Non-Revenue Water

Trainer's Manual

WAVE Pool-Zambia

giz

BMZ Federal Ministry for Economic Cooperation and Development

Non-Revenue Water

Trainer's Manual

WAVE Pool-Zambia

Compiled by:
Stanislas Chisakuta, NRDC
Kennedy Mayumbelo, LWSC
Kennedy Mulenga, LBTC
Ison Simbeye, Consultant

Reviewed by:
Willem Wegelin, WRP Consulting Engineers (PTY) Ltd (South Africa)
Ronnie Mckenzie, WRP Consulting Engineers (PTY) Ltd (South Africa)
Stuart Hamilton, Hydro Tec (United Kingdom)

Contents

List of abbreviations 7
Introduction 9
Background to the training module 9
Purpose and focus 9
The Zambian water sector 9
Limitations of the manual 9
Overview of the manual 10
Training methodology and approaches 10

UNIT 1: Introduction to Water Demand Management 15
Introduction to water use and management 17
Urgency for action in water management 17
Basis of water management principles: The Dublin Principles 18
What is Water Demand Management (WDM)? 19
What is Integrated Water Resources Management (IWRM)? 19
Integrated Water Resources Management Concept 19
Why is reducing water losses an important component of IWRM 20

UNIT 2: Water Loss Challenges Faced by Commercial Utilities 21
Water loss challenges faced by commercial utilities 23
Vicious cycle of Non Revenue Water 23
Benefits of implementing WDM 24
Issues influencing the implementation of WDM 24

Unit 3: The Concept of NRW and Its Application 27
The Concept of NRW and its application 29
The IWA International Standard Water Balance and terminology 29
Key steps for conducting a water balance 30
Improving the accuracy of water balance results 33

Unit 4: Developing a NRW Strategy and Implementation Plans 35
Developing a NRW strategy and implementation plans 40
Establishing the strategy development team 40
Importance of setting appropriate NRW reduction targets 40
Prioritising NRW reduction components 40
Basic premise of NRW reduction strategy: awareness, location and repair (ALR) 40
Budget considerations for implementing the strategy 41

Unit 5: Awareness Creation on the Strategy 43
Gaining high-level approval 46
Building staff awareness and consensus 46
Reaching out to customers 46

Unit 6: Understanding Commercial Losses 47
Definition of commercial losses 49
Commercial loss elements and management strategies 49
How to address customer meter inaccuracy 50
Unauthorised consumption 51

Unit 7: Understanding Physical Losses 53
Definition of physic al losses 55
Physical loss elements 55
Characteristics of leakages 56
Developing a leakage management strategy 56
Active leakage control (ALC) 57
Leak detection techniques 58
Pressure management 60

Unit 8: Sectorisation – Understanding District Meter Areas 63
Sectorisation – Understanding district meter areas 65
DMA establishment criteria and process 65
Using DMA results to reduce NRW levels 66
DMA management approach 68
Additional benefits of the DMA 69

Unit 9: Monitoring Performance of NRW Management 71
Monitoring performance of NRW management 73
Characteristics of performance indicators 73
Performance indicators for physical losses 73
Performance indicators for commercial losses 77
Implementing a monitoring programme 77

References 78

List of abbreviations

ALI	Apparent Loss Index
CAPL	Current Annual Volume of Physical Losses
DMA	District metered area
ILI	Infrastructure Leakage Index
IWA	International Water Association
IWRS	Integrated water resource management
l/c/d	Litres per service connection per day
LNF	Legitimate Night Flow
MAAPL	Minimum Achievable Annual Physical Losses
MNF	Minimum Night Flow
NNF	Net Night Flow
NRW	Non revenue water
NWASCO	National Water Supply and Sanitation Council, Zambia
PI	Performance Indicator
PRV	Pressure Reducing Valve
WBI	World Bank Institute
WDM	Water demand management

Introduction

Background to the training module

This module is the result of the initiative by InWEnt to develop the capacity of water services providers in the four countries of Uganda, Kenya, Tanzania and Zambia. A Training Needs Assessment (TNA) exercise conducted by InWEnt amongst the water sector institutions, in the countries mentioned, during the period August to December 2006 identified the area of Non-Revenue Water (NRW) as a key priority area.

In February 2007, InWEnt organized a two-day regional WAVE Pool planning workshop for selected stakeholders in the Water and Sanitation Sector from Uganda, Kenya, Tanzania and Zambia. The meeting was held in Swara Safari Hotel, Nairobi.

During the above mentioned workshop, Uganda and Tanzania confirmed the area of Non Revenue Water (NRW) as a priority area for capacity building in their countries. Zambia and Kenya confirmed that Consumer Commercial Orientation and NRW are priority areas for capacity building for their countries.

This participant's manual covers the subject of NRW and in compiling it, various materials from the InWEnt, World Bank Institute (WBI), the International Water Association (IWA) and Water Resources Publications (WRP) have been used. The main sources are the IWA, WBI.

The NRW Manual has undergone several stages of development; first based on work and exchange of experiences between WAVE Pools in Uganda, Kenya, Tanzania and Zambia. The best practices and lessons learnt in capacity building initiative, including training have been used in developing this manual. The WAVE Pool Team in Zambia compiled the first draft, which was reviewed by the peer reviewers. After peer review a NRW Source was produced on which this manual is also based.

The participants' manual Non-Revenue Water Source Book leads the reader or utility manager through the stages of addressing non-revenue water. This module targets middle managers, supervisors and other staff working in the water supply, finance and commercial departments, which have an influence on the reduction of NRW.

Purpose and focus

The main purpose of this manual is to serve as a reference to participants in NRW Training and to equip the participants with the knowledge and skills which will enable them to improve on their performance in the management of water supply schemes.

The primary focus of the module is on the improvement of performance of water service providers through the application of practical management skills aimed at reducing water losses and maximising revenue.

The capacity building focus of this module is primarily NRW, a gap identified during the training needs assessment in February in Nairobi, Kenya.

The Zambian water sector

NWASCO has since the year 2000, when most Commercial Utilities were formed, been monitoring and reporting the leakage levels using the terminology of Unaccounted For Water (UFW), which was renamed early in 2000 to NRW by the IWA Water Loss Task Force (WLTF). The NRW figures have not improved to meet the set benchmark requirement of 25% but remains at an average of 47% ranging from 31% to 58% (NWASCO Annual report, 2006/07).

Thus, high levels of water losses have remained one of the major challenges facing Commercial Utilities in Zambia, either through physical/real losses (leakage), from apparent losses through theft from the system or water users not being properly billed.

NRW is increasingly being understood as the key indicator for utility performance as a high NRW level normally indicates a poorly run water utility that lacks the governance, autonomy, accountability, and the technical and managerial skills necessary to provide reliable service.

NRW management has for too long been a major challenge for Commercial Utilities.

This training course shall therefore not be a stand alone event, but the beginning of a long term NRW management capacity building programme in Zambia.

Limitations of the manual

The design of the training manual on NRW is tailored to the Zambian capacity building situation. Therefore limitations exist in the applicability of the manual to other countries. However, the principles herein are applicable to any NRW situation of any water supply system with adaptation.

Overview of the manual

The module is divided into nine (9) main units as described in Table 1. Each unit is broken down into sessions based on topics relevant to the achievement of the unit objectives. Many of the sessions contain attachments that can be used as handouts for reference. A list of references materials and literature consulted during the preparations for each session is provided at the end of the unit.

The manual provides a practical model for the dissemination of knowledge on NRW using experiences derived from the local environment and situation. Although the designers of the module put emphasis on the applicability of the contents to Zambia, the module can easily be adopted for use in other countries experiencing problems with NRW.

The primary training methodology adopted by the module is a participatory and learner centred approach aimed at achieving a greater involvement of the participants in the learning process. Through guided discussions and presentations the participants are presented with practical cases based on real life situations in their areas of operations, and encouraged to come up with tangible solutions that can easily be replicated to the working environment. The module also incorporates field visits to water schemes to enable the participants' experience real life situations in the management of NRW.

Training methodology and approaches

This manual provides guidance to the facilitators on the training methodology to be used in each session. It mainly adopts the Participatory Adult Learning Approach (PALA) which aims at greater involvement of the participants in the learning process and is intended to equip the participants with skills that can be adapted to their work environments.

Through group work, exercises and case studies, participants are presented with practical cases based on real life situations in their areas of operations, and guided to come up with tangible solutions that can easily be replicated to the working environment.

PALA is as follows:

What it stands for:	Participatory adult learning
Meaning:	We learn together.
Trainer's role:	To facilitate learning
We believe that:	Learning is a conscious process. You get as much as you allow yourself.
Multiple realities:	Disagreements allow more space to learn. Let us exchange our realities.
So:	Bring yourself in and learn more.

Duration of the training

The training course will take five days, which covers presentation sessions, working group sessions, discussions and half a day of fieldwork. The fieldwork will involve visiting and observing activities in NRW management

Target group

The Zambian Water Sector is now fully commercialized in terms of formation of Commercial Utilities (CU). In total there are eleven CUs. The overview of water utilities is as follows:

No.	Commercial Utility	Start of operations	No. service towns	No. of connections	Level of economic activity	NRW %	Training Groupings
1	Lusaka WSC	1989	4	71,417	High	51	Bigger CUs
2	Nkana WSC	2000	3	41,403	High	38	
3	Kafubu WSC	2000	3	41,110	High	46	
4	Mulonga WSC	2000	3	40,242	High	42	
5	Southern WSC	2000	17	26,579	Medium	40	
6	Lukanga WSC	2006	6	12,706	Medium	52	Smaller CUs
7	Chambeshi WSC	2003	12	11,533	Low	50	
8	Northwestern WSC	2000	7	6,230	Medium	31	
9	Eastern WSC	2009		-	-	-	
10	Western WSC	2000	6	8,339	Low	47	
11	Luapula WSC	2009		-	-	-	

Adapted from the NWASCO Water Sector Report 2008/2009; Eastern and Luapula WSC are newly formed CUs and their statistics were not reported.

CUs are divided into two groups based on their size and economic activities and challenges experienced.

For both groups, this manual is prepared to be used for the following target group:

- Middle to senior management of water utilities
- Technical, Commercial and Finance managers of utilities.

Due difference in size, development and challenges faced by these two groups, training course are adapted to them accordingly.

Expected Outcomes

Participants understand and are able to apply NRW concepts and to establish water balances for their respective CUs. Further participants are able to interpret the water balance and develop/ or participate in the development and implementation of NRW Plans.

Expected Impact

Commercial Utilities have in place NRW plans, have embraced or integrated NRW management into their strategic plans and budgets, resulting in reduced NRW levels. These reduced NRW levels in turn result in improved service delivery to the community and thereby improving their living conditions on a sustainable basis.

Evaluation

The course will be evaluated at the reaction, learning and job behaviour/intermediate outcome levels.

At the reaction level, evaluation will seek to establish the feelings of the trainees about the general aspects related to the course administration and delivery of the sessions, including the environment. The evaluation will establish feedback on specific areas such as session/course objectives, course contents, facilitators, course organization and venue. This will be done through verbal questions and answer sessions by the facilitators during the delivery of learning, as well as reaction questionnaires or response sheets and at the end of the days' program.

However, in order to encourage objective thinking and increased participation by the learners, facilitators are encouraged to organize group debriefing at the end of each unit or day.

The second stage at which the manual will be evaluated will be at the learning levels. Evaluation at this stage will be aimed assessing the learning that has taken place in terms of knowledge, skills and attitudes. This will be carried through questionnaires at the course, and these shall be administered before and after the training.

The third stage is an evaluation of the participant's implementation of his/her learning during the course at his/her job in the CU after a period of 3 to 6 months.

Table 1: Matrix explaining module contents

Training Units	Outcome	Training Sessions				
		I	II	III	IV	V
1. Introduction to Water Demand Management	Participants will be able to understand the basics of water management, what water demand management and integrated water resources management are and link reducing water losses to them.	Water management principles and importance Reducing water losses				
2.Challenges of water losses faced by water utilities	Participants will be able to appreciate the significance of NRW to water service delivery and relate it to their own CU.	Typical challenges faced by Commercial Utilities in reducing NRW	Vicious cycle and virtuous cycle of Non Revenue Water	Governance and other crosscutting issues.		
3.The Concept of NRW and its application	Participants understand and are able to use the concept of NRW and its application, understand the water balance and its components and application.	The water balance and its components, key steps in conducting a water balance, improving accuracy of water balance results	Establishing the Water Balance using the WB-Easy-Calc software			
4.Developing NRW strategy and implementation plans	Participants understand and are able to contribute to the development of a company-wide strategy to reduce targeted components of losses identified in the water balance	Key steps in developing and implementing NRW plans	Leadership and management aspects	Intervention planning	Activity planning	
5.Awareness creation on the strategy	Participants understand the roles and responsibilities of each type of stakeholder in implementing the NRW reduction strategy; they also understand and are able to contribute to awareness and consensus building programmes	Approval, awareness and consensus building				
6.Understanding commercial/apparent losses	Participants understand and identify the different causes of commercial losses Participants understand and can handle strategies for reducing commercial losses	Commercial loss elements and management strategies				

Training Units	Outcome	Training Sessions				
		I	II	III	IV	V
7. Understanding physical/real losses	Participants understand and identify the different causes of physical losses	Physical loss elements and characteristics including and causes Developing a Leakage Management Strategy for reducing physical losses				
8. Sectorisation – understanding District Meter Areas	Participants understand the principles of DMAs, the importance of sectorisation and are able to create DMAs	DMA Management approach and its benefits: establishment criteria, process, use of results to reduce NRW levels				
9. Monitoring performance	Participants know characteristics of performance indicators Participants understand and are able to use performance indicators for physical and commercial losses	Monitoring and performance indicators for NRW, physical losses and commercial losses				

Unit 1:

Introduction to Water Demand Management

Session: 1	Water management principles and importance	Duration: 30 min

Learning Objectives

After completing this session, participants should be able to:

- Know and be aware of the importance and urgency for water demand management (WDM)
- Know and be aware of the what integrated water resources management (IRWM) is and how water demand fits in
- Know and appreciate why water losses reduction is an important part of water demand management and integrated water resources management
- Feel the urgency and be able take action to implement water demand management through water reduction measures

Methods of Delivery

Facilitator asks participants probing questions about what they know about WDM and IWRM for about 15 minutes. Using questions like:

- In your situation, what can you say is water demand management?
- What is Integrated Water Resources Management?
- What is the difference between WDM and IWRM?
- Why is IWRM important?
- Why is WDM important?
- How does water loss reduction contribute to WDM or IWRM?

Materials

- Flip charts
- Markers

Presentations

- Power point presentation: Water Management Presentation, found in day one programme folder

Session Guide

The facilitator must be aware that the participants have had access to the NRW Training manual which discusses this topic. His task is to prepare and ask probing questions that aim for:

- Checking that participants have studied the NRW manual. If not he or she summarises and highlights the importance of WDM and IWRM, how they are linked, how reducing water losses is an important part of WDM and IWRM.
- Ensuring that participants do feel the urgency to reduce water losses, and thus get engaged with WDM and IWRM

Key Reading Materials

Participants manual
Handout on Water Demand Management

Introduction to water use and management

Why IWRM? Key issues in water management

Facts

- Global water: 97% seawater, 3% freshwater. Of the freshwater 87% not accessible, 13% accessible (0.4% of total).
- Today more than 2 billion people are affected by water shortages in over 40 countries.
- 263 river basins are shared by two or more nations;
- 2 million tonnes per day of human waste are deposited in water courses
- Half the population of the developing world are exposed to polluted sources of water that increase disease incidence.
- 90% of natural disasters in the 1990s were water related.
- The increase in numbers of people from 6 billion to 9 billion will be the main driver of water resources management for the next 50 years.

The water governance crisis

Sectoral approaches to water resources management have dominated in the past and are still prevailing. This leads to fragmented and uncoordinated development and management of the resource. Moreover, water management is usually in the hands of top-down institutions, the legitimacy and effectiveness of which have increasingly been questioned. Thus, inefficient governance aggravates increased competition for the finite resource. IWRM brings coordination and collaboration among the individual sectors, and fosters stakeholder participation, transparency and cost-effective local management.

Securing water for people

Although most countries give first priority to satisfying basic human needs for water, one fifth of the world's population is without access to safe drinking water and half of the population is without access to adequate sanitation. These service deficiencies primarily affect the poorest segments of the population in developing countries. In these countries, meeting water supply and sanitation needs for urban and rural areas represents one of the most serious challenges in the years ahead. Halving the proportion of the population lacking water and sanitation services by 2015 is one of the Millennium Development Goals. Doing so will require a substantial re-orientation of investment priorities, which will be very much more readily achieved in those countries that are also implementing IWRM.

Securing water for food production

Population projections indicate that over the next 25 years food will be required for another 2-3 billion people. Water is increasingly seen as a key constraint on food production, equivalent to if not more crucial than land scarcity. Irrigated agriculture is already responsible for more than 70% of all water withdrawals (more than 90% of all consumptive use of water). With an estimated need for an additional 15-20% of irrigation water over the next 25 years, serious conflicts are likely to arise between water for irrigated agriculture and water for other human and ecosystem uses. IWRM offers the prospect of greater efficiencies, water conservation and demand management equitably shared among water users, and of increased recycling and reuse of wastewater to supplement new resource development

Protecting vital ecosystems

Terrestrial ecosystems in the upstream areas of a basin are important for rainwater infiltration, groundwater recharge and river flow regimes. Aquatic ecosystems produce a range of economic benefits, including such products as timber, fuel wood and medicinal plants, and they also provide wildlife habitats and spawning grounds. The ecosystems depend on water flows, seasonality and water-table fluctuations and are threatened by poor water quality. Land and water resources management must ensure that vital ecosystems are maintained and that adverse effects on other natural resources are considered, and where possible, reduced when development and management decisions are made. IWRM can help to safeguard an "environmental reserve" of water commensurate with the value of ecosystems to human development.

Urgency for action in water management

Water is vital for human survival, health and dignity and a fundamental resource for human development. The world's freshwater resources are under increasing pressure. Growth in population, increased economic activity and improved standards of living lead to increased competition for, and conflicts over, the limited freshwater resource.

- Water resources are increasingly under pressure from population growth, economic activity and intensifying competition for the water among users;
- Water withdrawals have increased more than twice as fast as population growth and currently one third ofthe world's population live in countries that experience medium to high water stress;
- Pollution is further enhancing water scarcity by reducing water usability downstream;
- Shortcomings in the management of water, a focus on developing new sources rather than managing existing ones, and top-down sector approaches to water management result in uncoordinated development and management of the resource.
- More and more development means greater impacts on the environment.
- Current concerns about climate variability and climate change demand improved management of water resources to cope with more intense floods and droughts.

Basis of Water Management Principles: The Dublin Principles

The water management principles, such as water demand management and integrated water resources management are based on the Dublin Principles formulated 1992 in Dublin.

The Dublin Principle

A meeting in Dublin in 1992 gave rise to four water management principles that have been the basis for much of the subsequent water sector reform.

- Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment. Since water sustains life, effective management of water resources demands a holistic approach, linking social and economic development with the protection of natural ecosystems. Effective management links land and water uses across all the catchment areas or groundwater aquifers.
- Water development and management should be based on a participatory approach involving users, planners and policymakers at all levels. The participatory approach involves raising awareness of the importance of water among policy-makers and the general public. It means that decisions are taken at the lowest appropriate level, with full public consultation and involvement of users in the planning and implementation of water projects.
- Women play a central part in the provision, management and safeguarding of water. This pivotal role of women as providers and users of water and guardians of the living environment has seldom been reflected in institutional arrangements for the development and management of water resources. Acceptance and implementation of this principle requires positive policies to address women's specific needs and to equip and empower women to participate at all levels in water resources programmes, including decision-making and implementation, in ways defined by them.
- Water has an economic value in all its competing uses and should be recognised as an economic good. Within this principle, it is vital to recognise first the basic right of all human beings to have access to clean water and sanitation at an affordable price. Past failure to recognise the economic value of water has led to wasteful and environmentally damaging uses of the resource. Managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources.

Source The International Conference on Water and Environment, Dublin, Ireland, January 1992

What is Water Demand Management (WDM)?

There are various definitions for Water Demand Management. In this manual, the following definitions have been adopted:

WDM is the development and implementation of strategies aimed at influencing water demand in order to achieve water consumption levels that are consistent with equitable, efficient and sustainable use of the finite water resources. (IUCN-WaterNet Postgraduate Training Module on Water Demand Management, 2003)

WDM is a management approach that has conservation of both the quality and quantity of water as its primary aim. This conservation is achieved by the control of demand through the use of specific incentives that promote the following aspects of water:

- Efficient and equitable use
- Efficient and equitable allocation

What is Integrated Water Resources Management (IWRM)?

IWRM is a process which promotes the co-ordinated development and management of water, land, and related resources in order to maximise the resultant economic and social welfare in an equitable manner, without compromising the sustainability of vital ecosystems (GWP-TAC4, 2000).

This brief introduction to IWRM is aimed at the various stakeholders who are targeted to be equipped with a basic understanding of IWRM principles. It highlights the need for IWRM approaches in water supply and sanitation especially in the context of NRW. The content covered and the approaches used for this unit do not make the course participants experts on IWRM. If you look at IWRM from a sector perspective, the introductory lecture provides the opportunity to look at the specific implications of IWRM in your own field, or, equally importantly, to recognise and link the key issues in water associated sectors (environment, agriculture, domestic/municipal water supply and wastewater treatment).

Integrated Water Resources Management Concept

Management is used in its broadest sense. It emphasises that we must not only focus on development of water resources but that we must consciously manage water development in a way that ensures long term sustainable use for future generations. Integrated water resources management is therefore a systematic process for the sustainable development, allocation and monitoring of water resource use in the context of social, economic and environmental objectives. When responsibility for drinking water rests with one agency, for irrigation water with another and for the environment with yet another; lack of cross-sector linkages leads to uncoordinated water resource development and management, resulting in conflict, waste and unsustainable systems.

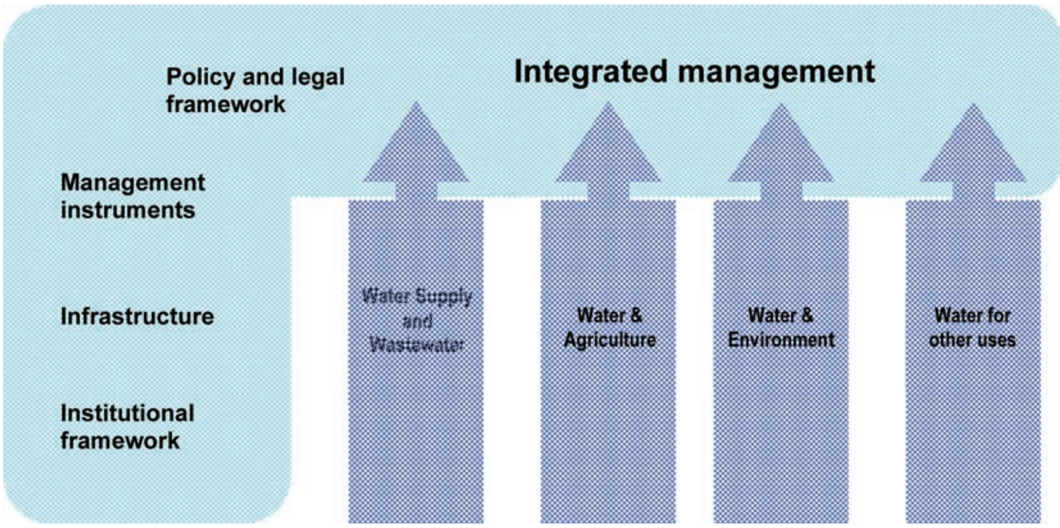


Figure 1 : IWRM and its linkage to the sub-sectors

The basis of IWRM is that the many different uses of water resources are interdependent. For instance, high irrigation demands and polluted drainage flows from agriculture mean less freshwater for drinking or industrial use; contaminated municipal and industrial wastewater pollutes rivers and threatens ecosystems; if water has to be left in a river to protect fisheries and ecosystems, less can be diverted to grow crops. There are plenty more examples of the basic theme that unregulated and other inefficient uses and practices such as high NRW are wasteful and inherently unsustainable.

Thus, all the different uses of water resources are considered together. Water allocations and management decisions consider the effects of each use on the others. They are able to take account of overall social and economic goals, including the achievement of sustainable development. The basic IWRM concept has been extended to incorporate participatory decision-making. Different stakeholders (water service providers, farmers, communities, environmentalists) can influence strategies for water resource utilisation and management. This brings additional benefits, as informed users apply local self-regulation in relation to issues such as water conservation and catchment protection far more effectively than central regulation and surveillance can achieve.

Why is reducing water losses an important component of IWRM

The importance of reducing water losses as a component of IWRM is evident in the water governance crisis, the need to secure water for people, the need to secure water for food production, the need to protect the ecosystem and other uses such as hydropower plants.

All these competing users have an obligation to use water resources efficiently in order not to negatively affect other users and ensure sustainability of water resources.

Reducing water losses in water supply schemes encourages efficient use of water resources by implementing water demand management measures and as such becomes part of Integrated Water Resources Management. Water demand management measures are part of Integrated Water Resources Management.

Policy and legal framework

Bringing some of the principles of IWRM into a water sector policy and achieving political support may be challenging, as hard decisions have to be made. It is therefore not surprising that major legal and institutional reforms are unlikely to take place until serious water management problems have been experienced.

In some cases, IWRM may be seen as a threat to donor-supported capital investment programmes. Some developing countries tend to be more concerned with increasing supplies through new infrastructure rather than with water efficiency or managing water demand. Indeed they fear that the new agenda of IWRM will lead to a reduction in capital investment for such projects. Attitudes are changing though. Officials are becoming more aware of the need to manage resources efficiently. They see too, that the construction of new infrastructure has to take into account environmental and social impacts and the fundamental need for systems to be economically viable for maintenance purposes. However, they may still be inhibited by the political implications of such a change. The process of revising water policy is therefore a key step, requiring extensive consultation and demanding political commitment.

Water legislation converts policy into law and should:

- Clarify the entitlement and responsibilities of users and water providers;
- Clarify the roles of the state in relation to other stakeholders;
- Formalise the transfer of water allocations;

- Provide legal status for water management institutions of government and water user groups;
- Ensure sustainable use of the resource.

Institutional framework
In order to bring IWRM into effect, institutional arrangements are needed to enable:

- The functioning of a consortium of stakeholders involved in decision making, with representation from all sections of society, and a good gender balance;
- Water resources management based on hydrological boundaries;
- Organisational structures at basin and sub-basin levels to enable decision making at the lowest appropriate level;
- Government to co-ordinate the national management of water resources across water use sectors.

Taking an integrated approach to improving water efficiency
Improving water efficiency allows countries to reduce water scarcity and maximize the benefits provided by existing water infrastructure. It also frees up water for other uses and reduces environmental degradation. Efforts to improve water efficiency can therefore contribute directly to the development goals of many countries, especially those that are chronically short of water or the capital to invest in water development. In 2002, the need to improve water efficiency was recognized and given new impetus by the World Summit on Sustainable Development (WSSD). Article 26 of the WSSD Plan of Implementation, which sets an action target for the preparation of "IWRM and water efficiency plans" by 2005, makes reference to water efficiency in two different ways:

> Art. 26 (a): "… introduce measures to improve the efficiency of water infrastructure to reduce losses and increase recycling of water"
>
> Art. 26 (c): "Improve the efficient use of water resources and promote their allocation among competing uses in a way that gives priority to the satisfaction of basic human needs and balances the requirements of preserving or restoring ecosystems and their functions, in particular in fragile environments, with human domestic, industrial and agriculture needs, including safeguarding drinking water quality."

As Article 26 highlights, improving efficiency has multiple aspects. It entails finding ways to maximize the value of water use and allocation decisions within and between sectors for sustainable social and economic development. It involves getting the most not only out of scarce water resources but also out of other natural, human and financial resources.

Article 26 does not only relate to the efficiency with which water is used, but the efficiency with which it is "produced", i.e. the efficiency of the processes that go into providing water when, where and in the appropriate quantity and quality needed for a particular use. All this emphasizes the need for a multi-faceted approach that considers wider social issues and values as well as physical and technical concerns.

Practical solutions and approaches to improve water efficiency
In practice, water efficiency can be improved using many approaches, including investing in physical improvements in infrastructure and technology, fostering changes in user behaviour, and developing integrated improvements in water management.

Improving infrastructure
One way of improving water efficiency is by investing in and improving infrastructure. However, any investment made must take into account a variety of factors, including a country's land, labour and capital endowments, and its ability to maintain the infrastructure it is investing in. Importantly, investment costs should never outweigh the benefits obtained in reducing leakage, as it is only cost-effective up to a point. Furthermore, it should be remembered that physical improvements are only part of the answer. Maximum gains in efficiency are only made when they are combined with better management practices. Options include investing in water loss reduction systems, strengthening regular maintenance programs, matching water supply to demand, encouraging recycling and reuse, and introducing better land-management practices.

Regular maintenance of infrastructure also helps to maintain water efficiency levels and is more cost-effective than rehabilitation. The best ways of ensuring that structures don't fall into disrepair (which results in plummeting water efficiency levels) is to get the users involved in their management and to set water user fees which are high enough to cover the cost of operation and maintenance. It does no good to develop new water infrastructure if it is not going to be maintained.

Unit 2:

Water Loss Challenges Faced by Commercial Utilities

Session: 1,2,3	Typical challenges faced by Commercial Utilities in reducing NRW; vicious cycle and virtuous cycle of Non Revenue Water, governance and other crosscutting issues.	Duration: 1 hour

Learning Outcomes

After completing this session, participants:

- Know, appreciate and are able to deal with challenges faced by water utilities in reducing water losses
- Are aware of the vicious cycle and the virtuous cycle of Non Revenue water
- Are aware and able to deal with governance and other crosscutting issues in water loss reduction

Methods of Delivery

Interactive session where the facilitator keeps probing participants to bring their experiences regarding challenges in reducing water losses. The facilitator looks at challenges in three categories consisting of infrastructure, political and management. Some questions can be (not limited) in relation to NRW:

- What are the challenges faced by your commercial utilities regarding infrastructure aspects?
- What are the challenges faced by your commercial utilities regarding political aspects?
- What are the challenges faced by your commercial utilities regarding management aspects?

He then summaries and adds from his or her experience (Normally this unit is given to staff from the regulator, NWASCO)

Training Preparation/ Materials

Facilitator to arrange the sitting to ensure interaction between the learners is promoted.

- Computer and Beamer
- Pens
- Assorted cards
- Participants' note books and pens
- Soft Boards
- Drawing pins

Exercise on challenges found in day one programme folder.

Session Guide

The facilitator must ensure that participants:

- Bring out challenges they are facing as Commercial Utilities, individually as CUs and as a group and arrange them according to the four pillars of commercial losses; four pillars of commercial losses consist of water accounting errors, water theft, meters under registration and meter errors
- Individually as CUs come up with possible solutions, resources requirements and allocate responsibility for action.
- Individually as CUs estimate % commercial losses.

Key Reading Materials

The National Water and Sanitation Act No. 28 of 1997, which outlines the powers that the water utility ahas in addressing water matters.

Water loss challenges faced by commercial utilities

Introduction

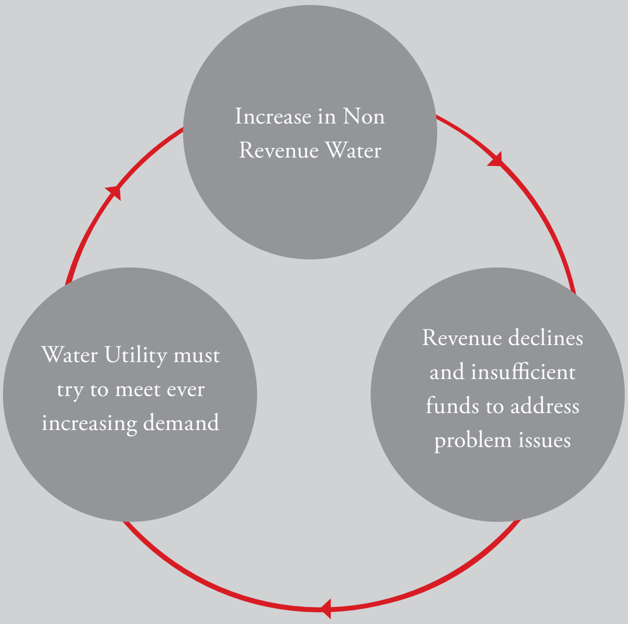
The global volume of non-revenue water (NRW) or water losses is staggering. Each year more than 32 billion m3 of treated water is lost through leakages from the distribution networks. An additional 16 billion m3 per year is delivered to consumers but not invoiced because of theft, poor metering or illegal use. A conservative estimate of the total annual cost to water utilities world wide is US$14 billion. In some low-income countries this loss represents 50 -60% of water supplied, with a global average estimated at 35%. Saving just this amount would supply water to an additional 100 million people without further investment (World Bank Discussion Paper No.8, December 2006).
In Zambia, on average the NRW is approximately 45% of the system input volume, ranging between 30% and 58%.

There are various challenges that have resulted in these high NRW figures and these relate to:

- Inadequate metering management and low metering ratios
- Poor quality infrastructure with high leakage levels
- Illegal connections/ high unauthorised water use.
- Limited skills in NRW management
- Governance

Vicious cycle of Non Revenue Water

The vicious cycle of NRW is shown in:



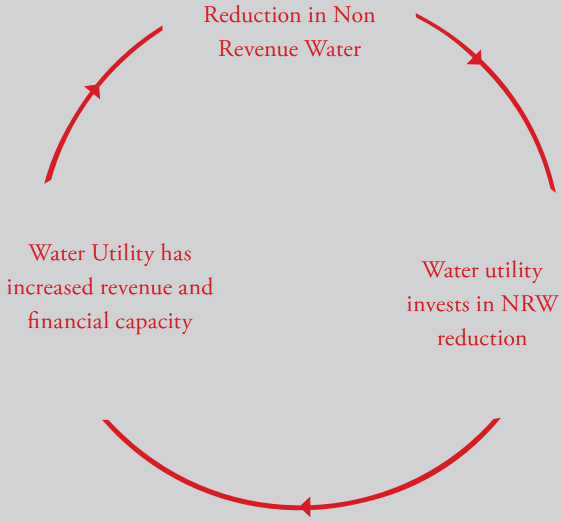


Figure 2: This vicious cycle cannot be sustained and often results in the total collapse of the water utility.
The challenge is to turn this cycle around into a virtuous cycle as shown in Figure 3

Figure 3: Virtuous cycle of Non Revenue water

Benefits of implementing WDM

Reducing NRW

Reducing NRW is a source of New Water and Money: In many places, reduction of excessive losses is the cheapest water source available and the reasons are as follows:

- Reducing commercial/apparent losses results in improved billing which is a significant source of new revenue
- Physical/real loss reduction allows utilities to postpone capital investments required in water source development schemes

Added benefits

Reducing excessive losses results in:

- More water being available for consumption that can be sold
- Delaying the need for capital investments
- Lower operating costs
- Reducing commercial losses will generate more revenue

Reasons given for failure to reduce NRW

It seems obvious what utilities have to do yet many Utilities do not do it, why? The following are some of the reasons given by various Utilities;

- **Denial:** The water utility denies the effects of NRW, reasons like, "we meet the norm or standard NRW figures, so there is no problem"
- **Illegal consumption:** Utilities claim that it's mostly illegal connections resulting in unknown consumption.
- **Network Age:** The water network and associated systems need total replacement as they are very old.
- **Political interference:** Politicians don't allow disconnection.
- **New Installations easier:** Network Capacity/expansion is politically more important than rehabilitation – new development areas etc easier to install than carry out repairs.
- **Skills competence:** Our company does not have the right kind of staff.
- **Intermittent versus sustained supply:** Intermittent or rationed supply keeps water losses low.

NRW reduction efforts

Many funding organisations, including the World Bank and the African Development Bank, have made efforts to reduce Non-Revenue Water in their projects, which have included the following:

- Prioritizing water loss reduction
- Inclusion of NRW reduction components
- Setting targets for reduced NRW as a condition for funding

However, many projects have not been as effective despite the above measures. Some of the reasons for the failure in reducing NRW include:

- Little understanding of the nature of water losses by the people tasked with this responsibility;
- Little or no appreciation of the impact of water losses;
- Poor project design;
- Grossly under estimated costs of water loss reduction resulting in this task being abandoned;
- "Lip service" to obtain international funding – "NRW reduction" used as a politically correct term that is included in project proposals when sourcing for international financing.
- Failure to realize that NRW reduction is:
    - not just an isolated technical problem
    - tied to overall asset management and operation
    - not a once-off activity, but one requiring long term commitment

NRW reduction dependant factors

The following are some of the factors on which NRW reduction depends:

- Proper Operation and Maintenance of infrastructure
- Customer support of the efforts made by the Utility
- Financial allocation to support NRW strategy or efforts
- Management support of staff and efforts to reduce NRW
- Capacity know how (NRW + Network)
- Commercial operations
- Asset management

Issues influencing the implementation of WDM

Lack of proper base - lining and planning

Quote from some consultant's report:

„We estimate that NRW is around 28% …… we assume that it will be reduced to 15% by 2010"

Most Utilities and other service providers do not have proper data on NRW or losses in their network from upon which planning and corrective measures can be based. The above quote gives a clear indication of the state of the baseline from utilities.

Governance

Governance, which is the transparent management of the national economy within a democratic, pluralist and free environment, is now recognized as imperative to development. Governance is based on a number of cardinal ethical values that include transparency, accountability and probity and entails a sound and disciplined management.

Corporate governance on the other hand is the relationship among share holders, management and the board as it determines the direction and performance of corporations. It refers to efforts to make top executives more accountable and responsive to shareholders' rights, and enhance value in the investment process of the company they manage. It involves accountability towards not only shareholders, but also the company's relevant stakeholders.

Stakeholder theory
Stakeholder is any group or individual who can affect or is affected by the achievement of the organization's objectives. The central claim of the stakeholder approach is that corporations are operated for the benefit of all those who have a stake in the enterprise, including customers, suppliers and the local community.

Corruption
Corruption is a worldwide phenomenon, and events all over the world attest to this assertion.

Corruption is the misuse of public power for private and personal benefit. It is distinguishable from other crimes by the fact that it is usually carried out in utmost secrecy and the act itself may not be immediately perceptible. More significantly, there is no direct obvious victim to complain of corruption and to help provide evidence. The victim is more often than not, the public at large. In effect successful prosecution is usually problematic.
Factors contributing to Corruption and unethical conduct.

- Political instability
- Inadequate laws
- Weak sanctions
- Weak administrative controls.
- Poor salaries.
- Lack of adequate facilities.
- Insecure and precarious tenure of office.
- Personal greed and ambition.
- Case backlog
- Weak procurement system
- Inadequate Civil society contribution

Effects of Corruption

- Raises the costs of goods and services
- Leads to compromises in quality standards
- Main causes of under development and poverty
- Reduces confidence in government/local government procurement procedures
- Injures competition

Ethics
Ethics refers to a set of accepted norms and standards of conduct that establishes the guiding principles of the public and private conduct of those who serve the public. It is a statement of values that promote decisions, actions, and behaviour for the common good, and by which those actions should hold public trust and may be judged good or bad or right or wrong.

Principles include selflessness, integrity, objectivity, accountability, openness, honesty and leadership.

Professionalism
Professional ethics and standards must be adhered to in the exercise of professional duty.

The players in the particular professional field (Engineering) must therefore be are aware of the ethics and standards that govern their professional service.

National Values
National values are a set of accepted principles of life and service, which promote the common good of all society, thus providing a basis for determining the ethical and moral obligation of the people to themselves and their society.

Integrity
Integrity refers to the quality of an individual or institution in respect to its completeness.

- When you have integrity your words and deeds match up.
- A person of integrity does not have divided loyalties.
- S/He does not have something to fear or hide.
- A person of integrity is one who has established a system of values against which all life is judged.

Accountability
Since all public officers are held in trust for the people, it is an incumbent upon those persons placed in positions of leadership or responsibility, in their work, to be answerable to the people. Public servants must regularly account for how they are discharging their responsibility through legally established mechanisms, audits, internal controls and reporting arrangements to demonstrate and account for performance and ascertain compliance.

Transparency
All public servants must communicate intentions, activities, their costs and benefits and the results to stakeholders and the public.

The public is entitled to know how public institutions apply the power and resources entrusted to them and therefore have the right to access information that relates to service delivery and governance.

Honesty/conflict of interest
Public Officers must be honest and selfless in the exercise of their responsibilities. They have the duty to declare any private interest relating to their public duties and take steps to resolve any conflict arising in a way that protects the public interest.

Gifts and benefits
A public officer must not solicit or accept any gifts, gratuity or benefits, in cash or kind, from persons or bodies with who he/she is offering a service or transacting business in his official capacity.

Leadership
Holders of public office should promote and support those principles of leadership by example.

Determination of values
Values are determined from various sources these include:

- Tradition and custom;
- Religious beliefs and practices;
- Governance;
- Professional services
- Business practices
- Fear of God

Human dignity
The constitution enshrines the value of human dignity as a basis for recognition, protection, exercise and enjoyment of human rights and freedoms of all people irrespective of their gender, race, social standing and disability.

Social Justice
Gender, racial and ethnic equity is a hall mark of society that prides itself in values of the fear of God and the dignity of the human person.

Gender
- Gender is a much broader term that refers to the cultural and social distinctions between women and men.
- These include the different attributes, status, roles, responsibilities, opportunities and privileges accorded to women and men as well as their access to, and control over, resources and benefits.
- All these distinctions differ and change according to time and place.
- Gender is a concept that refers to the social and cultural constructs that each society assigns to behaviours, characteristics and values attributed to men and women.
- Reinforced by symbols, laws, and regulations and institutions.
- These constructs are shaped by ideological, historical, ethnic, economic and cultural determinants.
- The concept of gender is used to understand the social and personal relations between men and women.
- It is also used in analyzing roles, responsibilities, constraints, opportunities and needs of men and women in a given context.

At this stage participants may share experiences on corruption and un ethical practices, either in plenary or group discussions, specific cases of corrupt/unethical practices in their areas, and how they impact directly on their businesses and propose remedies to mitigate against the problem.

Unit 3:

The Concept of NRW and its Application

Session: 1+2	The Water Balance and its components; how much is being lost and where is the water going Establishing the water balance using WB-EasyCalc software	Duration: 2.45 Hours

Learning Outcomes

After completing this session participants:

- Understand the water balance and are able to calculate NRW and its components
- Use WB-Easy Calc to establish water balances in their respective CUs.

Methods of Delivery

a) 1 hour interactive presentation where the facilitator:

- Explains the Water Balance and its components
- Explains how NRW and its components are calculated.
- Explains key steps in conduction a water balance
- Explains key steps in improving the accuracy of the water balance.

b) 1 hour 45 minutes, modelling using WB-EasyCalc.

Training Preparation/ Materials

- Computer and beamer
- At least five computers for modelling
- Flip charts

Exercise

Participants use their own CU data to practice the use of the Water balance model, WB-EasyCalc, developed by Roland Liemberger and can be downloaded at:
http://www.liemberger.cc/diverse_uploads/WBEasyCalc.xls

Key Reading Materials

NRW Participants Manual

Session Guidelines

This session consists of two parts; interactive presentation for one hour and modelling for one hour forty five minutes.

The facilitator when delivery the first part of the session must note that participants have had access to the NRW Participants manual which explains the Water Balance and its Components, including calculation of NRW and its Components.

During the second part of the session, the facilitator must take the participants through the WB-EasyCalc. The facilitator must check for the updated versions as these may be changed from time to time. The facilitator must promote learning and practice by observing and providing support.

The concept of NRW and its application

The concept of NRW and its application is based on the work of the IWA Water Loss Task Force (WLTF) and using the correct Performance Indicators (PIs) is best understood by first understanding the water balance.

The IWA International Standard Water Balance and terminology

Because of the wide diversity of formats and definitions used for water balance calculations (often within the same country), there has been an urgent need for common international terminology. Drawing on the best practice from many countries, the IWA WLTF produced an international 'best practice' standard approach for water balance calculations with definitions of all terms involved. *Figure 4* shows the IWA standard international water balance and terminology.

<table>
<tr><td rowspan="9">System Input Volume (corrected for known errors)</td><td rowspan="4">Authorized consumption</td><td rowspan="2">Billed authorized consumption</td><td>Billed metered consumption (including water exported)</td><td rowspan="2">Revenue water</td></tr>
<tr><td>Billed unmetered consumption</td></tr>
<tr><td rowspan="2">Unbilled authorized consumption</td><td>Unbilled metered consumption</td><td rowspan="7">Non-Revenue Water (NRW)</td></tr>
<tr><td>Unbilled unmetered consumption</td></tr>
<tr><td rowspan="5">Water losses</td><td rowspan="2">Commercial (apparent) losses</td><td>Unauthorized consumption</td></tr>
<tr><td>Customer metering inaccuracies and data handling errors</td></tr>
<tr><td rowspan="3">Physical (real) 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>

The definitions of the principal components of the IWA water balance are as follows:

- System input volume is the annual volume input to that part of the water supply system
- Authorised 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 authorised 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 authorised consumption. NRW consists of unbilled authorised consumption (usually a minor component of the water balance) and water Losses.
- Water losses are the difference between System Input Volume and Authorised Consumption, and consists of apparent (commercial) losses and real (physical) losses.
- Commercial losses, sometimes referred to as 'apparent losses', consist of unauthorised consumption and all types of metering inaccuracies
- Physical losses, sometimes referred to as 'real losses', are the annual volume lost through all types of leaks, bursts and overflows on mains, service reservoirs and service connections, up to the point of customer metering.

The components of the water balance should always be calculated as volumes before any attempt is made to calculate performance indicators. The separation of non-revenue water into components – unbilled authorised consumption, commercial (apparent) losses and physical (real) losses – should always be attempted.

Sometimes even the most basic information, such as system input volume, average pressure, supply time, length of mains, and the number of service connections, is not initially available. The process of calculating each of the water balance components and performance indicators will reveal such deficiencies. The utility management should then take corrective action to close these data gaps and improve data quality. Using incomplete or inaccurate data for the water balance calculation will not produce useful result.

When the entire system input is metered, determining the annual system input volume is a straightforward task. Utility managers must collect meter records regularly and calculate the annual quantities of the individual system inputs. This includes a utility's own sources as well as imported water from bulk suppliers. Ideally the accuracy of the input meters is verified using portable flow measuring devices.

Water utility managers need to accurately measure water produced from the treatment facility. Total water produced is a key input for the water balance.

Billed metered consumption includes all of the water consumption that is measured and charged to domestic, commercial, industrial or institutional customers. It also includes exported water that is measured and charged. The billed metered consumption period used in the calculation should be consistent with the audit period by processing it for time lags. In addition, NRW managers should determine the general accuracy of various domestic and non-domestic consumption meters for a possible 95% confidence limit by taking a sample of existing working meters from various locations and testing them on a standard recognised and calibrated meter test rig. Independent companies provide testing services if the water utility does not own a meter test rig. If several different customer meter brands are in operation, then the sample selection should include meters from each brand.

Determining the annual billed metered consumption goes hand in hand with detecting billing and data handling errors, information that utilities also require for estimating commercial losses. The volume of unbilled metered consumption should be established using a similar approach to that for billed metered consumption.

Unbilled unmetered consumption is any kind of authorised consumption that is neither billed nor metered. This component typically includes items such as fire fighting, flushing of mains and sewers, street cleaning, frost protection, etc. In a well-run utility, it is a small component that is very often substantially overestimated. Unbilled unmetered consumption, traditionally including water the utility uses for operational purposes, is often seriously overestimated. This is sometimes caused by simplification (e.g. using a percentage of total system input), or by deliberate overestimates to 'reduce' the amount of NRW.

Key steps for conducting a water balance

The utility needs to have certain information about the network to conduct a water balance such as:

- System input volume
- Billed consumption
- Unbilled consumption
- Unauthorised consumption
- Customer metering inaccuracies and data handling errors
- Network data
- Length of transmission mains, distribution mains and service connections
- Number of registered connections
- Estimated number of illegal connections
- Average pressure
- Historic burst data
- Level of supply service (24-hour, intermittent, etc)

The four basic steps to conduct an IWA water balance are summarised as follows:

- Step 1. Determine system input volume
- Step 2. Determine authorised consumption
  - Billed—total volume of water billed by the water utility
  - Unbilled—total volume of water provided at no charge
- Step 3. Estimate commercial losses
  - Theft of water and fraud
  - Meter under-registration
  - Data handling errors

- Step 4. Calculate physical losses
  - Leakage on transmission mains
  - Leakage on distribution mains
  - Leakage from reservoirs and overflows
  - Leakage on customer service connections

Confidence limits of up to 95% should be applied to all water balance data. These define the boundaries within which utility managers can be 95% sure that the true value for that particular component lies. Although the water balance is an important tool for understanding inflows, consumption, and losses, the general lack of data leads to problems. Data gaps make it difficult to quantify commercial losses and to pinpoint the nature and location of physical losses. However, the water balance can be improved using two other methodologies:

- Component analysis of physical losses, using the network information.
- Measurement of leakage, using analyses of night flows into District Meter Areas (DMAs)

Software for water balance calculations
WB-EasyCalc is one example of a tool to support water balance calculations in addressing NRW. Utility managers can use this spreadsheet-based software, developed by Liemberger and partners and supported by the World Bank Institute (WBI). The picture below shows the homepage of the software for 'getting started'.

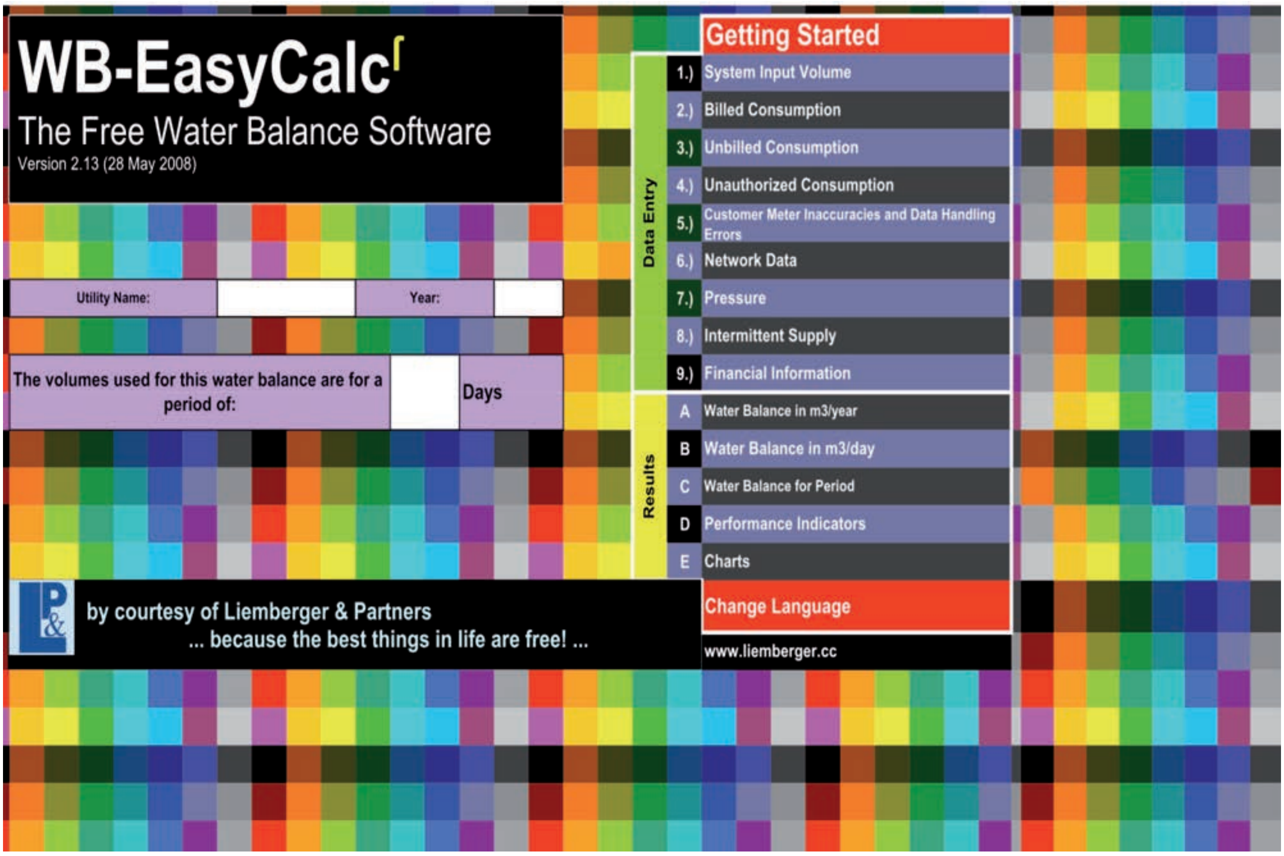


Figure 5 : Screen dump from WB-EasyCalc

One advantage of EasyCalc is that the software not only asks for physical data, but also for an assessment of the accuracy of that data. For example, when entering the production volume, the user must also estimate the accuracy of this data based on the type and age of production flow meters, if any, and the amount of maintenance carried out on the meter. Using these estimates, the software calculates NRW volume and its various components, in addition to the accuracy of these volumes. For example, EasyCalc may determine that NRW is 21% with an accuracy of +/- 66%— meaning that the actual NRW ranges between 7% and 35%.

WB-EasyCalc is available as a free download at *http://www.liemberger.cc/diverse_uploads/WBEasyCalc.xls.*

South African Water Research Commission Softwares
In the African context, the South African Water Research Commission has identified the reduction of non-revenue water as one of the key problem issues facing the continent. To assist water suppliers in addressing their losses, the Commission has developed a suite of models and associated documentation which can be downloaded freely from their web site. The models currently available include:

- The SANFLOW minimum night flow analysis model
- The PRESMAC pressure management model
- The ECONOLEAK active leakage control assessment model
- The AQUALITE water balance model

Other freely available models can be found on the internet and they generally perform similar functions to those listed above. One of the features of the Water Research Commission models is the fact that they all include a detailed user guide which is very helpful for any new water supply manager.

One advantage of the latest water balance models is that they include the facility to incorporate an error term which was first included in the SANFLOW Model and then incorporated into the BENCHLEAK water balance model which has recently been replaced by the latest AquaLite model. For example, when entering the production volume, the user must also estimate the accuracy of this data based on the type and age of production flow meters, if any, and the amount of maintenance carried out on the meter. Using these estimates, the software calculates NRW volume and its various components, in addition to the accuracy of these volumes. For example, AquaLite may determine that NRW is 21% with an accuracy of +/- 66%— meaning that the actual NRW ranges between 7% and 35%.

All of the WRC models listed above can be downloaded free of charge from *www.wrc.org.za* or *www.wrp.co.za*.

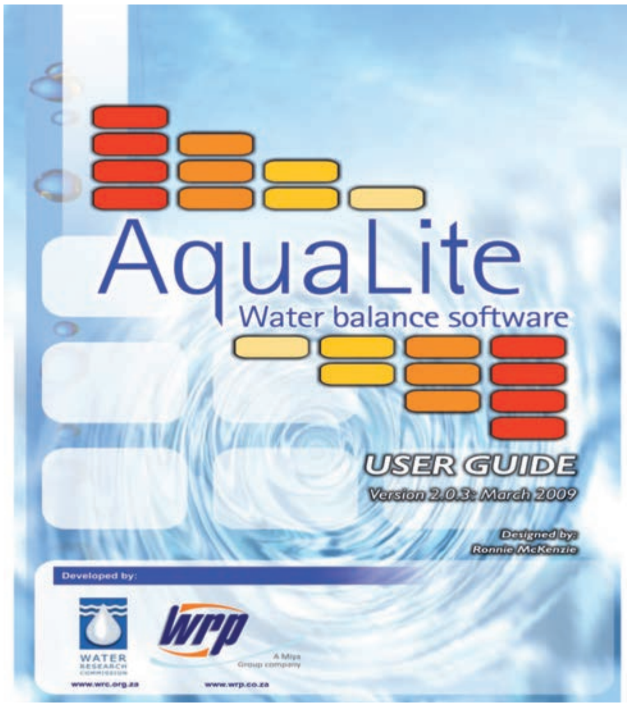


Figure 6.2: Cover Page from AquaLite Water Balance Model

production meters. The accuracy of customer metering depends on several factors, including meter type, brand, and replacement policy, maintenance, and water quality. The water utility should establish guidelines for all of these factors to ensure accuracy of customer consumption data.

Customer billing cycle

When calculating the NRW, many water utilities simply subtract customer consumption data from the production meter volume, and then are satisfied with the low result. However, this is often a false measurement of NRW because, unlike with the production meters, which are usually read on the same day of every month, customer meters are read over the full month. Information on the average billing cycle, or the time in days between meter reads, is critical. Utility managers should then factor the total consumption down to get the true consumption volume for the exact time period as the production meter volume measurement. Addressing the above issues greatly improves the accuracy of the NRW calculation, which utilities will use as the baseline in developing an NRW reduction strategy.

Improving the accuracy of water balance results

The accuracy of production meters, customer meter reading, and billing are the main factors affecting the NRW volume calculation.

Production meter accuracy

The accuracy of production flow meters is critical to calculating system NRW. Generally, the number of production flow meters is relatively small, meaning that a greater proportion of the flow is measured by each meter. This means that an error on one of these meters has a great impact on the total production measurement. Different meter types have different accuracies.

All meter types must be regularly maintained to ensure their continuing accuracy. Over time meters can be affected by a number of factors, including water quality, pipe vibration, dirt entering the meter, and electronic malfunction. Utility managers should regularly check the accuracy of both the electronic functionality of the meter if electronic, and the volumetric accuracy. The electronic functionality can be checked onsite using the meter manufacturer's test equipment. The volumetric accuracy can be checked using a second meter, which is generally a portable meter installed just for the test period. Some water utilities opt to install a second meter permanently as a backup in case the first meter fails.

Customer meter accuracy

The accuracy of customer meters is equally important, with the main difference being that there are many more customer meters in operation – and each measures a relatively smaller flow – than

Key Messages

- NRW is an indicator of water utilities' operating efficiency.
- Ensuring the accuracy of the NRW calculation is essential in understanding the full problem.
- The IWA standard water balance is an excellent method of breaking down the components of NRW, and tools are available to help utility managers calculate the water balance
- Accurate production and customer metering ensure that the true NRW level is measured
- The average billing cycle must be factored into NRW calculations to ensure that the time period used for the consumption volume measurement matches the production meter volume measurement.

Unit 4:

Developing a NRW Strategy and Implementation Plans

Session: 1	Key steps in developing and implementing NRW plans	Duration: 1.30 Hours

Learning Outcomes

After completing this session participants:

- Are able to take steps in developing and implementing an NRW strategy and plans.

Methods of Delivery

1 Facilitator makes a short presentation of key steps in developing and implementing NRW plans in 30 minutes (30) minutes.

2 Case study presentation of implementation NRW plans. One (1) hour.

Training Preparation/ Materials

- Computer and Beamer

Case Study

Kafubu Water and Sewerage Company
Northwestern Water Supply and Sewerage Company

Key Reading Materials

NRW Participants Manual

Session Guide

This session consists of two parts; presentation on "Key Steps in Developing and Implementing NRW Plans" for thirty (30) minutes and a case study on developing and implementing NRW plans for 1 hour. Currently there are two case studies available, one from Kafubu Water and one from North-Western Water.

The facilitator when delivery the first part of the session must note that participants have had access to the NRW Participants manual which explains the "Key Steps in Developing and Implementing NRW Plans".

The Case Studies outlines the practical approach for developing and implementing NRW in Water Utilities. It presents challenges faced by the water utilities and how they intended to overcome them.

Session: 2	Team Building	Duration: 1.30 Hours

Learning Outcomes

After completing this session participants:

- Appreciate the importance of teamwork and are able to implement teambuilding initiatives in their organisations.

Methods of Delivery

1 Participants do a role play and a video recording is done. The role play entails groups making a castle. Key observations are planning, coordination, organisation, communication and leadership.

Training Preparation/ Materials

- TV and Video player
- Video camera or camera.
- Computer and speakers
- Flip charts to be kept or stuck on wall
- Pens for flip chart
- Writing pads and pens

Session Guide

The facilitator makes appropriate Groups to encourage sharing and learning. As groups are building the castle a video recording is done ensuring taking in all the details. The video is then played back for participants to note key elements in team building.

Session: 3	Intervention Planning	Duration: 2 Hours

Learning Outcomes

After completing this session participants:

- Have prepared intervention plans for their respective water utilities.

Methods of Delivery

1 Facilitator makes a presentation on intervention planning, highlighting the tools involved such as IWA data requirement sheet, intervention planning sheet, prioritisation of interventions which is then used for activity plan schedules. Twenty (20) minutes.

2 Participants carryout intervention planning with guidance and support from the facilitator. One (1) hour and forty (40) minutes

Training Preparation/ Materials

- Water balance results
- Filled IWA data sheet
- Flip charts to be kept or stuck on wall
- Pens for flip chart
- Intervention planning sheets
- Writing pads and pens

Key Reading Materials

NRW Participants Manual

Session Guide

The facilitator explains intervention planning, highlighting key aspects such as need to have accurate data. At this stage the CU groupings would have done their water balance exercise based on actual data obtained from their water utilities whose authenticity is supported by their senior management.

The participants would require timely support in various parts of the planning components and for this reason the facilitator need to be knowledgeable and be able to provide the needed guidance.

Session: 2	Activity Planning	Duration: 3 Hours

Learning Outcomes

After completing this session participants:

- Have prepared draft activity plans for improvement and adoption in their respective water utilities.

Methods of Delivery

1 Facilitator makes a presentation of activity planning and on how the prioritised interventions can be used in activity plan schedules. Further the facilitator reviews prioritised interventions with participants and gives feedback. Twenty (40) minutes.

2 Participants carryout activity planning with guidance and support from the facilitator. One (1) hour and fifty (30) minutes.

3 Group work presentation, analysis and sharing of results among participants.
Activity plans are saved as action plans for later follow up. Fifty (50) minutes.

Training Preparation/ Materials

- Water Balance results
- Filled IWA data sheet
- Flip charts to be kept or stuck on wall
- Pens for flip chart
- Prioritised intervention plans
- Writing pads and pens

Key Reading Materials

NRW Participants Manual

Session Guide

The facilitator explains activity planning, emphasising the importance of prioritising interventions according to impact and budget. These activity plans are draft and thus have to be considered by the senior managements of the water utilities where the participants came from.

It should be mentioned that NRW management is not a single event, but an ongoing process in which consistence is required. Thus Water Utilities need to priories interventions into immediate or short term, medium term and long term. Further, since it may not be possible in many instances to implement all activities in all locations if the water utility operates in a large area, water utility groups should select smaller pilot locations for implementing prioritised interventions.

Developing a NRW strategy and implementation plans

The NRW challenge can only be properly understood after the NRW and its components are quantified, the appropriate performance indicators calculated, and the lost water volume is translated into its corresponding economic value. Development of the water balance reveals the magnitude of each NRW component. This chapter discusses how to identify the major NRW components and develop a company-wide strategy to reduce targeted components.

Establishing the strategy development team

The NRW reduction strategy team ensures that all components of NRW are covered and that the proposed strategy is feasible in terms of physical application and financial requirements. The team should comprise of members from each operational department, including production, distribution, and customer service. It may also include members from the finance, procurement, and human resource departments. Choosing the right members promotes ownership by the utility's various departments involved in the strategy's implementation, and also ensure consensus by senior management.

Importance of setting appropriate NRW reduction targets

The strategy development team should first set 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. In addition, water utilities may have an active regulator who will set performance indicators for NRW and other targets. Often, the NRW target is chosen 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 target, and it requires a comparison of the cost of water being lost versus the cost of undertaking NRW reduction activities.

Prioritising NRW reduction components

Once the utility-wide NRW target is set, utility managers should calculate the proposed volume of water saved by comparing the NRW baseline with the target level. The various components, as detailed in the water balance, are then prioritised 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 reductions in that component. On the other hand, focusing on another component may cost less while reducing the same volume. The water balance table shows the magnitude of NRW components in terms of volume, which utility managers can use to determine the corresponding financial values.

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 saving will be an immediate revenue increase and thus is based on the water sales tariff. The water sales tariff is higher than the variable production cost for all profitable water utilities; in some cases, the sales tariff is as high as three or four times the production cost. 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 prioritised.

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. If increasing water supply is the objective, then prioritising physical losses could enable customers to receive water 24 hours a day, or new customers to be connected to the supply system.

Basic premise of NRW reduction strategy: awareness, location and repair (ALR)

Once the utility-wide NRW target is set and the different components analysed to prioritise areas for achieving the desired reduction, then individual activities will be identified. The development of the strategy should be based on the concept of Awareness, Location, and Repair, or ALR. This concept states that any loss occurring from leaks, overflows, faulty customer meters, or other sources will have three stages which are as follows:

- Awareness time—time required for the utility to become aware of the leak
- Location time—time required to locate the leak
- Repair time—time required to repair the leak

The volume of water lost will continue to increase until the water utility is aware of the problem, locates and finally repairs it. An underground leak could run for several months or even years without anyone being aware that it exists. Therefore, the NRW strategy must ensure that the company improves its awareness, location, and repair times for all NRW components.

Many losses occur because of poor or limited maintenance, so in addition to reducing ALR, a fourth element of the NRW strategy should be system maintenance. This is critical to maintaining good asset condition and reducing the incidence of new leaks, meter failures, reservoir leaks, and other problems.

When developing a NRW management strategy, remember that reducing NRW is not a short-term process. The timeframe for implementing each strategy component should be outlined, with some activities possibly spanning years rather than months. NRW strategies spanning between four and seven years are reasonable—any less is ambitious, and any more will not be as cost-effective.

Budget considerations for implementing the strategy

The development and implementation of activities to achieve the targeted level of NRW incurs a financial cost. With some NRW management strategies lasting years, the overall cost could be quite substantial. A long term budget that is thoroughly discussed with key stakeholders will ensure that all parties are aware of the costs required and that the strategy is financially viable. Many NRW strategies start off at full speed but often fail due to budget cuts over time.

Undertaking pilot projects to demonstrate the effectiveness of the NRW strategy is useful. The pilot should cover a smaller area, be substantial enough to ensure that all components of the NRW strategy are tested, and operate under financial conditions that can be replicated when activities are implemented throughout the entire network. The analysis of the pilot results should be used in the development of the economic level of NRW for the entire system.

In preparing a budget, the utility manager needs to identify but not be limited to the following costs:

- Staffing – Include staff for both direct NRW works (e.g. leakage technicians) and indirect support (e.g. procurement staff).
- Equipment – Include equipment installed permanently (e.g. DMA meters) and those used on a day-to-day basis (e.g. leakage detection equipment).
- Vehicles – Include transportation costs, which can become an important issue in maximising the work rate of all staff. Small teams generally cover the entire supply system for undertaking NRW works.
- Works – Include the costs for the planning, design, construction and commissioning of equipment such as meters, pressure reducing valves and detecting and repairing of all leaks.

Key Messages

- The NRW reduction strategy team ensures that all components of NRW are covered and that the proposed strategy is feasible in terms of physical application and financial requirements. Choosing the right members promotes ownership by the various utility departments involved in the strategy's implementation, and also ensure consensus by senior management.
- Identifying the economic level of NRW should be the basis for setting the initial utility wide target for NRW reduction.
- Using the water balance to prioritise components for NRW reduction helps balance the financial and water supply objectives of the NRW strategy.
- The NRW reduction strategy should aim to shorten the awareness, location, and repair (ALR) times in order to minimise water losses.
- NRW reduction is a long-term process and the strategy may cover a period of four to seven years. Pilot projects can help water managers understand the full budget required to implement the entire strategy.

Unit 5:

Awareness Creation on the Strategy

Session: 1	Approval, awareness and consensus building	Duration: 45 min

Learning Outcomes

After completing this session participants:

- Understand the roles and responsibilities of each type of stakeholder in implementing the NRW reduction strategy
- Are able to contribute to awareness and consensus building programmes.

Methods of Delivery

1 Interactive session where the facilitator keeps probing participants to bring their experiences regarding awareness of NRW activities inside the CU and outside (of the customers).

He may ask question like:

- How could an awareness strategy look like in your utility?
- How would you inform the customers (make a concrete action plan)
- How can "high" decision makers in utilities be informed and their support gained?

2 He then summaries and adds from his or her experience

Training Preparation/Materials

Facilitator to arrange the sitting to ensure interaction between the learners is promoted.

- Computer and Beamer
- Pens
- Assorted cards
- Participants' note books and pens
- Soft Boards
- Drawing pins

Key Reading Materials

NRW Participants Manual

Session Guide

The facilitator must ensure that participants:

- Bring out challenges participants are facing as Commercial Utilities inside to create awareness of NRW as well as towards the outside, their customers.
- Bring out challenges they face in gaining acceptance and support from top management in developing and implementing NRW plans.
- Guide participants in the need to gain approval from top decision-makers, such as the board of directors, mayors or other political leaders, who are responsible for reviewing and approving the strategy.

He will then present an example of a well-documented case of awareness building with customers regarding the problems of NRW and how the utility is dealing with it.

Effectively addressing NRW requires a combined effort from management and staff throughout the utility. However, the number of staff with a good knowledge of NRW is usually limited to engineers or others working at an operational level. Everyone, from the Chief Executive Officer to the technicians, should understand the importance of NRW and how it affects their daily work and the utility. More specifically, the following groups should understand NRW and their role in reducing water losses:

- Top decision-makers, including the board of directors, mayors, or political leaders
- All levels of the utility's management and staff
- The general public, or consumers

The public's perception of NRW is shaped by information presented through the media, which often does not include full explanations of the complex issues involved. During the initial implementation period of the NRW reduction strategy, the public will be greatly affected when water supply is stopped to install meters, repair leaks, or undertake other work. The utility must ensure that the public is aware of the strategy and understands that service interruptions will result in long-term benefits for all.

This chapter describes the roles and responsibilities of each type of stakeholder in implementing the NRW reduction strategy. Outreach programs will help build awareness and consensus regarding the importance of reduction activities and the benefits of reducing NRW.

Gaining high-level approval

Top decision-makers, such as the board of directors, mayors or other political leaders, are responsible for reviewing and approving the strategy. A general presentation and discussion on NRW will help ensure that they understand the value of minimising NRW. The decision-makers should be informed of the present NRW level, the benefits of reducing NRW, operational activities required achieving reductions, and the budget required to carry out activities. Lack of approval at the highest levels or inadequate funding support can lead to the failure of NRW strategies.

Securing approval for the NRW reduction strategy from top decision-makers underscores its importance among staff. At the same time, the senior management will be accountable to the decision-makers for achieving results, and will report back on improvements to the strategy and any additional budget requirements.

Building staff awareness and consensus

The utility's staff needs to understand NRW and how the NRW reduction programme will improve the organisation. In certain cases, savings from the NRW reduction programme may be shared with the staff through bonuses or other incentives.

All staff, from the highest to the lowest position of employment, should understand the NRW reduction strategy and their role in achieving the NRW target. Middle managers should participate in briefing sessions to raise their NRW awareness and to provide input to strengthen the strategies. Managers should then brief their operational staff on upcoming activities and changes in policies and practices. Some examples of how individuals in various departments are involved in the strategy's implementation include:

- Meter readers must provide accurate readings as this will immediately affect the NRW calculation.
- Purchasing officers must complete equipment orders as quickly as possible, since delays in the purchasing process will then hinder these necessary installations and upgrades in the system. As a result, district meter areas (DMAs), which can play a key role in reducing NRW, will not be established in a timely manner.
- Financial officers must not delay payments to suppliers, as this may disrupt future equipment and supplies.
- Repair crews must repair burst pipes as quickly as possible so that water losses and water supply disruptions are minimal. Fast repairs increase the utility's efficiency and promote customers' willingness to pay their water bill.

In certain cases, contractors rather than utility staff will undertake repair works. These contractors should also understand NRW and any new repair standards or practices that are implemented.

Reaching out to customers

One of the goals of reducing NRW is also to provide better and more efficient services to the public. To accomplish this, the public must also understand how they can help manage NRW by reporting burst pipes, faulty valves, leaks, or other problems that limited utility crews may not detect. The earlier the utility becomes aware of a burst pipe or leak, the faster it will be repaired, thus reducing the losses.

Awareness programmes should be organised with a variety of stakeholders from the public, including politicians, community leaders, household and industrial consumers. Programmes generally focus on basic NRW concepts and how reducing NRW helps to ensure that communities receive better water supply and services.

After awareness programmes are conducted in each community, all staff should work to ensure that customer confidence in the utility's services is maintained. A key element in this is open communication. For example, the public should be able to easily contact the utility to report burst pipes, leakages, or other concerns. The utility should establish a system to receive information or complaints from customers, and then disseminate it to the relevant operational units so action can be taken quickly.

Key Messages

- Awareness at all levels, from top decision-makers to the end consumer, is critical to improving NRW.
- Building the understanding of top-level management on NRW and the budget required to reduce it supports the financial sustainability of the strategy.
- Middle 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.
- Reaching out to customers helps to increase their awareness of NRW and how reducing water losses will result in improved water supply and quality.

Unit 6:

Understanding Commercial Losses

Session: 1	Commercial loss elements and management strategies	Duration: 2 Hours

Learning Outcomes

After completing this session participants:

- Understand commercial loss elements and key management strategies; and are able to apply them in their work

Methods of Delivery

1	Facilitator makes an interactive presentation, taking participants through the elements of commercial losses, ensuring understanding. He or she then explains the management strategies required to address all the elements of commercial losses. Thirty (30) minutes.
2	Group work. Facilitator designs group and explains how the groups shall work and states the objectives of the group exercise. (Guidance and explanation presentation not more than five (5) minutes). Group work scheduled for one (1) hour.
3	Group presentation to share lessons and experiences. Thirty (30) minutes.

Training Preparation/ Materials

- Computer and Beamer
- Flip charts and pens
- Writing pads and pens
- Cards
- Commercial Losses exercise found day two folder

Key Reading Materials

- NRW Participants Manual
- Handout on understanding commercial losses.
- Power point presentation on understanding commercial losses

Session Guide

The facilitator must be aware that the participants have had access to the NRW Training manual which discusses this topic. His or her task is to encourage sharing, exchange and learning among and between participants.

Definition of commercial losses

Commercial losses, sometimes called 'apparent losses', include water that is consumed but not paid for by the user. In most cases, water has passed through the meter but is not recorded accurately. In contrast to leaks or reservoir overflows, the lost water is not visible, which leads many water utilities to overlook commercial losses and concentrate instead on physical losses.

Commercial losses can amount to a higher volume of water than physical losses and often have a greater value, since reducing commercial losses increases revenue, whereas physical losses reduce production costs. For any profitable utility, the water tariff will be higher than the variable production cost—sometimes up to four times higher. Thus, 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 losses and presents options to address them.

Commercial loss elements and management strategies

Commercial losses can be broken down into four fundamental elements as shown in Figure 7.

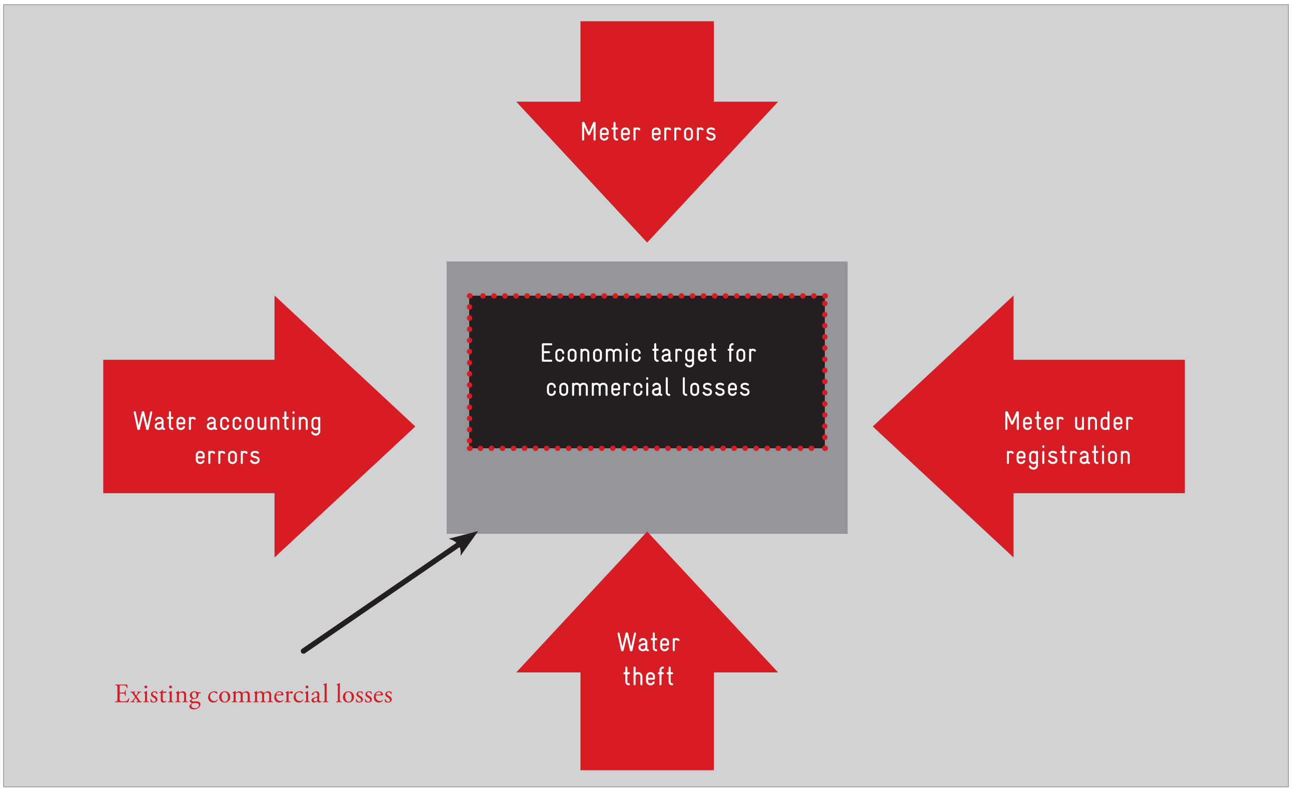


Figure 7: Four components of commercial losses

How to address customer meter inaccuracy

Inaccurate meters tend to under-register water consumption leading to reduced sales and therefore reduced revenue. Only very rarely do meters over-register consumption. Utilities should focus initially on large customers, such as industrial or commercial users, since they consume a larger volume of water and often pay a higher tariff. Using data from accurate meters to bill customers, rather than charging them based on an assumed per capita basis, ensures that customers are charged according to their actual consumption and encourages them to preserve water. The paragraphs below discuss common problems with customer meter accuracies and solutions for utilities.

Installing meters properly
Meters should be installed properly according to the manufacturer's specifications. For example, some meters require a specific straight length of pipe upstream and downstream of the meter. A meter stand should therefore be constructed onsite based on the design requirements and meter specifications. Utilities should purchase the meters on the customers' behalf, so that only standard, high quality meters are used. Meters should also be installed where meter readers can easily read them, and where it is easy to identify each property's meter. In addition, the management and staff responsible for meter installations should be trained on proper handling of meters. Improper meter installation leads to inaccurate data and billing errors.

Monitoring water quality
Poor water quality resulting from poor raw water, inadequate treatment processes, or dirt infiltration due to pipe shutdowns, may cause sediment to form in the pipes. These sediments can also build up on the internal parts of meters, especially mechanical meters. The build up in sediment affects the meter's accuracy by increasing frictional losses, which causes the meter to run more slowly and thus under-register consumption. Utilities must regularly monitor water quality and clean mechanical meters to minimise sediment levels and promote accurate meter measurements. An inline strainer before the meter can help prevent this from happening and should be considered on the larger high volumetric flow meters

Monitoring intermittent water supply
Where water supply is intermittent, i.e. the customer receives water only a few hours a day, customer meters will register a certain volume of air when the water supply is first turned on. In addition, the sudden large increase in pressure can damage the meter's components. Intermittent supply should be avoided for a number of reasons, including the negative impact on customer meter accuracy. There are modern meters that do not measure air but there is a cost element involved for such technology and this is not a solution to intermittent supplies.
Sizing meters properly

Customer meters work within a defined flow range, with the maximum and minimum flows specified by each manufacturer. Large meters will not register low flows when the flow rate is lower than the specified minimum. Therefore, utilities should conduct customer surveys to understand the nature of each customer's water demand and their likely consumption. This information helps to determine the correct meter size for households and businesses for both high and low flow profiles. Problems with extremely low flows can occur when a storage tank controlled by a ball or float valve, is installed on the customer's premises. These valves operate by slowly closing as the water level in the tank rises, which has the effect of reducing the flow through the meter, often below the minimum flow specification. This problem is compounded even further if the size of the storage tank is large in comparison to the customer's consumption because the ball or float valve will never fully open, and the flow through the meter will continually be low. New technology is available to allow the measurement of these low flows to take place.

Using the appropriate class and type of meter
Choosing the appropriate meter helps to ensure the accuracy of customer consumption data. Class B meters are a good choice where water quality is low, as the sediments will not greatly affect the meter. Class D meters are more preferable where roof tanks are used and water quality is good, since they have a lower minimum flow specification and will measure the roof tank inflow more accurately. Class C meters are a suitable compromise in most situations, since they can measure low flows better than Class B meters and are not as expensive as Class D meters.

Common types of meters include positive displacement (PD), multi-jet, single-jet, turbine, and electromagnetic. The most common type of meter for domestic and small commercial installations is the 15 mm and 20 mm PD meter. Single-jet and multi-jet meters are more accurate for small commercial and industrial installations that require 20 mm to 50 mm sizes. Electromagnetic meters are the best choice for sizes 100 mm and above.

Maintaining and replacing meters properly
All meters where possible should be installed above ground and located where they can be easily audited, by the meter readers. The utility should replace the meters systematically, beginning with the oldest meters and those in the worst condition. Poor maintenance will not only encourage inaccuracy but may shorten the life span of the meter. A scheduled maintenance and replacement programme should be in place to manage this problem.

Meter servicing is essential, especially in areas of poor water quality. The accuracy of mechanical meters changes over time as the mechanical bearings wear down, causing friction to increase and thus the meters to under-register. These changes will occur over a number of years, depending on the quality of manufacture. The water utility should regularly test a sample of its customer meters, including a range of meter brands and ages, using a calibrated meter test bench. This testing will determine the optimum age at which customer meters should be replaced.

Addressing meter tampering
Customers where low income is a problem will try numerous ways to reduce the consumption and revenue generated through the meter and may insert pins or other objects into the meter to disturb its

moving parts. Some try to affect the readings of metal meters by attaching a strong magnet to it. In other cases, customers can boil plastic meters in an attempt to melt the internal plastic parts.

Most reputable meter manufacturers now produce meters that are extremely tamper resistant, with non-metallic parts, strong clear plastic windows, and impenetrable casings. Although these meters may be more expensive, reduced tampering helps to reduce commercial water losses. For properties with older meters that are not as tamper-resistant, utility managers should conduct customer surveys to assess expected water usage according to the number of household occupants or the nature of businesses in commercial areas. A comparison of expected and actual water use will highlight cases of likely meter tampering.

Unauthorised consumption

Unauthorised consumption includes illegal connections, meter bypassing, illegal use of hydrants and poor billing collection systems. The following paragraphs describe common problems and possible solutions.

Finding and reducing illegal connections
Illegal connections involve the physical installation of a connection to water distribution pipelines without the knowledge and approval of the water utility. Illegal connections can occur during the installation of a new supply connection, or sometimes the customer's supply is cut off after non-payment and the customer cannot afford, or does not want to pay, to be reconnected.
During customer awareness programmes, customers should be encouraged to report illegal connections, and regulations should be in place to penalise the water thieves. Meter readers should also report cases of direct connections without accompanying meters that they see during their rounds.

Tackling meter bypassing
Some customers try to reduce their water bills by using a meter bypass, which is an additional pipe installed around the meter. This bypass pipe is often buried and very difficult to detect. This type of unauthorised consumption is usually committed by industrial and commercial premises, where only a small volume of the consumption goes through the meter and the rest through the bypass pipe.

Because large customers tend to steal large volumes of water, the discrepancy will show up when the utility conducts a flow balance analysis. The utility should then undertake customer surveys and site visit to conduct tests on commercial premises to determine where the missing flow occurs.

Preventing illegal use of fire hydrants
Although the only legal use of fire hydrants is for fire fighting, some use them illegally to fill tankers (normally at night) or to provide water supply to construction sites. The utility staff can detect these flows, often high volume over a short period of time, through appropriate flow measurements at DMA meters. Such high flows are not only incidences of water theft, but also a detriment to the pipe network and water quality, which affects the service to the customer. Through customer awareness programs, the utility staff should encourage customers to report cases of illegal uses of fire hydrants. In addition, the utility manager needs to cooperate with relevant local agencies or departments to identify owners of tankers suspected of drawing water illegally and without proper permission. Developing and enforcing regulations to penalise water thieves together with local agencies will also deter unauthorised consumption.

Actively checking the customer billing system
Sometimes connections are made legally, but the billing department is not notified of the new connection; therefore, the customer is never billed. These unregistered customers can be detected during the regular meter reading cycle when diligent meter readers find meters that are not in their reading book. However, this process may not identify all of the errors in the billing system.

Conducting a complete customer survey within each DMA, whereby utility representatives visit every property in the DMA – whether or not they are recorded in the billing system – is the best method of comprehensively identifying billing system errors. The survey should include the following information: property address, name of owner, and meter make and number. The representative should also conduct a meter test to ensure that the accurate flow is recorded. For metered areas, utilities should focus on large users by encouraging good customer relationships through frequent visits. Checking large customers' accounts monthly will help detect anomalies, which may be due to water theft. In areas of suspected high commercial losses, temporary DMAs can be established to analyse flows through standard monitoring activities, such as step testing and flow balancing, to pinpoint problematic areas.

Avoiding corrupt meter readers
Corrupt meter readers can significantly impact a utility's monthly billed consumption. For instance, the same meter reader who walks the same route for an extended period of time, thus becoming familiar with the customers and their monthly billed consumption, may collude with those customers to record lower meter readings in exchange for a monetary incentive. To reduce this risk, the utility manager needs to rotate meter readers to different routes on a regular basis.

Meter reading errors
Errors can be easily introduced through negligence, aging meters with difficult to read dials or corruption during the process of reading the meters and billing customers. Incompetent or inexperienced meter readers may read the meter incorrectly or make simple errors, such as placing a decimal in the wrong place. Dirty dials, faulty meters, and jammed meters can also contribute to meter reading errors. The meter readers should immediately report any observed problems, and the maintenance team should take action to remedy the problem immediately. If remedial action is too slow, meter readers may become demoralised and less inclined to report prob-

lems. Because meter readers are the utility's frontline in liaising with customers, their activities have an immediate impact on cash flow. Utility managers should therefore invest in training and motivating their meter readers to record and report information effectively and efficiently. The manager should also establish systems and procedures to prevent meter reading errors by improving meter reading and billing processes through greater supervision of meter readers, implementing rotating reading routes and frequent spot checks.

Data handling and accounting errors

The typical method of data handling and billing requires a meter reader to visit each property and read the customer meter. The data is recorded by hand in the meter reading book or form, taken back to the office, given to the billing department, and typed into the billing system. A bill is then printed and mailed to the customer. In this scenario, a variety of errors may occur at the different stages: the meter reader writes down incorrect data; the billing department transfers incorrect data into the billing system; or the bill is sent to the wrong address.

A robust billing database is one of the key elements of minimising these errors and should be the initial purchase of any water utility striving to improve its revenues. The latest billing software has built-in analysis functions that can identify potential data handling errors and report them for verification. In addition, billing software will report monthly estimate readings and zero reads, both of which may indicate a problem with the customer's meter. Site visits will help identify meters needing replacement.

Training of meter readers promotes diligence, good customer meter maintenance, and decreased meter reading errors. If financially viable, utilities should consider electronic meter-reading devices, which reduce data handling errors to a minimum since all data transfers to the billing system are done electronically.

Key Messages

- For any profitable utility, the water tariff will be higher than the variable production cost – sometimes up to four times higher. Thus, even a small volume of commercial loss will have a large financial impact.
- Commercial losses occur mostly through faulty or tampered meters and through errors committed during meter reading or processing in the billing system.
- Meters are essential tools for measuring water consumption and should be as accurate as possible.
- Coordination from the public and relevant local authorities is required to overcome illegal uses of water.
- Training meter readers, staff, and crews is a continuous process to ensure competent customer service.
- Investing in high quality meters and a robust billing system can result in higher returns.

Unit 7:

Understanding Physical Losses

Session: 1	Physical loss elements and characteristics, including developing a Leakage Management Strategy for reducing physical losses	Duration: 1 hour 30 minutes

Learning Outcomes

After completing this session participants:

- Understand losses and are able to identify them at their workplaces.
- Understand characteristics of physical losses and are able to deal with them.
- Understand developing a Leakage Management Strategy for reducing physical losses and can participate in developing it.

Methods of Delivery

1 Interactive session where the facilitator keeps probing participants to bring their experiences regarding physical losses

2 He then summaries and adds from his or her experience

3 Homework exercise is given to participants on physical losses.

Training Preparation/ Materials

- Facilitator to arrange the sitting to ensure that interaction between the learners is promoted.
- Computer and Beamer
- Pens
- Assorted cards
- Participants' note books and pens
- Soft Boards
- Drawing pins
- Physical losses exercise found in day two folder

Key Reading Materials

- NRW Participants' Manual
- Handout on physical losses

Session Guide

The facilitator must be aware that the participants have had access to the NRW Training manual which discusses this topic. His or her task is to encourage sharing, exchange and learning among and between participants.

The exercise is meant to make participants understand and be able calculate NRW, physical losses and commercial losses indicators, including night flows. The exercise attempts to make participants think and review their understanding of physical losses. Therefore, it is important that the facilitator spends time interactively explain the solutions after the participants have attempted the exercise.

Definition of physical losses

Water losses occur in all distribution networks, even new ones. Physical losses, sometimes called 'real losses' or 'leakage', includes the total volume of water losses minus commercial losses. However, the water balance process, as described in Unit 2 indicates that commercial losses are estimated and therefore the resulting leakage volume may be incorrect. Utility managers must therefore verify the results using component analysis (the top-down approach) or physical loss assessment (the bottom-up approach, see Unit 7 on aggregating night flows in DMAs).

The three main components of physical losses include:

- Leakage from transmission and distribution mains
- Leakage and overflows from the utility's reservoirs and storage tanks
- Leakage on service connections up to the customer's meter

The leakages from the reservoirs or storage tanks are normally visual if regular inspections take place so these are easy to rectify. The leaks from underground pipes be it either a water main or service pipe are not always visual and can leak for a considerable period of time before they are located causing a significant water losses.. This chapter describes these three types of losses and solutions for reducing them.

Physical loss elements

Leakage from transmission and distribution mains

Leakages occurring from transmission mains are usually large events, sometimes catastrophic, causing damage to highways and surrounding infrastructure. The majority of distribution bursts are usually not as severe although they do cause supply disruptions. Because of their size and visibility of some of these bursts are reported quickly and shut off soon afterwards so the volume of water lost is reduced. It is the non visual leaks that are the real problem. These can be either underground and therefore not visible on the surface or running above ground but in regions where there is little or no people present to report such incidents.

By using data from repair records, utility managers can calculate the number of leaks on mains repaired during the reporting period (usually 12 months) and estimate an average flow rate of the leaks. This gives the total annual volume of leakage from mains as follows:

Total annual volume of leakage from mains = Number of reported bursts x Average leak flow rate x Average leak duration

If no detailed data are available, utility managers can use approximate flow rates from Table 2.

Table 2: Flow rates for reported and unreported bursts

Location of Burst	Flow Rate for Reported Bursts [l/hour/m pressure]	Flow Rate for Unreported Bursts [l/hour/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 an active leak detection survey can discover them. Table 3 shows background losses from various components of the network with average infrastructure condition.

Table 3: Calculating background losses

Location of Burst	Litres	Unit of Measure
Mains	9.6	Litres per km of mains per day per metre of pressure
Service connection: mains to property boundary	0.6	Litres per service connection per day per metre of pressure
Service connection: property boundary to customer meter	16.0	Litres per km of service connection per day per metre of pressure

Source: IWA Water Loss Task Force

Excess losses include the water lost from leaks that are not detected and repaired under the current leakage control policy:

Excess Losses = Physical losses from water balance – known physical loss components

If this equation results in a negative value for excess losses, the assumptions for the physical loss component analysis (e.g. values for leak durations) should be rechecked, and if necessary, corrected. If the value is still negative after rechecking the assumptions, this indicates that faulty data was used in the water balance calculation. For example, utility managers may have underestimated system input or overestimated commercial losses), therefore all the components should be checked.

Leakage and overflows from the utility's reservoirs and storage tanks

Leakage and overflows from reservoirs and storage tanks are easily quantified. Utility managers should observe overflows then estimate the average duration and flow rate of the events. Most overflows occur at night when demands are low and therefore it is essential to undertake regular nightly observations of each reservoir. These observations can be undertaken either physical or by installing a data logger which will then record reservoir levels automatically at preset intervals. Leakage from tanks is calculated using a drop test where the utility closes all inflow and outflow valves, measures the rate of water level drop, and then calculates the volume of water lost. However, repairing these leaks is a major operation, requiring draining down the reservoir and planning an alternative supply.

Leakage on service connections up to the customer's meter

This type of leakage is usually more difficult to detect as it is sometimes not visible and leakage surveys have to be completed to identify these leaks. Due to the infrequent intervention period of the leakage survey programmes, these leaks result in the greatest volume of physical losses. Utility managers should calculate the approximate volume of leakage from service connections by deducting the mains leakage and storage tank leakage from the total volume of physical losses.

Characteristics of leakages

Having defined where leakage can occur in the transmission and distribution network, utility managers should familiarise themselves with the different types of leaks and understand the effect of the leak run time, or ALR, on the total volume of physical losses.
The type and location (e.g. main or service connection) of a burst influences the total run time:

- Reported bursts – Visible and usually quickly reported by the public or observed by water utility staff. They have a short awareness time.
- Unreported bursts – commonly occur underground and are not visible at the surface. They are usually discovered during leak detection surveys and often have a long awareness time.
- Background leakage – an accumulation of very small leaks that are difficult and not cost effective to detect and repair individually.

General conclusions concerning leakage include:

- Most leaks are invisible
- The majority of leaks do not come to the surface
- Managers need to be aware that most leaks are on service connections
- The absence of an active programme to detect invisible leaks is an indication of high levels of leakage

Developing a leakage management strategy

The four pillars of a leak management strategy include pressure management, repairs, active leakage control, and asset management Figure 8. These factors influence how leakage is managed—and therefore the volume and economic value of leakage—in any utility's distribution network.

The large square represents the Current Annual Volume of Physical Losses (CAPL), which tends to increase as the distribution network ages. But the rate of increase can be constrained by an appropriate combination of the four components of a successful leakage management strategy. The black box represents the Minimum Achievable Annual Physical Losses (MAAPL), or the lowest technically achievable volume of physical losses at the current operating pressure. Introducing or strengthening any of the four components will have an effect on the potentially recoverable losses.

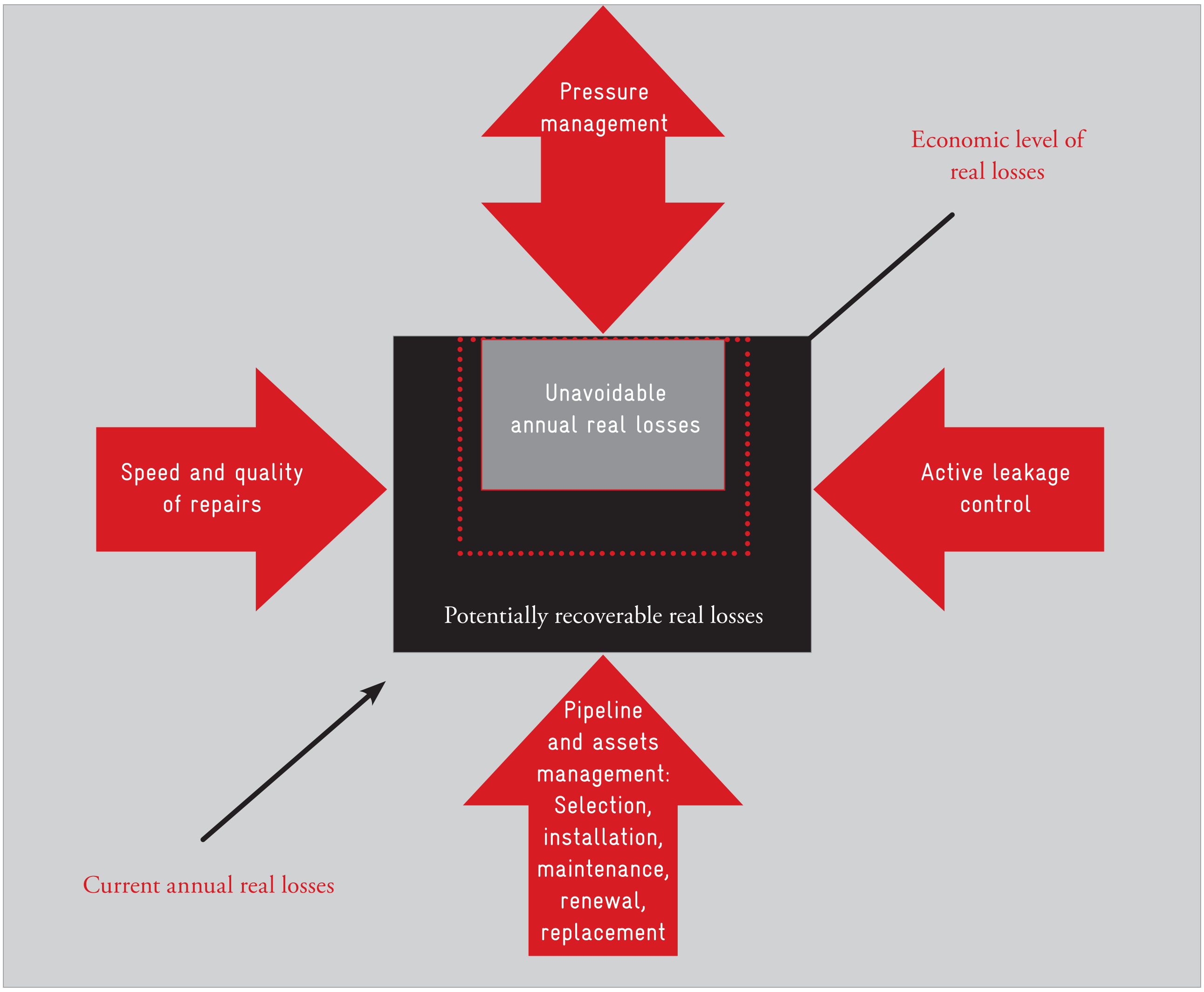


Figure 8: The four pillars of a successful leakage management strategy

Active leakage control (ALC)

Active leakage control (ALC) is vital to cost-effective and efficient leakage management. The concept of monitoring flows into zones, or district meter areas (DMAs), where bursts and leaks are unreported is now an internationally accepted and well-established technique to determine where leak location activities should be undertaken. The quicker the operator can analyse DMA flow data, the quicker bursts or leaks can be located. This, together with speedy repair, limits the total volume of water lost. The DMA concept, and the associated technology and equipment for leakage monitoring, detection, and location, is described in detail in Unit under Sectorisation.

There are many points in a distribution network where leakages can occur and where they can best be monitored (Figure 8). The DMA concept, and the associated technology and equipment for leakage monitoring, detection, and location is described in detail further down.

Modern flow metering and data capture technologies play a major part in quickly identifying bursts and in estimating the gradual accumulation of smaller leaks. Integrating data from DMAs via telemetry into their supervisory control and data acquisition (SCADA) systems is particularly effective when implemented together with an analysis package as it can help a utility manager identify DMAs that requiring leak location work.

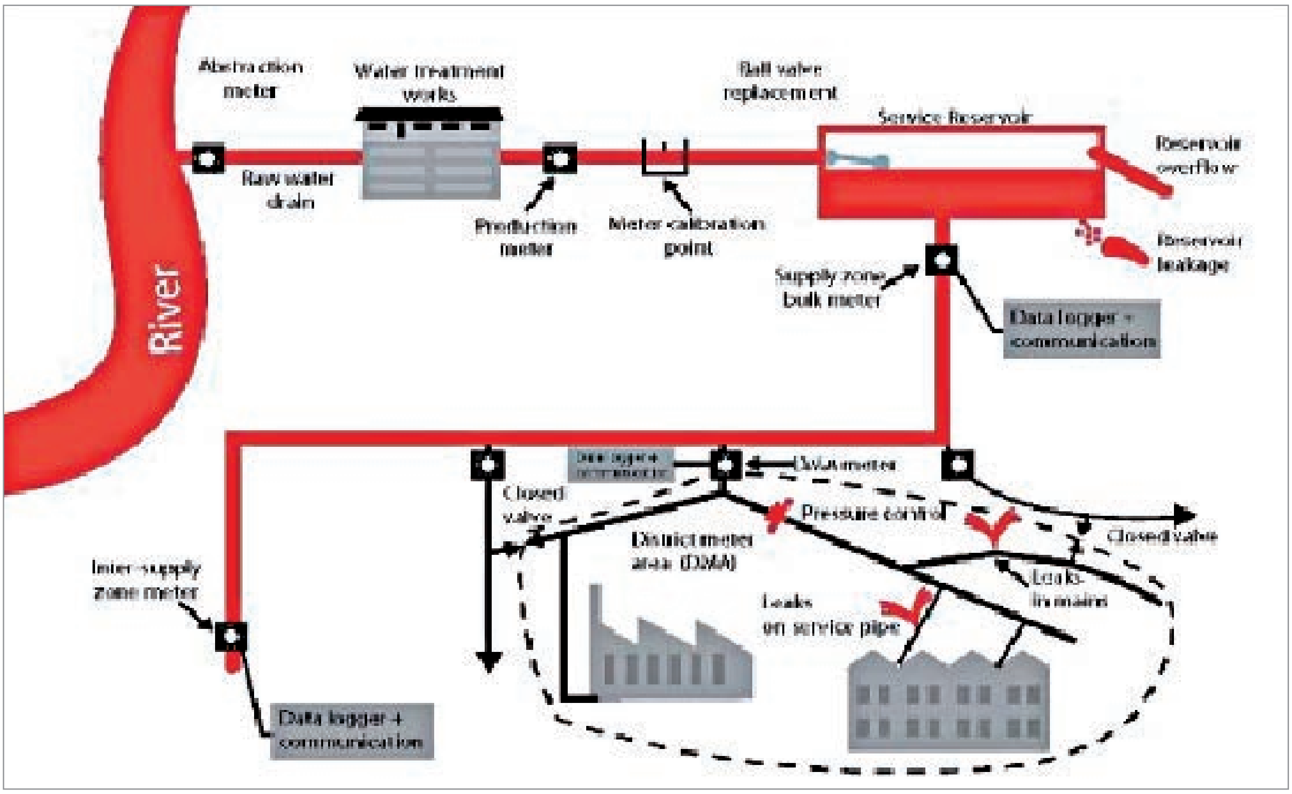


Figure 9: A typical distribution network
(Source: The Manager's Non-Revenue Water Hand book, A Guide to Understanding Water Losses by Malcom Farlley, Gary Wyeth, Zainuddin Bin Md. Ghazali, Arie Istandar and Sher Singh, 2008 Published by Ranhill)

Leak detection techniques

There are a vast number of techniques to detect where leakage is occurring in the network. All techniques fall into one of the LLP principal categories (Localise, Locate, Pinpoint) listed below are some approaches that can be used but certainly not limited to those items shown below and also this list changes as new technology is developed.

- Sounding Surveys (Localise)
- Use of leak noise loggers (Localiser)
- Variations of the traditional step test (Localise)
- Other techniques e.g. thermal imaging (Localise & Locate)
- Correlators (Locate)
- Internal acoustic device (Locate & Pinpoint)
- Electronic Microphones (Pinpoint)
- Manual Listening device (Pinpoint)

The noise characteristics of a leak have been used for many years to locate leaks – listening on valves, hydrants, stop taps, or at the ground surface above the line of the pipe.
Utility managers need to ensure a detailed process is undertaken to locate leaks:

- Use flow meter data to identify DMAs that contain unreported bursts or an accumulation of leaks
- Narrow down the area of leakage within the DMA
- Pinpoint the exact (or nearly exact) position of the leak.

This process requires reasonable accuracy at each step to avoid high excavation costs and 'dry holes' (excavations at suspected leak points that reveal no obvious leak). The basic method of detecting and locating a leak is to listen for the noise of the water being released from the pipe under pressure. The effectiveness of this activity is dependent on the system pressure, the distance between listening points, the size and shape of the leak, the pipe material and the pipe diameter.

For ensuring accuracy the utility now has available a wealth of acoustic equipments to pinpoint leaks and bursts, including noise loggers, leak noise correlators, ground microphones, and sounding sticks. Although these tools are extremely helpful for ALC, utility managers must understand the proper applications, training requirements to use each piece of equipment successfully and maintenance requirements of each tool to maximise their use.

Localise

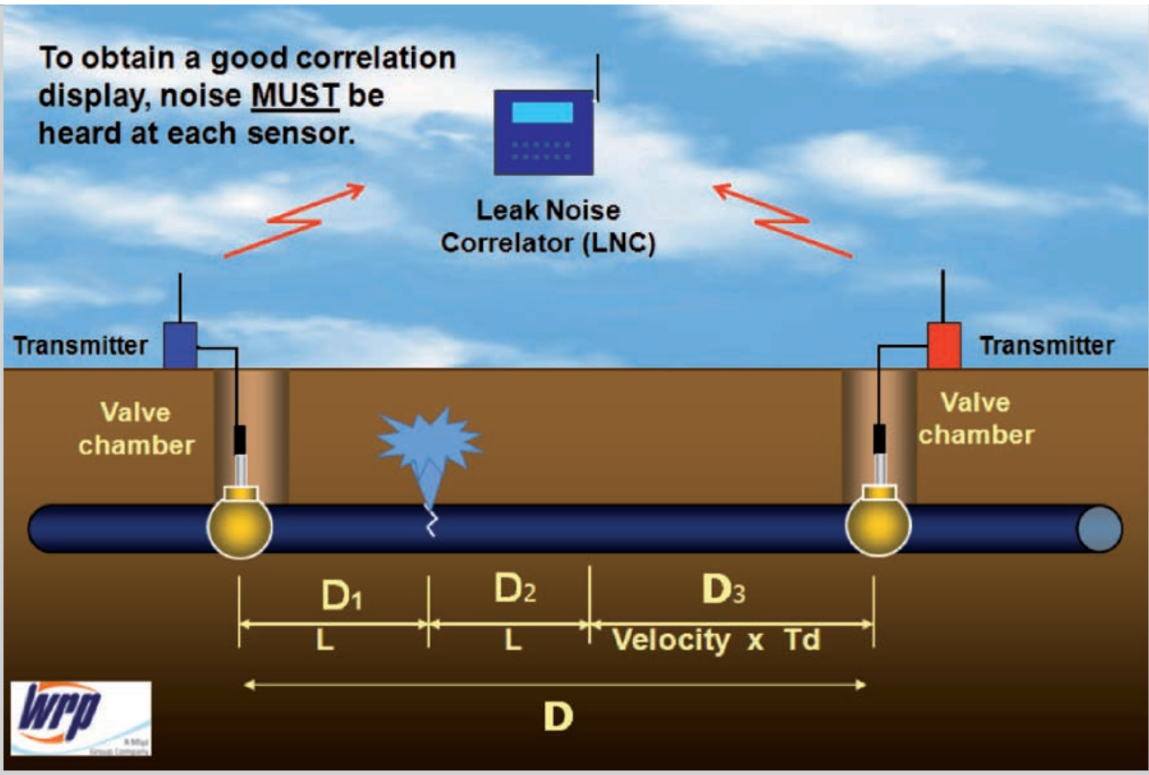
Noise loggers: Noise loggers narrow down areas of a DMA that contain suspected bursts or number of leaks. The use of Leak Noise Loggers for localising leaks has become a popular technique over the last few years. It is often used as an alternative to Step Testing and used as a method to "sweep" a zone for possible leaks.

The essential characteristics comprise a set of six or more loggers equipped with microphones. The units are magnetised and usually installed on adjacent fittings within the network (typically valves or hydrants) and are set to switch on at a predetermined time. The loggers "listen" and record the constant noise being generated by a leak – normally over a 2 hour time period. Analysis of the readings is completed by comparison of sound level and sound spread. If there is a consistent anomaly recorded further investigation for a leak will be required.

Locate

Leak noise correlators: The most sophisticated (and hence expensive) of acoustic location instruments, a correlator is regularly used as a tool to locate the position of a burst pipe. Instead of relying on the noise level of leak, it uses the velocity of sound made by a leak as it travels along the pipe wall towards the correlator microphones. It is important to note that its application will be dependent on the pressure and level of background noise within the network.

In the 'classic' correlation process, two sensors are deployed on pipe fittings ('dry connections' accelerometers) or connected to hydrants ('"wet connections' hydrophones). The sensors are then positioned on either side of the suspect leak position. Noise is created by the leak as it escapes from the pipe under pressure; this noise then travels in both directions away from the leak through the pipe wall as minute vibrations and through the water as a pressure wave.



Correlation Formula

L = D - (V x Td) / 2

L = Leak position (m) (meters)
V = Velocity of sound along pipe (m/ms)
(meters per millisecond)

D = Length of pipe (m) (meters)
Td = time delay (ms) (milliseconds)
Time delay occurs for the distance D3

Figure 10 : Principle of correlation

Essentially, the noise travels at a constant velocity (V), which depends on the material and diameter of the pipe, and arrives first at the sensor nearest to the leak. The arrival time at each sensor is then registered. The time difference / time delay (Td) between the two arrival times, combined with the knowledge of the pipe length and material allows the leak position to be calculated by the correlator.

Pinpoint

Ground microphones: The ground microphone electronically amplifies the sound of a leak. It can be assembled for use in either contact or survey mode. Contact mode is for sounding on fittings, similar to an electronic listening stick. Survey mode is for searching for leaks on lengths of pipeline between fittings. The technique involves placing the microphone on the ground at intervals along the line of the pipe and noting changes in sound amplification as the microphone nears the leak position. When a leak is detected by the leak noise loggers or leak noise correlator, the utility manager may use either mode to locate the leak.

Sounding Sticks: The sounding stick, or 'stethoscope', is an inexpensive, simple rod made of wood or metal with an ear piece attached to amplify sounds. The leakage engineers use it to listen to leak sounds on the surface of the highway or on directly exposed pipes and fittings.

All of the equipments above will not only detect the noise that a leak makes but also any other noise in the system, such as a pump, tap, air valve, etc. It is therefore important to have a team of experienced leakage detection staff who not only can use the equipment correctly but have the skills to identify leaks effectively.

Pressure management

Pressure management is one of the fundamental elements of a well-developed leakage management strategy. The rate of leakage in water distribution networks is a function of the pressure applied by pumps or by gravity. There is a physical relationship between leakage flow rate and pressure (Figure 6.4), and the frequency of new bursts is also a function of pressure:

- The higher or lower the pressure, the higher or lower the leakage
- The relationship is complex, but utility managers should initially assume a linear relationship (10% less pressure = 10% less leakage)
- Pressure level and pressure cycling strongly influence burst frequency

To assess the suitability of pressure management in a particular system, utilities should first carry out a series of tasks, including:

- Identify potential zones, installation points, and customer issues through a desktop study
- Identify customer types and control limitations through demand analysis
- Gather field measurements of flow and pressure (the latter usually at inlet, average zone point, and critical node points)
- Model potential benefit using specialized models
- Identify correct control valves and control devices
- Model correct control regimes to provide desired results
- Analyse the costs and benefits

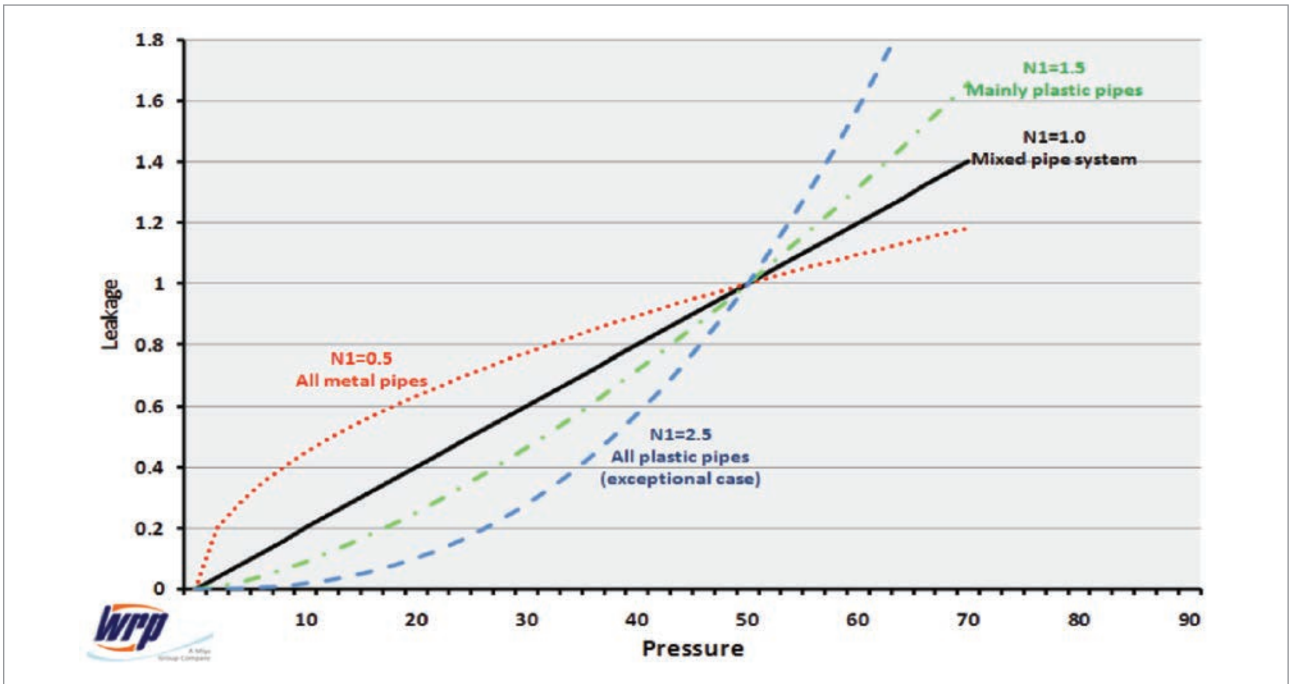


Figure 11 : Pressure/leakage relationship

There are a number of methods for reducing pressure in the system, including variable speed pump controllers and break pressure tanks. However the most common and cost effective is the automatic pressure reducing valve (PRV).

PRVs are instruments that are installed at strategic points in the network to reduce or maintain network pressure at a set level. The valve maintains the pre-set downstream pressure regardless of the upstream pressure or flow-rate fluctuations. PRVs are usually sited within a DMA, next to the flow meter. The PRV should be downstream of the meter so that turbulence from the valve does not affect the meter's accuracy. It is good practice to install the PRV on a bypass pipe to enable future major maintenance works.

Speed and quality of repairs

The length of time a leak is allowed to run affects the volume of physical losses, so repairs should be completed as soon as possible once a leak is detected. Repair quality also has an effect on whether the repair is sustained. Key issues to consider when formulating a repair policy include:

- Efficient organisation and procedures from the initial alert through to the repair itself
- Availability of equipment and materials
- Sufficient funding
- Appropriate standards for materials and workmanship
- Committed management and staffs
- Good quality of service connections—service connections are often the 'weakest link'

Asset management

Asset management is good engineering and business practice, and it includes all aspects of utility management and operations. Good asset management is a necessity for long-term economic leakage management, and the objective is to tackle leaks in the most cost-effective way. This requires priority setting and decisions on whether to repair, replace, rehabilitate, or leave the assets as they are, while simultaneously implementing pressure management and improving the operation and maintenance programme. The critical factors of asset management are:

- Understanding how assets are currently performing
- Collecting data and turning it into useful information for planning
- Good information systems

Particularly relevant to developing an NRW reduction strategy is the aging of the pipe network and making decisions on when to replace or renew the network infrastructure. This requires an understanding of the assets' conditions and deterioration rates. Burst frequency modelling, using data from burst records, helps prioritise pipe rehabilitation, renewal, or replacement. In addition, active leakage control will identify clusters of pipes in the network where bursts and repairs are a continuous occurrence.

When these activities do not lead to reduced leakages, utility managers should undertake a condition assessment programme to decide whether to replace pipes or conduct further repairs. During the decision process, utility managers should ask the following questions:

- If repairing, replacing, or rehabilitating assets, what materials should be used?
- Should pipes be replaced now or later during network extensions to address future demand increases?

Key Messages

- Physical losses include leakage on transmission and distribution mains; leakage and overflows from storage tanks; and leakage on service connections up to the customer meter.
- Leakages from transmission and distribution mains are usually large events so they are reported quickly by the public. They can cause serious damage unless they are repaired quickly. Less conspicuous types of leakage are more difficult to detect and repair.
- A successful leakage management strategy requires pressure management, active leakage control, pipeline and asset management, and speedy and quality repairs.

Unit 8:

Sectorisation – Understanding District Meter Areas

Session: 1	DMA Management approach and its benefits: criteria, process, use of DMA results to reduce NRW levels	Duration: 1 hour

Learning Outcomes

After completing this session participants:

- Understand what sectorisation is and are able to relate it to their situation in their utilities.
- Are knowledgeable of principles involved in sectorisation
- Know what DMAs are and are able plan how they can establish them.
- Are able to analyse DMA results and establish how they can use these results to reduce NRW levels

Methods of Delivery

1 Facilitator makes a presentation, highlighting key points. Thirty (30) minutes.

2 Participants do an individual exercise focussing on sectorisation. Twenty (20) minutes.

3 Facilitator checks answers interactively and sees how the participants solved the problem. Depending on the result, he appropriately explains the solution and provides more explanations where needed. Ten (10) minutes.

Training Preparation/ Materials

- Computer and Beamer
- Writing pads and pens
- Exercise on sectorisation found in day two folder

Key Reading Materials

- NRW Participants Manual
- Handout on sectorisation found in day two folder

Session Guide

The facilitator must be aware that the participants have had access to the NRW Training manual which discusses this topic. His or her task is to encourage sharing, exchange and learning among and between participants.

The facilitator must make sure that participants understand the key principles of sectorisation consisting of:

- DMA establishment criteria and process
- Use of DMA results to reduce NRW levels and how to calculate NRW in a DMA
- Estimation of physical losses in DMAs
- Using the DMA approach to reduce physical losses through leak detection and repair.

Sectorisation – Understanding district meter areas

Many water utilities operate their pipe networks as an open system where water is fed from more than one Water Treatment Plant (WTP) into an inter-connected pipe network. Water from each WTP will mix within the network, which continually affects system pressure and water quality. In an open system, NRW can only be calculated for the entire network, which is effectively an average level for the entire system. Determining the exact locations of NRW occurrence, and where NRW reduction activities should take place, can thus be quite a challenge, especially for large networks.

Generally NRW management in an open system is undertaken in a passive manner where NRW reduction activities are initiated only when the loss becomes visible or is reported. A more effective approach is to move towards Active NRW Management where dedicated teams are established and sent out to look for water losses or other causes of NRW such as reservoir overflows and illegal connections.

Active NRW Management is more cost effective when using zones to measure the NRW , where the system as a whole is divided into a series of smaller sub-systems for which NRW can be calculated individually. These smaller sub-systems, often referred to as District Meter Areas (DMAs) should be hydraulically isolated so that utility managers are able to calculate the volume of water lost within the DMA. When a supply system is divided into smaller more manageable areas, the utility can better target NRW reduction activities, isolate water quality problems, and better manage overall system pressure to allow for 24/7 water supply throughout the network.

Dividing the open network into smaller, more manageable areas called District Meter Areas (DMAs) enables network operators to manage the system more effectively in terms of pressure control, water quality, and NRW. This chapter describes how utilities should establish DMAs and then use information on flow and pressure to better manage NRW. It also discusses the benefits of using DMAs to improve water quality and supply for customers. The creation of DMAs is called Sectorisation.

DMA establishment criteria and process

The design of a series of DMAs is very subjective, and it is unlikely that two utility engineers working on the same network would come up with the same design. The engineer typically uses a set of criteria to create a preliminary DMA design that must be tested either in the field or using a network model.

These criteria includes:

- Size of DMA (e.g. number of connections—generally between 1,000 and 2,500);
- Number of valves that must be closed to isolate the DMA – should be kept to a minimum – natural boundaries should be used where ever possible;
- Number of flow meters to measure inflows and outflows (the fewer meters required, the lower the establishment costs and more accurate flow measurement);
- Ground-level variations and thus pressures within the DMA (the flatter the area the more stable the pressures and the easier to establish pressure controls);
- Easily visible topographic features that can serve as boundaries for the DMA, such as rivers, drainage channels, railroads, highways, etc.

To divide a large open system into a series of DMAs, it is essential to close valves to isolate a certain area and install flow meters. This process can affect the system's pressures, both within that particular DMA as well as its surrounding areas. The water utility therefore must ensure that the water supply to all customers is not compromised in terms of quality, pressure and supply hours.

Using a calibrated hydraulic network model of the supply system to simulate possible DMA designs will enable analyses of system pressures and flows without affecting supply to customers. However, many water utilities do not have existing calibrated hydraulic network models. Rather than wait for a model to be developed, which can take up to one year or more, a water utility should begin establishing DMAs in network areas that can be easily isolated, i.e. areas with a separate supply zone.

In establishing a DMA, the water utility should limit the number of inflows, which if kept to one meter enables the accurate measurement of water metering into the DMA which also helps to reduce the cost of design, setup and installation. To achieve this, it is necessary to close one or more boundary valves, which must remain shut permanently to ensure that any flow data accurately represents the total inflow for the DMA.

Utility managers will ensure that all pipes into and out of the DMA are either closed or metered by performing an isolation test or zero pressure test (ZPT)as follows:

- 1. Close all metered inlets.
- 2. 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.

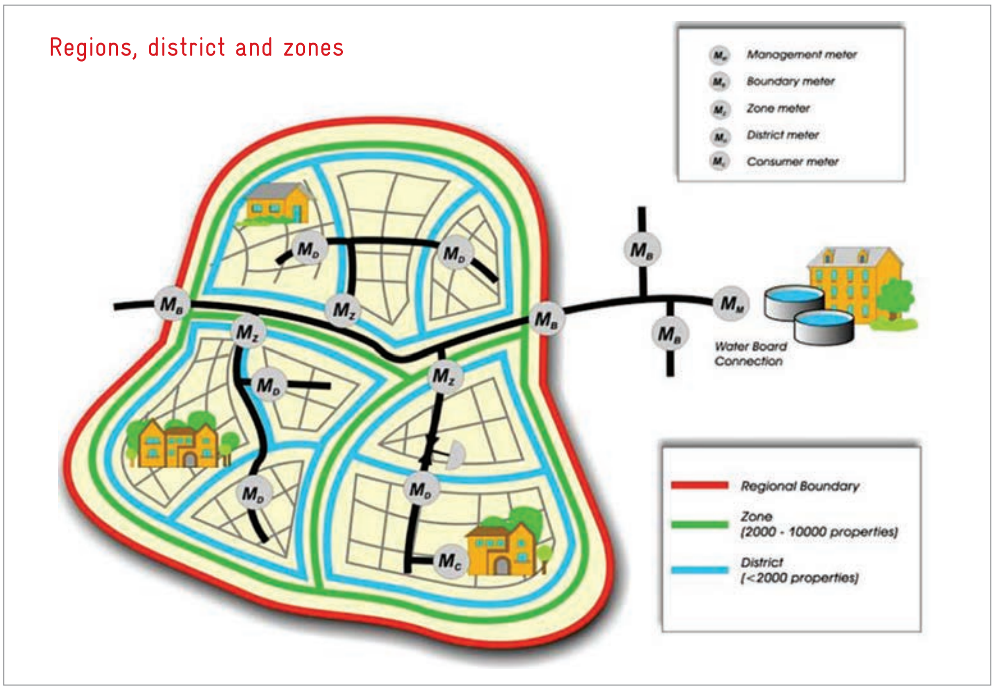


Figure 12 : Typical DMA layout

If the budget is limited, the water utility should initially establish larger zones of 5,000 or more connections. It can subsequently subdivide them into DMAs and sub-DMAs of 1,000 or fewer connections for those DMAs with high NRW and long lengths of pipework, as detailed in Figure 12.

For each DMA, utility managers should develop a detailed operations manual to assist future teams in managing the water supply. The operations manual includes a schematic of the pipe network; location drawings of the flow meters, pressure control valves, boundary valves, and a copy of the billing database for the DMA. The manual is a working document and operational data should be continually updated, including information on the following:

- Flow and pressure graphs
- Leakage step tests data
- Leak locations
- Illegal connection locations
- Legitimate night flow (LNF) test data
- Pressure T Factor test data

Using DMA results to reduce NRW levels

Once the DMA has been established, it becomes an operational tool for monitoring and managing both of the major components of NRW, physical and commercial losses. The calculation for NRW within a DMA is defined as follows:

DMA NRW = Total DMA Inflow – Total DMA Consumption

After flow meters are installed on all inlets to the DMA, the Total DMA Inflow can be measured using the increase in the totaliser, or the meter counter measuring the volume of water passing through the meter, for the calculation period.

The total DMA Consumption will depend on the customer meter coverage. If the DMA has a 100% domestic meter coverage, meaning all customers within the DMA have a meter, then the Total DMA Consumption can be calculated through a simple summation of all meter measurements for the calculation period.

If 100% domestic meter coverage does not exist within the DMA, then the Total DMA Consumption can be estimated by using per capita consumption figures. Initially, a survey of all properties within the DMA should be undertaken; this survey may be limited to counting the number of properties and estimating the average number of occupants per property. For a more detailed estimate, surveyors will interview all households and ask how many occupants live within each property.

Estimating physical losses

Most DMAs will not contain any reservoirs or trunk mains, so these components are not usually considered when analysing physical losses within a DMA. Physical losses within a DMA are effectively pipe leaks on the main pipes and customer connections. Leakage in the main distribution pipes and service connections will leak water over a 24-hour period and the volume lost will fluctuate as the pressure increases or decreases during the 24 hours and so, to compensate for this, the losses are calculated over a longer or shorter period of 24hrs which is calculated called the hour/day correction factor. Because leakage from the main pipes is continuous, while customer demand is minimal at night, water operators should monitor leakage during the night period. Figure 13 shows the flow pattern into a typical DMA with mainly domestic customers.

To estimate the level of leakage in the DMA the operator needs to calculate the system's Net Night Flow (NNF), which is determined by subtracting the Legitimate Night Flow (LNF) from the Minimum Night Flow (MNF).

The MNF is the lowest flow into the DMA over a 24-hour period, which generally occurs at night when most consumers are inactive. This MNF can be measured directly from the data logging device or the flow graph. Although customer demand is minimal at night, water operators still have to account for the small amount of legitimate night flow, i.e. the night-time customer demand, such as toilet flushing, washing machines, etc.

In a system with 100% metering, LNF is calculated by measuring the hourly night flow for all non-domestic demand and a portion (e.g. 10%) of domestic meters within the DMA. The utility will then estimate the total LNF in terms of litres per hour and litres per second.

For systems without 100% customer metering, water operators can approximate LNF based on estimated per capita night consumption. Utility managers should conduct a customer survey of all the properties, both domestic and non-domestic, within the DMA, and then determine the total number of connections per demand group (domestic, industrial, commercial, or others). Based on data from other areas with 100% customer metering, the utility can estimate a night-time flow rate for each demand group and multiply that by the number of connections within the demand group to get the total LNF.

To determine the level of Net Night Flow (NNF) or the portion of night flow directly attribute to leakage, subtract the LNF from the recorded MNF.

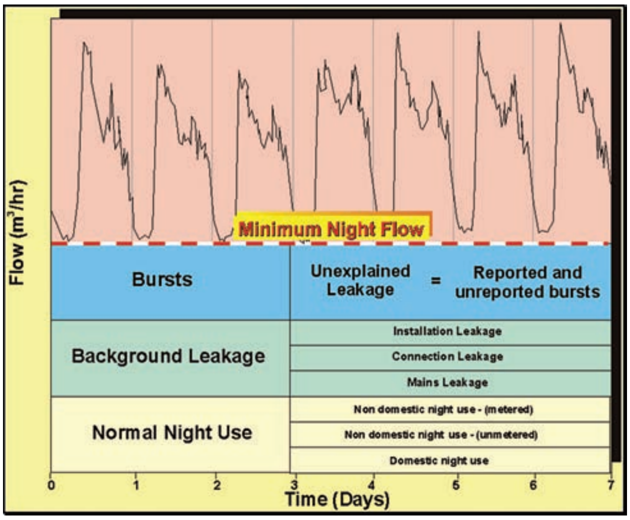


Figure 13 : Typical 24-hour DMA flow profile
(source: SANFLOW user Guide, WRC 1999)

NNF = MNF – LNF

Leakage is proportional to the pressure in the system. Similar to water flows into the DMA, the DMA average pressure will change over a 24-hour period. Pressure is directly proportional to flow due to frictional head losses within the system, and thus when the DMA has its lowest inflows, the pressure will be at its highest. Figure 14. This is because frictional headloss is proportional to velocity, so when flows are low, the velocities in the pipes are also low and less headloss occurs.

The NNF or leakage calculated for the minimum night flow period will therefore not be a true representation of leakage across a 24-hour period. Utility managers must also determine a pressure factor, or T Factor, that creates a true average 24-hour leakage value when applied to the NNF. The T Factor is calculated by using a data logger to record pressure over a 24-hour period, and then using those measurements to calculate the average 24-hour pressure. This average 24-hour pressure is compared to the system pressure during the minimum night period and a factor applied.

Determining commercial losses

The level of NRW within a DMA can be calculated by subtracting the recorded consumption from the inflow. The previous section shows how to determine the leakage level or NNF within each DMA using the minimum night flow. This section discusses how to calculate commercial losses through a simple subtraction of leakage from the NRW, as follows:

Commercial loss = NRW – NNF

Once utility managers identify the DMAs with significantly high commercial losses, they should investigation for faulty meters, tampered meters, and illegal connections. They may also conduct a series of customer surveys of each property within the DMA to verify the property's inclusion in the billing database, interview the occupants, and assess the water meter.

DMA management approach

When a DMA is first established, water utility managers should undertake the initial calculations of NRW, NNF, and commercial losses, and identify the main areas of concern. If the DMA has high leakage or high commercial losses, then NRW reduction activities should be implemented.

Once NRW is reduced to an acceptable level, the operations staff should set up a monitoring regime for DMA inflows. In its simplest form, this consists of a monthly reading of the flow meter totaliser. The installation of a data logger to record flows will however reveal more detailed data, including the daily NNF, which

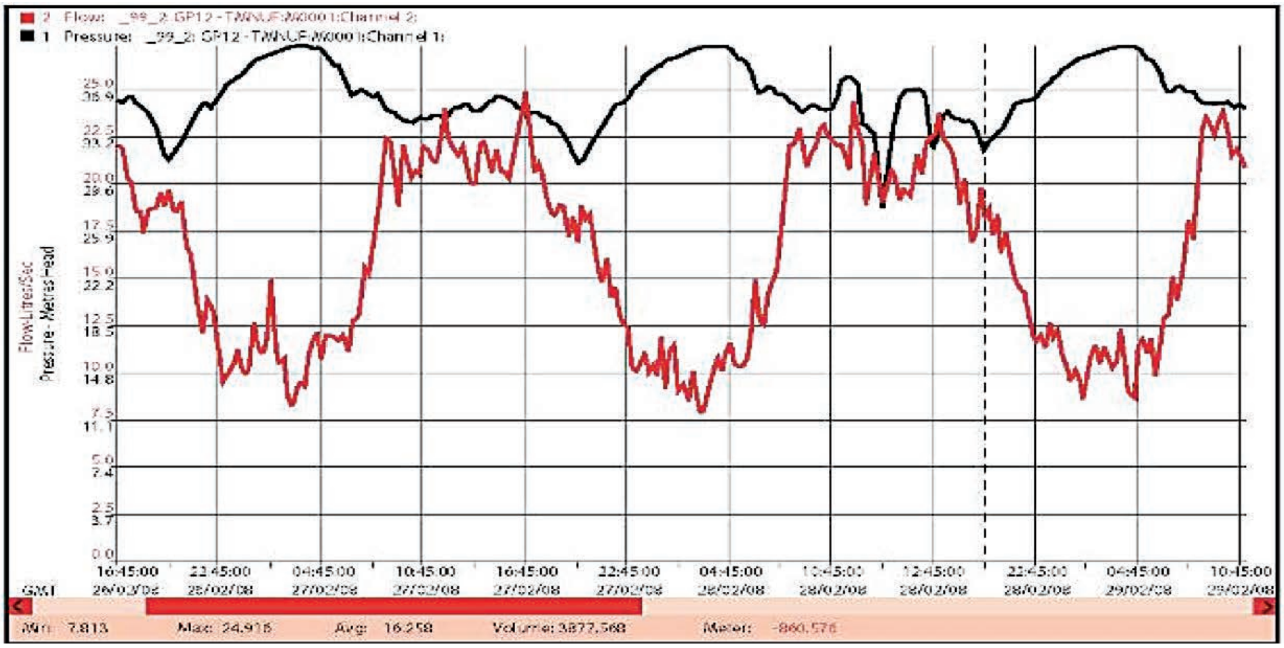


Figure 14 : DMA flow and pressure relationship over a three-day period.

Source: The Manager's Non-Revenue Water Hand book, A Guide to Understanding Water Losses by Malcom Farlley, Gary Wyeth, Zainuddin Bin Md. Ghazali, Arie Istandar and Sher Singh, 2008 Published by Ranhill.

enables more precise corrections to the system. Eventually, the NNF effectively becomes NRW with minimal levels of commercial loss. The daily NNFs can be plotted on a graph against time, to monitor DMA NRW levels (Figure 15).

Figure 15 shows that the NRW level within the DMA continues to increase, and the rate of increase depends on a number of issues, including pipe network age and condition, system pressures, and the number of illegal connections and tampered meters. For most water utilities, it is inefficient for leakage detection and customer survey teams to work in the DMA continually. The monitoring team should therefore set an intervention limit, or the level at which NRW becomes unacceptable. Once the intervention limit is reached, the teams should be sent in to detect and resolve losses. Generally, once the utility manager deploys teams into the DMA, they can reduce the NRW level within two to four weeks. Afterwards, the manager should ensure that the NRW level is monitored until the intervention level is reached again. This process is the optimal management cycle of an established DMA.

Water utilities should maintain a record of the time taken for NRW to return to the intervention level. If this time decreases between detection exercises, it indicates that losses within the DMA are occurring more frequently and that the system's assets are deteriorating. For such a case, water utility managers should consider asset rehabilitation such as pipe rehabilitation, relining, or replacement, rather than continual leak detection and repair (Figure 16).

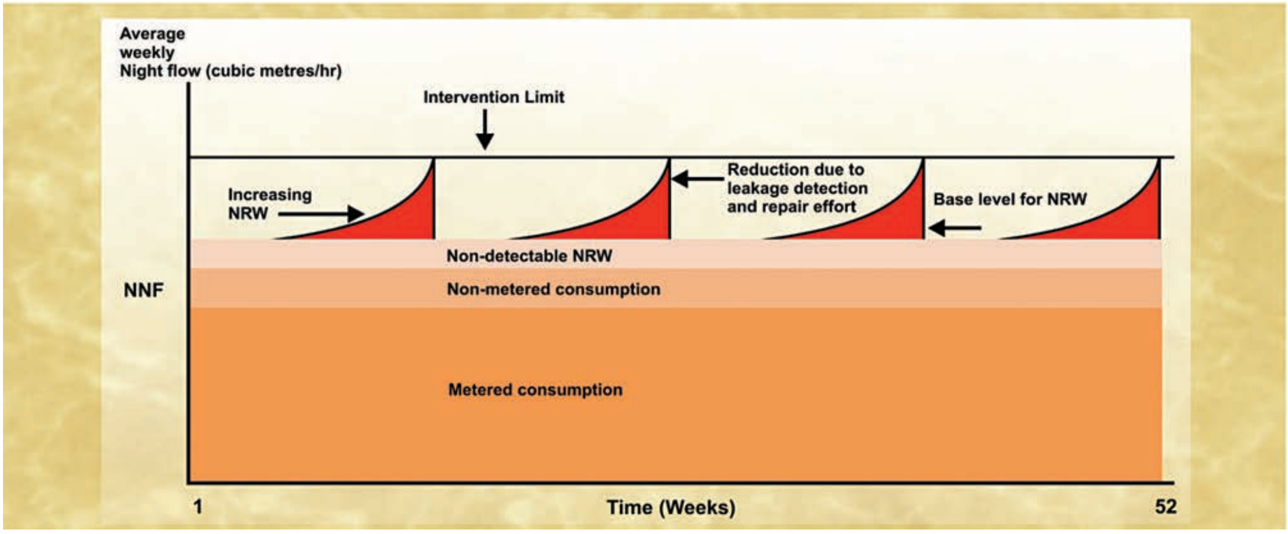


Figure 15 : NNF against time

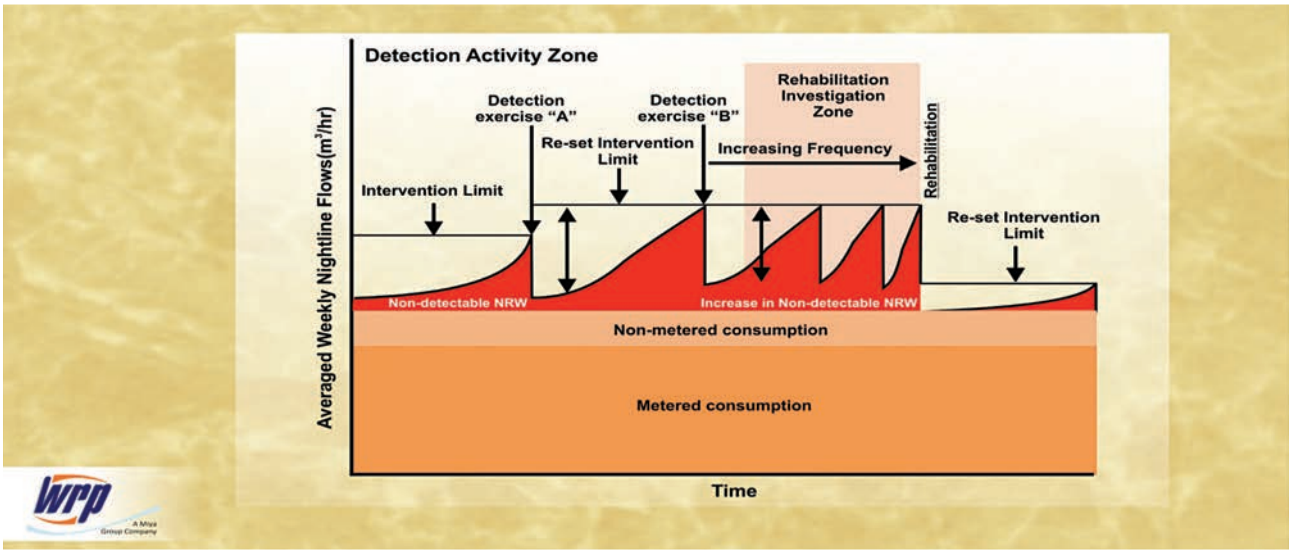


Figure 16 : Moving from leak detection and repairs to pipe rehabilitation

Upon completion of asset rehabilitation activities, the level of NRW typically decreases due to fewer leaks, especially underground or those previously undetected leaks. Monitoring teams should also detect a much slower increase in the NRW level over time with the much-improved asset condition, and the intervention level should be re-set to a lower level (Figure 16).

Additional benefits of the DMA

Establishing a series of DMAs not only targets NRW reduction but it also improves asset condition and customer service by:

- Maintaining asset life through pressure management
- Safeguarding water quality
- Enabling continuous water supply
- Improved pressure management

Establishing a DMA and the subsequent reduction in NRW will improve the water pressure within the DMA. As leaks are repaired, the flows within the DMA will decrease and thus the friction head losses are reduced, which has the effect of increasing DMA system pressures. These increases in pressure will become even more pronounced at night when demands are low and friction head losses are even lower.

Improved pressure control presents dual benefits of reducing leakages and stabilising system pressures, which increase asset life. Most pipe bursts occur not because of high pressure but rather due to ongoing pressure fluctuations that force the pipe to continually expand and contract, resulting in stress fractures. Installing a pressure control device, such as a pressure reducing valve (PRV), helps to reduce pressure throughout the day, stabilise fluctuations, and reduce stress on pipes.

By design, PRVs reduce pressure to a set level during the day and night-time. A pressure of 30 m is sufficient for most customer demand. The pressure in a gravity system can however be much higher at night when there is little customer demand. To activate a lower pressure at night and during periods of low demand, and to further reduce leakage levels, water utilities should install a timer device with two set levels—one for daytime when customers need water, and the second for night-time when demand is low. The night-time setting, generally adjusted between 15 m and 20 m pressure, is typically lower than the daytime setting,

Safeguarding water quality

Establishing DMAs helps water utilities to prevent water quality deterioration in the distribution network. Closing a number of boundary valves to isolate each DMA, as per standard DMA establishment protocol, reduces the ebb and varying flow of water within the pipe network. As a result, sediments accumulated in the bottom of the pipe will be disturbed less, thereby reducing water discolouration.

Water utilities benefit from decreased pipe leaks and repairs as a result of a more stable system pressure. Utilities can better locate pipe leakages that commonly cause infiltration of dirt and potentially contaminated groundwater into the pipes. The need for fewer repairs results in fewer system shutdowns, which in turn keeps sediments undisturbed.

Each DMA should include a water sampling point. Regular sampling and testing will help to identify water quality issues and assist asset rehabilitation teams in identifying pipes that need replacement or repair.

Providing continuous (24/7) water supply

In some systems, the water supply is not continuously available to customers 24 hours a day, so they tend to hoard water whenever it is available in case of delays in getting reconnected. As a result, they often store more water than is required for the period of non-supply. When the water supply is reconnected, they then discard the old water and hoard fresh water once again. Water consumption per capita per day is therefore often much higher in intermittent supply systems compared to continuous supply systems.

Converting to a 24-hour supply will result in lower water consumption and lower demand from the water production plant. However, turning the entire network into 24-hour supply remains a challenge since the process normally requires five to seven days for the water consumption to decrease to normal (or actual use) levels. During this period, the demand would be so high that the system pressure would be greatly reduced, causing people to continue hoarding water.

DMA principles can be applied to convert from an intermittent to continuous water supply system. First, the water utility should consider installing a small number of DMAs that gradually feed continuous water supply, leading users in those DMAs to adjust to the new system and reduce excessive collection of water. Once consumption stabilises, the inflow volume into the DMAs should decrease within the five to seven day period. The water utility should then undertake leak detection activities and customer surveys to reduce water losses to an acceptable level, creating spare capacity at the production plant. This spare capacity represents additional water that can be supplied to other areas. Once these first DMAs have successfully supplied water continuously and effectively reduced water losses, then the next set of DMAs can be established for conversion to 24-hour supply.

The additional benefit of having 24-hour supply is that the pipe will be constantly pressurised, meaning that infiltration from outside the pipe is minimal. This will ensure that the quality of the water is kept to a premium and that the customer receives water of an acceptable quality.

Key Messages

- Dividing the open network into smaller, more manageable DMAs enables utility managers to manage the system more effectively in terms of pressure control, water quality, and NRW.
- Criteria in establishing DMAs include the size (or number of connections); number of valves that must be closed; number of flow meters; ground-level variations; and visible topographic features that can serve as DMA boundaries.
- Utility managers use the minimum night flow (MNF) and legitimate night flow (LNF) to calculate the net night flow (NNF), along with commercial losses, to determine NRW in a DMA
- Establishing DMAs helps to manage pressure, improve water quality, and enable continuous water supply.

Unit 9:

Monitoring Performance of NRW Management

Session: 1	Monitoring and performance indicators for NRW, physical losses and commercial losses	Duration: 1 hour

Learning Outcomes

After completing this session participants:

- Understand why monitoring performance is important and are able to do it in their organisation
- Are aware of performance indicators for NRW, physical losses and commercial losses and how they can apply them in their organisations.
- Are aware and know the importance of performance indicators in monitoring performance and are able to use them in monitoring.

Methods of Delivery

1	Facilitator makes a presentation, highlighting key points. Thirty (30) minutes.
2	Participants do an individual exercise focussing on sectorisation. Twenty (20) minutes.
3	Facilitator checks answers interactively and sees how the participants solved the problem. Depending on the result, he appropriately explains the solution and provides more explanations where needed. Ten (10) minutes.

Training Preparation/ Materials

- Computer and beamer
- Writing pads and pens
- Exercise

Key Reading Materials

- NRW Participants Manual

Session Guide

The facilitator must ensure that participants understand two important aspects about performance monitoring consisting of:

- The need to put in place a performance monitoring mechanism
- Appropriate selection of performance indicators that may be used in monitoring performance

Monitoring performance of NRW management

NRW is a measure of a utility's efficiency in terms of both operational performance and financial performance. Managers, policy-makers, regulatory agencies, and financing institutions use NRW performance indicators (PIs) to rank the utility's performance against industry standards and other water utilities. This chapter reviews common performance indicators for physical and commercial losses and briefly describes monitoring programmes.

Characteristics of performance indicators

Performance indicators help a utility:

- Better understand water losses
- Define and set targets for improvement
- Measure and compare performance
- Develop standards
- Monitor compliance
- Prioritise investments

A good NRW PI should be clear and easy to understand and have a rational basis. It should also be easy to calculate using data that the utility gathers regularly. Finally, utilities should include standard performance indicators to measure performance to facilitate comparisons with other utilities. Tools such as decision trees are available for managers to select appropriate performance indicators for their utility's needs and operating context.

Utility managers can use Figure 17 to help choose PIs for their network. For example, in an urban network, where the housing density is usually greater than 20 connections per kilometre of mains, the answer to the question in the middle box in the bottom row would be 'NO' and the PI would be litres/service connection/day. To take account of networks with varying pressures, the utility can enhance the PI by expressing losses in litres per connection per day per metre of pressure (l/conn/day/m).

Performance indicators for physical losses

Expressing NRW as a percentage

NRW has traditionally been expressed as a percentage of input volume. Although this is preferable to setting no targets at all, it is misleading as a PI because it favours utilities with high consumption, low pressure, and intermittent supply. In addition, it does not differentiate between physical losses and commercial losses. Nevertheless, NRW as a percentage of input is sometimes useful for its 'shock value'—a high result can be a spur a utility to initiate a study of the network's operational performance and to conduct a water balance calculation. It is also useful as a measure of the utility's year-on-year financial performance, as long as the measurement principles are consistent.

In that case, it should be expressed as the value, not the volume, of water lost.

Other performance indicators for physical losses

Appropriate indicators of physical losses include:

- Litres per service connection per day (l/c/d)
- Litres per service connection per day per metre of pressure (l/c/d/m pressure)
- Litres per kilometre of pipeline per day (l/km/d)

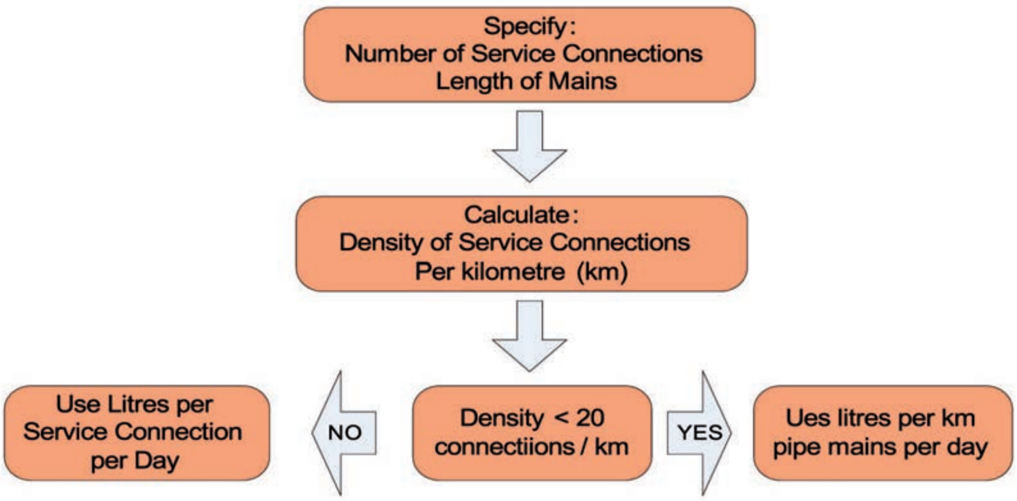


Figure 17 : Decision tree to select performance indicators
(Source: Malcolm Farley and Stuart Trow, Losses in Water distribution Networks, IWA Publishing, 2003)

Table 4 shows the Infrastructure Leakage Index (ILI) and other recommended NRW and physical loss performance indicators based on the IWA's Performance Indicators for Water Supply Services: IWA Manual of Best Practice. L/c/d gives a more accurate picture than NRW as a percentage of input volume, but taking system pressure into account (l/c/d/m pressure) is an even better indicator. The PIs are categorized by function and level, defined as follows:

- Level 1 (basic): 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 4: 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 (Intermed.)	[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 indictor 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 900222272

The Infrastructure Leakage Index (ILI)

The Infrastructure Leakage Index (ILI) is an excellent indicator of physical losses, one that takes into account how the network is managed. The IWA, which developed the index, and the American Water Works Association (AWWA) Water Loss Control Committee both recommend this indicator.

The ILI is particularly useful in networks where NRW is relatively low, for example below 20%, as the ILI can help to identify which areas can be reduced further.

The ILI is a measure of how well a distribution network is managed (i.e. maintained, repaired, and rehabilitated) for the control of physical losses, at the current operating pressure. It is the ratio of Current Annual Volume of Physical Losses (CAPL) to Minimum Achievable Annual Physical Losses (MAAPL).

ILI = CAPL/MAAPL

Being a ratio, the ILI has no units and thus facilitates comparisons between utilities and countries that use different measurement units. The complex initial components of the MAAPL formula have been converted to a format using a pre-defined pressure for practical use:

MAAPL (litres/day) = (18 x Lm + 0.8 x Nc + 25 x Lp) x P

Where Lm = mains length (km); Nc = number of service connections; Lp = total length of private pipe, property boundary to customer meter (km); and P = average pressure (m).

Figure 18 illustrates the ILI concept with the factors that influence leakage management. The large square represents the CAPL, which tends to increase as the distribution networks grow older. This increase, however, can be constrained by a successful leakage management policy. The black box represents the MAAPL, or the lowest technically achievable volume of physical losses at the current operating pressure.

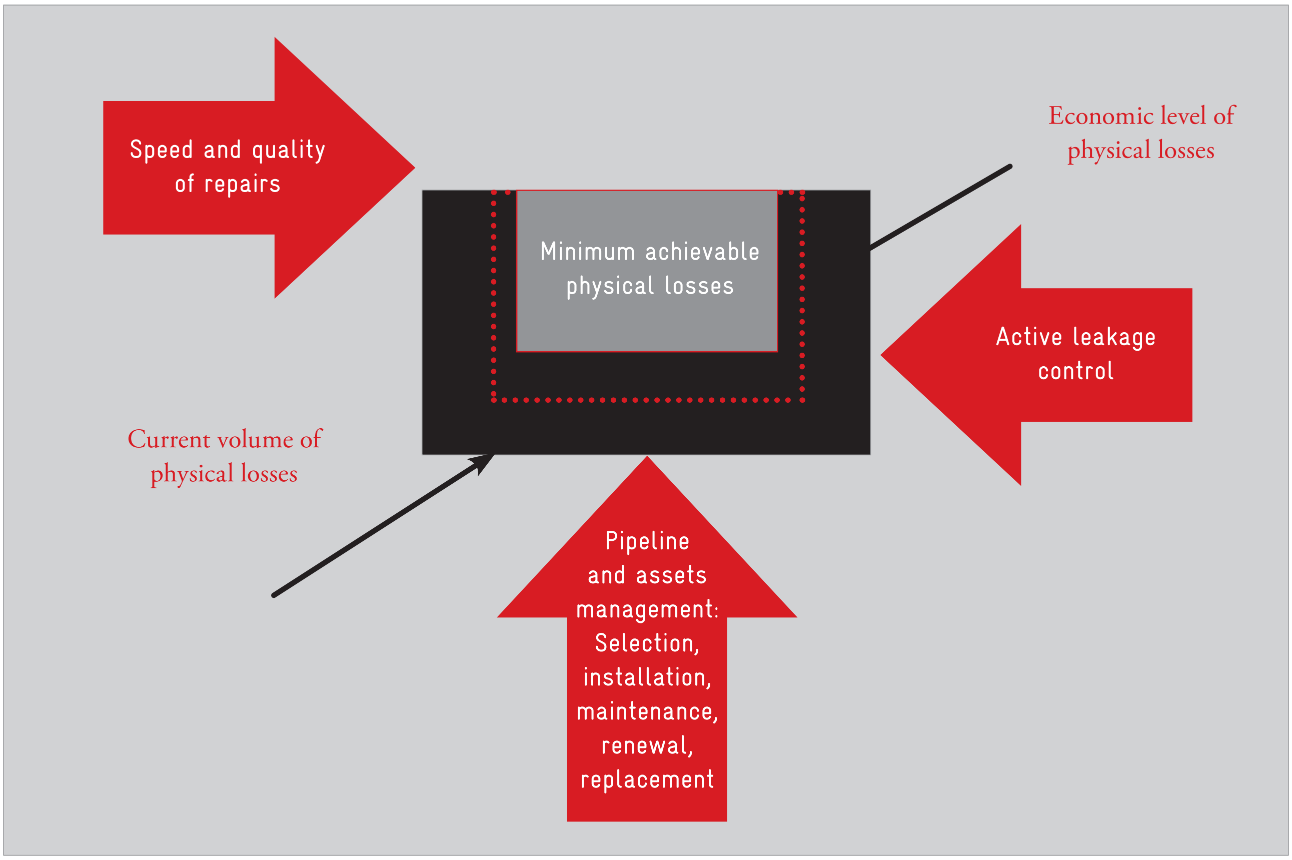


Figure 18 : The ILI Concept

The ratio of the CAPL to MAAPL, or the ILI, is a measure of how well the utility implements the three infrastructure management functions—repairs, pipelines and asset management, and active leakage control. Although a well-managed system can have an ILI of 1.0 (CAPL = MAAPL), the utility may not necessarily aim for this target, since the ILI is a purely technical performance indicator and does not take economic considerations into account.

Calculating the ILI

- Step 1. Calculate the MAAPL
- Step 2. Calculate the CAPL (e.g. from the Water Balance)
- Step 3. Calculate the ILI (CAPL/MAAPL)
- Step 4. Adjust for intermittent supply (divide MAAPL by the average number of supply hours per day)
- Step 5. Compare ILI with physical loss target matrix

The physical loss target matrix shows the expected level of ILI and physical losses in l/c/day from utilities in countries at differing levels of network pressure. Utility managers can use the matrix to guide further network development and improvement:

- Category A — Good. Further loss reduction may be uneconomic and careful analysis needed to identify cost-effective improvements.
- Category B — Potential for marked improvements. Consider pressure management, better active leakage control, and better maintenance.
- Category C — Poor. Tolerable only if water is plentiful and cheap, and even then intensify NRW reduction efforts.
- Category D — Bad. The utility is using resources inefficiently and NRW reduction programmes are imperative.

Table 5: Physical loss target matrix

Technical Performance Category		ILI	Physical Losses [litres/connection/day] (when the system is pressured) at an average pressure of:				
			10m	20	30	40	50
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 – 2	< 50	< 100	< 150	< 200	< 250
	B	2 – 4	50 – 100	100 – 200	150 – 300	200 – 400	250 – 500
	C	4 – 8	100 – 200	200 – 400	300 – 600	400 – 800	500 – 1000
	D	> 8	> 200	> 400	> 600	> 800	> 1000

Source: World Bank Institute

Performance indicators for commercial losses

The IWA Water Loss Task Force is also developing a performance indicator for commercial losses similar to the ILI. The indicator uses a base value of 5% of water sales as a reference, and the actual commercial loss value is calculated against this benchmark. This is the Apparent (Commercial) Loss Index (ALI).

Apparent Loss Index (ALI) =
Apparent loss value ÷ 5% of water sales

A commonly used indicator that expresses commercial losses as a percentage of water supplied is misleading because it does not reflect the true value of lost revenue.
Currently, the best indicator is to measure commercial losses as a percentage of authorised consumption.

Implementing a monitoring programme

A water utility embarking on the implementation of an NRW strategy needs to monitor its progress using some or all of the indicators detailed above. Since it is a utility-wide undertaking, an independent team should be established to audit progress. This NRW audit team should not be responsible for any physical activities to reduce NRW, but should be dedicated to auditing all of the departments involved with NRW strategy activities.

The implementation of the NRW strategy is a long-term process, often requiring four to seven years to complete. During this time, staff changes will occur, and the NRW audit team should train all incoming staff on the NRW strategy and its importance to the company.

The NRW audit team should also establish yearly targets for each department using one or more of the indicators, and monitor progress on a monthly progress. The number and type of indicators depends on the department and its activities. For example, the Network Department may be responsible for leakage detection and repair; in this case, the physical loss indicators of litres/connections/day and litres/connections/km can be used.

A monthly NRW strategy progress meeting should include representatives from all departments, with discussions on progress and hindrances. A senior member of the management team should chair the meeting, to stress the importance of the NRW strategy implementation. The head of the NRW audit team will support the chair by providing technical details and progress reports.

Key Messages

- Utility managers use performance indicators to measure progress in reducing NRW, develop standards, and prioritise investments.
- The best performance indicator for physical losses is the Infrastructure Leakage Index (ILI).
- Currently, the best commercial loss indicator is to measure it as a percentage of authorised consumption.
- Utility managers must establish an independent NRW audit team to monitor progress in the NRW strategy implementation.
- Performance targets should be set on a yearly basis with progress monitored and reported monthly.

References

- 'The Manager's Non Revenue Handbook, A guide to understanding Water Losses' by Malcom Farley, Gary Wyeth, Zainuddin Bin Md. Ghazali and Sher Singh, 2008 Runhill
- 'Losses in Water Distribution Networks, A practitioner's guide to Assessment, monitoring and Control' by Malcom Farley and Stuart Trow, 2003 IWA Publishing.
- Best Practice Performance Indicators for Non Revenue Water and Water Loss Components. A Practical Approach. Mckenzie, R and Lambert, AO. Water 21, Magazine of the International Water Association, August 2004.
- 'Illustrative Water Demand Management Plan and Guide for Preparation' Australia Environment Protection (Water) Policy 1997
- "Development of a standardised approach to evaluate bursts and background losses in water distribution systems in South Africa - SANFLOW". Report TT109/99, by the South African Water Research Commission, June 1999. ISBN No. 1 86845 490 8.
- "Development of a pragmatic approach to evaluate the potential savings from pressure management in potable was distributions in South Africa": PRESMAC. Report TT152/01 published by the South African Water Research Commission, July 2001. ISBN No. 1 86845 722 2
- "Development of a Windows based package for assessing appropriate levels of active leakage control in potable water distribution systems: ECONOLEAK. Report TT 169/02 published by the South African Water Research Commission, April 2002. ISBN No. 1 86845 832 6
- Aqualibre: A New Innovative Water Balance Software. Liemberger, R, and McKenzie, R. Paper presented at the IWA & AWWA Conference on Efficient Management of Urban Water Supply, Tenerife, April 2003.
- Water Demand Management Cookbook. Mckenzie, R, Buckle, H, Wegelin, W and Meyer, N. Manual on WDM produced for the UN Habitat, Rand Water,& WRP ISBN 0-620-30734-X, November 2003.
- 'Reducing Water Distribution System Losses, Best management practices: reducing water distribution system losses' by BCWWA for British Columbia, 2004.
- 'Water Demand Management, Guideline Training Material' by International Development Research Centre (IDRC), The World Conservation Union, version 1.1, 2004
- International Benchmarking of Leakage from Water Reticulation Systems. Seago, CJ, Mckenzie, RS & Liemberger, R. Proceedings from the International Water Association Specialist Conference:Leakage 2005, Halifax, Nova Scotia, Canada, pp 48-61. 12 - 14 September 2005.
- Benchmarking of Leakage from Water Reticulation Systems in South Africa. Mckenzie, RS & Seago, CJ. Report to the South African Water Research Commission. Report number TT 244/05, ISBN 1-77005-282-8. March 2005
- An assessment of Non-Revenue Water in South Africa. Seago, CJ and Mckenzie, RS. Report to the South African Department of Water Affairs and Forestry and the Water Research Commission. Report Number TT 300/07, ISBN 978-1-77005-529-2, January 2007.
- Hidden benefits of small-scale performance based Public Private Partnerships. Mckenzie, RS., Wegelin, W., Mohajane, P., and Shabalala, S. Proceedings from the International Water Association Specialist Conference: Leakage 2007, Bucharest, Romania, September 2007.
- 'Towards Climate Change Adaptation, Building Adaptive Capacity in Managing African Transboundary River Basins, Case Studies from African practitioners and researchers' by InWEnt, GTZ and other partners, 2008
- The Benefits of Non- Domestic Meter Audits and Retrofitting. Wegelin, WA. Mckenzie, R. & Davidson, D. Paper presented at the 2009 IWA Water Loss 2009 Conference in Cape Town, 26 to 30 April 2009.
- Implementation of Water Demand Management in South African Municipalities. Mckenzie, R. & Wegelin, WA. Presentation at the 2009 IWA Water Loss 2009 Conference in Cape Town, 26 to 30 April 2009.

Imprint

Wave Pool Zambia
Non-Revenue Water
Training Manual

Compiled by:
Stanislas Chisakuta, NRDC
Kennedy Mayumbelo, LWSC
Kennedy Mulenga, LBTC
Ison Simbeye, Consultant

Reviewed by:
Willem Wegelin, Wrp Consulting Engineers (PTY) Ltd (South Africa)
Ronnie Mckenzie, Wrp Consulting Engineers (PTY) Ltd (South Africa)
Stuart Hamilton, Hydro Tec (United Kingdom)
Supervision: Dieter Anders (GIZ)

Published by:
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
04519 Rackwitz (Zschortau), Germany

Layout: Nicole Fritsch
Photography: © giz

Germany, 2011

Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Lindenstr. 41, Zschortau
04519 Rackwitz
T +49 34202 845-0
F +49 34202 845-777
E info@giz.de
I www.giz.de