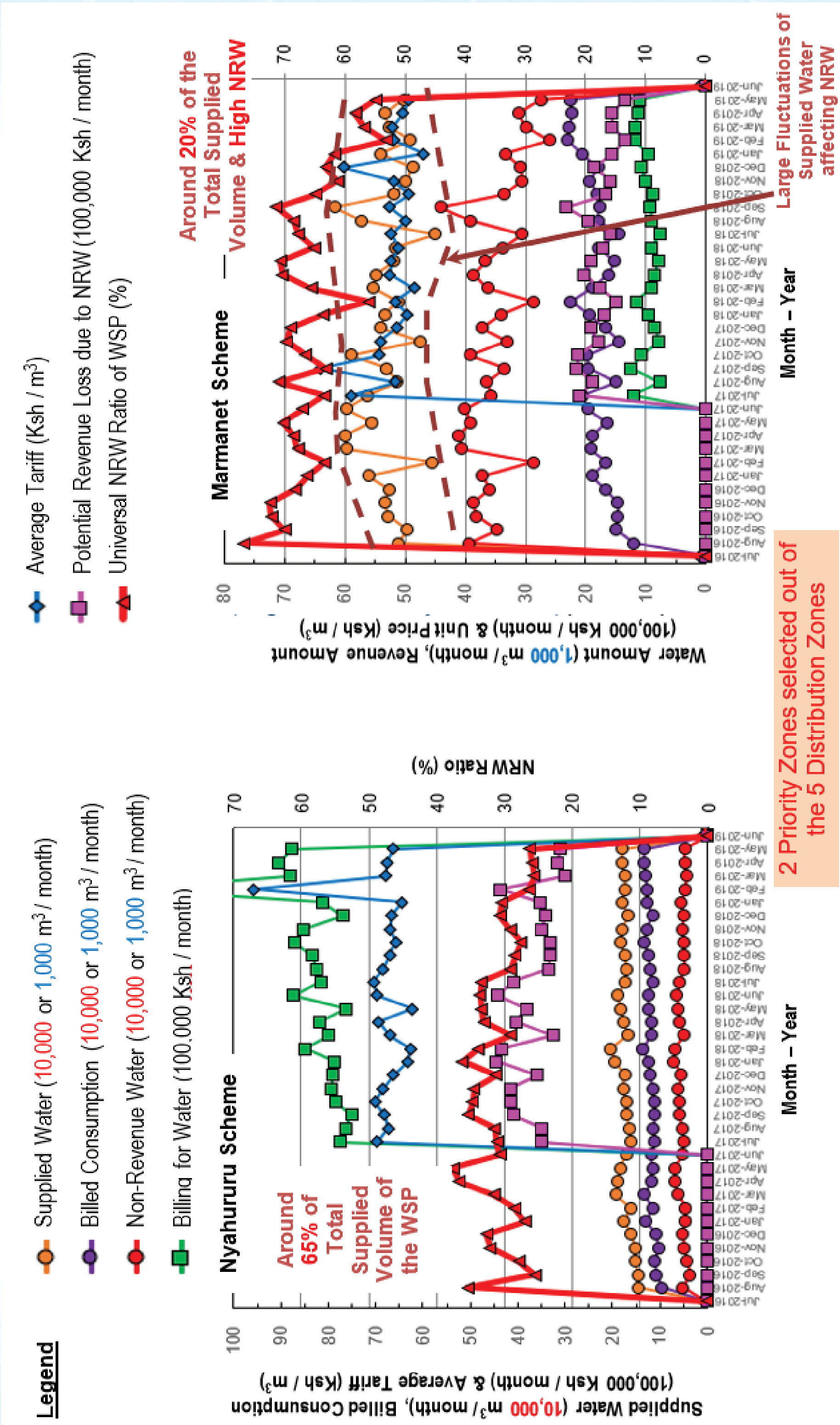


Figure. 5.4: Comparison of Zonal Monthly NRW and Selection of Priority Zones in Nyahururu WSP

5.3.2 Subdivision of Zones into DMAs in Developed Countries

Zoning of distribution networks in each WSP should be carried out primarily for controlling flow and pressure within the networks. In developed countries, distribution systems are usually well separated as hydraulically isolated DZs by default. In those countries, water is usually distributed to each DZ at a suitable pressure from a certain distribution reservoir/tank or a certain set of distribution pumps without water crossing over the boundaries of DZs unless it is required for emergency. The number of inlets for each DZ is usually limited to only one or a few, and zonal bulk meters are installed at the inlets by default. DZs can be separated into pressure zones by installing pressure reducing valves (PRVs) and/or brake pressure tanks (BPTs), which can be counted as DMAs if bulk meters (DMA meters) are installed on the inlet pipes at those pressure reduction facilities (see Chapter 10 Pressure Reduction/Management including Zoning by Reservoirs). As illustrated in Figure 5.5, large DZs can be further subdivided into DMAs without pressure reducing facilities for more detailed monthly monitoring of NRW and regular measurement of minimum night flow that indicates the amount of leakage if water supply is continuous. Once the established DMAs become operational, the DMAs can be used for monthly monitoring of NRW at DMA level, besides the monthly NRW monitoring at the universal and DZ levels, in order to manage both physical and commercial losses in each area.

Wherever possible, there should be only one permanent inlet into a DMA to ease management. Each DMA may have about 500 to 1,000 connections but, more importantly, hydraulic isolation of DMA should be easy enough for practical and sustainability purposes and, the number of inlets should be limited.

What if a WSP has heavily interconnected distribution network and does not have hydraulically separated DZs by default? This is the case for most WSPs in Kenya. Lack of well separated DZs has caused a lot of difficulties not only in controlling water flow and pressure but also in reducing NRW and leakage because DZs separation is not easy and DMAs creation without clear DZs is even more difficult.

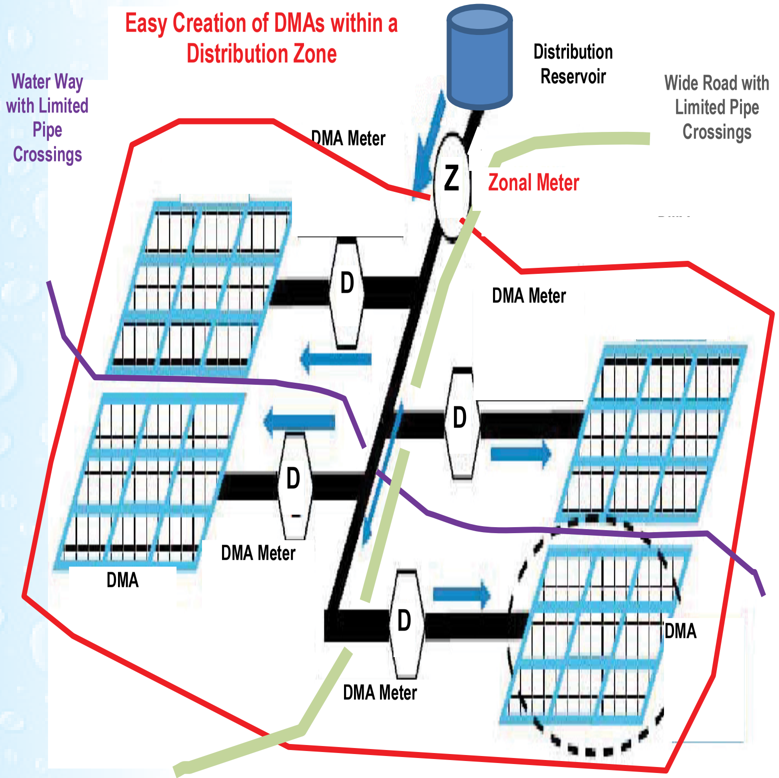


Figure. 5.5: Concept of Subdividing a Large Distribution Zone into DMAs

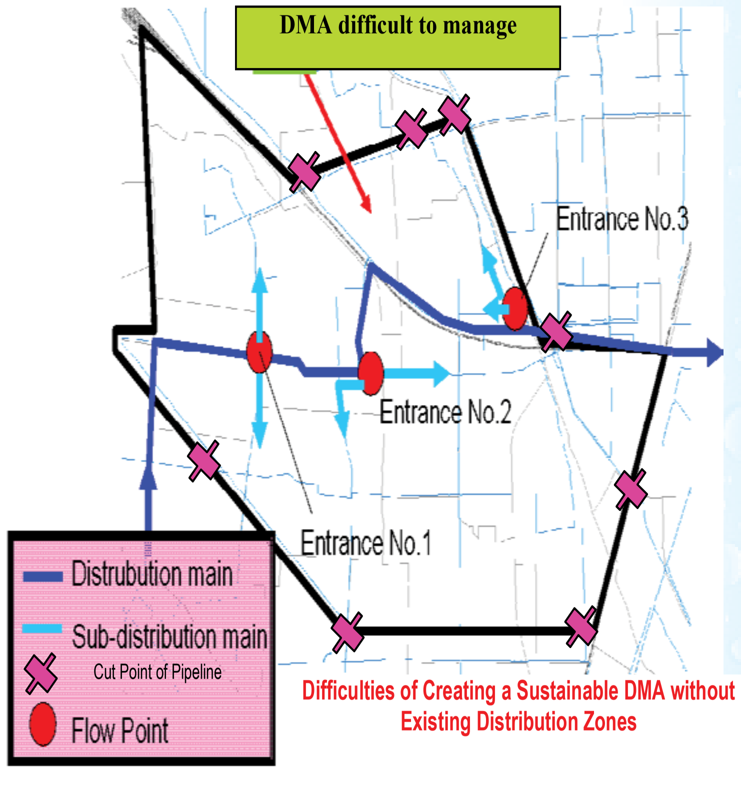


Figure. 5.6: Example of a DMA with Multiple Inlets & Many Cuts of Existing Pipes that are Difficult to Manage

5.3.3 Difficulties of Creating DMAs in Urban Areas without Hydraulic DZs

If a WSP has no technical capacity and resources to separate the distribution systems hydraulically into DZs, it may rush to create a small-scale isolated area as a DMA for the sake of a new trial of NRW reduction. It may create a pilot DMA in a peripheral rural area where distribution system can be separated easily.

However, if a WSP is suffering from a large amount of NRW occurring within built-up areas, establishing a trial DMA in a peripheral area does not make much sense although it is much easier than establishing a DMA in the built-up area.

As illustrated in Figure 5.5, if DZs are well-established even in built-up areas, a WSP may be able to start creating multiple DMAs easily just by dividing one of the DZs along the rivers and/or wide roads, etc; which have a few pipe crossings. On the contrary, a WSP would probably face many failures if it tries to establish a DMA within built-up areas where distribution systems are intermingled without clear separation of DZs. The failures may include incomplete isolation of the area, installation of an unmanageable number of bulk meters on many inlets/outlets, creation of obstacles against proper separation of DZs in the future, etc.

As shown in Figure 5.6, if a WSP does not have well-established DZs, establishing a DMA in a built-up area would require creation of an encircling boundary by cutting many existing pipes and installing multiple DMA meters. The pipes disconnected while establishing a DMA in a built-up area may be reconnected whenever there is water shortage occurs in the area in order to obtain emergency water supply from the adjoining area. This would undermine NRW calculation in the DMA. Moreover, the more meters a DMA has on its inlets/outlets, the more difficult it is to ensure their accuracy.

In realization of these points, a WSP may feel lost on what to do next for NRW reduction. There is an answer to this. While gradually separating the distribution system into hydraulically isolated DZs based on sound engineering considerations (see Chapter 10), a WSP should prioritize expansion of the basic NRW reduction activities which do not require hydraulically isolated areas to implement. Examples are reduction of estimated consumptions in billing through replacement of faulty meters, reduction of visible leaks and obvious water thefts, internal standardization of service connections, etc.

5.3.4 Other Benefits of Having Well-established Hydraulic DZs

Under intermittent water supply, a large portion of water flows down to low-lying areas especially if the distribution system is heavily interconnected. Under continuous water supply, the water pressure in low-lying areas may build up quite high. Therefore, separation of DZs needs engineering considerations to limit the unevenness of water distribution and the high pressure, besides considerations of monthly NRW monitoring and minimum night flow measurement for leakage amount approximation. These engineering considerations for even water supply and adequate pressure is further explained separately in Chapter 10.

A WSP may have administrative boundaries in the distribution systems which it uses to assign the various teams to different areas in customer meter reading, O&M of distribution networks, etc. These administrative boundaries should be converted to hydraulic boundaries once the hydraulic separation of DZs is done for better management of water supply services including NRW reduction.

5.3.5 Refining Universal NRW Monitoring into Individual DMAs

Division of the distribution networks into small DMAs needs a lot of resources and probably cause many technical difficulties such as failure in sustaining hydraulic isolation and reliable inflow measurements; and in identifying all the customers within each DMA. Therefore, reliable calculation of NRW volume and ratio should be established well through monthly monitoring practices; first for the entire service area, then for each DZs before dealing with the DMA level. If monitoring starts at DMA level (like in a pilot DMA) before the higher levels (universal and zonal), not much impact on the overall NRW reduction can be expected. If a WSP faces difficulties to reduce NRW effectively in some DZs even through monthly NRW monitoring for each of those zones is properly done, then only those particular DZs with difficulties may be further subdivided into DMAs so that the WSP can avoid using too much resources for the subdivisions. If a WSP has a relatively high technical capability and resources, the subdivision of established zones into many DMAs (and division of large existing zones into more DZs by constructing new transmission lines and distribution tanks, etc.) can be planned as shown in Figure 5.7.

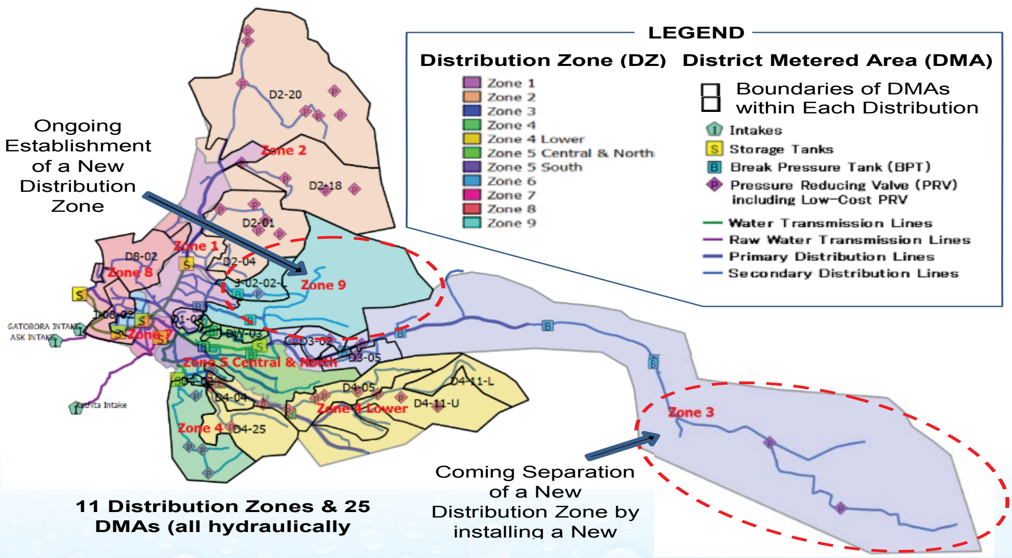


Figure. 5.7: GIS Plan Development to Increase Zones & DMAs at Meru WSP

The total inflow and total billed consumption can be determined to calculate the volume and ratio of NRW by hydraulically isolating a distribution network, installing bulk meters at all the inlets, and identifying all the customers within the isolated area. (Note: NRW in the entire service area, each zone or DMA are calculated by deducting Total Billed Consumption from Total Amount Supplied. In calculating universal NRW, the total production should be used as per WASREB definition of NRW. Outflows should be deducted from the total supply if the DZ or DMA has outlets).

5.3.6 Leak Detection at DZ Level to Minimize Costly Subdivision into DMAs

Under continuous water supply condition, in addition to DZs, DMAs can also be used to regularly measure minimum night flow that indicates the amount of leakage. However, before creating many DMAs which require a lot of resources not only to establish but also to maintain their effectiveness, it is important to consider the use of step test to reduce leakage at DZ level. In a step test the changes of minimum night flow (MNF) need to be measured continuously while closing branch distribution pipelines one by one in order to identify the areas causing a large amount of leakage. Each branch distribution pipeline needs to have operational isolation valves at their roots for the temporary closure. However, unlike establishment of permanent DMAs for each branch pipeline, identification of all the customers connected to each branch directly or indirectly and installation of bulk meters at their roots are not required for step test.

DZs can also facilitate real-time identification of incidences such as pipe bursts within each zone by installing pressure gauges or loggers in addition to flow meters on the inlet pipes. The zonal meters and pressure loggers are sometimes linked to a central control station via telemetry (e.g., part of a supervisory control and data acquisition (SCADA) system) so that flow data are continuously recorded and displayed. Effective abnormal flow monitoring for quick identification of bursts, leaks and water thefts may require installation of additional flow meters (including DMA meters) at strategic points within DZs.

5.3.7 Zoning of Existing Distribution Networks

1) Ensure that establishment or improvement of hydraulically isolated DZs is planned well with a map (preferably on GIS) showing boundaries of the planned DZs, required network modifications and existing/additional required zonal bulk meters for water distribution improvement and zonal NRW monitoring. This is, for example, aimed at limiting the elevation differences within each DZ to reduce pressure and pumping-power consumption; balancing the capacity of production facilities and the water demand in the different geographical areas; and full utilizing the storage capacities. Construction of new distribution reservoirs, transmission pipelines, pumping stations, etc. required for optimizing zoning may need to be compromised for quick and economical implementation of zoning.

2) Ensure that establishment or improvement of priority DMAs to split the large and/or problematic DZs is planned well with a map showing the boundaries of the priority DMAs, required network modifications and existing/additionally required zonal bulk meters (preferably on GIS) for more effective zonal NRW monitoring.

3) Ensure that the planned establishment or improvement of DZs is successfully implemented by hydraulically isolating the DZs.

   An example is to permanently cut existing interconnecting pipes, installing isolating valves on interconnecting pipes, installing standby bulk meters for measuring inter-zonal flow in case of emergencies requiring opening of isolating valves, confirming isolations by conducting zero-pressure test and properly installing all the zonal bulk meters required for the planned zonal NRW monitoring (e.g. with improved meter chambers in which portable clamp-on UFM can be mounted for testing the bulk meters, with strainers to prevent trash entering zonal bulk meters, and with air valves to release air from the meters, etc).

   Note: to conduct a zero-pressure test, close all the inlets/outlets first. Check whether the water pressure within the DMA drops to zero, since no water should now be able to enter the area.If the pressure does not drop to zero, then it is likely that another pipe is allowing water into the area and therefore needs to be addressed.

4) Ensure that the planned establishment or improvement of DMAs is successfully implemented by hydraulically isolating the priority DMAs and properly installing all the bulk meters necessary for the DMAs.

5) Based on the results of ongoing zonal NRW monitoring, ensure that additional DZs, DMAs or sub-DMAs are planned and established with additional bulk meters (as the need arises in cases where further subdivision of monitored DZs or DMAs with high NRW ratio and/or leakage is necessary to focus on the areas causing high NRW and/or leakage).

5.3.8 Zoning of Existing Distribution Networks

Monthly Calculation of NRW Volume and Ratio

1) Ensure that bulk meters of each DZ and DMA are always read monthly to accurately calculate monthly total inflow into each DZ and DMA (and Sub-DMA if required). It is recommended that all bulk meters should be read once daily by 9.00am for effective flow monitoring and to detect leakage/bursts problems early before too much water is lost.

2) Ensure that the accuracy of each zonal bulk meter is monitored based on the fluctuation of its monthly flow and periodically tested with a portable clamp-on UFM (e.g., semi-annually, annually, etc.) for timely servicing, replacement and/or calibration of any inaccurate bulk meters.

3) Ensure that:

    i) the monthly total billed consumption in each DZ and DMA is always calculated as scheduled without delay, and

    ii) the calculation is accurately done based on an accurate sorting of customers into each DZ and DMA. The meter reading route assigned to each customer in the meter reading/billing system may be usedto sort customers data. However, accurate sorting of customer datanormally requires locations of customer meters to be overlaid with DZ or DMA boundaries on GIS for confirmation. Addition of new data fields to the meter reading/billing system may be required at this stage to assign DZ and DMA names/codes to each customer for accurate sorting of customer data into DZs and DMAs.

4) Ensure that monthly calculation of NRW volume and ratio (and other prioritized PIs related to NRW volume if any) for each DZ and DMA is continuous and accurate based on synchronized bulk meter reading and customer meter reading in each DZ and DMA.

5) Ensure that fluctuations of monthly inflow, total billed consumption, NRW volume and NRW ratio of each DZ and DMA over the previous several months (i) are tabulated and plotted on graph(s) that are updated every month to analyse the causes of fluctuations and effects of NRW reduction activities.

6) Ensure that tables and graphs updated every month for zonal NRW monitoring are used effectively in monthly and other meetings held among relevant staff including manager(s) to improve NRW reduction activities, such as the prioritization of certain DZs or DMAs.

7) Ensure that monthly calculation of NRW volume and ratio in each DZ and DMA is integrated into a NRW management module of the existing meter reading /billing system.

5.3.9 Abnormal Flow Monitoring

1) Ensure that the zonal bulk and DMA meters are frequently read (e.g., daily, every few days or weekly, etc.) to monitor abnormal flow take timely intervention measures.

2) Ensure that the bulk meters on high-risk transmission and distribution pipelines (with recurrent bursts, leaks and illegal water uses) are selected and read frequently to monitor abnormal flow.

3) Ensure that additional bulk meters are installed on high-risk pipelines and frequently read to improve abnormal flow monitoring.

4) Ensure that fluctuations of flow rate at each bulk meter used for abnormal flow monitoring are quickly analysed based on the meter readings in order to identify any unusual increase in flow. Such an increase may be a hint that there is a burst, large leak or large illegal water use (e.g., irrigation at night).

5) Ensure that immediately there is any unusual flow increase hinting that there may be a problem, quick action is taken to confirm and resolve the problem on site.

6) Ensure that a free cloud-based online spreadsheet (e.g., Google Sheet in Google Drive) is created and is always used for recording bulk meter readings on site using smartphones; and promptly obtaining results of an automated analysis on abnormal flow; followed by quick intervention (without going back to the office to report the readings and receive result of analysis).

7) Ensure that abnormal pressure drops which may be hints of bursts, large leaks or large illegal water use are adequately monitored on high-risk pipelines including the outlet pipes of high-head pumps through frequent pressure measurements.

8) Ensure that GSM, GPRS, AMR or SCADA is introduced and frequently used to collect bulk meter readings and/or pressure data to monitor abnormal flows or pressure drops.

5.4 Preparation and Useof a Water Balance Table

5.4.1 Difficulties in Creating Reliable Water Balance Table

In developed countries, the entry point of NRW measures for a relatively large water utility may be to develop a global picture of how much and where water is being lost in the system. This process is called the water balance analysis or water audit. Table 5.3 shows the Water Balance Table defined by the International Water Association (IWA).

Table 5.3: Water Balance Table

<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="4">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td></tr>
<tr><td>Unbilled Unmetered Consumption (e.g., Hydrant)</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Commercial (Apparent) Losses</td><td>Unauthorized Consumption (e.g., illegal connections)</td><td rowspan="5">Non- Revenue Water (NRW)</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

This table shows the components of NRW and focuses on how much water is physically lost in which part of the water supply system, how much water is legally or illegally consumed, billed, etc. System Input Volume is obtained by measuring the volume of water distributed, and Billed Metered Consumption is obtained from customer water meters. Many components of the Water Balance Table are often very difficult to estimate accurately. Table 5.4 explains the terminologies used in the Water Balance Table and defined by IWA. In reality, it is impossible to calculate the volume and percentage of each water component described with reliable accuracy based on the many assumptions in most WSPs in Kenya especially in WSPs which have not fully analysed their commercial losses and/or where water supply is intermittent. When the supply is intermittent, minimum night flow cannot be measured to cross-check the amount of leakage calculated by deducting the amount of estimated commercial losses from the amount of NRW.

Table 5.4: IWA Terminology for Water Balance Table

System Input Volume	**This is the Volume of treated water that is input into the supply system where water balance is to be calculated.**
Authorized Consumption	This is the Volume of metered and/or unmetered water consumed by registered customers, water supplier and others who are authorized by the water supplier. This can be residential, commercial and industrial use. It also includes water exported across operational boundaries. Authorized consumption may include water for firefighting and training, flushing pipes and sewers, street cleaning, watering municipal gardens, public fountains, frost protection and for building works etc. These may be billed or unbilled, metered or unmetered consumption.
Water Losses	This is the difference between System Input Volume and Authorized Consumption. Water losses consist of Physical (real) Losses and Commercial (apparent) Losses.
Billed Authorized Consumption	This is the part of Authorized Consumption that is billed and earns revenue (also known as Revenue Water). This is the sum of Billed Metered Consumption and Billed Unmetered Consumption.
Unbilled Authorized Consumption	This is the part of Authorized Consumption that is legitimate but not billed, therefore does not earn revenue. This is the sum of Unbilled Metered Consumption and Unbilled Unmetered Consumption.
Commercial (apparent) Losses	This includes all types of inaccuracies associated with customer metering as well as data handling errors (meter reading, estimates on flat rates and billing), plus unauthorized consumption (theft or illegal use). **Note:** over-registration of volume of use by customer meters leads to under-estimation of Physical Losses. Under-estimation of volume of use leads to over-estimation of Physical Losses.
Physical (Real) Losses	This is water lost starting from the storage tank to the point of customer use. In metered systems, the point of customer use will be the customer water meter and in unmetered situations this will be the point of use (tap) within the property. The total annual volume of water lost through all types of leakages, breaks and overflows depends on the frequency, flow rate and average duration of individual leakages, breaks and overflows.

System Input Volume	**This is the Volume of treated water that is input into the supply system where water balance is to be calculated.**
	Note: Although leakages occurring after the point of customer use (tap) are not included as Physical Losses, this does not mean that these leakages are insignificant or should be ignored.
Billed Metered Consumption	This is all metered water consumption that is billed. It includes all categories of customers such as domestic, commercial, industrial or institutional. It also includes water transferred across operational boundaries (water exported), which is metered and billed.
System Input Volume	This is the Volume of treated water that is input into the supply system where water balance is to be calculated.
Billed Unmetered Consumption	This is all billed water consumption based on estimates or norms but is not metered. This may be a very small component in a fully metered system but can be a key consumption component in systems without full meter coverage. This may also include water transferred across operational boundaries (water exported), which is unmetered but billed.
Unbilled Metered Consumption	This is metered water consumption, which is unbilled. This may include metered consumption by the utility itself or water provided to institutions free of charge and water transferred across operational boundaries (water exported) which is metered but unbilled.
Unbilled Unmetered Consumption	This is any kind of authorized consumption that is neither billed nor metered. This component typically includes water used for firefighting, flushing of pipes and sewers, street cleaning, frost protection etc. In a well-run utility, this component is small, but very often over-estimated. In rare cases, this component may also include water transferred across operational boundaries (water exported) which is unmetered an unbilled.
Unauthorized Consumption	This is any unauthorized use of water. This may include illegal water use from hydrants (for example, for construction purposes), illegal connections, bypassing meters or meter tampering.
Customer Metering Inaccuracies and Data Handling Errors	These are Commercial (Apparent) Losses caused by customer meter inaccuracies and data handling errors in meter reading and billing system.

System Input Volume	This is the Volume of treated water that is input into the supply system where water balance is to be calculated.
Leakages in Service and/or Distribution Pipes	This is water loss from leakages and breaks on service and distribution pipes. These may be small leaks which are unreported (for example small leaks at joints) or large leakages that are reported and repaired but stayed leaking for some time.
Leakages and Overflows at Utility Storage Tanks	These are leakages from leaking storage tanks or overflows of tanks caused by operational or technical problems.
Leakages in Service Connections up to point of Customer Metering	This is water lost between the service connection (customer meter in case of metered systems and first point of use (tap) within a property in case of unmetered systems) to the point of customer use. These kinds of leakages are predominantly small and those that do not surface therefore will run for long periods (often years).
Revenue Water	This is authorized consumption, which is billed and produce revenue (also known as Billed Authorized Consumption). It is equal to Billed Metered Consumption + Billed Unmetered Consumption.
NRW	This is the component of System Input that is not billed and do not produce any revenue. It is equal to Unbilled Authorized Consumption + Physical (Real) and Commercial (Apparent) Water Losses.

5.4.2 Water Balance Table Part 1

Authorized Unbilled Consumption and Commercial Losses

Note: This part of the table can be prepared before WSPs shift focus to the difficult underground leak detection and expensive pipe replacement.

◆ Authorized Billed Consumption (Revenue Water) and Authorized Unbilled Consumption (Part of NRW)

1) Ensure that preparation of IWA universal water balance table for the entire SA of WSP for a recent year (or the last 12 months) is commenced by filling the annual billed metered authorized consumption (including sold exported water) and the annual billed unmetered authorized consumption (e.g., unmetered use of hydrant for firefighting). The World Bank Easy Calc (free Excel-based software) can be used to preparethe water balance table.

2) Ensure that annual metered authorized unbilled consumption for the SA is estimated with good accuracy based on metered consumption of each metered authorized unbilled water use type.

3) Ensure that annual unmetered authorized unbilled consumption for the SA is estimated based on the type of each unmetered authorized unbilled consumption. For example, if a formular is used, the calculation should be based on reliable records of each occurrence.

◆ **Commercial Losses (Data Handling Error, Meter Accuracy Error and Illegal Water Use)**

4) It is well understood by WSP staff working for NRW reduction that the accuracy of water balance table is largely dependent on the accuracy of estimating different types of commercial water losses and that the WSPs not actively trying to reduce commercial losses have a very strong tendency to underestimate their levels of commercial losses (and thereby overestimating physical losses) due to limited reliable data for estimating commercial losses. Therefore, active reduction of all components of commercial losses is prerequisites for establishing a representative (not misleading and harmful) water balance table of the WSP).

5) Ensure that commercial loss of the most recent year that was not accurate due to data handling errors (inaccurate and/or improper estimates of customerconsumptions due to missing meters, unreadable meters, obviously stalled meters, estimating without analysing past consumption data, etc.) is accurately estimated.

6) Ensure that commercial loss of the most recent year that was not accurate due to customer meters errors (metered consumptions were used for billing without being replaced with properly estimated figures) is accurately estimated. These components should be estimated based on the results of active meter accuracy tests to a sufficiently large number of sampled customer meters having different consumption levels (but not those tested passively to deal with complaints on meter accuracy or suspected over-registration from customers).

7) Ensure that commercial loss due to found and unfound illegal water uses is accurately estimated based on records of illegal water use identified in the past including results of active investigation of a sufficient number of suspected customers.

8) Ensure that the percentages of authorized unbilled consumption and commercial losses are continuously calculated in the universal water balance table to confirm the extent of reduction and the outstanding volumes; and shared with relevant staff for discussions.

5.4.3 Water Balance Table Part 2:

Physical Losses and Additional Zonal Analysis

◆ **Physical Losses (Completion of the Universal Water Balance Table)**

1) Ensure that the total annual physical water loss in the SA is estimated by deducting the total of annual authorized unbilled consumption and annual commercial losses from the total annual NRW volume.

2) Ensure that the estimated total physical loss is subdivided into:

   (a) leakage and overflow at water treatment, storage and pump facilities,

   (b) bursts and leaks from transmission and distribution pipelines, and

   (c) bursts and leaks from service connections up to customer meters.

   These should be based on the annual number of found overflows, bursts and leaks, the estimated number of remaining overflows and leaks and their estimated lost water volume for the three components.

3) Ensure that the universal water balance table is prepared (by entering the estimated volume and percentage of each physical loss component) and shared with relevant staff for discussions to improve NRW activities.

◆ **Additional Analysis on Physical Losses and Illegal Water Use in Each DZ/ DMA**

Note: In preparing the IWA universal water balance table, all commercial losses need to be estimated first to calculate the total volume of physical losses. In the following measures, the physical losses and illegal water use are estimated first

4) Ensure that the MNF at the inlet point(s) of DZ(s) or DMA(s) is recently measured with zonal bulk meter(s) and/or portable UFM(s) to roughly estimate the total volume of physical water losses and illegal water uses (part of it occurs at night) in each DZ or DMA.

   Note: MNF measurement is difficult to conduct under significantly intermittent water supply conditions.

5) Ensure that thorough active leak detection on distribution and service pipes is conducted recently in DZ(s) or DMA(s) to estimate the physical losses from distribution pipes and service connections separately.

6) Ensure that any results from the above two measures of analysing NRW components at DZ or DMA level (preferably from multiple areas of different characteristics) are used to cross-check the percentages of different NRW components shown in the universal water balance table of a recent year.

Chapter 6

Reduction of Commercial (Apparent) Water Losses

6.1 Metering of Customers

Connections of large consumers should be mapped well priority so that they receive special attention regarding accurate metering, billing, consumption pattern and water availability. Analysis of these parameters for large consumers should be done continuously to detect any abnormality for quick intervention where appropriate.

In order to determine the total consumption volume, full knowledge of all customer meters is crucial, hence 100% operational and accurate customer metering is necessary. Flat rates (where a meter is not installed) are still used in many WSPs. Some WSPs are still using flat rate connections because they lack fundsto procure and install meters. Consumers on flat rate connections are normally not cautious on water conservation, take advantage to use large amounts of water and generally misuse water by leaving it running for no purpose.

Water demand increases with increase in the number of customers. In order to meet the increased demand, additional water resources may need to be developed.

Without accurate water consumption data, the appropriate water resources would be difficult to develop and more funds than necessary would be used. The aim of managing NRW is to reduce water wastage. For this to happen, the general policy requires that all customer connections be installed with working and accurate meters. Even in areas where flat rate is applied, the zones should have bulk water meters to measure the water volume consumed within the area. Installation of water meters require funds and time. It is not always easy for WSPs with financial difficulties to prioritize meter installation. This can be better addressed by giving special attention to large consumers because they are the ones that can providethe desired large amount of revenue. It is important to plan for meter installation during project formulation, planning and design stages because in the long term, it is more beneficial to have fully operational meters for all customer.

The accuracy of customer meters depends on several factors such as meter type, brand, replacement policy and maintenance. Water quality is not good in some regions and it is advisable to install strainers on distribution pipes (Figure 6.1 and 6.2) to protect the moving parts of the meters from damage by debris. Therefore, WSPs should install water meters that are appropriate for the supplied water quality.

Figure 6.1: Strainer (Installed at outlet of Water Treatment Plant) (Meru WSP)

Figure 6.2: Roots at Customer Meter (Embu WSP)

6.2 General Condition of Commercial Losses

Reducing commercial losses is a key factor for NRW reduction in developing countries. NRW ratio can be reduced to as low as 30%, by only reducing commercial losses. In Kenya, lack of integrity of WSP staff was identified as one of the challenging factors that significantly contribute to commercial losses.

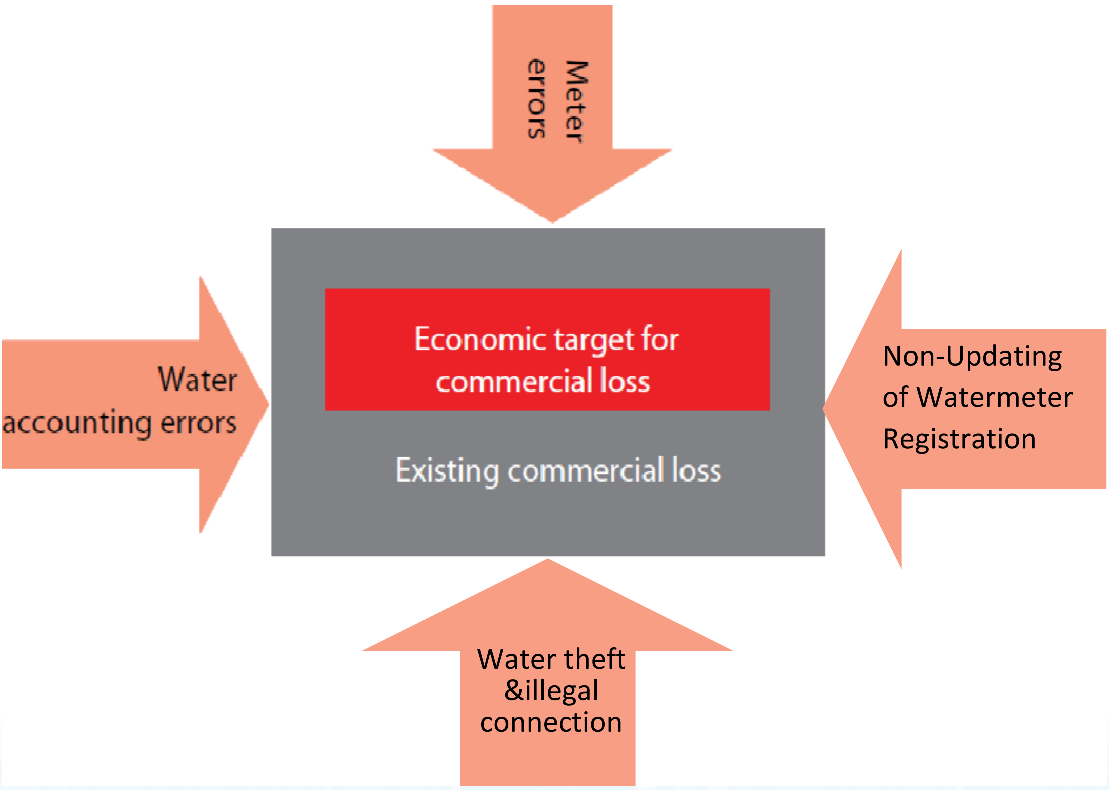


Figure 6.3: Four Pillars of Commercial Losses

Water lost through Commercial Losses, also known as Apparent Losses is not a visible loss and is therefore often overlooked by WSPs which, in most cases, focus on physical losses.

Commercial loss can result in a higher volume of water loss than physical loss and often has a greater value since reducing it increases revenue, whereas physical loss reduces production costs. For any commercially viable utility, the water tariff will be higher than the variable production cost. Therefore, even a small volume of commercial loss will have a large financial impact. An additional benefit in reducing commercial losses is that it can be accomplished quickly and effectively. This chapter reviews the four main elements of commercial loss and the options of addressing them.

6.3 Reduction Measures for Commercial Losses

6.3.1 Introduction

Commercial Losses can be broken down into four fundamental components:

- Meter errors (customer meter inaccuracy)
- Under registration of connected meters
- Water theft and illegal connection
- Water accounting error

Measures to reduce commercial loss do not require high investment but the results can be attained relatively quickly. For these reasons, measures for reducing commercial losses should be focused at the beginning of the NRW reduction program. It however requires continuous commitment of the management, political will and support by the local community.

The “customer meter reading and billing analysis tool” also known as the “frequency analysis” is an MS Excel template that was developed by the JICA Project for analysing meter reading and billing data over a period of time. It is recommended that the meter reading and billing data should be for a period of6 to 12 months. The analysis categorises customers based on the WSP’s tariff bands starting with the highest consumption tariff band (e.g., consumption>300m3/month =C1, 101 to 300 =C2, etc. (Figure 6.1)). The tariff bands are also categorized as Very Large (C1 & C2) Large (C3 & C4) etc. Conducting the analysis reveals the following information:

- Customer meters that were not read, in which months and the frequency of not reading
- stopped meters and the months of stoppage
- meters that malfunctioned and the months

- meters that need resizing
- accounts not billed and the months
- accounts billed on estimate and the months
- category of each customer based on water consumption amount (very large, large, medium, small)

Table 6.1: Customer Categorization and Frequency Analysis of Consumption Estimation

Customer Categories by Consumption		Customers with Billed Consumption Data		Ratios of Customers by the Number of Months when Consumption was Estimated during the 12 Months from June 2017 to May 2018			
		Num.	Percentage	0 Time	Only 1 Time	2 Times	3 Times or More
Very Large	C1: > 300 m3/month	19	0.1%	26%	16%	37%	21%
	C2: 101-300 m3/month	219	1%	27%	23%	13%	37%
Large	C3: 51-100 m3/month	701	3%	20%	15%	12%	53%
	C4: 21-50 m3/month	2,796	13%	12%	14%	11%	62%
Medium	C5: 7-20 m3/month	14,575	69%	6%	8%	8%	78%
Small	C6: 0-6 m3/month	2,721	13%	18%	20%	19%	43%
Total		21,031	100%	9%	11%	10%	70%

Other information such as identifying the category of specific customers can be obtained through filtering.

The results from the analysis provides an indicator of the level of commercial loss that is incurred in the system and is a powerful tool for guiding WSPs in prioritising NRW reduction activities that bring quick wins. It is therefore recommended that whenever a WSP conducts a capacity self-assessment, it should always include a frequency analysis of all customers to reveal the level to which customer bills are being estimated.

Frequency analysis of estimated consumption is especially important for those WSPs that do not give enough attention to commercial losses despite their high NRW ratio (e.g., NRW> 30%). All WSPs in Kenya can greatly benefit from and need to carry out periodic analysis (see Sec. 6.4 for further explanation).

It is therefore recommended that WSPs conduct the analysis annually or semi-annually and follow up by prioritizing the large consumers as they narrow down to the small consumers.

The most effective prioritization of tackling the meters is: -service the meter →test the meter →resize if necessary and replace the meter

- Start by tackling stopped meters of very large consumers
- Tackle under-registering/malfunctioning meters of very large consumers
- Tackle stopped meters of large consumers
- Tackle under-registering/malfunctioning meters of large consumers
- Tackle stopped meters of medium size consumers
- Tackle under-registering/malfunctioning meters of medium size consumers
- Tackle stopped meters of small size consumers
- Tackle under-registering/malfunctioning meters of small size consumers
- Continue monitoring the very large and large customers, as a priority, without ignoring the medium and small customers.

The WSP must be proactive in making quick decisions. If servicing a meter is not possible, replace it and try to service it later in the workshop. If testing of a meter for accuracy is not possible, replace the meter and try to test it later in the workshop. If resizing of a meter is not possible, replace it anyway and resize later. Always give priority to customers with potential for the highest revenue loss if the meter stops/ under-registers/malfunctions.

This way, the WSP can increase their billed consumption which in-turn results to revenue increase within a short period of time and with little investment.

6.3.2 Meter Errors

Normally, inaccurate meters have the tendency to under-register water consumption and very rarely over-register. This means that inaccurate meters result into revenue loss. To reduce inaccurate meters, meter testing exercise should be carried out by an experienced team (maybe NRW Team). Use of simple testing methods like calibrated buckets and test meters of known accuracy (Figure 6.4) is highly recommended especially for small WSPs which may not have a meter testing bench.

Figure 6.4: Meter Testing using Portable Test-meter and Calibrated bucket

When surveying for inaccurate meters, water meters of large consumption consumers should be prioritized first, as the revenue lost from such consumers isa lot. Billing customers based on actual consumption is always preferable to flat rate billing.

Below are typical causes of meter inaccuracies and their solutions:

a) Proper installation of customer meters

A water meters should be installed in accordance with the manufacturer's specifications to avoid unnecessary inaccuracies that may occur due to poor installation.

b) Water quality

Poor water quality due to inadequate treatment or dirt infiltration into pipes may cause sediments to settle in the water meters thereby leading to inaccuracy.

c) Intermittent water supply

Water meters in areas that receive water intermittently (or where water rationed) register the air volume at the begin before the arrival of water. This normally happens when supply is resumed after a certain period of no supply. The sudden increase in water pressure can also damage some components of a meter. Intermittent water supply should therefore be avoided as much as possible since it greatly affects the accuracy of meters and hence the readings.

d) Meter Size

Each customer meter is made to function within a defined flow range. Maximum and minimum flow volumes are normally defined by the meter manufacturer, and in many cases, large meters will not register water flow when the flowrate is lower than the specified minimum flow rate. It is therefore important to conduct customer survey to understand the nature of each customer's water demand and their likely consumption This helps to determine the size of meter required for each customer (refer to Chapter 7 for more details).

e) Class and Type of meter

Choosing the correct class and type of meter for each customer will ensure accuracy of customer consumption reading.

(i) Class of Meter

Classification of meters is based on the accuracy with Class A being the least accurate and Class D the most accurate.

(ii) Type of Meter

There are different types of flow meters which can be used to measure the flow with the mechanical type of flow meter being the most commonly used in Kenya. Different types of meters have different levels of accuracy as indicated in Table 6.2. The accuracy level of the flow meters must be put into consideration before installation since any errors will have a great impact on the measurement of the total water volume.

Table 6.2: Indicative Example of Meter Accuracy

Equipment / Method	Approximate Accuracy Range
Electromagnetic Flow Meters	<0.15-0.5%
Ultrasonic Flow Meters	0.5-1%
Insertion Meters	<2%
Mechanical Meters	1.0-2%
Venturi Meter	0.5-3%
Meas Weirs in open channels	10-50%
Volume calculated with pump curves	10-50%

Source: World Bank Institute, 2007

f) Maintenance of meters

Water meters should be replaced systematically, beginning with the oldest meters and those that are in bad conditions. Poor maintenance of meters results in meter inaccuracy and shortens their lifespan. A scheduled maintenance and replacement plan should be established to manage this problem such as tracking the age of each meter through the billing system. In some countries like Japan, meters are replaced at the age of 8 years. However, in developing countries, each WSP should formulate and periodically review a policy to ensure regular meter replacement,taking its financial capacity into account.

6.3.3 Updating Water Meter Register

It is important to continually update water meter registers, as water consumption bills are based on information in the register. Updating may range from a simple change of customer name or change from domestic to commercial user, to correcting information errors in the register.

There may be cases where information of newly installed water meters/connections is not entered in the billing system. In such cases, customers are not billed leading to revenue loss. It is possible for trained and diligent meter readers to detect unregistered water meters during regular meter reading cycles, as unregistered meters will not appear on the meter reading book.

The best method for identifying billing system errors is by conducting a complete customer survey in the supply area. In this survey, each property, whether registered or not, should be visited to determine whether the connection is registered or not.

Customer survey should confirm the following information: name of customer, property address, type of meter and meter number, active or inactive meter, whether it is a high consumption meter, and year of installation, etc.

Figure 6.5: Updating of Water Meter Register

6.3.4 Water theft and illegal connections

Illegal water connections and meter bypasses (water theft) are all part of unauthorized consumption.

Some of the more common problems and possible solutions are described below:

a) Detecting and Reducing Illegal Connections

An illegal connection involves establishing a physical connection to a water distribution pipe without the knowledge of the service provider. Meter readers should always be aware during their rounds and report any illegal connections immediately. Customers should also be made aware of the negative impacts of illegal connections and encouraged to report illegal connections when found. At the same time, strict regulations should be set in place to penalize illegal connections.

b) Meter Bypassing

An additional pipe can be installed around the water meter, so that water bypasses the meter. In such a case, water bills are reduced, as true consumption volumes are not recorded. Often, the bypass pipe is buried underground and it is very difficult to detect it. Customer surveys and conducting leakage Step-Test can help in determining meter bypassing.

c) Meter Tampering

This is manipulating a meter so that it records a lower reading than the true reading. Meter functionality is tampered with or disrupted by inserting a pins or other small objects into the meters. Most reputable meter manufacturers now produce meters that are difficult to tamper with. Such meters are non-metallic with strong clear plastic windows and casings that are difficult to penetrate.

d) Impact of informal Settlements on commercial losses

The low social-economic status in informal settlements renders it difficult to install customer meters for each household. This results to insufficient focus being given to the water supply in informal settlements. Nevertheless, since it is generally impossible to correctly determine the volume used in each house-holds, it is important to at least know the amount of water distributed in the slum areas.

In order to determine the volume of water distributed in an informal settlement, the area should first be isolated. The water entering the area should then be measured at the few created entry points - indicated in red dots (Figure 6.6).

Another method of determining the volume of distributed water is to use basic unit for consumed water volume per capita.

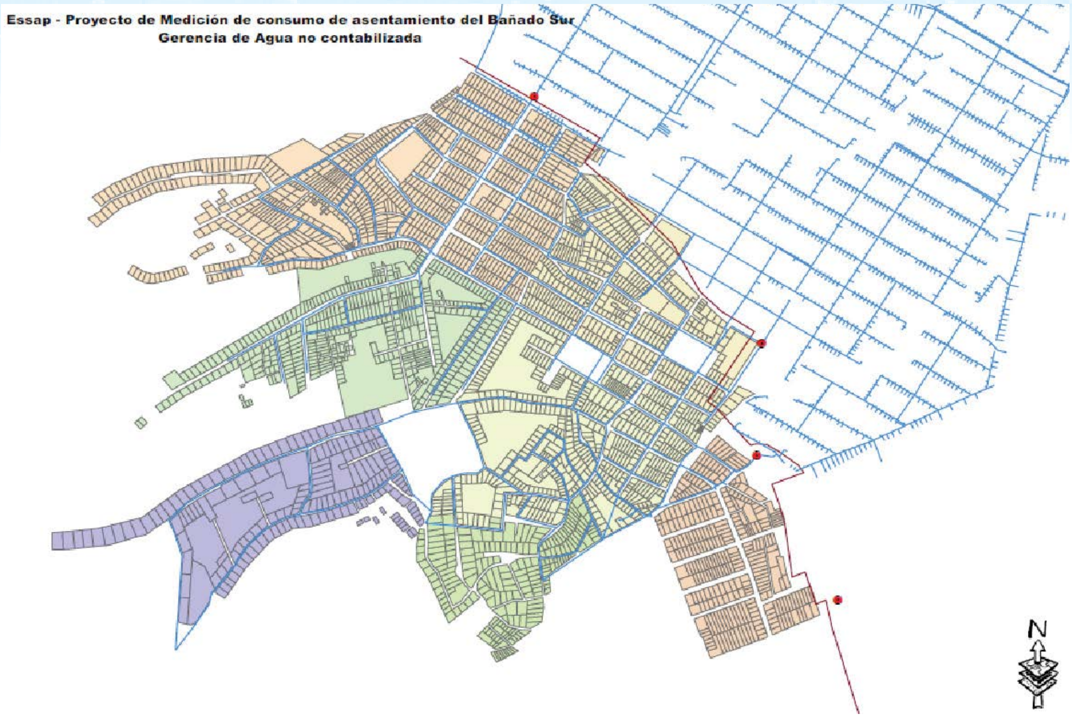


Figure 6.6: Measurement of consumption in informal settlements

6.3.5 Water Accounting Errors

a) Corrupt Meter Readers

Corrupt meter readers can cause significant impact on a WSP's monthly revenue. When the same meter reader is assigned to the same route for a long period of time, he/she may become very familiar with the customers in that route and collude with them to record lower meter readings in exchange for monetary incentives. In order to reduce this risk, the reading routes of meter readers should be rotated regularly.

b) Meter Reading Errors

Meter reading errors may occur due to incompetent or inexperienced meter readers, or simple errors while recording the readings by e.g., putting the decimal points in the wrong place. Errors can also occur due to dirty or faulty meter dials.

Meter readers should immediately report any problem observed, and the maintenance team should take immediate action to remedy the problem. Meter readers' activities are in the frontline; liaising directly with customers therefore their activities have an immediate impact on the cash flow. Investments should be made in training and motivating meter readers for accurate and efficient work.

c) Data Handling and Accounting Errors

Typically, the procedure for data handling and billing starts with meter readers visiting each water connection to read the customer meters. The data is recorded by hand on a form and submitted to the billing office. The billing office then keys the readings into the billing system and prints and mails the bills to the customer.

In this process, a variety of errors may occur at various stages of the process. Firstly, the meter reader may read incorrectly and/or record the reading incorrectly; secondly, the incorrect data may be logged into the billing system at the billing department; thirdly, the bill may be sent to the wrong address.

One of the key factors in minimizing errors is to have a robust billing database and such a database should be the first investment for any WSP that is striving to improve its revenues.

The latest billing software has built-in analysis functions that can identify data irregularities, which could lead to potential identification of data handling errors.

If a WSP is financially capable, it should invest in electronic meter reading devices. The devices can electronically transfer data to the billing system thereby drastically reducing data handling errors.

Figure 6.7: Water Meter Covered in Mud

It is common to see customer meters buried in mud, garbage or submerged in water causing the readers to read them incorrectly.

Meters should be installed in accessible locations where readers can easily read them.

6.3.6 Others Issues

a) Introduction of GIS Database

GIS was introduced as a platform for water network management, especially due to its characteristic capacity to manage maps and databases comprehensively. GIS is used in areas such as graphic management, customer registers, revenue collection, etc to ensure develop maintain maps of water networks including customer meter locations among other system facilities which is crucial in NRW management.

b) Efficient Billing System

For efficiency and accuracy, a computerized billing system should be used. Among the in-built reports produced by an efficient billing system should be DMA/Zonal and overall NRW water volumes and ratios once supplied volumes are keyed in. The efficiency of a billing system can contribute greatly in NRW management by maintaining accurate data and producing relevant reports as needed.

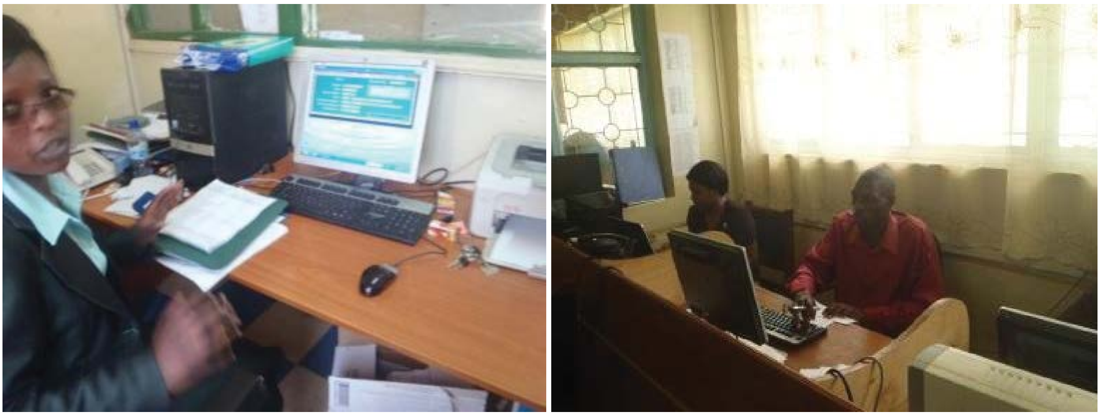


Figure 6.8: The Billing Unit for Narok and Embu respectively

c) Customer Care System

To manage customer complaints, a customer care system such as Enterprise Resource Planning (ERP) should be installed to easily share information among all the company staff. The system should handle problems related to meter reading errors, lack of water supply, dirty water or insufficient water pressure in a quick and efficient manner. Giving customers careful attention increases customer trust leading to better payment of bills and hence stable revenue.

Figure 6.9: Customer Care System

6.4 Analysis of Meter Reading and Billing Data

Even WSPs with a metering ratio close to 100% often have many faulty and inaccurate meters at customer points. This causes frequent and unending estimation of customers’ consumption resulting in a huge volume of NRW. Therefore, the status of recent metered and billed consumption data for each customer should be analysed to understand the following:

a) The composition (frequency analysis) of the customers categorized by average billed consumption (preferably 12 months), e.g., large customers consuming more than 100m3/month on average.

b) Monthly percentage of estimated consumptions by customer category. All the estimations can be found in the analysis by identifying the billed consumptions which are different from their corresponding metered consumptions.

c) The main and other reasons for the identified consumption estimations.

d) Inconsistency between current status of disconnected customers and their recent meter reading and billing records (customers with disconnected status may currently have metered consumption, and/or may be receiving bills, or may be using water illegally).

e) The frequency of estimated consumption for each customer during the last 12 months (e.g., categorized into 1 time, 2 or 3 times, more than 3 times, etc) and its continuity (e.g., the number of months that usually pass before stopped or obviously-faulty meters get replaced) by customer category.

Results from the above analyses should be shared widely among WSP staff including managers and discussed to improve commercial loss reduction activities (especially those of large customers).

6.5 Reduction of Commercial Losses starting from Large Customers

The frequency of the estimated customer consumption (especially those of large customers) should be reduced through:

1) Servicing and/or replacing obviously faulty meters. Installation of strainers and, elimination of visible leaks and overflow can be done at the same time.

2) Conducting active on-site accuracy tests of customer meters. The passive customer meter accuracy test that is normally conducted for complaining customers should not be considered as part of this active accuracy tests.

   (**Note:** meters of large consumers should be checked more frequently. The costly replacement of old meters for small customers (those consuming less than the upper limit of the lowest tariff bracket may not decrease NRW or increase revenue significantly.

3) Investigating illegal connections and underground leaks (e.g., with DPD chlorine tablets, listening sticks, etc) around customer meters can be conducted at the same time with servicing and replacement of faulty meters and/or accuracy testing of active meters.

4) The above activities should be supported by the following activities:

   i) Use of printed GIS maps showing target customer meters to identify their locations on site

   ii) Use of online map (e.g., QGIS Cloud), mobile mapping/GIS software installed on smartphones (e.g., MAPinr) and/or PC-based GIS software on Windows tablets (e.g., QGIS) to navigate to the target customer meters.

   iii) Use of electronic form(s), e.g., Kobo Toolbox/Collect to collect data.

5) The following equipment and facilities are used to conduct meter accuracy tests on site or in the workshop:

   i) 10 or 20 litres ready-made calibrated buckets/jerry cans (larger sizes can be fabricated in the workshop.

   ii) Portable clamp-on UFM (see Sub-section 13.2.4)

   iii) Portable meter tester (e.g., ready-made having a 15mm test-meter inside or hand-made with Class C copolymer piston-type meters up to 25mm and hose pipes)

   iv) Meter test bench (e.g., ready-made with flow rate control and calibrated tanks or hand-made with a table, valves, calibrated buckets, inline UFM of known accuracy, etc. (See Sub-section 13.2.4)

   v) Workshop well equipped for servicing of removed meters

6.6 Additional Focused Management of Large and Medium Customers

1) Frequent visual inspection, additional reading of large consumer meters (e.g., weekly, etc) and/or installation of additional meters in series should be conducted to minimize revenue loss caused by meter inaccuracy that may worsen between monthly meter readings.

2) Proper customer meter sizing for large consumers based on maximum flow rate should be implemented.

(Note: Small customer meters (may have low "maximum" or "cut-off flow" rate that is lower than the expected high water flow rate" at the beginning of each intermittent water supply period should be avoided especially in low laying areas with high water pressure and short water supply hours.

3) Multiple customer meters serving the same customer should be integrated into one account for each customer so that the billed amount increases properly in accordance with the incremental water tariff (also possibly by replacing them with a single larger customer meter).

4) Metering for residents in large residential buildings (where water theft may exist inside the building) should be effective and/or improved to reduce illegal connections and leakages (e.g., by relocating individual meters outside of buildings or by installing a master meter for the building owner/landlord outside and collecting water charge based on master meter readings).

5) Installing large high accuracy non-mechanical (i.e., electromagnetic and/or ultrasonic) meters which cannot stall easily and that have long-life battery, data logging ability and anti-tamper function (may have remote reading function such as GSM and AMR) for very large customers.

6) Installing small high accuracy ultrasonic smart meters with built-in battery and; AMR and anti-tamper function (or anti-tamper mechanical meters with mounted AMR devices) and; compatible software and data receivers for AMR (e.g., many relay antennas and a mobile antenna mountable on automobile, etc) for large and/or medium customers.

6.7 Reduction of Unbilled, Unmetered and Illegal Water Uses based on Customer Identification Survey

◆ **Unbilled Authorized Consumption**

1) The necessity and actual conditions of authorized unbilled public water uses (e.g. public parks, public toilets, public taps, fire hydrants and supply to special areas such as low income areas) should be well assessed, and the relevant policies developed/improved (including those for reducing authorized unbilled

consumption and, improving its metering) (e.g. through introducing subsidies or instalment payment plans of connection fees for low income population, identifying excessive public water uses and awareness raising).

2) Actual conditions and necessity of authorized unbilled consumption for WSP's institutional uses (e.g., flushing of distribution pipes with water, cleaning of distribution tanks, losses during installation of service pipes and customer meters, etc) should be assessed and relevant policies developed/improved (e.g., through identification of excessive institutional water uses and awareness raising).

◆ **Unmetered, Unregistered and illegal Water Users/Customers**

3) Customer meters should be installed for all customers who are supposed to be billed based on metered consumption to reduce commercial losses and excessive water use.

4) CIS should be conducted to identify unregistered consumers (missing from the meter reading/billing system) and illegal users (including customers recorded as disconnected but still consuming water for free after illegal reconnection or unsuccessful disconnection; NB: disconnection at the offtake/tapping point may be required), etc. Accurate GPS coordinates of customer meters (and possibly offtake point), connection No. of each customer, meter type and conditions etc should be captured in a CIS preferably with free data collection software (e.g., Kobo Toolbox/Collect) or free mobile GIS (e.g., QField) on smart-phones and hand-held GPSs (i.e., a combinational use for higher GPS accuracy).

◆ **Problematic Customers and Areas with Recurring Illegal Water Use**

5) Cases and scale of illegal uses (e.g., meter tampering, meter bypass, illegal connection, Illegal reconnection, meter reversal, fetching before meter) in informal settlements, at large non-residential customers and high-income customers with large gardens, should be well analysed and discussed for prioritizing customer types or areas for reducing illegal uses. (Note: Both Illegal self-reconnections of disconnected customers having stopped meters and unsuccessful disconnections with faulty stop cocks and stopped meters can cause large a NRW amount without being noticed for a long time if they are not given special attention).

6) Active patrolling for recurring illegal water uses at problematic customer types (e.g., factories, farms, construction sites) and/or in certain types of areas (e.g., illegal connections, meter tampering, meter bypass, illegal self-reconnections) should be conducted by dedicated inspectors supported by the WSP's top managers (with the use of chlorine DPD tablets, electronic conductivity meter, leak detection equipment, etc).

6.8 Preventive Measures at Installation of Service Connections and Customer Meters

6.8.1 Installation of Customer Meters

Factors to take into consideration when installing customer meters are the reliability of meter performance, ease of reading and ease of replacing and maintenance.

Figure 6.10: Actual Installation of Customer Water Meter

(1) Location for Installation of Water Meters

The following factors should be considered when selecting a site for installation of meters:

i) Meters should be located at points where meter reading, inspection, and maintenance can be easily performed.

ii) Selected sites should be located in dry areas away from wastewater

iii) Meters should be installed in locations away from contaminated air or exhaust fumes.

iv) Meters should not be easily exposed to vandalism, theft or accidents

v) Meters should be located in areas free from water logging and flooding

vi) Meters should not be installed in areas with excessively high temperatures

vii) Meters should not be installed in a location where water pressures fluctuate excessively

viii) Meters should not be located in areas where they are subjected to shocks or vibrations

ix) The GPS location of each meter should be taken and updated on the GIS map for ease of management like meter reading, etc.

Figure 6.11 and 6.12 show recommended installation for customer meters

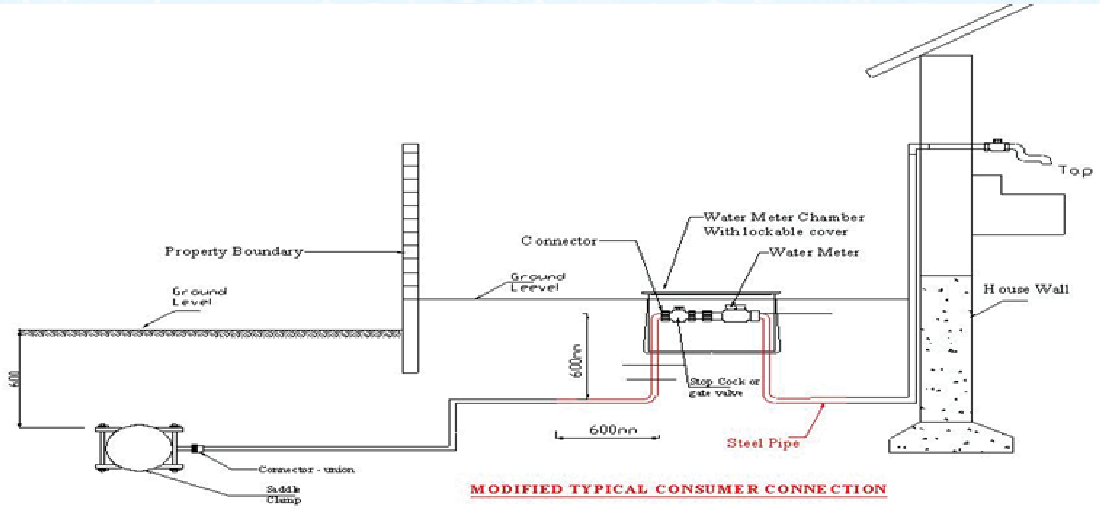


Figure 6.11: Recommended customer meter installation with meter box

There are many cases in Kenya where meter readers cannot read customer meters as they are buried underground. This can cause errors in meter reading. It is recommended to install water meters above the ground in order to facilitate meter reading. In Kenya, water meter installed above ground are more susceptible to theft. In theft-prone areas, copolymer resin body meters are recommended.

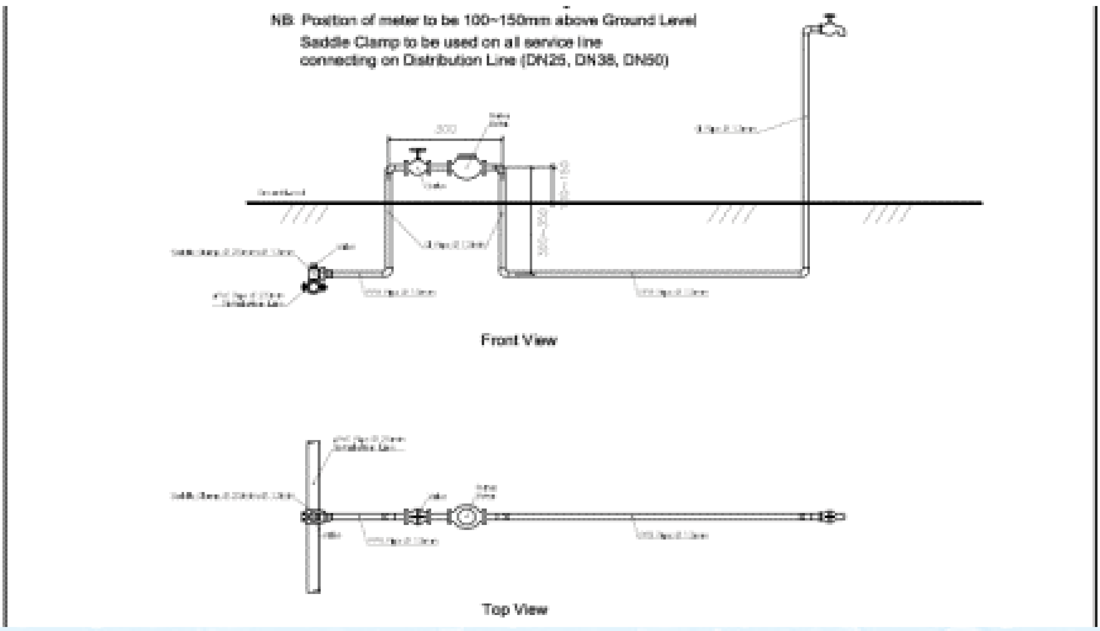


Figure 6.12: Recommended customer meter installation without meter box

(2) Precautions for Installation

Poor installation can impact negatively on the performance of meters. The following precautions should be taken at the time of meter installation to minimize sub-standard performance of meters.

i) Clean the interior of pipes thoroughly of any sand and foreign debris. "Recording errors" occur if the strainer of a meter is clogged. The meter can also be damaged by foreign objects.

ii) Install meters horizontally at the designated location, with the arrow on the lower case facing towards the direction of the flow of water. When meters are not installed horizontally, meter sensitivity and durability can be highly compromised.

iii) Meters should be installed with enough pipe length on both sides of the meter. Inadequate length or bent pipes will affect the accuracy of meters and may also strain the meters. In cases where the length of pipes is too long, it will be necessary to make sure the meters are structurally well supported for stability.

iv) Use gaskets that properly match the diameter of the meters. Instrumental errors may occur when gaskets are projecting inwards.

v) For Woltmann horizontal type, Venturi-tube bypass type and propeller meters, a straight tube should be installed on the upstream of the meter. The straight tube should be at least five times longer that the meter diameter and at least three times longer than the meter diameter on the downstream.

vi) Upon completion of installation, care should be taken to open the stop valve slowly when admitting water for the first time, in order to prevent water hammer.

6.8.2 Maintenance

Maintenance of water meters means making sure that meters remain accurate at all times. It involves always being ready to replace meters.

(1) Maintenance for Accuracy

In order to maintain meter accuracy, the following must be done:

i) Analyse actual consumption based on the data obtained from meter readers on a monthly basis

ii) Conduct surveys to keep track of actual consumption flow rate

iii) Replace meters based on the planned schedule for replacement

(2) Management of Meter Installation

Meters installation should be managed as follows:

i) Ensure that quality certification is properly affixed on the meter

ii) Ensure that meter boxes are not buried in sand or mud

iii) Ensure that meters are installed horizontally to ensure accuracy is maintained during operation

iv) Ensure that there are no leakages around meters

6.8.3 Measures against Meter Theft

In order to prevent theft of meters and metallic meter boxes in developing countries, meters are installed in concrete chambers with heavy hard-to-open concrete lids. This hampers meter reading and leak control activities.

Copolymer material was previously poor but has greatly improved. Hence, copolymer meters and boxes can now be used to replace metallic ones.

Chapter 7

Meter Selection and Commercial Loss Reduction

7.1 Customer Meters

7.1.1 Introduction

Customer water meters provide important basic data necessary for billing and NRW ratio calculation. It is therefore crucial to connect customer meters to each household.

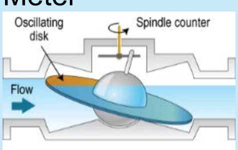
Selecting water meters involves both size and type of meter. Too often, size is chosen merely to match the pipe size; but oversized pipe is often installed to allow for possible future increase in water use or to reduce pressure loss in long pipes. The tendency to install oversize meters is sometimes driven by the desire to use meters large enough to meet the customers' maximum demand and not to incur additional expense in case a small meter becomes inadequate. However, it is recommended to always install the right size meter as the overall commercial loss due to over-size meter can be quite large over time. WSPs should ensure that meter sizing activity is scheduled to ensure the performance of existing meters is review regularly.

a) Meter Type

Four types of water meters used in Kenya are (i) displacement meters, (ii) velocity meters, (iii) UFM and (iv) electro-magnetic Meters.

Table 7.1 briefly describes the types of water meters and their applicability. Table 7.2 elaborates the meter types and lists their merits and demerits.

Table 7.1: Water Meter Technology Options

Meter Type	Description	Applicable under the following conditions
Displacement Meter 	Displacement water meters rely on the water to physically displace the moving measuring element in direct proportion to the amount of water that passes through the meter. The piston or disk moves a magnet that drives the register. There are two main types of displacement meters: nutating disc and oscillating piston (rotary piston).	o Displacement water meters are suitable for low to medium water flow rates with diameters typically ranging from 13 to 50 mm. They tend to be more accurate than velocity meters at low flow rates.

Meter Type	Description	Applicable under the following conditions
		o Due to its inner structure, displacement meters are sensitive to turbid water. Hence, an external strainer needs to be installed upstream when metering water with considerable amounts of suspended particles. The additional external strainer and the often-in-built sieve/ strainer have to be regularly cleaned. o In case of high possibility for meter air flow, displacement meters have shown to be less sensitive.
Velocity Meter 	A velocity meter measures the velocity of the flow through a meter of a known internal capacity. In order to determine the actual consumption, the speed of flow is converted into flow volume. Two main types of velocity meters are used in Kenya: single jet meter and multi-jet meters. o Single jet meters incorporate a single tangential jet. o In a multi-jet meter, a tangential opening in the chamber directs the water flow across a multi-vanned rotor. The output speed of the rotor is proportional to the quantity of water passing through the measuring chamber. The meter works mechanically much like a single jet meter except that the flow at the rotor is directed equally from several points, not just one; this minimizes uneven wear on the rotor and its shaft.	o The single jet meter is applicable for small flow rates (diameters typically range from 15 to 50 mm). o The multi-jet water meter is suitable for small and medium flow rates (diameters typically range from 15 to 150 mm). o When metering water with considerable amounts of suspended particles, velocity meters tend to be less prone to clogging compared to displacement meters. This results in less additional effort for servicing. If the specific turbidity level is very high, an additional external strainer should be installed as well. Both, the external strainer and the often-in-built sieve/strainer have to be cleaned regularly.

Meter Type	Description	Applicable under the following conditions
Ultrasonic Flow Meter 	Ultrasonic Flow Meters (UFMs) use sound waves to determine the velocity of a fluid flowing in a pipe.	o UFMs are mainly used for measurement of bulk flows (diameters typically range from 15 to 1,800 mm) and commonly used as 'clamp-on' meters to calibrate large diameter velocity meters. UFMs are typically supplied with a transducer that can be used in a range from 75 to 1,800 mm. By procuring a second transducer (smaller), the UFM can be used in a range of 15 to 75 mm.
Electro- magnetic Meter 	An electromagnetic meter measures the flow rate of water by its electromagnetic properties instead of measuring it mechanically. The installation configuration should be such, that the transmission main is filled with water at all times (e.g., through installed non return valves).	o Since no moving parts are incorporated, waste water and water even with high number of suspended particles can be metered accurately. o Electromagnetic water meters are more sensitive to low flows. o Its usual diameter ranges from 2 to 1,800mm.

Table 7.2: Merits and Demerits of Common Water Meters Types

Type of Water Meter			Merits	Demerits
Small and Medium Customer Meters	Conventional Mechanical Meter[1]	Volumetric/ Piston	• Sensitive at low flow • Vertical installation is allowed	• Easily clogged by silt, etc. • Over-registers with air • Rather expensive compared to single and multi-jet meters

Type of Water Meter			Merits	Demerits
		Single-Jet	• Low cost	• Deteriorates rather quickly over time (years) • Over-registers with air
		Multi-Jet	• Rather sensitive at low flow	• Deteriorates rather quickly over time (years) • Over-registers with air
	Smart Meters	Mechanical Meter + Data Transmission Unit	• Relatively low cost • Data transmission unit for remote meter reading can be attached later to avoid a large initial investment	• Vulnerable due to attachment of data transmission unit. • Over-registers with air • Often stalls and breaks down due to mechanical parts
		Ultrasonic Flow Meter with Data Transmission Functions	• Robust against meter tampering • Does not stall unless battery runs out	• Very expensive • High flow above cut-off rate at start of supply after shut-down cannot be registered • Under-registers with air
Large Customer and Bulk Meters	With or Without Data Transmission Device	Mechanical (Woltmann) Type	• Low cost • Does not need power (or battery) for measurement	• Relatively low accuracy • Stalls and breaks down due to mechanical parts (Y strainer required for protection) • Over-registers with air

Type of Water Meter			Merits	Demerits
		Ultrasonic (In-line type)[2]	• Does not stall • Relatively sensitive even at low flow	• Relatively high cost • Under-registers with air • Battery often runs out fast
		Electromagnetic (In-line type)	• Does not stall • Higher flows can be measured	• High cost • Under-registers with air • Battery often runs out rather quickly
		Electromagnetic (Insertion type)	• Possible to be installed later on straight pipes • Higher flow can be measured	• Relatively high cost • Difficult to install and maintain accuracy through calibration • Under-registers with air

Notes: *1. Copolymer body is recommended for mechanical customer meters to avoid meter theft.*
2. Clamp-on (not in-line) portable ultrasonic flowmeter is recommended for on-site bulk meter testing

b) Old Meter Classification

Based on ISO 4064:2005 and OMIL R49:2003, water meters can be divided into four classes: A, B, C and D. Each class sets a range of flow rates within which the meter must maintain its accuracy. A has the narrowest range and D is the widest. Each meter can be considered perfect in the range of flow rates for which it is designed.

i) **Class B:** used for low water quality areas since it's not easily affected by sediments.

ii) **Class D:** used where water quality is good since it's easily affected by sediments. It can measure low flow rates. However, it is more expensive than class B.

iii) **Class C:** is a compromise between Class B and D i.e., less affected by silt and can measure low flows better than class B, but it's cheaper than class D.

iv) **Class A:** is not normally used in water supplies in Kenya.

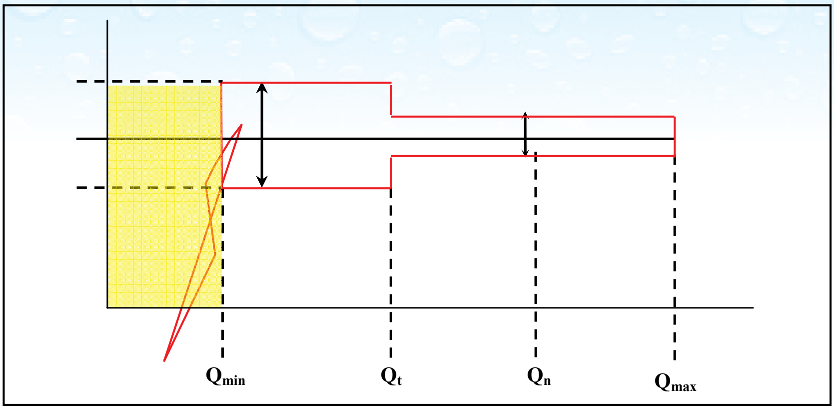


Figure 7.1: Curve of Relative Error in Water Meters

Table 7.3: Water Meter Classification (Flow rates in Litres/Hour)

Nominal dia, mm (inch)			Class A		Class B		Class C		Class D	
	Q_n	Q_{max}	Q_{min}	Q_t	Q_{min}	Q_t	Qmin	Q_t	Q_{min}	Q_t
15 (½”) V	1,000	2,000	-	-	-	-	-	-	7.5	11.5
15 (½”) H	1,500	3,000	60	150	30	120	15	22.5	11.25	17.25
20 (¾”) H	2,500	5,000	100	250	50	200	25	37.5	18.75	28.75
25 (1”) V	3,500	7,000	140	350	70	280	35	52.5	26.25	40.25
25 (1”) H	6,000	12,000	240	600	120	480	60	90	-	-
32 (1¼) H	6,000	12,000	240	600	120	480	60	90	-	-
40 (1½) H	10,000	20,000	400	1000	200	800	100	150	-	-

Key

- V-Vertically installed (for volumetric meters only); H - Horizontally installed
- Minimum flowrate (Qmin) - The lowest flow rate at which the water meter is required to operate within the maximum permissible error.
- Transitional flowrate (Qt) - Flow rate which occurs between the nominal flow rate and the minimum flow rate and that divides the flow rates into two zones, the upper flow rate zone and the lower flow rate zone, each characterized by its own maximum permissible error.
- Nominal flowrate (Qn) - The highest flow rate within the rated operating conditions at which the water meter is required to operate in a satisfactory manner within the maximum permissible error.
- Maximum flowrate (Qmax) - The highest flow rate at which the water meter is required to operate for a short period of time within its maximum permissible error whilst maintaining its metrological performance when it is subsequently operated within its rated operating conditions.

Note:

(1) Qn and Qmax remain constant across the classes and only Qmin and Qt decrease from Class A towards D, thereby widening the accurate range.

(2) Between Qmin and Qt, the meter accuracy is ±5%. From Qt to Qmax the accuracy is ±2

(3) Vertically installed meters have a shorter accurate range hence cause higher NRW and are easily overloaded and damaged than horizontally installed.

Class B was the most commonly used due to its acceptable minimum flowrate and affordability.

This classification by ISO 4064:2005 is no longer in force and it has been replaced by OIML R49:2013.

c) New Water Meter Classification (R-Series)

In the latest standards (ISO 4064:2014 and OIML R49:2013), a new system based on the Reynard series was established and the flowrates on Figure 7.1 renamed as follows: Qmin → Q1, Qt → Q2, Qn→ Q3, and Qmax→ Q4; but the system yields completely different values.

Also note that values of “Q3” and “R” (R = ratio Q3/Q1) are marked on the meter instead of the old system where Qn and Qmax were the values marked.

The value of the normal flow Q3 shall be chosen from Table 7.4.

Table 7.4: Value of normal flow, Q3 (in m3/hr)

1	1.6	2.5	4	6.3
10	16	25	40	63
100	160	250	400	630
1,000	1,600	2,500	4,000	6,300

The value of the ratio R (R = Q3/Q1) shall be chosen from Table 7.5.

Table 7.5: Value of Ratio R (R = Q3/Q1)

40	50	63	80	100
125	160	200	250	315
400	500	630	800	1,000

Further, the values of Q2 and Q4 shall be as per the formulas below:

Q2 = $1.6Q_1$

Q4 = $1.25Q_3$

Note: The WSP has to decide on the value of R and Q^3 from the tables above. The higher the R value for the same Q_3 value, the lower the Q_1 and Q_2 values hence the more the accuracy of the meter. But the value of Q_4 remains the same.

Example 1: Let us assume 15mm diameter class B meter (old classification system) is subjected to the new system analysis, taking R=200:

Q3 = Qn = 1.5 m3/h

Therefore, Q1 = Q3/R

Q1 = (1.5 x 1000)/200	= 7.5 lts/h (compare with Qmin = 30 lts/hr – Table 7.3)
Q2 = 1.6 x 7.5	= 12 lts/hr (compare with Qmin = 120 lts/hr)
Q4 = 1.25 x 1.5	= 1.875 m3/hr (compare with Qmin = 3m3/hr)

From the above calculation, choosing Q3 = 1.5 and R = 200 yields a more accurate meter than class B but fairly low maximum flowrate compared to class B.

Example 2: Let us assume that we need a 15mm diameter meter with Q_4 that is similar to Q_{max} of 15mm diameter class B meter i.e., Q_{max} = 3m^3/hr), keeping R=200:

The value of Q_3 must be more than 1.5m^3/hr used in example 1 above. Let us take the next Q^3 value on Table 7.3 = 2.5 m^3/hr

Q_3 = Qn =2.5 m^3/hr

Therefore, $Q_1 = Q_3/R$

Q_1 = (2.5 x 1000)/200 = 12.5 lts/hr (compare with Qmin = 30 lts/hr – Table 7.3)

Q_2 = 1.6 x 12.5	= 20 lts/hr (compare with Q_{min} = 120 lts/hr)
Q_4 = 1.25 x 2.5	= 3.125 m^3/hr (compare with Q_{min} = 3m^3/hr)

From the above calculation, choosing Q_3 = 2.5 and R = 200 yields a more accurate meter than class B but maximum flowrate is equivalent to 15mm diameter class B meter.

The same calculation can be carried out using other values from Table 7.4 and Table 7.5 to come up with other meter sizes, accuracy and capacity including bulk meters.

It is important to note that the two tables do not specify the diameter of the meter and the WSP is free to decide.

However, WSPs should carry out market surveys to find out whether the meter design they have decided on is easily available in the market.

From the examples above, it is clear that it is not easy to compare meters under R-series and Precision system on a table and any confirmation has to be through calculation.

Under the old classification system, class B is the most commonly used meter and its performance is satisfactory under the prevailing conditions.

An equivalent size 15mm diameter meter to class B under R-series is R250 and $Q_3 = 2.5\ m^3/hr$ as shown in example 2 above.

7.1.2 Selection of Customer Water Meters

In selecting customer water meters, it is important to select the meter that is most suitable for the consumption trend of each customer. Considerations to the maximum monthly consumption and maximum flow rate are important for selecting a meter that will assure steady performance for a long period of time.

The following are the criteria to use when selecting meters:

a) Material used in meter construction

Meters are made from brass, copolymer resin, cast iron, electronic, etc. Metallic meters are more prone to theft in Kenya. As a result, some WSPs install copolymer resin meters instead.

Figure 7.2(a): Metallic Type

Figure 7.2(b): copolymer resin meter

Figure 7.2 shows the various types of customer meters. Metallic water meters are better in terms of accuracy and durability, but they are more expensive and prone to theft. On the other hand, copolymer resin water meters are cheaper and have a low vulnerability to theft but relatively less durable.

b) Using consumption data to size customer meters

Undersize meters can cause huge NRW especially when used for customers that consume large volumes of water because of under-registering during low flowrate periods. Proper sizing (or resizing) of meters, especially for large and medium non-domestic customers, is therefore quite important.

In order to correctly size customer meters, typical consumption patterns must be summarized and the monthly maximum and minimum consumption determined.

Table 7.6 is a guide on meter sizing (or resizing)

Table 7.6: Meter Sizing based on Maximum Monthly Consumption that Each Meter Size Can Handle

Meter Size (DN)		Nominal Flow (m^3/hr)	Meter Capacity (m^3/hr)	Maximum Monthly Consumption (m3/connection/month) that Each Meter Size Can Handle for Each Assumed Total Time of Passing Water Listed Below						
				Assumed Total Time Each Customer Takes Water Through Meter (Heavily Intermittent ← Common Intermittent → Continuous)						
inch	mm	ISO: Qn (or OIML: Q_3)	Required Qmax (or Q4)[5]	0.5 hr/ day3	0.75 hr/ day	1 hr/day[2]	1.5 hr/day	2 hr/day	4 hr/day[4]	8 hr/day
1/2	15	1.5 (2.4)	3 (3.125)	45	68	90	135	180	360	720
3/4	20	2.5 (4)	5 (5)	75	113	150	225	300	600	1,200
1	25	3.5 (6.3)	7 (7.875)	105	158	210	315	420	840	1,680
1.25	32	6 (10)	12 (12.5)	180	270	360	540	720	1,440	2,880
1.5	40	10 (16)	20 (20)	300	450	600	900	1,200	2,400	4,800
2 (m)1	50	15 (25)	30 (31.25)	450	675	900	1,350	1,800	3,600	7,200
2 (u)	50	25 (40)	50 (50)	750	1,125	1,500	2,250	3,000	6,000	12,000
3 (m,u)	80	40 (63)	80 (78.75)	1,200	1,800	2,400	3,600	4,800	9,600	19,200
4 (m,u)	100	60 (100)	120 (125)	1,800	2,700	3,600	5,400	7,200	14,400	28,800
6 (m,u)	150	150 (250)	300 (312.5)	4,500	6,750	9,000	13,500	18,000	36,000	72,000
8 (m,u)	200	250 (400)	500 (500)	7,500	11,250	15,000	22,500	30,000	60,000	120,000

Notes 1: The values for meter size 2-inch (50mm) and larger are for flanged mechanical (m) bulk meters (specifically Woltmann type) and ultrasonic (u) bulk meters.

Note 2: 1 hr/day is recommended as the period a non-domestic customer takes water under intermittent (rationing) water conditions that is common in Kenya. During this period, non-domestic customers refill their water receiving tanks within a limited time when water becomes available after the daily rationing period. Since meter size 0.5 inch (15mm) is sufficient for almost all domestic customers, this table is not very relevant for sizing domestic customers' meters. However, 1 hr/day can also be recommended for domestic customers if the following daily water use is assumed: showering 5 persons x 5 mins, cistern flashing 5 persons x 3 mins, dishwashing 2 times x 5 mins, laundry and cleaning 10 mins (i.e., total = 1 hour/day).

Note 3: 0.5 hr/day may be applied for non-domestic customers under water rationing conditions such as getting water for a limited time every two days; hence, they have to fill their water tanks quickly within a very limited time every two days before the supply to their area ends.

Note 4: 4 hours/day may be applied for non-domestic customers under continuous water supply conditions in which they may take water from the distribution network for 4 hrs/day (i.e., half of 8hrs, the common business operating hours).

Note 5: If a high-performance meter capable of measuring higher than the standard value of Qmax is used, then meter sizing should be based on the actual Qmax. E.g., the Qmax of electromagnetic flowmeters can be much higher than the standard values shown in the table, hence calculate the maximum monthly consumption which the meter can handle based on the actual Qmax of such a meter (i.e., maximum monthly consumption the meter can handle (m3/month) = Actual Qmax (m3/hr) x hours of taking water (hr/day) x 30 (days/month)).

- Firstly, assume or estimate the number of hours in a day a customer would take water through the meter, and
- The amount of water each customer will consume per month based on experience and data obtained from the same or similar areas.
- From Table 7.6, determine the appropriate meter size for the assumed monthly consumption and hours of taking water.

Intermittent (rationing) water supply is predominant in most WSPs in Kenya. Therefore, to select the required meter size for each customer, it is recommended to assume that the total duration a customer takes water through the meter over a 24hr period as 1 hour/day as explained in Note 2.

Most normal domestic customers consume below 30m3/month. From the table, meter size ½" (15mm) can handle upto 90m3/month hence it's quite adequate.

Therefore, domestic customers should mostly be installed with meter size ½" (15mm).

Table 7.6 is therefore useful when sizing meters for medium and large customers.

c) Smart Metering

Meters can be upgraded by incorporating an automatic meter reading (AMR) device (that reads and stores data in memory card) onto any mechanical or other meter. The meter then becomes "smart".

The data can be retrieved by use of a data cable onto a computer or by a data communication module

Communication with the meter (to retrieve data or issue command) can be done using any kind of protocol such as GSM/GPRS mobile phone network (most common).

AnAMR is the technology of automatically collecting consumption, diagnostic, and status data from water (or electric, etc) meter and transferring that data to a central database for billing, troubleshooting, and analysing. This technology mainly saves a utility the expense of periodic trips to each physical location to read a meter.

Another advantage is that billing can be based on near real-time consumption rather than on estimates (based on past or predicted consumption). This timely information coupled with analysis can help both the WSP and customers control water consumption better.

AMR technologies include handheld, mobile and network technologies based on telephony platforms (wired and wireless), radio frequency (RF), or powerline transmission.

Figure 7.3 is a diagram of an AMR system. However, due to the specialized nature of the system, these guidelines cannot go into details and other suitable source of information is advised.

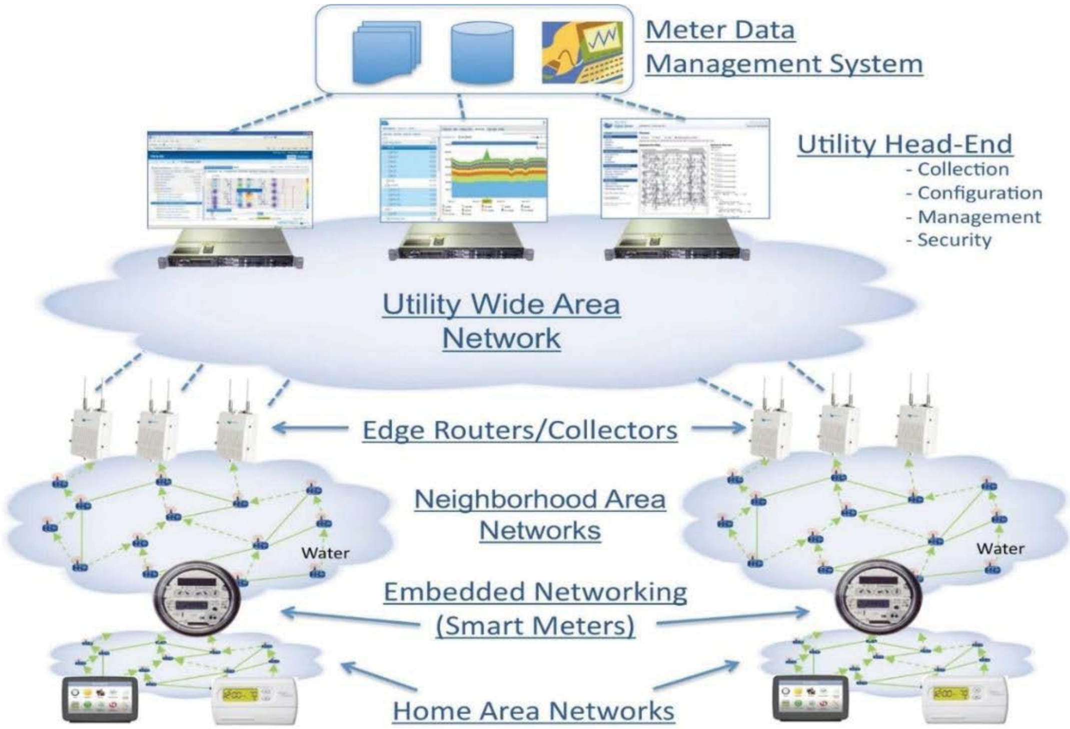


Figure 7.3: Typical AMR (Smart meter reading) system

7.1.3 Metering Objectives and Installation Site Considerations

Selecting the right meter requires identifying and addressing the considerations that may be unique to each metering objective and installation conditions as below:

a) Metering Objective

A meter needs to address objectives such as:

- Operational improvements – e.g., install smart meters to curb meter tampering
- Support water management initiatives and goals - e.g., billing and water bill verification from unmetered connections
- Water conservation programs and goals - metered data required to monitor consumption and costs review

b) Installation Site Consideration

- Determine the expected range of water flow and pipe size
- Determine the accuracy requirements over the flow range
- Identify any physical installation requirements for meter location, straight length of pipe, available communications (access road)
- Consider standardization on communication between meters and other data acquisition systems
- Determine how the data will be collected and processed
- Select and install the meter.

7.2 Meter Accuracy Test

7.2.1 Program of tests applicable to all water meters

All meters should undergo the following program of tests. Meters that pass this program should be considered safe to use.

Meter Test Programme

a)	Static pressure	e)	Flow reversal
b)	Error of indication	f)	Pressure loss
c)	Water temperature	g)	Discontinuous flow durability
d)	Water pressure	h)	Continuous flow durability

a) Static Pressure Test

Maximum permissible pressure is desirable to be 1.0 MPa including verification that there are no leakages.

b) Error of Indication Test

Error of indication should be used to determine meter accuracy. Although this is a program, each individual test must be thoroughly understood independently. Error of Indication test will be revisited with Meter Accuracy Test.

To test the relative error, the fundamental requirement is to maintain pressure constant. The tolerable range of pressure oscillation depends on the test method, but it should be maintained in the range of ±2.5%～±5.0%. To test the relative error in a specific meter, test of intrinsic errors is conducted with 7 points of flows and the measurement is conducted twice.

c) Water Temperature Test

Under standard conditions, the standard temperature is 20°C, and the test is conducted under 30°C.

d) Water Pressure Test

Minimum permissible pressure must be 0.03 MPa (0.3 bar) while the maximum permissible pressure must be at least 1 MPa (10 bar), except for meters of DN ≥ 500, where the maximum admissible pressure shall be at least 0.6 MPa (6 bar) (refer BS EN ISO 4064-1:2014).

e) Flow Reversal Test

The tolerance for this test is the same as the tolerance for normal flow.

f) Pressure Loss Test

Pressure loss within flow range from Q_{min} to Q_n should not exceed 0.063 MPa.

g) Discontinuous Flow Durability Test

This is the number of interruptions created in 100,000 with 15 seconds intervals.

h) Continuous Flow Durability Test

There may be variances in duration of durability test depending on the volume of maximum flow; however, the standard for 15 mm diameter meter is 100 hours.

7.2.2 Meter Accuracy Test

a) Relative error

Relative error occurs when volume of water measured by meters compared with the real volume of water shows excess or less volume. As the ISO Standard, relative error could be represented in percentage calculated as follows:

$$\text{Relative error E (\%)} = \frac{I - Q}{Q} \times 100$$

Where:

I: Indicated volume

Q: Real volume

b) Sensible water curve and relative error

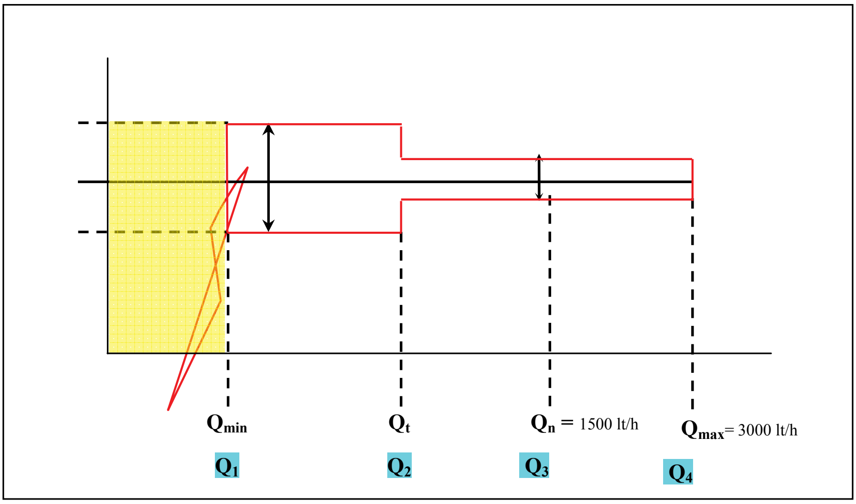


Figure 7.4: Curve of Relative Error in 15mm-dia Class C Meters

Where:

QminorQ$_1$	= Minimum flow
QtorQ$_2$	= Transitional flow
QnorQ$_3$	= Normal/Permanent flow
QmaxorQ$_4$	= Maximum/Overload flow

Metrological Requirements of Water Meter Classification

Before conducting a meter test, it is important to understand class specifications of each meter. Under the old classification (Class A, B, C and D) flowrates are denoted as Minimum flow (Q_{min}), Transition flow (Q_t), Normal or Permanent flow (Q_n) and Maximum or Overload flow (Qmax) (Section 7.1.2(d)). Q_n and Q_{max} are marked on the meter. Q_{min} and Q_t are normally derived from characteristic performance curves of the meter.

In the latest standards, ISO 4064:2014 and OIML R49:2013, a new system based on the Reynard (R-series) was established. Minimum flow (Q_1), Transition flow (Q_2), Normal or Permanent flow (Q3) and Maximum or Overload flow (Q4) (Section 7.1.2(e)). A number called Reynard, R (= Q_3/Q_1) together with Q_3 are marked on the meter. $Q_2 = 1.6Q_1$ while $Q_4 = 1.25Q_3$.

Figure 7.5: Water meter test bench

Approximately 10% of all water meters in a target area should be randomly selected for meter testing. The selected water meters should be categorized by class. Meters in Q_{min} (Q_1) to Q_t (Q_2) flow range must operate within 5% of specified tolerance. Meters in Q_t (Q_2) to Q_n (Q_3) to Qmax (Q_4) flow range must operate within 2% of specified tolerance.

c) Meter Class

Based on ISO 4064:2005 and OMIL R49:2003, water meters can be divided into four classes: A, B, C and D. Each class sets a range of flow rates within which the meter must maintain its accuracy. A is the narrowest, D is the widest. Each meter can be considered perfect in the range of flow rates for which it is designed.

However, in the latest standards, ISO 4064:2014 and OIML R49:2013, a new system based on the Reynard series was established. The Reynard number R, is determined by the ratio between permanent flow (Q3) and minimum flow rate (Q1).

7.3 Servicing and Replacement of Customer Meters

7.3.1 Meter Maintenance

Maintenance of water meters involves making sure that meters maintain accuracy and being ready to replace meters at all times.

a) Meter Maintenance for Accuracy

In order to maintain meter accuracy, the following must be done:

i) Analyse actual consumption based on data obtained from meter readings on a monthly basis

ii) Conduct surveys to keep track of actual consumption rates

iii) Replace meters based on planned replacement schedule

b) Management of Meter Installation

Meter installation should be managed by the following:

i) Ensure that meter boxes are not buried in sand or mud

ii) Ensure that meters are installed horizontally

iii) Check that there are no leakages around meters

iv) Check that quality certification is properly affixed on the meter

7.3.2 Expired Water Meters

Expiry date of water meters is established in accordance with the weights and measures Law. For example, in Japan, water meters expire eight (8) years from the date of installation. Expiry of meters is not regulated in Kenya. It is therefore recommended that WSPs start documenting the lifespan of the various meter models and use this data for future decision-making not only in meter expiry period but also during procurement.

7.3.3 Replacement of Defective Meters

In developed countries, customer meters are required, by law, to be replaced periodically (in Japan, customer meters must be replaced with new meters every eight (8) years whether the meter is malfunctioning or not).

Replacement of meters is not regulated by law in developing countries. Furthermore, low quality meters, cheap new meters and even used meters are sold in the market. Cases of recycled meters being installed as replacements is not uncommon.

Customer meters are the most important element for any utility; therefore, it is important to install customer meters that will give high performance and a long life. Using cheap and inferior new meters may seem economical. However, in the long run it will prove to be costly as it will not last long and accuracy is compromised.

Before replacement of defective meters, a "Notification for Replacement of Expired Water Meter", and "Schedule for Replacement of Expired Water Meters" must be issued to the client whose meter is due for replacement. The schedule for meter replacements must be formulated by the relevant department in the utility and the meter replacements must be conducted in accordance with this schedule.

7.4 Improvement of Meter Reading and Billing System

1) A robust computerized meter reading/billing system with high data handling and reporting capabilities should be used for identifying stalled meters and possible illegal water uses (based on its abnormality reports) as well as for improving work efficiency and reducing data handling errors.

2) Updating and cleaning of customer data register in meter reading and billing system should be done (e.g., registration of illegal/unbilled water users identified through CIS and cleaning of previous customers having outstanding balances).

3) Hand-held meter reading devices (e.g., smartphones with meter reading software program linked to meter reading/billing system) should be used to improve meter reading accuracy and reduce data handing errors.

4) Rotation of meter readers' routes (e.g., every 6 months) should be effectively done to reduce corruption and inaccurate meter reading.

5) Spot check of meter readings (e.g., by meter reading supervisor) and systematic validation of meter readings (e.g., automatically by a software system or manually by system operators) should be effectively done to improve meter reading accuracy.

6) The accuracy of estimated customer consumption (when required) should be improved by estimating based on reliable past consumption in order to reduce NRW resulting from improper estimation.

7) Warning and disciplinary action on staff who intentionally continue submitting wrong meter readings or unjustifiable underestimation of consumption should be exercised in order to reduce staff involvement in wrongdoing.

7.5 Improvement of Billing Software Utilization

7.5.1 Sorting Billing Anomalies on the Basis of Consumption

Most of the very large and large WSPs use sophisticated meter reading and billing software (e.g., Majics, ERP) which have meter-related anomalies reports. Nevertheless, many WSPs have too many stalled meters to handle in one month. This results to the anomalies report on stalled meters not being resolved on the basis of the billed (including estimated) consumption. This therefore causes difficulties in prioritizing the stalled meters of large (e.g., ≧ 100 m3/month) and medium (e.g., ≧ 20 m3/month) customers for meter servicing and replacement.

In such cases, the billing system administrator should, each month, export the billing data of each customer (including anomalies, billed consumption and billed amount in Ksh) to MS Excel (through .csv files) for the NRW Unit/Section to prioritize large and medium customers for meter servicing and replacement. These data (together with customers' contact information and their coordinates) may be extracted directly from the billing system by using free relational database management software such as MySQL and PostgreSQL for quick action. This simple improvement can make a huge reduction in NRW and a drastically revenue increase.

7.5.2 Rules for Estimating Consumption

In cases of meter stops, a policy for estimating consumption should be formulated and applied (e.g., average of the last three properly measured monthly consumption). Such a policy is not well formulated in the billing systems and many WSPs are forced to estimate manually. Manual estimation tends to underestimate consumption, resulting in huge revenue losses. Therefore, the automatic (billing system) and manual (billing clerk) estimates should be carefully reviewed as part of NRW reduction efforts.

The meter-related anomalies (e.g., meter reversing or meter tampering) reported by meter readers are quite useful to reduce metering errors and eliminate illegal water use. However, resolving anomalies of the active customers is not enough to effectively reduce illegal water use. Illegal water use often happens when disconnected customers illegally reconnect. Therefore, checking disconnected customers (by regularly reading their meters and investigating for possible illegal connections) is important.

However, the status of each customer connection (e.g., active, disconnected, terminated, etc.) in the billing system is often outdated, which make it very difficult for the NRW Unit/Section to detect suspicious customers who may have illegally reconnected. To reduce illegal water-use by disconnected customers, the connection status of each customer should be updated every month in the billing system.

7.5.3 Other problems

Other NRW-related problems observed in WSPs' billing systems are:

- Mis-categorization of non-domestic customers as domestic customers. These are the most serious issues because incorrect use of domestic water tariff by non-domestic customers reduces the revenue substantially.
- Miscalculation of total billed consumption,
- Errors in entering customer account numbers in the billing system,
- Outdated meter reading routes (or walk numbers) of some customers, etc.

7.6 Internal Improvements against Illegal Water Use

1) WSP's policies against illegal water use (e.g., heavy penalties) should be well incorporated in the county water act and/or supported by the county government.
2) Enhancement of law enforcement against water theft should be well supported on the ground by the county.
3) Effective legal procedures including settlement with illegal water users should be well established with strong support from the management.
4) Each occurrence of illegal water use should be quantified through a well-defined and documented formula (e.g., period water illegally used x typical flow (including analysis of the number and scale of illegal water uses)) or other transparent method for imposing illegal water use charge including a substantially deterrent penalty.
5) Prevention measures against involvement of WSP staff (e.g., plumbers and meter readers involved in illegal connections, meter bypass, meter tampering, etc) should be well established through better materials, stock management, interrogation of illegal users on their accomplices, etc.
6) Incentives for whistle blowers to report illegal use and vandalism to the water supply facilities should be well established.

Chapter 8

Reduction of Physical (Real) Water Losses

8.1 Components of Physical Losses

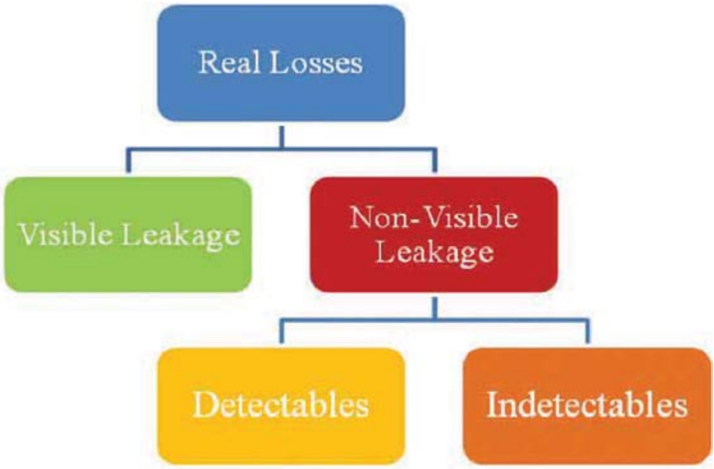


Figure 8.1: Component of Physical Losses

Physical Losses can be divided into visible leakage (surface leakage) and invisible leakage (underground leakage). Surface leakages occur in areas with high water pressure, whereas underground leakage occur in areas with low water pressure and therefore difficult to detect. In general, more leakages occur in service pipes compared to distribution pipes.

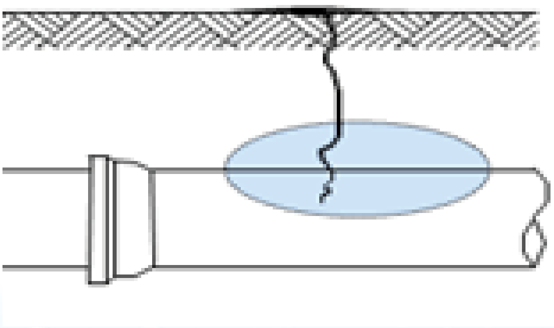


Figure 8.2: Visible Leakage (Surface leakage)

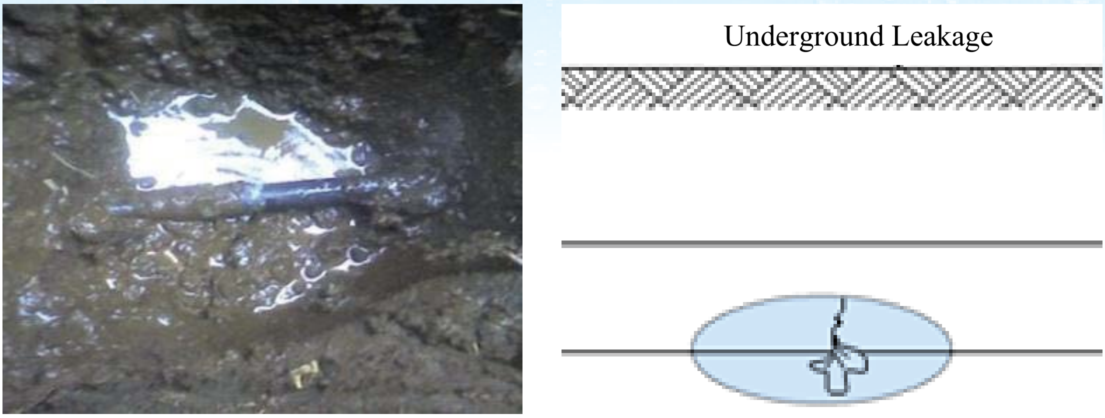


Figure 8.3: Underground (Invisible) Leakage

Generally, a leakage starts off as a small leak that develops into a medium then to a large leak as time passes. Small leaks may remain undetected underground for a long time. In cases of medium size leaks, some may stay undetected, but others will surface to the ground. Most large size leaks are detected on the surface within a few days of the leak appearing up to several months. Some leaks may remain underground for years or forever. This all depends on the surrounding conditions of the laid pipes such as the condition or type of soil, presence of underground structures, and pipe material.

Repairing surface leakages alone cannot reduce NRW ratio when the ratio is less than 30%. In order to decrease this ratio, underground leakages must be detected and repaired. Underground leakages can go without repair since they are difficult to detect, and underground leakages often overwhelmingly exceed the number of surface leakages by more than ten times.

Thicker pavements on roads usually indicate a higher ground water level, which indicates lower water pressure in the buried pipes. Detection of underground leakages become more difficult as depth of buried pipes increases.

When leakages occur, extending the area of repair around the point of leakage will decrease recurring leakages around the same area. Planning for replacement of pipes must take into consideration the number of leakage repairs in the pipe and the age of pipes.

8.2 Main Causes of Physical Losses

Leaks can occur anywhere in the pipeline due to various factors such as age of pipes and traffic loads on the road. Table 8.1 shows the factors that can cause leakages (physical losses).

Table 8.1: Main Causes of Physical Losses

Causes of Physical Losses	
Factors	**Causes**
Poor quality of pipe material and accessories (fittings)	• Material and/or mechanical defects • Lack of corrosion resistance • Age and/or deterioration • Galvanic corrosion
Technicality in pipe laying or poor workmanship.	• Design errors • Poor jointing of pipes • Inappropriate backfilling • Contact with other structural objects • Defective corrosion protection methods
Poor Conditions	• Unsuitable water pressure (usually high pressure) • Water Hammer • Water quality (internal corrosion)
Environment of underground pipes	• Increase in traffic loads • Corrosive soils such as marine clay • Ground subsidence caused by excessive pumping etc. • Effects of other construction works
Human interference	• Vandalism • Construction works, e.g., roadworks

8.3 Reduction Measures for Physical Losses

Table 8.2 shows measures to reduce physical losses.

Table 8.2 Reduction Measures for Physical Losses

Measures		Activities
Pipe Work	Pipe Mapping	• Development of accurate pipeline drawing (Refer to Chapter 4)
	Zoning	• Determination of DMA or measurement blocks • Isolation of measurement blocks (Refer to Chapter 5)
	Taking Measurements	• Understanding leakage volume in measurement blocks by measuring MNF and implementing Step-Test (Refer to Chapter 8)
	Leak Detection	• Detection of leakages by using leak detector (Refer to Chapter 9)
	Leak Repair & appurtenance maintenance	• Adoption of optimum leakage repair method and good quality materials • Adoption of appurtenance maintenance scheduling

Measures		Activities
Pipe Replacement	Planning	• Preparation of pipe replacement plan based on statistical analysis of the Pipeline network. • Determine correct pipe type and pipe diameter
	Implementation	• Implementation of pipe replacement
Water Pressure Control	Pressure equalization (Refer to Chapter 10)	• Zoning of distribution network • Installation of PRVs • Installation of Flow Meters and Pressure gauges
	Setting up Pressure Control facilities	• Construction of distribution reservoirs and/or pumping station
	Pressure Control at pumping station	• Pressure control by proper pump sizing

8.4 Quantifying Physical Losses

8.4.1 General

In order to control leakages, it is a basic requirement for WSPs to know the existing leakage volume of the target leak survey area. Based on the existing leakage volume, the most appropriate and effective pipeline maintenance strategy can be established. At the same time, leak survey blocks can be selected; best maintenance methods can be determined whether it be simply repairing of pipes or total replacement of pipes and overall improved effective control of leakages can be implemented.

Leakage volume can be measured by the following methods: -

a) Estimation Method, by collecting leakage volume at the actual leakage point

b) Direct Measurement Method

c) Minimum Night Flow (MNF) Measurement

8.4.2 Estimation Method by collecting leakage volume at the actual leakage point

Leakage volume per minute can be established by measuring the actual leakage at the leakage point. By multiplying this value by the number of leakage points, the leakage volume of the target area can be estimated as follows:

Total annual volume of leakage = Number of reported bursts x Average leak flow rate x Average leak duration from mains

If no detailed data is available, utility managers can use approximate flow rates from Table 8.3 below.

Table 8.3: Approximate Flow Rates of Leakages/Bursts

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

Source: IWA Water Loss Task Force

Utility managers can then add estimates for background losses and excess losses (current undetected leaks). Background losses are individual events (i.e., small leaks and weeping joints) that flow at rates too low for detection by an active leak detection survey. They are finally detected either by chance or after they have worsened to the point that only an active leak detection survey can discover them. Table 8.4 shows background losses from various components of the network with average infrastructure condition.

Table 8.4: Calculating Background Losses

Location of Bursts	**Litres**	**Unit of measurement**
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 connection 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

Leakage measurement is shown in Figure 8.4

Figure 8.4: Measurement at Actual Leakage Point

8.4.3 Direct Measurement (DM) Method

To measure leakage using the Direct Measurement Method, a measuring block consisting of approximately 3 to 5 km of distribution pipes and/or 100 to 500 customer meters needs to be selected. All peripheral valves in the measuring block as well as all customer valves must be closed. The flow rate into the measuring block is then measured at one point. It is preferable to conduct this method after midnight to avoid inconveniencing customers.

This method is time consuming and requires manpower and this makes it unpopular among WSPs.

Figure 8.5: Close all peripheral valves of the block and all the customer valves completely

Figure 8.6: Measure the flow volume into the block

8.4.4 Minimum Night Flow Measurement Method

Figure 8.7 shows a typical Water Demand Characteristic Curve. Water demand varies with respect to the time of day. Diurnal peaks typically occur in the morning and in the early evening, while lowest water usage occurs during night hours.

By studying the Minimum Flow of this diagram, it is possible to estimate the volume of water leakage.

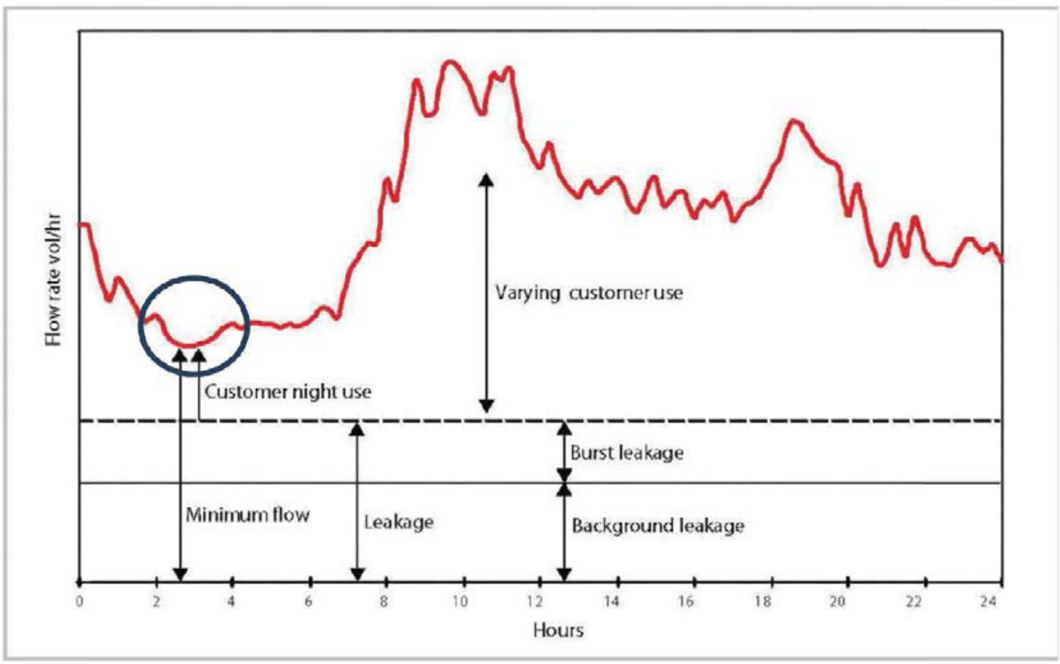


Figure 8.7: Typical Water Demand Characteristic Curve

MNF measurement method in NRW Management refers to a method of estimating the volume of leakage within a target area or a pilot area by accurately measuring the Minimum Night Flow (MNF). In a pilot area, MNF normally occurs between 1:00 am and 4:00 am. It is only necessary to accurately measure the volume of water flow during this particular time period. When mechanical flow meters are used for measuring, it is better to have shorter measuring periods, for example 10 minutes. The results of the reading should be put on a graph and the lowest point on the graph is the MNF. This method of measuring the volume of water flow does not require closing the customer meter valves. Therefore, there is no interruption of the water supply. Using an electro-magnetic flow meter or an ultrasonic flow meter can increase the accuracy of the readings. When implementing the MNF measurement, it is important to have the target area or the pilot area perfectly isolated from the adjoining areas. In general, the adequate size of a leak survey is considered to be 700 to 1,500 households, or 2,100 to 5,000 persons.

Based on the results obtained from the MNF Measurement, NRW Reduction measures should be implemented. Measurement “Before” and “After” the implementation of measures should be recorded to understand the effectiveness of the measures applied.

8.5 Reduction of Visible Leaks by Active Patrolling and Quick Quality Repair

1) Overflow from water retaining facilities such as distribution tanks/reservoirs and break-pressure tanks (BPT) should be reduced; e.g., by:

i) improving the operation of transmission pumps

ii) detecting whether tanks/reservoirs are leaking by observing water-level-gauge for 24 hours with closed inlet and outlet valves after filling up the reservoir,

iii) preventing tampering of BPTs/tanks float valves by locking lids with tamper-proof keys and regularly maintaining the valves, etc.

2) Active patrolling along pipelines should be adequately done for early detection of visible (surface) leaks from sluice valve, air valve, hydrant, wash-outs, exposed and buried pipes; and storage tanks/BPTs, etc; and water theft including illegal connections. (These patrols may simultaneously cover other aspects irrelevant to NRW such as sewage overflow and water quality problems to improve overall work efficiency of the WSP)

3) Customers should be advised well to stop overflows from their water tanks and visible leakage from the part of service pipes after customer meters to save water as WSP staff are patrolling along pipelines or working around customer meters.

4) The speed and quality of burst and leak repairs should be improved (e.g., by adopting optimum leakage repair methods, using cloud-based/online workflow/task management system, etc)

5) Reports of bursts and visible leaks from the public and all WSP staff should be well registered and responded to without failure through improvement and utilization of relevant ICT system (e.g., WASREB's MajiVoice, WSP's customer care system, supervisors, etc).

6) Detailed records of bursts and leaks including GPS coordinates, pipe diameter, material, type and cause of burst/leak, amount of water loss, date of detection, time taken for repair, etc should be accumulated (e.g., by using free data collection software such as Kobo Toolbox/Collect) to analyse them later with tables, graphs and GIS.

8.6 Daily Use of Low-Cost Listening Sticks and Hand Pumps for Leak Detection

1) Listening sticks (also called sounding bars) should be used daily and extensively (by field staff in charge of initial installation, customer meter servicing and replacement staff, NRW task team, meter readers, etc) at and around customer meters to detect abnormal sound of invisible leakage (and/or illegal connections). Electrical leak detection equipment may be used to confirm the existence and location of suspected leaks and illegal connections.

2) Listening sticks should be used daily (by O&M staff) at appurtenances on transmission and distribution pipelines (to detect abnormal sound hinting at

invisible leakage from valves and hydrants, to locate buried valves and, to check water tightness of valves). Electrical leak detection equipment may be used to confirm the existence and location of suspected leaks.

3) Listening sticks should be used (e.g., by the staff in charge of disconnection and reconnection of customers) when investigating potential illegal water use at disconnected customers

   Note:

   - A listening stick can be used to check whether there is water flow for customer meters that have zero consumption on previously disconnected service pipes. The flow can then be investigated as to whether it is due to completely stopped faulty meters or not and whether the disconnected connection is illegally self-reconnected or not.
   - Illegally self-reconnected customers with stopped meters cause large amounts of illegal water use without being noticed for a long time.
   - Unsuccessful disconnections with faulty gate valves or stopcocks that do not close fully and stopped meters cause large commercial water losses without being noticed and for long periods.

4) Listening sticks should be used to detect leaks where new distribution pipelines of relatively small diameter are tested under pressure with hand pumps during installation to confirm non-existence of leaks from the pipelines

5) Larger pipelines including transmission lines should be tested at installation probably by the contractor with a powered pump.

6) The data collected should be analysed and remedial measures taken to prevent future recurrence.

8.7 Introduction of Quality Materials, Adequate Valves, and Small-Scale Pipe Replacement

1) Adequate sluice valves (AVK type or equivalent, but not brass gate valves which are commonly used and that are prone to leakage) should be installed on transmission and distribution pipelines and kept accessible and operational to:

   i) limit the volume of water losses, e.g., when draining the pipelines for burst and leak repairs which often require suspension of water supply,

   ii) limit the areas affected by the intermittent water supply, and

   iii) evenly distribute water to different areas especially under intermittent water supply conditions

2) Good quality pipe materials (e.g., HDPE pipes) effective in preventing leakage and illegal connections and should be used for installation of:

   i) new transmission and distribution pipelines, and

   ii) new service connections

   (Note: pipes and fittings; and customer meters for new connections should be provided by the WSP to customers at a fee for better quality control of service connections.

3) The few parts of transmission or distribution pipelines with frequent bursts and heavy leaks (e.g., heavily deteriorated GI pipes or low pressure-rated PVC pipes that are under high pressure, etc) that are assessed to be very difficult to stop, should be replaced selectively with good pipes.

4) Spaghetti service connections causing leakage should be replaced with branch/ tertiary distribution pipelines and shorter service pipes.

5) Old leaking pipelines that are aligned parallel with better pipelines with adequate capacity should be removed or completely closed.

6) Existing problematic pipelines passing through road-side vegetation, along watercourses, etc. should be relocated to road reserves to make the patrollers' work of detecting leaks and illegal use easier.

8.8 Large-scale Replacement of Deteriorated Pipelines and Service Connections

The procedure below is only for WSPs which would consider large-scale replacement of deteriorated pipes

1) Ensure that the types and sizes of problematic pipelines requiring replacement (e.g., asbestos cement pipes, old galvanized iron (GI) pipes, cast iron and steel pipes with corrosion holes or rust incrustation significantly blocking flow, pipes with low pressure rating (e.g., PN 7.5) in high pressure areas); or rehabilitations (e.g., relining) are analysed (preferably with GIS) based on available data (e.g., installation year of each pipeline and records of past bursts and leaks).

2) Ensure that the necessity and priority of large-scale replacement/rehabilitation of transmission, distribution and/or service pipes (and rehabilitation of leaking tanks, etc.) are discussed well among relevant staff and managers based on results from the above analysis before planning.

3) Ensure that large-scale replacement/rehabilitation of problematic pipes and appurtenances, leaking tanks, etc. are planned (including rough cost estimates) from long-term financial and technical prospects (such as expected reduction in NRW, increase in revenue, and future water demand increase).

4) Ensure that planned large-scale replacement/rehabilitation of problematic pipelines are incorporated into the latest strategic plan (partly for seeking external funds) and/or into the tariff adjustment application of WASREB with required budgetary provision.

5) Ensure that design, bill of quantities, detailed engineer's cost estimates and tender documents for the planned replacement/rehabilitation are prepared for bidding.

6) Ensure that the planned replacement/rehabilitation are implemented soonest or as funds permit.

8.9 Standardization of Pipe and Jointing Materials

a) Leakages still occur even when distribution and service pipes are all replaced, if excavation, pipe laying and construction workmanship are poor.

b) The Importance of a site manager and his/her supervisory role in construction work is often ignored leading to sub-standard pipe-work.

c) Leakages often occur at pipe joints, especially on service pipes, and many pipe breakage incidents occur due to shallow pipedepth.

d) Leakages also occur immediately the pipes are replaced if the construction work is poor. This is ineffective use of resources.

e) Customers should not be connected directly onto the transmission line, neither should they be allowed to provide their own materials, all materials should be procured by the WSP.

This section focuses on construction management and methods of pipe connection, particularly for sub-mains (PVC and HDPE pipes).

8.9.1 Standardization of Pipe and Jointing Materials

The most important issue in Kenya is adoption and consistent use of standards for materials and construction methods. Use of uPVC couplings and bends that are fabricated through heating on fire for pipe repairs and connections is common in Kenya. This is due to lack of knowledge and proper training on pipes and other materials standards, and good construction practices. It is also due to lack of collaboration with manufacturers to ensure quality control.

Kenya uses both inches and millimetres and, in addition, ISO standards in pipe specification in manufacturing. This leads to variations in thickness and external diameter of pipes and fittings; thereby requiring adjustments to fit them on site if from different manufacturers. There are also informal fabricators (Jua Kali sector) which manufacture pipe fittings without following any standard. Therefore, regardless of the construction quality, problem with water tightness still occurs.

WASREB should establish standards targeting improvement in the quality (both materials, manufacturing process and dimensions) of pipes and fittings.

Figure 8.8: Making Fire Coupling (used for pipe connections in Kenya)

Figure 8.9: Degradation of pipe caused by excessive heat on the UPVC pipe.

Figure 8.10: Plastic Pipe Bend (used for pipe connections in Kenya)

Figure 8.11: Checking Pipe diameter Internal and External using vernier calliper

Figure 8.12: Using Ultrasonic Thickness Gauge to determine Pipe thickness

Figure 8.13: Socket of pipe connection

Figure 8.14: ISO Standard Pipe Couplings（Meru WSP)

8.10 Inspection of Pipe-Work

8.10.1 Inspection of Pipe-Work

Leakages continue to occur if the quality of construction is poor. Construction management is vital to ensure good quality construction that prevent occurrence of many leakages. In cases where construction work is done in-house, the utility must ensure that the construction team is well trained in terms of quality. In cases where construction work needs to be outsourced, the WSP must effectively supervise the construction work to ensure quality work.

The following are some important quality standards:

(1) Pipe laying

- Pipe depth (top of pipe) should be more than the standards (0.3m)
- Pipe laying at the site should conform to the applicable design.
- There should be no cross connection
- Necessary and adequate pipe protection (thrust blocks, anchor blocks, etc) should be installed. The protection-pipe method should be confirmed with the design.
- Pipes should be appropriately jointed and laid?
- Distribution pipes should not be connected directly to rising mains since it introduces water hammer pressure in the pipes thereby weakening the pipelines. It is also difficult to control the pressure without special pumps.
- The pipes should satisfy the material and structural standards of installation.

(2) Equipment (e.g., customer meter, sluice valve, etc)

- The equipment should satisfy the material and structural standards of installation.
- The equipment should be appropriately jointed.
- Chambers or meter boxes should satisfy the material and structural standards of construction.

(3) Water pressure

- There should be no leakage from joints; or any other defects seen at the standard test pressure.

(4) Area Around Water meter

- Water meters should be appropriately installed without any obstruction to its reading and replacement.
- Chambers with lockable covers and strainers should be appropriately installed.
- Appropriate preparation for meter installation like ensuring proper meter spacing should be done.

(5) Others

- Line markers for pipelines should be installed.
- Confirmation of whether installation is good or not (in case of direct connection of service line)
- Valves and other appurtenances should be appropriately installed.

8.10.2 Example of Supervision and Inspection of Construction Work

a) General

The following are some of the key elements in inspection of Pipe-work:

i) Trenching to the required depths

ii) Suitable material (e.g., sand or murram) for bedding before pipe laying
iii) Pipe connections (joints), supporting and anchoring
iv) Backfilling and compaction as required in construction works
v) Water pressure test
vi) Record keeping with photographs (for evidence)

As an example, the key elements and extent/level of inspection work in Japan are explained in below.

b) Backfilling

The following should be ensured:

- Pipe depth (top of pipe) is more than 0.3m
- Good quality sand for bedding and, where necessary, backfilling around the pipe.
- Compaction is done in accordance with construction work standards

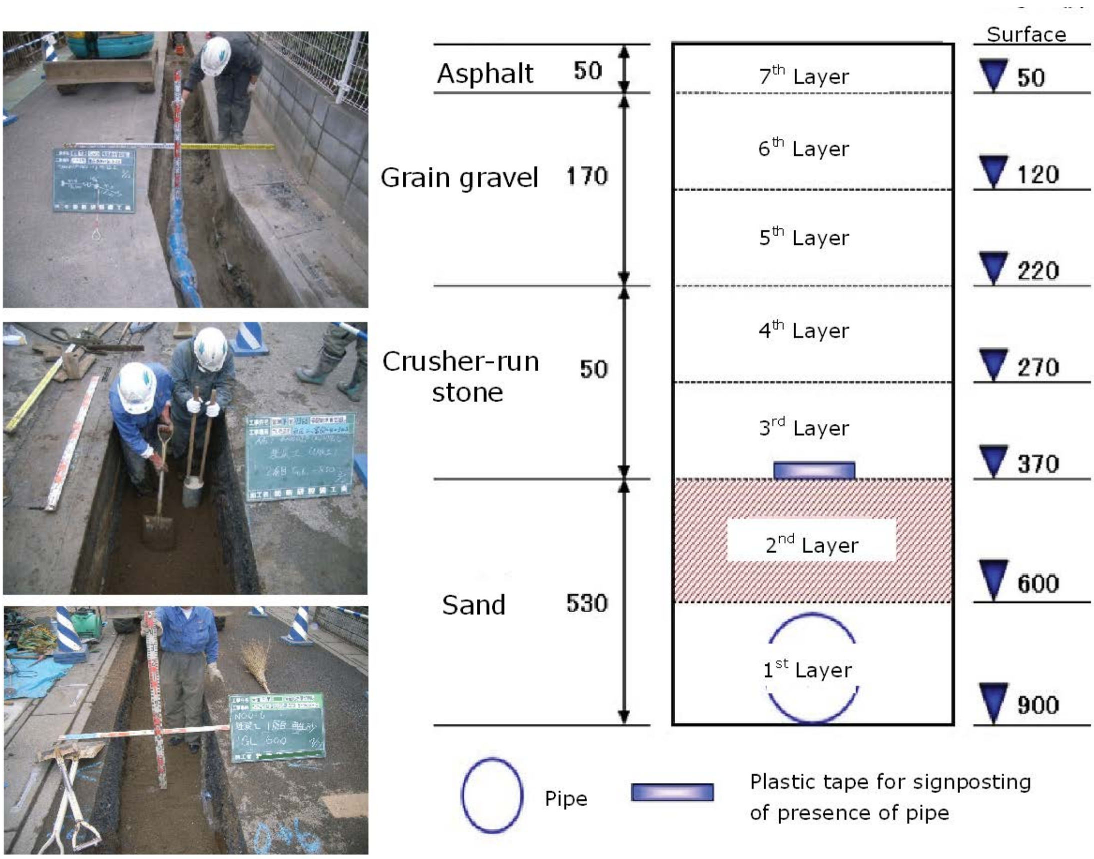


Figure 8.15: Backfilling work of pipe (Japanese Case)

c) Connections (Joints)

Enough length of pipe jointing is necessary for effective jointing.

Figure 8.16: Connection work of Pipe (Japanese Case)

d) Water Pressure Test

Water Pressure Test must always be done after the construction work to confirm that there are no leakages.

During Water Pressure Tests, water pressure in the pipe should be increased up to 1.5 times the normal working pressure of the pipe.

Figure 8.17 Water Pressure Test

e) Record keeping with photograph

Photographs should always be taken at leakage repair site and replacement of service and distribution pipes. Records must be immediately mapped and reflected in a water ledger as below.

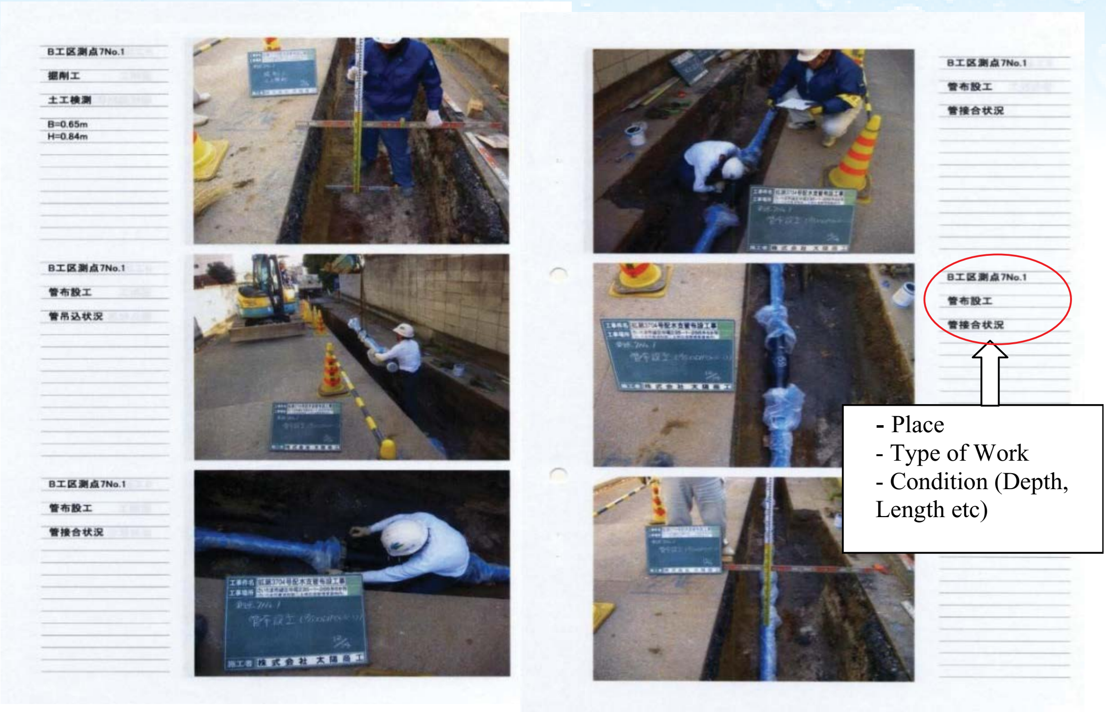


Figure 8.18: Water Ledger for Recording after Construction Work (Japan)

Chapter 9

Leak Detection and Pipe Replacement

9.1 Strategic Approach to Underground Leak Detection

1) Priority areas (e.g., DZs and DMAs) of ongoing or future underground leak detection activities should be selected from the entire service area (based on the results of monthly zonal/DMAs NRW monitoring with bulk meters, MNF measurements, tabulated or mapped records of past bursts and leaks, etc).

2) Suitable combination(s) of applicable leak detection methods should be selected for each priority area based on the conditions of the area and WSP's resources (e.g. adaptability of Step Test such as continuity of water supply, security to conduct MNF, availability of functioning gate valves on branch pipelines, cooperation from customers when closing the stop corks on service connections, existence of pavement over buried pipes, availability of leak detection equipment and skilled workers, etc).

3) Door to door survey with listening sticks and other selected method(s) is/are then conducted well in combination with well-established day-to-day activities for underground leak detection.

9.2 Minimum Night Flow Measurement and Step Tests

9.2.1 Introduction

Minimum Night Flow (MNF) is the lowest steady flowrate into a DMA/zone in a 24 hours period. It is therefore a range of flows over a period of time and not one instantaneous flowrate. Figure 9.1 is a typical graph of 24 hours flow in a zone. The lowest flow is 22 lts/hr and occurs between 02:30 am and 04:00 am.

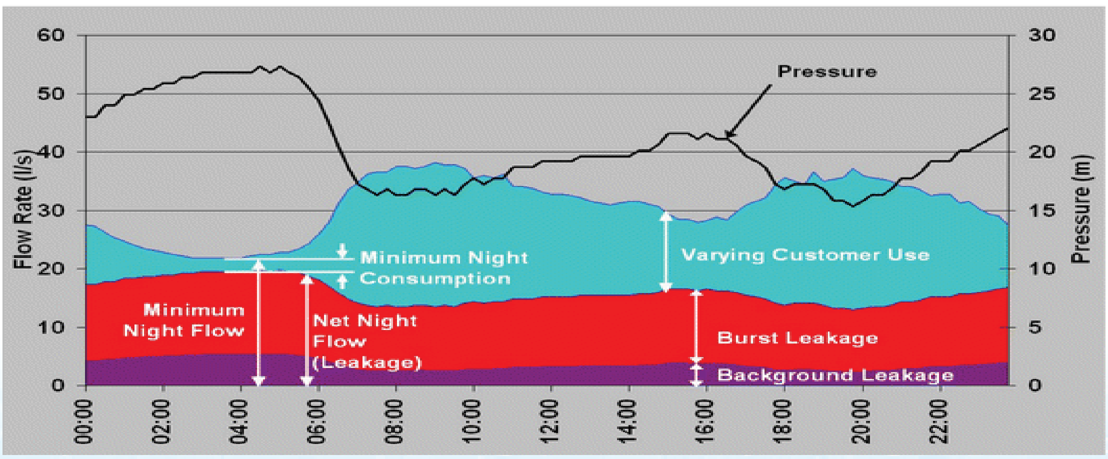


Figure 9.1: Typical Graph of 24 hrs Flow in a Water Supply

Figure 9.1 is a 24 hours graph of Kangaru Zone, Embu Water Co. The lowest steady flowrate was 190m3/hr occurring between 00:00am and 06:00am.

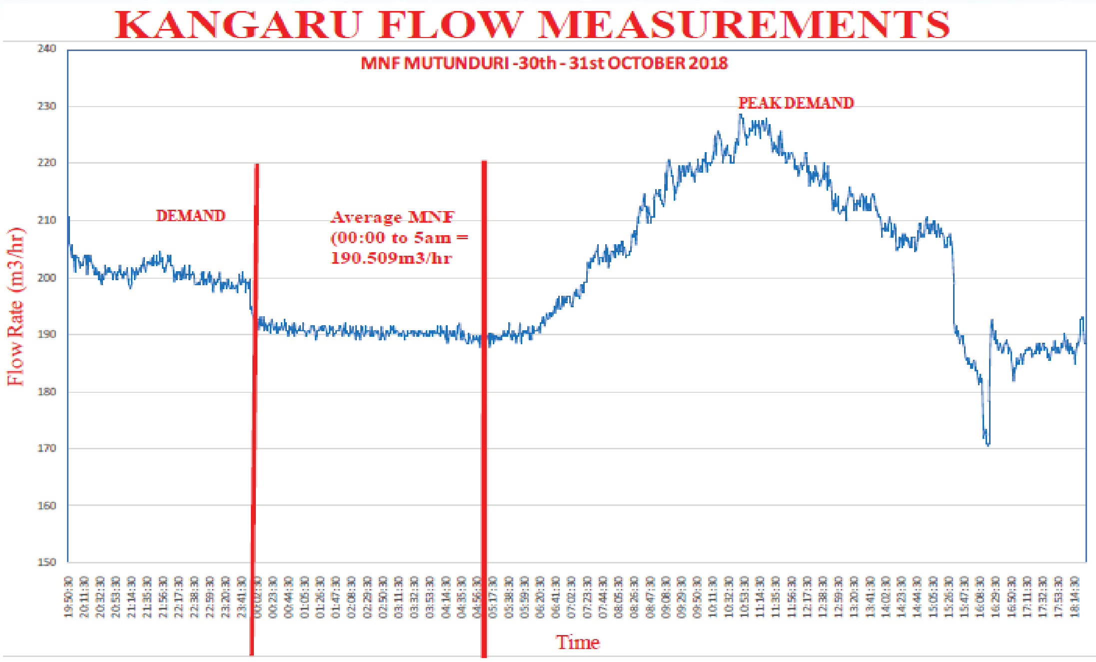


Figure 9.2: Graph of 24 hours Flow in Kangaru Zone, Embu Water Co., Kenya

The period of the lowest flow is unique for each distribution network and depends on the customer types and other factors. Table. 9.1 is a guideline on the recommended time of the night to conduct MNF measurement.

Table. 9.1: Recommended Time to Conduct MNF Measurement

	Customer Category	Time of MNF Measurement	
		Earliest Start Time	Latest Stop Time
1	Rural areas	11:00 pm	04:00 am
2	Peri-urban areas	00:00 am (midnight)	04:00 am
3	Urban areas	02:00 am	04:00 am

MNF comprises the following:

a) water consumed by customers (flushing toilets, washing machines, night clubs, industries, hospitals, prisons) including filling and overflowing storage tanks at customers' premises.

b) illegal use

c) leakage and overflows from WSP tanks downstream of the measurement location.

MNF measures the total of (a) to (c). (a) is normally determined by manually reading customer meters for a sample of domestic customers and the flow estimated for all the customers in the DMA/zone. For large customers, the meters can be read manually; or by automatic meters; or portable meters. This is done simultaneously with the MNF measurement. The total of (b) and (c) is the physical loss.

The purpose of measuring MNF is to determine and understand the level of physical losses occurring in a water supply network. Once this is determined, leak detection and repairs should commence and NRW monitored to achieve as low leakage level as possible.

Note:

a) If the supply system is intermittent make a provision to supply the area continuously for at least 24 hours before starting MNF measurement. The continuous supply may need to be extended to cover at least three nights without any interruption.

b) If the DMA has multiple inflow lines from other areas or outflow lines to other areas, each line should be metered. The readings from all the meters should then be aggregated and the minimum aggregated flow taken as the MNF.

c) It is recommended to measure water pressure in the pipeline simultaneously with the MNF measurement. The pressure gauge should be installed next to the UFM//bulk meter. The purpose of pressure measurement is to ensure that there is adequate pressure in the pipeline during the MNF measurement.

9.2.2 Rough Measurement of Minimum Night Flow using Bulk Meter

Most WSPs have no financial capacity to procure a UFM with their own resources. However, this should not be a hindrance to start leak detection.

MNF measurement can be conducted using any of the following methods:

- Recording bulk meter readings at 5- or 10-minutes intervals.
- Attaching data logger to a bulk meter – it stores the reading for a certain period.
- Attaching data logger and transmission gadget to a bulk meter – continuously transmits the readings to a computer.
- Automatic Meter Reading (AMR) gadget – continuously transmits the readings to the computer.

9.2.3 Case Study: Rough Minimum Night Flow Measurement on Two Inflow Pipes into Kanyoni DMA, Nakuru Town WSP

The NRW staff of Nakuru WSP were conducting MNF measurement using a UFM. However, the UFM did not have the capacity to transfer data to a computer. They therefore had to manually read the data from the UFM and record in the computer.

Figure 9.3 and 9.4 are the graphs of meter readings from the two inlets lines into Kanyoni DMA in September 2018 indicating MNFs of 8.0 and 12.0 m3/hr respectively. The readings were at 15 minutes intervals.

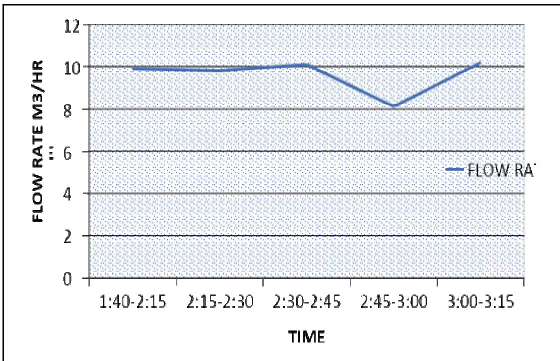


Figure 9.3: City Mission Line: MNF (Sep. 2018) = 8.0 m3/hr

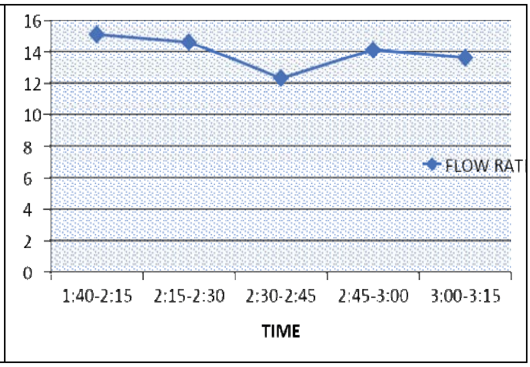


Figure 9.4: Scan Line: MNF (Sep. 2018) = 12.0m3/hr

The staff then conducted leak detection and repaired the leakages in Table 9.2.

Table 9.2: leakages detected and repaired in Kanyoni DMA, Nakuru Town WSP after the MNF measurement September 2018

	Location	Type of Leak Identified	No.
1.	Kanyoni estate	Leaks on meters liners	17
2.	Kanyoni estate	Leakage on 8" dia pipe	2
3.	Kanyoni estate	Leakage on 2" dia pipe	1
4.	Kanyoni estate	Leakage on 1.5" dia pipe	1
6.	Kabachia estate	Leakage from 12" dia sluice valve spindle	1
7.	Kabachia estate	Leakage from 12" pipe	1
8.	Shadrack Kimalel	Leakage from 12" dia sluice valve spindle	**1**

Figure 9.5 and 9.6 are graphs of meter readings from the two inlets lines into Kanyoni DMA in December 2018 indicating MNFs of 2.7 and 3.9 m3/hr respectively. The readings were at 15 minutes intervals.

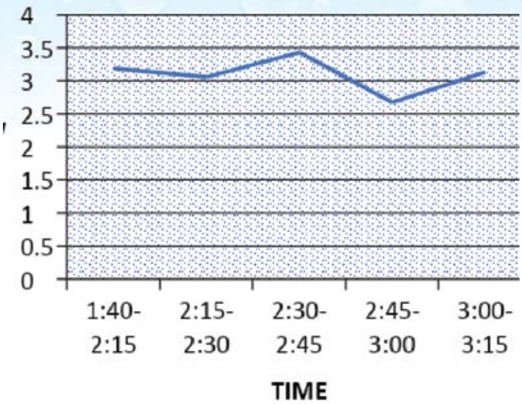


Figure 9.5: City Mission Line: MNF (Dec. 2018) = 2.7m3/hr

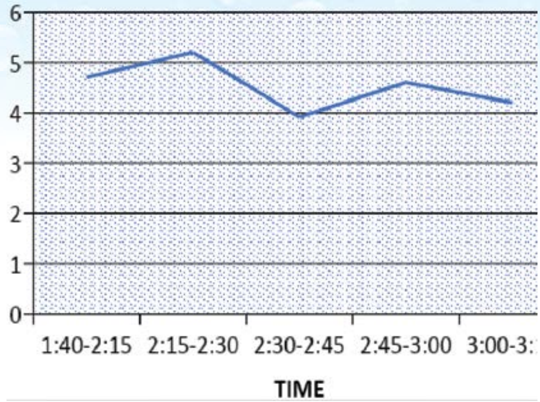


Figure 9.6: Scan Line MNF (Dec. 2018) = 3.9m3/hr

9.2.4 Step Test Measurement

The Step Test allows detection of abnormal flow in an isolated distribution area. By measuring the MNF of a sub-block and comparing the obtained readings to previous MNF records of same sub-blocks any abnormal flow can be detected and can be a pointer to possible leakage.

The procedure for Step-Test Measurement is as follows: -

- The leak survey block should be completely isolated from adjoining blocks, and the survey block must be divided into sub-blocks using sluice valves.
- There should only be one flow meter for the leak survey block, and water should be allowed to flow into each sub-block, one by one, by utilizing sluice valves.

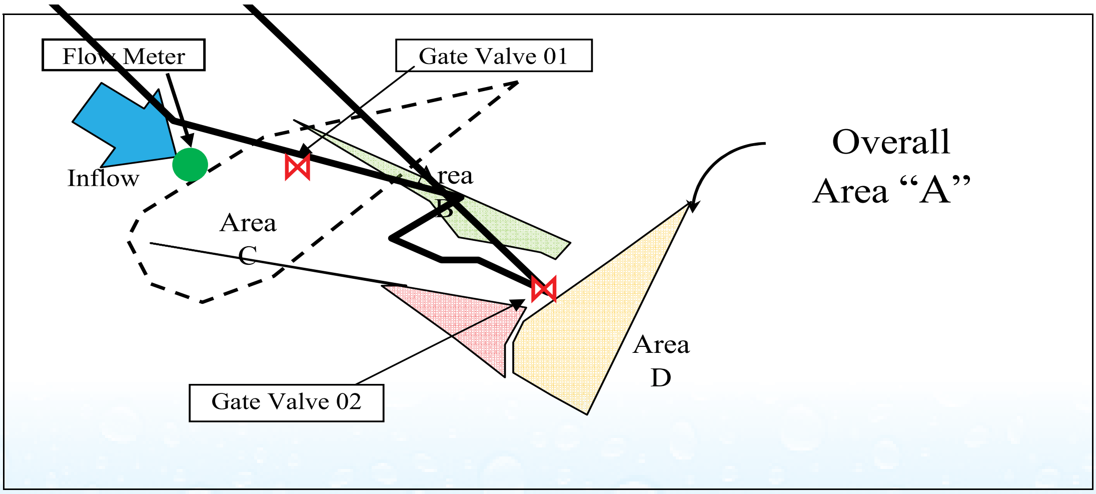


Figure 9.7: Schematic Diagram of Leakage Monitoring Block (Step Test)

The volume of water flow is measured by the flow meter as shown in Figure 9.7.

a) Measure the volume of minimum flow for overall area “A”.

b) Close gate valve 02 and measure the volume of minimum flow for “B+C”.

c) The difference between volume of “A” and “B+C” is minimum flow volume of D, i.e., D= A - (B＋C)

d) Similarly, close valve 01 and measure the volume of minimum flow for “C”.

e) It can be determined that the difference between “B+C” and “C” indicates the volume of minimum flow of “B”, i.e., B = (B＋C) - C.

f) Therefore, the volume of minimum flow for all can be determined.

g) All measurements are recorded and compared to previous volume of minimum flow records.

These comparisons can confirm any abnormal flow and presence of leakage.

Figure 9.8: Flow Meter Reading

Figure 9.9: Closing Gate Valve

Figure 9.10 shows a map of part of Embu WSP distribution network and the result of step test. The network was divided into 7 blocks and Step Tests conducted.

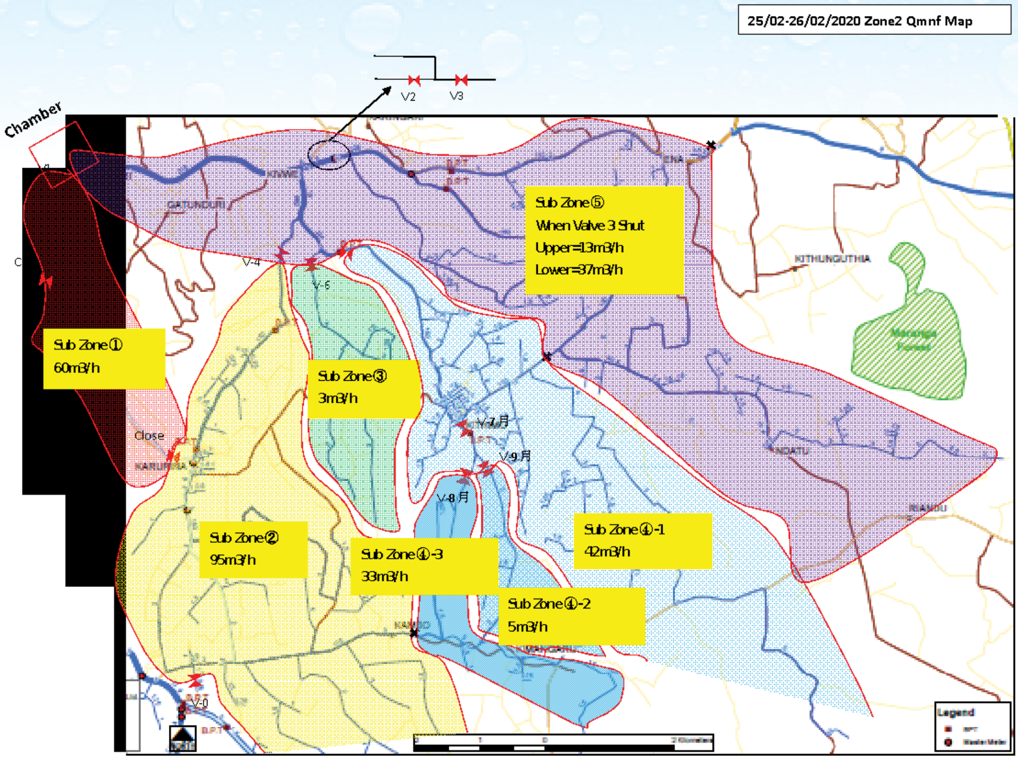


Figure 9.10: Qmnf Volume Map for Step Test(Case of Embu WSP)

Source: Embu WSP

The best step test measurement is normally done with an ultrasonic flow meter.

Figure 9.11 shows the results of the step test in the Embu WSP distribution network on Figure 9.10 above.

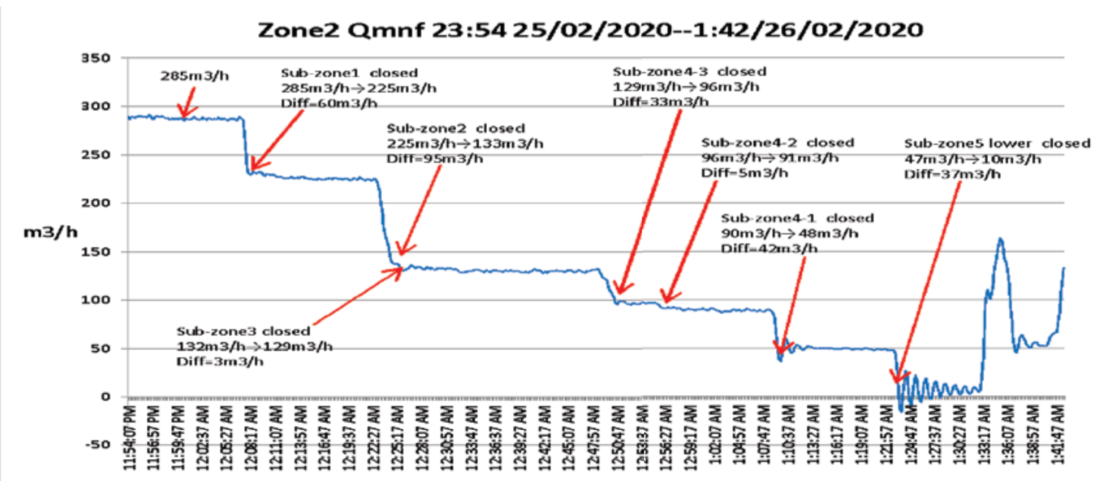


Figure 9.11: Results of Step Test (Case of Embu WSP)

However, step test measurement can also be measured with a bulk meter by taking a video of the bulk meter dial using a Timestamp camera. The camera can add a timestamp watermark (the time the video is taken) on the video in real time. The camera is the only App that can record videos with a time watermark accurate to millisecond (0.001 second). The App can be downloaded from play store (onto smartphone) or the following web link.

https://play.google.com/store/apps/details?id=com.jeyluta.timestampcamerafree&hl=ja&gl=US

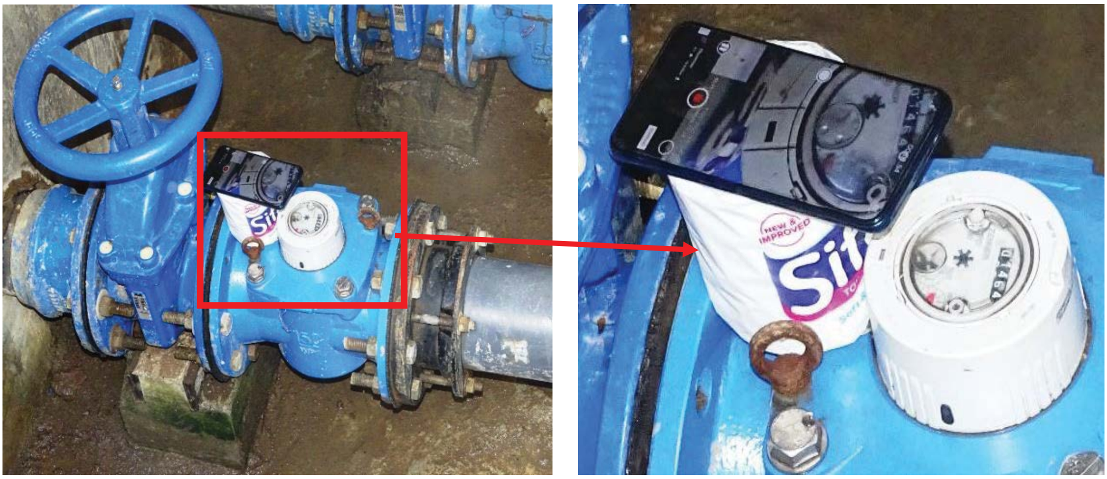


Figure 9.12: Smartphone recording video of bulk meter with timestamp camera

Note: When recording videos or taking photos using a timestamp camera, it is recommended that the current time and location be turn on. Once the video of the bulk meter is taken, the meter readings can then encoded from the video every 30 seconds or 1 minute.

Figure 9.13 is a sample of bulk meter readings recorded with a timestamp camera and the resultant graph of the flowrate at 30 seconds interval.

Video Time	Meter Readings of Bulk Meter 1 (from the Video)	Frow Rate of Bulk Meter 1 (m3/hr)
15:21:18	146461.021	25.68
15:21:48	146461.245	26.88
15:22:18	146461.473	27.36
15:22:48	146461.688	25.80
15:23:18	146461.902	25.68
15:23:48	146462.118	25.92
15:24:18	146462.342	26.88
15:24:48	146462.570	27.36
15:25:18	146462.790	26.40
15:25:48	146463.004	25.68
15:26:18	146463.222	26.16
15:26:48	146463.450	27.36
15:27:18	146463.676	27.12
15:27:48	146463.894	26.16
15:28:18	146464.108	25.68
15:28:48	146464.324	25.92
15:29:18	146464.547	26.76

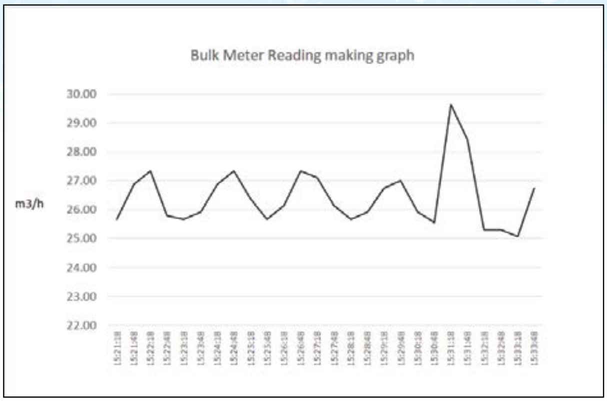


Figure 9.13: Sample timestamp camera data and graph

Abnormal flow cannot be determined solely by flow volume. It is important to understand and take into consideration the seasonal movement of inhabitants, building developments, operation status of big consumers like hospitals and construction works, etc. Characteristics of the area as well as past experiences must also be considered. If abnormal flow is noted in a sub-block, a leakage detection team should be dispatched the following day to determine the cause. If the cause is leakage, repair works should be done immediately.

9.3 Improvements Necessary for Underground Leak Detection

8.3.1 Leak Detection

Non-visible Leakages (Underground Leakages) are often difficult to detect. In order to detect underground leakages, it is necessary to use leak detectors such as listening sticks and electronic leak detectors. Using leak detectors often require specific skill and experience; hence training of staff is important.

Underground leakages are usually detected by using a leak detector, which is placed on the ground surface or on the pipe wall, to detect leak noises. The sound and quality of leak noises vary depending on factors such as soil properties, pipe material, pipe diameter, depth of pipes, magnitude of leakage, water pressures and others. Detecting leak noises in clay soils or pipes with large diameters is not easy and requires experience.

(a) Necessary equipment for Leak Detection work

The following are the minimum requirements for implementation of leakage control work. However, each WSP should prioritize depending on its self-assessment and availability of appropriate resources:

- Listening stick
- Pipe locator (for metallic and non-metallic pipes)
- Hand pump for water tightness test
- Water pressure gauge
- Pipe thickness gauge
- Electronic leak detector
- Electromagnetic flow meter
- Ultrasonic flow meter

The following are typical leak detection equipment and how to operation them: -

(b) Listening Stick

Listening Sticks have been used for many years to detect leaks easily and they are the origin of electronic leak detectors which are presently widely used. Its mechanism is very simple. It consists of a steel rod/bar and a small circular vibration plate connected to the end of the bar at right angle. It is a kind of stethoscope without an electronic amplifier.

Figure 9.14: Listening Stick

Figure 9.15: Leak detection using Listening Stick

Figure 9.16: Leak detection using Listening Stick

The leak noises can be heard by putting the tip of the stick on a meter or a pipe fitting, The ear is the placed on the vibration plate at the top of the stick to listen to leak noise. This method can only confirm the existence or non-existence of leakage near the listening stick but cannot locate the leak point. Listening Stick requires a lot of skill to distinguish the real leak noises from other similar noises. The equipment is still widely used.

(c) Electronic Leak Detector

An electronic leak detector consists of the main unit, a sensor (or pick up), a headphone and a remote-control unit. Leak noises are detected by placing the sensor on the ground surface. An amplifier is used to amplify the noise. The operator wears a headphone to listen to the amplified noise. The leak noise will become clearer and louder as the sensor nears the leak location. Using this device requires skill and experience.

As with the listening stick, this device is used mainly at night when there is less surrounding noise. Electronic Leak Detectors can greatly improve the efficiency of leak detection work.

Figure 9.17: Electronic leak detector

Figure 9.18: Leak detection using electronic leak detector

Figure 9.19: Leak detection using electronic leak detector

(d) Digital Leak Noise Correlator

Leakages occurring in pressurized pipes continuously generate random leak noises, which travel in the pipe in both directions. The device transforms the noise that is detected into electrical signals which is displayed on the monitor of the correlator. This is not only to detect existence of leakages, but also their location by looking at the peaks of wave points. IWA's "Download Leak Detection Technology and Implementation" for detailed explanations and procedures on using a correlator from the following link.

https://library.oapen.org/bitstream/handle/20.500.12657/33035/578133.pdf?sequence=1&isAllowed=y

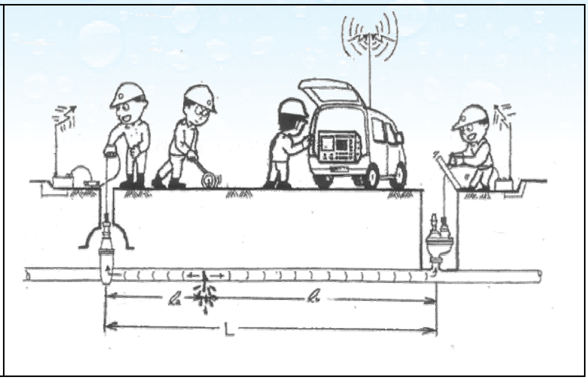


Figure 9.20: Digital leak noise detector	Figure 9.21: Concept diagram of cross- correlation type leak detector

(e) Other Leakage Detection Methods

i) Water quality examination method

Testing water quality at various points can determine whether there is contamination of water and therefore leakages. Generally, this test is conducted on water that flows through construction sites, basement of buildings or simply water flowing out onto the road. The quality of tested water must match that of tap water. The parameters to be examined are residual chlorine, PH, electric conductivity, water temperature, odour, etc. Additional test for trihalomethane may also be conducted.

8.3.2 Buried Pipe Detection Technologies

In the absence of accurate drawings showing the exact location of buried pipes, it is important to be able to identify the exact location of distribution and service pipes to conduct leakage surveys. Some examples of methods of detecting buried pipes are outlined below: -

a) Hammering Method

This method has been used for many years. A hammer is used in a uniform rhythm and strength on the road surface around the area where pipes are estimated to be buried. By using a listening stick or an electronic leak detector, the strength and changes of the sound is followed to identify the exact location of buried pipes.

b) Metallic Pipe Locator

Metallic pipe locator is used to locate metallic pipes. In this method, the pipe locator is placed on the ground above the buried pipes and a magnetic field is generated from a loop antenna with transmission coils. The magnetic current is conducted through the pipes and a secondary magnetic field is generated around the pipe, which can be detected by a separate antenna.

Figure 9.22: Metallic Pipe Locator

(c) Metal Locator

This locator is used to locate buried metal lids or other devices installed on pipes such as sluice valves, fire hydrant chests and customer meter boxes, etc. These may be buried due to construction pavements. The operation principle is the same as the Metallic Pipe Locator, but the metal locator has a capacity to detect metal up to 50cm in depth.

Figure 9.23: Metal Detectors

9.4 Recurrence of Leakage

Recurrence of leakages refers to new leakages that occur near previously repaired leakages of the same pipe. When water distribution pipes are worn out, no matter how many leakages are repaired, there will be a great tendency for new leakages to occur. In order to further lower the leakage ratio, detection of leakages and repair work must outpace leakage occurrence. In cases where leakages still occur in the same pipe, or if the pipe is well past its lifespan, the water pipe must be replaced with newer and stronger pipe.

Figure 9.22 shows the concept of recurrence of leakage.

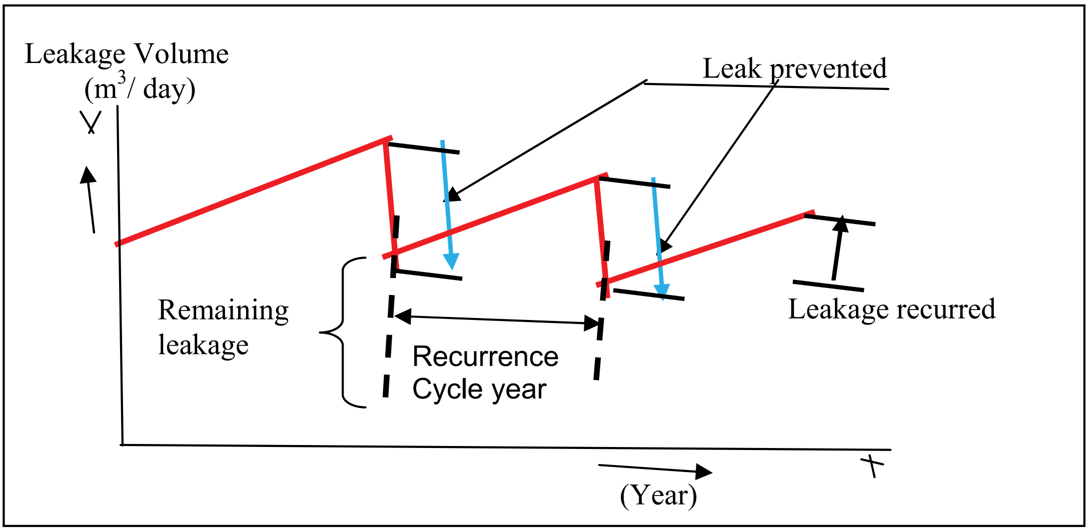


Figure 9.24: Concept of Leakage Recurrence

9.5 Large-scale Replacement of Deteriorated Pipelines

WSPs planning large-scale replacement of deteriorated pipes should following procedure:

1) The types and sizes of problematic pipelines requiring replacement (e.g., asbestos cement, old GI, cast iron and steel pipes having corrosion holes and/or rust incrustation significantly blocking flow; pipes of low-pressure rating (e.g., PN 7.5) in high pressure areas, etc) or rehabilitation (e.g., relining) should be analysed (preferably with GIS) based on available data (e.g., installation year of each pipeline and records of past bursts and leaks).

2) The necessity and priority of large-scale replacement/rehabilitation of transmission, distribution and/or service pipes (and rehabilitation of leaking tanks, etc) should

then be discussed well among relevant staff including managers based on the results from the above analysis before starting the planning process.

3) The large-scale replacement/rehabilitation should be planned (including rough cost estimation) from long-term financial and technical prospects (such as expected reduction in NRW, increase in revenue, and future water demand increase).

4) The planned replacement/rehabilitation should then be incorporated into the latest strategic plan (partly for seeking external funds) and/or into the tariff adjustment application of WASREB with required budgetary provision.

5) The design, bill of quantities and detailed cost estimates should then be prepared for tendering.

6) The replacement/rehabilitation should then be implemented as funds permit.

Chapter 10

Pressure Reduction/Management Including Zoning Using Reservoirs

10.1 Pressure Management to Reduce Physical Losses

10.1.1 Relationship between Excessive Pressure and Water Losses

Low water pressure in a distribution system interferes with adequate water supply to customers and also prevents leaks from being visible on the ground surface. On the other hand, the frequency of pipe bursts and leakage volume are usually high when pressure is high. Therefore, the water pressure in the distribution system should be kept within a suitable range (e.g., 15 to 40m of water head) as much as practical. Reduction of excessive pressure in transmission lines, distribution networks and service connections in relatively low-lying areas is quite important to reduce the number and volume of pipe bursts and leaks.

Figure 10.1 shows the effect of pressure reduction on the number of pipe bursts. If a WSP has many pipes whose pressure rating is not high enough (e.g., PN10) compared to the pressure in those pipes or; has pipes installed without proper fittings, even a limited reduction of pressure (e.g., by 10%) may reduce pipe bursts drastically (e.g., by 25%) like the red trend line in the figure. Leakage volume from leak points can also be reduced by lowering the water pressure as shown in Figure 10.2.

Reduction of water pressure (e.g., by 20%) would reduce leakage drastically (e.g., by 40%) especially if the pipes are mostly plastic as shown in this figure. The value of the exponent N in this figure depends on the nature of the pipes and shape of the leakage opening. For rigid pipes (e.g., thick-walled metal pipes), N is equal to 0.5; but if the pipe is flexible and the leak opening size changes with the change in pressure the value of N increases and reaches up to 2.5.

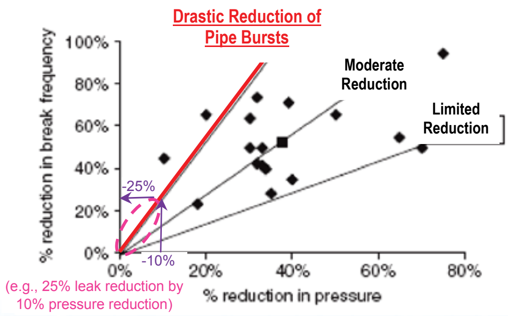


Figure 10.1: Possible Relationship between Pressure Reduction & the Frequency of Bursts

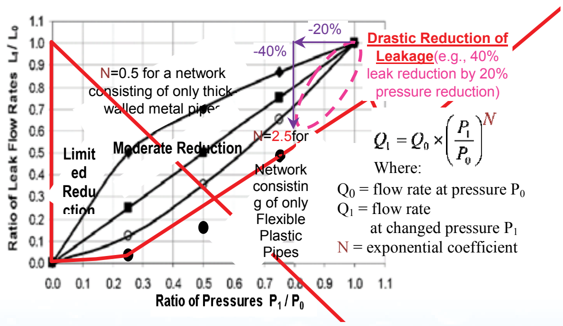


Figure 10.2: Generalized Relationship between Pressure Reduction & Leak Flow

10.1.2 Solving Low-Pressure Problems to Enable Reduction of Excessive Pressure

Managing pressure in low pressure spots is also beneficial for pressure reduction. A WSP may be unable to reduce pressure at all in a high-pressure area just because there is a single under-sized pipe causing a large pressure loss therefore creating a localized low-pressure spot and serious trouble to a few customers. In such a case, a WSP may not dare reduce the overall high pressure of a low-laying area if some of the customers living there suffer from serious low pressure. Figure 10.3 is an example of a large friction pressure loss caused by a small-diameter (e.g., 50mm) distribution pipeline.

Just like a single small pipe causing a large pressure loss, the existence of a single but large hidden leak causing a large pressure loss may also become a serious obstacle in reducing the excessive pressure over a high-pressure area. As shown in Figure 10.4, when the flow rate in a pipe increases due to demand increase or leakage, the friction pressure loss increases.

Therefore, before trying to reduce excessive pressure in order to reduce bursts and leaks in a high-pressure area, small spots of low pressure within the area including those on hills and on small diameter pipes should be resolved first so that the pressure reduction can be applied to the area without resulting into serious complaints from the customers already suffering from low water pressure.

The above is an example of why pressure reduction is complicated and often becomes customer complaints management especially if the system is under intermittent (rationing) water supply conditions.

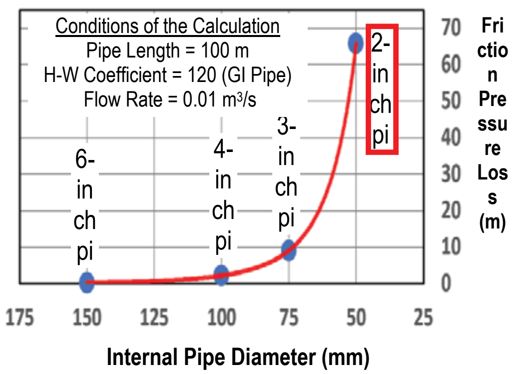


Figure 10.3: Effect of Small Diameter on Pressure Loss calculated with Hazen-Williams Formula

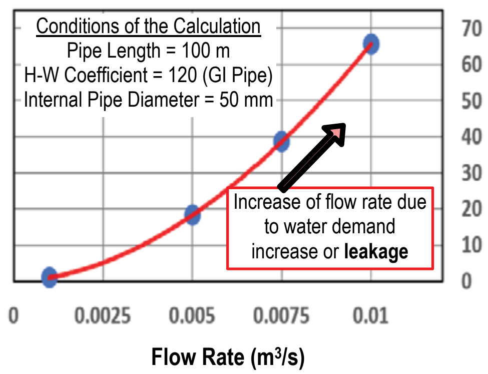


Figure 10.4: Effect of the Increase of Flow Rate on Pressure Loss calculated with Hazen-Williams Formula

10.2 Pressure Measurement to Identify Problematic Areas

10.2.1 Pressure Measurement and Mapping

Water pressure within distribution systems vary relative to the terrain (e.g., elevation difference from upstream tank), pressure losses in upstream pipes, and water supply and demand conditions at a given time (e.g., dry season, night time, etc.). Low-laying areas often get high pressure while high elevation areas and ends of long distribution lines often get low pressure. If a WSP uses pressure regulating facilities and equipment such as pumps and pressure reducing valves (PRVs) the pressure within a distribution system also depends on their specifications and settings.

In order to identify all the high-pressure areas where pressure can be reduced without causing unacceptably low pressure to some customers, a large number of pressure measurements would be required in many areas.

Figure 10.5 is results of pressure measurement mapped on GIS. The daytime pressure should be taken not only at the low-lying locations where high pressure usually occurs but also at the ends of distribution pipes, on hills and upstream and downstream of pressure regulating facilities such as PRVs. This enables to fully understand the existing conditions during high-water-demand hours and the possibility of pressure reduction at different locations.

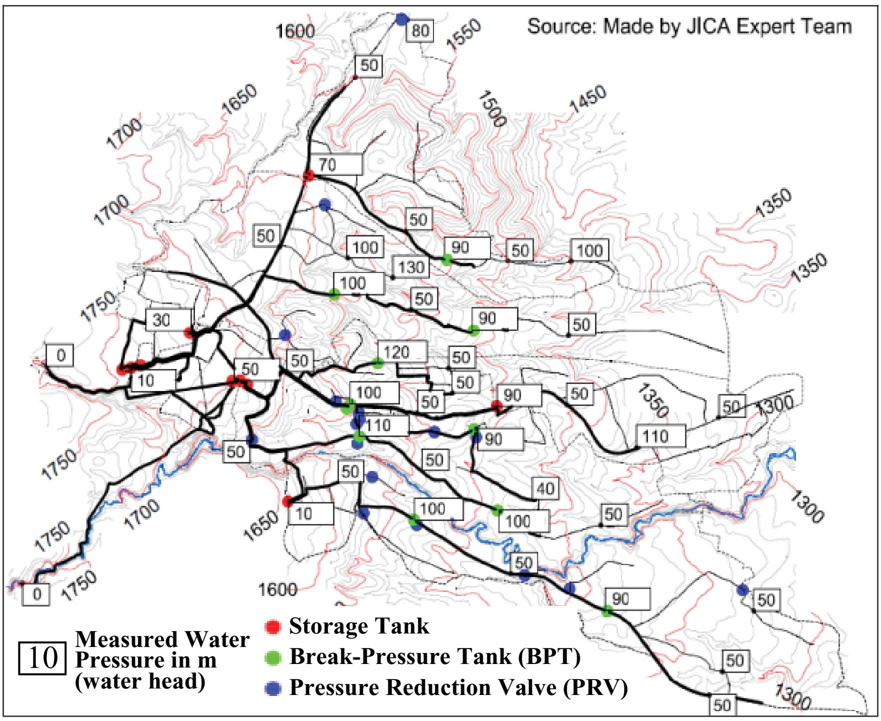


Figure 10.5: Mapped Daytime Pressure Measurements over a Hilly Terrain Area

To cover a large area and/or many pressure measurement points, it is more practical to use pressure gauges than pressure loggers. If pressure gauges with red maximum pressure pointer (Figure 10.6) are available, they can be used to record the hourly maximum pressure that normally occurs overnight to understand the necessity and expected effects of pressure reduction during night-time. From around mid-night to 4.00 am when people use little water, the slowed water flow in distribution pipes cause less friction pressure loss. This results in higher residual pressure in pipes and more pipe bursts and leakage per hour.

After identifying high-pressure areas where pressure reduction may be possible, pressure loggers can be used to understand pressure fluctuations at locations of relatively low pressure within high-pressure areas. This is in order to make sure the planned pressure reduction will not cause unacceptably low pressure at these locations even during peak hours of water demand. As shown in Figure 10.7, pressure loggers used to log flowrate fluctuations while logging pressure changes. This helps to understand the reasons for the measured pressure changes over time.

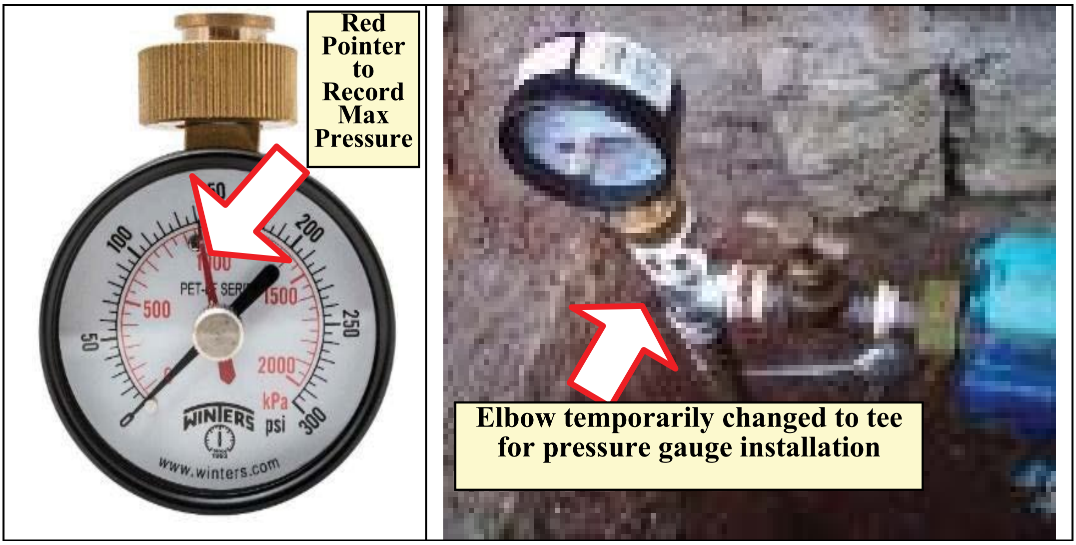


Figure 10.6: Pressure Gauge with a Red Pointer to Record Maximum Pressure over Night and its Installation on the Standpipe of a Domestic Customer Meter

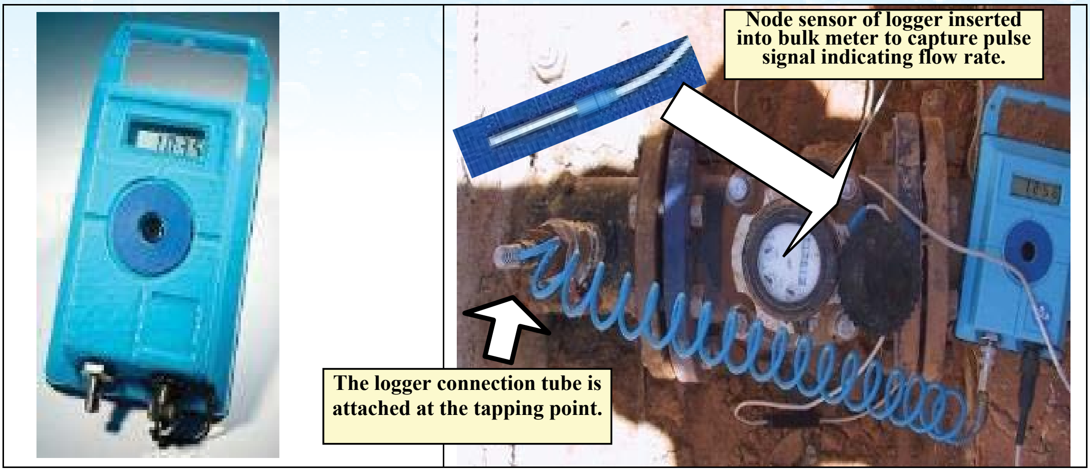


Figure 10.7: Pressure Logger and its Installation inside a Bulk Meter Chamber for the Logging the Fluctuations of Pressure (with the blue spiral tube) and Flow (with the gray colour electric cable)

The mapped pressure measurements should be analysed in relation to the terrain, existing distribution network (e.g., pipe length and diameter, performance of existing pressure regulation facilities, etc.) and hourly water demand changes. This is to identify high-pressure areas where pressure reduction is possible and also understand the reasons behind the high pressure; and to determine the most effective and sustainable interventions to deal with the high pressure.

When a WSP tries to reduce pressure in a relatively small area, the pressure within the area may be measured at many locations with a relatively high density to visualize the measured results as pressure contour maps like those in Figure 10.8 (e.g., before and after the installation of a PRV for pressure reduction).

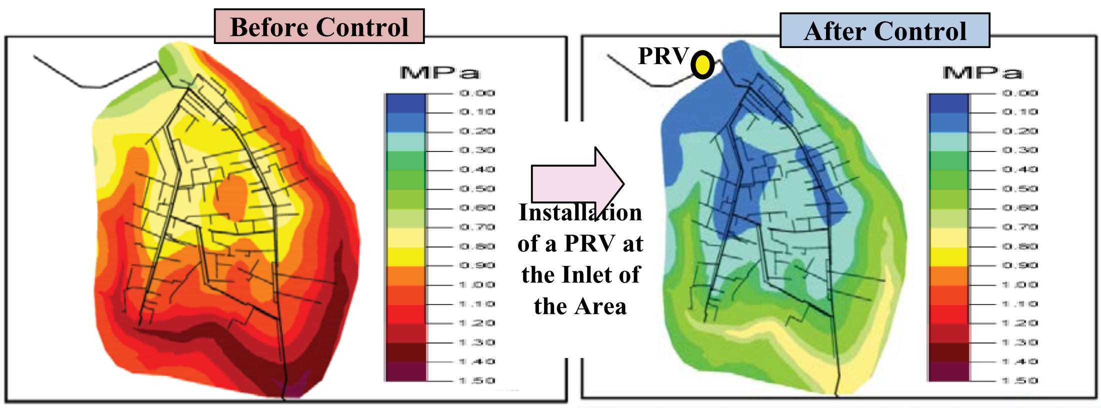


Figure 10.8: Example of Pressure Mapping to Visualize Results of Installing PRV for Pressure Reduction at Embu WSP

10.2.2 Identification of Problematic Areas Through Pressure Measurement

Note: The procedure below is only for WSPs that have or may have excessively high pressure causing more bursts and leaks in the distribution systems.

1) Ensure that flow of water from intakes to distribution pipelines is well understood on printed maps and/or GIS map and they are showing boundaries of existing distributing zones (DZs) and smaller pressure zones (possibly DMAs); and intake, production, transmission and distribution facilities (including pipelines, distribution reservoirs/tanks, pump stations; pressure reduction facilities such as break-pressure tanks (BPTs) and pressure reducing valves (PRVs)).

2) Ensure that elevation difference within each DZ and/or pressure zone is well understood (e.g., by overlaying elevation contours, zone boundaries and facilities on GIS; and tabulating elevation of storage facilities, lowest and highest customers, elevation difference between the lowest and highest customers, range of static pressure, etc. in each zone).

3) Ensure that the status (e.g., in use, bypassed), type, capacity and condition (e.g., leaking, overflow) of existing pressure reducing facilities (e.g., distribution reservoirs/tanks, BPTs, PRVs) are identified through visual observation, maintenance, etc.

4) Ensure that priority zones for pressure reduction are selected (based on static water pressure range calculated from elevation differences, occurrences of bursts and leaks, types and age of existing distribution pipelines and service pipes, conditions of existing pressure reducing facilities, MNF measurements (if possible). in each zone).

5) Ensure that adequate pressure measurement points (e.g. at fittings around customer meters to where pressure gauges can be easily installed) are planned for the selected prioritized zone(s) on map (preferably with GIS), especially in the areas where high and low residual pressure are expected (e.g. around ground distribution reservoirs, ends of branch distribution pipes going up or down hills, ends of long small-diameter pipelines including long service pipes, etc.) and upstream and downstream of existing PRVs/BPTs, for measuring maximum pressure (which usually happens after midnight when water demand become lowest) and running pressure (during day time when the gauges are installed or removed). (Note: minimum pressure during highest-water-demand hours may also be measured to avoid pressure reduction resulting in unacceptably low pressure on existing low-pressure lines).

6) Ensure that a map showing the planned pressure measurement points for prioritized zones are shared with surveyors who measure pressure. (If measurement is planned using GIS, this can be done using free online GIS (e.g., QGIS Cloud) or free mobile GIS on smartphone (e.g., QField, MAPinr and Google Earth)).

7) Ensure the maximum and running pressure (at the planned pressure measurement points) are measured with pressure gauges having red maximum pressure pointer and/or pressure loggers. (Note: free data collection software such as Kobo Toolbox/Collect can be used for the pressure measurement).

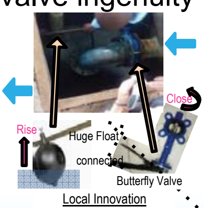
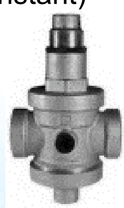
8) Ensure pressure data measured in priority zones are mapped (e.g. over zone boundaries, distribution facilities and elevation contours) and analysed spatially (preferably on GIS) to confirm the necessity for pressure reduction in the prioritized zones and identify especially problematic high-pressure areas and/or pipelines which can be improved with relatively small investments (e.g. replacing a limited span of pipeline with high pressure rating pipes, installation of PRV and/or BPT) as opposed to large investments (e.g. zoning with reservoirs, replacement of pumps).

10.3 Pressure Reduction Measures

10.3.1 Selection of Suitable Pressure Reduction Measures

There are different ways of reducing excessive pressure in distribution networks. Table 10.1 shows a range of measures for pressure reduction seen in Kenya.

Table 10.1: Measures for Pressure Reduction in Water Supply Systems

Category	**Large-scale Impact & Sustainable**	**Medium-scale Impact with low Sustainability**		**Small-scale Impact with Demerits**
Facility / Equipment	Ground distribution reservoir 	Common Pressure Reducing Valve (PRV) capable of keeping outlet pressure constant 	Break-Pressure Tank (BPT) with a local float valve ingenuity 	Low-cost PRV usually used for tertiary Pipes, Boiler, etc. (its outlet pressure cannot be kept constant) 

Category	Large-scale Impact & Sustainable	Medium-scale Impact with low Sustainability		Small-scale Impact with Demerits
Advantage (Pro) and Disadvantage (Con)	Pro: (1) can cover a large area (2) easy to maintain Con: needs a large capital investment	Pro: its downstream pressure can be adjusted. Con: (1) can be expensive or low quality depending on manufacturer. (2) high-maintenance.	Pro: relatively inexpensive and low-maintenance Con: (1) its downstream pressure cannot be adjusted. (2) cannot supply water to surrounding households at same elevation. (3) may cause overflow.	Pro: low cost Con: (1) cannot reduce pressure very much at night (e.g., only 10m/1bar). (2) cannot be modelled in hydraulic analysis.

If a WSP has a heavily interconnected distribution network with large elevation differences, the network should be clearly separated into zones with ground reservoir(s), elevated tank(s) or distribution pump(s) dedicated for each zone. As shown in Table 10.1, using ground reservoirs would be the most effective and sustainable way to reduce excessive pressure over large areas although it requires a large capital investment.

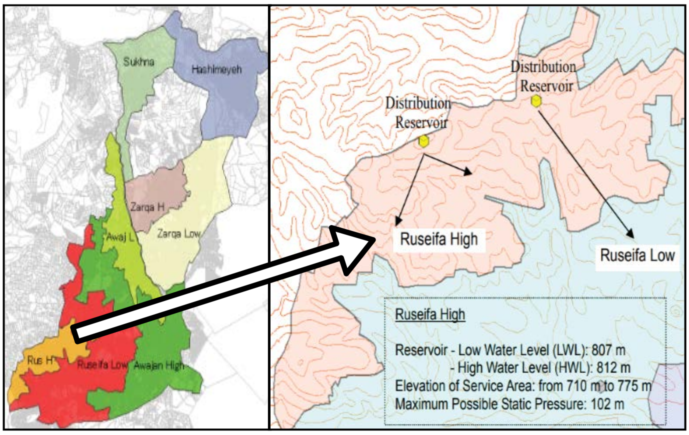
If a WSP has some high-pressure areas within separated zones, pressure reducing valves (PRVs) and/or break-pressure tanks (BPTs) can be used to reduce the high-pressure areas inside the zones.

If there are groups of customers who continuously draw water from high pressure branch distribution pipelines, low-cost PRVs incapable of keeping the downstream pressure at a constant level (see Table 10.1) may be installed on those distribution pipes or on their common service pipes for small-scale pressure reduction. However, the low-cost PRVs installed on branch distribution pipes may cause disruptively large pressure loss during high water demand hours and would probably reduce only 1 to 2 bar (10 to 20m) during late-night hours when pressure in distribution pipes is usually at its peak due to the limited water use at night.

10.3.2 Construction of Reservoirs/Elevated Tanks

Well planned water distribution from ground reservoirs is the best solution for large-scale pressure reduction. Pumping should only be used to distribute water to areas where gravity flow cannot reach, to transmit water into ground distribution reservoirs from which water is distributed by gravity or pumped; and to lift water to elevated tanks for gravity distribution. The main advantages of gravity flow distribution systems are that the pressure in distribution pipes remain relatively stable, water distribution is continuous even during power failures and; complicated operation of multiple distribution pumps (to follow hourly water demand changes) can be avoided.

Figure 10.9 and Table 10.2 is an example of how to zone distribution systems in a way that each DZ will supply to a limited elevation difference for pressure reduction using a ground reservoir for gravity distribution. When planning a gravity flow distribution from a ground reservoir or elevated tank, the boundary of DZ should be carefully considered with reference to elevation contours in order to keep water pressure within acceptable range. Selection of adequate pressure rating (e.g., PN16) for distribution and service pipes is also important to withstand the expected pressure and reduce pipe bursts and leaks, especially in areas where it's difficult to avoid high pressure. This is the example in Jordan as shown below.



Source: WAJ & JICA (2011) Guidelines on Distribution Network Management for NRW Reduction

Figure 10.9: Zoning of Distribution Systems conducted in Zarqa Governorate, Jordan

Table 10.2: Elevation Variation of Each Created DZ in Zarqa Governorate, Jordan

S.N.	Zone	Reservoir		Elevation variation in service area (m)	Static pressure Min ~ Max (m)
		Elevation (LWL–HWL) (m)	Capacity (m^3)		
1	Ruseifa High	807 – 812	1800	710 ~ 775	32 ~ 102
2	Ruseifa Low	750 – 756	6300	650 ~ 715	35 ~ 106
3	Awajan High	694 - 700	6300+ 4500	600 ~ 660	34 ~ 100

S.N.	Zone	Reservoir		Elevation variation in service area (m)	Static pressure Min ~ Max (m)
		Elevation (LWL–HWL) (m)	Capacity (m^3)		
4	Awajan Low	638 - 643	1800	550 ~ 600	38 ~ 97
5	Zarqa High	710 - 714	2500	615 ~ 708	2 ~ 99
6	Zarqa Low	645 - 654	14000+ 4000	530 ~ 625	20 ~ 124
7	Hashemeyeh	625 - 629	1500	530 ~ 610	15 ~ 99
8	Sukhna	585 - 589	1000	480 ~ 560	25 ~ 109
9	Hettein	786 - 790	3000 + 500	770 ~ 650	16 ~ 140

Source: WAJ & JICA (2011) Guidelines on Distribution Network Management for NRW Reduction

10.3.3 Pressure Reducing Valves and Break-Pressure Tanks

Pressure Reducing Valves (PRVs) and Break-Pressure Tanks (BPTs) can be used to reduce excessive pressure in relatively small areas compared to ground reservoirs. Figure 10.10 is an example of the effect of installing PRVs at the inlets of low-lying areas where the water pressure is highest in a DZ. Areas having PRVs or BPTs can be considered as DMAs if they have operating bulk meters at their inlets.

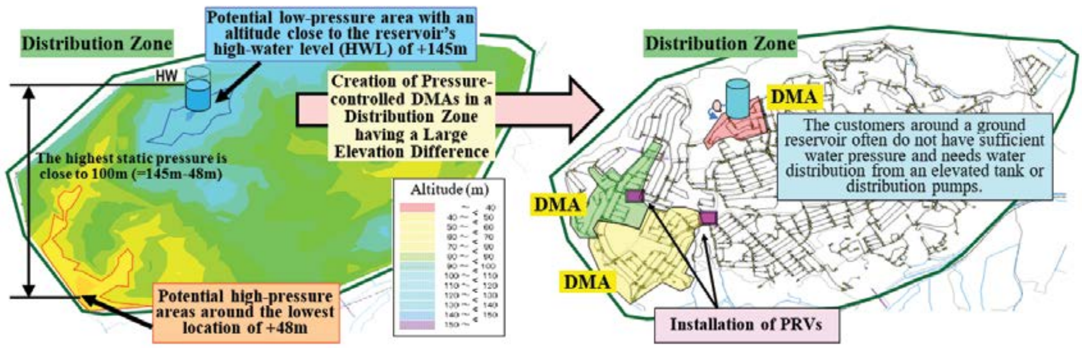


Figure 10.10: Establishing Pressure-controlled DMAs for Pressure Reduction within a Distribution Zone with a Large Elevation Difference

Low cost PRVs are more suitable than BPTs in built-up areas for the following reasons.

1) The outlet pressure of a PRV can be adjusted after installation and as the area develops over time and increase in the number of high-rise buildings.

2) The pressure at the outlet is not zero unlike for BPTs. Therefore, a PRV can be used to supply water to its nearby customers who are at a ground elevation similar to that of the PRV.

3) The site selection is easier for a PRV because the chamber of a PRV can be constructed on the roadside where the pipe is usually laid; unlike for BPT which requires larger spaces.

Use of PRVs is therefore recommended in urban areas. Unlike low-cost PRVs shown in Table 10.1, common PRVs for water distribution can keep the outlet pressure constant regardless of flow rate and upstream water pressure.

Advanced models of PRVs can automatically lower the downstream water pressure setting during late-night hours when water pressure is usually high due to low water demand. However, the maintenance cost of low-cost PRVs high especially where supplied water is silty and/or intermittent.

The PRV diameter need to always match the pipe diameter. Smaller diameter PRVs than the pipe should be provided with calming sections (10D and 5D lengths of the same diameter upstream and downstream respectively) to avoid cavitation which may occur causing damage to the PRV, hence the need for care in size selection.

Especially, when the range of pressure reduction is large, cavitation causes serious vibrations and noise, thereby wearing-off the valve seat.

Installation of isolation valves, strainer, air valve and bypass pipe inside the PRV chamber should also be considered to make the troublesome maintenance work of PRVs easier and sustainable.

On the other hand, BPTs that are simple structures with relatively fewer possibilities of breakdown can be recommended mainly for rural areas.

As shown in Table 10.1, local innovation using butterfly valve can be used to make more effective and sustainable float valves.

BPTs are sometimes vandalized to create overflow for irrigation purposes. The BPT should therefore have a tamper-proof locking mechanism to enable easy detection of overflow (e.g., by discharging overflow water onto the road surface instead of into a grass covered side ditch) to reduce water wastage.

10.3.4 Proper Use of Pumps for Direct Water Distribution and Water Hammer Prevention

Direct water distribution to customers by pumping instead of by gravity flow from storage tanks is currently not common in Kenya. However, with continuous improvement of distribution systems, such options will no doubt become available.

In a direct pumped distribution system, the flow rate of the distributed water varies greatly with time due to hourly water demand fluctuations. The maximum hourly flow rate of a distribution system can be ten times higher than the minimum hourly flow rate. This difference in flow rate may cause a larger pressure difference in pump-distributed areas than in gravity-distributed areas basically due to the pump characteristics (i.e., Pump-Head Curve). When the water demand reduces at late night, the friction pressure loss in pipes reduces and residual pressure rises. In addition to this, the discharge pressure of a distribution pump may also rise when its discharge flow rate reduces at night (as illustrated in Figure 10.11).

In order to prevent build-up of excessive pressure at late-night, it is necessary to carefully adjust the pump discharge pressure at a distribution pump station. One method of controlling the discharge pressure of pump is to adjust the number and combination of large and small capacity pumps that are operating at a given time in accordance with the hourly water demand fluctuations.

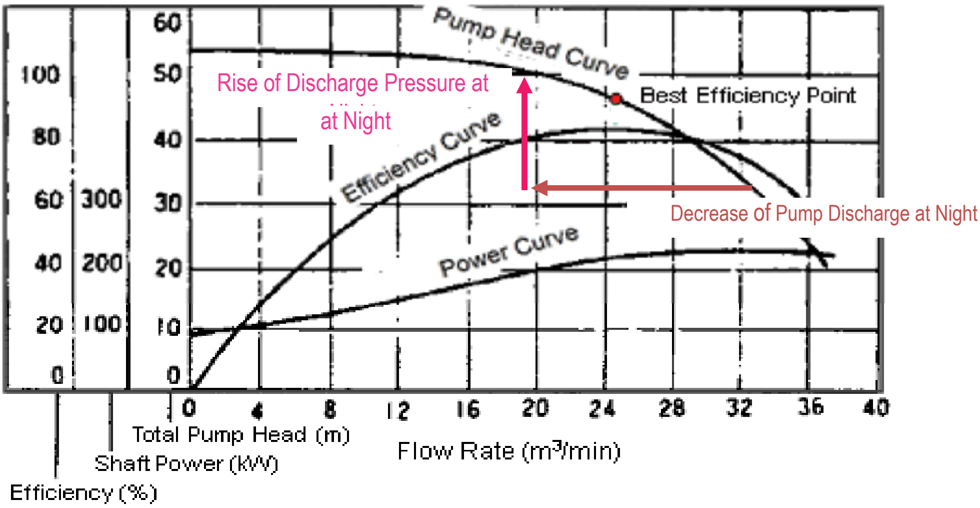


Figure 10.11: Typical Pump Characteristics showing Increase in Discharge Pressure due to Decreased Flow Rate

As illustrated in Figure 10.12, in a hilly area where water can only reach by pumping, limiting the extent of pump-distributed areas as much as practically possible is quite important to reduce the bursts and leaks caused by pressurized water as well as to reduce the number and size of the required pumps and power consumption.

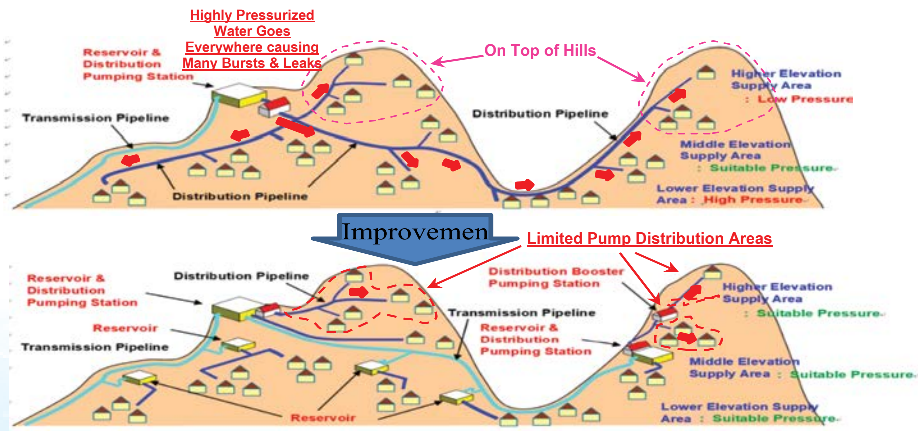


Figure 10.12: Suitable Use of Distribution Pumps & Booster Pumps for Limited Areas Only

Water hammer is a surge of pressure caused by a sudden stop of water flow in pipes. The sudden changes in water velocity due to pump-stop, for example, generates pressure waves which are rapidly transmitted through the pipeline system to the other end(s) where they bounce back. These pressure waves drastically increase and decrease pressure in the pipe network and damage facilities including causing pipe bursts. Water hammer increases when the pipeline is long and straight and has high flow velocity and fewer branches.

Figure 10.13 shows a typical distribution pumping station layout and installation points for common protection devices against water hammer. These devices (in order of increasing price and O&M cost) are check valve, flywheel on pump, air inlet valve, and air chamber (or one-way surge tank, surge tower, etc.).

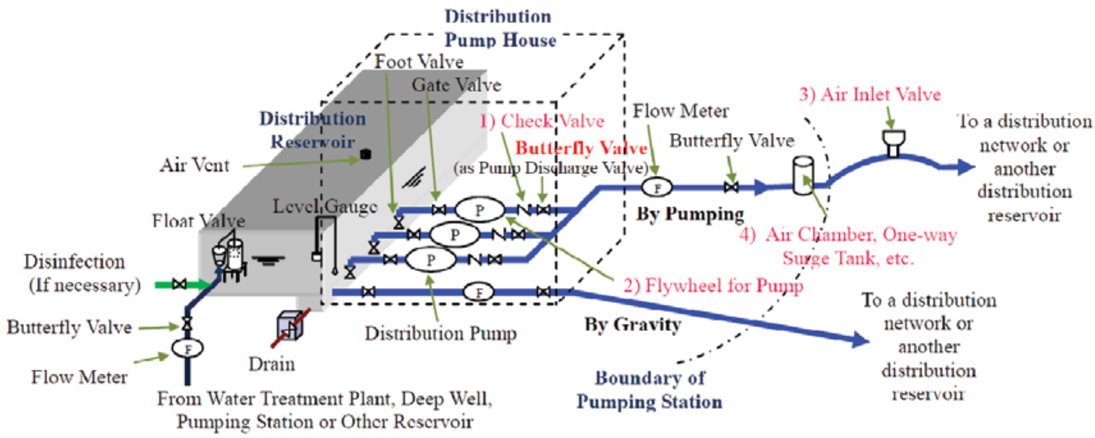


Figure 10.13: Common Water Hammer Protection Devices at a Distribution Pump Station

10.3.5 Different Levels of Hydraulic Analysis for Pressure Reduction

Hydraulic calculation is important to manage pressure throughout the water supply systems. Lengthy distribution pipes or service pipes of adequate diameter for the respective water demand often results in low pressure in certain areas. These low-pressure spots make pressure reduction over larger areas quite difficult. This is because serious water shortages would likely occur at the low-pressure spots if pressure is reduced without first resolving the low-pressure spots. The water shortage would also cause many customer complaints and eventual abandonment of the pressure reduction initiative. WSP staff should therefore routinely conduct hydraulic calculations to ensure suitability of new pipe sizes before installation to prevent any troublesome low-pressure spots.

Figure 10.14 shows the different hydraulic calculations for water pipes.

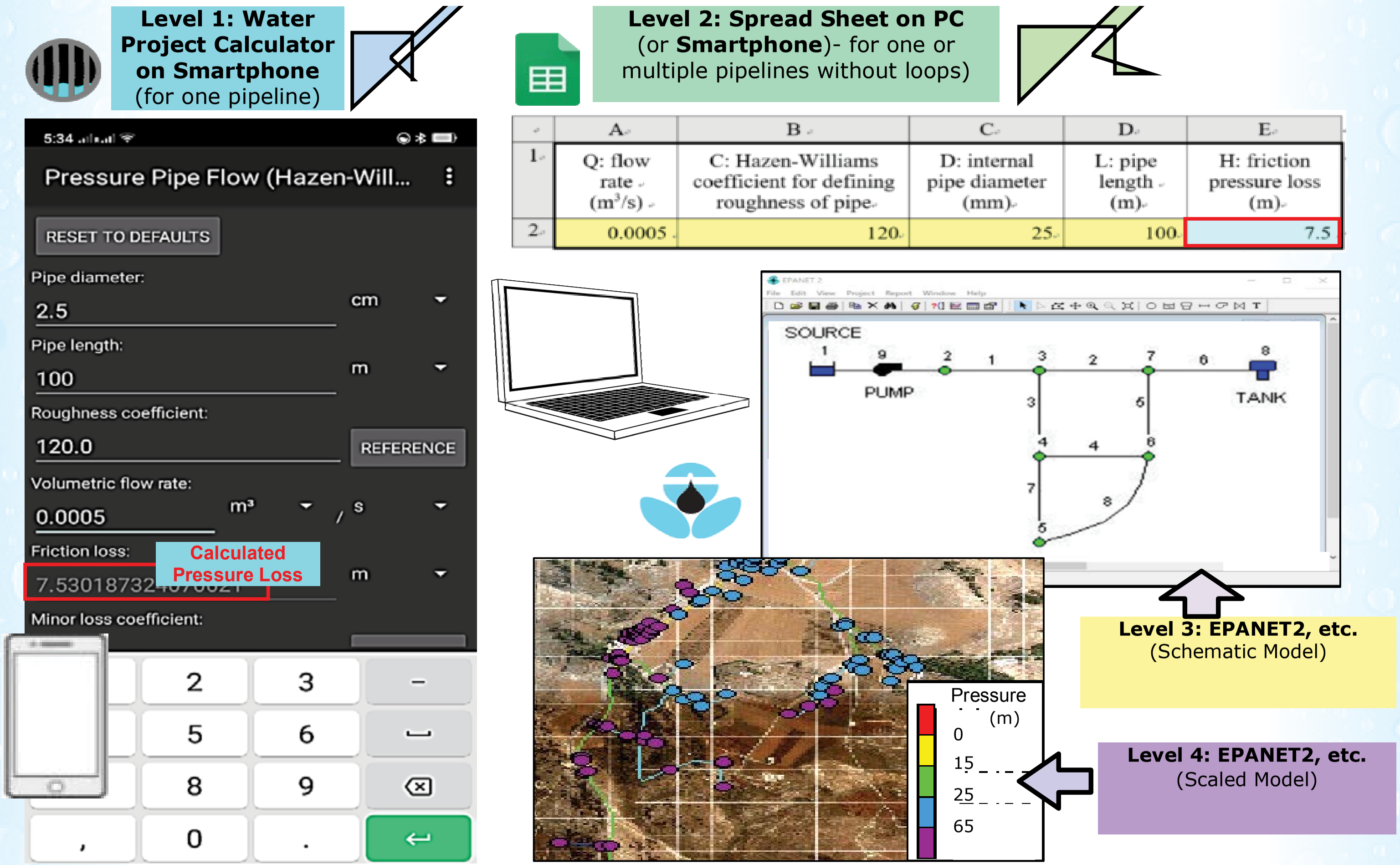


Figure 10.14: Selection of the Proper Level of Hydraulic Analysis and Appropriate Free Software

- If the target of hydraulic calculation is a single pipeline, a free software program called Water Project Calculator can be used (see Level 1 of Figure 10.14) to check the expected friction pressure loss in the pipe.
- If the target is multiple pipelines (different in sizes and/or material) connected in series, a spread sheet program like MS Excel on a PC may be used to calculate the total pressure loss in the pipelines (see Level 2).
- If the target is a distribution network having loops of pipelines, a free hydraulic analysis software program called EPANET 2 can be used. A transmission system or a rural distribution system can easily be modelled as a schematic model using EPANET 2 (see Level 3),
- However, a distribution network in populated areas probably requires a scaled model, which can be created on a scaled background map (e.g., satellite imagery with elevation contour lines) imported onto EPANET 2 (see Level 4).

Figure 10.15 explains how to calculate the friction pressure loss of a single pipeline using Hazen-Williams Formula on MS Excel.

< Hazen-Williams Formula in SI Units >

$$H = 10.666 * Q^{1.85} / C^{1.85} / (D/1000)^{4.87} * L$$

Wherein, H: frictional pressure loss (m), Q: flow rate (m^3/s), C: Hazen-Williams coefficient for defining roughness of pipes, D: internal pipe diameter (mm), L: pip length (m)

Calculation of Friction Pressure Loss using MS Excel

The below table (in an Excel Spreadsheet) shows an example of calculated friction pressure loss at one of the conditions shown in the figure above.

	A	B	C	D	E
1	Q: flow rate (m^3/s)	C: Hazen-Williams coefficient for defining roughness of pipe	D: internal pipe diameter (mm)	L: pipe length (m)	H: friction pressure loss (m)
2	0.0005	120	25	100	7.5

Enter this equation of the Hazen-Williams formula!

E2=10.666*A2^1.85* B2^-1.85*(C2/1000)^-4.87* D2

Figure 10.15: Calculation of Friction Head Loss in a Pipeline using Hazen-Williams Formula in MS Excel

10.3.6 *Pressure Reduction/Management with Relatively Small Investments* (e.g., PRV, BPT, etc.)

(**Note:** The procedure below is only for WSPs considering implementation of pressure management with relatively small investments)

1) Ensure that pressure reduction/management measures with relatively small investments listed in Table 10.3 below, such as sub-zoning with PRV and/or BPT, removal of bottleneck pipes, etc. (excluding large investments such as construction of distribution reservoirs and/or pump stations for large-scale zoning of distributing networks) are considered, planned and implemented for the identified problematic areas and pipelines having high pressure and/or many bursts (within zones prioritized for pressure measurement and reduction).

Table 10.3: Pressure reduction/management measures with relatively small investments

a) Replacement of pipelines experiencing high pressure with high-pressure rating (e.g., PN16) pipes effective for leak reduction (e.g., long rolled HDPE pipes)	
Better Pressure Control	b-1) Pressure reduction by installing PRVs (which are adjustable and capable of distributing water to the customers around them due to the residual downstream pressure but of high maintenance) and/or constructing BPTs (which are neither adjustable nor capable of distributing water to the surrounding customers due to zero residual downstream pressure but of relatively easy maintenance)
	b-2) Installation of a booster pump for a limited high area instead of using a high-head distribution pump for a large area encompassing the high area
	b-3) Prevention of water hammer in long pumped pipelines (e.g., installation of non-return and butterfly valves on the discharge pipe of pump, flywheel to the pump shaft, air inlet valve, air chamber, on-way surge tank on the pipeline, etc.)
c) Inclusion of high-pressure pipelines into a neighbouring zone having relatively low pressure by shifting the zone boundary with minor network modifications	

2) To reduce pressure without causing serious complaints of excessively low pressure in certain areas, ensure the following supporting measures are well considered (and implemented if necessary):

   (i) Removal of bottleneck or long pipes causing high pressure losses (especially pipelines going up hills) by replacing with larger pipes or augmenting capacity with additional pipes.

(ii) Removal of air trapped at high locations of pipelines (i.e., air lock) using additional air valves, etc.

(iii) Detection and repair of hidden large leaks causing localized large pressure drops.

3) Ensure that facilities improvement for pressure reduction are planned based on the following hydraulic considerations (in addition to pressure measurements and analysis of terrain around target pipelines using elevation contours):

(i) hydraulic calculation for pipeline with free software on smartphone (e.g., Water Project Calculator).

(ii) hydraulic analysis for multiple pipelines without loops using spread sheet (e.g., MS Excel).

(iii) schematic or scaled hydraulic modelling of pipe network with free software (e.g., EPANET 2).

4) Ensure that pressure measurements, identification of problematic areas, planning and implementation of pressure reduction measures are also carried out in other zones (that were not initially prioritized).

10.3.7 Pressure Reduction/Management with Relatively Large Investments

(e.g., Zoning with Reservoirs, Pump Replacement, etc.)

Note: This procedure is only for WSPs considering implementation of pressure management using relatively large investments

1) Ensure that the necessity of taking the following pressure reduction/management measures that require relatively large investments (that probably cannot be budgeted from the operational revenue of the WSP) are considered.

(i) Large-scale zoning of distribution pipes with additional reservoirs, elevated tanks and pump stations to limit elevation difference of each DZ.

(ii) Separation of distribution pipes from transmission pipelines to control pressure in distribution pipes or keep sufficient pressure in transmission pipelines even when a large amount of water is extracted directly from the transmission lines for distribution.

(iii) Replacement of existing pumps having excessive pressure head with pumps with suitable head.

2) Ensure that application of pressure reduction/management measures (using relatively large investments) deemed necessary through the above consideration are planned (including future water demand projection and rough cost estimates).

(**Note:** these relatively large investments should not be planned only for pressure reduction but also for improving zonal NRW monitoring, equalizing water distribution and resilience against risks such as power cuts, service areas expansion, etc).

3) Ensure that the planned improvements with relatively large investments are incorporated into the latest WSP's strategic plan (partly for seeking external funds) and/or into the tariff adjustment application of WASREB with required budgetary provision.

4) Ensure that the design, bill of quantities, detailed engineer's cost estimates and tender documents for the planned improvements are prepared for bidding.

5) Ensure that the planned improvements are implemented soonest or as funds permit.

Chapter 11

Cost-Benefit Analysis

11.1 Outline of Cost-Benefit Analysis

Cost-Benefit Analysis is the comparison of the change (increment or decrement) of the benefit from the current status.

It is probably fair to say that most utilities would benefit from an NRW management programme. However, the big question is usually the extent of the potential benefits. Therefore, it is important for water utilities to consider conducting Cost-Benefit Analysis when they are trying to determine the scope of the NRW reduction measures that should be implemented. Cost-Benefit Analysis will show the effects of the invested cost by comparing the benefit obtained with the cost invested.

Normally cost and benefit are correlative. Therefore, when more cost is invested, more benefit can be expected. In the application of NRW reduction measures however, when a certain level of low NRW ratio is achieved, the correlative benefit cannot be expected, no matter how much more cost is invested. This is usually observed around the NRW ratio of 15% although it depends on the conditions of the water utility.

In Kenya where the average NRW ratio is at 41% or above, the priority should be placed on bringing down the NRW ratio to the sector benchmark of 20%. Once a low NRW ratio of below 20% is achieved, then a detailed Cost-Benefit Analysis can be performed to assess whether injecting cost to NRW reduction measures is advantageous or not.

11.2 Cost of NRW Reduction Measures

For this purpose, the actual cost spent during the implementation of Pilot Project NRW reduction measures should be used. The following items and the costs associated with the items should be used as reference when extending the NRW activities to adjacent areas.

- Organizational maintenance cost: personnel cost, office maintenance cost
- Purchase of equipment and material and maintenance cost for equipment
- Cost of establishing DMAs/LMBs
- Cost for installing measuring devices
- Cost of servicing and testing/replacing all customer meters
- Cost of leakage / water theft control
- Cost of pipe replacement

Attention must be paid to the extent to which costs for renewal of facilities such as pipes and/or water meters are included, especially if regular or periodic facility replacement plan is not in place.

It is absolutely imperative to have a proper sustainable O&M guideline for any water utility to function well. Sustainable O&M measures should be obviously included in the ordinary facility replacement plans.

Adequate budget for the implementation of NRW reduction plan should be provided in accordance with the strategic objectives and prioritization of activities of the WSP.

Planning for facility replacement according to the ages of the facilities is the more suitable planning method, rather than including it as part of NRW reduction measures.

Facility replacement should therefore be considered as the duty of waterworks utilities, and not be included as part of NRW reduction activity. Cost-benefit analysis for NRW reduction measures should only include cost of those pipes requiring urgent replacement as a result of frequent numerous leaks.

Existence of pipes with frequent numerous leaks may be a reflection of the status of the utility.

11.3 Benefits of NRW Reduction Measures

The calculation of "benefit" for NRW reduction measures takes into consideration the volume of NRW reduction before and after the implementation of the reduction measures. Once the figures are obtained, either:

a) Profit from increase in volume of revenue water: - in utilities where water demand is much higher than distributed water, the volume of water saved as a result of implementation of the NRW reduction measures can be considered as increase in volume of revenue water. In other words, the water that is "saved" as a result of NRW reduction measures can now be tariffed water and considered as "benefit".

b) Raw water/treated water/profit from reduced cost of water distributed: - in utilities where volume of water distributed meets the water demand, the cost of producing the volume of water "saved" can be considered to be profit. Reduction in operational cost such as chemical cost and/or electricity costs associated with reduced production of water can be considered as "profit".

11.4 NRW Management Considering Cost-Benefit Performance

When estimating the economic value or cost/benefit of NRW projects, consider the following:

i) The additional revenue that will be generated owing to higher volume of water
ii) The reduction in operating costs that may occur
iii) Improvement in service delivery
iv) The cost of implementing the projects

It is strongly recommended that cost-benefit analysis should be conducted based on the results obtained from the Pilot Project. The results should then be extended to other adjacent areas. The purpose of conducting a cost-benefit analysis to obtain maximum effects and benefits. Through the cost-benefit analysis, the profit-loss break-even point is determined (Figure 11.1).

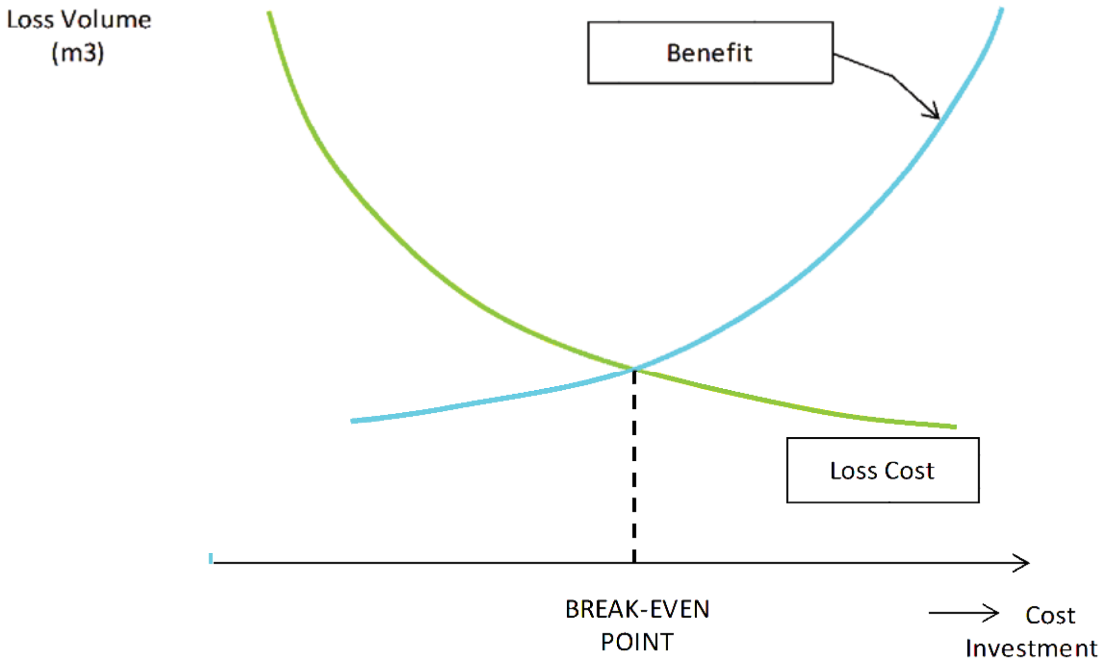


Figure 11.1: Graph of Cost-Benefit Analysis

The Graph depicts the cost-benefit analysis with the assumption that funds invested into NRW reduction measures are most effectively used when the funds are injected at the profit-loss break-even point.

In regard to the cost-benefit calculation, the figures may greatly change depending on the level of consideration that is placed on the cost and the benefit.

The most difficult point regarding calculation of cost-benefit is determining the extent to which the cost of leakage repairs and pipes replacement can be considered as NRW reduction costs. Decisions of this nature may highly depend on the policies and/or strategies of the water utility, because leakage repairs and pipes replacement are considered as part of the fundamental and mandatory operations of water utilities. For this reason, therefore, it is normal that only those costs associated with replacement of pipes that have numerous/frequent leakage occurrence are considered as part of the NRW reduction costs but costs associated with planned pipe replacement should not be considered as part of NRW reduction costs.

"Cost" for the cost-benefit analysis of the pilot project should reflect the amount of funds spent. In regard to the "benefit", the amount of benefit that was achieved by the implementation of NRW reduction measures must be calculated. Cost must then be compared to the benefit and the disparity must be checked. In most cases, the final decision on what NRW reduction measures to be implemented will be conducted based on the results obtained by cost-benefit analysis. In addition to the results obtained, there will be policy and/or strategy including political factors to be considered.

Such considerations are necessary because implementing the ideal NRW reduction measures require tremendous amount of funds and labour. It will be difficult for the majority of the water utilities in the developing countries to implement the full-scale activities. Often, items such as full-scale construction of DMAs are omitted from the activities to be implemented.

11.5 Example of Cost-Benefit Analysis

The following is an example of cost-benefit calculation of Embu WSP from the results of an implemented pilot project.

The real costs of implementing the project and real results (benefit) achieved are used in the example. The results should be used as a basis for preparing NRW reduction plans for adjacent areas within the supply area.

The performance data of the Embu WSP Pilot Project was:

- NRW ratio : 48%
- Total length of distribution pipe : Approx. 700 km to 1000 km
- Total number of connections : 5000 to 6000 connections
- Population served: 15,000 to 20,000 people
- The structure of Embu WSP NRW Reduction Measures Team was composed of: Supervising Engineer : 1 person
- Technicians : 4 people
- Skilled staff : 10 people
- Administration staff : 2 people

Table 11.1 to 11.3 provide an example of Cost-Benefit Analysis from a pilot project in Embu WSP.

Table 11.1: Cost Items (costs from NRW reduction measures)

Cost Item		Formula
1	Labour cost	Average salary x number of persons
2	Purchasing cost of materials and equipment	Unit price of leak detector, MNF measuring car, etc. x respective quantity
3	Construction cost of DMA and LMBs	Purchasing expenses of flow meters, pressure gauges and valves + construction expenses
4	Installation cost of trunk measuring equipment	Purchasing expenses of flow meters and pressure gauges
5	Replacement cost of malfunctioning customer meters	Purchasing expenses of customer meters
6	Office maintenance cost	Annual office maintenance expenses
7	Repair cost of leaks and illegal connections	Unit repair expenses of leaks and illegal connections x respective quantity
8	Pipe replacement cost	Unit replacement expenses of mains and service pipes x respective quantity

Note: Usually, most costs of No. 2, 3, 4, 5, 7 and 8 are considered as mandatory costs.

Table 11.2: Benefit Items (benefit from effects of NRW reduction measures)

Benefit Item		Formula
1	Profit from increase in revenue water	Unit sales price x Annual volume of increased water x no. of years accrued
2	Profit from reduced operating cost	Unit production cost x Annual volume of reduced leakage x no. of years accrued
3	Profit from postponement of development cost of new water resources	Unit cost of developing new water resources x Annual volume of reduced leakage
4	Profit from postponement of construction cost of new waterworks facilities	Unit facilities construction cost x Annual volume of reduced leakage

Table 11.3: Calculation (Cost-Benefit Analysis)

Cost (for 3 (three) years)	
Cost of staff related with NRW reduction	14,490,000
Cost of pipe replacement (including construction cost)	1,750,000
Cost of meter replacement	949,000
Sub-total of Costs	**17,189,000**
Benefit	
Reduced volume	434,472
Unit price of water tariff	65
Sub-total of Benefits = KShs (434,472x65)	28,240,680
Profit over 3 yrs (= 28,240,680 - 17,189,000)	**1,105,680**

Chapter 12

Example of Workflow in a Pilot Project

⇔ WASPA's NRW Roadmap

12.1 Basic and Pilot Activities

The proposed roadmap includes 4 main components

1) Raise company-wide awareness and support (aimed at capturing the attention of the management on the magnitude of the Water lost both as % and volumes and appoint a task team with duties and responsibilities to carry-out the defined duties).

2) Obtain a clear picture of the NRW problem for the entire company (This activity is meant to showcase insights of underlying issues and the proposed response strategies).

3) Divide the NRW problem into manageable pieces and conduct pilot NRW reduction measures. The step-by-step implementation of activities should be tracked, starting with selection and isolation of prioritized area. Implementation of activities and daily monitoring on the focus area should be sequenced to ensure reduction and sustainability are clarified well.

4) Prioritize response measures in a Performance Improvement Plan. (The pilot serves to make a business case for scaling up the demonstrated approach to the entire supply area. A Performance Improvement Plan (PIP) that is well aligned to the corporate goals should highlight priorities on the basis of their contribution to the achievement of corporate objectives and anticipated results) refer to WASPA Roadmap to NRW Reduction athttps://rb.gy/rdwmlo

12.2 Preparation (Basic) Activities

12.2.1 Selection of Priority Areas (DZ or DMA)

Selecting a pilot DMA

The general characteristics of a supply system are important aspects to be considered for the selection of a pilot DMA. The understanding of the water source, means of supply/distribution (gravity/pumping) as well as the system characteristic (continuous/ intermittent) should inform the selection.

Important criteria for selecting a pilot area include:

- “High NRW’ area (suspected commercial and/or physical losses)
- Manageable number of connections (about 500 connections)
- Relative ease of isolating the DMA with as few district meters as possible (i.e., clear out-skirts of distribution network and if possible, with minimum number of bulk meters)
- 24/7 water availability (since lack of water/low pressure levels undermine reliability of meter readings and the subsequent water balance calculations and night flow measurements)

12.2.2 Isolation of the Pilot Area

Zoning of the supply area

Since acting in the entire supply area at the same time is impossible, the area should be divided into manageable pieces. The most important criteria for zoning are:

- topography and water pressure
- pipeline network layout (i.e., natural DMA catchments and NOT administrative boundaries)
- number of customers (500 to 1,500 connections per DMA)
- water availability

Isolate the pilot DMA (while developing the block map)

At the start of the pilot project, the NRW team requires to:

a) Install meters and valves in tamper-proof chambers on all incoming lines (into DMA) and outgoing lines (from DMA) and,

b) Verify which consumers are (and are not) supplied by the incoming lines (by closing valves and verifying whether or not they still receive water) and deliberately including (or excluding) them in the DMA water balance calculations.

12.2.3 Customer Identification and Visual Meter Inspection

Door-to-door consumer and meter survey

This survey serves to:

a) confirm/link consumer data in the field with billing data and update consumer details (name, telephone number, email) and meter details (brand, type, size, material, date installed, serial number, GPS coordinates7), and

b) identify and address potential meter by-passes and illegal connections.

12.2.4 Monthly Bulk Meter Reading & Initial NRW %

Zero reading of all district and consumer meters followed by a second reading two weeks later to establish the NRW baseline value

a) To optimize the accuracy of the water balance calculation, it is recommended that all valves on incoming and outgoing lines be closed before reading all district and consumer meters (on day 1 and day 16), before resuming the supply

b) Subject to the reduced NRW levels in a given month, two-weekly or monthly readings will suffice depending on the scope of the NRW reduction measures taken or planned – the impact of which can be evaluated on the basis of the next two-weekly or monthly water balance calculation.

c) Daily monitoring of DMA consumption levels (e.g., done in Meru & Nyeri) serves as an early (leakage) warning tool, while monthly monitoring of consumer specific consumption levels serves to identify outliers requiring in-field inspection of potential meter inaccuracies or illegal consumption.

12.2.5 Customer Identification and Visual Meter Inspection

Door-to-door consumer and meter survey

This survey serves to:

a) confirm/link consumer data in the field with billing data and update consumer details (name, telephone number, email) and meter details (brand, type, size, material, date installed, serial number, GPS coordinates7), and

b) identify and address potential meter by-passes and illegal connections.

The result: new billing system entries and/or cleaned-up double or ‘ghost’ entries.

12.2.6 Mapping of Customer Meters & Distribution Facilities

Initiate the mapping and collection of attribute data for all assets

Required for:

a) the system as a whole to demarcate DMAs), and

b) the pilot area i.e., showing incoming/outgoing DMA meters, valves, service connections/meters, etc.

Basic steps in reducing and sustaining NRW levels in the pilot DMA

This involves implementing activities pertaining in all 4 categories of commercial and physical losses (Figure 12.1).

The sequence of the proposed steps naturally speaking focusses on addressing ‘quick wins’ first i.e., meter inaccuracies, meter reading data collection and entry reliability, unauthorized consumption (commercial losses) and visible leakages (physical losses).

Key activities in the (pilot) DMA(s) include: -

a. Zero reading of all district and consumer meters followed by a second reading two weeks later to establish the NRW baseline value.

b. Repair all visible leakages and pressure level measurement/management

c. Door-to-door consumer and meter survey

d. Testing and calibration of production and district meters

e. Testing and servicing/replacement of all faulty and under-registering consumer meters

f. Reduce the number of gate-locked cases

g. Inspect all ‘disconnected’ consumers and ‘dormant’ connections

h. Minimum Night Flow (MNF) measurements (entire DMA) and step testing (DMA branches) to quantify and localize invisible leakages

i. Improve the speed and quality of repairs

j. Improve the quality of materials

k. Daily monitoring of DMA consumption levels monthly monitoring of customer specific consumption levels.

Implement the ‘full-scale’ NRW reduction/management activities in a pilot DMA

The main purpose of this activity is to demonstrate how the piloted NRW reduction/ management approach can be scaled up to other District Metering Areas.

The four internationally (IWA) recognized categories (and related response strategies) for both commercial and physical losses are presented below: -

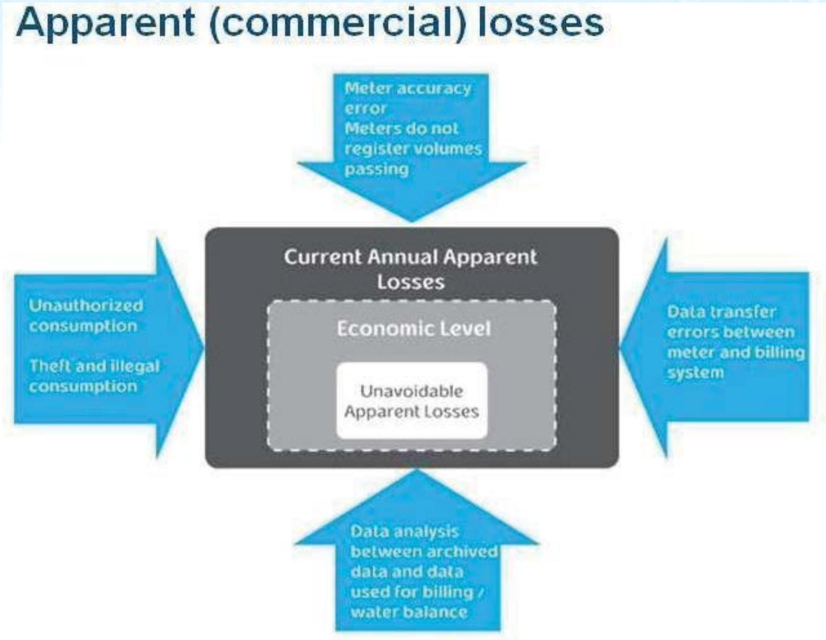


Figure 12.1: Components of apparent (commercial) losses

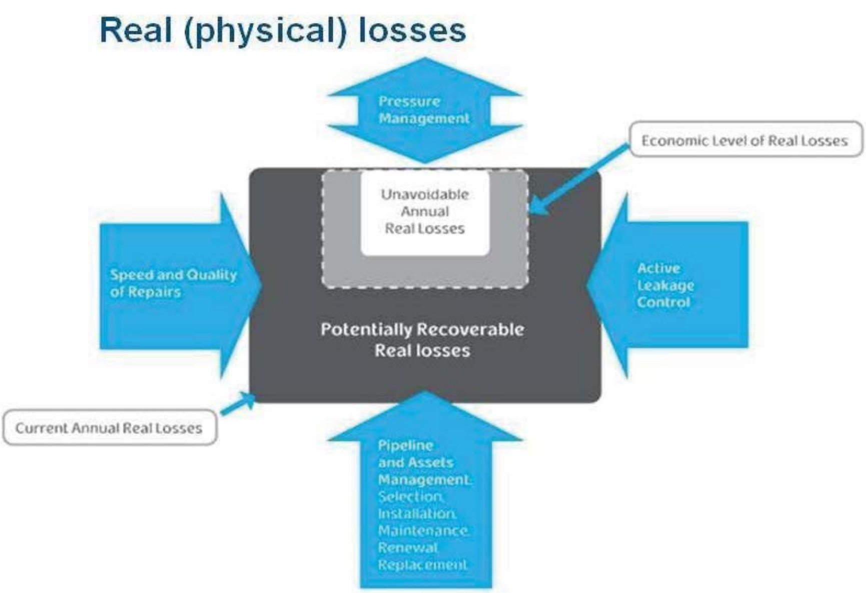


Figure 12.2: Components of real (physical) losses

12.3 Relatively Low-cost and/or Easy (Basic) Activities

12.3.1 Repair of Surface Leakage

a) Visible leakages repair and pressure measurement/management

As part of the longer-term objective to develop a comprehensive asset management strategy, this activity involves the development (or refinement of existing) line patrolling and/or leak identification and reporting procedures. The assessment and management of pressure should be included as part of this activity.

b) Improve the speed and quality of repairs

While most WSPs have established leak reporting procedures, very few actually analyse the leakage trends (number in time, number per zone, number per pipe size, number per cause), locations (so as to identify recurrent leaks that point to dilapidated infrastructure, poor quality material and/or poor-quality repairs) and accurately record the time of leak discovery and repair (the basis for evaluating the speed of repairs)

c) Improve the quality of materials

Most WSPs have taken deliberate steps to improve the quality of materials, e.g., by using:

- Class D or even Class E PVC for transmission mains - an improvement from the lower PVC Classes used by the Municipal Councils in earlier years and,
- PPR (6m pipes e.g., Nakuru WSP) or HDPE (100+ meter rolls e.g., Nyeri WSP) materials for service connections.

Nonetheless, (recurrent) leaks are often caused by a combination of the following factors:

- Quality of repair: classic examples include poor quality PVC connections glued under wet conditions in the absence of upstream control valves and/or the absence of appropriate fittings between pipes of different materials and sizes,
- Quality of materials: Class C (or lower) PVC pipes that are vulnerable to high pressure
- Other factors: exposed lines due to shallow depth of installation/erosion/poor backfilling and, direct & ‘spaghetti’ connections to transmission mains.

12.3.2 Improvement of Customer Meter Registration and Reading

Meter Reading

Improvement of customer meter registration and reading needs to consider the following:

- Optimization of meter reading routes and workload (e.g., meters/day) for teams and individuals by, e.g., using Google Earth.
- Use of 'rotational' meter reading method or 'motivational' (caretaker) meter reading method
- Combination of meter reading, consumer contact information validation, scanning for (potential) illegal connections etc. in one data collection sheet.
- Sample-based verification of meter reading accuracy by independent staff; e.g., the NRW coordinator.
- Retroactive billing of gate-locked consumers based on meter testing variance with the reading.

Note: validation of samples of reported consumer meter readings, meter reading entries in the billing system, 'gate-locks' (12.3.5 (a), disconnected consumers and dormant connections (12.3.5 (b) by the NRW Coordinator or other (independent) technical staff can serve to keep meter readers on their toes and minimize (potential) consumer-staff collusion.

Transfer of Meter Reading data

- Use of data loggers to minimize transfer (wrong accounts) and consumption (volume) errors.
- Verification of a sample of meter reading data entries in the billing system by independent staff e.g., the NRW coordinator.

12.3.3 100% Metering & Replacement of Obvious Faulty Meters

100% metering of all consumers is essential in determining the actual NRW level and calculate the percentage commercial loss.

Testing and servicing/replacement of all faulty and under-registering consumer meters. The analysis of the causes of faulty and under/over-registering meters (dirt, sub-standard specifications, sub-standard quality, age) and locations of leakages are important for a comprehensive asset management strategy.

Note 1: meter testing can be combined with the door-to-door consumer/meter survey.

Note 2: by monitoring the consumption patterns of individual customers (zero and/ or low consumption connections) (e.g., based on DMA averages), specific customer meters can be identified for inspection.

12.3.4 Meter Accuracy Test and Replacement of Inaccurate Meters

Meter accuracy

- 'Quality assurance' through rigorous technical specifications (e.g., accuracy of low flow measurement) in the procurement process and validation of compliance upon delivery.
- Use of strainers to minimize damage to mechanical meters as result of poor water quality (e.g., little stones damaging impellers).
- Testing of small diameter meters with portable meter testing kits, test-meter in series or meter testing benches e.g., every 3 years and/or triggered by client specific consumption monitoring after installation/servicing/replacement.
- Testing of large diameter (production and district) meters with Ultrasonic 'clamp-on' Flow Meters e.g., every 3 months.
- Sealing of tested meters to prevent future tampering.
- Backdated billing of over/under-registering meters based on the testing variance.

12.3.5 Identification and Prevention of Illegal Uses

a) Reduce the number of gate-locked cases

This activity requires the team to pro-actively engage 'gate-locked' consumers through phone/SMS/email and (subsequently) disconnect non-compliant consumers. In doing so, the number of bills based on estimates and (potential) water theft can be reduced. This serves to improve water balance accuracy and revenue collection.

b) Inspect all 'disconnected' consumers and 'dormant' connections

This activity aims to minimize (potential) water theft by verifying that disconnected customers are not consuming water illegally and dormant connections are not receiving water (again).

c) Provide rewards for information that lead to discovery of illegal connections.

Many companies reward consumers and/or staff for providing information leading to identification of illegal connections e.g., Kshs 10,000 (Nyeri). Examples of disincentives to consumers include Kshs 15,000 fines for illegal connections/by-passes and back-dating of bills by 24 months (Nakuru).

12.4 Relatively High-cost and/or Difficult (Pilot) Activities

12.4.1 Use of specialized equipment

Some utilities have the Specialized NRW equipment.

WASPA acquired some equipment under PEWAK program. The equipments are availed to WSPs on hire. WASPA also provides training on their use for effectiveness.

KEWI, being a member of the JICA program, formulated a training course on use of NRW equipment for interested WSPs using the equipment procured under the program. WSPs with practical experience in daily use of the equipment should ensure that the acquired skills are utilized for RW reduction/management activities.

12.4.2 Detection and Repair of Underground Leakage

(a) Minimum Night Flow (MNF) measurements (entire DMA) and step testing (DMA branches) to quantify and localize invisible leakages

MNF measurements serve to quantify the invisible leakages by measuring the flow into a DMA branch when consumers are asleep (i.e., between 12.00am and 4am) and consumption has dropped to a bare minimum, The prevalence of premises storage tanks and their filling time (if at all at night) should be taken into account.

The lost volume due to invisible leakages can be detected by conducting MNF measurements on DMA branches, thus enabling trained staff to locate the leak with specialized equipment (listening sticks, ground microphones, leak noise correlators, etc.).

Note: the location of distribution lines, valves and other assets must be known (mapped) for planning and implementation of MNF and step-test measurements.

12.4.3 Water Pressure Control

Pressure management

- Measuring and monitoring high pressure in suspected areas.
- Use of PRVs/BPTs to lower pressure and minimize water losses (Nyeri, Meru, Embu).

12.4.4 Replacement of Distribution & Service Pipes Aspects (26) & (27)

a) Improve the speed and quality of repairs

While activity 12.3.1(a) focuses on the repair of earlier unnoticed/unreported visible leaks and activity 12.4.2(a) focuses on the identification and repair of invisible leaks within the (pilot) DMA. This activity aims to assess, evaluate and improve the speed and quality of repairs for the supply area as a whole.

While most WSPs have established leak reporting procedures, very few actually analyse the leakage trends (number in time, number per zone, number per size, number per cause and locations to identify recurrent leaks that point to dilapidated infrastructure, poor quality material and/or poor-quality repairs) and accurately record the time of identification and repair (the basis for evaluating the repairs speed).

b) Improve the quality of materials

Most WSPs have taken deliberate steps to improve the quality of materials, for example by using:

- Class D or even Class E PVC for transmission mains - an improvement from the lower PVC Classes used by the Municipal Councils in earlier years, and PPR (6meter pipes e.g., Nakuru) or HDPE materials (100-meter rolls e.g., Nyeri) for service connections.

12.4.5 Introduction of Smart Customer Meters

Smart meters or Automatic Meter Reading (AMR) gadgets continuously transmits the readings to a receiver such as a computer. The data can then be used for billing, customer consumption pattern analysis, etc.

Some WSP’s have adopted the technology, which has its Pros & Cons.

WSPs are advised to try on pilot basis before going full scale which would be a substantial investment.

12.5 Evaluation for Expansion of Activities

12.5.1 Confirmation of Reduced NRW (%) & MNF

By conducting MNF measurements on the incoming line(s) after identifying/repairing all visible leakages (assuming there is no authorized unbilled consumption), the remaining commercial losses can be estimated by subtracting the MNF volume from the total NRW volume.

12.5.2 Analysis of Effective Measures

To monitor and evaluate the extent to which activities have contributed to the achievement of the corporate objective of NRW reduction, (among others), regular reporting on prioritized Performance Indicators (PI's) is a must:

a) Current status: progress vis-à-vis the PI baseline value and target.

b) Time frame: Progress vis-à-vis set timelines.

c) Strategy and actions: Evaluation of the effectiveness of the adopted strategy and actions to achieve the set PI target(s).

d) Budgets: Budget utilization and refinement.

e) Other needs: Supplementary requirements pertaining to staff (e.g., NRW team capacity, training), equipment (e.g., leak detection) etc.

f) Risks: Foreseen and emerging risks of pursuing individual/parallel NRW reduction measures.

g) Partner WSP(s): to contact/visit for benchmarking and learning.

12.5.3 Expansion of Activities to Reduce Overall NRW Ratio

a) Documentation of the action-learning process and results is crucial.

- Increase the understanding of the main causes and contributions of commercial and physical losses to the total 'volume of water and money lost',
- Refine the response strategy based on emerging evidence as to what works and what does not, and
- Future up-scaling efforts.

b) Develop a business case for scaling-up the demonstrated approach to other supply zones

The business case must be preceded by an up-scaling strategy that spells out the sequence of activities to:

- Quantify and localize (the highest) NRW losses through zoning of the entire supply area (as was done for the pilot DMA),
- Replicate the piloted approach to: (a) DMAs with the highest NRW losses - NRW baseline volumes established through water balance calculations, or (b) DMAs identified on the basis of other criteria (if the entire network has NOT yet been divided into DMAs)

- Gradually develop and implement a comprehensive asset management strategy that considers all aspects of asset selection (e.g., choice of material), installation (e.g., depth of distribution lines, quality of connections), maintenance, renewal and replacement.

Informed by the results from the pilot and 'up-scaling' DMAs, the business case serves to project the additional costs and anticipated revenues of the NRW reduction/management activities for endorsement by the Management Team and Board of Directors.

c) Organizational measures

Organizational measures that positively contribute to the achievement of any overall objective, including NRW, are presented below:

- **Agreeing on roles and responsibilities**

It is important to clearly define the roles and responsibilities of all stakeholders in the process. This creates a common understanding of each person's envisaged contribution and underpins the collaborative effort towards achievement of a common goal.

- **Organizing planning and review meetings**

While weekly team meetings help to keep staff focused, emerging issues should be discussed on a day-to-day basis as they arise. An open-door policy by top and mid-level managers further allows lower cadre staff to voice their (possibly divergent) opinions and provide suggestions based on experience on the ground.

- **User to be part of Inspection and Acceptance Committee**

The integrity of the Inspection and Acceptance Committee (I&AC) must be held high. Deterrent measures for corrupt (I&AC) members, including surcharge and loss of job. Maintain transparency in all procurements.

- **'Caretaker approach'**

Experience in supporting water utilities to reduce NRW levels world-wide has led M/S Vitens Evides International (VEI), a Dutch company, to develop and promote a 'caretaker approach' in which a dedicated area manager, referred to as a 'caretaker', is given the responsibility to lead a joint (commercial/technical team) effort to reduce and sustain NRW achievements within a designated DMA. This arrangement ensures that NRW reduction/management activities are embedded in the organizational setup.

Competitions between zonal and/or DMA teams should be encouraged.

Documentation of the action-learning process and results is crucial to:

a. Increase the understanding of the main causes and contributions of commercial and physical losses to the total ‘volume of water and money lost’,

b. Refine the response strategy based on emerging evidence as to what works and what does not, and

c. Future up-scaling efforts while focusing on quick wins, medium and longer-term objectives requiring action now must also be considered. A comprehensive asset management and development strategy, for example, requires unknown distribution lines and valves to be identified and mapped, attributes (e.g., size, material, depth, date of installation) to be registered etc.

Chapter 13

The Project for Strengthening Capacity in NRW Reduction in Kenya (JICA, 2016-2021)

A Summary of Experience from Output 4 of the Project

13.1 Introduction

Non-Revenue Water reduction is one of the fields in which many water utilities have been struggling to improve in low-income countries. It is also the field in which international aid agencies are struggling to find effective support because the methods of NRW reduction used in high-income countries are often incompatible with or inadequate for the conditions in developing countries.

Unlike water utilities in advanced countries, water utilities in developing countries are likely to face:

- scarce budgets for NRW reduction,
- intermittent water supply conditions,
- disorderly distribution networks,
- recurrent and chronic water theft, etc.

These situations often make adoption of the technical skills from advanced countries ineffective or unsustainable. Moreover, the number of water utilities which an aid agency can directly support in each target country is limited. In addition, the water utilities targeted for assistance by the aid agencies on NRW reduction have more serious immediate concerns, which is - “performance over the entire service area”; and not only small areas like a pilot DMA that is often created during the projects.

Even though the ultimate goal of these projects is to create a nation-wide impact for effective NRW reduction, the available resources for NRW reduction are of course inadequate on both sides (i.e., the aid agency’s’ project period and human resource are limited; while the water utilities in low-income countries often lack adequate budget and other resources).

The main question is: “How is it possible, with the limited resources, to achieve a nation-wide NRW reduction under the difficult conditions in developing countries?”

This chapter intends to provide some potential answers to this question based on recent experiences of the project in Kenya. The alternative strategy presented here is to target the entire distribution service areas of each water utilities from the beginning instead of investing heavily in one or a few pilot areas first.

JICA started implementing the “Project for Strengthening Capacity in Non-Revenue Water Management” (the Project) in Kenya from October 2016. The project aimed to support Kenya to reduce the national NRW ratio from 42% in 2015 to 30% by 2030.

This was through provision of technical assistance to nine large and medium size water utilities in Eldoret, Kisumu, Nakuru, Nyahururu, Mavoko, Ruiru-Juja, Embu, Meru and Kilifi-Mariakani. Targeting nine water utilities as pilot utilities was quite ambitious for JICA's NRW reduction technical cooperation projects, which usually target one to three utilities.

The alternative strategy adopted in this project on handling the nine utilities may provide some possible answers to the question above.

In addition, this Project had the aim of establishing a NRW reduction support mechanism at the national level, thereby which would strengthen the roles and capacity of the relevant national agencies. The supporting mechanism included the long-term NRW public sensitization in the form of water education, which is related to the alternative strategy and is discussed at the end of this introduction.

First, we shall explain the conventional strategy often adopted by international aid agencies in NRW reduction in developing countries. We shall then discuss the alternative strategy adopted with the nine water utilities.

Aid agencies often promote NRW reduction activities isolating small areas as pilot projects as an initial step to figure out which NRW reduction activities are effective, while at the same time providing various OJTs for underground leak detection, meter accuracy tests, etc, before expanding the effective activities over other areas of a utility. However, the activities tried in the pilot area are very often never expand to other areas because of several reasons:

- Largely, the activities conducted in the pilot area are often too expensive and/ or too complicated to be expand to other areas without additional budget by the utility or support from the aid agencies.
- Efficient expansion of activities from the limited pilot area to larger areas usually require other or additional skills which are often not taught in pilot activities.
- Difficulties in detecting underground leakage and, especially, in evaluating leaks under intermittent water supply conditions are also major reasons for the failure to expand. These difficulties are never taken into consideration.
- Difficulties in isolating DMAs especially when the distribution network is complicated and/or not properly documented.
- Difficulties in sustaining the accuracy of the bulk meters and in factoring the seasonal fluctuation of NRW ratio (noted mainly under intermittent water supply conditions, which makes evaluation of activities in pilot areas very difficult).

Since it was realised that the chances of effectively expanding and evaluating the various activities often tried out in pilot areas is low, the Project limited the activities in the pilot areas to underground leak detection only (only if the water supply was continuous) on trial basis and; pressure reduction (only if high pressure was a priority) as a way of efficiently utilizing the available resources.

To implement the two activities as well as evaluate their effects, hydraulic isolation of the target areas is necessary. By taking this approach of implementing limited activities in the pilot areas, the Project was able to allocate resources, mainly the consultants' time, to the alternative strategy of targeting the entire service area from the beginning.

Various methods were developed under this strategy to reduce both commercial and physical water losses; and tried out in the nine water utilities. Some of the methods failed while others worked very well. As a result, five out of the nine utilities had significantly reduced their overall monthly NRW ratio by between 10 and 15% over a period of 12 to 24 months before the time of the Project interim report in 2019.

One of the most effective methods of this strategy was the analysis of the monthly meter readings and billing data for all the customers over a period of 12 or more months in each pilot water utility. The results revealed that a huge portion of their customers were billed based on estimated water consumption even though almost all the customers had meters installed. The findings were presented to the managers as well as the staff of the technical and commercial departments of each utility. As a result, everybody in the utilities realized that many meters, even of large water consumers, had stalled or stopped for a long time, thus creating a huge and continuing revenue loss.

After extensive discussions on the malpractices in meter readings and billing that were exposed through the analysis, the pilot WSPs were strongly urged to use their limited resources to prioritize on large customers regardless of their location.

The other successful method used in the Project was the introduction of innovative templates for capacity assessment, annual and medium-term planning, performance monitoring and review.

Several methods were also developed using smartphones, mobile and cloud GIS and also data collection and video software to efficiently expand the various activities over the entire distribution service area.

In addition to assisting the nine WSPs, the Project also aimed at establishing a NRW reduction support mechanism for water utilities at the national level. The NRW Unit of the MWS&I was encouraging water utilities to engage in systematic and long-term sensitization activities to the public on NRW.

One of the activities was water education for schools within WSPs' service areas. This is where pupils are invited to learn about water treatment and the cost of water production. Embu WSP has been inviting grade 6 or 7 pupils to their water treatment plant for some time. The objectives of inviting students are: to enhance their knowledge on water production and the role of the water company and to sensitize their parents and relatives on the importance of water conservation and NRW reduction through the pupils. After the visit, the pupils were encouraged to discuss about what they learned during the visits with their family and practise water conservation at home. The gradual education of customers through their children can enhance the nation-wide reduction of NRW in Kenya where water theft, meter theft, visible leaks, etc. are still common though the effect may not show quickly. Many people still believe that provision of safe water does not cost money and therefore water should be free. Thus, investing in children (living in WSPs' service areas) by offering water education can be a complimentary method to the alternative approach for immediate expansion of the various activities to the entire service area.

Other effective approaches for NRW reduction that were developed under the project are discussed in details in the following sections.

13.2 Strategies to Solve Problems

Problems related to NRW reduction were identified at each Pilot WSP through baseline survey and specific strategies used to deal with the problems while conducting NRW reduction activities. The following strategies, which are only part of a large number of NRW reduction activities, were confirmed as effective through the project activities conducted so far.

13.2.1 Expansion of Activities targeting the Entire Service Area

In order to realize a quick large-scale reduction of NRW, NRW reduction activities that are relatively easy to expand (e.g., identification of unbilled customers, ensuring and sustaining meter accuracy for large customers, patrolling for visible leaks, standardization of service connections, etc.) were prioritized for expansion over the entire service area. As a result, 5 Pilot WSPs (Kisumu, Nakuru, Nyahururu, Ruiru-Juja, and Eldoret) managed to reduce their NRW significantly. Meanwhile, the effectiveness of leak detection and pressure reduction in the distribution network, which are more effectively if implemented in hydraulically isolated areas, were confirmed at DZs (or DMAs) selected as pilot areas before expanding to other areas.

13.2.2 Support for Voluntary Restructuring and Strengthening of the Organization

Each Pilot WSP was encouraged to strengthen their organization (e.g., by engaging the commercial department in NRW reduction activities and/or increasing the NRW Unit staffing) through the activities (e.g., frequency analysis [by customer category] of estimated billed consumption [due to faculty meters, etc] and planning of activities based on capacity self-assessment) by involving the entire WSP or its multiple departments. As a result, organizational strengthening was implemented by 4 WSPs (Embu, Kisumu, Nakuru and Eldoret) while similar efforts were going on at another 2 WSPs (Ruiru-Juja and Kilifi-Mariakani).

13.2.3 Ensuring Credibility of Universal NRW Ratio

Abnormal fluctuations of NRW ratio caused by faculty bulk meters can be checked by analysing the changes in monthly NRW ratio and other main performance indicators over the previous few years. Problems with production bulk meters or those used to calculate the total supply volume should be resolved as early as possible. The accuracy of the most important bulk meters in Embu WSP was improved while similar improvement was going on in Meru and Kilifi-Mariakani WSPs.

On the other hand, one strategy failed to work as initially expected.

Initially, an interactive electronic form was created to guide the Pilot WSPs through some activities related to problems around customer meters (e.g., faulty meters, water theft, leaks on service connections). However, although the form was being continuously improved to accommodate as flexibly as possible the differences in WSPs' organizational setup, work flows and prioritizations, it reached a point where these improvements could not accommodate all the requirements. Therefore, instead of using the same form for all WSPs, each Pilot WSP started developing its own electronic form for each activity to suit its needs.

Moreover, NRW reduction activities such as those that take place around customer meters were, at the beginning, grouped based on their location to enable handling of multiple activities together. However, these activities were later regrouped based on their technical fields. Other problems and strategies are explained in the subsequent sub-sub-sections based on the categories used to regroup NRW reduction activities.

13.2.4 Capacity Assessment for NRW Reduction Plan Preparation

Pilot WSPs had managed to prepare their medium-term and annual NRW reduction plans for the previous 3 years. However, the assessment of the current conditions, which is necessary before planning, was initially not adequate. Therefore, for the third year, a list of about 250 points, which can display the assessment results automatically on a graph, was developed as a template for capacity self-assessment (with a checkbox function and MS Excel formulas). The template was developing with checkboxes because it seemed that not many WSPs in Kenya can adequately assess their capacity on the basis of the existing guidelines and report its findings without assistance.

13.2.5 GIS Development and Zoning

The development of GIS database for three Pilot WSPs was started from scratch while the project supported improvement of the existing GIS database for the remaining six Pilot WSPs. Two out of the three WSPs continued using their newly developed GIS databases on a continuous basis for NRW reduction activities.

Planning for Zoning of distribution systems (the entire service area) into separate DZs (and DMAs when required) was carried out for seven of the Pilot WSPs. At each of these WSPs, it was planned that separation of the distribution zones would be implemented gradually.

Meanwhile, the Pilot WSPs were facing difficulties in expanding their leak detection activities over the entire service area, which is often a mixture of areas of continuous and intermittent supply. Since the methods suitable for leak detection depend on the water supply condition, the current or near-future water supply condition of each DZ and DMA were mapped on GIS at three Pilot WSPs. Thereafter, the areas where different leak detection methods are applicable were discussed with the help of the GIS map to gradually expand leak detection activities.

The sustainability and expandability of the leak detection methods taught by the JICA Experts during OJTs were expected to improve through this type of support.

13.2.6 Monitoring of NRW Reduction Progress

Monthly meetings between the various departments on NRW reduction have become more common in Pilot WSPs following the start of this project. However, the effects of their NRW reduction activities can be quite difficult to distinguish especially when the data used in the meetings is limited and shows changes in NRW ratio over just a few months. This is because NRW ratio often fluctuates a lot on seasonal basis. Therefore, in order to distinguish between the effects of NRW reduction activities from seasonal fluctuations, it is recommended that WSPs should analyse the following 3 types of monthly data over at least the last 3 years:

- Supplied volume,
- Billed consumption,
- Revenue from billed water (Kshs)

4 indicators should be calculated from this monthly data and displayed on a single graph with the graph being updated every month. These are:

- NRW ratio, Volume of NRW = Supplied Water - Billed Consumption
- NRW ratio (%) = volume of NRW x 100 / Supplied Water volume
- Average Tariff of water billed = Billing for Water / Total Billed Consumption
- Potential Revenue Loss due to NRW = Average tariff x [Supplied Water - Billed Consumption])

13.2.7 Measures against Commercial Water Losses

The monthly meter readings and billing data of all the customers for at least 1 year were analysed at each Pilot WSP to determine the frequency of using estimated consumption for billing. The results were that Ruiru-Juja WSP had the highest frequency of using estimated consumption for billing. After the WSP increased the number of meter readers and replaced many faulty customer meters, a large increase in t revenue from billed water was realised.

To a large extent, Kisumu and Nakuru WSP also successfully reduced their NRW ratio by strengthening their strategy against large customers. Eldoret WSP, which had many large customers, also targeted large customers in an effort to improve customer meters accuracy and deter illegal connections with substantial support from the managers.

Meanwhile, requests for support in evaluating the recent improvement in meter readings and billing through repeat analysis were made by some WSPs. However, analysis on data spanning 12 months or more is quite tedious and time consuming for WSPs. Therefore, a simplified analysis method that uses only two-month data (one data before and another after the improvement) developed and applied for 3 WSPs.

13.2.8 Measures against Physical Water Losses

Minimum night flow (MNF) measurements and step tests were applied in one or more pilot areas selected at each Pilot WSP to determine the level of the existing leakage and the areas having large amounts of leakage. Leak detection was conducted in these areas based on the results of the two measures. However, it is difficult to conduct accurate MNF measurements and understand the level of leakage under intermittent supply conditions.

Meanwhile, leakage once reduced in the pilot areas often increases again over time. Therefore, data on hourly fluctuation of water flow under intermittent supply and the trend of recurring leaks after leak detection were collected and analysed at a few Pilot WSPs to assess how to improve leak detection activities.

13.3 Results of Implementing the Strategies

[Planning and Implementing Realistic NRW Reduction Activities for Each WSP]

13.3.1 Preparation of NRW Reduction Plans and Self-Capacity Assessment

Assessment of a WSP's current capacity is necessary for preparation of a NRW reduction plan. In order to improve the assessment, a list of about 250 points on a template was developed. The template was simplified by providing checkboxes to be used for the capacity self-assessment. The template groups all the activities and attributes of NRW reduction into 4 large categories, 14 sub-categories and 33 sub-sub-categories. By clicking the checkboxes, the achievement level in NRW reduction at a WSP can be calculated and displayed on a graph.

Moreover, each WSP can set its NRW target levels for the next 1 to 5 years and the improvement priorities on each sub-sub category of the assessment. The target levels and the achievement levels are displayed on the same graph to ease the next planning process. Trials on using the template are now complete. Use of the template to formulate NRW reduction plans and to share the plans within each WSP has become more efficient.

This template enabled all the Pilot WSPs to update their medium-term plans and to prepare the annual plans for NRW reduction for the year 2019 based on the results of a comprehensive capacity self-assessment.

Figure 13.1 shows the results of Nyahururu WSP's self-assessment of its current situation.

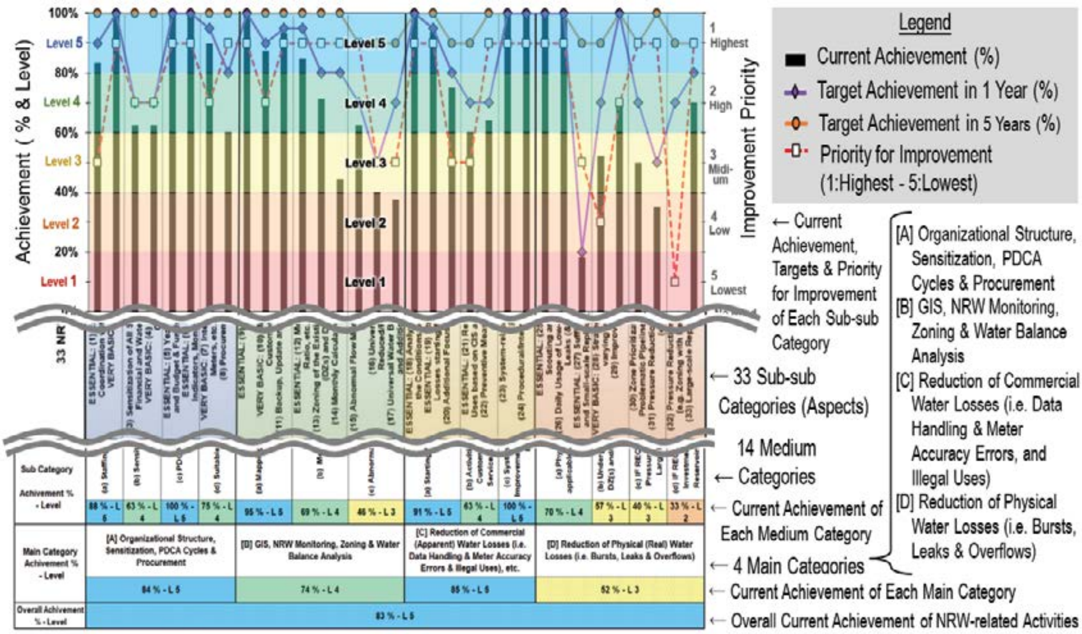


Figure 13.1: Results, Targets & Improvement Priority of the Self-Capacity Assessment at Nyahururu WSP

13.3.2 GIS Development and Zoning of Distribution Systems

The mix of continuous and intermittent water supply areas at each Pilot WSP makes it difficult for them to visualize how to expand leak detection activities over the entire service area. It is therefore important for WSPs to discuss and determine the current and near-future water supply conditions in the current and planned DZs and DMAs on GIS.

Figure 13.2 shows Ruiru-Juja WSP's expansion plan of leak detection activities for areas with a mix of continuous and intermittent supply. The plan was developed based on their DZs and DMAs plan of the entire service area. Areas of continuous supply where step tests can be used for leak detection are shown in red while areas of intermittent supply, which are a high priority for leak detection are shown in blue. Previously, the WSP had difficulties in selecting the pilot areas suitable for leak detection methods taught in OJTs. This hampered the efficiency of their capacity development and leak detection activities. Higher perspective use of GIS based on their zoning plan improved selection of the pilot areas, thereby making the OJT more meaningful and expansion of leak detection activities more sustainable.

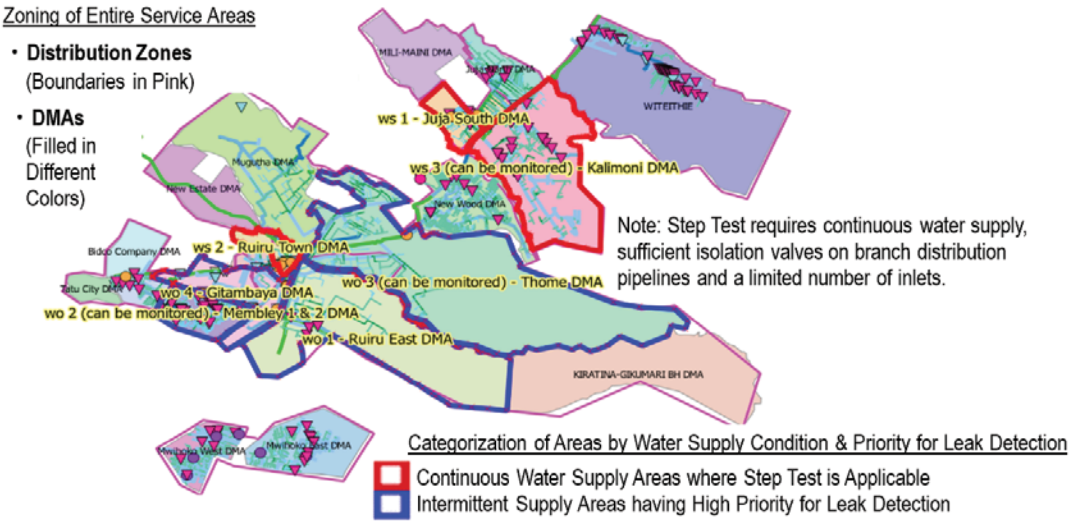


Figure 13.2: Zoning of the Entire Service Area at Ruiru-Juja WSP and Selection of Priority Areas and Leak Detection Methods

13.3.3 Monitoring of Progress in NRW Reduction

Figure 13.3 shows a 3-year data graph with 3 types of raw monthly data and 4 indicators calculated from the raw data for Nyahururu WSP. The data and indicators are plotted on one graph so as to understand the seasonal fluctuations of NRW ratio and the effect of the NRW reduction activities.

The 3 types of raw monthly data are:

- Total Supplied water [Orange ○]
- Total Billed consumption [Purple ○]
- Revenue from billed water (Kshs)

While the 4 types of indicators calculated from the raw data are:

- Volume of NRW [Red ◯] (= Supplied Water - Billed Consumption)
- NRW ratio [Red ◯] (= volume of NRW x 100 / Supplied Water volume)
- Average Tariff of water billed [Blue◯] (= Billing for Water [Green ▫] / Total Billed Consumption)
- Potential Revenue Loss due to NRW [Pink ▫] (= Average tariff x [Supplied Water - Billed Consumption])

In this graph, the NRW ratio decreased by about 10% over the last two years with seasonal fluctuation every few months. The seasonal fluctuations are due to the shallow wells used by the small customers as alternative water sources. When the wells dry up in the dry seasons, this results to a corresponding increase in both the total Supplied Water and total Billed Consumption. Consequently, while the volume of NRW did not change much, the NRW Ratio decreased for a few months in each dry season.

The decrease in average tariff in each dry season can be attributed to the increase in piped-water consumption among the small customers whose average water charge per 1m3 is relatively low due to their lower tariff block.

At WSPs in Kenya, shortage of water sources and intermittent water supply conditions often substantially affect the total amount of supplied water while the fluctuations in water demand again substantially affect the total billed consumption. These values therefore fluctuate repeatedly due to seasonal changes in temperature and precipitation.

This trend whereby the NRW ratio rises and falls every few months was found to be common in Kenya.

From Figure 13.3 the following information can be obtained:

- The variations in the monthly amount of Supplied Water [Orange ◯] is a useful indicator to presume the progress of physical water loss reduction.
- The total Billed Consumption [Purple ◯] and the total amount of Billing for Water [Green ▫] are effective indicators for understanding the progress in reducing commercial losses caused by low meter accuracy and water theft.
- Moreover, the Average Tariff [Blue ◇], which usually increases when billing of large customers is improved, can be an indicator of how well large customers are targeted in commercial loss reduction.
- The volume and ratio of NRW for the entire service area [Red ◯ and Red ◯], and the potential revenue loss due to NRW [Pink ▫] are useful indicators for quantitative evaluation of the overall effect of NRW reduction activities.

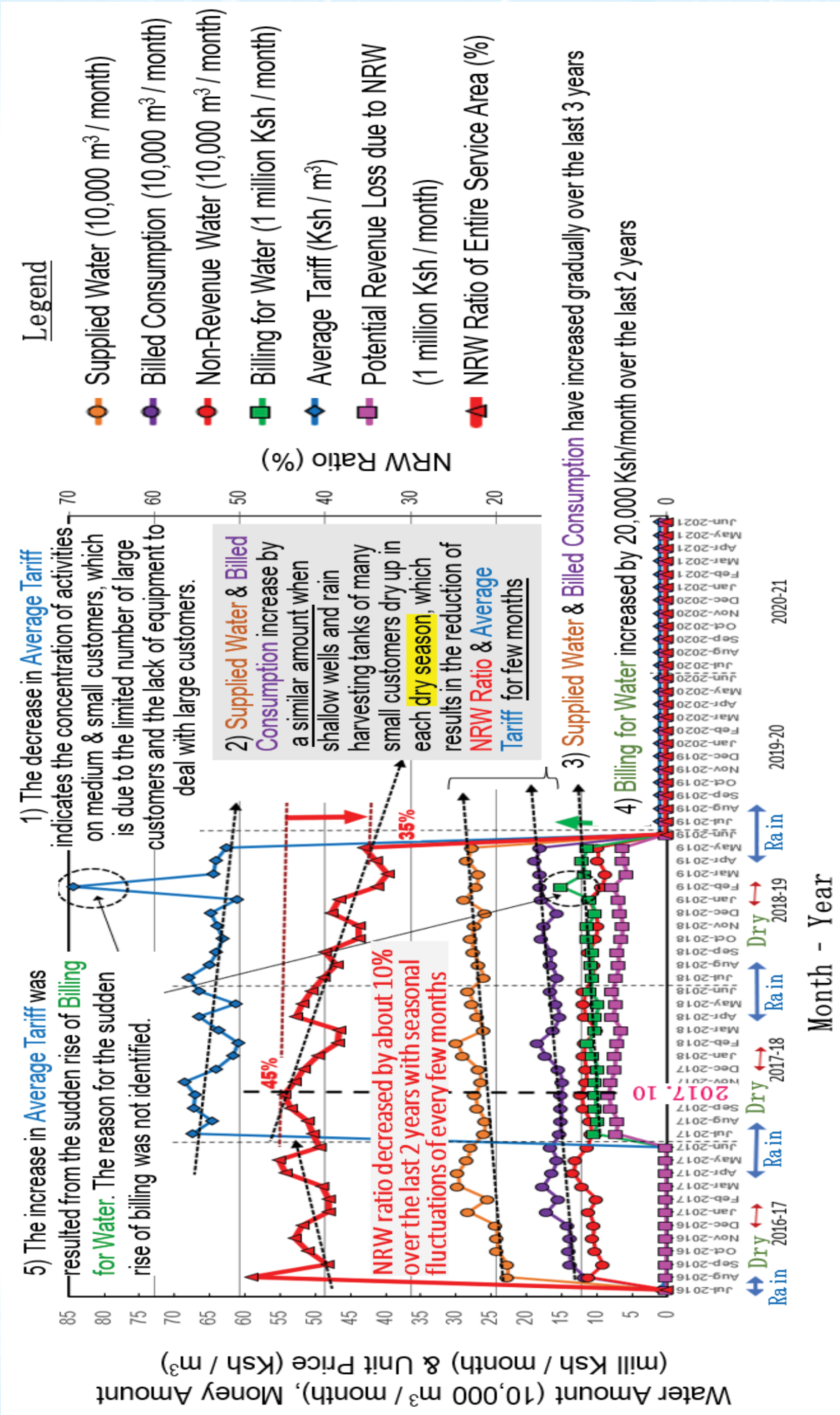


Figure 13.3: Seasonal Fluctuation of NRW Ratio & Effect of NRW Activities in Nyahururu WSP

This method of using a line graph is much easier and often more effective than filling a complicated water balance table for the entire service area once a year.

Kisumu WSP carried out the rigorous monitoring of large customers' consumption using ultrasonic flow meters to reduce meter errors and water theft; and replacing faulty meters after conducting meter accuracy tests targeting large and medium customers.

Figure 13.4 shows the variations and relationship between several additional monthly indicators and the amount or results of certain NRW reduction activities. These are used to identify factors substantially affecting NRW reduction. The following were the findings:

- Replacement of faulty customer meters to reduce estimated billed consumption [Green line △] was quite effective in reducing NRW ratio [Red line △],
- Increasing the budget for pipeline maintenance such as selective replacement of aged pipes [Yellow line □] may reduce the number of leaks and bursts found and repaired per month [Pink line □].

13.3.4 Reduction of Commercial Water Loss

Table 13.1 shows a comparison of data before and after the improvement of meter reading and billing (e.g., reduction of meter accuracy errors) at Nakuru WSP. This is an alternative to analysing meter reading and billing data for one year.

This analysis shows that active reduction of estimated billed consumption for large customers results in a large increase in the total billed consumption and total billing.

13.4 Lessons and Innovations of Project Implementation

The following lessons were learnt from the project activities.

13.4.1 Importance of Selecting Target Areas

Expansion of NRW reduction activities from the pilot areas to other areas is often not successful.

In order to realize a quick large-scale reduction in NRW, it is more effective to first prioritize the improvement of meter readings and billing (e.g., meter accuracy starting with large and medium customers) and expanding over the entire service area. By using this approach, 5 of the Pilot WSPs reduced their NRW significantly.

Meanwhile, it is more effective to try leak detection and pressure reduction in pilot areas to confirm their effectiveness before expanding to other areas.

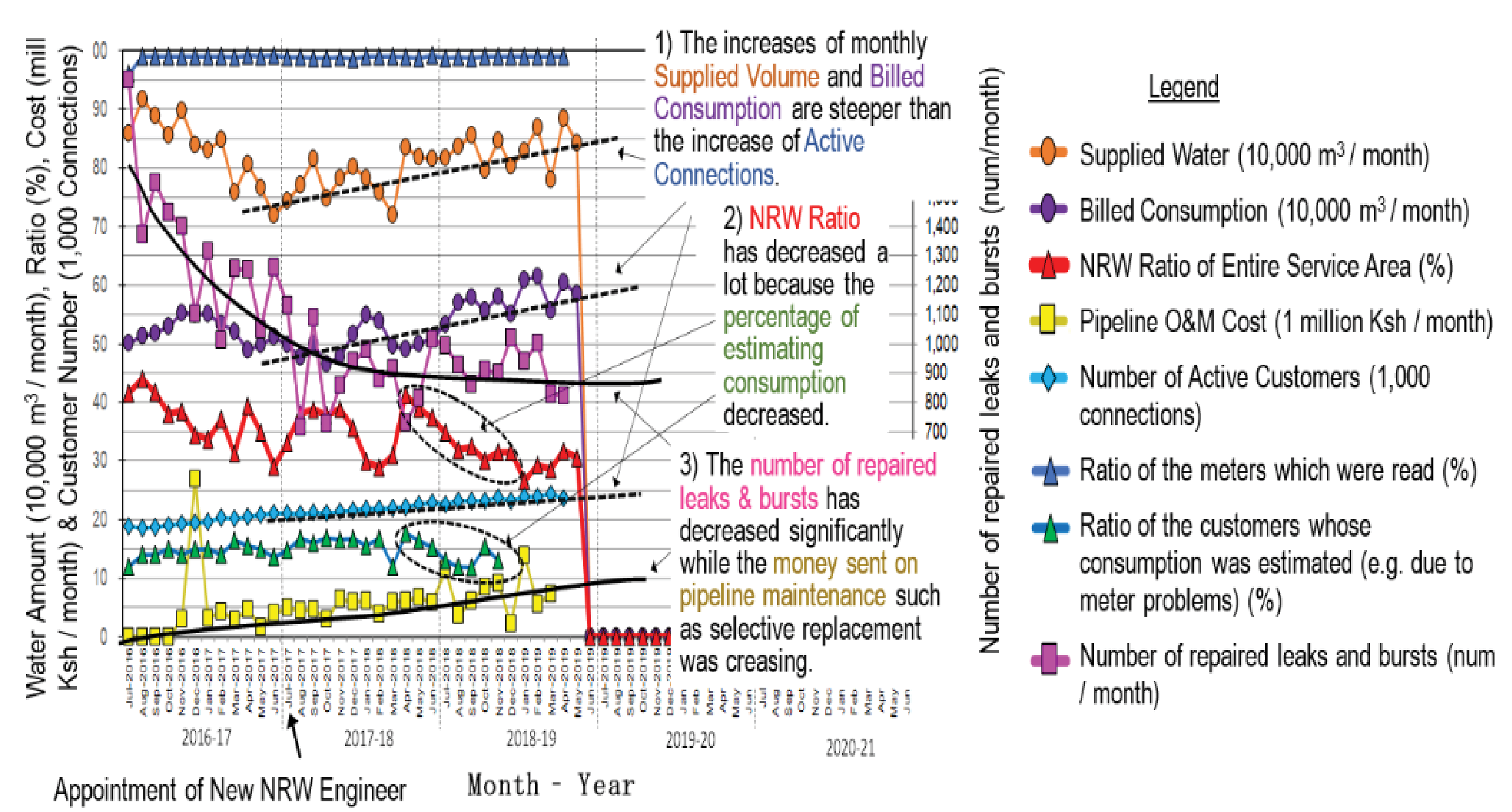


Figure 13.4: Factor Analysis of NRW Reduction based on Additional Monthly Indicators at Kisumu WSP

Table 13.1: Analysis on the Reduced Frequency of Estimating Billed Consumption by Customer Category at Nakuru WSP

Customer Category by Average Billed Consumption	Year - Month	Number of Connection		Billed Consumption			Customers whose Consumption is Estimated			Number of Customers for Each Type of the Consumption Estimation			
		[1] Num	Distribution %	[2] Total Volume (m^3/month)	Distribution %	[3](=[2]/[1]) Average (m^3/month/customer)	[4] Num	Distribution %	[5] (=[4]/[1]) Frequency %	Increase from no consumption	Increase from other than no consumption	Change to no consumption	Decrease to other than no consumption
										0↑X	+X	X↓0	-X
C1: > 300 m3/month	2017 - October	130	0.3%	115,732	18.1%	890.2	17	0.2%	13.1%	15	1	0	1
C2: 101-300 m3/month	2017 - October	465	1.2%	74,839	11.7%	160.9	64	0.8%	13.8%	36	18	0	10
C3: 51-100 m3/month	2017 - October	1,077	2.7%	73,597	11.5%	68.3	155	1.9%	14.4%	110	27	0	18
C4: 21-50 m3/month	2017 - October	4,664	11.6%	144,864	22.6%	31.1	891	10.9%	19.1%	[illegible]			
C5: 7-20 m3/month	2017 - October	15,330	38.0%	181,004	28.3%	11.8	4,800	58.6%	31.3%	[illegible]			
C6: 0-6 m3/month	2017 - October	18,630	46.2%	49,882	7.8%	2.7	2,267	27.7%	12.2%	1989			
Total	2017 - October	40,296	100.0%	639,919	100.0%	15.9	8,194	100.0%	20.3%	7,464	437	9	284
C1: > 300 m3/month	2019 - May	114	0.3%	130,787	18.9%	1,147.3	4	0.1%	3.5%	2	0	0	2
C2: 101-300 m3/month	2019 - May	601	1.4%	94,577	13.7%	157.4	43	0.6%	7.2%	23	11	0	9
C3: 51-100 m3/month	2019 - May	1,375	3.3%	93,946	13.6%	68.3	127	[illegible]	9.2%	95	14	0	18
C4: 21-50 m3/month	2019 - May	5,769	13.7%	177,675	25.7%	30.8	[illegible]	11.1%	14.0%	726	44	0	35
C5: 7-20 m3/month	2019 - May	16,971	40.4%	199,200	28.8%	11.7	3,959	54.7%	23.3%	3702	192	0	65
C6: 0-6 m3/month	2019 - May	19,437	46.2%	50,480	7.3%	2.6	2,058	28.4%	10.6%	1767	163	14	114
Total	2019 - May	44,267	100.0%	746,666	100.0%	16.9	6,996	100.0%	15.8%	6,315	424	14	243

Effective focus on large & medium custo
(reduction of about 10% to 5%)

Increase of customers by around 4,000 (10%)

Large increase of billed consumption by more than 100,000 m^3/month (17%)

Reduction of the number of customers whose consumption is estimated by around 1,200

Reduction of the estimated consumption for billing by 4.5% on average

Mainly by replacing the faulty meters which are completely stalled.

13.4.2 Encouraging Organization-wide NRW Reduction Activities

In order to get the full involvement of the commercial staff in NRW reduction efforts and get commercial loss reduction into full swing, the meter readings and billing data of all customers for the last 1 to 2 years should be analysed, the problems identified (e.g., many faulty meters, and frequent and continuous under-estimation of billed consumption even for large customers) and shared with all staff including managers.

This analysis made an impact on all Pilot WSPs and encouraged them to hold more joint meetings between the technical and commercial staff for NRW reduction. Moreover, through the activities that involved many staff (e.g., those related to customer meters, capacity assessment, and planning), the Pilot WSPs became encouraged to implement self-motivated organizational strengthening. As a result, 4 of the Pilot WSP strengthened their organizational setups for NRW reduction, while Ruiru-Juja and Kilifi-Mariakani WSPs commenced the same.

13.4.3 Sustainable and Extensive Utilization of ICT

Applications of ICT including smartphones for data collection and mapping were tried out to find more efficient ways to carry out NRW reduction activities. In the early stage of this project, a free software program called Open Data Kit (ODK) was used to create a versatile interactive electronic form for guiding different WSPs in collecting relevant data related to NRW reduction activities around customer meters. However, the electronic form had limitations mainly because different WSPs have different organizational structures and priority activities.

A shift was therefore made to another free software called Kobo Toolbox/Collect which is easier to use. By using this software, WSPs can now setup their own cloud space for data sharing, create an original electronic form for each activity and automatically map the collected data. This will make it possible to expand the use of ICT applications to more staff and to cover the entire service area in a more sustainable way.

13.4.4 Flexible Training for Each WSP

There were challenges in providing uniform and intensive trainings because of delays in procuring the necessary NRW equipment. Flexible OJTs based on the available equipment at each WSP and those procured by WSBs were therefore conducted by training on the operation of the equipment.

Meanwhile, due to delay in procuring potable ultrasonic flow meters, which are developed specifically for the water supply field and essential for NRW reduction, certain low-cost industrial ultrasonic flow meters were tried as potential alternatives. However, they were found to be difficult in setting up and ensuring accuracy.

Another alternative, video recording functions of smartphone was used for logging the ever-varying flow rate as a trial. Figure 13.5 shows the process of a taking video of a mechanical bulk meter counter with a smartphone and later extracting the flow rates from the video file at a certain time interval. This method can make minimum night flow measurements and step tests easier without using a potable ultrasonic flow meter and may help many WSPs in their leak detection.

Various trials were carried out in liaison with the Pilot WSPs in this project. Continuous trials to challenging problems without placing a large financial burden on WSPs and sharing the information and experiences with other parties are important especially now that the capabilities of smartphones and free software available in the market continue to increase.

Figure 13.5: Measurement of Hourly Water Flow with Smartphone and Free Software

Figure 13.6: Meter Accuracy Test on Site Using Bucket and Meter Tester

Figure 13.7: Flow Measurement at Mavoko WSP

APPENDIX 1

Appendix-1 - Revised Templates for Annual Review, Assessment, Planning & Monitoring (WASREB website)

APPENDIX 2

Appendix-2 - Customer Meter Analysis of 2017 Data - Embu WSP (WASREB website)

2) -2 Non-Revenue Water Management in Kenya VOLUME2 Handbook

MINISTRY OF WATER, SANITATION AND IRRIGATION

Non-Revenue Water Management in Kenya

VOLUME 2

Handbook

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Water is an important natural resource to all forms of life and for mankind. It is the backbone of economic growth and a nation's prosperity. Kenya as the rest of the world is becoming more and more water scarce due to deterioration of water sources resulting mainly from global warming and population explosion. Construction of new water schemes to meet the growing demand for water services is expensive, requires more time to develop and comes with new challenges. Alternative sources of water are water re-use, desalination and rainwater harvesting. However, reduction of Non-Revenue water is the cheapest way to alleviate the water stress.

The Government of Kenya is committed to ensuring the sustainability of Water Service delivery universally and the right to water and sanitation as envisaged under the bill of rights in the constitution. However, among the challenges to achieving the Kenyan dream includes a high level of Non-Revenue Water(NRW) which is estimated at an average of 47% of the total water production in the country. The water services provision has been developed in the Count Government and therefore, it is timely to ensure an elaborate mechanism is put in place for the proper management of Non-Revenue Water in the country.

Kenya Vision 2030 recognizes that Kenya is a water scarce country and therefore emphasizes water conservation and prudent use for the limited available portable water. In this regard, the Government of Kenya has instituted specific strategies to raise the standards of the country's overall water supply and resource management among others. The National Water Resources Management Strategy and the National WATER Services Strategy aim at ensuring the water resources are conserved and maintained and Non-Revenue Water at water supply and sanitation systems is reduced to acceptable levels. Accordingly the Ministry of Water , Sanitation and Irrigation in conjunction with Japanese International Cooperation Agency (JICA) has developed standards for Non-Revenue Water Management in order to cut down on Operation and Maintenance (O&M) costs and avail more water that could otherwise be lost to consumers.

The Non- Revenue Water reduction management standards consisting of the Guidelines and Handbook are meant to provide a practical approach to reduction of NRW in Kenya. The effective utilization of the standards will result in significant education of NRW and all the Water Service Providers are encouraged to use them.

Cabinet Secretary,
Ministry of Water,Sanitation and Irrigation

PREFACE

The water sector reforms started with the enactment of the Water Act of 2002 which introduced great and positive fundamental transformation in the water entire sector. The national goal as stated in the Kenya Vision 2030 is to ensure that improved water and sanitation services are available and accessible to all Kenyan citizens.

However, Non-Revenue Water (NRW) level currently estimated at 47% as the national average remains a big challenge against the achievement of universal access to water in Kenya. Revenues of Water Service Providers continue to be lost annually due to high NRW ratio. WASREB estimates that the sector is losing about KES 10 billion annually because of NRW.

The Ministry of Water, Sanitation and Irrigation has put in place elaborate and sustainable measures to deal with the challenges of NRW. Among these measures include the development of NRW Standards that aim to provide a practical approach to reduction of NRW.

This NRW Handbook is part of these Standards that is intended to offer a simplified NRW reduction manual that will guide the water utilities technical staff on procedures on NRW management as it focuses on the daily activities technicians and field personnel perform. It consists of illustrations in the form of diagrams and photographs to make it user friendly and easy to comprehend.

The Ministry Water, Sanitation and Irrigation worked tirelessly in collaboration with water sector institutions namely: WASREB, KEWI, WASPA and JICA, to ensure that the journey to produce the Handbook was successful. At this juncture, the Ministry would like to congratulate all the stakeholders that participated in the production of the Handbook. It is my sincere hope that the WSPs will utilize this Handbook effectively to realize our common goal of reducing our National NRW to acceptable levels.

Principal Secretary,
Ministry of Water,Sanitation and Irrigation

ACKNOWLEDGMENTS

The completion of the NRW Handbook (Non-Revenue Water Management in Kenya,Volume2) could not have been possible without the support of several individuals and organizations whose invaluable support and input the development of this guidelines would not have been possible.

I therefore would like to extend my sincere gratitude to the following organizations in particular: Water Services Regulatory Board(WASREB),Kenya Water Institute (KEWI),Water Service Providers Association (WASPA),Japanese International Cooperation (JICA) and the JICA expert team, Netherlands Development Organization (SNV), Vitens Evides International (VEI) for their co-operation and contribution of information related to Non Revenue Water activities.

Nyeri Water & Sewerage Company (NYEWASCO) for their readiness to share best practices of the Non Revenue Water Reduction activities which has provided a learning platform to other water services providers.

I wish to thank the nine WSPs we have been piloting with namely; Meru,Embu, Kisumu, Eldoret, Nyahururu, Mavoko, Kilifi-Mariakani, Mombasa and Ruiru-Juja for their commitments in reducing Non-Revenue Water.

Finally,I would like to thank my colleagues in the Ministry particularly Non-Revenue Water Unit who have tirelessly devoted their time, energies and knowledge in ensuring successful publication of these guidelines and handbook.

The war on Non-Revenue Water cannot be won by a single person,it requires concerted efforts by all stakeholders and calls for commitments by everyone in the organization. I therefore urge all the Water Service Providers in the country to make maximum use o both the guidelines and handbook to sustain the war on Non-Revenue Water reduction to attain acceptable levels of below twenty percent.

God bless you all.

Eng. SAO Alima
Water Secretary
Ministry of Water,Sanitation and Irrigation

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ABBREVIATIONS

DMA	-	District Metered Area
DN	-	Diameter Nominal – internal diameter of a pipe or fitting
DZ	-	Distribution Zone
GS/GI	-	Galvanized Steel or Iron
GIS	-	Geographical Information System
HDPE or PE	-	High-density polyethylene or polyethylene
hr	-	hour
ISO	-	International Standards Organization
JICA	-	Japan International Cooperation Agency
KS	-	Kenya Standard
MD	-	Managing Director
MPa	-	Megapascal
m^3	-	Cubic meter
NRW	-	Non-Revenue Water
PN	-	Pressure Nominal (in bars) - pressure that a pipe is designed to safely withstand
TM	-	Technical Manager
uPVC	-	unplasticized polyvinyl chloride
uPVC-D/E	-	unplasticized polyvinyl chloride class D or E
WSP	-	Water Services Provider
WSPs	-	Water Services Providers

EXECUTIVE SUMMARY

The current levels of national NRW stands at an average 47%, for 2019/2020. In other words WSPs only get 53% of revenue from the water they produce (100%).In monetary perspective the sector is losing slightly more than Kshs. 11.61 Billion and a volume of 151 million cubic meters. This is adequate to serve Nairobi County with a daily demand of 750,000M3/day for approximately six and a half months. (Wasreb Impact ReportNo.13/2021)

The performance indicator with respect to NRW has been on a marginally upward trajectory as per trend shown from 41% in 2017/2018 , 43% in 2018/2019, 47% in 2019/2020. There is a significant need to reverse the trend as this is far from the National Water Services Strategy [NWSS] target of less than 30% and Vision 2030 goal of less than 25%.

High levels of NRW result from poor infrastructure maintenance and, above all, poor commercial practices(corruption).They are detrimental to the commercial viability, sustainability of the WSPs as well as the safety of the water it supplies(where related to leakages). Also, coupled with the overall reduction in water production, they result in less water being available for an increasing number of consumers.

This Non-Revenue Water (NRW) management standard aims to provide a practical approach to reduction of NRW in Kenya. The target group includes: the Utility Managers, technical personnel, operators and those who are in charge of NRW Management in the Water Service Provider (WSP).

It aims to provide a basis to address current challenges of NRW management that exist in Kenya and suggest procedures and measures that do not require use of sophisticated equipment, high level of skills and major investments.

The effective utilisation of the standards will result in significant reduction of NRWin Kenya. This will further contribute to the progressive realization to the right to water and sanitation as envisaged under the bill of rights in the constitution of Kenya (CoK–2010).

The following is a brief outline of each chapter in the handbook.

Chapter 1: This seeks to target all Water Services Provider's Staff and illustrates their designated roles in combating NRW. This chapter focuses on Sensitization of Staff in Non Revenue Management.

Chapter 2: This chapter explains on standards of different water pipe materials, types of pipe joints and the pipe repairing procedures. This chapter targets staff include: design, procurement, construction, operations and maintenance.

Chapter3: It explains how to: lay water pipe lines after trenching, handling of pipes during laying, how to backfill the trench, pipeline pressure testing, disinfection and a detailed procedure on installing service connections and service meters.

Chapter 4: This chapter is on maintenance of water supply network. It explains the need to prepare and institutionalise maintenance schedules, how to maintain valves and formulate a maintenance schedule.

Chapter 5: Provides the procedure of carrying out leak detection which is crucial particularly for all the NRW staff. Procedures on how to use various equipments are explained such as the: listening sticks, electronic leak detectors, ultrasonic flow meter (UFM).This chapter also covers how to conduct minimum night flow and step test method in order to detect water leakage

Chapter6: It explains how to measure p ressure inexisting pipe network and its significance. This chapter also explains how to use the pressure data logger to measure pressure.

Chapter 7: This chapter is on pressure testing of pipelines; it details the importance of pressure testing of pipelines and procedure to conduct pressure testing of pipelines.

Chapter8: This chapter covers maintenance and testing of accuracy of customer and bulk meters. It explains in detail show to conduct customer meter servicing, calibrate the customer meter sand how to test customer meters using the meter test bench.

Chapter 1

SENSITIZATION IN NON-REVENUE WATER MANAGEMENT

(Target Group: All Water Services Provider's Staff)

1.1 Introduction

The Non-Revenue Water phenomenon traverses the whole Water Service Provider (WSP) to such an extent that each and every staff member has a role to play in its prevention and reduction. If the headache of managing NRW were to be removed as an activity in a water supply, it would be noted that the overall workload would be greatly reduced.

1.2 Managing Director

The Managing Director (MD) bears the overall responsibility of all the WSP's activities, including NRW management. This responsibility includes formulating policy, planning, organizing, staffing, training, directing, controlling and leadership.

In reduction of NRW, the MD must take full responsibility and always facilitate the staff to enable them undertake the necessary intervention measures.

It is therefore imperative that he/she understands NRW issues in order to be the leader rather than the hindrance of NRW reduction and low-level sustenance.

The MD must especially ensure that:

- staff and customers are sensitized on NRW issues
- All the staff including NRW Unit staff are adequately trained on water loss prevention and reduction in their areas of operation
- NRW reduction is prioritized and allocated with adequate resources
- NRW reduction indicators are monitored, evaluated and continuously improved
- Every staff member recognizes and plays their NRW reduction role
- NRW reduction activities are well coordinated.
- External stakeholders (County Government, MPs, etc.) are sensitized to make formulate and gazette policies and laws aimed at reducing NRW.

1.3 Technical Manager

Most NRW reduction processes, including several under commercial department are technical in nature and therefore require technical guidance. The WSP looks up to the Technical Manager (TM) to lead the way in all technical matters.

It is therefore imperative that the TM is well trained in NRW matters including practical experience in techniques and equipment handling. This ensures the WSP has a reliable technical capacity.

The NRW Unit is most often under the technical department. Even though the NRW Unit is the one carrying the day-to-day NRW activities, the TM should be fully in charge of and drive the process including ensuring adequate and prompt facilitation of materials, equipment, transport, etc.

He/she should ensure specifications for all materials and services are prepared or revised well in advance before procurement and filed for easy retrieval.

Monthly materials usage and restocking levels should also be prepared or revised before the budgeting process. This revision provides the opportunity to raise NRW issues with the management and make the appropriate arrangements for NRW intervention measures during the coming financial year.

1.4 Commercial Manager

Staff under commercial department often assume that NRW reduction is the responsibility of the technical department. This belief or attitude may cause blame game between the technical and commercial departments' staff when the NRW ratio rises or remains high.

The commercial manager must debunk this belief and take up his/her rightful place in NRW reduction effort. Meter and billing related water loss (e.g., meter reading errors, unread meters, stopped/inaccurate meters, leaking connections, illegal water use, inaccurate billing data entry, billing adjustment errors, unbilled customers, failure to report leaks/bursts, unregistered customers, customers without address or with wrong address, disconnected customers consuming water, meter tampering, etc.) account for high NRW ratio in many WSPs.

Similarly like the TM, specifications for all materials and services; and monthly materials usage and restocking levels should be prepared or revised well in advance before the budgeting process and procurement commencement. This revision again provides the opportunity to raise NRW issues with the management and make the appropriate arrangements for NRW intervention measures during the coming financial year.

1.5 Procurement staff

Often, implementation of NRW and other activities delay or fail due to late or no procurement of related goods and services. Successful and timely procurement is a precursor to good coordination of activities and processes. The manager should:

- Request for specifications of all materials and services from departments and file well in advance before the annual tender/quotation documents preparation.

- Coordinate timely preparation of procurement plans, annual tenders, stocks re-order levels, etc.
- Place, if possible, all goods and services in annual tenders to reduce procurement workload of quotation preparation.
- Maintain several suppliers for each item to enable quick change in case of supply delay.
- Initiate set-up (in consultation with the line managers) and maintain standing tender/quotation evaluation committees. Such committees include pipes and fittings, water treatment chemicals, water meters, building materials and general works, electromechanical works and materials, insurance, evaluation committee, etc. This ensures only competent staff are involved in evaluation and therefore quality is assured.
- Similarly, set-up and maintain various inspection and acceptance committees.

1.6 Stores staff

Efficient management of the stores is critical for NRW reduction. The stores staff should always be watchful to ensure no stock-out situations occur by:

- Timely documenting and orderly storage of materials in stores for easy retrieval.
- Regular revision of monthly usage cycle, restocking levels and timely reports on likely stock-outs.

Most WSPs have installed Enterprises Resource Planning software (ERP) for efficient stocks monitoring.

Storage of materials must always be in accordance with the manufacturers' specifications. This is especially important for unplasticized polyvinyl chloride (uPVC) and PE pipe which must be stored in flat areas and covered against sunlight. Stacking must not exceed specified height to avoid damage.

1.7 NRW Unit staff

The role of NRW Unit is to:

- collect, analyze and interpret NRW data
- Proactive leak detection by various methods and equipment/tools
- recommending on NRW reduction measures to be taken
- Coordinate timely meter replacement, servicing and testing
- Prepare monthly NRW reports

This team should understand the opportunities for water loss in other sections and activities of the WSP. It should therefore be staffed with competent and well-trained personnel on NRW reduction strategies.

1.8 Water Production Staff

Large water losses often occur in treatment facilities through leaking valves, overflowing reservoirs due to poor maintenance. Lack of plumbers responsible for the water treatment area is the main cause. The in-charge should always seek the TM's intervention to ensure leakages are repaired promptly.

1.9 Design and Construction Staff

Designing and implementation of pipelines and other facilities should be carried out by qualified technical personnel. The reality is that many WSPs do not have a design section in their establishments. This leaves design work to unqualified staff thereby resulting in poor planning.

It is recommended that design sections be created in WSPs to handle routine minor design works and to be liaison in sophisticated design work by professionals.

1.10 Water Distribution Staff

They are responsible for all the repairs of pipe leaks/bursts and therefore must be well trained.

They should always strive to do repairs properly (desisting from jua kali repair methods and materials) and within the shortest time possible.

1.11 Connection and Meter Installation Staff

The key issues regarding staff in charge of connecting customers and installing meters are:

- Delay in installation of connections/meters
- Digging inadequate trench depths prone to pipe damage, and/or leaving uneven trench bottom prone to cause air entrapment service lines
- Inadequate backfilling prone to pipe damage
- Poor workmanship in jointing thereby leaving leaking pipes
- Poor positioning of service line and meter
- Improper recording of the connections and/or meters including drawing service line maps, capturing coordinates for Geographical Information System (GIS) mapping, errors in meter serial numbers, interchanging meters between customers, etc.
- Delay in submission or loss of documents for connections/meters installation, etc.

The staff should therefore be properly sensitized also needs to be very well coordinated to ensure they are

1.12 Meter Servicing and Testing Staff

Over time, customer meters become clogged by debris/silt depending on the quality of the water. This clogging gradually obstructs the moving parts of the meter thereby causing the meter to slow down or stop altogether. This results in revenue loss to the WSPs. Servicing of meters restores accuracy of measurement and extends their lifespan thereby postponing replacement to a later date.

Analysis of customer water consumption should be conducted on monthly basis to generate the list of customer meters for illegal use and leakage-in-premises investigation; or meter servicing and accuracy testing.

Meter accuracy testing before servicing helps to resolve some of the customer bill complaints.

Recently, some WSPs have installed a few non-serviceable meters which if inaccurate (due to clogging with silt, etc.) can only be disposed. It is difficult to guarantee consistently good water quality everywhere in the water supply hence WSPs should consider carefully before installing such meters.

Accurate NRW ratio depends on accurate bulk meters. Bulk meter should therefore be serviced regularly. Annual servicing schedules (depending on water quality) should be prepared and implemented to ensure accurate measurement of water supplied.

1.13 Meter Reading Staff

It is expected the team must visit ALL the customer meters every month record:

- Accurate customer meter reading
- Any leaks noticed
- Any meter tampering, broken seal, etc.
- Any other abnormality (e.g., buried meter, illegal consumption, stopped meter, etc.)

This performance of the team can assist to report substantial water leaks at the meter and some surface leaks on pipelines as they go about their work.

1.14 Disconnection/Reconnection and Meter Sealing Staff

Meter tampering increases water loss and hence should be prevented through meter sealing and monitoring. The method and scope of sealing should be carefully chosen to ensure its effectiveness.

The team must ensure that their activities do not leave leakages at the meter liners and should report such leakages for prompt repair if unable to by themselves.

1.15 Billing Staff

WSPs should ensure the billed volume generated by the billing system are correct (in some cases, for the lowest consumers category [say 0 to 6m3], all consumptions lower than 6m3 are rounded off to 6m3 resulting in a higher total consumption volume hence lowering the NRW ratio). This can be confirmed by comparing manually calculated total consumption with the system generated figure.

The billing staff should be good data encoders to prevent encoding.

1.16 Customer Care Staff

Customer care staff is the contact point between the WSP and customers. A comprehensive customer care system should be installed to manage customer reports which should include leaks reports from the public and staff.

Reports or incidents of leaks, etc. should be shared with the relevant staff as soon as they are received for action and resolution.

A customer service charter should be formulated, disseminated to all staff and monitored for compliance and improvement.

Water utilities should incorporate sensitization activities for schools and communities within their service areas as an important part of their NRW reduction efforts. Sensitization activities, if correctly executed, help WSP in their daily operations such as voluntary reporting of water leakages and unauthorized water users to the WSP.

Sensitization activities can be categorized as short and long term.

In short term sensitization activities, the utility sensitizes the water users and other stakeholders to take instant actions such as reporting meter thefts or water conservation.

Long term sensitization activities aim to nurture water stewardship among water users and other stakeholders. An example is to educate children about water processing and the cost of producing and distributing safe and clean water to customers.

The goal of sensitization is to change the behavior of water users and stakeholders for the benefit of all.

The WSP should plan and conduct sensitization activities such as open days for the community. There, they inform about the role in enhancing the good performance and sustainability of the water services, and responding to the concerns of community needs.

Public events such as agricultural show or World Water Day events (March 21st) are good venues for the utilities to sensitize the communities. The WSP can exhibit educational materials such as posters or demonstrate activities on related topics. Social medias are also important tools to communicate messages.

Engaging schools to enhance students' understanding of the water supply operations and the importance of water and sewerage play in public health have a long-lasting impact. Inviting schools pupils for facility tours or visiting schools to give presentations by the utility staff require minimum resources.

The activities targeting pupils 5-7th grade is particularly appropriate as school curriculum in Kenya includes water treatment. It is important thatthe pupils are encouraged to share their experiences with their families and friends. This is meant to foster a more informed and responsible community.

The contents of sensitization activities for pupils can be as follows:

- Explanation of water treatment processes. Explaining where raw water is coming from and how clean and safe water is produced and distributed to the customers?
- Visiting facilities such as treatment plant, pump house, laboratory, etc. which majority of pupils only read/learn about in the text book will leave a strong impression on them.
- Learning about the quality of water improves through comparing raw water and treated water and the role of chemicals.
- Giving them a quiz or chance to speak about what they learned from the visit.
- It is important to encourage pupils to discuss about their visits with their parents and families. The Utility can teach them about the importance of water conservation, prevention of unauthorized water use, and reporting of malpractices to their parents or families.

1.17 Mapping/GIS Staff

A comprehensive mapping of the water supply network is critical for NRW management.

In the past, GIS mapping software was too costly to most WSPs. Not anymore. Easy to use free GIS mapping software such as MAPinr and GPS Essentials; and field data collection tools such as kobo collect toolbox are downloadable from the internet. Digital GIS mapping is hence replacing paper maps thereby easing information update and sharing within the utility and with other related infrastructure agencies to facilitate communication.

No WSP therefore has any excuse to continue using paper maps and therefore should upgrade soonest.

Digital mapping should, where possible, be integrated with database systems such as billing system, customer care module, stores module, etc. This captures a vast array of information about the distribution network on one platform thereby easing work considerably.

The mapping staff should be upto the task of accurately and efficiently updating the maps. This will enable other staff to undertake their daily activities more efficiently and hence result in faster NRW reduction.

1.18 All Staff

All the staff have a responsibility to look out for and report any leaks/bursts, illegal water use, system vandalism, etc., immediately they notice or become aware for repair.

1.19 Customers

Reduction of NRW leads to better provision of better and more efficient services to the public. This can be accomplished by teaching the public to understand their role in managing NRW by reporting burst pipes, faulty valves, leaks, vandalism, illegal connections or other problems that may not occur in or around their neighborhood., Awareness programmes are therefore key and should be organized with targeted participants including a variety of stakeholders from the public, political leaders, community leaders, industrial and household consumers.

Such awareness programmes should be conducted with the help of suitable tools such as posters, fliers and SMSs to customers through by focusing on basic NRW concepts and how reduction of NRW helps ensure that communities receive better water supply and other services from WSPs.

It's prudent that after conducting awareness programmes in various communities the WSP staff work hard to maintain customer confidence in the WSP service. Maintenance of open communication is also key and WSPs should establish systems to efficiently receive, process and resolve complaints from consumers.

CHAPTER 2

WATER PIPE STANDARDS AND JOINTING/REPAIR PROCEDURES

(Target Staff: Design, Procurement, Construction, Network Maintenance/Repair)

2.1 Introduction

The following passage in italic is an extract of Section 16.1 and 16.2 of the "Ministry of Water and Irrigation - Practice Manual for Water Supply Services in Kenya - October 2005".

a) General

Preferred Standards

- Locally manufactured items shall be to Kenya Bureau of Standards (KS) Specification. Where a KS Specification is not published then the items should meet the requirements of the International Standards Organization (ISO). Where neither a Kenya Standard nor an ISO Specification are published then the locally manufactured item should be in accordance with the relevant British Standard Specification (BS) or other National Standards.
- Imported items should meet the requirements of the International Standards Organization (ISO). Where an ISO Specification is not published then the item should be in accordance with the requirements of the National Standards of the Country of origin (i.e., BS for British Manufacture, DIN for West German Manufacture etc.) with the proviso that

  i) the Standards Specification lays down requirements not less than those required by the British Standards Institution

  ii) the Standards Specification exists in official English translation

New Standards

- The list of KS, BS and ISO standards are expanded continuously and old standards are revised. It is therefore important that design engineers keep up to date with the development.

Standards for Material used in Existing plants

- For existing plants where other standards than KS were used originally, the same standards may be kept for the completion and extension work.

b) Standards Relating to Water Supply

Standards valid in 2005

KS, BS and ISO Standards, which can be expected to have some application in water supplies, can be found in Appendix C.

The above extract is an indication of the great importance of specifying the Standard during procurement of materials. This ensures that the inspection and acceptance committee of the WSP has the criteria to receive conforming materials and reject non-conforming materials without ambiguity or confusion, which is common in WSPs.

2.2 Standards

2.2.1 Definition and Benefit of a Standard

A standard is a level of quality or achievement, especially a level that is thought to be acceptable.

The definition of a standard is something established as a rule, or basis of comparison. An example of standard is a guideline governing the thickness of 20mm diameter UPVC class E pipe, or the length of a pipe socket, etc.

In essence, a standard is an agreed way of doing something. It could be about making a product, managing a process, delivering a service or supplying materials; hence, standards can cover a huge range of activities undertaken by organizations and used by their customers.

The benefits of Standards are that consumers (e.g., WSPs) can have confidence that their products are safe, reliable and of good quality.

2.2.2 Sources of Standards

Kenya Bureau of Standards (KEBS) develops and approves Kenya Standards in corroboration with relevant stakeholders in the various fields. Standards developed by KEBS are designated as KS.

KEBS also participates in development of international standards under International Standards Organization, ISO. Those standards resulting from such participation are designated as KS ISO.

Standards approved in other countries such as British Standards (BS), German Standards, DIN etc. are also applicable in Kenya where a Kenya Standard is not available.

WSPs can purchase standards online from KEBS website at reasonable prices (upto Kshs 20,000) depending on the standard.

2.2.3 Importance and Necessity of using Standards

In any society there are some people who want to make profit without providing commensurate value. The water sector in Kenya is not exempt especially with regards to pipe materials with cases of merchants supplying lower class than specified. WSPs rarely possess copies of material standards thereby forcing them to receive whatever is supplied without adequate inspection. This is dangerous especially for the inspection and acceptance committees who are at a risk of blame for poor materials.

WSPs should therefore identify, purchase and institutionalize use of available standards.

2.2.4 Testing of Materials

In a factory, ingredients are mixed in specified proportions and passed through the manufacturing process to produce, say pipes. It is normal procedure for samples to be taken at regular intervals (e.g., every 1 hour) and various tests conducted to confirm compliance with the standard and test certificates filed. As already stated in Section 2.2.3, some unscrupulous manufacturers increase the proportion of the cheaper ingredient to save on production cost thereby decreasing the quality of the final product. This enables them to give lower prices during tendering therefore winning most of the tenders. WSPs without proper inspection skills are therefore left exposed to poor materials despite their best effort to manage NRW.

WSPs should therefore:

a) send relevant staff on factory tours to sensitize them on the various tests and the parameters to check during inspection while referring to standards.

b) Include submission of test certificates as requirement during tendering

c) Institutionalize sample testing of materials before payment.

2.2.5 How to check whether pipes and fittings are as per the Specified Standard

Most WSPs in Kenya procure pipes and fittings without specifying the standard but only generally specifying the pressure rating (e.g., uPVC-E). Even where the standard is specified (which is very rare), they are rarely check for compliance during inspection and acceptance from the suppliers. This has often resulted in the materials being of lower class and/or very poor standard thereby contributing to serious leakages.

It is important to note that receiving pipe materials by simply referring to the colour coding (which is the common practice among WSPs) is grossly inadequate.

In addition to the above, WSPs rarely check for manufacturing defects when receiving materials.

The procedure below should be followed when inspecting pipes and fittings before acceptance:

a) Obtain a copy of the specified standard for procurement of the materials

b) Decide the proportion of the materials to be checked (say 5% if large quantity)

c) Inspect the sample materials for manufacturing or handling defects. The pipes/fittings should be smooth, even and symmetrical and without bubbles, cuts, slugs, holes, breaks, etc.

d) For each pipe, measure the outside (od) and internal (id) diameters of the non-socket non-chamfered part using vernier caliper (Figure 2.1 & 2.2)and compare with the standard.

e) Also measure theoutside (od) and internal (id) diameters of the pipe socket

f) For fittings, measure the id and od of the socket part

g) Calculate wall thickness, t = (od-id)/2

h) For pipes, confirm that od and t are as per the standard

i) For fittings and pipe sockets, confirm that the id and t are as per the standard

j) Repeat the measurement for the 5% of the materials

k) If at least 95% of the materials comply, accept and receive the materials, otherwise reject all. Alternatively, check all the materials and reject those not complying. The WSP should come up with a policy on receiving of materials, goods and services.

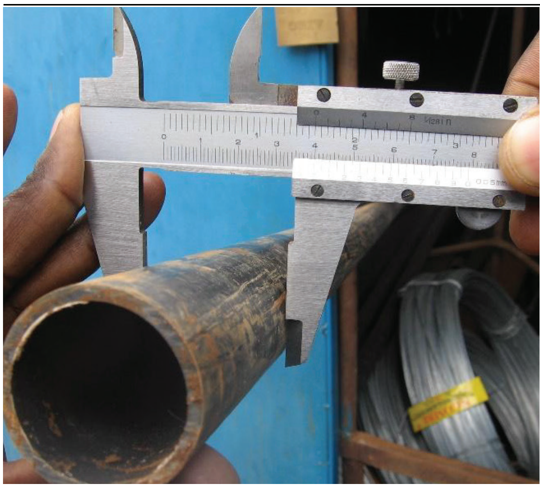


Figure 2.1: Measuring outside diameters of uPVC pipe with vernier caliper

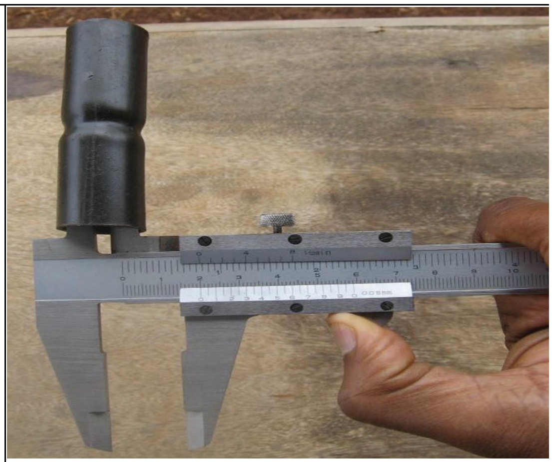


Figure 2.2: Measuring inside diameters of uPVC repair coupling with vernier caliper

WSPs can device methods to confirm other parameters on site.

2.3 Working and Testing Pressure

- Working (or normal pressure) is the maximum pressure the pipe will be subjected to under normal operating situation in the field. This pressure should always include any likely water hammer pressure.
- Testing pressure is the maximum pressure the pipe should be subjected to during testing after installation in the field (Table 2.1).

Table 2.1 Testing Pressure for Water Pipe Materials

	Pipe Material	Testing Pressure
1	uPVC (Polyvinyl Chloride	1.5 x working pressure
2	High-density polyethylene (HDPE) or Polyethylene (PE)	1.2 x working pressure
3	GS/GI (Galvanized Steel/Iron)	Depends on material grade & pipe size
4	CI (Cast Iron)	Depends on material grade & pipe size
5	Epoxy coated/lined	Depends on manufacture recommendations

	Pipe Material	Testing Pressure
6	Concrete coated/lined	Depends on manufacture recommendations
7	PPR	1.5 x working pressure

2.4 Unplasticized Poly-Vinyl-Chloride (uPVC) Pipe Materials

2.4.1 General

PVC (Polyvinyl Chloride) is strong but lightweight plastic pipe. It is made softer and more flexible by addition of plasticizers. If no plasticizers are added, this makes it rigid, hard and strong, and it is called unplasticized polyvinyl chloride, uPVC.

2.4.2 uPVC Pipe Classification

uPVC pipes and fittings are classified by the maximum working pressure rating and identified by colour coding (Table 2.2) and in addition manufactured with electronic identification print on the pipes at every 2m (indicating manufacturer's name, date of manufacture, manufacture standard, pipe class).

Table 2.2: uPVC Pipes Pressure Rating and Colour Code

uPVC Class	Maximum Working Pressure			Colour Code
	(MPa)	(PN/bar)	(m head of water)	
B	0.6	6	60	Red
C	0.9	9	90	Blue
D	1.2	12	120	Green
E	1.5	15	150	Brown

2.4.3 How to Select uPVC Pipes and Fittings Standards

Table 2.3 indicates pipes with varying outside diameter and wall thickness.

Table 2.3: Dimensions of UPVC pressure pipes as per KS 06-149 Standard

NOMINAL OUTSIDE DIAMETER mm		OUTSIDE DIAMETER mm		WALL THICKNESS mm							
				CLASS A P = 0.60 MPa (6bar)		CLASS B P = 0.90 MPa (9bar)		CLASS C P = 1.2 MPa (12bar)		CLASS D P = 1.5 MPa (15bar	
		min	max	min	max	min	max	min	max	min	max
*	20	20.0	20.3	-	-	-	-	1.40	1.80	1.40	1.80
	25	25.0	25.3	-	-	-	-	1.40	1.80	1.60	2.00
*	32	32.0	32.0	-	-	1.40	1.80	1.70	2.10	2.10	2.60
	40	40.0	40.3	-	-	1.60	2.00	2.10	2.60	2.60	3.10
	50	50.0	50.3	1.40	1.80	2.00	2.40	2.60	3.10	3.20	3.80
*	63	63.0	63.3	1.70	2.10	2.50	3.00	3.30	3.90	4.10	4.80
	75	75.0	75.3	2.00	2.40	3.00	3.50	3.90	4.50	4.80	5.50
*	90	90.0	90.3	2.40	2.90	3.60	4.20	4.70	5.40	5.80	6.60
*	110	110.0	110.4	3.00	3.50	4.40	5.10	5.80	6.40	7.10	8.00
	125	125.0	125.4	3.40	4.00	5.00	5.70	6.50	7.40	8.00	9.00
	140	140.0	140.4	3.80	4.40	5.50	6.30	7.30	8.30	9.00	10.30
*	160	160.0	160.5	4.30	5.00	6.30	7.20	8.30	9.40	10.30	11.60
	200	200.0	200.6	4.80	5.50	7.10	8.00	9.40	10.60	11.60	13.00
*	225	225.0	225.7	5.40	6.20	8.00	9.00	10.50	11.80	13.00	14.50
	250	250.0	250.8	6.00	6.80	8.90	10.00	11.70	13.10	14.40	16.00
*	280	280.0	280.9	6.70	7.60	9.90	11.10	13.10	14.70	16.20	18.10
*	315	315.0	316.0	7.60	8.60	11.20	12.60	14.70	16.40	18.20	20.20
	355	355.0	356.1	8.50	9.60	12.60	14.10	16.60	18.50	20.50	22.80
	400	400.0	401.2	9.60	10.80	14.20	15.90	18.70	20.80	23.10	25.70
	450	450.0	451.4	10.80	12.10	16.00	17.80	21.00	23.30	26.00	28.80
	500	500.0	501.7	12.00	13.40	17.70	19.70	23.40	26.00	28.90	32.00

** Preferred pipe sizes in Kenya*
Source: Ministry of Water and Irrigation - Design Manual for Water Supply in Kenya - October 2005".

Figure 2.3: is an extract of ISO 4422: PART 2: 1996 Standard for uPVC Pipes.

The Standard is tight in both outside diameter and wall thickness of pipes allowing no slack. This helps to ensure tight joints and prevent leaks.

Nominal Outside Diameter	PN = 6 Bar	PN = 6.3 Bar	PN = 10 Bar	PN = 12.5 Bar	PN = 15 Bar
	Nominal wall thickness (mm)				
20	-	-	-	-	1.5
25	-	-	-	1.5	1.9
32	-	-	1.6	1.9	2.4
40	-	1.5	1.9	2.4	3
50	-	1.6	2.4	3	3.7
63	1.9	2	3	3.8	4.7
75	2.2	2.3	3.6	4.5	5.6
90	2.7	2.8	4.3	5.4	6.7

PN = Nominal Pressure

Figure 2.3 Extract of UPVC Pressure water pipes as per ISO 4422:Part2:1996 (International Standards)

Note:

1. Meru WSP managed to maintain relatively low NRW ratio (below 25%) by strict use of uPVC-E to ISO 4422: PART 2: 1996.
2. ISO 4422: PART 2: 1996 has already been replaced by KS ISO 1452-2:2009

2.4.4 uPVC Pipe Joints

2.4.4.1 General

Figure 2.4: Rubber ring couplings (dia≥63mm) and Bonding Joint Couplings (dia<63mm)

Pipe jointing work is very important in leakage prevention. Those who supervise pipe work installation should not depend on the skills and experience of the workers but should themselves have adequate knowledge, experience and understanding of the principle of various types of joints.

WSPs are advised to set up standards for pipe jointing in liaison with the manufacturer.

There are three types of joints for uPVC pipe system:

a) Bonding Joint (only used for pipes of diameter < 63mm in Meru WSP)
b) Rubber ring joints (used for pipes of diameter ≥ 63mm in Meru WSP)
c) Special Joints (Connecting Pipes of Different Materials)

Figure 2.4 shows couplings for rubber ring joint and bonding joint.

2.4.4.2 uPVC Pipe Taper Socket Bonding Joint

a) The Principle of Taper Socket Bonding Joint

This method uses a joint with a tapered end (Figure 2.5) and utilizes the swelling and elasticity of polyvinylchloride when combined with an adhesive.

i) As adhesive is applied to the pipe and socket, swelling approximately 0.1mm thick is produced on the surfaces. This facilitates insertion of the pipe. After the pipe is inserted to the point of stopper, the swollen layers bond to join the surfaces together. The diameter of the tapered socket is smaller than the diameter of the pipe thereby resulting in a squeezing counterforce on the pipe from the expanded socket. This counterforce also has the effect of tightening the joint.

ii) Before applying adhesive, the following procedure is necessary:

- Measure the coupling length (Figure 2.5).
- Temporarily and tightly insert the pipe into the socket and check to ensure the engagement length is 1/3 – 2/3 of coupling length

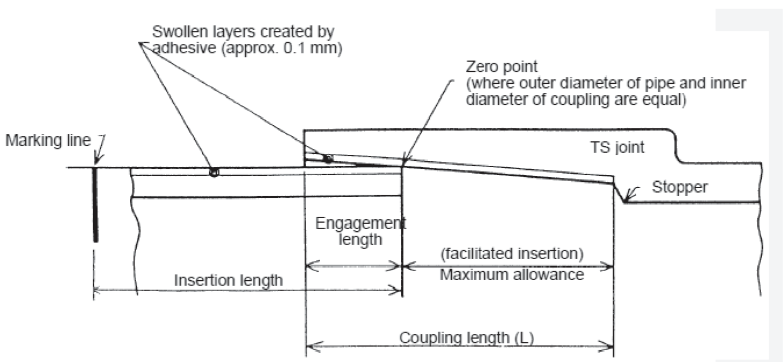


Figure 2.5 Detail of PVC bonding joint

iii) Quick-drying adhesive should be used as a rule. The pipe should be inserted as soon as the adhesive is applied, especially if it is under a hot sun where adhesive is likely to dry very quickly.

iv) It is wrong to assume that the more the adhesive is applied, the better the bonding. When too much adhesive is applied, the vapor weakens the pipe. Further, the adhesive disturbs water meters and also causes odour in the water.

v) To obtain strong adhesion, the surfaces to be joined should be clean and dry. Any oil sticking on the surfaces decreases the adhesive strength since the adhesive rejects oil and does not expand as in (i) above. The adhesive also rejects water, dust and other particles.

vi) In order to confirm that the pipe is inserted upto the stopper, the marking length of the insertion (or coupling length, L) before inserting is necessary.

vii) After inserting, it is necessary to hold the pipe and socket firmly together for a specified period of time to prevent the counterforce of the expanded socket from pushing the pipe out of the socket.

b) Procedure of Taper Socket Joint

i) Cut PVC pipes so that the end is straight

ii) Deburr (remove the rough edge left after cutting) the cut section by lightly chamfering (cutting away a right-angled edge or corner to make a symmetrical sloping edge)

iii) Clean the joint end and outer surface of the pipe spigot. Oil and water should be cleaned off completely

iv) Measure the joint coupling length (L) on the pipe from the pipe end and draw a marking line.

Note:

- For joints with a diameter between 20mm and 40mm, a marking line should be drawn at a point equal to the zero-point distance plus the adhesive length specified in the table below away from the pipe end. The zero point should be determined with the pipe lightly inserted in the joint as it depends on the dimensional tolerances of the outer diameter of the pipe and inner diameter of the joint coupling.

v) When the pipes are connected at a right angle using a joint such as elbow or bending coupling for a tap, indicate joining marks on the pipes and joint

vi) Apply PVC adhesive over the inner surface of the joint and outer surface of the pipe spigot. The adhesive layer must be thin and uniform.

vii) Do not apply PVC adhesive beyond the marking line on the pipe.

viii) If too much adhesive is applied, it may enter the pipe and cause disturbance to the water meters; and abnormal smell and taste.

ix) Rapidly insert the pipes straight into the joint. Hold them for a period of time not shorter than that shown below:

Table 2.4: Standard holding time for Taper Socket joints

Diameter (mm)	50 or less	63 or more
Standard holding time	30 sec. or more	60 sec. or more

x) If you release the pipe and socket before the specified holding time elapses, the pipe may eject out of the joint.

xi) Check and ensure that the pipe is inserted to the marking line.

xii) In case the insertion is improper, do not repeat the above steps using the same pipe surfaces and same joint. Cut off the pipe where adhesive has been applied and replace the joint with a new one.

xiii) Any adhesive forced out of the joint surfaces during insertion should be wiped off immediately.

b) Precautions for Prevention of Leakages

i) PVC pipes are susceptible to heat. Their structural strength decreases with rise in temperature. They are softened around 180°C.

ii) PVC pipes are susceptible to cold weather. In a cold area, they are easily broken by an external impact. They become brittle at -18°C.

iii) PVC pipes expand much with heat. They expand and contract more with temperature changes than steel pipes.

iv) PVC pipes are susceptible to solvents, especially antiseptics (creosote oil) and acetone. They are also affected by pipe adhesive.

v) PVC pipes are not suitable for use in temperatures exceeding 50°C or low temperatures. A straight PVC pipeline exposed to extreme temperatures should be supported with expansion joints at intervals of 30 to 40m.

vi) PVC pipes should be protected from direct sunlight. Do not stack them to a height over 1m. do not throw them, especially in cold weather.

2.4.4.3 uPVC Pipe Rubber Ring Socket joint

Experience in Meru WSP suggests that pipelines of 63mm diameter and above should be connected using rubber ring socket joints since they are easier to dismantle and reuse hence more convenient.

Rubber ring joints provide a water seal by compressing a rubber ring housed in the socket of a pipe (or fitting) when the spigot is passed into the socket. Correct jointing rings should always be supplied with the pipes or fittings.

Always follow manufacturer’s jointing instructions including the recommended jointing lubricant. Other lubricants may not be suitable for drinking water contact and may affect the ring. Cooking fat can also be used as lubricant.

How to Joint Pipes/Fittings with Rubber Ring

a) Pipes may be jointed out of the trench but it is preferable that jointing be done in the trench to prevent possible “pulling apart” of the joint during pipe transfer to the trench.

b) Check that the spigot end has (been supplied with) a chamfer of approximately 12° to 15° to the pipe axis (Figure 2.6). For spigot end of pipe that is cut in the field chamfer must be made with a chamfering tool (or a body file ensuring sharp edge, which may cut the rubber ring is not left).

c) Deburr (remove sharp edges on the inside rim of) the pipe using a deburring tool (or round body file). Do not break or chip the inside edge (Figure 2.7).

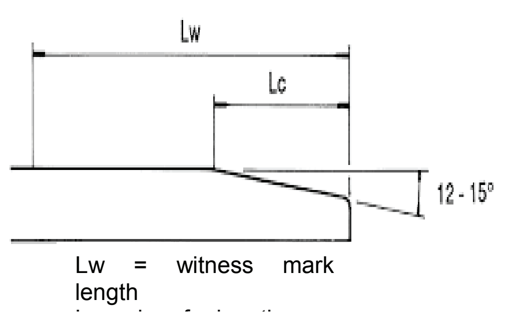


Figure 2.6: Unchamfered spigot

Figure 2.7: Unchamfered dimensions being deburred

d) Clean and dry the socket with a piece of cloth, especially the ring groove. Do not use rag with lubricant on it.

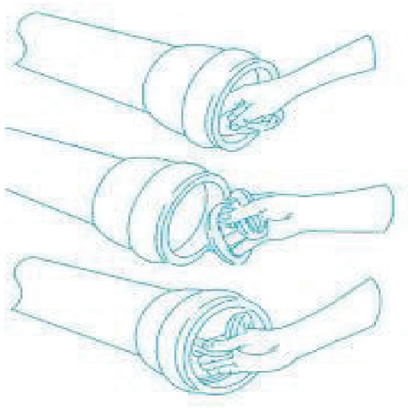


Figure 2.8: Inserting rubber ring into pipe socket

e) Clean and dry the rubber ring and insert it into the groove as per manufacturer's instructions (the fins of the rubber always go into the socket first) (Figure 2.8).

f) Run your finger around the lead-in angle (slight edge on inner ring surface which is the first part the spigot touches as it enters the socket) of the rubber ring to check that it is correctly seated, not twisted, and that it is evenly distributed around the ring groove.

g) Clean the spigot end of the pipe as far back as the witness mark

(**Note: f**or spigot end of any pipe that is cut in the field, make the witness mark as per manufacturer's instructions (witness mark ensures the spigot leaves adequate compression gap to the socket end in case of earthquake or temperature movement) (Figure 2.9).

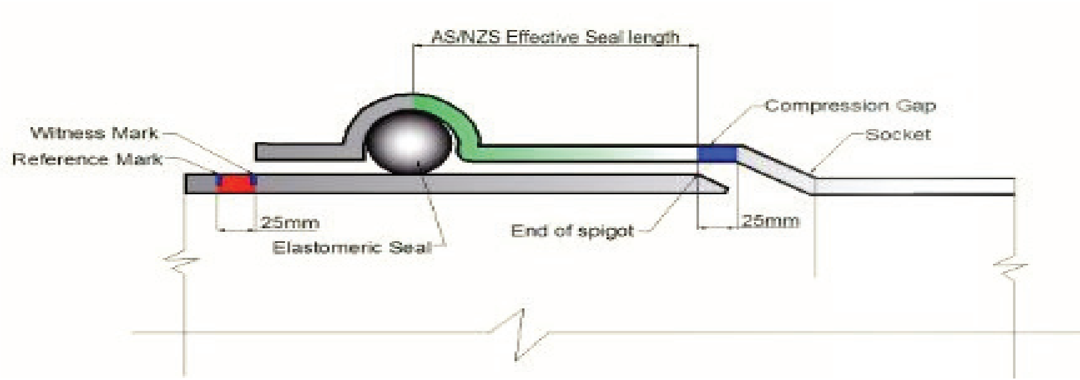


Figure 2.9: Witness mark on pipe spigot

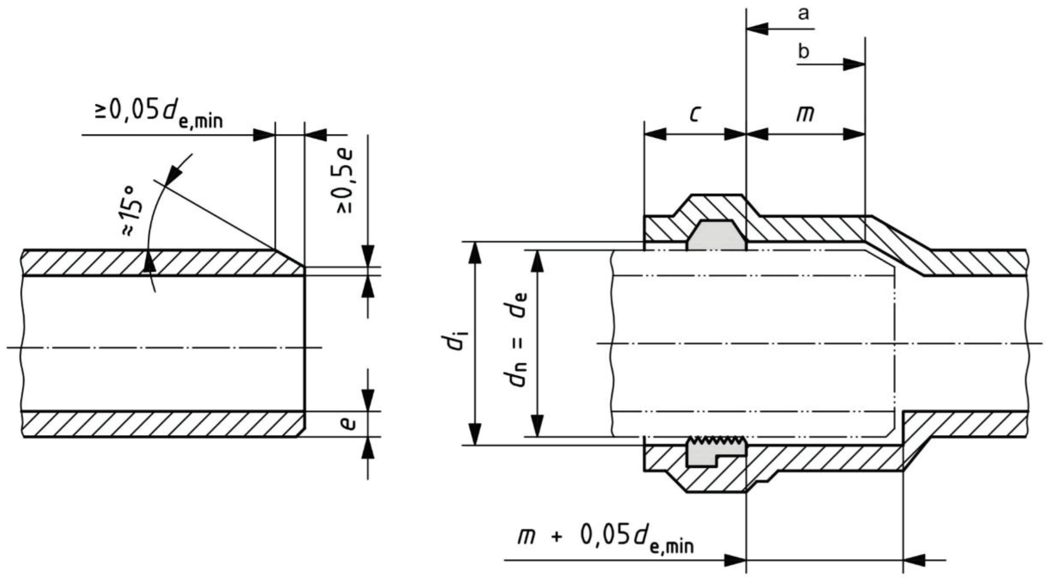


Figure 2.10: Dimensions of socket & spigot end for pipe with rubber ring

Table 2.5: Dimensions of Sockets for Solvent Cementing as per KS ISO 1452-2:2009(E)

Nominal inside diameter of socket, dn	Minimum mean inside diameter of socket, dim,min	Minimum depth of engagement, mmin	Length of socket entrance & sealing area, c
20	20.3	55	27
25	25.3	55	27
32	32.3	55	27
40	40.3	55	28
50	50.3	56	30
63	63.4	58	32
75	75.4	60	34
90	90.4	61	36
110	110.5	64	40
125	125.5	66	42
140	140.6	68	44
160	160.6	71	48
180	180.7	73	51
200	200.7	75	54

Nominal inside diameter of socket, dn	Minimum mean inside diameter of socket, dim,min	Minimum depth of engagement, mmin	Length of socket entrance & sealing area, c
225	225.8	78	58
250	250.9	81	62
280	281.0	85	67
315	316.1	88	72
355	356.2	90	79
400	401.3	92	86
450	451.5	95	94
500	501.6	97	102

h) Apply jointing lubricant to the spigot end as far back as the witness mark and especially to the chamfered section.

Note: Keep the rubber ring and ring groove free of jointing lubricant until the joint is actually being made.

i) Align the spigot with the socket and apply a firm, even thrust to push the spigot into the socket. It is possible to joint 63mm to 150mm diameter pipes by hand.

j) For pipes larger than 150mm diameter, a bar & timber block lever (Figure 2.11) or a pipe puller (Figure 2.12) may be used. Insert the spigot upto the socket end or the witness mark (as per manufacturer's instructions).

Note:

- If excessive force is required to make a joint, it may mean that the rubber ring has been displaced.

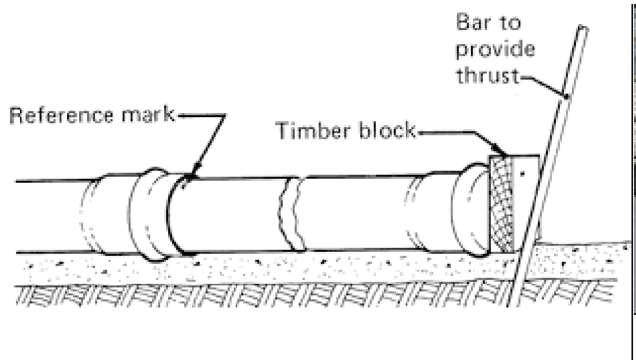


Figure 2.11: Bar & timber block lever


Figure 2.12: Pipe puller

k) Check whether the ring is properly placed (without dismantling the joint) by either:

- Inserting a feeler gauge all round between the socket and pipe to check even placement, or
- Shine a torch through the pipe. If there is anything protruding on the inside, the ring is not properly placed.

l) If a ring is not properly placed, dismantle the joint and repeat the procedure with a new rubber.

m) Brace or support the socket end of the line so that previously jointed pipes are prevented from sliding backwards.

n) Inspect each joint to ensure that the witness mark is just visible at the face of each socket.

o) With mechanical assistance, rubber ring joints can be recovered and remade years after the original joint was made.

p) New rubber rings should be used for recovered joints and care should be taken to ensure that there is no damage to pipe or socket.

2.4.4.4 Poor Pipe Repair Practices

Reduction of NRW in Kenya has been difficult in the past and even currently mainly due to poor repair practices like use of couplings made by heating pipes on fire. A fire-made coupling is repair coupling made from a piece of uPVC pipe by heating the pipe and inserting another unheated pipe into the heated end to make a socket.

Heating a pipe denature the pipe material thereby weakening it and destroying its elasticity. Further, the resulting socket is of no specific standard and loosely fits onto the pipe inserted thereby leaving a gap for leakage.

This practice was common in Meru WSP as shown in Figure 2.13 to 2.15 below. However, after staff training by KEWI and introduction of proper repair couplings and other repair materials, the practice was abandoned resulting in a substantial and sustained reduction in NRW.

Figure 2.13: Softening Pipe by Heating

Figure 2.14: Making Fire-made Coupling from Softened Pipes

Figure 2.15: Poor Repairs with Fire-made Couplings

Poor pipe repair practices are due to:

- lack of knowledge that heating plastic causes it to deteriorate thereby losing elasticity and strength which are very crucial in its performance
- lack of knowledge on the serious long-term consequences of poor pipe repair practices on NRW
- lack of training on proper pipe repair practices
- failure by WSPs to prioritize procurement of proper pipe repair materials
- corrupt tendencies whereby staff pilfer repair materials
- lack of training on integrity and therefore lack of understanding on the future consequences of corruption
- lack of adequate and severe action on wayward staff

WSPs must decisively deal with these issues if they expect to make positive and sustainable impact of progressively and speedily bringing down their NRW to acceptable level. It is the high time that Kenya becomes the leader in NRW management.

2.5 PE Pipe Materials

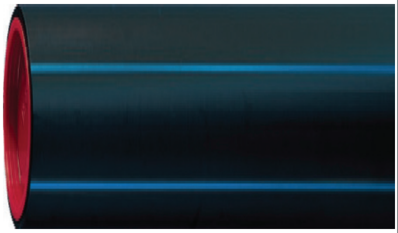
2.5.1 General

HDPE is the material used for high pressure pipes. There are two qualities thus PE80 (most commonly named MDPE) and PE100 (which is the improved from PE80).PE100 is recommended since it offers additional long-term strength and performance over PE80 while allowing for thinner pipe walls for the same operating pressure.

2.5.2 PE Pipes Classification

PE pipes come in various colours depending on the purpose (Table 2.6) and pressure rating.

Table 2.6: Purpose Coding of PE Pipes

	Pipe Colour	Purpose	Portable water Pipe
1	Black	Industrial applications	
2	Blue, or black with blue stripes	Potable water	
3	Yellow, or black with yellow stripes	Gas conduits	

Pressure Coding

Further, PE pipes are coded depending on pressure class thus: PN4-Yellow, PN6-Red, PN10-Blue, PN16-Green. However, WSPs should always inspect the pipes to confirm the outside diameter and wall thickness using vernier caliper (Section 2.2.5).

PE pipes must have electronic prints every 2m indicating manufacturer’s name, manufacturing date, standard and pipe class.

2.5.3 Connecting PE Pipes

2.5.3.1 Types of PE pipes joints

PE pipes can be connected using the following joints:

- Compression (quick-connection) joints
- Butt fusion joints
- Electrofusion sleeve joints

2.5.3.2 Compression (Quick-connection) Joint

A compression fitting is a type of coupling used to connect two pipes or a pipe to a fixture (or valve). A compression fitting has three components:

- Main body
- O-ring
- Wedge ring

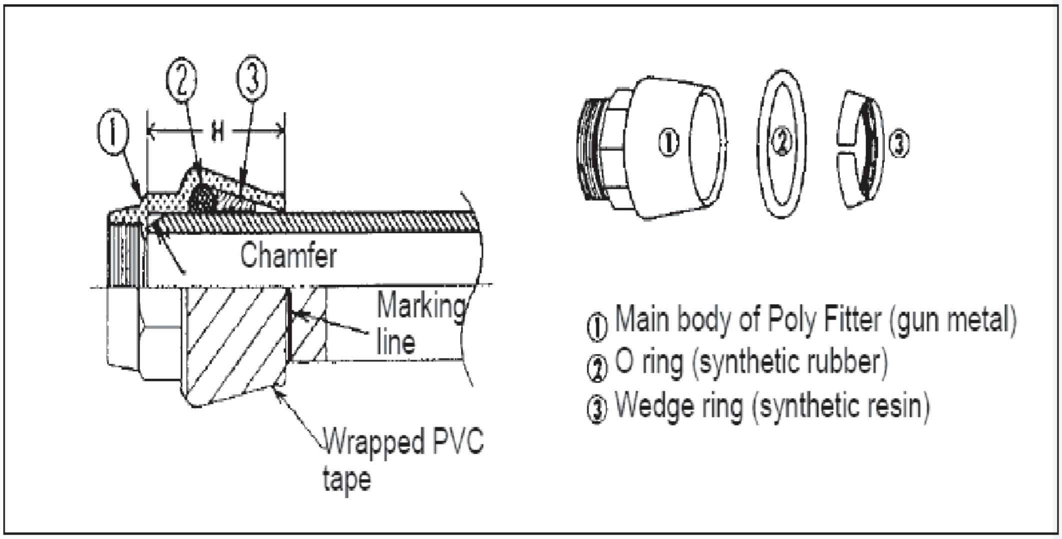


Figure 2.16: Quick-Connection Joint

As the nut is tightened, the compression ring is pressed into the seat, causing it to compress against the pipe and the compression nut thereby providing a watertight connection.

a) Assembling Compression Joint

i) Clean the pipe end and ensure it is free from burrs.

ii) Taper the pipe end down to ¾ of the pipe wall thickness. Remove cutting chips (since any remaining cutting chips may affect the water meters).

iii) Draw a marking line on the pipe to indicate the coupling or insertion length, H as per the manufacturer's specification (H is to ensure that the pipe is fully inserted).

iv) Check that the O-ring and wedge are:

- without damage.
- without twisting.
- installed correctly.

v) Insert the pipe spigot into the fitting socket.

vi) If the pipe has to be removed from the joint because of improper insertion, cut off the pipe by the length of the spigot and replace the O-ring and wedge ring with new ones.

ii) When the coupling is disassembled for re-use, replace the O-ring and wedge ring with new ones.

iii) After the pipe is connected, wrap the polyfitter with vinyl tape over more than ⅔ of its surface to prevent intrusion of sand and other foreign matter through any gap in the joint end.

iv) When the pipe is to be bent, bending radius should be more than 20 times the diameter of the pipe (Figure 2.17).

Pipe Diameter (mm)	**Minimum Bending Radius, R (cm)**
20	54 or more
25	68 or more
40	96 or more

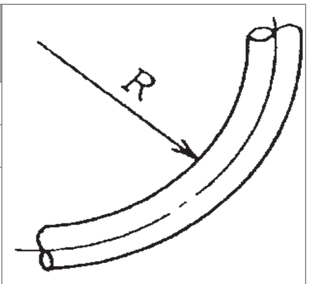


Figure 2.17: Minimum bending radius of PE pipes

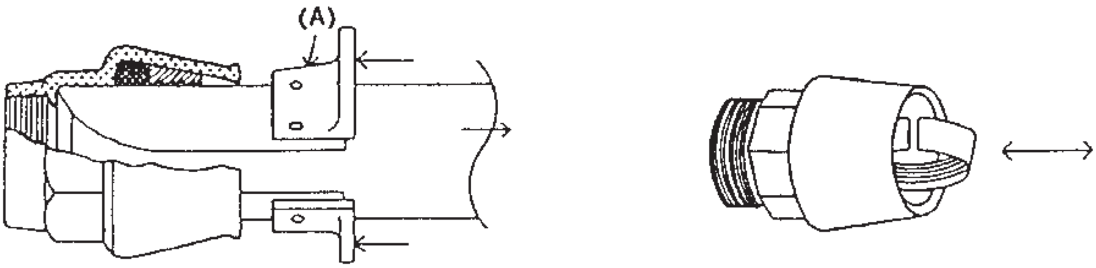


Figure 2.18: Disassembling Quick-Connection Joint

PE Compression Tee

PE Compression union/coupling

PE Compression Adaptor

Figure 2.19: PE Compression joint fittings

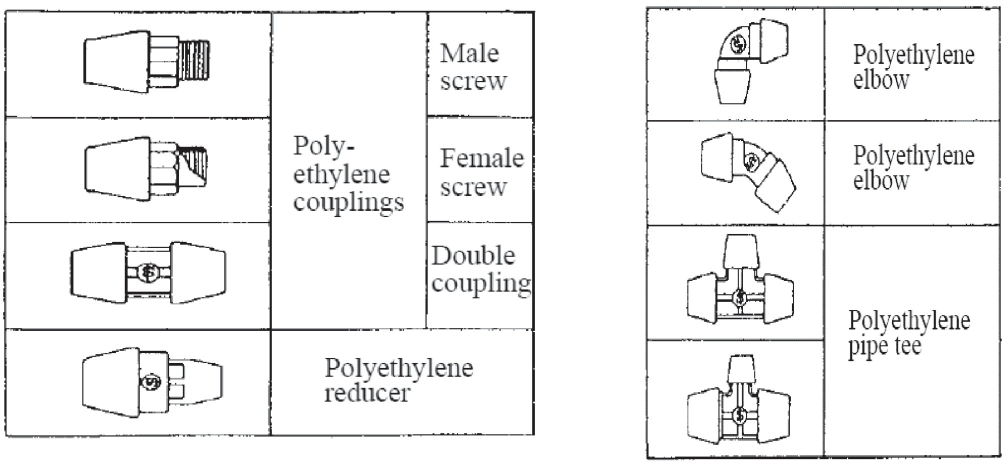


Figure 2.20: Types of Quick Connection/Compression Joints

c) Precautions for Prevention of Leakage

i) PE pipes have a lower tensile strength. Their strength is only about 1/5 of that of PVC pipes. Since they have soft surfaces, they tend to be easily damaged externally.

ii) They are combustible. Their strength decreases as the temperature rises. They soften around 90°C.

iii) They are susceptible to organic solvents and gasolines

iv) White coloured ones quickly age if exposed to direct sunlight for an extended period

v) Depending on the water quality, black coloured PE pipes react with chlorine to generate air bubbles. Very thin layers may peel off the inner surface after an extended period.

vi) It is preferable to store them indoors. When they are stored outdoors, they should be protected from direct sunlight and well ventilated. They should be stacked on a flat floor to a height not exceeding 1.5m regardless of whether they are in coils or not.

vii) Joints should be stored as packaged in an indoor location where they are not exposed to sunlight.

2.5.3.3 Butt fusion joints

Butt fusion means pipes are welded together end to end. PE pipes are butt fused using a properly sized butt fusion machine for the pipe size to be joined. The procedure is as follows:

i) Install and clamp the pipes in the butt fusion machine with pipe supports on both ends of the machine to support the pipes on the machine center line

ii) Align the pipe ends using the clamps on the fusion machine

iii) Face (or machine) the pipe ends to mechanical stops to ensure clean, parallel pipe ends for the heating process.

iv) Apply heat to prepared pipe ends and then push the pipe ends together with a pre-determined force to make a permanent butt fusion joint (a temperature-controlled heater is installed in the machine and the pipe ends are heated according to the butt fusion standard ASTM International F2620)

v) Once the heating criteria is met, the heater is removed and the pipe ends are brought together at the pre-determined force. This force is held on the joint for the time required by the standard. At this point, the pipe can be removed from the machine and visually inspected before putting down the pipeline

Note: Each butt fusion machine comes with the necessary manual detailing the procedure and specifications for butt fusion of pipes.

Figure 2.21: Butt welding Machine

Figure 2.22: Butt Weld Joint

2.5.3.4 Jointing PE Pipes by Electrofusion sleeve joints

Electrofusion welding uses the heat generated by an electric current flowing through a resistance to join pipes. Electric current is passed through resistive metal coils implanted in a fitting which is placed around the two ends of the pipes to be joined. The resistive heating of the coils melts small amounts of the pipes and the fitting, and upon solidification, a joint is formed. The procedure is as follows:

i) Wash pipe ends to create clean surfaces for joining
ii) Square pipe ends to facilitate optimal fit-up
iii) Clean area where coupler will be placed with isopropyl alcohol
iv) Mark the pipes slightly beyond half the length of the coupler, to indicate where scraping will take place in later steps
v) Mark the area to be scraped
vi) Scrape pipe in marked areas to remove surface layer, allowing clean pipe material to contact the coupler
vii) Examine scraped area thoroughly, making sure that fresh pipe material is exposed throughout the area
viii) Insert pipe ends into coupling to appropriate depth
ix) Secure coupler using clamp
x) Connect fitting to control box using electrical leads
xi) Apply fusion cycle
xii) Allow joint to be undisturbed for the entire prescribed cooling time

Note: Each electrofusion welding equipment comes with the necessary manual detailing the procedure and specifications for electrofusion of pipes.

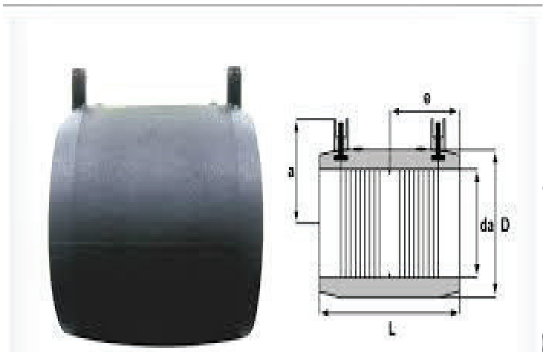


Figure 2.23: Electrofusion Sleeve Coupling

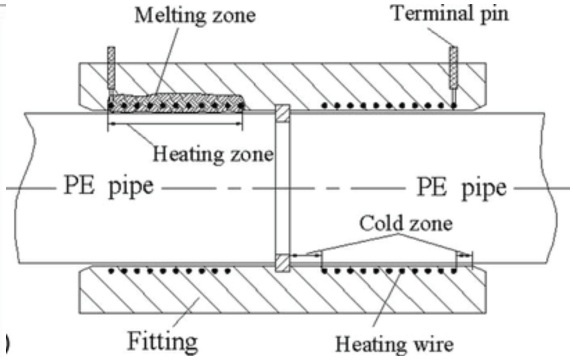


Figure 2.24: Electrofusion Sleeve Coupling Details

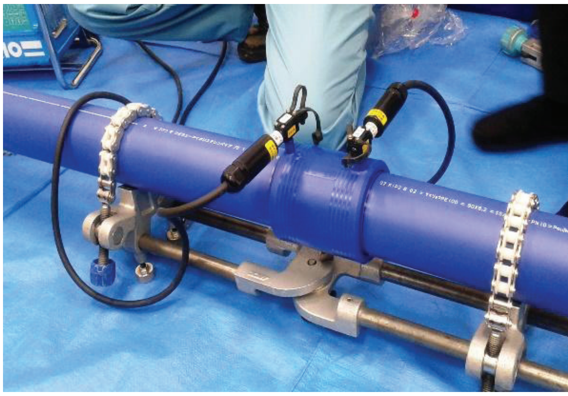


Figure 2.25: Electrofusion Welding in progress

Figure 2.26: Electrofusion Welded Joint

2.6 PPR Pipe Materials

Polypropylene Random (PPR) pipes are most reliable in plumbing inside the building due to their chemical features and fusion welding, which ensures perfect seal-tight joints.

PPR pipes are made to KS-ISO 15874 Standard.

In the water industry, PPR pipes are used in plumbing inside buildings such as residences, offices, etc. PPR pipes are not suitable where the pipe is exposed to sunlight due to deterioration.

Handheld tools are used to fuse PPR pipes of diameter 16 to 63mm. The tools come inside a case that contains the welder and a sheet that shows the welding parameters (diameter, pipe insertion depth, heating time, fusion time and time prior to testing).

Figure 2.27: Hand held PPR pipe fusion tools

Figure 2.28: Male & female fusion sockets (die pairs)

Figure 2.29: Heating PPR pipe & tee socket

The following is the procedure of making PPR fusion joint:

i) Mount the cold plate on the tool case as per the instruction sheet.

ii) Assemble (screw) the die pairs of the right diameter (corresponding to the pipe diameter to be joined) on the cold plate.

iii) Connect the welder to the power supply and switch power on (the cold plate and die pairs start heating).

iv) Wait for the sound signal that informs that the required temperature has been reached (see the user's manual of the welder).

v) Cut the pipe perpendicularly to its axis using the suitable pipe cutter.

vi) Mark the insertion length on the pipe.

Note: PPR Piping System mark a longitudinal sign (or line) on the external surfaces of the pipe and fitting as a reference to avoid turning the components to be welded while performing the welding procedure

vii) Place the ends to be welded close to each other to be able to begin the heating process of the material simultaneously

viii) After checking the surface temperature of the die pairs, insert the pipe inside the female die pair without rotating it and the fitting into the male die pair up to the sign previously marked for the heating time specified in the manual

Note: Do not heat up the parts to be welded twice.

ix) After the heating time, quickly remove the pipe and fitting from the die pairs and insert them one inside the other, within time the specified time, until you reach the insertion depth previously marked.

x) Hold the fused pipe pieces together and straight in line, not at an angle for 30 seconds.

Note:

(1) Be careful not to rotate the pipe into the fitting and carefully align the reference longitudinal signs

(2) PPR pipe heats very quickly and cools very quickly. Within 30 seconds, the pieces will have cooled enough to have fused into one piece of PPR pipe

xi) You can then put the fused pipe down and move on to your next task

Table 2.7 indicates the dimensions of PPR pipes as per KS-ISO 15874 Standard

Table 2.7: PPR Pipe Dimensions to KS-ISO 15874 Standard

PN 20 Pressure Rating	Pipe dia (mm)	20	25	32	40	50	63	75	90	110
	Wall thickness (mm)	3.4	4.2	5.4	6.7	8.3	10.5	12.5	15	18
PN 16 Pressure Rating	Pipe dia (mm)	20	25	32	40	50	63	75	90	110
	Wall thickness (mm)	2.8	3.5	4.4	5.5	6.9	8.6	10.3	12.3	15.1

Note: PPR pipes are manufactured with electronic identification print on the pipes (Indicating manufacturer's name, date of manufacture, manufacture standards, pipe class)

2.7 Galvanized Iron (GI) Pipes

2.7.1 General

GI pipes for domestic water supply mostly use threaded connections piping system. The pipes are normally supplied with threaded ends and one socket. Due to the many complex classification of GI pipes, a more simplified classification is normally adopted as in Figure 2.30 GI pipes sizes range from 0.5 to 6 inches in diameter.

Figure 2.30: GI Pipe Classification

Table 2.8: Galvanized and Black Steel Pipes as per KS 06-259 and BS 1387

	Type, Class & Colour Mark	Normal Bore	Wall Thickness	Approx. Outside Diameter	Weight of Black Pipes Plain End	Weight of Black Pipe Threaded & Socketed	Weight of Galvanized Pipe Threaded & Socketed
	mm	in	mm	mm	Kg/m	Kg/m	Kg/m
LIGHT 'A' YELLOW	15	½"	2.00	21.3	0.95	0.96	1.04
	20	¾"	2.35	26.9	1.41	1.42	1.53
	25	1"	2.65	33.7	2.01	2.03	2.19
	32	1¼"	2.65	42.4	2.58	2.61	2.82
	40	1½"	2.90	48.3	3.25	3.29	3.55
	50	2"	2.90	60.3	4.11	4.18	4.51
	65	2½"	3.25	76.2	5.8	5.92	4.39
	80	3"	3.25	88.9	6.81	6.98	7.54
	100	4"	3.65	114.3	9.89	10.2	11.02
MEDIUM 'B' BLUE	15	½"	2.65	21.3	1.22	1.23	1.33
	20	¾"	2.65	26.9	1.58	1.59	1.72
	25	1"	0.33	33.7	2.44	2.46	2.66
	32	1¼"	3.25	42.4	3.14	3.17	3.42
	40	1½"	3.25	48.3	3.61	3.65	3.94
	50	2"	3.65	60.3	5.10	5.17	5.58
	65	2½"	3.65	76.2	6.51	6.63	7.16
	80	3"	4.05	88.9	8.47	8.64	9.33
	100	4"	4.50	114.3	12.10	12.40	13.39

	Type, Class & Colour Mark	Normal Bore	Wall Thickness	Approx. Outside Diameter	Weight of Black Pipes Plain End	Weight of Black Pipe Threaded & Socketed	Weight of Galvanized Pipe Threaded & Socketed
	mm	in	mm	mm	Kg/m	Kg/m	Kg/m
	125	5"	4.85	139.7	16.2	16.7	18.04
	150	6"	4.85	165.1	19.2	19.8	21.38
HEAVY 'C' RED	15	½"	3.25	21.3	1.45	1.46	1.58
	20	¾"	3.25	26.9	1.9	1.91	2.06
	25	1"	4.05	33.7	2.97	2.99	3.23
	32	1¼"	4.05	42.4	4.43	4.47	4.83
	40	1½"	4.05	48.3	4.43	4.47	4.83
	50	2"	4.50	60.3	6.17	6.24	6.74
	65	2½"	4.50	76.2	7.9	8.02	8.66
	80	3"	4.85	88.9	10.1	10.3	11.12
	100	4"	5.40	114.3	14.4	14.7	15.88
	125	5"	5.40	139.7	17.8	18.3	19.76
	150	6"	5.40	165.1	21.2	21.8	23.54
	200mm & 250mm Galvanized and Black Steel Pipes (Detailed specification on request						
	200	8"	5.20	219.1	27.71	28.56	30.84
	200	8"	6.00	219.1	31.82	32.57	35.18
	250	10"	6.00	267.0	39.09	40.01	43.23

Note: GI pipes are identified by colour code and in addition manufactured with electronic identification print on the pipes after every 2mtrs, (Indicating manufacturer's name, date of manufacture, manufacture standards, pipe class)

2.7.2 GI Pipe Joints

Threaded GI to GI pipes is connected with threaded female coupling. PTF tape or hemp/boss white are used as sealant to prevent leakage.

Figure 2.31: Threading of pie with diestock

Figure 2.32: Threaded Joint

Care must be taken to ensure the thread length is adequate and the joint is watertight.

2.8 Jointing Different Pipe Materials (Special Pipe Joints)

Joints of different materials are called special joints. The following are special joints used in water supply:

2.8.1 Connecting Steel and PVC Pipes

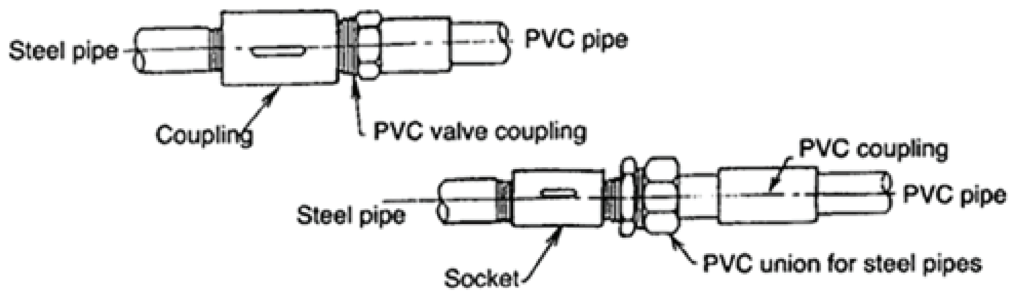


Figure 2.33: Connecting Steel pipe to PVC pipe using: (1) Steel coupling/PVC valve coupling; (2) Steel coupling/PVC union for steel pipes

2.8.2 Connecting Steel and PE Pipe

Figure 2.34: Stub end joint (Connects flanged steel pipe and PE pipe)

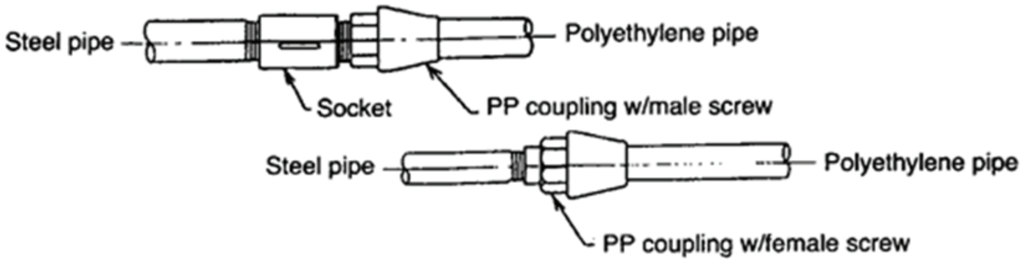


Figure 2.35: Connecting Steel Pipe to PE Pipe by (1) PE male coupling, (2) PE female coupling

2.8.3 Connecting uPVC and PE Pipes

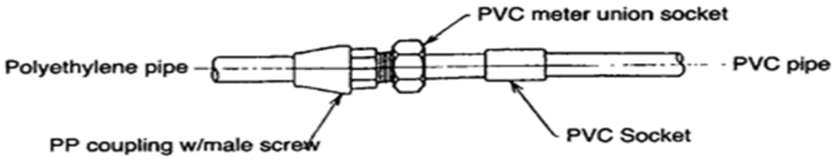


Figure 2.36: Connecting PE pipe to PVC pipe by PE male coupling/PVC union socket

2.8.4 Universal Joints

These are joints that can be used for any pipe materials

Figure 2.37: VJ/ Ranger Coupling

Figure 2.38: VJ Adaptor

Figure 2.39: VJ Dismantling joint

Figure 2.40: Pipe repair clamp

2.9 Comprehensive Specification of Materials for Procurement

Poor pipe and fittings materials are sometimes received from suppliers leading to NRW increase once used in the water supply. Below are some reasons for poor materials:

i) Poor project design
ii) Providing Poor and/or inadequate or no specifications of materials
iii) Failure to specify the materials standard
iv) Failure to provide the specifications to the inspection and acceptance committee members for use during inspection
v) Failure to understand implication of various standards to the project
vi) Failure to carry out adequate inspection of materials before accepting
vii) Having inexperienced or incompetent staff as members of inspection and acceptance committees for materials
viii) Failure to train inspection and acceptance committee members on how to do inspection
ix) Inspection and acceptance committee members being compromised by suppliers
x) Failure by managers to confirm quality of materials before approval for payment
xi) Failure to understand the implications of accepting poor quality materials
xii) Corruption

It is always prudent to ensure that materials specifications are adequately detailed to remove any ambiguity. This should include attaching brochures, or any materials that may assist in clarifying the requirements. Below is an extract of a bill of quantities for tendering in Meru WSP:

Table 2.9: Extract of comprehensively specified bill of quantities

S/Nr	Description	Unit	Quantity	Rate	Amount
1	PE100 Adaptor male 20mm dia PN16 to EN 12201-2 Standard	No	1		
2	PVC-U Bend 20mm dia x 90o PN15 to ISO 4422	No.	1		
3	PE100 Coupling 20 mm dia PN16 to EN 12201-2 Standard as per Annex-1 or equivalent	N0.	1		
4	PE100 Coupling 40 mm dia PN16 to EN 12201-2 Standard as per Annex-1 or equivalent	No.	1		
5	Float valve 4” dia PN10 cast iron as per Annex-6 or equivalent	No.	1		
6	PE100 Pipe 63 mm dia 100m long roll PN16 to EN 12201-2 Standard as per Annex-1 or equivalent	No.	1		
7	PVC-U Pipe 90mm dia PN15 to ISO 4422	No.	1		
8	PVC-U Saddle clamp 40x20mm (1 ¼’’ x ¾”) dia PN15 as per Annex-9 or equivalent	No.	1		
9	Sluice valve 80 mm (3”) dia PN16 flanged to DIN 3352 part 4 / NF E 29-324 as per Annex-10(a) and specifications in Annex-10(c) or equivalent including Stem Cap Type 3 as per Annex-10(d)	No.	1		
10	Swivel ferrule 20mm (¾”) dia as per Annex-7 or equivalent	No.	1		
11	PVC-U Valve socket 50mm dia PN15 to ISO 4422	No.	1		

CHAPTER 3

HOW TO LAY WATER PIPELINES

(Target Staff: Design, Construction, Network Maintenance/Repair, NRW, Connection installation)

3.1 Introduction

A water supply starts developing weakness to leakage at design stage (if design is poor). Further weakness is introduced during implementation and finally during operation and maintenance.

It is therefore very important to ensure that quality control is exercised at every stage of the system.

This chapter specifies the steps to take during implementation to minimize leakage and hence NRW.

3.2 Trenching for Water Pipelines

a) Trenching excavation should be in such a manner as to minimise slips fall or disturbance to the sides and bottom of the excavation and therefore maintain the stability of all roads and other adjacent structures or works.

b) Trenches for pipes should be excavated to a sufficient depth to enable the pipe and the specified joints, bedding, haunching (side support) and surround to be accommodated. Unless otherwise stated, the width of the trench should be equal to the nominal diameter of the pipe plus 700 mm.

c) Any over-excavation beneath the pipe or bedding should be filled with well rammed selected general excavation material as per requirement specification of a qualified engineer. Any surplus excavated material not required for backfill should be dispose.

d) The sides of trenches should be adequately supported at all times or ensure that the side slopes of the excavation are sufficient for stability.

e) Where rock or boulders are present in the sides or base, the trench should be trimmed so that when the pipeline is laid, no projection of rock comes within 200mm of the outside of the pipe at any point.

3.3 Handling Pipes and Fittings

a) Before any pipes are delivered to site, all the staff handling the pipes (e.g., Stores staff, inspection and acceptance committee staff) should read and understand this section for handling pipes during transport, in store and during laying.

b) Always take into account any recommendations made by the pipe manufacturer in making arrangements for handling pipes.

c) Ensure all the materials (pipes, fittings, etc) are of good quality and quantity.

d) Pipes and fittings should only be transported on properly constructed or adapted vehicles with no pipes overhanging outside.

e) During transport and in store, pipes should not rest on narrow supports likely to cause damage to the pipe or its coating.

f) Pipes and fittings should not be subjected to rough handling at any time

g) Pipes should not be loaded or off-loaded from a vehicle by tipping or dropping; or be allowed to collide with one another

h) Any materials or pipes found defective or that have been dropped from a vehicle should immediately be rejected

i) Any pipes exceeding 200kg should be handled by means of a crane. Any WSP handling such heavy materials should acquire and maintain a suitable mobile crane for all loading, unloading, transferring between vehicles and lowering such pipes into the trench. The crane should be fitted with a sling of ample width. Wire rope slings or hooks at pipes ends should not be used for pipes or fittings of any diameter or mass.

3.4 Pipe Laying

a) Immediately before pipes are placed in any trench, the bottom should be cleared of all stones and other debris

b) Prior to placing in the trench, all pipes should be inspected for damage. Any end caps or discs placed on the pipes for protection during transit should not be removed until immediately before the pipes are jointed

c) Pipes should be laid in straight lines unless otherwise shown on the drawings

d) All lines should be cleaned after all installation work

e) When pipes are installed, all ends should be suitably plugged until final fixing of fixtures can be carried out. Pieces of cloth or stones should not be permitted inside

f) Construct:
i) Concrete thrust blocks to support the pipe at bends and ends.
ii) Concrete anchor blocks should be constructed at steep slope.
iii) Concrete surrounds over pipeline across roads/rails

3.5 Pipeline Backfilling

a) Pipes should be firmly bedded throughout their length to the required alignment and level so that they are concentric at each joint.

b) All pipes should be suitably wedged, shored (prop) or restrained to prevent movement during testing and backfilling but such restraints should not be left in place permanently

c) Filling should begin with selected fill consisting of easily compacted material from which all stones larger than 25mm and all lumps of clay larger than 75mm have been removed

d) The selected fill should be deposited equally on each side of the pipe and carefully compacted in layers not more than 150mm thick. Care should be taken to ensure that no voids are left under the pipe.

e) The filling should be continued to a level of 300mm above the crown of the pipe

f) The remainder of the trench should be filled with excavated material and compacted in 150mm thick layers. The trench should be filled flush with the surrounding ground surface.

g) Where pipes have to bedded or surrounded with concrete, it should be in accordance with specifications from a qualified engineer

h) All pipes crossing driveways and roads should be surrounded with concrete for the entire length of crossing before trench backfilling

3.6 Pipeline Pressure Testing

a) Gauges used for pressure testing pipelines should be of the conventional circular type, not less than 200 mm diameter, calibrated in metres head water; or should have a digital indicator capable of reading increments of 0.1 m head.

b) Before any gauge is used, it should be checked for accuracy.

c) As the installation of the pipework proceeds, the various sections should be tested before they are built in, concealed, or finally connected. The sections should be about 300m long.

d) All the necessary records of the tests and results should be submitted for filing
e) All pipe systems should be hydraulically tested for 1 hour
f) The testing pressure should not be less than 1.5 times the design working pressure.
g) During the test, each branch and joint shall be examined carefully for leaks and any defects observed should be rectified and the section re-tested.
h) Before any length of main is charged with water, each pipe in that length should be covered to a depth sufficient to prevent uplift. The necessary backfilling should be such that each joint is left completely clear for inspection during testing unless it is practically impossible.

The pressure testing should be carried out as follows: -

i) Before testing, valves should be checked and blanked off (or closed)
ii) The sections of the mains should be filled with water and the air released.
iii) After filling, the pipelines should be left under operating pressure for 24 hours so as to achieve as stable as possible for testing.
iv) The pressure in the pipeline should then be raised steadily until the specified test pressure is reached in the lowest part of the section, and the pressure shall be maintained at this level, by pumping, if necessary, for a period of 1 hour.
v) The pump shall then be disconnected, and no further water should be permitted to enter the pipeline for a further period of 1 hour.
vi) At the end of 1 hour the original pressure should be restored by pumping and the loss measured by drawing off water from the supply line until the pressure as at the end of the test is again reached.
vii) Calculate the water loss as flows:

$$\text{Water loss} = \frac{Q \times 24}{D_n \times L \times (P_L \times P_u)/2}$$

Where:

Q	=	water drawn from supply line over the 1-hour testing time (litres)
D_n	=	nominal pipe diameter (m)
L	=	length of pipeline being tested (km)
P_L	=	Pressure at lower end of pipeline (m)
P_u	=	Pressure at upper end of pipeline (m)
24	=	24 hour (means loss over 24-hour period)

The water loss should not be higher than the permissible loss.

The permissible loss is *2 litres per metre nominal bore per kilometre length per metre head (calculated as the average head applied to the section) per 24 hours.*

j) In addition to the test on separate sections, the whole pipeline shall be tested on completion to the same pressure and by the same procedures as that outline for individual sections.

k) On completion of a main, the whole length of the main shall be subjected to a final test under pressure with all valves along the length of the main fully open.

l) During pressure testing, air valves shall be isolated. Testing should not be permitted against closed line valves or washout valves.

3.7 Pipeline Disinfection

3.7.1 General

Disinfection of pipelines is not an NRW reduction factor. However, majority of WSPs in Kenya do not carry out this critical requirement thereby placing water consumers in grave danger. This handbook provides the right opportunity to sensitize WSPs on the need and procedure of pipeline disinfection.

When a pipeline is laid or upgraded, some contamination almost always gets into the pipes from the soil, mud and water in the trench, and from the feet or boots of the workers. It is important to kill any germs which may be in the pipeline before it supplies water to the community.

There are two forms of chlorine products suitable for making the disinfecting solution for pipelines. These are calcium hypochlorite (HTH) or sodium hypochlorite (liquid bleach). Normally, a 0.2% solution of chlorine should be made from either product.

3.7.2 Preparing chlorine solution for disinfecting pipelines

a) Safety for operators handling chlorine

- The operation and maintenance of equipment for dosing chlorine from cylinders should only be undertaken by trained and authorized personnel.
- Chlorine is a hazardous substance. In solution it is highly corrosive and splashes can cause burns and damage the eyes. When handling concentrated chlorine solutions, appropriate precautions should be taken. Ideally, gloves and protective eye glasses should be won. In the event of splashes and especially splashes to the eyes, it is important immediately to rinse thoroughly with water.

- All containers in which chlorine is stored should be labelled, identifying the contents, and with a hazard warning in a form which is readily understood locally.
- Storage sites for chlorine in any form should be secure against unauthorized access and especially against children.

b) Sodium Hypochlorite or liquid bleach

Liquid bleach is normally bought in bottles sachets. Check that the contents are sodium hypochlorite and water only. The normal concentration of chlorine in liquid bleach is 5%, but this may be lower if the bottle has been opened or stored for a long time.

Using Sodium Hypochlorite (liquid bleach) to make a chlorine solution

- Fill three plastic buckets with clean water up to 5cm from the top to allow for the bleach to be added. Most commercially available buckets hold 12.5 litres, but the quantity of water should be checked.
- Add enough liquid bleach to bucket to make up a 0.2% solution of chlorine as follows:

Capacity of bucket of 12.5 litres water = 12,500 milliliters

We need 0.2% or 0.2 grams of chlorine per 100 milliliters of water

Therefore, $\frac{2500 \text{ ml} \times 0.2\text{g}}{100 \text{ ml}}$ = 25g chlorine is needed per bucket

Liquid bleach is assumed to contain 4% or 4 g of chlorine per 100 ml,

Therefore, to make 25 g of chlorine we need $\frac{25 \text{ g} \times 100 \text{ ml}}{4 \text{ g/100ml}}$ = 625 ml

Hence 625ml of 4g/100ml liquid bleach must be added to each 12.5 litres of water to make 0.2% solution of chlorine.

- Mix the water and bleach well before use.

c) Calcium hypochlorite or High Test Hypochlorite (HTH)

Calcium hypochlorite comes as white granules. It is stronger than liquid bleach and does not lose strength so quickly. It comes in concentration ranging from 20 to 70% chlorine.

The best type of chlorine to use is HTH as it normally contains 50 to 70% chlorine. Always check with the supplier or on the side of the container to be sure of the percentage chlorine content.

Using calcium hypochlorite (HTH) 50% to make chlorine solution

- Fill three 12.5 litres plastic buckets with clean water to about 5cm from the top to allow for the hypochlorite to be added. Most commercially available buckets hold 12.5 litres, but the quantity of water should be checked.
- Add enough calcium hypochlorite to each bucket to make a 0.2% solution of chlorine as follows:

Capacity of bucket of 12.5 litres water = 12,500 milliliters

We need 0.2% or 0.2 grams of chlorine per 100 milliliters of water

Therefore, $\frac{12500 \text{ ml} \times 0.2\text{g}}{100 \text{ ml}}$ = 25g chlorine is needed per bucket

If calcium hypochlorite contains 50% chlorine or 50g of chlorine per 100 g powder, then 25 g (amount of chlorine needed in a bucket) is contained in

$\frac{25 \text{ g} \times 100 \text{ ml}}{50 \text{ g}/100\text{g}}$ = 50 g of powder

Hence 50 g of 50% HTH must be must be added to each 12.5 litres of water to make 0.2% solution of chlorine.

- Mix the water and bleach well and leave to dissolve for an hour. Some white sediments will sink to the bottom of the bucket. Only the clear liquid should be used to disinfect the pipeline and the sediment thrown away.

3.7.3 Disinfecting pipelines

When a pipeline is to be disinfected

- Close the pipeline with a plug or blank flange or valve at the lower end.
- Fill the pipeline with a 0.2% chlorine solution and leave it for at least 6 hours contact duration to kill any germs.
- Ensure customers DO NOT DRINK the chlorine water.
- Drain the disinfectant water flush the pipeline with treated water until residual chlorine of 0.2 to 0.8 mg/litre is reached (monitor the residual chlorine using a Lovibond comparator or electronic chlorine tester).
- Put the pipeline into operation.

3.8 Procedure of Installing Service Connections and Customer Meters

a) Application form for installation of service connections and customer meters

Installation of a service connection normally begins with receipt of an application from a customer. the application form should be designed such that it is easy for customers to fill. it should also contain information that will assist the field staff to locate the customer premises such as mobile no., name of the next neighbour with a connection, nearest known landmark, etc. a sketch map should be attached to ease the locating.

b) Survey for installation of service connection

Preparation for installation begins with a field visit to assess the site conditions and come up with a list and type of materials to be used, and labour requirements.

the connection is then installed once approved and resources allocated.

points to note:

All materials for connection installation including the meter should be procured by the WSP to ensure quality control. Situations where customers procure their own materials should be stopped.

c) Procedure for installation of service pipe

i) excavate a trench from the distribution pipe to the customer connection point (customers may be allowed to excavation the trench for the service pipe but under competent supervision).

ii) the trench should be at least 0.6m deep by 0.6m wide and straight (unless unavoidable); and follow the shortest route possible.

iii) the trench bottom level should be even i.e., without ups and downs.

iv) adequate working space should be provided around the distribution pipe (sideways and underneath) where the tapping will be done.

v) use good quality sand or soil for bedding. ensure no hard or sharp objects (stones, etc.) that can damage the pipe.

d) Tapping and laying the service pipe

Water supplies in Kenya have a history of tapping using locally (jua kali) fabricated saddle clamps which are of no specific standard. Rubber from vehicle tyre tube is then used as the seal against leakage. Due to the poor quality of the resulting joint, leakage almost always occurs sooner than later.

Another tapping method has been to cut the distribution pipe and install a tee fitting. This really weakens the main pipe and is a cause of recurring leakages. The other problem is using gate valve for controlling water. Gate valves rust over time and eventually start leaking hence contributing to NRW.

These methods should be stopped if reduction of NRW is to bear fruits.

Materials for service pipes should be good quality (use good standards), without blemishes and of good class (PN10 and above depending on the local water pressures. Use PN16 saddle clamp (clamp) and ferrule).

Note: pipes weaken with time hence a good allowance should be provided.

e) Location of the meter

i) Ensure that the meter will be located at points where meter reading, inspection, and maintenance can be easily performed.

ii) Sites selected for the meter should be located in a dry area away from wastewater, water logging, flooding, contaminated air or exhaust air.

iii) Meters should not be exposed to vandalism, theft or accidents. in Kenya, water meter installed above ground are more susceptible to theft. in such cases plastic body water meters are recommended.

iv) Meters should not be installed in areas with excessively high temperatures or where water pressures fluctuate excessively

v) Meters should not be located in areas where they are subjected to shocks or vibrations.

vi) Meters should be installed as close to the distribution pipeline as possible

vii) Factors to take into consideration when installing customer meters are the reliability of meter performance, ease of reading and ease of replacing and maintenance.

f) Tapping and laying the service pipe

the following procedure should be used when tapping:

Figure 3.1: Tapping with standardized saddle clamp and ferrule (tap)

source: Meru WSP

i) Ensure the exposed distribution pipe is clean all round (wash with water if possible)

ii) Tie thread tape PTF over the ferrule threads and fix the ferrule tap onto the saddle clamp

iii) In case of more than one service line, ensure adequate spacing is provided for maintenance

iv) Remove the ferrule tap and use a drill to bore a hole on the top side of the distribution pipe

v) Remove the drill and allow water to flow out for a few seconds to clean the cut hole ensuring the cut pipe piece comes out and does not fall into the pipe.

vi) Screw back the tap and close the water.

vii) Connect the service pipe to the ferrule and lay in the usual manner. Use only factory manufactured and standardized fittings such as socket couplings, socket bends/elbows, socket reducers, etc.

viii) Connect two horizontal GI pipe pieces, say 2.5ft long to the service pipe to ensure firm support of the meter. Only one pipe piece is necessary if meter is next to the distribution pipe

ix) Connect vertical GI pipe pieces to raise the meter to the required level (e.g., 0.5ft above the ground level or the level stipulated for the meter box) (connect a stop cork (called WSP stop cork) (not gate valve since it is often obstructed from closing by silt)

x) Connect the meter horizontally with the arrow on the lower case facing towards the direction of water flow. When meters are not installed perfectly horizontally, its sensitivity and durability are highly compromised.

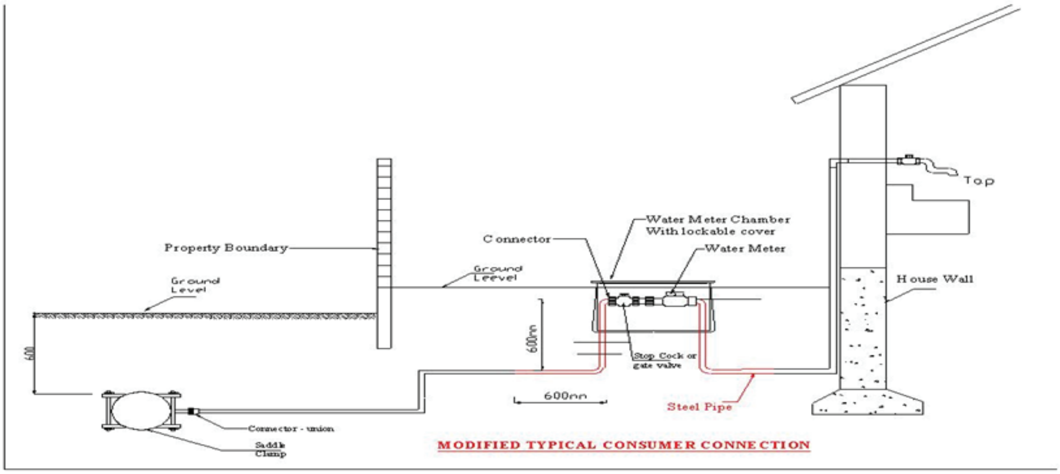


Figure 3.2: Customer Meter Installation with Meter Box

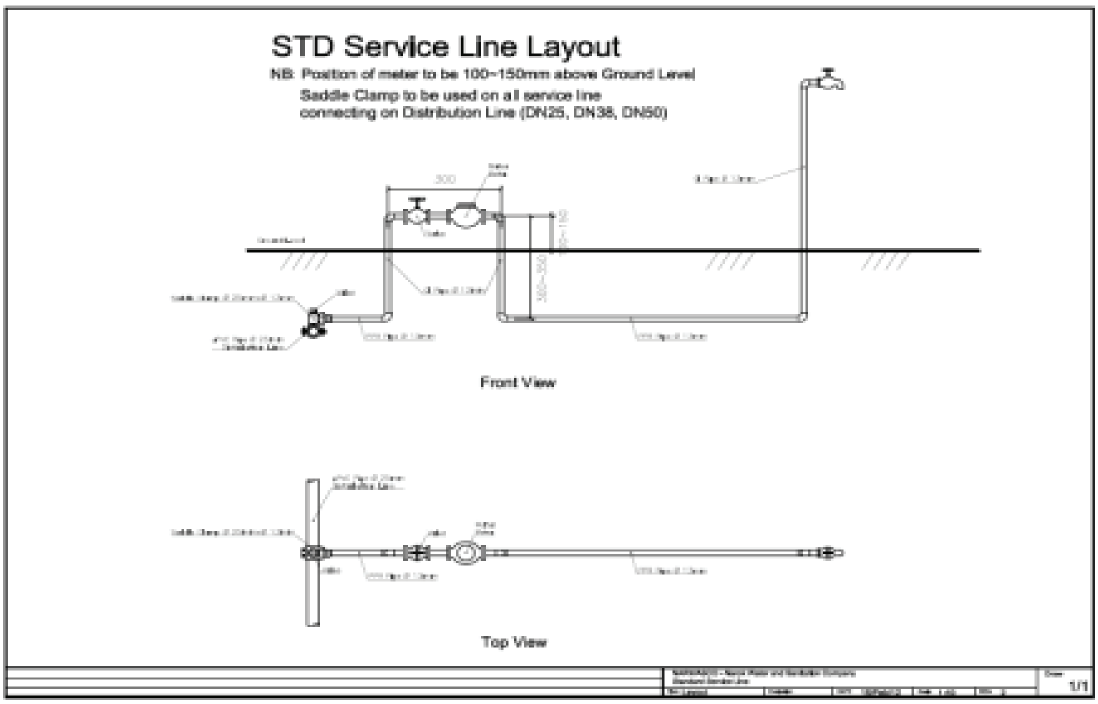


Figure 3.3: Customer Meter Installation without Meter Box

xi) It has been found advisable to install another stop cork immediately after the meter (called customer stop cork) to give the customer control of water without interfering with fittings between the saddle clamp and the meter.

xii) In case of more than one connection, provide adequate spacing between the pipes and also the meters for maintenance

xiii) No service pipe should cross over another service pipe

xiv) Connect the service pipe to the customer connection point

xv) Lightly backfill the trench leaving the joints exposed and allow connecting adhesive to dry

xvi) Close the WSP stop cork, customer stop cork, and all the taps and valves in the premises

xvii) Open the water at the ferrule and check for leakage at the joints between the saddle clamp and the WSP stop cork

xviii) Open the WSP stop cork slowly for the first time, in order to prevent water hammer.

xix) Open customer stop cork and ensure no leakage at the meter connections.

xx) Open the customer stop cork and check for leakage in the customer pipe system

xxi) Alternatively, carry out pressure testing of the system to see any leakage

xxii) Repair any leakage in the new service pipe and advise the customer to repair all leakages in his/her pipe system before commissioning the connection

xxiii) Complete backfilling and adequately compact the trench

xxiv) Draw a sketch map of the connection with measurements

xxv) Take GPS location of the saddle clamp and meter and record on the sketch map Update the records on the relevant forms and take a picture of the installation

xxvi) Submit the connection records to the office

g) Backfilling

i) Use good quality sand or soil for backfilling. Ensure no hard or sharp objects (stones, etc.) that can damage the pipe.

ii) Water meter should be appropriately installed and there should be no obstruction to reading and replacement of meters.

iii) Install meter boxes ensuring that they are not buried in soil or mud

Photo 3.1: Installation of Customer Meters without meter box

Photo 3.2: Installation of Customer Meters in a meter box

3.9 Installation of Large Meters

Any pipe appurtenance such as sluice valves or pipe bends, cause turbulence in water flow. This turbulence can cause a meter installed nearby to record the flow inaccurately.

To prevent such errors being introduced in flow measurement, all meters should be installed well away from any obstruction from appurtenances or bends, reducers and tees. The distance between the meter and any such obstruction is called the calming distance since it calms the water so that the flow is not turbulent as it passes through the meter.

The minimum recommended calming distance from the nearer end of the meter is 10D on the upstream and 5D on the downstream, where D is the pipe diameter.

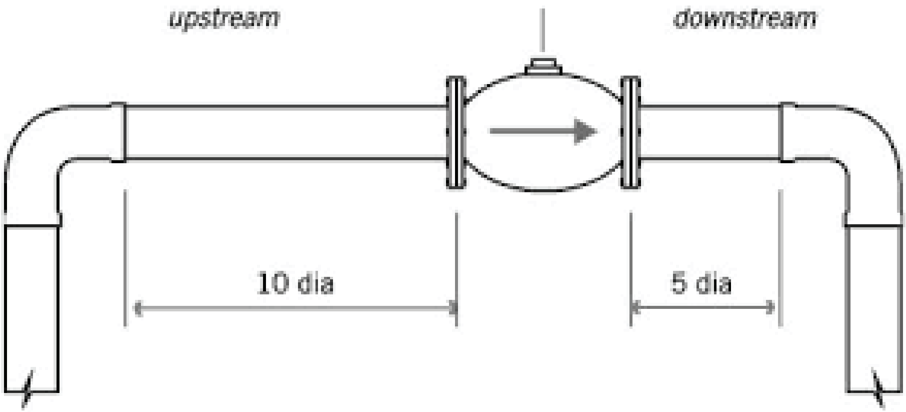


Figure 3.3 Calming sections for water meters

Small diameter meters come with meter liners that ensure compliance to this rule hence do not require further consideration. However, in some cases, such meters are installed directly without meter liners thereby introducing obstructions to the meter hence causing metering errors.

3.10 Meter Sizing

Undersized meters can cause huge NRW (especially when they are used for customers consuming large volumes of water) due to their under-registration of consumption. Hence, proper sizing (or resizing) of meters, especially for large and medium non-domestic customers, is quite important. The procedure of sizing customer meters is well documented in the NRW Guidelines. The Non-Revenue Water Guidelines in Kenya.

CHAPTER 4

MAINTENANCE OF WATER SUPPLY NETWORK

(Target Staff: Construction, Network Maintenance/Repair)

4.1 Institutionalizing Maintenance Schedules

Due to inadequate knowledge, most WSP staff in Kenya assume that water shortage that forces them into rationing is caused by inadequate water supply capacity in the face of a growing demand. They therefore, in most cases, advocate for new projects development to solve the problem. This problem can, to a large extent, be solved by ensuring that the water infrastructure is maintained at the level it was first constructed. However, due to aging, neglect, etc., it has over time fallen into disrepair and inefficiency.

Lack of properly functioning bulk meters to accurately monitor flow is an example. Failure to read them regularly enough (daily on minimum) to provide useful data for decision-making is another form of lack of maintenance. This lack of maintenance is widespread among other components of the water supply, including sluice valves, float valves, etc.

WSPs need to institutionalize comprehensive preventive activity schedules (Appendix-1) for all the water supply management components and not wait until breakdowns occur. Inclusion of maintenance for each component in the annual budget should also be institutionalization.

The most effective strategy to maintain appurtenances and equipment is to prepare and institutionalize maintenance schedules.

4.2 Maintaining Good Water Quality to Reduce NRW

a) How Water Quality Affects NRW

Does poor water quality contribute to increase in NRW? The answer is YES.

Poor water quality is most obvious when turbidity is high. High turbidity affects customer meters through clogging thereby causing lower meter indication than the actual consumption or even complete stoppage. This therefore increases commercial loss.

Experience in Kenya has shown that water turbidity should be kept below 2 NTU to ensure low level of water meter stoppage.

The following are the strategies to ensure low water turbidity:

b) Cleaning water supply intakes

Surface water intakes receive raw water which comes with tree trash, stones, sand, mud, etc. These require regularly cleaning to ensure free flow of water and to reduce dirt at the treatment plant which increases treatment chemicals requirement.

- Clean the reservoir and intake chambers by disludging the mud, removing trash from the trash racks and clearing the bush around the intake are necessary. The tools required are such as shovels, rakes, jembes, and slashers.
- Flush the intake pipe at the first and second wash out to ensure mud does not reach the intake.
- Paint any metallic parts of the intake once annually to ensure durability

NB: take care to prevent accidents such as drowning in deep intakes.

c) Flushing wash outs

- Flush wash outs along raw water mains depending on the season, i.e., more often in rainy season depending on the flow of the water in the pipelines.
- Flush wash outs along distribution lines at least twice per year and whenever a major burst is repaired.

d) Installing and regularly cleaning trash strainers

Most WSPs have had their bulk meters damaged by trash due to failure to install strainers before the meter especially on raw water mains. Appendix-2 is a sketch of a basket strainer that can easily be fabricated using locally available materials (such as steel pipe sections) and at a reasonable cost. The inner basket can be made from a steel sheet perforated with 5mm diameter holes such that its flow capacity before clogging is at least twice the maximum flow capacity of the pipe.

It is recommended that such strainers be installed on all raw water mains to protect the bulk meters against damage. A sluice valve should also be installed before the strainer for isolation during servicing.

This type of strainer is the easiest to clean as follows:

- Close the sluice valve before the strainer.
- Open the top cover of the strainer.
- Remove the strainer basket and clean the trash
- Return the basket
- Reassemble the top cover
- Open the sluice valve

e) Disludging sedimentation and flocculation basins

Sedimentation basins should be disludged regularly depending on the rainy/dry season to ensure efficient removal of turbidity from the water. The depth of disludge can be measured with a long broomstick which are available in treatment plants. Basins are normally in twos or more and hence can be cleaned in alternate days to maintain the supply.

Disludge as follows:

- Close the water inlet valve.
- Open the drain pipe for the sludge to drain away while stirring with long brooms.
- Scrub the walls and floor with a hose pipe until clean.
- Close the drain pipe and open the water inlet pipe.
- Start water treatment

f) Regular replacement of filter media

Often, the quality of filter media is left to deteriorate and this leads to poor water quality. The quality of the media should be monitored regularly and replenished or replaced at the right time.

g) Proper backwashing of filters

Staff should be trained on the backwashing process.

h) Regular cleaning of storage and break pressure tanks

A cleaning schedule should be prepared and followed to reduce clogging of meters by silt from tanks.

i) How to service air valves

- Isolate the air valve by closing the isolating valve between the valve and the pipe.
- Depressurize the valve by opening the depressurizing valve (refer to manufacturer's manual for procedure) and drain the water.
- Dismantle the top cover
- Clean the top cover to ensure no debris is settling inside the cover or obstructing the vent.
- Remove the float assembly and clean the top seal and any other moving parts to ensure free movement
- Reassemble the valve
- Close and tighten the depressurizing valve.
- Carefully open the isolating valve.

4.3 How to Maintain Valves and other Appurtenances

Management of a water supply is impossible without proper functioning control valves and other appurtenances. Evidence of poorly maintained appurtenances include leaking valves, overflows, airlocks, etc.

a) Appurtenances (sluice valves, etc.) should be painted and/or greased regular (say annually) to prevent rust and deterioration.

b) Worn out parts (e.g., leaking gaskets and valve spindles) should be tightened or replaced

c) Tank level gauges should be greased for free operation

4.4 How to Formulate a Maintenance Schedule

a) Make a table list of all and every component in the water supply starting with the intake structures, raw water mainlines wash-outs, air valves, sluice valves, break pressure tanks, storage tanks, pressure reducing valves, pump sets, etc., including location (pipeline name), material, diameter and class (if possible).

b) Break down each component into its various parts.

c) List the type of maintenance required by each component, including cleaning, greasing, oiling, painting and spares.

d) List how often each component requires maintenance.

e) List how the maintenance period will be monitored for each component.

f) Prepare the specifications of the maintenance and spares required for each component

g) Make a bill of quantity of the estimated cost of maintaining each component

h) List the person responsible for the maintenance of each component

i) Prepare a maintenance schedule for each component.

j) Prepare a structured annual plan of expenditure for the financial year for each component.

k) Submit the annual plan of expenditure to the budget preparation coordinator

l) Justify the need to allocate budget during the budgeting process.

m) Implement the maintenance schedule.

n) Repeat the process every year without fail.

CHAPTER 5

HOW TO CARRY OUT LEAK DETECTION

(Target Staff: NRW Staff)

5.1 Procedure of Customer-to-Customer Leak Survey with Listening Stick

5.1.1 What is a Listening Stick?

It consists of a steel rod/bar and a small circular vibration plate which is connected to the end of the bar at right angle. It is a kind of stethoscope without an electronic amplifier

Figure 5.1: Listening Stick

Figure 5.2: Leak detection using Listening Stick

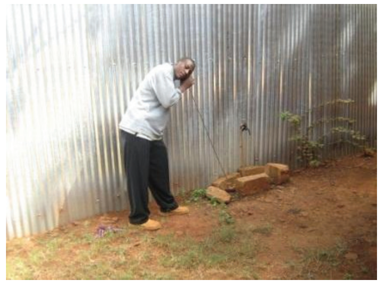


Figure 5.3: Leak detection using Listening Stick

5.1.2 Procedure of Customer-to-Customer Leak Survey with Listening Stick

Although it seems easy to use the equipment it requires some skills and lengthy training to detect small leaks and to distinguish the real leak noises from other similar noises.

To achieve the best result, the following procedure must be followed:

i) Gently hold the rubber part of the ear pad. Don't hold the metal bar.

ii) Don't press your ear against the ear pad as it will be harder to hear. Your ear should be slightly away from the pad.

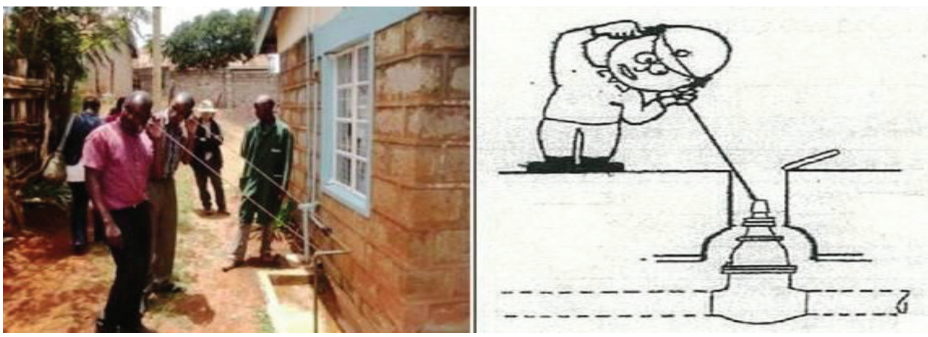


Figure 5.4: Leak detection using listening stick on pipe fittings

iii) Find the best condition for you to hear sounds by gently tapping the bar with your finger.

iv) Listen on the ear pad to hear the leak noises

v) Since most of the pipe facilities are buried, place the stick directly onto those elements with open boxes like taps, meters, valves, stand pipes, a pipe fitting, followed by placing worker's ear on the vibration plate set at the top of the bar. Listening Stick requires a lot of skill to distinguish the real leak noises from other similar noises.

vi) This method can only confirm the existence or non-existence of leakage near the listening stick but cannot locate the leak point.

vii) Where possible, the steel rod can be pushed through the soil along the top of the pipe (Figure 5.5) to come as close to the leak as possible. The louder the noise, the closer the leak. Therefore, the strength and changes of the sound is followed to locate leak.

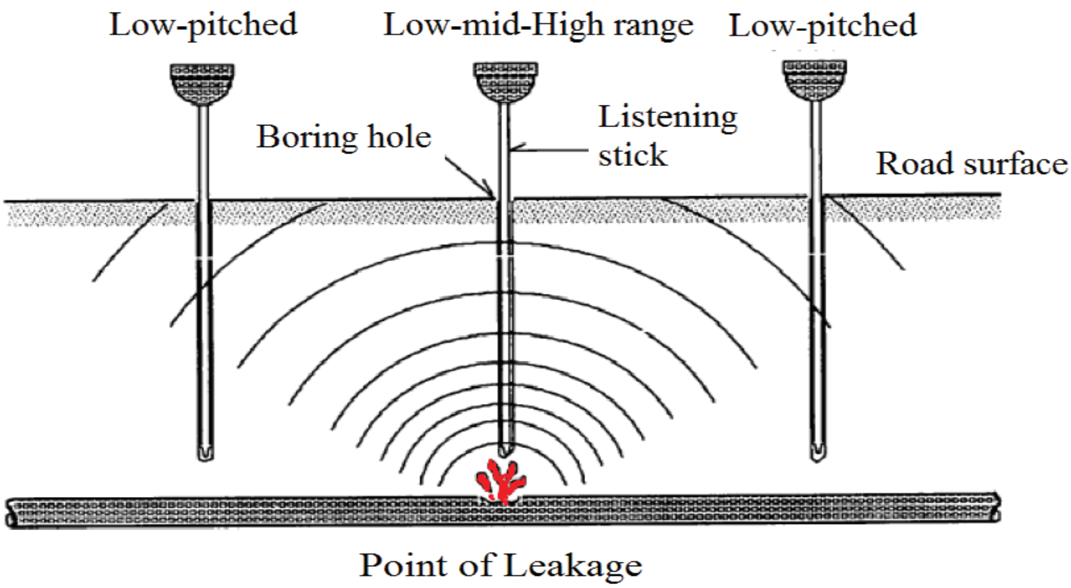


Figure 5.5: Leak detection using listening stick along pipeline

5.1.3 How to Differentiate Between Various Leak Sounds

In order to detect a leak, there is need to differentiate the various sounds coming through the ear pad. Table 5.1 shows some examples of leak and other sounds.

Table 5.1: Examples of leak and other sounds

SOUND	SITUATION ON SITE	TYPE OF LEAK
“hissssss”	If pipe has good water pressure	Small leak
“whoossssh”	If pipe has good water pressure	Main break or big leak
Rapid “thumping” noises of water against soil in cavity or “clink, clink, clink” of small stones bouncing against pipe.	May be you are very close (4-6m) to a leak	Leak
Water splashing on the pipe	May be you are close to a leak or water is traveling along a pipe for long distance	May or may not be a leak
Pipe resonance noises (i.e., always very constant sound) as follows: “ummmm or ringinginging”	There are power transformers or motors nearby	Not a leak
Pipe resonance noises as follows: “Click, click, click”	It may be a meter turning	Not a leak
Pipe resonance noises as follows: Intermittent and on/off again noises		Not a leak

5.1.4 Points to note in leak detection with listening stick

i) For most complete surveys, listen at every stop cork, meter, hydrant, valve, etc.
ii) For iron and steel pipelines, listen at hydrants or meters every 100 to 200m.
iii) For AC pipe, listen at hydrants and at a curb stop/stop cork/meter between them (max distance between points: 100m).
iv) For 20mm to 160mm PVC pipe, listen at maximum intervals of 150m.
v) For PVC pipe larger than 150mm, listen at maximum intervals of 100m
vi) When listening at curb stops/meter boxes, pick side of the street with shorter length services.
vii) Listen at hydrants, Valves, meters, curb stops, and other exposed sections / fittings.
viii) If there is no leak sound, then there is no leak nearby.
ix) If there is no sound at all, then no leak nearby.

5.1.5 *Documentation of Detected Leaks*

a) Manual Documentation

All leaks detected must be repaired, documented and mapped for further analysis and future reference.

Table 5.2 is a sample report as a guide.

Table 5.2: Sample Leakage Report

WATER LEAKAGE REPORT IN (WSP NAME):				**Report No:**
Date:	**Estate:**	**Road:**		**Pipeline:**
Method of Leak Survey (e.g., Listening Stick)	**Leakage on** (e.g., Service Connection, Main Pipe, Pipe Saddle or Ferrule, Pipe Fitting, Valve, Hydrant, Air Valve, Bulk Meter, Pump, etc.)	**Pipe DN (e.g., 63mm)**	**Pipe Material (e.g., PVC)**	**Estimated Leakage Rate (m^3/hr)**
Block Map No.:	**Comments:**			
Sketch of Location:				
Report Issued by:	**Report approved by & date:**	**Repair Instruction to & date:**		**Work done by & date:**

b) Electronic Documentation

With advancement in technology, there are now free cloud-based software applications (e.g., kobocollect toolbox, input, etc.) that can be downloaded from Play Store to smartphones and used to collect data from the field and automatically download it on to GIS maps on a computer. These applications greatly ease work for staff and also ensure accurate and timely data collection and sharing with other staff.

WSPs that have not yet adopted this technology are therefore advised to adopt this data collection methods without further delay. Refer to Volume 2 - Guidelines for further information on this topic.

5.2 How to Detect Leakage Using Electronic Leak Detector

5.2.1 Introduction

Underground leaks are usually detected by a leak detector which can catch the leak noise generated at leak holes by the leaking water using a sensor placed on the ground surface/ (or pipe wall) near the leakage.

The volume and quality of leak noise vary depending on the soil properties, kind of pipe materials, pipe diameter, underground depth of pipes, magnitude of leakage, water pressure, distance between the leak point and the sensor of the detector, etc., especially, in case of clay soils or large pipe diameter

Leak detection work requires a lot of skills by virtue of heavy awareness of leak noises.

Electronic leak detector comprises the follows components:

i) Central Processing Unit (CPU) with monitor
ii) Head phones
iii) Transducer - vibration pick-up unit that is sensitive to sounds coming from the pipe system. If a sound is detected in the unit, it is transmitted to the CPU at a higher frequency. Since leaking water makes sound, the sound is used to detect leaks in pipes using electronic leak detector.
iv) Connecting cables
v) Carrying bag and strap

5.2.2 Operating Principle of Electronic Leak Detector

a) The leak detector catches the leak noise electronically.
b) The principle is that a vibration pick-up unit is placed on the ground to detect the vibration sound of a leakage that is transmitted underground.
c) This vibration energy is converted by the pick-up unit to electrical energy which is then amplified for indication by a meter or listening through a head phone.

d) A leak detector amplifies sound and filters (or cuts out the lower and higher) frequencies of vibration sounds. This enables the remaining sound to be listened to more clearly.

e) Different pipe materials have specific sound frequency (or filter) bands in which leak noise can be detected more clearly as shown in Table 5.3.

Table 5.3: Leak Detector Filter (Sound Frequency) Bands for Various Pipe Materials

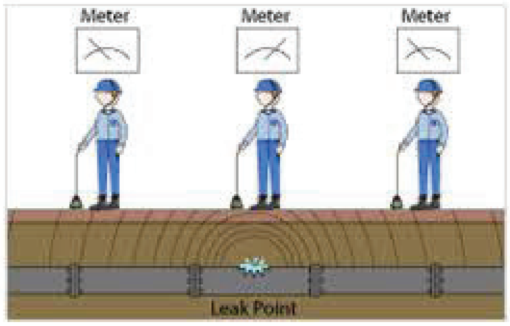
Sound frequency (Hz)	**100**	**200**	**400**	**600**	**800**	**1200**
Cast Iron Distribution Pipe		←	—	—	→	
PVC Distribution Pipe	←	—	—	→		
PVC Service Pipe		←	—	—	→	
GI Service Pipe			←	—	—	→

Key: Filter Range (CIP: Cast Iron Pipe), (PVC: Polyvinyl chloride Pipe), (GI: Galvanized Steel Pipe)
Source: Fuji water leak detector (Operation Manual)

5.2.3 How to Detect Leakage using Electronic Leak Detector

a) Ensure the equipment is fully charged
b) Decide the pipeline on which leak detection will be conducted
c) Move to the ground
d) Plug in the head phones and the transducer to the CPU and turn the volume to the lowest
e) Hang the CPU around your neck, wear the head phones and switch on the equipment
f) Adjust the volume to your comfort by gently tapping the transducer with the hand
g) Select the Filter (Sound Frequency) Bands to use based on the pipe material of the pipeline as per Table 5.3 above.
h) Place the transducer on the ground above the pipeline and listen for leak noise for a few moments while at the same time observing the meter
i) Shift the position of the transducer along the pipeline and repeat (h) above
j) The position where the meter indicates the highest noise is the location of the leak
k) Fill Table 5.2 and submit for repairs.

Figure 5.6 indicates the three types of display meters on a leak detector CPU.

<table>
<tr>
<td>The photos show the 3 types of display meter on Electronic Leak Detector CPU monitor and indicates a leakage as follows:
● Pointer - Indicates to the right
● Bar - Indicates tallest bar
● Digital – indicates highest number</td>
<td>
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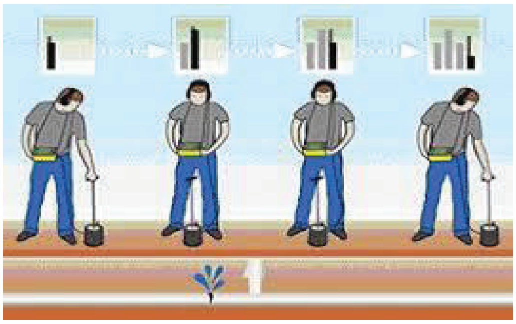
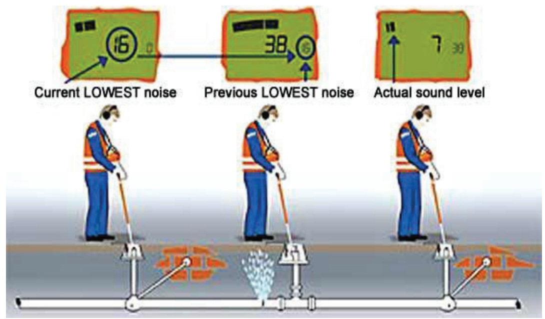
<td></td>
<td>
</td>
</tr>
</table>

Figure 5.6: The Three Types of Meters on the CPU

5.3 How to Operate Ultrasonic Flow Meter for Flow Measurement

5.3.1 Introduction

Ultrasonic Flow Meter measures flow without interrupting the water supply. It is normally attached to the external surface of the pipe using its clamp-on features called sensors. The equipment does not interact with the water inside the pipe.

5.3.2 Functions/Uses of Ultrasonic Flow Meter

i) Flow measurement
ii) Bulk meter testing
iii) Leak detection

5.3.3 Components of Ultrasonic Flow Meter

i) MAIN UNIT – Portable Flow Meter

ii) Clamp-on Sensors (usually one or two pairs- one pair for small pipes, and one pair for large pipes (depending on pipe sizes to be measured)

iii) Sensor Mounting Accessories
iv) Coupling Component (gel or Vaseline)
v) Measuring Tape
vi) Operating Instructions manual (hand copy and CD)
vii) Downloading Cables and Software or USB port for data extraction

Figure 5.7: Ultrasonic Flow Meter and accessories

5.3.4 General Requirements for UFM Use

The following are required in order to use UFM:

a) Knowledge of existing pipe data (e.g., pipe location, material, lining) is crucial.

b) At the supply point of the pipe (i.e., starting point of the distribution zone (DZ) or district metered area (DMA) or pipe branch) select a straight part of the pipe with adequate length considering the 10D/ 5D rule (D = outside diameter).

c) Expose the area around the pipe and create a clear and adequate working space.

d) Clean the pipe off all dirt (the pipe may need to be washed with water) and wipe dry.

e) Measure the pipe dimensions (Circumference (C)) using the measuring tape.

f) For equipment requiring input of the Outside diameter use the formula Circumference = πD2/4 to obtain the diameter.

g) Measure the pipe thickness using thickness gauge

5.3.5 How to Measure Flow in a Pipe Using Ultrasonic Flow Meter

a) Switch on the instrument - Main menu is displayed.

b) Check the battery level and ensure it is fully charged (if the battery is full, the unit is fully charged. Check the equipment manual on charging: - most equipment require charging for 8-12 hours to fully charge an empty battery).

c) From the Main Menu select the Installation Menu/Set-up Menu to enable you to update the site details as follows:

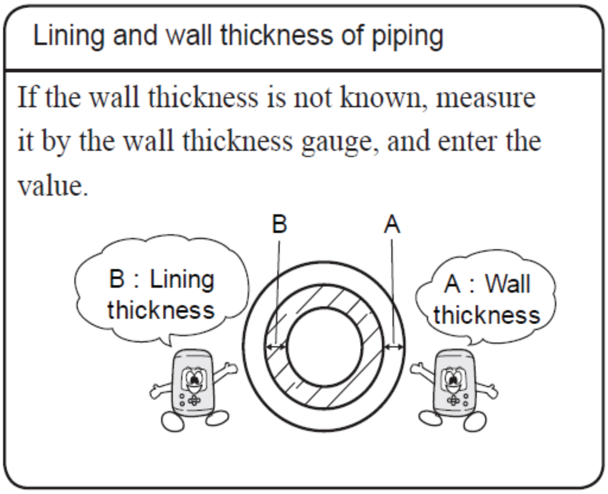


Figure 5.8: Lining and wall thickness of piping

d)

i) Select dimension units (usually millimeters - mm)

ii) Select pipe features:

- Material,
- Size: - Circumference or Outside Diameter (O.D)
- Presence/Absence of lining:
  - -Lining Material
  - -Lining thickness (if present)
- Pipe wall thickness

iii) Select the MEDIUM or FLUID in the pipe

- In this case it is water.

e) Select Sensor Mounting Mode Information

Theoretically, sensors can be mounted in four different modes: slash (/), reflex (V), N, and W. Selection of a particular mode depends upon several factors such as pipe diameter, expected maximum velocity of water, type of sensors available, ease of working at site, and whether or not a mounting rack is available.

Reflex (V) is the most commonly used mounting mode.

Figure 5.9: UFM mounted on pipe

Figure 5.10: Sensor blocks

(Kindly refer to the specific equipment operational manual)

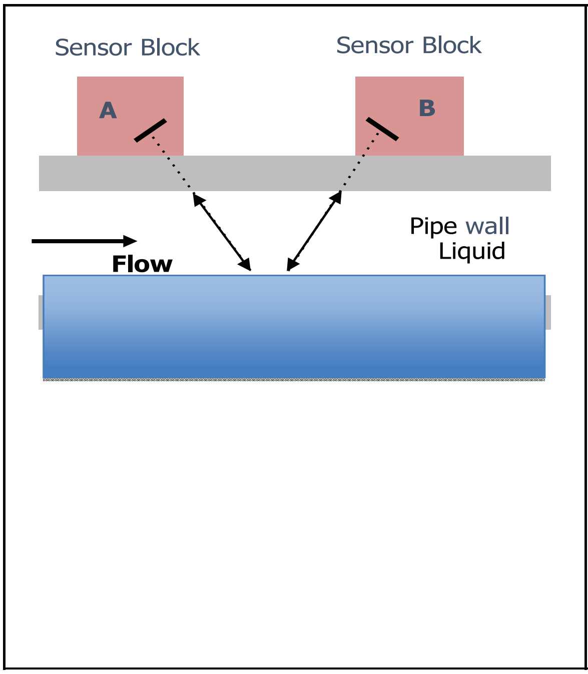


Figure 5.11: Clamped Sensors - Reflex Mode (top view)

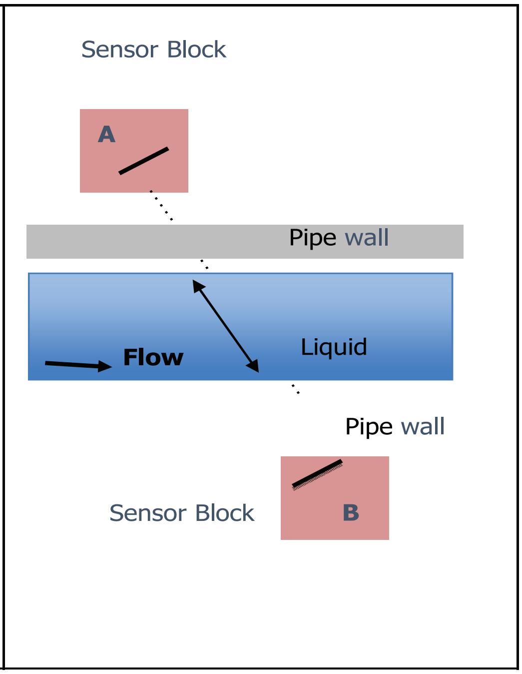


Figure 5.12: Clamped Sensors - Diagonal Mode (top view)

f) For a horizontal pipe:

Select a location where the transducers can be mounted on the side of the pipe (Figure 5.13) NOT top of pipe (Figure 5.14), so that the sound waves emitted by the transducers propagate horizontally in the pipe. In this way, the solid particles deposited on the bottom of the pipe and the gas pockets developing at the top will not influence the propagation of the signal.

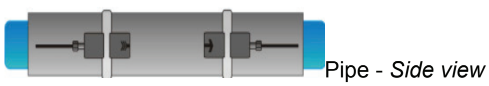


Figure 5.13: Sensors mounted on the side of pipe – Correct mounting

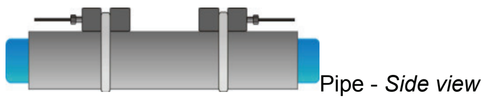


Figure 5.14: Sensors mounted on top of pipe –Wrong mounting

g) Clean the pipe off all dirt (may need to wash with water) and wipe dry.

h) Select the appropriate guide-rail, using the data entered, set the sensor separation distance on the measurement rail and clamp rail on pipe in the best position in a horizontal plane.

i) Apply couplant (or coupling gel) to both sensor-blocks and attach to the pipe using appropriate mounting hardware.

j) Slide the sensors into the rail and tighten thumbscrew fully compressing the coupling gel

k) Connect the sensor-blocks to the main unit of the Ultrasonic Flow Meter via provided cables observing the flow direction.

Figure 5.15: Side-mounted sensors on PVC pipe

Check the connection signal; the signal strength depends on the model of the UFM. It is usually displayed as a percentage (%), graphical Display or wave form.

(e.g., for better accuracy, the signal strength should be above a certain range specified by the manufacturer. A signal strength of above 80% should be aimed for).

l) Press “enter” to start flow measurement. (FLOW UNITS CAN BE CHANGED BY PRESSING APPROPRIATE KEYS e.g., m3 or Litres and UNITS OF TIME e.g., Hr, Min or Sec.

m) The UFM will automatically record the flow in the pipe for the period of measurement and store in its memory.

n) Data Storage/Logging: This stores data for retrieval after the measurement period has elapsed.

   Note: Kindly refer to logging procedure on the specific equipment manual.

o) Data Retrieval or Download or Transfer

To transfer the measured values to a computer, use the compatible software as follows:

i) On the flow meter, go back to the main menu
ii) Connect the UFM to the computer using the serial cable
iii) On the computer, open the software
iv) On the toolbar, start the data download or data transfer.
v) **NB:** Some models allow data retrieval/download/transfer using an external data storage device e. g. USB flash/memory card (if USB slots are integrated on the UFM (Figure 5.16 below)).
vi) The data can now be viewed on the computer and the necessary analysis conducted (Figure 5.17).

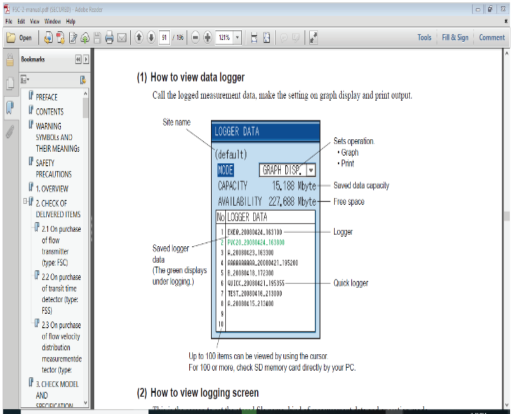


Figure 5.16: Data screen display

Figure 5.17: Data analysis

5.4 Minimum Night Flow Measurement

5.4.1 Introduction

Minimum Night Flow (MNF) is the lowest steady flowrate into a DMA/DZ during a 24 hours period. It is therefore a range of flows over a period of time and not one instantaneous flowrate. Figure 5.18 is a typical graph of 24 hours flow in a DZ. The lowest flow is 22 lts/hr and occurs between 02:30 am and 04:00 am.

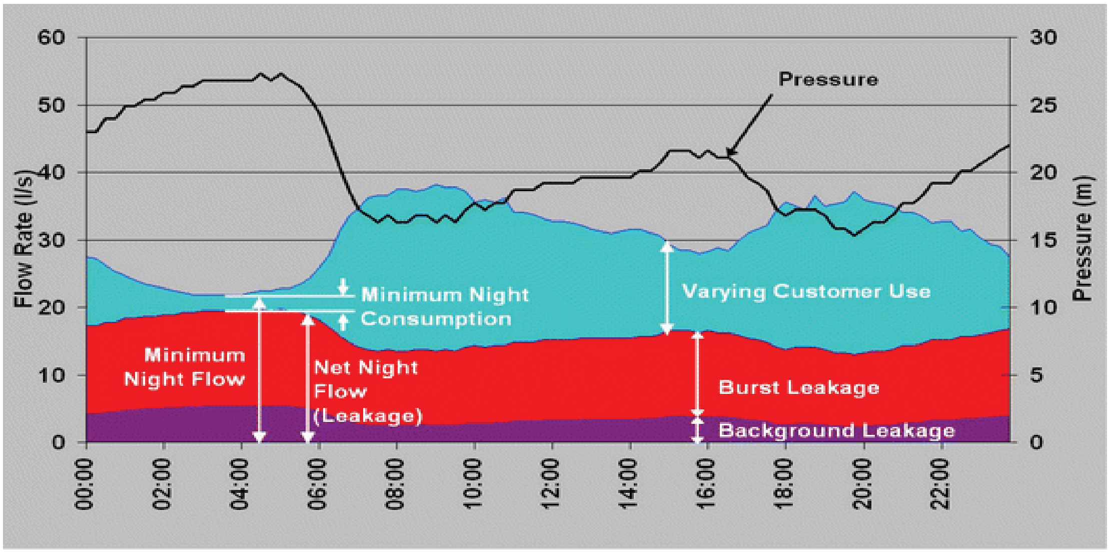


Figure 5.18: Typical Graph of 24 hrs Flow in a Water Supply

Figure 5.19 is a 24 hours graph of Kangaru DZ, Embu Water Co. The lowest steady flowrate was 190m3/hr occurring between 00:00am and 06:00am.

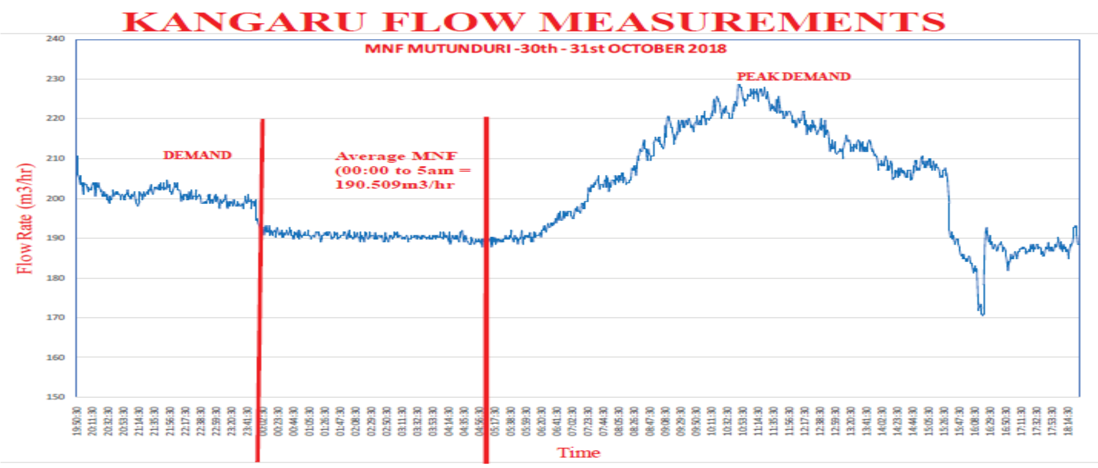


Figure 5.19: Graph of 24 hours Flow in Kangaru DZ, Embu Water Co., Kenya

The period of the lowest flow is unique for each distribution network and depends on the customers type and other factors. Table. 5.4 is a guideline on the recommended time of the night to conduct MNF measurement.

Table. 5.4: Recommended Time to Conduct MNF Measurement

	Customer Category	Time of MNF Measurement	
		Earliest Start Time	Latest Stop Time
1	Rural areas	11:00 pm	04:00 am
2	Peri-urban areas	00:00 am (midnight)	04:00 am
3	Urban areas	02:00 am	04:00 am

MNF comprises the following:

a) water being consumed by customers (flushing toilets, washing machines, night clubs, industries, hospitals, prisons) including filling and overflowing storage tanks at customers' premises.

b) illegal use

c) leakage and overflows from WSP tanks downstream of the measurement location.

MNF measures the total of (a) to (c) above. (a) is normally determined by manually reading customer meters for a sample of domestic customers and the flow estimated for all the customers in the DMA/DZ. For large customers, the meters can be read manually; or by automatic meters; or portable meters. This is done simultaneously with the MNF measurement. The total of (b) and (c) is the physical loss.

The purpose of measuring MNF is to determine and understand the level of physical losses occurring in a water supply network. Once this is determined, leak detection and repairs should commence and NRW monitored to achieve as low leakage level as possible.

Note:

a) If the supply system is intermittent make a provision to supply the area continuously for at least 24 hours. before starting to measure the MNF. The continuous supply may need to be extended to cover at least three nights without any interruption.

b) If the DMA has multiple inflow lines from other areas or outflow lines to other areas, each such lines should be metered. The readings from all the meters should then be aggregated and the minimum aggregated flow taken as the MNF.

c) It is recommended to measure water pressure in the pipeline simultaneously with the MNF measurement. The pressure gauge should be installed next to the

UFM//bulk meter. The purpose of pressure measurement is to ensure that there is adequate pressure in the pipeline during the MNF measurement.

5.4.2 Relationship Between Water Flow Rate and Water Pressure in Pipelines

At around midnight people are in bed and water taps in houses are closed hence water consumption in a DMA becomes zero in general. However, there is a little flow in the distribution pipes at this time and this water volume is assumed to be leakages or water thefts, etc. This water comprises a little usage which are metered or not metered in houses and leaks.

Figure 5.20 shows an example of a service area composed of several DMAs. The red (●) circle in the figure shows the measurement point of MNF for DMA1. It is recommended to set a water pressure meter just downstream of the red circle. Figure 5.21 shows typical fluctuation records of water flowrate and its pressure over 24 hours. It shows the general relation between water flowrate and pressure and indicating that as the water flowrate reduces in the middle of the night the pressure rises. However, if there is some amount of water usage in other DMAs located upstream of the distribution main, the inlet water volume and its pressure at the red circle will be forced to reduce. In such a case, the minimum flow measured is an “apparent value” because it is affected by factors outside DMA1.

By simultaneously measuring water pressure and MNF, fluctuation of both flow rate and the pressure can be track as in Figure 5.21. If for example, a point such as the yellow vertical arrow where the flowrate is reducing while the pressure is gradually rising or remains steady, it can be said that the real MNF is measured.

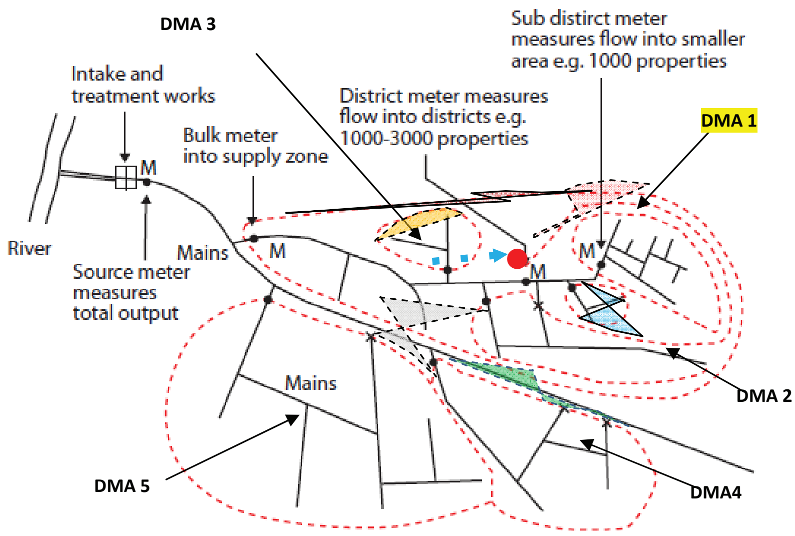


Figure 5.20: Model Plan of Water Service Area and Related Facilities

Source; “The Manager’s Non-Revenue Water Handbook”

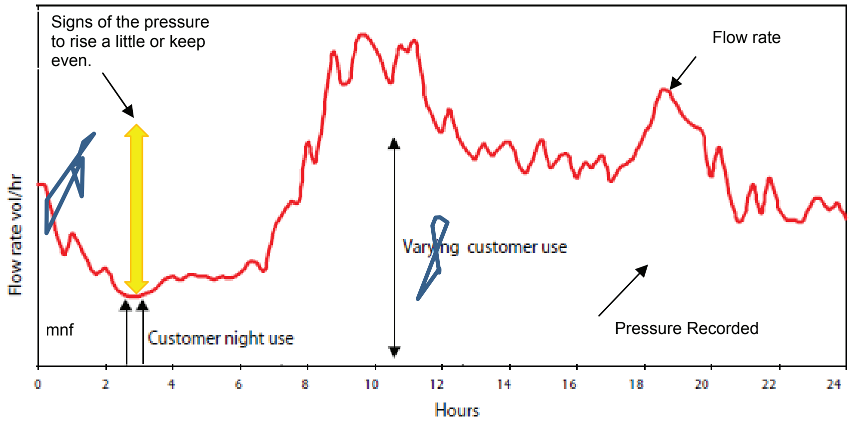


Figure 5.21: Relations between Flow Rate and Pressure in a Qmnf point

5.4.3 How to Measure Minimum Night Flow Using UFM

a) Identify the DZ/DMA/pipeline for Minimum Night Flow measurement.

b) If the DMA has other inflow lines from other areas or outflow lines to other areas, plan to measure flow in each line or closed them.

c) Determine the time of measurement based on Table 5.4 above.

d) Confirm that there is steady and adequate flow of water in the DZ/DMA/pipeline for the last say 2 to 3 days.

e) Plan and conduct flow measurement using UFM at the appointed time following the procedure in Section 5.3 above. Measure water pressure in the pipeline as MNF measurement progresses.

f) If possible, measure the water pressure at the UFM location (see Section 2.7 for procedure).

g) Monitor the supply tank(s) to ensure it is continuously full during the measurement period.

h) Downloaded the data.
i) Aggregate the data from all the measuring points.
j) Plotted a graph of the data
k) Interpret the data to determine the MNF.

5.4.4 Methods of Approximating Minimum Night Flow

Most WSPs may not have the financial capacity to procure UFM from their own resources. However, this should not be a hindrance to commence leak detection.

MNF can be approximated using any of the following methods:

- Recording bulk meter readings at 5- or 10-minutes intervals.
- Attaching data logger to a bulk meter – it stores the reading for a certain period.
- Attaching data logger and transmission gadget to a bulk meter – continuously transmits the readings to a computer.
- Automatic Meter Reading (AMR) gadget – continuously transmits the readings to the computer.

5.4.5 A Case Study of Minimum Night Flow Approximation

The NRW staff of Nakuru Town WSP has been conducting MNF measurement using a UFM. However, the UFM does not have the capacity to transfer data to a computer. They therefore have to manually read the data from the UFM and record in the computer.

Figure 5.22 and 5.23 are the graphs of meter readings from the two inlets lines into Kanyoni DMA in September 2018 indicating MNFs of 8.0 and 12.0 m3/hr respectively. The readings were at 15 minutes intervals.

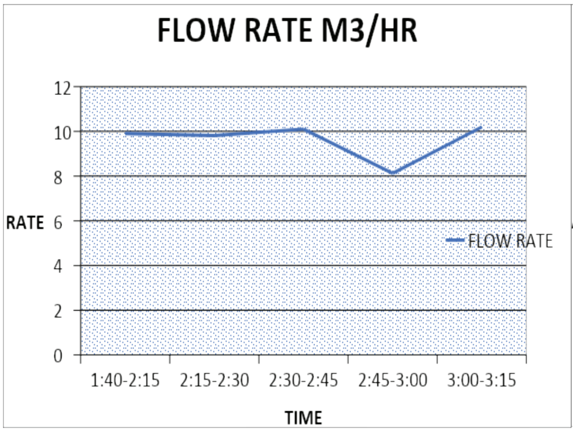


Figure 5.22: City Mission Line: MNF (Sep. 2018) = 8.0 m^3/hr

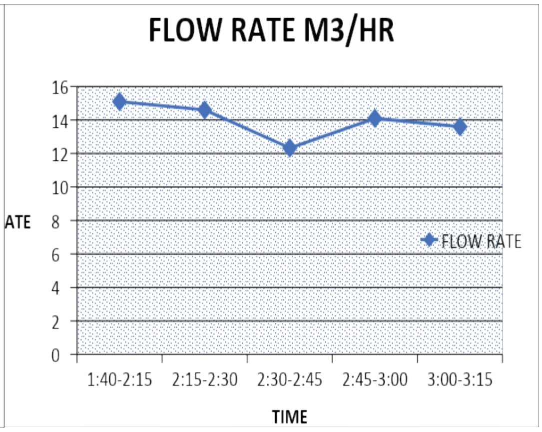


Figure 5.23: Scan Line: MNF Sep. 2018) = 12.0m^3/hr

The staff then conducted leak detection and repaired the leakages in Table 5.5 below.

Table 5.5: leakages detected and repaired in Kanyoni DMA, Nakuru Town WSP after the MNF measurement September 2018

	Location	Type of Leak Identified	No.
1.	Kanyoni estate	Leaks on meters liners	17
2.	Kanyoni estate	Leakage on 8” dia pipe	2
3.	Kanyoni estate	Leakage on 2” dia pipe	1
4.	Kanyoni estate	Leakage on 1.5” dia pipe	1
6.	Kabachia estate	Leakage from 12” dia sluice valve spindle	1
7.	Kabachia estate	Leakage from 12” pipe	1
8.	Shadrack Kimalel	Leakage from 12” dia sluice valve spindle	1

Figure 5.24 and 5.25 are the graphs of meter readings from the two inlets lines into Kanyoni DMA in December 2018 indicating MNFs of 2.7 and 3.9 m3/hr respectively. The readings were at 15 minutes intervals.

The results indicate that leak detection is still possible even without a properly functional UFM.

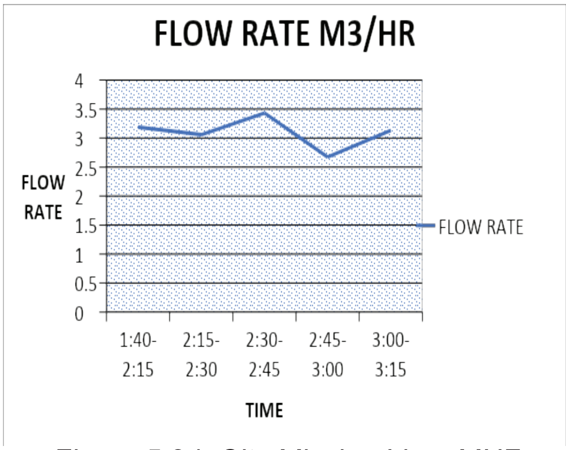


Figure 5.24: City Mission Line: MNF (Dec. 2018) = 2.7m³/hr

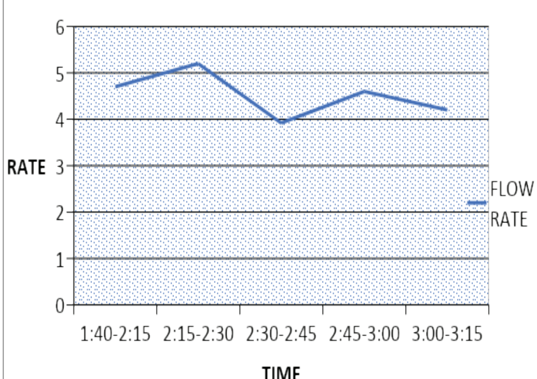


Figure 5.25: Scan Line MNF (Dec. 2018) = 3.9m³/hr

5.5 Procedure of Leak Detection Using Step Test Method

5.5.1 Introduction

Step test leak detection is a MNF measurement to determine water losses due to leakage from specific sections of a pipe network.

The test can be conducted by three methods:

a) continuous measurement using UFM
b) using an installed bulk meter
c) moving from one pipe section to another
d) at the supply point (starting point) of the DMA or DZ.

5.5.2 Procedure of Step Test Leak Detection by Continuous Measurement using UFM

a) Ensure that the DMA/DZ has only one inlet pipe (If more than one, a bulk meter should be installed on each and readings done for all at the same time).

b) Ensure that there are no pipe loops in the DMA/DZ. A Sluice Valve (SV) should be installed and closed to eliminate looping.

c) Ensure all the SVs in the DMA/DZ are open and the water supply is adequate and steady (not distorted by rationing or interruption).

d) Ensure you have a map or sketch of the DMA/DZ with all the SVs indicated and labelled.

e) Ensure all the SVs are easily accessible and are operating properly (can completely close the flow and are not leaking).

f) Flow measurements should be conducted between 00:00 am (midnight), and 04:00am when most customers are asleep, hence any flow is likely to be leakage. Note:

   i) Some flow may be due to ongoing filling of some customers' tanks.

   ii) Some large customers like hospitals, industries and prisons operate 24 hours thereby causing flow.

g) Mount the UFM on the pipe at the starting point of the DMA/DZ (Section 5.3).

h) Start flow measurement and let the UFM continuously record for 10 to 15 minutes to ensure that flow is about constant. Do not stop the UFM.

i) Prioritize the pipe networks and close the furthest subzone as measurement continues. Record the time of closure and the subzone.

j) Continue the process until all subzones are closed with continuous measurement.
k) Stop and unmount the UFM.
l) Open all the valves for water to flow to customers at the end of the exercise.
m) Download the measurement data and draw a graph (Figure 5.26).
n) Calculate the differences between inflows of consecutive subzones.

o) Rank the pipe networks for leak detection with the smallest network which has high flow as the highest rank (where leak detection will be easiest to conduct); e.g., S/No. 2 is priority No. 1, etc.

p) Detect and repair as many leakages as possible within the shortest time possible (starting with priority No.1, then 2, etc.) while monitoring to confirm that the total DMA/Zonal daily flow is reducing.

q) If no more leakages are detected and further reduction of losses is still necessary, repeat the step test and again prioritize the networks as above.

r) If necessary and possible, conduct step test on those networks with high flow yet no more leaks are detected.

s) After achieving the desired low flow in the whole DZ/DMA, maintain this condition by patrolling (preferably with listening sticks) for visible or underground leaks and prompt repairs.

t) After repair of identified leaks a repeat step test can be conducted to detect the lines with relatively high flow for enhanced leak reduction.

Figure 5.26 is a graph of a step test by continuous measurement using UFM conducted in DZ 2 of Nakuru Town WSP on 26th February 2020.

The flow into each sub-zone is indicated as the difference between the step flows, e.g., subzone2 has the highest flow at 95 m3/hr.

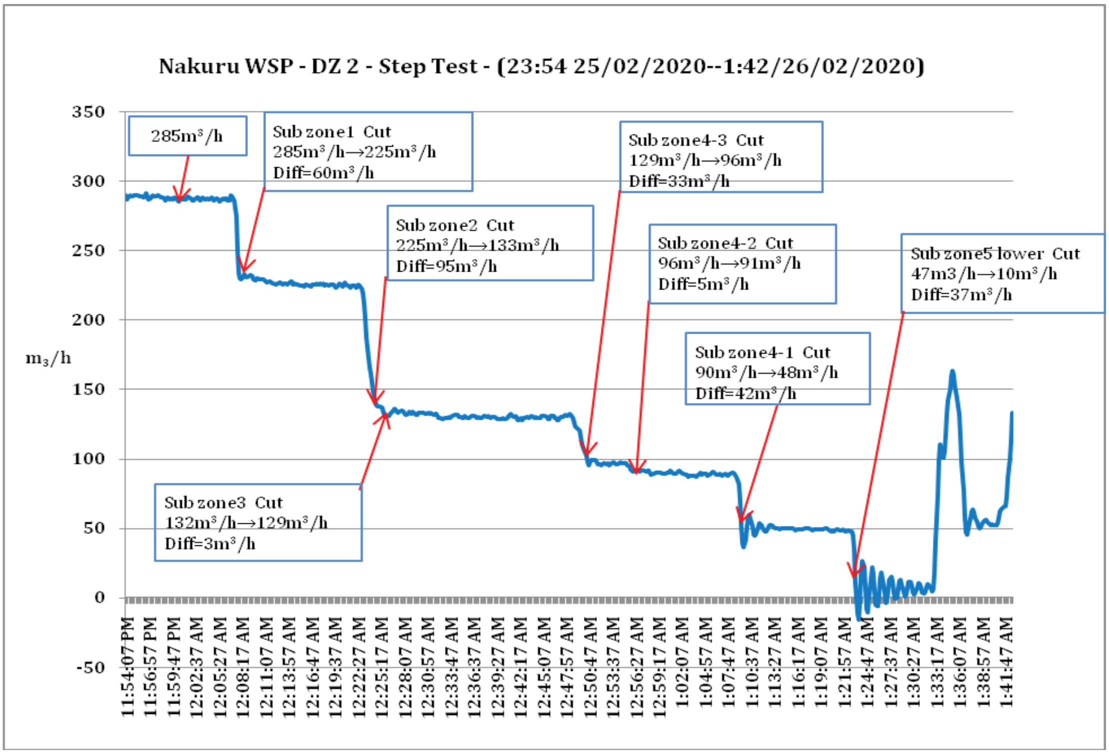


Figure 5.26: Step Test by continuous measurement using UFM (conducted in DZ 2 of Nakuru Town WSP - 26th February 2020)

5.5.3 Procedure of Step Test Leak Detection Using UFM (or Bulk Meter) without Continuous Measurement

Figure 5.27 is a map of DZ 2 in Meru WSP where a step test was conducted on 27th July 2019.

A transmission pipeline delivers water from the water treatment plant to the zonal tank (Tank ST-02) from where it is distributed to the customers. The yellow text boxes indicate sluice valves used to conduct the step test with data and analysis shown on Table 5.7. The pipelines are named either as (e.g.)

Table 5.6: Meaning of notations in Figure 5.27 and Table 5.7

Notation (bold part)	Meaning
J-02-02	J means pipeline dia≥ 90mm
D2-02	D means dia = 63mm
J-02& D2	means the pipelines are in DZ 2
J-02-02& D2-02	means pipe No. 2 in the DZ
J-02-02-1 or D2-02-1	means tertiary pipes 40mm dia
SV	means Sluice Valve

Pipelines J-02-01 and J-02-03 run on either side of the road although they seem as one pipe on the map.

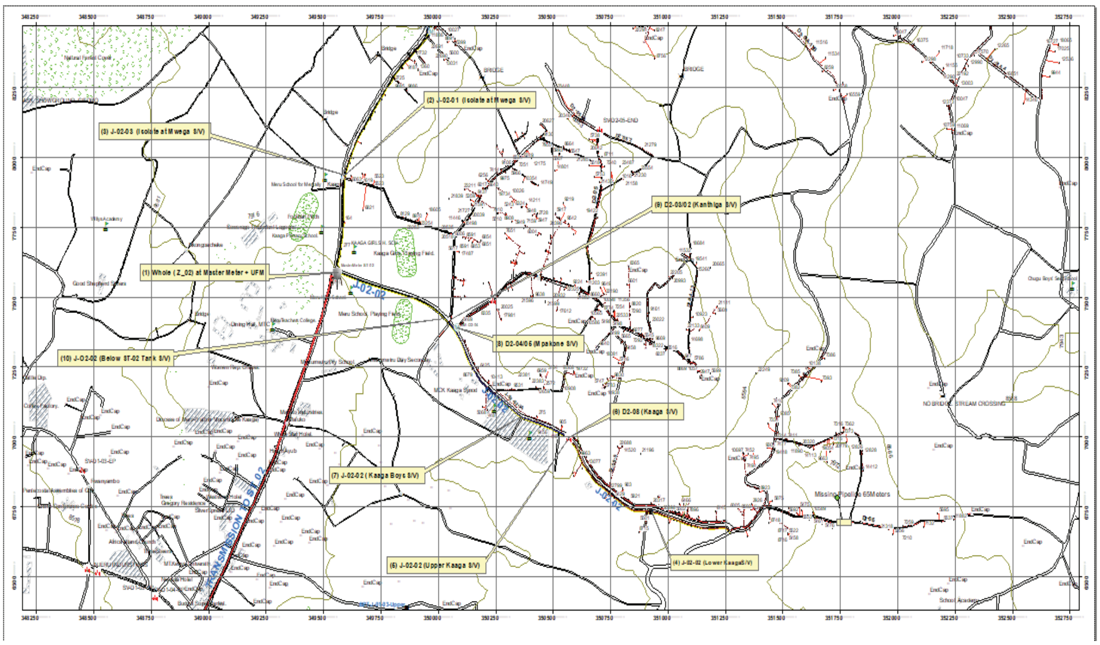


Figure 5.27: Map of DZ 2, Meru WSP Showing Sluice Valves Used for Step Test on 27th July 2019

Table 5.7: Data & Analysis of Step Test for DZ 2, Meru WSP, on 27th July 2019

a	b	c	d	e	f	g	h	i	j	k	l
S/ No.	**Pipeline Name**	**Pipeline Section Measured**	**Time of Measurement**	**Meter Reading**	**Flow in Unclosed Network**	**Flow in Closed Network**	**Priority for Leak Detection**				
		From	To	Starting	Stoppage	At Start	At stop	(= h - g) m3/10min	(= i x 6) m3/hr	(= upper – lower row) m3/ hr	
1	Whole DZ 2	ST-02 Tank	Whole DZ	00:47 am	00:57 am	368475.95	368481.05	5.10	30.6	N/A	N/A
2	J-02-01	Mwega SV	End	01:02 am	01:12 am	368484.35	368485.93	1.58	9.48	21.12	1
3	J-02-03	Mwega SV	End	01:16 am	01:26 am	368486.51	368488.08	1.57	9.42	0.06	-
4	J-02-02	Lower Kaaga SV	End	01:29 am	01:39 am	368488.04	368489.60	1.56	9.36	0.06	-
5	J-02-02	Kaaga SV	Lower Kaaga SV	01:42 am	01:52 am	368490.00	368491.01	1.01	6.06	3.3	2
6	D2-08	Kaaga SV	End	01:55 am	02:05 am	368491.30	368492.20	0.9	5.4	0.66	7
7	J-02-02	Upper Kaaga SV	Kaaga SV	02:07 am	02:17 am	368492.44	368493.19	0.75	4.5	0.9	3
8	D2-04/05	Mpakone SV	End	02:21 am	02:31 am	368493.45	368493.89	0.44	2.64	1.86	4
9	D2-03/02	Kanthiga SV	End	02:35 am	02:45 am	368494.03	368494.20	0.17	1.02	1.62	6
10	J-O2-02 (Tank ST-02)	ST-02	Mid SV	02:50 am	03:00 am	368494.21	368494.22	0.01	0.06	0.96	5

Source: Meru WSP

The procedure was as follows:

a) Ensure that the DMA/DZ has only one inlet pipe (If more than one, a bulk meter should be installed on each and readings done for all at the same time).

b) Ensure that there are no pipe loops in the DMA/DZ. A Sluice Valve (SV) should be installed and closed to eliminate looping.

c) Ensure all the SVs in the DMA/DZ are open and the water supply is adequate and steady (not distorted by rationing or interruption).

d) Ensure you have a map or sketch of the DMA/DZ with all the SVs indicated and labelled (Figure 5.27 above).

e) Ensure all the SVs are easily accessible and are operating properly (can completely close the flow and are not leaking).

f) Flow measurements should be conducted between 00:00 am (midnight), and 04:00 am when most customers are asleep, hence any flow is likely to be leakage. Note:
   i) Some flow may be due to ongoing filling of some customers' tanks.
   ii) Some large customers like hospitals, industries and prisons operate 24 hours thereby causing flow.

g) Mount the UFM on the pipe at the starting point of the DMA/Zone (Section 5.3). If a UFM is unavailable, an installed accurate bulk meter may be used.

h) Record the starting meter reading and time (use Table 5.7).

i) Allow the water to flow for 10 minutes and record the reading and time again.

j) Prioritize the pipe networks and close the SVs starting with the furthest valve; and record the start and stop meter reading for each SV.

k) Continue the process until all SVs are closed and data obtained at each closure.

l) Open all the valves for water to flow to customers at the end of the exercise.

m) Calculate columns I to K.

n) Rank the pipe networks for leak detection with the smallest network which has high flow as highest rank (where leak detection will be easiest to conduct); e.g., S/No. 2 is priority No. 1, etc.

o) Detect and repair as many leakages as possible within the shortest time possible (starting with priority No.1, then 2, etc.) while monitoring to confirm that the total DMA/Zonal daily flow is reducing.

p) If no more leakages are detected and further reduction of losses is still necessary, repeat the step test and again prioritize the networks as above.

q) If necessary and possible, conduct step test on those networks with high flow yet no more leaks are detected.

r) After achieving the desired low flow in the whole DZ/DMA, maintain this condition by patrolling (preferably with listening sticks) for visible or underground leaks and prompt repairs.

5.5.4 Step Test Leak Detection Method by Moving from One Pipe Section to Another Using UFM

Refer to Figure 5.28 and Table 5.8 below for this sub-section.

This method is employed where the following conditions prevail:

i) The DMA/DZ has no bulk meter or the bulk meter is not accurate.

ii) High water flow is detected in a certain pipeline or a leakage is suspected but the leakage cannot be located by patrolling or listening stick or electronic leak detector.

The Step test can be conducted in two ways:

- At night from 00:00am (midnight) to 04:00am: - ideal method when it is necessary minimize interruption of supply to customers since they are asleep. The accuracy of measurement is higher since the flow is steadier.
- During day time: - this method is used in sparsely populated rural areas where overall consumption is expected to be low. Step test should be conducted when customers are expected to be out of the house (working). If possible, all the customer service pipelines should be closed at the stop-cork and the customers sensitized.

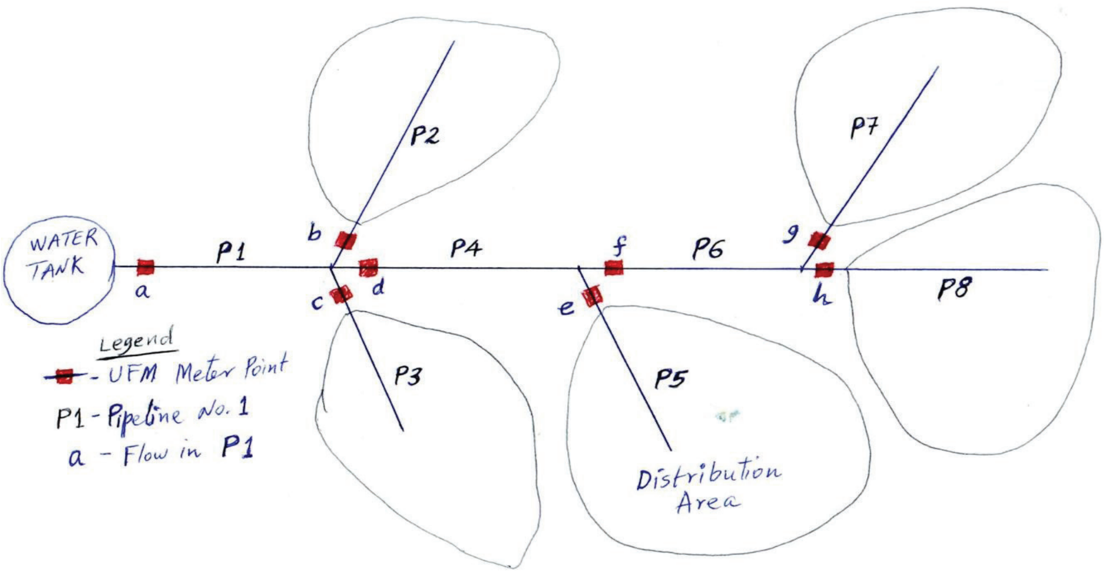


Figure 5.28: Sketch Illustrating Step Test by Moving from Pipe to Pipe Using UFM

Procedure

a) Locate the main distribution pipe into the DMA/DZ. If more than one main, each main should be considered separately (Figure 5.28).

b) Locate the main branches including their take-off points.

c) Ensure there is adequate, steady and continuous/uninterrupted flow into the DMA/DZ (it is not possible to conduct step test if water is inadequate or being rationed).

d) Excavate and expose the starting point of the main pipe and branches.

e) Measure flow (see Section 5.3 for procedure) in each pipe using UFM starting with the main pipe and then the branches.

f) Record the data in Table 5.8

g) Calculate Column H and the water losses within each pipe section (Column I).

h) Prioritize the pipelines for leak detection.

i) Conduct leak detection by patrolling, listening sticks and/or electronic leak detector.

j) Document the leaks detected in Table 5.2 (above) and submit for repair and mapping.

k) Monitor monthly NRW to confirm reduction.

l) Repeat the exercise to confirm and prioritize leak detection again to further reduce NRW.

Table 5.8: Results and Analysis of Step Test by Moving from Pipe to Pipe Using UFM

A	B	C	D	E	F	G	H	I	J
S/ No.	**Pipe Name**	**Time of Measurement (measure for 10 min)**		**Meter Reading**		**Flow through UFM**		**Water Loss in Pipeline**	**Priority for Leak Detection**
		Start time	**Stop time**	**At Start**	**At stop**	**(= F - E) m3/10min**	**(= G x 6) m3/hr**		
1	P1	0:00am	…….am	…….	…….	…….	…….	= a-b-c-d	…….
2	P2	…….am	…….am	…….	…….	…….	…….	= b	…….
3	P3	……am	……am	…….	…….	…….	…….	= c	…….
4	P4	…….am	…..am	…….	…….	…….	…….	= d - e - f	…….
5	P5	…….am	…….am	…….	…….	…….	…….	= e	…….

A	B	C	D	E	F	G	H	I	J
S/ No.	**Pipe Name**	**Time of Measurement (measure for 10 min)**		**Meter Reading**		**Flow through UFM**		**Water Loss in Pipeline**	**Priority for Leak Detection**
		Start time	**Stop time**	**At Start**	**At stop**	**(= F - E) m3/10min**	**(= G x 6) m3/hr**		
6	P6	…….am	…….am	…….	…….	…….	…….	= f - g - h	…….
7	P7	…….am	…….am	…….	…….	…….	…….	= g	…….
8	P8	…….am	…….am	…….	…….	…….	…….	= h	

…….

5.5.5 How to Narrow Down on a Leak through Step Test Leak Detection Method Using UFM

This method assumes the following conditions that are common in Kenyan WSPs:

i) There is no bulk meter installed or it is inaccurate/unreliable.
ii) Sluice valves spacing is long or they do not function effectively

Under such conditions, it is difficult to locate some underground leakage by patrolling, listening stick or electronic leak detector.

In such cases, a step test can be conducted using a UFM to narrow down the search area.

The Step test can be conducted in two ways:

- At night from 00:00am (midnight) to 04:00am: - ideal method when it is necessary minimize interruption of supply to customers since they are asleep. The accuracy of measurement is higher since the flow is steadier.
- During the day time: - this method is used in sparsely populated rural areas where overall consumption is expected to be low. Step test should be conducted when customers are expected to be out of the house (working). If possible, all the customer service pipelines should be closed at the stop-cork and the customers sensitized.

Proceed as follows to narrow down on the leakage:

a) Select the pipeline, (AJ) where the location of a leak needs to be narrowed down (Figure 5.29)

Location Name	A	E	C	F	B	G	D	H	J
Pipeline									
Position	0	⅛	¼	⅜	½	⅝	¾	⅞	1
Priority	1st	4th	3rd	4th	2nd	4th	3rd	4th	

Figure 5.29: Narrowing Down on a Leak by Step Test Method

- Leak location

b) Mark the pipe beginning - 'A', ½-way –'B', ¼-way – 'C' and ¾-way – 'D'.

c) Excavate and expose the four points and prepare the area for leak detection using UFM as in Section 5.3.4 above.

d) Measure the flow at both 'A' and 'B' and record in Table 5.9.

e) For the purpose of this table, the pipe section between points 'A' and 'B' is (AB) while the water flowing between them is ab and so on,

f) If the difference aj – bj is high, then there probably is a leakage between 'A' and 'B'.

g) To narrow down on the leak further, measure flow at 'C'.

h) If flow aj – flow cj is low, then the leak is between 'C' and 'B'

Figure 5.30: Flow Measurement Using UFM

i) If necessary, further narrowing can be done by measuring flow at ‘F’ and this will indicate that the water loss is between ‘C’ and ‘F’.

j) Depending on the length of the pipe section (CF), further subdivision of the pipe can be done and additional narrowing down conducted as above.

k) Once enough narrowing down has been attained, the leak can be located by patrolling or listening stick or electronic leak detector or even excavating along the section (CF).

l) Any leak along the pipe (AB) can therefore be located by this method using a UFM.

m) Record and analyze the data as per Table 5.9.

5.6 Procedure of leak detection using leak noise correlator

5.6.1 Introduction

Leakages occurring in pressurized pipes continuously generate random leak noises, which travel in the pipe in both directions. A leak noise correlator equipment transforms the noise that is detected into an electric signal that is then displayed on the monitor of the correlator. It not only detects the existence of leakages, but also displays the location of the leak as a peak of the wave points.

For a comprehensive description of how to use a correlator, refer to the Leak Detection Technology and Implementation published by International Water Association (IWA) by downloading it from the following link:

https://library.oapen.org/bitstream/handle/20.500.12657/33035/578133.pdf?sequence=1&isAllowed=y

Below is a brief description on leak noise correlator equipment.

Leak noise correlation works by comparing the noise detected at two different points in the pipeline. Assuming consistent pipe material and diameter, the noise travels from the leak in both directions at a constant velocity, so that if the leak is not equidistant then these sensors will detect the same noise at different times. This difference in arrival times is measured by the correlation process.

The sound velocity depends on the pipe material, pipe diameter, and to a lesser extent, on the surrounding soil.

Table 5.9: Data and Analysis of Narrowing Down on a Leakage by Step Test Leak Detection on a Pipeline Using UFM

	Pipeline Name: ……………………….							**Date: ……………**	
A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
S/ No.	**UFM Location on Pipe**	**Time of Measurement (measure for 10 min)**	**Meter Reading**	**Flow through UFM**	**Flow in Pipeline**	**Priority for Leak Detection**			
		Start time	Stop time	At Start	At stop	(= F - E) m3/10min	(= G x 6) m3/hr		
1	'A' (0)	0:00am	…….am	…….	…….	…….	…….	(AJ) = aj	…….
2	'B' (1/2)	…….am	…….am	…….	…….	…….	…….	(BJ) = bj	…….
								(AB) =aj-bj	…….
3	'C' (1/4)	……am	……am	…….	…….	…….	…….	(CJ) = cj	…….
								(AC) = aj-cj	…….
								(CB) = cj-bj	…….
4	'D' (3/4)	…….am	…..am	…….	…….	…….	…….	(DJ) = dj	…….
								(BD) = bj-dj	…….
5	'E' (1/8)	…….am	…….am	…….	…….	…….	…….	(EJ) = ej	…….
								(AE) = aj-ej	…….
								(EC) = ej-cj	…….
6	'F' (3/8)	…….am	…….am	…….	…….	…….	…….	(FJ) = fj	…….
								(CF) = cj-fj	…….
								(FB) = fj-bj	…….
7	'G' (5/8)	…….am	…….am	…….	…….	…….	…….	(GJ) = gj	…….
								(BG) = bj-gj	…….
								(GD) = gj-dj	…….
8	'H' (7/8)	…….am	…….am	…….	…….	…….	…….	(HJ) = hj	…….
								(DH) = dj-hj	…….

Figure 5.31: Leak noise correlator kit

A Leak Noise Correlator is a highly specialized leak detection equipment used to detect water leaks by electroacoustic means. The word “Electroacoustic” is any process involving the transfer of a signal from acoustic to electrical form.

A Leak Noise Correlator device is used in combination with various microphones/ Accessories.

5.6.2 Characteristics of leak noise correlator.

- It is costly
- It can be used to detect leaks over a distance of not more than 100m at a time; hence leak detection over the whole water supply takes a long time.
- For leak detection, the equipment sensors must be placed on sluice valves, hydrants or on the metallic pipe. For non-metallic pipes, a saddle clamp can be tied to the pipe to facilitate a place for the sensor.
- The spacing of the sensors must be 100m or less for the equipment to detect leakage.

It is therefore recommended that use of leak noise correlator should only be considered when the overall NRW ratio has been reduced to below 10% using other leak detection methods.

5.6.3 How a Leak Noise Correlator Works

- Sensors pick the leak sounds transmitted on the pipe walls.
- Leak sound will travel down the pipe wall away from the leak.
- Pre-Amplifiers/Transmitters amplify leak sounds and transmit them continuously to main processor (CPU).
- The CPU compares (Correlates) sound and displays correlation results.
- The CPU calculates the exact distance to the leak.
- These speeds of the noises transmitted are programmed into a software so that a mathematical formula is used to determine the time difference leak noise takes to reach two or more sensors from the point of the leak.
- Three inputs are generally needed to do the calculations which include the pipe material, pipe diameter, and the soundtrack (length) of pipe between the sensors.
- It can even find multiple leaks in the section between the sensors at the same time.
- A best practice is to verify the correlation by verifying the location with a ground microphone in case of errors in the data entered to do the leak noise correlation.

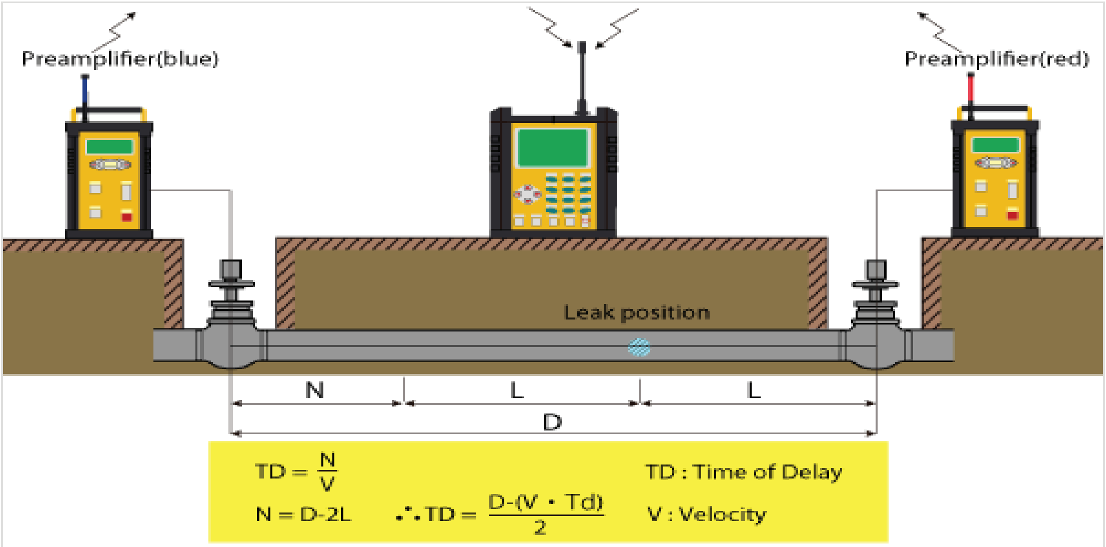


Figure 5.32: Using Leak Noise Correlator to Detect and Locate a Leak

5.6.4 Leak Noise Correlator Procedures & Mounting

- Mount the Blue and Red-amp transmitters (or Pre-amplifier) to the access points which are pipe fittings such as meters, valves, hydrants or on the pipe itself if it is metallic. Where metallic location is not available, it can be created by, say, tying a metallic clamp on the pipe.

- Switch the Main Processor and the Transmitters to ‘’ON’’ position.
- In PIPE DATA Input, select the pipe material, diameter, and length for every section of pipeline between the two sensors.
- Up to six pipe sections can be entered to the Main Processor (always in order from the “Blue” sensor to the “Red” sensor).
- The Main Processor Unit displays the correlation “picture” and the distances to the leak from the red pre-amplifier transmitter and the blue pre-amplifier transmitter.
- The Correlator samples the noise for a given period of time and stores the same in memory. This process is repeated severally over the period and added to the original information and averaging done.
- During correlation, any pipe branches located between the two sensors should be closed.

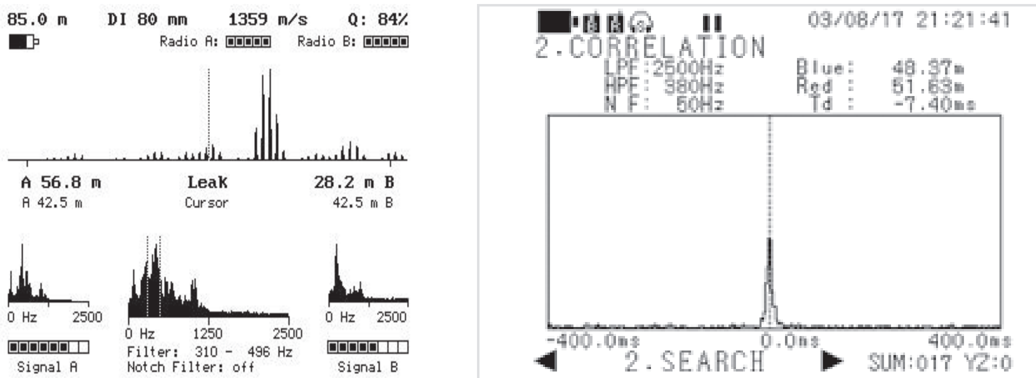


Figure 5.33: Two types of graphical representation of leak position from sensors blue and red

Chart Interpretation

- Where the graphs are high it indicates leaks or branches take-off points from the line under investigation.
- The graph height indicates the magnitude of leakage.
- The charts also indicates the distances of leakage or take-off points from the blue and the red preamplifiers.

5.7 Advanced Analysis of Leak Detection Data

Advanced analysis of leakage data enables to identify the most effective priority sub-zone or pipeline on which to focus leak reduction intervention measures. Table 5.10A, B & C below are derived from leak detection data.

NRW can be defined (or measured) using the following five indicators:

No. 1	No.2-1	No.3-1	No.4-1	No.5
NRW (%)	**NRW** (Ltr/con/da	**NRW** (Ltr/km/mi	**CAPL** / **MAAPL or UARL**	**MAAPL (UARL)**

(1) Indicator 1: NRW as a percentage, %
(2) Indicator 2: NRW as Leakage volume per connection per day (Ltr/con/day)
(3) Indicator 3: NRW as Leakage volume per km per minute (Ltr/km/min)
(4) Indicator 4: NRW as Current Annual Physical Losses (CAPL) / Unavoidable Annual Real Losses (UARL) = Infrastructure Leakage Index (ILI)
(5) Indicator 5: Minimum Achievable Annual Physical Loss (MAAPL) is the same as UARL in (4)

NRW in (2-1), (3-1) and (4-1) can also be replaced by Qmnf (Volume Minimum Night Flow) as below if Qmnf is considered as an approximation of the physical losses.

No. 1	No.2-2	No.3-2	No.4-2	No.5
NRW (%)	**Qmnf** (L/con/day)	**Qmnf** (L/km/min)	**Qmnf** / **MAAPL or UARL**	**MAAPL (UARL)**

Having defined the five indicators above, the following examples serve to describe how to apply the indicators in practice.

(I) Indicator 1: NRW as a percentage, %

In Table 5.10A, Column 9 indicates the NRW or Qmnf of each pipeline (Note: if a pipeline has a high Qmnf, the it will also have a high NRW%). The pipelines are then ranked based on the volume of leakage (highest Qmnf). Leak detection can then be conducted starting with pipeline Rank No. 1; then Rank No. 2, etc.

Table 5.10A prioritizes leak detection on the basis of the sub-zone with the highest flow rate.

Table 5.10A: Result of Step Test Measurement for DZ 8 Lower (Kambakia) –10th January 2020

	Column No.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
slno.	**Pipeline No**	**pipeline route**		**Time to be measured**		**Meter Reading**		**Flow (3)**	**Flow (4)**	**Flow in Pipeline M^3/hr (5)**	**Rank**
		From	**To**	**Starting**	**Stoppage**	**At starting time**	**t stoppage tim**	**(6)-(5) $M^3/10min$**	**(7)*6 M^3/hr**		
1	**WHOLE**	Origin	End	23:47 hrs	23:57 hrs	332259.35	332261.92	2.57	**15.42**		
2	**D8-04 (Rwanyambo)**	Origin	End	00:03 hrs	00:13 hrs	332262.65	332264.96	2.31	**13.86**	**1.56**	**No. 3**
3	**D8-04 (Stream)**	Origin	End	00:25 hrs	00:35 hrs	332265.95	332268.12	2.17	**13.02**	**0.84**	**o.k**
4	**D8-04A (WILLY'S)**	Origin	End	00:50 hrs	01:00 hrs	332270.08	332272.19	2.11	**12.66**	**0.36**	**o.k**
5	**D8-02 Lower (Kambakia)**	Origin	End	01:10 hrs	01:20 hrs	332272.95	332275.02	2.07	**12.42**	**0.24**	**o.k**
6	**D8-02 Upper (police)**	Origin	End	01:35 hrs	01:45 hrs	332275.95	332276.75	0.8	**4.8**	**7.62**	**NO. 1**
7	**J-08-02(v/ chamber)**	Origin	End	02:00 hrs	02:10 hrs	332277.23	332277.95	0.72	**4.32**	**0.48**	**o.k**
8	**D8-03 (Kenya-RE)**	Origin	End	02:20 hrs	02:30 hrs	332278.35	332278.38	0.03	**0.18**	**4.14**	**NO. 2**
9	**J-o8-02 (kenya-Re)**	Origin	End	02:45 hrs	02:55 hrs	332278.45	332278.46	0.01	**0.06**	**0.12**	**o.k**

(II) Indicator 2: NRW as Leakage volume per connection per day (Ltr/con/day)

In Table 5.10B(1), Column 9* are the values of Qmnf from Table 5.10A above. The values are subjected to further evaluation by converting to 24hour flow and dividing the flows by the number of connections on each pipeline to obtain Indicator2 in Ltr/con/day (Column No. 13). The pipelines are then ranked based on Table 5.10B(2) which is a World Bank's Physical Loss Target Matrix of a distribution system whose average water pressure is 50m (assumed average pressure in most WSPs in Kenya).

The pipelines with high "Indicator2" value (E is highest) are then prioritized for leak detection.

Table 5.10B(1): Result of Step Test Measurement for DZ 8 Lower (Kambakia) on 10th Jan. 2020 (Note: 9 - Table starts with Column 9 of Table 5.10A)*

	Column No.	[9]*	[11]	[12]	[13]	[14]**
	Indicator 2 (Ltr/con/day)					
s. no.	**Pipeline No.**	**Qmnf (m^3/h)**	**No. of Con.**	**Ltr/con/h**	**Ltr/con/day**	**Rank**
1	Whole	n/a	n/a	n/a	n/a	n/a
2	D8-04 (Rwanyambo)	1.56	217	7	173	B
3	D8-04 (Stream)	0.84	100	8	202	B
4	4-D8-04A (Willy's)	0.36	80	4	108	A
5	D8-02 Lower (Kambakia)	0.24	60	4	96	A
6	D8-02 Upper (Police)	7.62	325	23	563	D
7	J-08-02 (v/chamber)	0.48	2	240	5,760	E
8	D8-03 (Kenya-Re)	4.14	86	48	1,155	E
9	J-o8-02 (Kenya-Re)	0.12	0	#DIV/0!	#DIV/0!	D
		Total	870			
	Note: Column 14** - Ranking is based on Table 5.10B(2)					

Table 5.10B(2): Physical Loss Target Matrix (Indicator2 – Leakage Volume per Connection per Day) (Source: World Bank Institute - see Table 5.11)

Indicator2 (Ltr/con/day)	Index
＜125	A
125 to ＜250	B
250 to ＜500	C
500 to ＜1000	D
1000 & above	E

This index is used when there seems to be a lot of physical leakage in the service pipes.

Note: The true value CAPL cannot be known without direct measurement of flow. When it is judged that there is a lot of water leakage in the service pipe, a suitable survey method for measuring flow is formulated.

(III) Indicator3: NRW as Leakage volume per km per minute 9Ltr/km/min)

In Table 5.10C(1), Column 9* are the values of Qmnf from Table 5.10A above.

The values are subjected to further evaluation by converting the per hour to per minute flow and dividing the flows by the total length of each pipeline in km to obtain Indicator3 in Ltr/km/min (Column No. 16). The pipelines are then ranked based on Table 5.10C(2) which is the ILI recommended by the Japan International Cooperation Agency (JICA) NRW Project.

The pipelines with high "Indicator3" (Ltr/km/min) value (E is highest) are prioritized for leak detection.

Table 5.10C(1): Result of Step Test Measurement for DZ 8 Lower (Kambakia) on 10th Jan. 2020 (Note: 9 - Table starts with Column 9 of Table 5.10A)*

	Column No.	[9]*	[15]	[16]	[17]
	Indicator 3 (Ltr/km/min)				
	Pipeline No.	**Qmnf (m^3/h)**	**Length (km)**	**Ltr/km/min**	**Rank**
1	Whole	n/a	n/a	n/a	n/a
2	D8-04 (Rwanyambo)	1.56	0.104	250.0	E
3	D8-04 (Stream)	0.84	0.773	18.1	B
4	4-D8-04A (Willy's)	0.36	1.980	3.0	A
5	D8-02 Lower (Kambakia)	0.24	0.578	6.9	A
6	D8-02 Upper (Police)	7.62	1.065	119.2	E
7	J-08-02 (v/chamber)	0.48	0.404	19.8	B
8	D8-03 (Kenya-Re)	4.14	0.557	123.9	E
9	J-o8-02 (Kenya-Re)	0.12	0.350	5.7	A
		Total	5.811		

Table 5.10C(2): Physical Loss Target Matrix (Indicator3 – Leakage Volume per km per min.

Indicator3 (L/km/min)	Index
< 10	A
10 to < 20	B
20 to < 50	C
50 to < 100	D
100 & above	E

This index is used when there is a lot of physical leakage in the water distribution pipes.

(IV) Indicator 4: NRW as Current Annual Physical Losses (CAPL) / Unavoidable Annual Real Losses (UARL) = Infrastructure Leakage Index (ILI)

$$\text{Indicator 4:} \quad = \quad \text{Infrastructure Leakage Index (ILI)}$$

$$= \quad \frac{\text{Current Annual Physical Losses) (CAPL)}}{\text{Unavoidable Annual Real Losses (UARL)}}$$

Table 5.11: Physical Loss Target Matrix

Technical Performance Category		ILI	Physical Losses [litres/connection/day] (when the system is pressured) at an average pressure of:				
			10 m	20 m	30 m	40 m	50 m
Developed Countries	A	1 - 2		< 50	< 75	< 100	< 125
	B	2 - 4		50 - 100	75 - 150	100 - 200	125 - 250
	C	4 - 8		100 - 200	150 - 300	200 - 400	250 - 500
	D	> 8		> 200	> 300	> 400	> 500
Developing Countries	A	1 - 4	< 50	< 100	< 150	< 200	< 250
	B	4 - 8	50 - 100	100 - 200	150 - 300	200 - 400	250 - 500
	C	8 - 16	100 - 200	200 - 400	300 - 600	400 - 800	500 - 1000
	D	> 16	> 200	> 400	> 600	> 800	> 1000

Source: World Bank Institute

Book Source: The Manager's Non-Revenue Water Handbook (A Guide to Understanding Water Loss)

In Table 5.11 above:

- Is the ***Infrastructure Leakage Index, ILI.***
- Is Indicator2 (***Ltr/con/day***) which shows the numerical value based on the average water pressure in the system. Table 5.10B(2) is modified to include <125 which is not in Table 5.11.

The value of ILI for each pipeline in Table 5.10A is calculated in Table 5.12 below.

(**Note:** The setting value of the indicator is different from ILI of Handbook).

Please See Sheet ILI Cal in ``Night flow 10.01.20 DZ 8 LOWER(JICA2020.07.01) rev. xlsx

Table 5.13, MAAPL (Ltr/day) =((18×Lm) + (0.8×Nc) + (25×Lp)) ×P

Where: -

Lm - Length of mains (km)
Nc - Number of service connections
Lp - Total Length of service pipe from property boundary to customer meter (km)
P - Average operating pressure in m (assumed 30m water head)
CAPL = k x Qmnf

Note: CAPL is obtained through direct flow measurement. However, measurement or calculation of CAPL is very difficult.

Therefore, CAPL value is normally estimated through common sense by multiplying Qmnf by a coefficient, k with value range 0.5 to 0.9 (Table 5.12).

This coefficient, k varies depending on:

- the setting, i.e., urban or rural setting.
- number of service pipes in the DZ.
- amount of wave amplitude on the Qmnf graph.

For example, CAPL in Meru WSP data tentatively calculated using 0.9xQmnf.

Table 5.12: A Guide to Coefficient k (estimated through common sense)

NRW%	Reference coefficient	Urban	Rural
20	0.6 to 0.8	0.6 to 0.7	0.7 to 0.8
30	0.7 to 0.85	0.7 to 0.8	0.75 to 0.85
40	0.75 to 0.9	0.75 to 0.85	0.8 to 0.9
50	0.8 to 0.9 or higher	0.8 to 0.9	> 0.9

Table 5.13: Infrastructure Leakage Index (ILI) Calculation for DZ 8

	Column No.	[11]	[18]	[19]	[20]	[21]	[22]	[9]	[23]	[24]
			Lm (Km)	Nc	Lp (1 tapping =30m): Km	P	MAAPL (Ltr/day)	Qmnf (m^3/h)	CAPL (Qmnf*90%) Ltr/day	ILI
		No. of Connection s	Length of mains	service connection s	Total Length of service pipes	Pressure (mca)				
	Pipeline No.			=[11]	=[19]x30/100 0		= (18x[18])+ (0.8 x [19])+ (25x[20])x[21]		= (9)x0.9x 24x1000	= (23)- (22)
1	**Whole**	**870**	**5.81**	**870**	**26.10**	**30**	**43,593**	**15.36**	**331,776**	**7.6**
2	D8-04(Rwanyambo)	217	0.10	217	6.51	30	10,147	1.56	33,696	3.3
3	D8-04 (STREAM)	100	0.77	100	3.00	30	5,067	0.84	18,144	3.6
4	4-D8-04A(WILLY'S)	80	1.98	80	2.40	30	4,789	0.36	7,776	1.6
5	D8-02 Lower (kambakia)	60	0.58	60	1.80	30	3,102	0.24	5,184	1.7
6	D8-02 Upper(police)	325	1.07	325	9.75	30	15,688	7.62	164,592	10.5
7	J-08-02(v/chamber)	2	0.40	2	0.06	30	311	0.48	10,368	33.3
8	D8-03 (Kenya-RE)	86	0.56	86	2.58	30	4,300	4.14	89,424	20.8
9	J-o8-02 (Kenya-Re)	0	0.35	0	0.00	30	189	0.12	2,592	13.7

Table 5.14: Calculated ILI (from Table 5.13

	Pipeline No.	ILI
1	**Whole**	**7.6**
2	D8-04 (Rwanyambo)	3.3
3	D8-04 (STREAM)	3.6
4	4-D8-04A (WILLY'S)	1.6
5	D8-02 Lower (Kambakia)	1.7
6	D8-02 Upper (police)	10.5
7	J-08-02 (v/chamber)	33.3
8	D8-03 (Kenya-RE)	20.8
9	J-o8-02 (Kenya-Re)	13.7

ILI Recommended by JICA NRW Project

LI=Indicator4 (CAPL/UARL	
1-4	**A**
4-8	**B**
8-16	**C**
16-20	**D**
＞20	**E**

ILI from Manager's Handbook

Technical Performance Category		ILI
Developed Countries	A	1 - 2
	B	2 - 4
	C	4 - 8
	D	> 8
Developing Countries	A	1 - 4
	B	4 - 8
	C	8 - 16
	D	> 16

Table 5.15: Recommended Priority Pipelines Using Recommended ILI Above

	Pipeline No.	**ILI**	**Prioritized Pipelines**
1	**Whole**	**7.6**	**B**
2	D8-04 (Rwanyambo)	3.3	A
3	D8-04 (STREAM)	3.6	A
4	4-D8-04A (WILLY'S)	1.6	A
5	D8-02 Lower (Kambakia)	1.7	A
6	D8-02 Upper (police)	10.5	C
7	J-08-02(v/ chamber)	33.3	E
8	D8-03 (Kenya-RE)	20.8	E
9	J-o8-02 (Kenya-Re)	13.7	C

Note: E is the highest priority for leak detection

JICA Project ILI

CHAPTER 6

MEASURING PRESSURE IN EXISTING PIPE NETWORK

(Target Staff: Design, Construction, Meter/Connection Installation)

6.1 Importance of Measuring Pressure in Existing Pipe Network

The rate of leakages increases with increase in pressure. It is therefore prudent to keep the pressure in pipelines low to reduce the amount of leakage.

The minimum allowable pressure at the customer point is 10m head. It is therefore not necessary to maintain higher than the minimum pressure, where possible, so that leakage remains low.

The purpose of measuring pressure in the network is to determine the pressure distribution (or pressure map) which can then be used to manage pressure thus:

- reduce pressure using pressure reducing valves or break pressure tank where pressure is unnecessarily high
- increase pressure using booster pumps where pressure is inadequate

This is normally best achieved by carefully considering the various options of combining booster pumps and PRVs/storage/break pressure tanks to come up with an energy-efficient network.

6.2 Procedure of Pressure Measurement using Pressure Gauge fitted with Min/Max Drag Pointer

Figure 6.1: Red pointer pressure gauge

1) General

A drag pointer is a red additional pointer with an arm that is pushed by the primary gauge pointer (black) upto when the pressure drops and the drag (or max pointer) remains at peak pressure, indicating max pressure achieved. This gauge can also function similarly as a min pointer on vacuum or compound ranges.

Figure 6.1: Red pointer pressure gauge

2) Where to Install the Min/Max Drag Pointer Pressure Gauges

a) A point at or near where the branch supplying a DZ starts.
b) Points at the end of a pipe network.
c) Peak points of a pipeline (where the minimum water pressure occurs).
d) Points at just in front and just behind a pressure reducing valve (to verify the reliability of pressure reducing valve).
e) Points where water hammer tends to start (e.g., Pump outlet pipe)
f) On a pipeline at 2 to 4 km intervals (for information on water leakage).
g) Around the customer meter.

3) How to Install a Pressure Gauge.

The following are required to enable installation of a pressure gauge:

- Pressure gauge,
- Fitting spanners,
- Thread tape or a rubber gasket
- Pressure tapping point.

Figure 6.2: Pressure gauges installed on pipes

Procedure

- Open the tapping point to release air if any
- Appy thread tape to the threads or fix the rubber gasket appropriately.
- Fix the gauge firmly screw the pressure gauge into the tapping point ensuring watertight seal (no leaks) for accurate readings.
- Open the facility tap and wait for a few seconds before reading.
- Live pressure can then be recorded.

Note: this method is best used to test static water pressure. If water is moving anywhere in the system, that may cause a false low reading.

4) How to Measure Maximum Pressure

a) Select the type of target pressure you want to measure (i.e., Maximum, minimum or running pressure)

b) Select the type of location to install the pressure gauge from sub-section (2) above.

c) If the gauge is to be installed along the pipeline, prepared a pressure point in advance (install a branch connection (using saddle clamp or tee) with suitable adaptor for the pressure gauge inlet), while if it is along a customer line, the meter liner point would be most suitable.

d) Adjust the gauge to suit the type of pressure being measured:

- To measure maximum pressure, adjust the drag (red) pointer anti-clockwise to lean against and above the black pointer and leave the gauge at that point overnight. Record the maximum pressure achieved by checking the reading of the drag pointer.
- To measure the minimum pressure, adjust the red pointer clockwise to lean against and below the black pointer. Record the lowest pressure achieved by checking reading of the drag pointer.

Figure 6.3: Pressure gauge installed at customer metering point

e) Record the location coordinates with GPS.

- If around a customer meter, record the connection number and meter serial number.
- Record the initial or running pressure indicated by the black pointer immediately after installation.
- Leave the gauge overnight
- In the morning, record the pressure indicated by the red gauge (this is the maximum or minimum pressure in the pipeline at this location)
- You can opt to repeat the exercise in case of doubt or as a confirmation.

Table 6.1 is a conversion table for pressure units for reference

1 bar = 0.987 Atm	1 KPa = 0.00987 Atm	1 psi = 0.068 Atm	1 Atm = 1.013 bar	1 m = 0.09804 bar
1 bar = 10 m	1 KPa = 0.01 bar	1 psi = 0.0689 bar	1 Atm = 101.3 KPa	1 m = 0.0968 Atm
1 bar = 14.504 psi	1 KPa = 0.14504 psi	1 psi = 6.8947 KPa	1 Atm = 14.696 psi	1 m = 9.804 KPa
1 bar = 100 KPa	1 KPa = 10 m	1 psi = 0.7032 m	1 Atm = 10.335 m	1 m = 1.45 psi

6.3 How to Measure Pressure Using Pressure Data Logger

Water pressure loggers make it easy to verify low water pressure complaints, locate water pressure spikes, and even provide water distribution system modeling data. The water pressure logger's large memory buffer will store a huge amount of water pressure readings with user defined intervals from 1 second to more than 1 year.

You can easily capture momentary pressure spikes and dips with the water pressure logger's fast 10 water pressure samples per second sampling mode. (Note: fast recording will reduce battery life.)

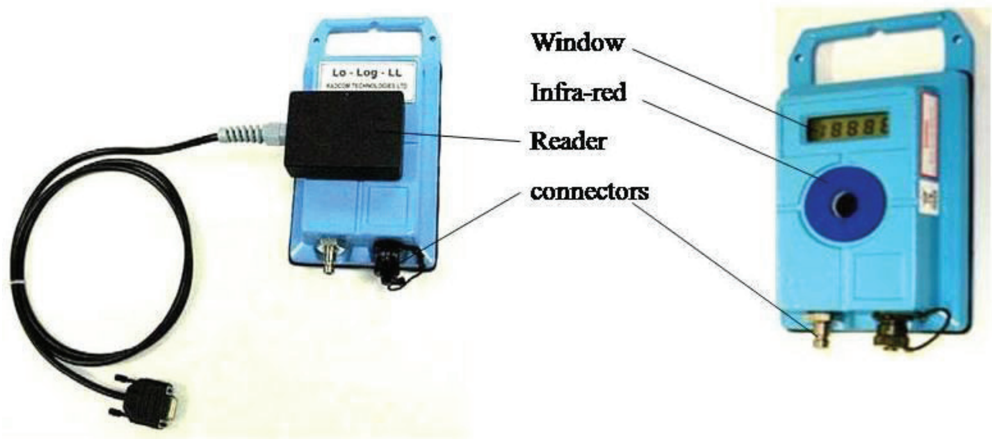


Figure 6.4: Pressure data loggers

Pressure loggers have programmable start and stop alarm times that make it possible to synchronize multiple water pressure data loggers to start at the same time, delay starting until a preset time, or limit the number of recordings during a day. They can also record water pressure data just about anywhere required as most of them are harsh weather resistant.

Applications

It is used in the monitoring and reporting of pressure levels for the following Potable Water Applications:

- DMA and General pressure Logging
- Water Demand Managements/Assessments
- Customer Metering Diagnostics
- Pressure mapping

Step 1: Software installation

Water Pressure Data Loggers are equipped with a standard USB data port and includes user friendly Windows software, which allows for easy setup, calibration, upload, and water pressure data transfer to a spreadsheet program on your laptop or desktop PC. They include a USB cable for communication between the water pressure logger and your computer.

Note: different loggers use different software the user should use the guidelines given to install software.

Step 2: Data Input (Set up)

This involves configuring the logger using the installed software to facilitate data collection in the field. This includes Channels to be used, transducer data, logging intervals, start time, pressure units etc. Finally upload the logger.

Figure 6.5: Data transfer from pressure logger to computer

Figure 6.6: Pressure Logger Installed on Pipe

Step 3: How to Install Data Logger

Note: The logger is water resistant but it is advisable to install it in a chamber or box.

- Using the pressure flex tube, connect the logger to the pipe tapping point (Figure 6.6).
- Logging will start automatically as per set time.

Step 4: Downloading data

- Connect the data logger to a computer using infrared or wire cable and follow steps provided.
- The users can then interpret the data, develop graphs or covert to other formats.

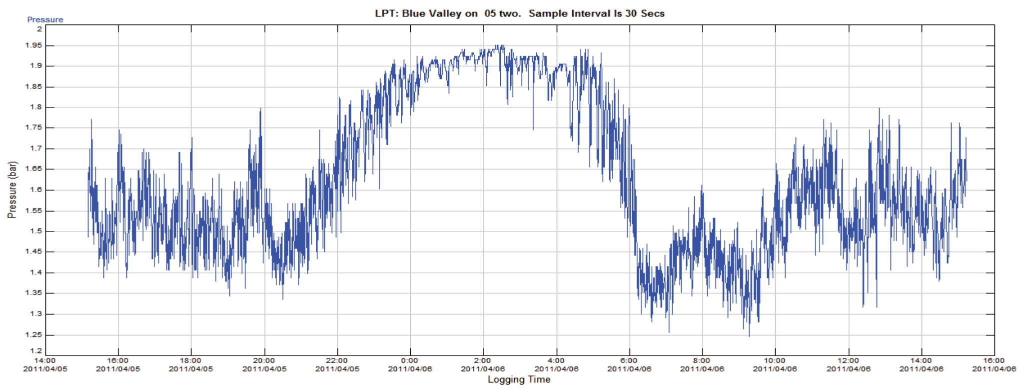


Figure 6.7: Pressure log graph

Maintenance

Check the batteries frequently and calibrate the equipment as per recommended logging hour's expiry

6.3.1 Self-Recording Water Pressure Measuring Instruments

This is a device that measures hydraulic pressure after connecting to a hydraulic fitting on a pipeline using a dedicated connecting fitting (coupling) and a water pressure sensor. (See Figure 6.8)

The recorder has a "pen" attached to an arm interlocking with a Bourdon tube that expands and contracts with change in pressure (there are both fixed and portable loggers). The recording paper can record for over 24 hours and uses a built-in clock (see Figure 6.8 to 6.10)

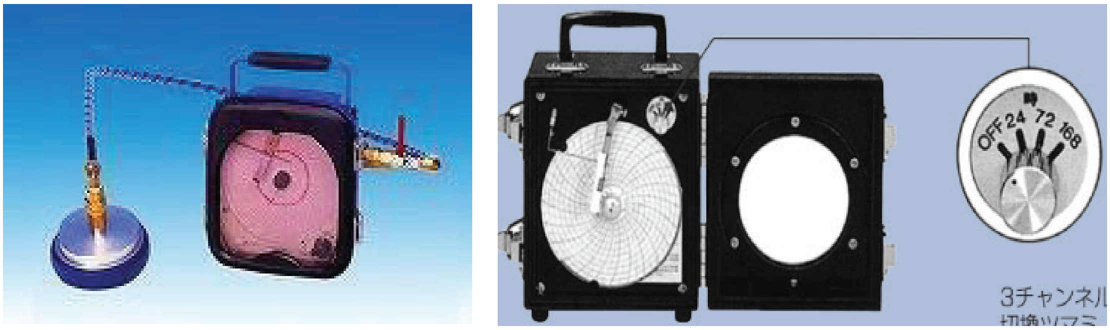


Figure 6.8: Self-recording water pressure measuring device models

Figure 6.9: Self-recording water pressure measuring device model

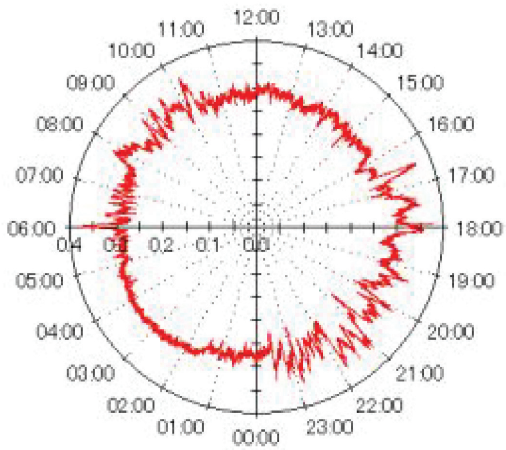


Figure 6.10: Water pressure recording paper

CHAPTER 7

PRESSURE TESTING OF PIPELINES

(Target Staff: Design, Construction, Meter/Connection Installation)

7.1 Importance of pressure testing of pipelines

Once a new pipeline is laid, its condition is unknown unless and until it is tested for pressure tightness. The practice of commissioning new pipelines without first subjecting to pressure tests (which is a common practice) is imprudent and leads to high NRW from the beginning. Pressure testing provides an opportunity to rectify any defects at the initial stage before heavy losses are incurred through water loss through leakage, revenue loss and leak detection costs later on.

Pressure testing of pipelines can also be conducted on an existing pipeline to determine its soundness. This is normally carried out in combination with leak detection to reveal any leakage points.

7.2 Procedure of Pressure Testing Pipelines Using Hand Pump

a) Select the pipeline on which to conduct the pressure test with handpump (e.g., newly installed connection, service line that has been replaced, connection with road crossing etc.).

b) Confirm that the gate valve or ferrule at the off-take point from the mainline is accessible and properly functional

c) Record the coordinates of the saddle or ferrule point using a GPS.

d) Confirm the pressure class of the pipe to be tested (pipe specifications) to ensure it will withstand the testing pressure (usually 1.5 times the expected maximum pressure at that point at night). If the pipe cannot withstand the testing pressure, replace it with the right pipe. Note: the testing pressure for all pipes is usually 1.5 times the rated pressure).

e) Confirm that the pipe is full of water at the time of the test.

f) check the condition of the trench in which the service line or connection has been installed. The pipeline should be half backfilled with the joints exposed so that any leakage will be visible.

g) Connect the pump on the far end from the ferrule ready for use and set the maximum pressure to be applied during test (usually 1.5 times the expected maximum pressures in that area at night).

Figure 7.1: Hand pump connected on different pipe materials ready for use

h) Close the gate valve or ferrule at the off-take point and pump water into the pipe column under test to the set pressure reading on the gauge. Remove air that might be in the column by opening the air valve on the pump.

i) After achieving the set pressure, wait for about 5 minutes to see if the pressure will sustain at the set level.

j) If the pressure drops, it indicates there is possibly a leakage in the pipe and therefore patrol the pipeline to locate it. If the pressure remains steady after 5 minutes, it means the pipeline has no leakage.

The test can be repeated for verification if need be and the results recorded for certification purpose.

7.3 Pressure Testing of Large Pipelines

Refer to Section 3.6 for detailed procedure.

CHAPTER 8

MANAGEMENT OF CUSTOMER AND BULK METERS

(Target Staff: NRW, Meter Servicing/Repair)

8.1 Meter Servicing and Accuracy Testing

8.1.1 Introduction

Meter Servicing refers to the opening up and cleaning of the internal parts of a meter from dirt and silt particles resulting from inadequately treated water or dirt infiltration (through leak holes) due to pipe shut downs. These sediments build up on the internal parts of meters, especially mechanical meters wearing out bearings thereby increasing friction between moving parts. This then causes the meter to slow down and thus under-register consumption. Utilities must sustain the turbidity of the treated water below 2 NTU and regularly monitor water quality in addition to servicing mechanical meters to minimize sediment levels and promote accurate meter measurements.

Wearing out of meter moving parts occur over time depending on the quality of the meter. Accuracy testing a range of meter brands and ages will determine which meters should be replaced.

8.1.2 Procedure of Customer Meter servicing

Meter servicing and repair is a very delicate exercise that should only be handled by trained and experienced staff.

Proceed as follows:

a) Identify the stopped meters while at the office from the meter stopped report from the billing system
b) Trace and confirm the meter locations
c) Move to the ground
d) Confirm the meters serial numbers and the current readings
e) Close the water supply by the stop cork
f) Remove the installed meter
g) Clean the external of the meter
h) Break or remove the seal
i) Dismantle the meter into its basic components of the shell/case, (upper and lower part for propeller meter; and side-by-side shells for volumetric meter), the register, and the measuring chamber. A vice is necessary to hold the meter.

Note: Do not hit the meter with pipe wrench to make it easy to dismantle. It will get damaged and its accuracy deteriorated.

Instead, use custom-made spanners as shown below while holding the meter using a pipe wrench:

Figure 8.1: Custom-made spanner for Propeller Type Meters

Figure 8.2: Custom-made spanner for Volumetric Type Meters

j) Confirm that the threads on the inlet and outlet of the meter are in good condition to avoid leakage.

k) Confirm that the threads if any) between the two casings are in good condition also

l) Cleaning internal plastic parts: use soft cloth and some soap. Never use wire brush or the meter will be permanently damaged. Replace worn out or broken parts.

m) Cleaning internal metallic parts: use soft brush and some soap. Never use wire brush or the meter will be permanently damaged. Replace worn out or broken parts.

n) Cleaning external surface: use wire brush or sand-blast or bead-blast and finish with Sand Paper P80 and finish with Sand Paper 0 (zero). Spray paint for a good finish.

o) Reassemble the meter (for volumetric meter, ensure the narrower side of the piston is placed on the upper side while the wider side is on the lower side or the meter will over-register)

p) Finally test the accuracy of the serviced meter. If accuracy is not within acceptable limits, try replacing the working chamber and retest.

q) If accuracy is still not acceptable, then discard the meter.

Figure 8.3: Debris trapped meter strainer

r) Re-sealing the meter

s) Re-install back the meter.

8.1.3 Procedure of Customer Meter Testing Using Calibrated Bucket

Meer testing is usually done immediately after meter servicing, on customer request or as a normal routine (based on consumption category prioritization) to determine accuracy. The target is to reduce commercial losses by increasing billed amount and hopefully the collection amount as well.

The test is usually done on-site and has an error margin of +/-5% (instead of the initial threshold of +/-2%) at flow rates above transitional flow rate (Qt or Q2).

Proceed as follows:

a) Identify the stopped meters or prioritized meters while at the office from the meter stopped report from the billing system or from the ‘meter reading & billing analysis’.
b) Trace and confirm the meter locations
c) Move to the ground
d) Confirm the meter serial numbers and the current readings
e) Close the water at stop cork ensuring complete stop of flow (
f) Record the initial reading of the meter Including the litres (red digits)
g) Place the empty 10 (or 20) litres calibrated bucket at the tap to make sure it captures every drop
h) Fully open the tap to measure the maximum flow and stop the water when the bucket fills to the 10 (or 20) litres mark.
i) Record the final meter reading at the end of the test including the litres (red digits)
j) Calculate the meter error as follows as a percentage of the volume of the bucket

$$\text{meter error (\%)} = \frac{\text{(Final reading – Initial reading) x 100\%}}{\text{Volume of bucket (e.g., 10 (or 20 litres))}}$$

As earlier indicated, the permissible error margin is ±5%.

k) Repeat the test with the tap half open (assumed medium flow)
l) Repeat the test with the tap adjusted to achieve a low flow rate which is assumed to be the minimum flow rate.
m) NB: For a meter to be deemed accurate it should be within the permissible error margin in all the three tests conducted with the different flow rates.
n) The test can be repeated for confirmation purposes if need be.

Figure 8.4: Testing a meter using calibrated bucket and a portable test meter

8.2 Procedure of Customer Meter testing Using Meter Test Bench

8.2.1 Components of a Meter Test bench

a) Water Meter Test Bench - 1 set (see Figure 8.5)
b) Recording paper - 1 set
c) Stopwatch - 1 set
d) Water meters to be tested - 6 to 10 pieces
e) Tool and materials: - pipe wrenches for opening/closing, thread tape PTF, etc.

Figure 8.5: Water Meter Test Bench (EMBU WSP procured model)

8.2.2 *Confirmation of water meter specification (ISO-Class)*

The two specifications of water meters are illustrated in Figure 8.6. They are ISO 4064-1993 (Old Standard), and JIS B 857-2013 / ISO 4064-2005 (New Standard)

On the two meters, the specifications are shown inside the red circle thus:

- Old standard: Qn:1.5m3/h, Class C-H, PN16 bar, 40°C; while
- New standard: Q3=2.5 (m3/h), R=100

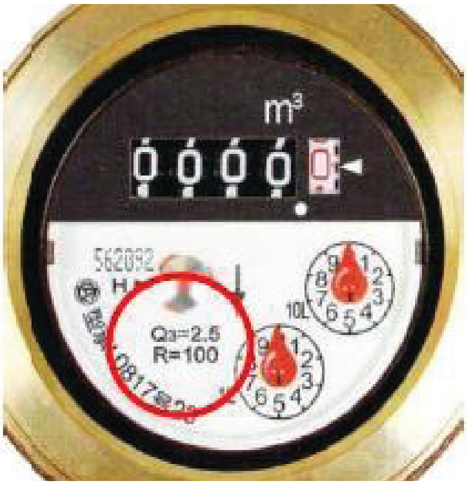
ISO 4064-1993 (Old Standard)

Type= multi-jet dry-radial vane

Class C-H (H=when installed horizontally)

DN =15mm

Qn =1.5m3/hr



JIS B 857-2013 / ISO 4064-2005 (New Standard)

Single-jet dry-radial vane

R= Q3/Q1 =100

DN=15mm

Q3 = 2.5 m3/hr

Figure 8.6: Confirmation of water meter specification to be tested (ISO-Class)

For the old standard, Table 8.1 indicates the formulae to calculate Q_{min}, Qt, and Q_{max}.

Table 8.1: Coefficients of small caliber meters (ISO 4064-1993) (Horizontally Installed)

<table>
<tr><th>Classes (ISO 4064-1993)</th><th>Meters of Qn < 15m³/h (Small meters)</th><th>Qn (m³/h)</th><th>DN (mm)</th></tr>
<tr><td></td><td></td><td>1.5</td><td>15</td></tr>
<tr><td></td><td></td><td>2.5</td><td>20</td></tr>
<tr><td>Class A</td><td></td><td colspan="2" rowspan="12">Values of Nominal Diameter (DN mm)</td></tr>
<tr><td>Value of Q_{min}</td><td>0.04 x Q_n</td></tr>
<tr><td>Value of Q_t</td><td>0.1 x Q_n</td></tr>
<tr><td>Value of Q_{max}</td><td>2.0 x Q_n</td></tr>
<tr><td>Class B</td><td></td></tr>
<tr><td>Value of Q_{min}</td><td>0.02 x Q_n</td></tr>
<tr><td>Value of Qt</td><td>0.08 x Q_n</td></tr>
<tr><td>Value of Q_{max}</td><td>2.0 x Q_n</td></tr>
<tr><td>Class C</td><td></td></tr>
<tr><td>Value of Qm_{in}</td><td>0.01 x Q_n</td></tr>
<tr><td>Value of Q_t</td><td>0.015 x Q_n</td></tr>
<tr><td>Value of Q_{max}</td><td>2.0 x Q_n</td></tr>
</table>

8.2.3 Conditions necessary to conduct meter testing with test bench

a) Temperature of water used: 20 ± 5 ℃
b) Water Quality:

- The test water shall be tap water or equivalent water quality.
- The water should not have objects (e.g. air bubbles, floating objects, etc.) that will adversely affect the meter operation.

c) Water pressure: A steady positive water pressure of at least 0.03 MPa at the meter outlet should be ensured.
d) Ambient (weather) temperature range: 15 ℃ to 35 ℃
e) Range of peripheral relative humidity: 25 ° C to 75 ° C
f) Range of surrounding atmospheric pressure: 86 kPa to 75 kPa
g) The pressure loss of the water meter shall be within the operating conditions and shall not exceed 0.063 MPa (6.3 m = 0.63 kg/ cm²) at rated maximum water flow.

8.2.4 Range of flow rate for meter testing

The accuracy of a meter is measurement at four flow rate points.

a) Rated minimum flow rate Q_{min}
b) Transitional flow rate Q_t
c) Nominal flow rate Q_n
d) Limiting flow rate Q_{max}

The four flow rates are obtained from Table 8.2 (as per ISO 4064-1993 Classification).

Table 8.2: Water meter classification to ISO 4064-1993 (flowrates in litres/hour)

Nominal dia, mm (inch)			Class A		Class B		Class C		Class D	
	Q_n	Qm_{ax}	Q_{min}	Q_t	Q_{min}	Qt	Q_{min}	Q_t	Q_{min}	Q_t
15 (½”) V	1,000	2,000	-	-	-	-	-	-	7.5	11.5
15 (½”) H	1,500	3,000	60	150	30	120	15	22.5	11.25	17.25
20 (¾”) H	2,500	5,000	100	250	50	200	25	37.5	18.75	28.75
25 (1”) V	3,500	7,000	140	350	70	280	35	52.5	26.25	40.25
25 (1”) H	6,000	12,000	240	600	120	480	60	90	-	-
32 (1¼) H	6,000	12,000	240	600	120	480	60	90	-	-
40 (1½) H	10,000	20,000	400	1000	200	800	100	150	-	-

Key

- V-Vertically installed (for volumetric meters only); H - Horizontally installed

In the latest standards (ISO 4064:2014 and OIML R49:2013), a new system based on the Reynard series has been established and the flowrates on Figure 8.7 are renamed as follows: $Q_{min} \rightarrow Q_1$, $Q_t \rightarrow Q_2$, Qn $\rightarrow Q_3$, and $Q_{max} \rightarrow Q_4$. However, the values of Q_1 to Q_4 are not the same as Q_{min} to Q_{max} respectively.

The values of normal flow Q3 and R (R = Q3/Q1) are written on the meter while the values of Q_2 and Q_4 are derived from the formulae:

$Q2 = 1.6Q_1$

$Q4 = 1.25Q_3$

8.2.5 Error specification for test flow rate (ISO-4064-2005)

At minimum 3 points calibration point, the test should be conducted in the following flow rate adjustment range (Figure 8.7).

a) First point = between Q_1 and $1.1Q_1$
b) Second point = between Q_2 and $1.1Q_2$
c) Third point = between $0.9Q_3$ and Q_3

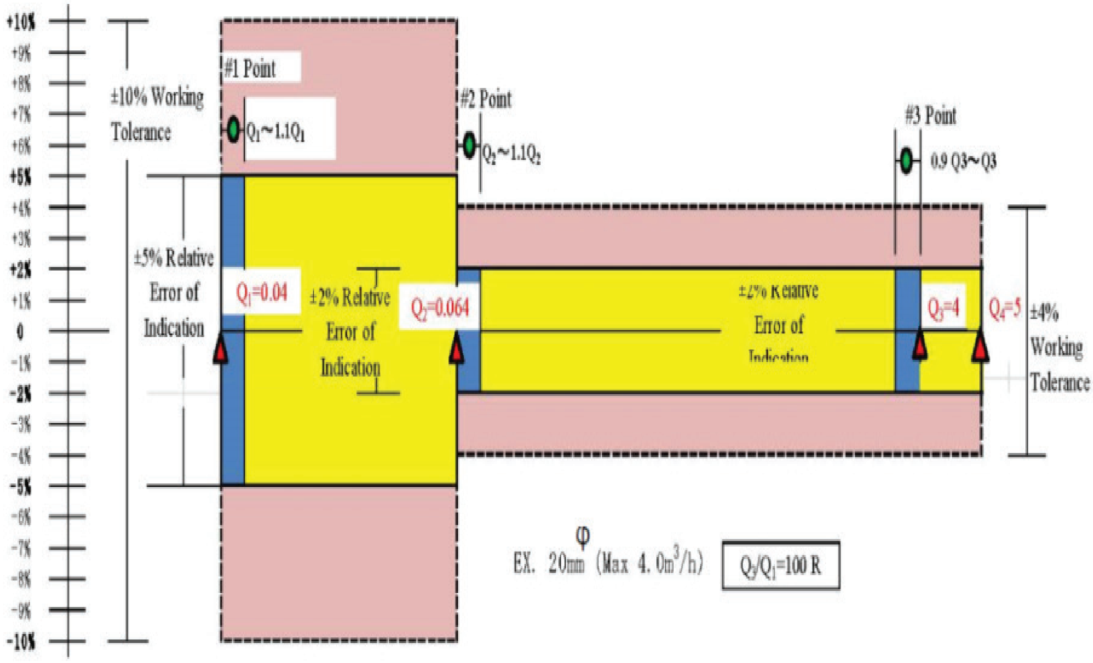


Figure 8.7: Concept of Detail Error Range of Test Flow

8.3 How to evaluate meter test result

8.3.1 Calculation method of equipment error ratio

Meter error indicates the ratio between the amount indicated by the meter and the actual amount of water.

$$\text{Relative Error of Indication (\%)} = \frac{I - Q}{Q} \times 100$$

I= Meter's Indication Q= Actual Volume

8.3.2 Acceptance criteria tolerance

The allowable range for judging acceptance or rejection of product inspection is shown in Table 8.3 and Figure 8.7.

a) It must be less than the test tolerance of each flow rate.

b) If only one flow rate exceeds the test tolerance, the test must be repeated three times, two times within the test tolerance, and the arithmetic mean of the three measurement results shall be within the test tolerance

Table 8.3: Example of Allowable Tolerance

JIS B 8570-2			
Test tolerance			Flow area
Rated minimum flow rate	Q_1 and above	±5%	Small flow rate range
Transitional flow rate	Below Q_2		
Nominal flow rate	Q_3 and above	±2% (Water temperature < 30 °C)	High flow rate range
Limiting flow rate (max.)	Below Q_4		

8.3.3 Data sheet

Table 8.4 is a sample of meter accuracy test measurement data sheet where all the parameters are set and regulated as recommended in the standard meter testing.

During On-Job Training different types of meters (old and new) were subjected to accuracy test on a test bench and the following the results obtained.

8.4 Procedure of Sealing Meters

8.4.1 General

Some customers do tamper with meters to reduce the volume of water going through the meter and therefore reduce the bill amount. Since tampering attracts penalties, customers devise various inconspicuous methods of tampering.

Some notorious customers even proceed to vandalize the meter so that it malfunctions to his advantage, or to stops its functioning altogether.

Meter Sealing refers to safeguarding or protecting a meter and the meter liners in such a way that any tampering with the meter and/or meter liners (especially the upstream liner) is easily detected with proof of the tampering being available as evidence.

This evidence can then be a basis to build a case against a customer and to come up with measures for compensation to the WSP.

Before sealing a customer meter, the water must be stopped. Four methods to close the water are:

a) Closing the stop cork upstream of the meter.

This is not very effective due to often failure of stop corks to properly close, leaving a trickle of water.

Table 8.4: Sample meter accuracy test measurement data sheet

Result of Joint OJT at EMBU — 2017-June-22 @ EWASCO

P1 inlet pressure - 0.4 bars						P2 outlet pressure = bars						ISO STD	Your STD
						Flow Rate: Qn (1500 l/h)							
						Total flow vol = 200 lts							
No	Classification	Sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Quantity of accumulated total (m3)	START	END	DIFRENCE		Error	Comments ±4 % (in use)	Comments
Volume used ; 200 lts=0.2 m3						0.2	R1 (m3)	R2 (m3)	R2-R1	%	100%		
1	Old	AC175298	PSM		15	3576.782	3576.782	3576.974	0.192	96%	-4%	Pass	
2	Customer	13081721	psm		15	2355.6125	2355.6125	2355.8089	0.1964	98%	-2%	Pass	
3	**New**	**15-05855**	**MJET**	**Kiambu WSP**	**15**	**0.4081**	**0.4081**	**0.6058**	**0.1977**	**99%**	**-1%**	**Pass**	**±2 % (New)**
4	Customer	7090712	psm		15	163.3051	163.3051	163.5014	0.1963	98%	-2%	Pass	
5	**New**	**15-05853**	**MJET**	**Kiambu WSP**	**15**	**0.3868**	**0.3868**	**0.5848**	**0.198**	**99%**	**-1%**	**Pass**	**±2 % (New)**
6	Above 1000	H570060	SJET		15	2779.702	2779.702	2779.891	0.189	94%	-6%	**Reject**	
7	Above 500	05-1059537	SJET		15	686.1175	686.1175	686.1175	0	0%	-100%	**Reject**	
8	In Service	8024018	psm		15	0.7072	0.7072	0.9016	0.1944	97%	-3%	Pass	

P1 inlet pressure - 0.4 bars						P2 outlet pressure = bars						ISO STD	Your STD
						Flow Rate: Qt (120 l/h)							
						Total flow vol= 50 lts							
No	Classification	Sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Quantity of accumulated total (m3)	START	END	DIFRENCE		Error	Comments ±10% (in use)	Comments
Volume used: 50 lts= 0.05 m3						0.05	R2	R3	R3-R2	%	100%		
1	Old	AC175298	PSM		15	3576.974	3576.974	3576.975	0.001	2%	-98%	**Reject**	
2	Customer	13081721	psm		15	2355.8089	2355.8089	2355.8585	0.0496	99%	-1%	Pass	
3	**New**	**15-05855**	**MJET**	**Kiambu WSP**	**15**	**0.6058**	**0.6058**	**0.6562**	**0.0504**	**101%**	**1%**	**Pass**	**±5 % (New)**
4	Customer	7090712	psm		15	163.5014	163.5014	163.5525	0.0511	102%	2%	Pass	
5	**New**	**15-05853**	**MJET**	**Kiambu WSP**	**15**	**0.5848**	**0.5848**	**0.6355**	**0.0507**	**101%**	**1%**	**Pass**	**±5 % (New)**
6	Above 1000	H570060	SJET		15	2779.891	2779.891	2779.938	0.047	94%	-6%	Pass	
7	Above 500	05-1059537	SJET		15	686.1175	686.1175	686.11	-0.0075	??	??	**Reject**	
8	In Service	8024018	psm		15	0.9016	0.9016	0.9524	0.0508	102%	2%	Pass	

P1 inlet pressure - 0.4 bars						P2 outlet pressure = bars						ISO STD	Your STD
						Flow Rate: Qmin (30 l/h)							
						Total flow vol = 20 lts							
No	Classification	Sr.no	Model/ type	Year of manufacturer	Caliber (mm)	Quantity of accumulated total (m3)	START	END	DIFRENCE		Error	Comments ±10% (in use)	Comments
Volume used: 20 lts						0.02	R3	R4	R4-R3	%	100%		
1	Old	AC175298	PSM		15	3576.975	3576.975	3576.974	-0.001	??	??	**Reject**	
2	Customer	13081721	psm		15	2355.8585	2355.8585	2355.8585	0	0%	-100%	**Reject**	
3	**New**	**15-05855**	**MJET**	**Kiambu WSP**	15	**0.6562**	**0.6562**	**0.6756**	**0.0194**	**97%**	-3%	**Pass**	±5% (New)
4	Customer	7090712	psm		15	163.5525	163.5525	163.5716	0.0191	95%	-5%	Pass	
5	**New**	**15-05853**	**MJET**	**Kiambu WSP**	15	**0.6355**	**0.6355**	**0.6541**	**0.0186**	**93%**	-7%	Pass	±5% (New)
6	Above 1000	H570060	SJET		15	2779.938	2779.938	2779.958	0.02	100%	0%	Pass	
7	Above 500	05-1059537	SJET		15	686.11	686.11	686.11	0	0%	-100%	**Reject**	
8	In Service	8024018	psm		15	0.9524	0.9524	0.9718	0.0194	97%	-3%	Pass	

b) Placing a plastic block washer between the meter and the upstream meter liner.

This is the most popular method due to the ease and high efficiency of water closure. For large customer meters where block washers may not be available or practical, closure with water tight sluice gate or sluice valve is effective.

c) Closing water at the offtake point of the service line.

This method is employed for customers who routinely tamper with meters. It can involve closing the water using a gate valve or ferrule (if using standard saddle clamp).

d) Uprooting the service line.

This is an extreme method of closure for very notorious customers who reconnect even closures at offtakes. The WSP should consider carefully before employing this method of closure.

e) Automatic meter closure

This is closure of water by remote method. It is only possible with smart meters since they can be remotely controlled from the office or pass-by.

8.4.2 Why Undertake Meter Sealing?

a) To secure a disconnection
b) To deter meter tampering during water supply service
c) Customer categorization (e.g. blue for large consumer or red for disconnected account, etc.).

8.4.3 Methods of Meter Sealing

There are two methods of sealing meters:

a) Using sealing wire, sealing lead and sealing pliers

This is the relatively cheap method.

b) Using serialized (or un-serialized) plastic seals (these are still very new in the market)

The method is being preferred since it is:

- easy to clamp on the meter
- completely tamper-proof (once broken it cannot be reused hence the tamper evidence remains intact [and if serialized, the serial code can be traced])

8.4.4 Meter sealing Procedure Using Sealing Wire, Sealing Lead and Pliers

a) Insert the sealing wire through the holes on the meter liner that is upstream of the meter and then through the holes on the meter body and bring the two ends together.

b) Insert the sealing wire ends through the holes in the sealing lead.

c) Where a meter is being disconnected without taking it away, it is recommended to first close the stop cork/gate valve and then tightly tie the sealing wire around the handle of the stop cork/gate valve in such a way that it cannot be opened without breaking the wire, before passing both ends of the wire through the sealing lead. Confirm that the water is not flowing and the wire cannot be untied before the next step.

d) Press the sealing lead using a sealing pliers to ensure the sealing wire ends are firmly held and cannot become loose.

e) It is recommended that each sealing plier are engraves a unique number on sealing leads to identify the staff member who did the sealing.

Figure 8.8: Meter sealed by sealing wire and sealing lead

Figure 8.9: Sealing Pliers

Figure 8.10: Sealing lead stamped by Pliers No. MWS14

8.4.5 Meter Sealing Procedure Using Plastic Seals

A plastic seal comprises two halves of a rigid circular plastic band with flattened out ends (Figure 8.11). The flattened ends have either a hole or a knob. To seal a meter,

a) Place the two halves of the seal around the upstream union nut of the meter (one on top and the other underneath) with the hole of each half aligned to the knob of the other half.

b) Press the knobs against the holes and "snap" into the respective holes to clamp tightly onto the union.

Once clamped, they two halves cannot be separated without breaking. This ensures that the meter cannot be tampered with without leaving tamper evidence.

Note:

i) for more effective sealing, a second seal can be clamped on the downstream nut of the meter (Figure 8.12)

ii) the plastic seal can be engraved with a serial number for record purposes

iii) different color-coded plastic seals can be used to indicate different status of accounts, e.g.

- disconnected account – e.g. red seal,
- tamper suspect (under close monitoring) account – e.g. pink seal; or
- certain consumer categories – e.g. large consumer – yellow.

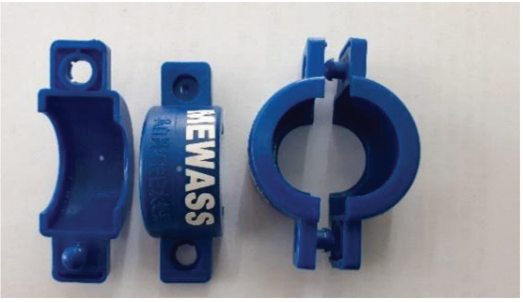


Figure 8.11: Plastic Seals

Figure 8.12: Meter Sealed Using Plastic Seals

8.5 Accuracy Testing of Bulk Meters

8.5.1 General

Testing of bulk meters for accuracy is an elaborate procedure only achievable by an accredited organization such as KEBS.

Fortunately, some WSPs such as Nyeri WSP is already accredited for meter testing and has been assisting WSPs in this regard.

Nevertheless, it is possible to conduct a rough check on the accuracy of a bulk meter using a UFM as below:

8.5.2 Rough Accuracy Testing of Bulk Meters

The procedure involves setting up the UFM on the same pipe and next to the bulk meter as detailed in Section 5.3. The flow through the pipe is then measured simultaneously using the UFM and the bulk meter. The two flows are then compared to determine the error level.

8.5.3 Testing Accuracy of Bulk Meters Using UFM

a) Introduction

Accuracy of bulk meters is important since the measured volumes are used to calculate the water balance. Their accuracy is usually tested using ultrasonic flow meter instead of installing a test meter in series thereby eliminating the need to cut the pipe.

b) Procedure of Bulk Meter Accuracy Testing

i) Ensure a timer (watch or stop watch) is available to time the bulk meter flow

ii) Ensure the bulk meter to be tested is easily accessible for reading

iii) Expose enough clear length of the pipe (away from pipe fittings) near the meter to accommodate the ultrasonic meter sensor spacing (from the manual)

iv) Mount the ultrasonic sensors on the pipe (at least 10 times pipe diameter from any fitting/bend/valve/etc.) and input the parameters required by the ultrasonic meter for logging (on start the ultrasonic meter) (refer to manual)

v) Start the ultrasonic meter. It will be logging the flow at the time intervals set and with the option of totalizing the flow volume

vi) Simultaneously note (and record) the bulk and ultrasonic meter readings and the time. Note the readings again after a time interval, say 1, 5, or 10 minutes (full reading in litres should be taken)

vii) Compare the flow volume of the bulk meter to that of UFM (Note: the UFM can directly print the data or the logged data can be downloaded later depending on the model) (the difference should be within acceptable limits)

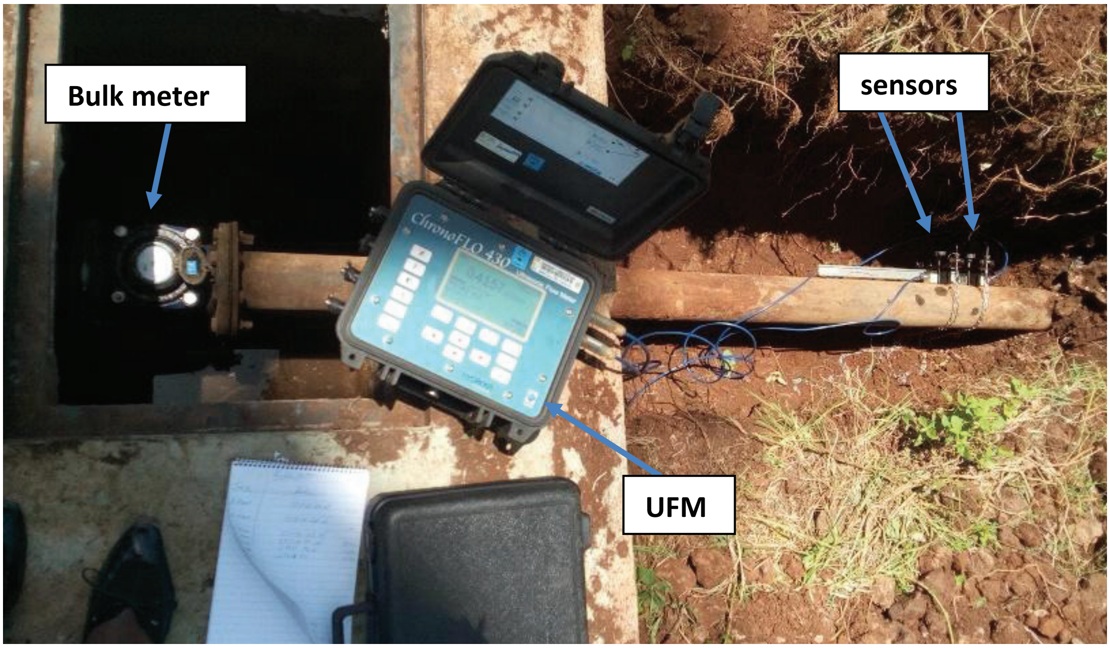


Figure 8.13: Bulk meter accuracy test using UFM

8.5.4 Accuracy Test of Zonal Bulk Meter with Air Intrusion

The zonal bulk meters installed at the outlets of distribution reservoirs are often affected by air intrusion especially under intermittent (rationing) water supply conditions. This air intrusion may cause significant over-estimation of flow (meaning that the meter reading may indicate higher flow than the actual flow). Air normally enters the bulk meter when the water level in the distribution reservoir is close to the bottom. When the trunk and branch distribution mains have no water, they are full of air. If the air valves on the trunk and distribution mains are not working well, this air normally comes up backwards through the bulk meter when the trunk and branch distribution mains are getting filled. This air affects the accuracy of the bulk meters.

It is difficult to check the accuracy (with a potable UFM) of a bulk meter that is in a system with air intrusion because UFM (or electromagnetic flow meter) has the tendency to under-register (measure less) flow when there is air in the pipe. Furthermore,

- There may not be enough space to set the UFM in the bulk meter chamber ,or
- Exposing the pipe outside the meter chamber may be very difficult due to pipe size and/or depth.

Therefore, alternative methods to deal with air intrusion and/or check the accuracy of bulk meters with air intrusion are quite important. This is so especially when the affected zonal bulk meters are:

- Used for calculating the universal NRW ratio, and/or
- Used as the basis for paying for bulk supply.

The following are alternative methods of dealing with air intrusion or checking the accuracy of bulk meters with air intrusion:

a) Measuring the Water Level of Distribution Reservoir

If the reservoir does not have a water level gauge, a long, fabricated ruler (or measuring tape attached to a straight bar) can be fixed to the side of a ladder into the reservoir from the access manhole on the roof. Thereafter,

- Close the inlet pipe to the reservoir,
- Measure the drawdown of the water level (volume of water discharged from the reservoir during a certain period, e.g. 30 mins
- Compare this with the flow measured by the bulk meter.

For accurate synchronization of the bulk meter readings and the water level measurements at the beginning and the end of a certain period, take a video of the bulk meter using a Timestamp Camera (a free smartphone software). Of course ensure staff safety inside a reservoir.

b) Bulk Meter Relocation to a Depressed Part of the Trunk Distribution Main

If the accuracy of a bulk meter with air intrusion cannot be ascertained or is unacceptable, it may be relocated to the first depressed part of the trunk main (e.g. just before the first washout) where the pipe will always be full of water. If the first depressed part is not possible, consider the second and then the third.

Trunk distribution mains are often metallic pipes of large diameter hence difficult to modify for the meter relocation. In such cases, a battery-powered insertion electromagnetic flow meter or a fixed installation clamp-on UFM may be a solution although these meters have a risk of stopping if their battery is not replaced on time.

c) Valve Control

If there is a gate valve or flow control valve just after (downstream of) the bulk meter with air intrusion, the valve may be closed to a certain degree when the reservoir water level is low (or when the trunk distribution main is not filled with water) so that water fills the section with the bulk meter without air coming in. However, this valve operation may be difficult to sustain manually and may make distribution of water difficult for some hours.

8.5.5 Use of Free Software as a substitute for potable UFM

A potable UFM is an effective equipment for NRW reduction. However, it is expensive compare to listening sticks that are the most cost-effective for NRW reduction. The following methods can be used as arrangements are made to procurement UFM.

- A “Timestamp Camera Free” can be installed on a smartphone (from Play Store) and used to take a video of the bulk meter dials and the reading vs time data used to calculate the flow rate of each time interval (e.g. every 30 seconds).
- A free software called GOM Player can be installed in a PC and a preferred video player play-back skip interval set to read the bulk meter. The data can then be used to analyse the change in flow rate over time. This technique can be used for minimum night flow measurement, step test and for checking the flow rate of bulk meter during high water demand hours to ascertain the adequacy of the meter size (by comparing measured flow rate to Qmax or Q4 of the bulk meter). The technique can also be used even after procuring a UFM, especially where it is difficult to install a potable UFM due to the depth of the buried pipe and/or inadequate space in the meter chamber.

When conducting MNF measurement and step testing on a distribution network with many inlet and/or outlet bulk meters, videos of the bulk meters can be taken simultaneously with multiple smartphones instead of borrowing several potable UFMs.

However, reading bulk meter dials accurately (between the graduations) at a certain interval on video requires skills and patience. If a UFM does not have data logging function (or the data logging software is not available), a Timestamp Camera and GOM Player can be used to take a continuous video of the active screen of a UFM to manually create a flow rate change graph over time from the video.