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THE MANAGER'S NON-REVENUE WATER HANDBOOK FOR AFRICA

A GUIDE TO UNDERSTANDING WATER LOSSES



MARCH 2010

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CONTENTS

- 1. INTRODUCTION 1**
- 1.1 BACKGROUND TO NRW..... 1**
- 1.2 CHALLENGES IN AFRICAN WATER UTILITIES 1**
- 1.3 IMPACTS OF NRW: THE VICIOUS AND VIRTUOUS CIRCLES 3**
- 1.4 ADDRESSING NRW 4**
 - 1.4.1 Reasons For Failure—And The Road To Success 4
 - 1.4.2 The Manager’s NRW Manual For Africa 6

- 2. KNOWING YOUR WATER LOSSES: THE WATER BALANCE 9**
- 2.1 HOW MUCH WATER IS BEING LOST? 9**
- 2.2 WATER BALANCE COMPONENTS: WHERE ARE YOUR LOSSES OCCURRING? 10**
- 2.3 KEY STEPS FOR CONDUCTING A WATER BALANCE 12**
- 2.4 IMPROVING THE ACCURACY OF WATER BALANCE RESULTS 16**
 - 2.4.1 Production Meter Accuracy..... 16
 - 2.4.2 Customer Meter Accuracy 17
 - 2.4.3 Customer Billing Cycle 18

- 3. DEVELOPING A STRATEGY TO REDUCE AND MANAGE NON-REVENUE WATER. 19**
- 3.1 ESTABLISHING THE STRATEGY DEVELOPMENT TEAM..... 19**
- 3.2 IMPORTANCE OF SETTING APPROPRIATE NRW REDUCTION TARGETS..... 19**
- 3.3 PRIORITISING NRW REDUCTION COMPONENTS 20**
- 3.4 BASIC PREMISE OF NRW REDUCTION STRATEGY: AWARENESS, LOCATION, AND REPAIR (ALR)..... 22**
- 3.5 BUDGET CONSIDERATIONS FOR IMPLEMENTING THE STRATEGY..... 24**

- 4. RAISING AWARENESS ON THE STRATEGY 27**
- 4.1 GAINING HIGH-LEVEL APPROVAL 27**
- 4.2 BUILDING STAFF AWARENESS AND CONSENSUS 28**
- 4.3 REACHING OUT TO CUSTOMERS..... 31**

- 5. UNDERSTANDING COMMERCIAL LOSSES 35**
- 5.1 DEFINITION OF COMMERCIAL LOSSES..... 35**
- 5.2 COMMERCIAL LOSS ELEMENTS AND MANAGEMENT STRATEGIES 35**
 - 5.2.1 How To Address Customer Meter Inaccuracy..... 36
 - 5.2.2 Unauthorised Consumption 41

| | |
|---|-----------|
| 5.2.3 Meter Reading Errors | 42 |
| 5.2.4 Data Handling And Accounting Errors | 43 |
| 6. IDENTIFYING PHYSICAL LOSSES | 45 |
| 6.1 DEFINITION OF PHYSICAL LOSSES | 45 |
| 6.2 PHYSICAL LOSS ELEMENTS | 45 |
| 6.2.1 Leakage From Transmission And Distribution Mains | 45 |
| 6.2.2 Leakage And Overflows From The Utility's Reservoirs And Storage Tanks | 46 |
| 6.2.3 Leakage On Service Connections Up To The Customer's Meter | 47 |
| 6.3 CHARACTERISTICS OF LEAKAGES | 47 |
| 6.4 DEVELOPING A LEAKAGE MANAGEMENT STRATEGY | 48 |
| 6.4.1 Active Leakage Control (ALC) | 49 |
| 6.4.2 Pressure Management | 53 |
| 6.4.3 Speed And Quality Of Repairs..... | 56 |
| 6.4.4 Asset Management..... | 56 |
| 7. UNDERSTANDING DISTRICT METER AREAS..... | 59 |
| 7.1 DMA ESTABLISHMENT CRITERIA AND PROCESS | 59 |
| 7.2 USING DMA RESULTS TO REDUCE NRW LEVELS | 62 |
| 7.2.1 Estimating Physical Losses | 63 |
| 7.2.2 Determining Commercial Losses | 65 |
| 7.3 DMA MANAGEMENT APPROACH..... | 66 |
| 7.4 ADDITIONAL BENEFITS OF THE DMA..... | 67 |
| 7.4.1 Improved Pressure Management..... | 68 |
| 7.4.2 Safeguarding Water Quality..... | 68 |
| 7.4.3 Providing Continuous (24/7) Water Supply | 68 |
| 8. MONITORING PERFORMANCE OF NRW MANAGEMENT | 71 |
| 8.1 CHARACTERISTICS OF PERFORMANCE INDICATORS..... | 71 |
| 8.2 PERFORMANCE INDICATORS FOR PHYSICAL LOSSES..... | 71 |
| 8.2.1 Expressing NRW As A Percentage..... | 71 |
| 8.2.2 Other Performance Indicators For Physical Losses | 72 |
| 8.2.3 The Infrastructure Leakage Index (ILI)..... | 73 |
| 8.3 PERFORMANCE INDICATORS FOR COMMERCIAL LOSSES..... | 75 |
| 8.4 IMPLEMENTING A MONITORING PROGRAM..... | 76 |
| 9. BUILDING CAPACITY TO MANAGE NRW THROUGH UTILITY-TO-UTILITY TWINNING PARTNERSHIPS: CASE STUDIES..... | 77 |
| 9.1 TWINNING APPROACH | 77 |

| | |
|--|------------|
| 9.1.1 Facilitating Linkages | 77 |
| 9.1.2 Understanding Priorities And Setting Goals..... | 78 |
| 9.2 TWINNING ACTIVITIES IN AFRICA..... | 79 |
| 9.2.1 Water Operator Partnerships (Wops) | 79 |
| 9.2.2 The Kiwasco Model | 80 |
| 9.3 TWINNING ACTIVITIES IN ASIA..... | 81 |
| 9.3.1 The Bac Ninh Model | 81 |
| 9.4 PROMOTING TWINNING PARTNERSHIPS | 82 |
| | |
| ANNEX 1: GLOSSARY..... | 85 |
| ANNEX 2: LOCATING AND REDUCING UNAUTHORISED CONSUMPTION | 40 |
| ANNEX 3: STEPS FOR CALCULATING NRW USING THE IWA WATER BALANCE TABLE..... | 95 |
| ANNEX 4: SAMPLE WATER AUDIT CHECKLIST..... | 101 |
| ANNEX 5: SELF-ASSESSMENT MATRIX FOR NRW MANAGEMENT..... | 105 |

TABLES, FIGURES, AND BOXES

TABLE

| | |
|---|----|
| Table 2.1: Indicative Examples Of Meter Accuracy | 16 |
| Table 3.1: Volume And Cost Analysis For NRW Management Activities | 22 |
| Table 6.1: Flow Rates For Reported And Unreported Bursts..... | 46 |
| Table 6.2: Calculating Background Losses | 46 |
| Table 8.1: Recommended Indicators For Physical Losses And NRW | 73 |
| Table 8.2: Physical Loss Target Matrix | 75 |

FIGURE

| | |
|--|----|
| Figure 1.1: The Vicious NRW Circle..... | 3 |
| Figure 1.2: The Virtuous NRW Circle | 3 |
| Figure 1.3: Reducing NRW Is Everyone’s Responsibility | 5 |
| Figure 2.1: Water Balance Showing NRW Components..... | 9 |
| Figure 3.1: Identifying The Economic Level Of NRW | 20 |
| Figure 3.2: The Effect Of Time On The Total Volume Lost..... | 23 |
| Figure 4.1: Chart To Help Staff Understand NRW Components..... | 30 |
| Figure 5.1: Four Pillars Of Commercial Losses | 36 |
| Figure 6.1: Leak Run Time And Volume Of Water Loss..... | 48 |
| Figure 6.2: The Four Pillars Of A Successful Leakage Management Strategy..... | 49 |
| Figure 6.3: A Typical Distribution Network..... | 50 |
| Figure 6.4: Pressure/Leakage Relationship..... | 54 |
| Figure 7.1: Typical DMA Layout | 61 |
| Figure 7.2: Typical 24-Hour DMA Flow Profile..... | 64 |
| Figure 7.3: DMA Flow And Pressure Relationship Over A Three-Day Period..... | 65 |
| Figure 7.4: NNF Against Time..... | 66 |
| Figure 7.5: Moving From Leak Detection And Repairs To Pipe Rehabilitation..... | 67 |
| Figure 8.1: IWA Decision Tree To Select Performance Indicators | 72 |
| Figure 8.2: The ILI Concept..... | 74 |

BOX

| | |
|--|----|
| Box 1.1: Why Do Utilities Struggle With NRW Reduction? | 3 |
| Box 2.1: WB-EASYCALC | 14 |
| Box 2.2: AQUALITE | 15 |
| Box 7.1: Network Modelling..... | 60 |
| Box 9.1: Twinning And Water Operator Partnerships | 77 |
| Box 9.2: Twinning Principles | 78 |
| Box 9.3: Basic Steps In Establishing Twinning Partnerships | 79 |

FOREWORD

One of the major challenges facing water utilities in the developing world is the high level of water losses—from physical losses (leakage), theft of water from the system, or because water users are not being properly billed. This difference between the amount of water put into the distribution system and the amount of water billed to consumers is known as “Non Revenue Water” (NRW). This has a serious effect on the financial viability of water utilities through lost revenue, lost water resources, and increased operational costs, reducing their capacity to fund necessary expansions of service, especially for the poor.

For too long NRW management has been given low priority by government officials, utility managers, donors and the water sector in general. However, over the last decade perceptions have changed rapidly, particularly in the developed world. The International Water Association (IWA) has acknowledged this trend by forming the Water Loss Task Force (WLTf), which over the last 8 years has played a major role in developing, standardizing and disseminating methodologies for addressing NRW.

It is now widely acknowledged that NRW is a key indicator of a utility’s operational and financial performance. A high level of NRW normally indicates a water utility that lacks good governance, autonomy, accountability, and the technical and managerial skills necessary to provide a reliable service.

The African Water Association (AfWA) has identified NRW as a priority issue within its capacity building programs, delivering technical sessions to raise the awareness of African water utilities to NRW. Challenges include:

- Old pipe networks dating from the independence period of the 1960s
- Lack of knowledge of the water networks (inadequate records, rapid urbanization)
- Low perception of NRW by utility management

Recently established in Kampala, Uganda, AfWA’s African Water Academy is dedicated to leadership development and change management, specializing in capacity building for senior utility managers. The Water Operators’ Partnership Africa Program (WOP Africa) is also enhancing utility to utility capacity building. These are two major instruments that AfWA will be using to deliver high level management and technical training to address NRW.

The Manager’s Non-Revenue Water Handbook for Africa: A Guide to Understanding Water Losses—is a timely publication. Written in a clear style and in user-friendly language the Manual’s structure gives managers and technical staff the opportunity to understand the factors that influence NRW and the solutions for managing it. Drawing on case study examples and key messages from African utilities the manual aims to offer practical solutions to the NRW challenges, so that in future utility managers will be in a better position to tackle the challenges associated with this issue.

Water utility managers are encouraged to use the Manual, taking advantage of the depth of knowledge and experience that has been developed in recent years. This will enable managers to build up a skilled NRW management team, and to acknowledge the challenges and shortfalls within their particular utility. This will in turn encourage the water sector in Africa as a whole to come closer to achieving the **Millennium Development Goals** for water and sanitation services.

Sylvain Usher
Secretary General, African Water Association

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The manual has been adapted for African utility managers by Malcolm Farley, using case studies and other material from several sources:

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1. INTRODUCTION

1.1 BACKGROUND TO NRW

The global volume of non-revenue water (NRW) is staggering. Each year more than 32 billion m³ of treated water are lost through leakage from distribution networks. An additional 16 billion m³ per year are delivered to customers but not invoiced because of theft, poor metering, or corruption. A conservative estimate of the total annual cost to water utilities worldwide 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 half of this amount would supply water to an additional 100 million people without further investment.¹



By reducing water losses, water utilities have additional supply to expand services to underserved areas.

Other benefits from reducing NRW include the following:

- Water utilities gain access to a further US\$3 billion in self-generated cash flow
- Reducing illegal connections supports greater fairness between users
- More efficient and sustainable utilities improves customer service
- New business opportunities creates thousands more jobs

In Africa, many water utilities operate under the jurisdiction of municipal, provincial, or central governments. These utilities often rotate or appoint senior managers and directors with backgrounds in various disciplines beyond the water sector. As a result, senior managers entering these positions have limited knowledge of water supply operations, especially on the vital technical and institutional requirements for effectively managing NRW and water losses. This handbook serves to assist senior managers of water utilities in better understanding the definition, causes, and practical solutions to address NRW, a key performance indicator for a utility's operations. It provides the information that managers need when discussing NRW-related issues with their staff. By design, it is not a hands-on technical guide for engineers to manage NRW, but rather is a reference for senior managers.

Lessons from utilities' own experiences, case studies, and examples of twinning projects have contributed to the development of *The Manager's Non-Revenue Water Handbook for Africa*.

1.2 CHALLENGES IN AFRICAN WATER UTILITIES

There are areas of plentiful water across Africa, just as there are water-scarce areas, as a result of both regional geography and a country's ability to develop and efficiently manage water systems. The photos below illustrate the inequity of water availability between communities. Although reducing NRW cannot

¹ Source: World Bank Discussion Paper No. 8, December 2006.

solve such regional contrasts, it can help to improve the quantity and quality of water available in water-scarce areas.



A NRW reduction strategy can help to improve the quantity and quality of water supplies, and the burden of collecting water, in water scarce areas.

Not all countries or regions of Africa have the infrastructure and established operational procedures to begin tackling NRW. Many are struggling to ensure that customers receive a reasonable water supply to sustain health and life. Water utility managers in most African countries will invariably face greater challenges including the following:

- Rapid urbanization
- Diminishing water supply
- Environmental pollution
- Outdated infrastructure
- Poor operations and maintenance policy, including ineffective record-keeping systems
- Inadequate technical skills and technology
- Greater financial constraints, including an unsuitable tariff structure and/or revenue collection policy
- Political, cultural, and social influences
- A higher incidence of commercial losses, particularly illegal connections

However, African utility managers also have a number of strengths they can build on:

- A high work ethic and level of industriousness
- Ability to make do with available resources and materials
- Motivated staff with the potential for developing high technical capacity

These factors all influence the scope for managing losses and demand, and affect the pace of change. At the same time, continued NRW limits the financial resources available to tackle these challenges facing water utilities in Africa. This handbook enables water utility managers in the region to address the limitations, acknowledge the challenges, and make gradual improvements to current policies and practices.

1.3 IMPACTS OF NRW: THE VICIOUS AND VIRTUOUS CIRCLES

The ‘Vicious Circle’ of NRW (Figure 1.1) is one of the key reasons for poor company performance and results in both physical and commercial losses (see Chapters 5 and 6). Physical losses, or leakages, divert precious water from reaching customers and increase operating costs. They also result in larger investments than necessary to augment network capacity. Commercial losses, caused by customer meter inaccuracies, poor data handling, and illegal connections, reduce income and thereby financial resource generation.

The challenge for water utility managers is to turn the Vicious Circle into the ‘Virtuous Circle’ (Figure 1.2). In effect, reducing NRW releases new sources of both water and finances. Reducing excessive physical losses results in a greater amount of water available for consumption and postpones the need for investing in new sources. It also lowers operating costs. Similarly, reducing commercial losses generates more revenues.

BOX 1.1: WHY DO UTILITIES STRUGGLE WITH NRW REDUCTION?

- Not understanding the problem (magnitude, sources, costs)
- Lack of capacity (insufficient trained staff)
- Inadequate funding to replace infrastructure (pipes; meters)
- Lack of management commitment
- Weak enabling environment and performance incentives

Bill Kingdom, Roland Liemberger, Philippe Marin, “The Challenge of Reducing Non-Revenue Water in Developing Countries-- How the Private Sector Can Help: A Look at Performance-Based Service Contracting”, World Bank, Paper No. 8, Dec 06.

FIGURE 1.1: THE VICIOUS NRW CIRCLE

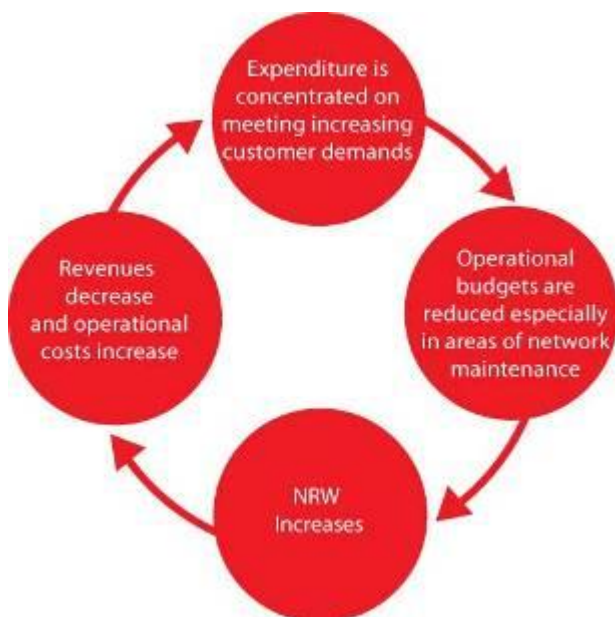


FIGURE 1.2: THE VIRTUOUS NRW CIRCLE





Replacing aging infrastructure requires financial capacity, which can be gained through NRW reduction.

1.4 ADDRESSING NRW

Water utilities anywhere in the world can use a diagnostic approach, followed by the implementation of solutions that are practicable and achievable to reduce NRW. The first step is to learn about the network and operating practices. Typical questions during this process include:

- How much water is being lost?
- Where are losses occurring?
- Why are losses occurring?
- What strategies can be introduced to reduce losses and improve performance?
- How can we maintain the strategy and sustain the achievements gained?²

1.4.1 REASONS FOR FAILURE—AND THE ROAD TO SUCCESS

Although minimising non-revenue water should be a priority for water utilities, many still struggle to achieve acceptable NRW levels. The reasons NRW strategies fail range from not understanding the magnitude of the problem to lack of financial or human resource capacity. There may also be inadequate funding to replace infrastructure, lack of management commitment, or a weak enabling environment and performance incentives.

NRW management is not a one-off activity, but one requiring a long-term commitment and involvement of all water utility departments. Many utility managers do not have access to information on the entire network, which would enable them to fully understand the nature of NRW and its impact on utility operations, its financial health, and customer satisfaction. Underestimating NRW's complexity, and the potential benefits of reducing NRW, often lead to reduction programmes' failure. Successful NRW reduction is not about solving an isolated technical problem, but is instead tied to overall asset management, operations, customer support, financial allocations, and other factors (Figure 1.3).

² Kingdom, B., R. Liemberger, and P. Marin, 2006. "The Challenge of Reducing Non-Revenue Water in Developing Countries—How the Private Sector Can Help: A Look at Performance-Based Service Contracting", World Bank, Paper No. 8, Dec 2006.

FIGURE 1.3: REDUCING NRW IS EVERYONE'S RESPONSIBILITY



Poor governance also affects NRW reduction. Utility managers often lack the autonomy, accountability, and technical and managerial skills necessary to provide reliable service. The utility's management should also tackle organisational challenges, such as policy barriers, inadequate technical capacity, and aging infrastructure. Finally, poor project design hinders efforts to reduce NRW, particularly underestimating the required budget.

However, utility managers' understanding of the institutional dimension of NRW is growing. In addition, a number of tools are emerging to support sustainable NRW reduction:

- New methodologies that quantify physical and commercial losses more accurately
- More effective technical approaches to manage leakage and reduce system pressure
- New instruments for engaging the private sector, such as performance-based contracts

1.4.2 THE MANAGER'S NRW MANUAL FOR AFRICA

Most developed countries have a solid infrastructure and established operational practices for managing and controlling non-revenue water (NRW). This is not always the case in developing countries; many are struggling to ensure that customers receive a reasonable supply of safe drinking water, often via a pipe network that is inadequate, with poor record systems and a low level of technical skills and technology. Customer metering is not always universally applied, and tariff systems and revenue collection policies often do not reflect the true value of water supplied. This limits the utility's cost recovery and encourages customers to under-value the service.

Developing countries in Africa face similar challenges in reducing NRW, including aging infrastructure, financial constraints, poor governance, and poor project design. However, many utilities in the region can draw on examples of good practice by other utilities. They can also usually depend on motivated and industrious staff to implement solutions once the challenges of reducing NRW have been identified.

Using some key messages, the Manager's NRW Handbook for Africa leads the utility manager through the stages of addressing NRW; first, understanding and quantifying NRW, and then developing a strategy to address it.

Chapter 1 examines the scale of NRW, and emphasises the challenges to African water utilities. Utility managers and operational staff should be committed to managing NRW as a long-term process that incorporates numerous aspects of water operations. Addressing NRW is the responsibility of managers across the water utility, including finance and administration, production, distribution, customer service, and other departments. Utilities must end a cycle, known as the 'Vicious Circle', where companies face increased NRW, financial losses, limited investment and poor service. Instead, utilities should follow the 'Virtuous Circle' that enables them to decrease NRW, improve efficiency, preserve financial resources and promote strong customer satisfaction and willingness to invest.

Chapter 2 highlights the need to understand and accurately quantify NRW as an indicator of a water utility's operating efficiency. The International Water Association (IWA) water balance is an excellent method for utility managers to break down and identify the key components of NRW. Ensuring the accuracy of data used to calculate the level of NRW is also essential in understanding the full problem. Collecting accurate data from production meters and customer meters helps to measure the true NRW level. In addition, the customer 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.

Chapter 3 considers the requirements to develop an NRW reduction strategy. Utilities need to consider establishing an NRW management team to develop a strategy, ensure that all components of NRW are addressed, and verify that the proposed strategy is feasible and practicable in terms of the workload and budget. Choosing the right team members promotes ownership among the various utility departments involved in the strategy's implementation, and also facilitates consensus at the senior management level. As a first step in developing the strategy, the team should set an initial utility-wide target for NRW reduction based on the economic level of NRW. The team can balance the financial and water supply objectives of the strategy using the water balance results, while aiming to shorten the awareness, location, and repair (ALR) times in addressing water losses. The NRW strategy may cover a period of four to seven years. As a result, pilot projects can help water managers understand the full budget and resources required to implement the entire strategy.

Chapter 4 emphasises the level of awareness required at all levels—from top decision-makers to the end consumer—that is critical for a successful NRW reduction programme. Support from the programme’s top-level management, and the budget required, has a ‘cascade effect’ on other levels of management and promotes 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. Also, reaching out to customers helps increase their awareness of NRW and how reducing water losses results in improved water supply and quality.

Chapter 5 addresses commercial losses. Commercial losses represent lost revenue, and even a small volume will have a large financial impact. They occur mostly through tampered meters, aging and improperly maintained meters, unauthorised connections, administrative errors and even corrupt practices during the meter reading and billing process. Utilities should invest in training for meter readers, staff, and crews, as well as in accurate meters and a robust billing system, which can directly result in higher returns. In addition, collaboration from the public and certain government departments is required to overcome theft and illegal use of water.

Chapter 6 examines physical losses. These include leakage on transmission and distribution mains; leakage and overflows from storage tanks; and leakage on service connections up to the customer meter. Leakage from transmission and distribution mains are usually large events that can cause serious damage, but the public typically reports them rapidly, followed the utility repair on an emergency basis. Other 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.

Chapter 7 deals with zoning. Dividing an open water supply network into smaller, more manageable zones or district meter areas (DMAs) is now internationally accepted best practice. It enables the utility to better understand the network, and to more easily analyse pressure and flows in problem areas. The criteria for 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.

Chapter 8 gives an indication of the range of performance indicators (PIs) available to utility managers. PIs are an aid to measuring progress in reducing NRW, developing standards, and prioritising investments. The International Water Association (IWA) recommends the Infrastructure Leakage Index (ILI) as the best performance indicator for physical losses. Currently, the best PI for commercial losses is to express them as a percentage of authorised consumption. The IWA is developing another indicator for commercial losses - the Apparent Loss Index (ALI). Utility managers should develop and implement monitoring programs to ensure their NRW targets are being met.

Chapter 9 discusses some options for building capacities for managing NRW through ‘twinning’ arrangements, or utility to utility partnerships. Water service providers worldwide have demonstrated the value of twinning, or focused and sustained exchange between practitioners, in promoting the adoption of improved policies and best practices, and in building human and institutional capacity. Twinning partnerships rely on counterpart exchange to help strengthen the capacity of a utility to improve services delivery (such as NRW reduction), expand services or convert to continuous water supply. Effective

twinning partnerships are demand driven, address the interests and priorities of partners, are results oriented and aim at the adoption and replication of best practices from one partner to another. There are several good examples of twinning projects in Africa, supported by AfWA and WOP, which disseminate, replicate, and strengthen the results of such twinning partnerships.

NRW is a global problem requiring a management strategy that can be globally applied. Developing such a strategy requires a diagnostic approach—firstly to identify the problem, and then to use the available tools to reduce or remove it. Following a step-wise process - asking some basic questions about the utility policies and practices—then applying the appropriate tasks to answer them—is the basis of a successful strategy development.

The philosophies, concepts and recommendations contained in the Managers' NRW Handbook closely reflect international best practice, particularly those recommended by the IWA and the World Bank Institute. If African utilities apply the approach recommended in the Handbook they will rapidly benefit from a greater understanding of their networks' performance, and will have an increased knowledge of the tools available to identify and reduce their levels of NRW.

Key Messages

- Reducing NRW increases both financial resources and the water available to utilities.
- Developing countries in Africa face challenges in reducing NRW, such as aging infrastructure, financial constraints, poor governance, and poor project design; however, they may draw on examples of good practice demonstrated by other African utilities to transfer knowledge and motivate staff.
- The Vicious Circle leads to increasing NRW and financial losses, while the Virtuous Circle leads to decreasing NRW and financial resources.
- Managing NRW is a long-term process that must incorporate numerous aspects of water operations.
- Addressing NRW is the responsibility of managers across the water utility, including finance and administration, production, distribution, customer service, and other departments. *The Manager's NRW Handbook for Africa* can help utility managers identify sources of NRW and develop a strategy for reducing them.

2. KNOWING YOUR WATER LOSSES: THE WATER BALANCE

To most water utilities, the level of NRW is a key performance indicator of efficiency. However, most utilities tend to underestimate NRW because of institutional and political pressures, as well as a lack of knowledge to properly determine the NRW level. Reports of low levels of NRW are eagerly accepted by senior managers. However, *reported* low levels of NRW, whether due to deliberate misinformation or, more likely, a lack of accurate information, will not help the water utility to reduce its costs or increase revenue. Instead, it will mask the real problems affecting the water utility’s operating efficiency.

Only by quantifying NRW and its components, calculating appropriate performance indicators, and turning volumes of lost water into monetary values, can the NRW situation be properly understood and the required actions taken. The utility manager now has a powerful tool to support this first step—the water balance calculation. This chapter introduces the water balance concept and gives two examples of water balance software, WB-EasyCalc and Aqualite. This software assists managers in developing the water balance while also indicating the level of accuracy of the NRW calculation.

2.1 HOW MUCH WATER IS BEING LOST?

The first step in reducing NRW is to develop an understanding of the ‘big picture’ of the water system, which involves establishing a water balance (also called a ‘water audit’ in the US). This process helps utility managers to understand the magnitude, sources, and cost of NRW. The International Water Association (IWA) has developed a standard international water balance structure and terminology that has been adopted by national associations in many countries across the world (Figure 2.1).

FIGURE 2.1: WATER BALANCE SHOWING NRW COMPONENTS

| | | | | |
|---|---|---------------------------------------|--|-------------------------------|
| System Input Volume (allow for known errors) | Authorized Consumption | Billed Authorized Consumption | Billed Metered Consumption | Revenue Water |
| | | | Billed Unmetered Consumption | |
| | | Unbilled Authorized Consumption | Unbilled Metered Consumption | Non-Revenue Water (NRW) |
| | | | Unbilled Unmetered Consumption | |
| | Water Losses | Commercial Losses | Unauthorized Consumption | |
| | | | Customer Metering Inaccuracies and Data Handling Errors | |
| | | Physical Losses | Leakage on Transmission and/or Distribution Mains | |
| | | | Leakage and Overflows at Utility’s Storage Tanks | |
| | Leakage on Service Connections up to Point of Customer Use | | | |

Water Losses refer to the total amount of water flowing into the water supply network from a water treatment plant, borehole system or imported bulk water supply (the ‘System Input Volume’) minus the total amount of water that consumers (domestic, commercial, industrial and institutions) are *authorised to use* (the ‘Authorised Consumption’)

Non-revenue water (NRW) is equal to the total amount of water flowing into the water supply network from a water treatment plant, borehole system or imported bulk water supply (the ‘System Input Volume’) minus the total amount of water that consumers (domestic, commercial, industrial and institutions) are authorised to use *and are billed for* (the ‘Billed Authorised Consumption’).

$$NRW = \text{System Input Volume} - \text{Billed Authorised Consumption}$$

This equation assumes that:

- System input volume has been corrected for any known errors
- The billed metered consumption period for customer billing records are consistent with the System Input Volume period

Utility managers should use the water balance to calculate each component and determine where water losses are occurring, as described in the next sections. They will then prioritise and implement the required policy changes and operational practices.

NRW components cover the entire water utility supply system from the water treatment plant, borehole system or imported bulk water supply outlet meters to the customer meters, which means that managing NRW is the responsibility of the entire operations department. Water utilities often set up a dedicated ‘NRW team’, with disappointing results as everyone else in the company leaves NRW management to this team. As illustrated in Figure 1.3, and discussed further in Chapters 3 and 4, an NRW reduction strategy should encompass all staff with each department’s responsibilities outlined in detail.

2.2 WATER BALANCE COMPONENTS: WHERE ARE YOUR LOSSES OCCURRING?

Abbreviated definitions of the principal IWA water balance components are outlined in this section (see Annex 1: Glossary for other definitions)³:

- **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.

³ See more detailed descriptions of each component and their measurement in the IWA reference manual by Farley, M. and S. Trow, 2003. *Losses in Water Distribution Networks—A Practitioner’s Guide to Assessment, Monitoring, and Control*. IWA Publishing: ISBN 1 900222 11 6. <http://www.iwapublishing.com/template.cfm?name=isbn1900222116>

- **Water Losses** is the difference between System Input Volume and Authorised Consumption. It consists of Commercial Losses and 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 volumes lost through all types of leaks, bursts and overflows on mains, service reservoirs and service connections, up to the point of customer metering.

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 results—‘garbage in, garbage out’.



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

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. 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 (see Section 2.4.3 on ‘Customer billing cycles’ below). There is generally a lag of up to 30 days between the time when water is consumed and when the meter is read. 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 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 authorised 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 authorised 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.

Note: The water balance is an annual **volume** calculation. Commercial Loss volumes result in a loss of income to the company but they are based on actual volumes distributed to the customer that have not been measured correctly or paid for.

Loss of **income** through poor collection efficiency, debt recovery etc. is a **financial** loss to the company - one that can be addressed through a more efficient bill collection policy. But it is not part of the standard annual water balance.

2.3 KEY STEPS FOR CONDUCTING A WATER BALANCE

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

- 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 a water balance are summarised below (see a detailed description in Annex 3: Steps for Calculating NRW Using the IWA Water Balance):

- 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 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 methodologies⁴:

- Component analysis of physical losses (see Chapter 6), using the network information required listed in Table 2.1
- Measurement of leakage, using analyses of night flows into District Meter Areas (DMAs) (see Chapter 7)

⁴ These methodologies are briefly outlined Chapters 6 and 7, and explained in more detail in Losses in Water Distribution Networks.

BOX 2.1: WB-EASYCALC

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'.

One advantage of EasyCalc is that the software not only asks for physical data, but also for an assessment of the accuracy of those data. For example, when entering the production volume, the user must also estimate the accuracy of these 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.

BOX 2.2: AQUALITE

Aqualite is another example of water balance software. It is widely used in South African and other African utilities. The methodologies used in Aqualite also draw strongly on those recommended by IWA, and, like WB-EasyCalc, includes 95% confidence limits. The Aqualite model was developed by Ronnie Mckenzie and can be downloaded from the Water Research Commission (WRC) web site: www.wrc.org.za or obtained from: orders@wrc.org.za or:

Water Research Commission, Private Bag X03, Gezina 0031, South Africa

| Aqualite Water Balance Model - Version 2.0.1 (March 2007) - aqualite1.wbm | | | | |
|--|--|--|--|---|
| Water Balance For: AN Other Water Company | | | | |
| All Units: cubic meters | | | | |
| Period: January 2004 to December 2004 [366 days] | | | | |
| System Data Water Balance Performance Indicators | | | | |
| Total System Input (corrected for known factors) 23,000,000.00 ±2.6% | Authorised Consumption 12,000,000.00 ±1.6% | Billed Authorised Consumption 9,000,000.00 ±2.0% | Billed Metered Consumption 6,000,000.00 ±2.7% | Revenue Water 9,000,000.00 ±2.0% |
| | | | Billed Unmetered Consumption 3,000,000.00 ±2.4% | |
| | | Unbilled Authorised Consumption 3,000,000.00 ±2.4% Rand 15,000,000 | Unbilled Metered Consumption 1,000,000.00 ±3.2% | Non-Revenue Water 14,000,000.00 ±4.5% Rand 44,733,333 |
| | | | Unbilled Unmetered 2,000,000.00 ±3.2% | |
| | Water Losses 11,000,000.00 ±5.7% Rand 29,733,333 | Apparent Losses 2,577,777.78 ±1.9% Rand 12,888,889 | Unauthorised Consumption 1,500,000.00 ±3.2% | |
| | | | Customer Meter and Data Errors 1,077,777.78 | |
| | | Real Losses 8,422,222.22 ±7.5% Rand 16,844,444 | | |

More information on Aqualite can also be obtained from Ronnie Mckenzie, MD, WRP (Pty) Ltd. ronniem@wrp.co.za

2.4 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.

2.4.1 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, as shown in Table 2.1.

TABLE 2.1: INDICATIVE EXAMPLES OF METER ACCURACY

| Equipment/Method | Approximate Accuracy Range |
|------------------------------------|----------------------------|
| Electromagnetic Flow Meters | <0.15 - 0.5% |
| Ultrasonic Flow Meters | 0.5 - 1% |
| Insertion Meters | <2% |
| Mechanical Meters | 1.0 - 2% |
| Venturi Meter | 0.5 - 3% |
| Weirs in open channels | 10 - 50% |
| Volume calculated with pump curves | 10 - 50% |

Note: Actual meter accuracy will depend on many factors (like flow profile, calibration, meter installation, maintenance), and has to be verified case by case.

Source: World Bank Institute, 2007.

All meter types detailed above must be regularly maintained to ensure their continuing accuracy. Over time these 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.

AFRICAN UTILITY EXPERIENCE: USING THE WATER BALANCE TO MEASURE PERFORMANCE OVER TIME

| Water Balance : 2003 (m3/year) | | | | Water Balance: 2007 (m3/year) | | | | |
|----------------------------------|--|--|--|-------------------------------|--|---|--|----------------------------|
| Performance of Entebbe's Network | System Input Volume 2,512,357 (+/- 4%) | Authorized Consumption 1,717,886 | Billed Consumption 1,716,286 | Revenue Water 1,716,286 | System Input Volume 2,317,811 (+/- 2%) | Authorized Consumption 1,921,205 | Billed Consumption 1,919,105 | Revenue Water 1,919,105 |
| | | Water Losses 794,471 (+/- 12.6%) | Unbilled Consumption 1,600 (+/- 36.4%) | NRW 796,071 (+/- 12.6%) | | Commercial Losses 247,289 (+/- 14.9%) | Unbilled Consumption 2,100 (+/- 38.5%) | |
| | Physical Losses 547,182 (+/- 19.6%) | | Commercial Losses 177,101 (+/- 12.5%) | | Physical Losses 219,505 (+/- 23.4%) | | | |
| | | | | | Performance of Entebbe's Network | | | |

In Entebbe, one of the 22 towns in Uganda operated by National Water and Sewerage Corporation, the Water Balance was used to demonstrate the improvement in NRW reduction between 2003 and 2007: System Input Volume reduced and Billed Consumption increased—reducing the NRW by almost half.

The illustrations also show the 95% confidence limits around each of the calculated components.

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



Roof tanks with faulty float valves and aging meters are two sources of meter under-registration.

2.4.3 CUSTOMER BILLING CYCLE

When calculating the NRW value, 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 exactly the same 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.



Field verification of the network data is crucial to understanding where water losses originate and setting NRW baseline level.

AFRICAN UTILITY EXPERIENCE: ACCURATE NRW BASELINES

Ouagadougou, capital of Burkina Faso and managed by ONEA, is well performing public utility for the region, with a management emphasis on efficiency. Basic data to construct a water balance is available and accurate:

- Production metering is in place, with electromagnetic meters installed after 2005.
- A customer meter replacement program was completed in 2007.
- Customers are fully metered and there are no individual roof tanks.
- A service contract has resulted in a customer census, a meter workshop, improved collection efficiency and redesign of service connections.
- Commercial losses from illegal connections, meter under-registration, meter tampering and meter reading and data handling errors could be quantified.
- Verification of physical losses was done by carrying out measurements over 24 hours in one large zone.

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 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 time period used for the consumption volume measurement matches the production meter volume measurement.

3. DEVELOPING A STRATEGY TO REDUCE AND MANAGE NON-REVENUE WATER

The NRW challenge can only be properly understood after 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.

3.1 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.

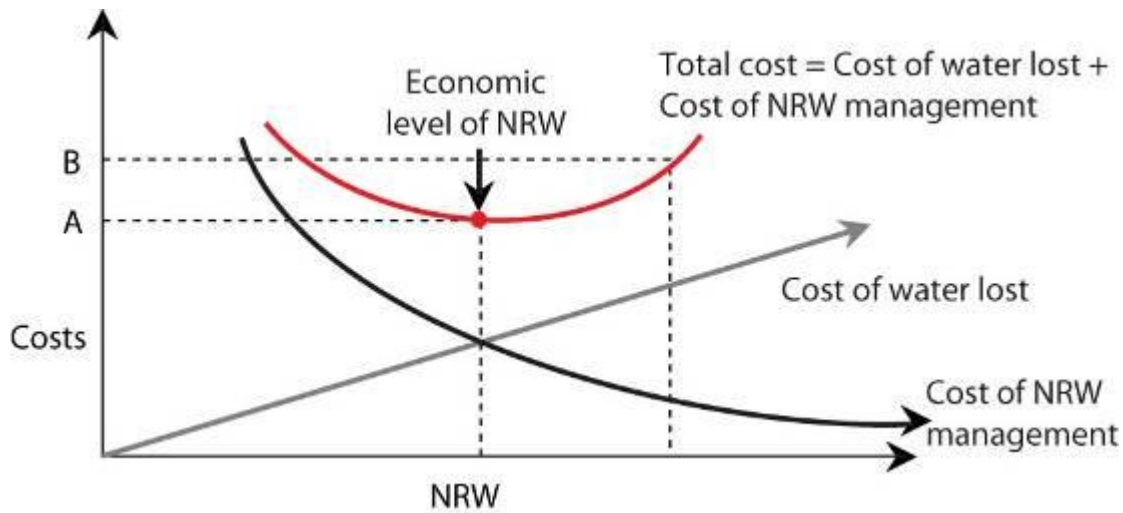
3.2 IMPORTANCE OF SETTING APPROPRIATE NRW REDUCTION TARGETS

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.

Figure 3.1 highlights how the economic level of NRW is determined. The two components that must be determined are the *cost of water lost* and the *cost of NRW management*:

- The cost of water lost is the value of the water lost through both physical and commercial losses. The volume of physical losses should be multiplied by the variable operational costs, including manpower, chemicals, and electricity. The volume of commercial losses should be multiplied by the average customer tariff. As NRW increases, the cost of water lost increases proportionally.
- The cost of NRW management is the cost of reducing NRW, including staff costs, equipment, transportation, and other factors. As NRW decreases, the cost of NRW management increases.

FIGURE 3.1: IDENTIFYING THE ECONOMIC LEVEL OF NRW



Adding the two cost components together gives the total cost. In Figure 3.1, the intersection of the two component lines coincides with the minimum total cost (cost A), which is the economic level of NRW.

The graph shows that letting NRW increase past the economic level reduces the cost of NRW management, but the total cost (cost B) will rise. Similarly, reducing NRW lower than the economic level of NRW will cost more than the potential savings. However, utility managers may sometimes decide to push NRW below the economic level, for example in areas where raw water is scarce or the image of the country requires low losses. In such cases, the difference between the cost of NRW management and the savings are usually subsidised by the government.

The economic level of NRW constantly changes with shifts in water tariffs, the cost of electricity and chemicals, staff salaries, and equipment supply costs. Managers should assess the economic level of NRW on a yearly basis and adjust the NRW target accordingly to ensure the efficient use of resources.

3.3 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.



Ensuring customer meter accuracy is just as important as sealing pipe leakages. Faulty meters require immediate replacement.

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.

AFRICAN UTILITY EXPERIENCE: PROGRAMME TO IMPROVE COMPANY REVENUE

Morogoro Urban Water Supply and Sewerage Authority (MORUWSA), Tanzania, is an independent utility supplying 15000 active customers.

MORUWSA has an impressive record of reducing commercial losses and improving collection efficiency between 1997 (40% efficiency) and 2007 (92% efficiency). How?

- About 80% of the customers are metered.
- Most meters are less than 5 years old but in some cases installation layout is wrong.
- A bonus of TSh 15000 (USD 12) for reporting an illegal connection or bypass.
- An even higher bonus of TSh 100,000 (USD 80) for reporting customer meter theft or vandalizing.
- As a result, Illegal connections are not considered to be a significant problem (100 connections reported in 2006/2007).
- Customer meter bypasses are considered to be the main problem (around 1000 bypasses detected every year).

Where a water utility has a shortage of treated water, and thus some customers receive less than a 24-hour supply or the supply coverage is less than 100%, then a 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 for new customers to be connected to the supply system.

Table 3.1 shows an analysis of NRW actions according to volume and cost, which provides rational support when deciding how to proceed in NRW planning.



Developing an NRW reduction strategy requires water balance results, appropriate targets, and cost-benefit analyses to determine the return on investments.

TABLE 3.1: VOLUME AND COST ANALYSIS FOR NRW MANAGEMENT ACTIVITIES

| | | Cost | | |
|--------|--------|--|---|----------------------------------|
| | | High | Medium | Low |
| Volume | High | Leakage on mains (P) Leakage on service connections (P) | Unauthorised consumption (C) | Unbilled metered consumption (U) |
| | Medium | Customer meter replacement (C) | Customer metering inaccuracies and data handling errors (C) | Pressure management (P) |
| | Low | Reservoir leakage (P) | Unbilled unmetered consumption (U) | Reservoir overflows (P) |

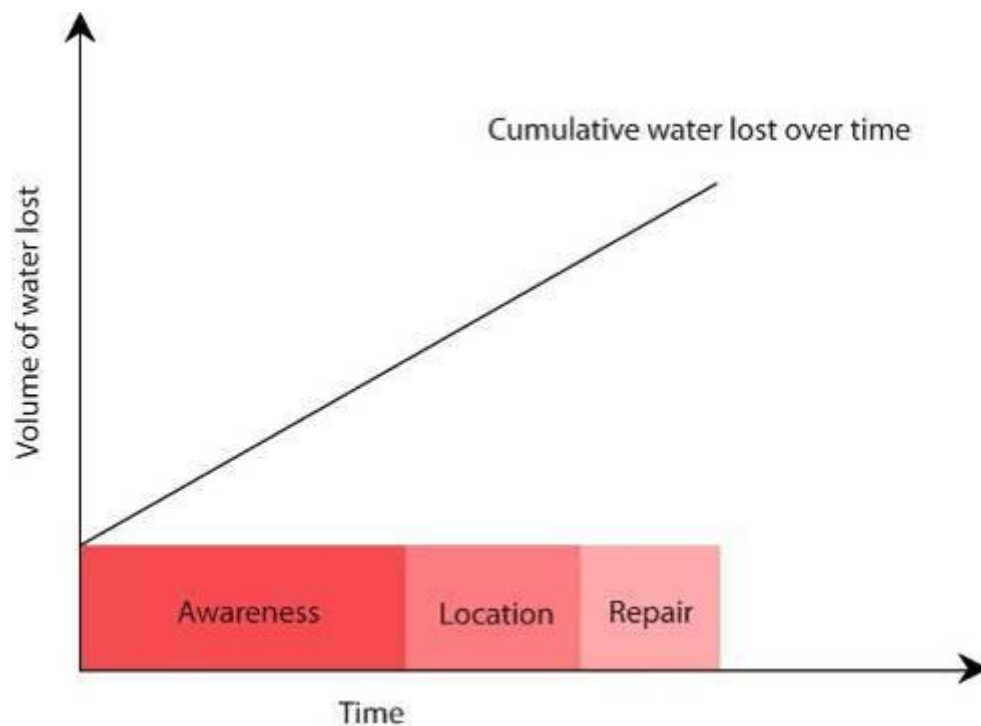
NRW Type: U=Unbilled authorised consumption, C=Commercial losses, P=Physical losses

3.4 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 as shown in the diagram below.

- 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.

FIGURE 3.2: THE EFFECT OF TIME ON THE TOTAL VOLUME LOST



The volume of water lost will continue to increase until the water utility is aware of the problem, locates or pinpoints it, and finally repairs or resolves 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 reduces 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.

Chapters 5, 6, and 7 detail the activities required to shorten the ALR periods. When developing an NRW management strategy, remember that reducing NRW is not a short-term process, especially in aging, large, open, or high pressure systems. 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.

3.5 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.

The budget should identify the following costs:

- Staffing—Include staff for both direct NRW works (e.g. leakage technicians) and indirect support (e.g. procure
- 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 installing all equipment, such as meters and pressure reducing valves, and also detecting and repair all leaks.



Managers reviewing the most cost effective and applicable investments to implement water loss reduction activities.

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 reduce the awareness, location, and repair (ALR) times in addressing water losses.
- NRW reduction is a long-term process and the strategy may cover a period of 4-7 years. Pilot projects can help water managers understand the full budget required to implement the entire strategy.

A TOOL FOR SETTING NRW TARGETS FOR AFRICAN UTILITIES

A team comprising RTI International (USA)* and colleagues from African utilities are in the process of developing a new analytical tool for NRW target setting, developed specifically for conditions in Africa. The model utilizes many of the concepts presented in this manual, and tools developed by various International Water Association (IWA) NRW Task Force Members. But the new model incorporates additional elements not covered in the Economic Level of Leakage (ELL) approach illustrated in Figure 3.1. These include:

- Commercial losses.
- The annualized cost of water supply capacity expansion.
- Situations where production capacity does not meet demand.

In its current form, the model computes optimal NRW for a given utility, from a modest, commonly known, set of site specific data, and uses default values where specific in-country data are not readily available. Some clear multi-country trends emerge, which provide a simple method to find preliminary estimates of optimal NRW. Therefore, the current model allows individual, regional, or national utility managers and regulators to establish reasonably accurate NRW targets and to optimally allocate resources to NRW management.

More detailed studies and applications are underway in Zambia and Uganda. More studies are planned in collaboration with utilities in Tanzania, Ghana, South Africa and other non-African countries. These efforts should likely yield country specific models and handbooks for general use, and will allow refinement of the general model.

The model provides the optimal levels of NRW, commercial losses and physical losses all in litres / connection / day. It also gives guidelines on optimal meter replacement programs, the optimal period for Active Leakage Control surveys and computes the Economic Infrastructure Leakage Index (see Section 8—Monitoring Performance).

*Wyatt, Alan S., & Romeo, Kyle J. *Application of a Financial Model for Determining Optimal Management of Non-Revenue Water in Developing Countries*. Proceedings of the 3rd ACWUA Best Practice Conference—Non Revenue Water Management in the Arab Region; Rabat, Morocco, January 20-21, 2010. Available from www.iea.ma.

4. RAISING AWARENESS ON THE STRATEGY

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 meter readers and crew, 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.

4.1 GAINING HIGH-LEVEL APPROVAL

Top decision-makers, such as the Board of Directors, the mayor, 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 to achieve reductions, and the budget required to carry out activities. Lack of approval at the highest levels or inadequate funding support has led to the failure of many 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.



Awareness can be raised in schools education programmes and at community meetings.

4.2 BUILDING STAFF AWARENESS AND CONSENSUS

The utility's staff need 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 senior management to the crew, 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 are as follows:

AFRICAN UTILITY EXPERIENCE: ENTEBBE'S NRW STRATEGY AND ACTION PLAN

Entebbe has been making reforms and developing a NRW strategy on several fronts since 1999.

Management and Leadership

- Setting priorities.
- Restoring customer confidence in NWSC operations and mobilising public support.
- Giving managers autonomy to take operational decisions.
- Increasing Operations performance accountability and commitment by apportioning operating risk through performance-based pay mechanism.
- Worker involvement to enhance transparency and strategy ownership.

Institutional Strengthening

- Implementing a series of PIP with focus on reducing NRW.
- Introducing incentive based management contracts—with NRW as a parent indicator.
- Regular monitoring & evaluation of performance—checking system.
- Encouraging internal competition between regional utilities.

5 year Action Plan

- Using a participatory approach - with clear time bound objectives & strategies—(eg reduce NRW from 32% to 15% by 2008).
- Establishing a GIS and carrying out a comprehensive documentation and mapping of the whole network area.
- Sharing experience and information with sister utilities on the challenges and initiatives of NRW reduction.

Pilot Studies

- Setting up three DMAs—with demarcated customer accounts.
- Appointing 'zonal leaders' accountable for zone performance and regular zone performance monitoring.
- Aligning the billing system with the zones for consistent monitoring.

Initiatives to Reduce Physical Losses

- Establishing a 24 hr (standby) leak management unit—*equipped with newly acquired leak detection equipment.*
- In house and external training of staff on effective leak detection, repair & monitoring.
- Establishing a routine programme for finding & locating non-visible leaks—*mainly done at night.*
- Sensitizing and encouraging the public to vigorously report water leaks and bursts—*with a reward for each case reported*
- Repairing identified leaks in < 6hours.
- Computerising the leak reporting register for easy tracking and monitoring.
- Introducing pressure management by installing pressure reducing valves (*14 PRVs installed in high pressure areas.*)
- Routine inspection & servicing of valves & fire hydrants.
- Monitoring leak 'clusters' to help planning for mains replacement.
- Developing a medium term investment plan—rehabilitating worn-out segments of the distribution network.

Initiatives to Reduce Commercial Losses

- Carrying out investigations to detect and disconnect illegal connections (declared Monday an 'illegal connection day', investigating cases of suspected illegal connections).
- Working closely with local communities to identify illegal cases.
- Offering incentives/rewards to informers of illegal users and establishing fines/ penalties for illegal connections (\$305 + value of 2 years estimated consumption).
- Establishing amnesty programmes to attract back illegal consumers.
- Regular spot checks on large customers and construction sites.
- Spot checks and auditing of meter readings and rotation of meter readers (*every 6 months*).
- Identifying and replacing old and worn out consumer meters with new ones (an ongoing exercise based on the meter age database).
- Universal metering of customer accounts (*all accounts are metered and over 70% of the meters are less 6 years old*).
- Prompt updating of customer database.
- Effective disconnection for non-payment .
- Right sizing of meters - based on the flow—for effective recording, particularly large consumer meters.
- New Connection Policy—NWSC procures and installs all water pipes and fittings and also maintains the service line—ensuring standardization and quality control of pipes & fittings.

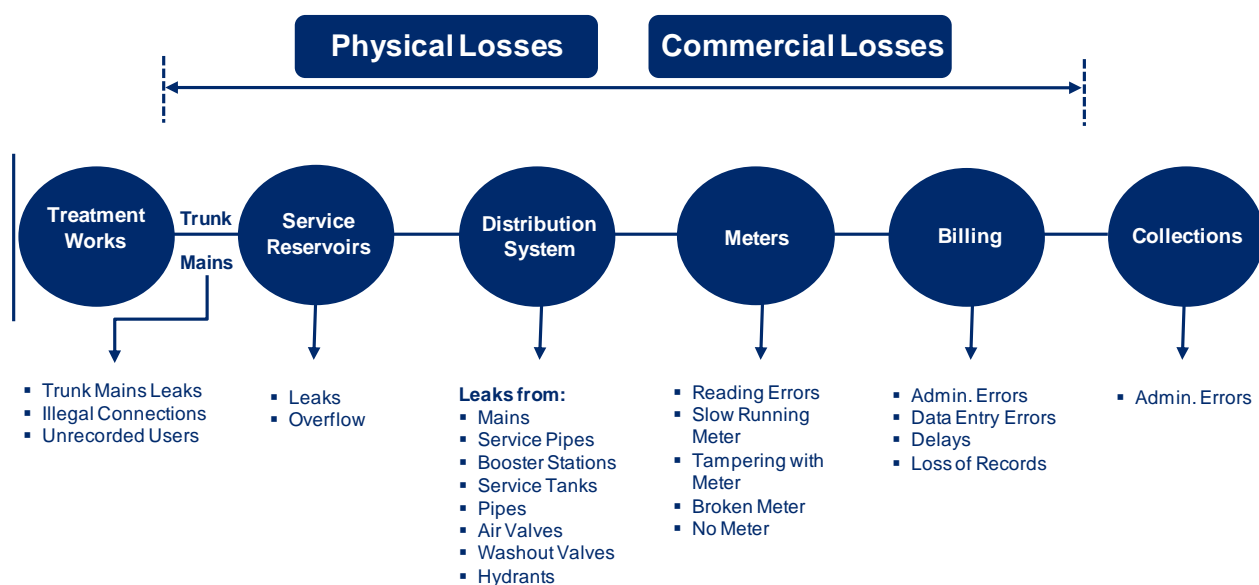


It is important to mend reported leaks as quickly as possible.

- 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 or meter supplies.
- Crew 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.

FIGURE 4.1: CHART TO HELP STAFF UNDERSTAND NRW COMPONENTS

Typical Losses From A Water Supply System



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.



Water utility senior managers participating in NRW awareness sessions to understand the causes of water loss.

MALAYSIAN UTILITY EXPERIENCE: NRW AWARENESS PROGRAMME

The NRW management team of Ranhill Water Services, a Malaysian water utility, organised an NRW Strategy Road Show in eight operational districts, with two additional sessions at the headquarters, to ensure that all 1,700 staff members could attend the NRW awareness sessions. After the awareness programme was completed, the Corporate Communication Department conducted a survey to assess staff members' understanding of NRW. The results showed that after the Road Show, staff awareness of NRW increased significantly. The Road Show produced other benefits: staff members were more motivated to do their work; planning became more effective; and inter-department communication and communication between managers and crews improved.

4.3 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 (see Figure 3.2 in section 3.4 on the relationship between awareness, location, and repair times and water losses).

Awareness programmes should be organised with a variety of stakeholders from the public, including politicians, community



Engaging customers helps water utilities target water loss sources, such as house connection leakages, water theft, and meter tampering.

leaders, and household and industrial consumers. Programmes generally focus on basic NRW concepts and how reducing NRW helps ensure that communities receive better water supply and services.

AFRICAN UTILITY EXPERIENCE: COMMUNITY AND EDUCATION AWARENESS CAMPAIGNS

The South African Department of Water Affairs and Forestry (DWA) is committed to the introduction and enforcement of water conservation and water demand management. The Sebakong/Evaton project was a one-year DWA initiative, in which several hundred local residents were interviewed to select 50 'Community Liaison Officers'. These were required to visit every household in the 50 wards that make up the Sebakong/Evaton area, supplying water to 500,000 residents. Numerous posters and pamphlets were designed in several languages. These were distributed throughout the supply area, including all schools, to create an awareness of the value of water, and how it should be used in an efficient and sustainable manner.

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 to disseminate it to the relevant operational units so action is taken quickly.



Customers aware of poor service caused by water losses will report defective connections.



Readily visible, easy to remember and free telephone numbers encourage the public to call.



Call centres receive information from the public.

AFRICAN UTILITY EXPERIENCE: CUSTOMER CALL CENTRE

Operating a 24/7 customer call centre with dedicated toll-free lines for customers to report leaks encourages the public to provide information on any problems with the water supply.

In Ouagadougou, Burkina Faso, members of the public are encouraged by the water utility, ONEA, to report visible leaks using a readily visible, easy to remember and free number.

ONEA has 5 permanent repair crews, on shift at the same time as the call centre staff and available to react to leaks quickly.

In 2005, in direct response to call centre leads, the teams repaired 1,090 mains leaks and 3,496 house connections—all repaired within 4 hours from the time of receiving a call.

Key Messages

- Awareness at all levels, from top decision-makers to the end consumer, is important.
- 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.

5. UNDERSTANDING COMMERCIAL LOSSES

5.1 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 gone through the meters 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.

5.2 COMMERCIAL LOSS ELEMENTS AND MANAGEMENT STRATEGIES

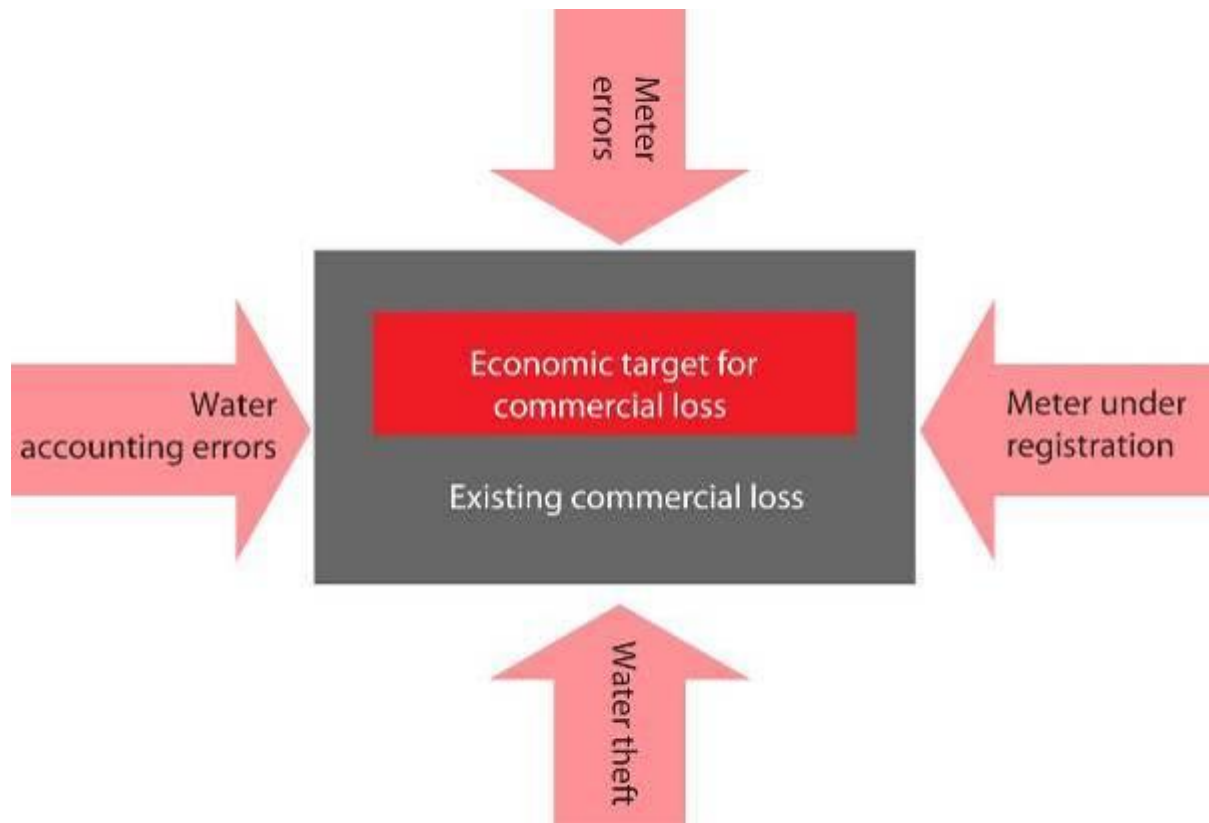
Commercial losses can be broken down into four fundamental elements, which are:

- Customer meter inaccuracy.
- Unauthorised consumption.
- Meter reading errors.
- Data handling and accounting errors.



Examples of an illegal bypass around a meter—another form of theft and one of the causes of commercial losses.

FIGURE 5.1: FOUR PILLARS OF COMMERCIAL LOSSES



Water utilities should aim for commercial losses that are no more than 4-6% of authorised consumption. Reducing commercial losses requires a low level of investment with a short payback period, but it needs sustained management commitment, political will, and community support. Utilities should focus on commercial losses in the beginning of an NRW reduction programme since the activities can be undertaken in-house with little effort and the payback is immediate.

5.2.1 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



Improper meter installation leads to inaccurate data and billing errors. Meter readers in the pictured situation will find it difficult to determine which meter belongs to which property.

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. Therefore a standard meter stand should be designed and constructed onsite. 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.

AFRICAN UTILITY EXPERIENCE: CUSTOMER METERING PROGRAMMES

In **Ouagadougou** customers are fully metered, and, although there are no individual roof tanks customer meter accuracy was seen as a weakness. A service contract was initiated in 2001, resulting in:

- A customer census to establish correct billing records and improved collection efficiency
- A meter workshop to support a regular customer meter sampling and testing program
- A meter replacement program and total customer meter replacement
- Redesign of service connections
- Installation of a modern IT customer management and billing system
- Improved control of metering and corruption at community fountains

In **Entebbe** the utility's metering programme included:

- Regular spot checks on large customers and at construction sites
- Spot checks and auditing of meter readings
- Rotation of meter readers (every 6 months)
- Identification and replacement of old and worn out consumer meters with new ones (an-ongoing exercise based on a newly developed meter/age database)
- Universal metering of customer accounts (all accounts are now metered and over 70% of the meters are less 6 yrs old)

Monitoring Water Quality

Poor water quality—resulting from poor raw water, inadequate treatment processes, or dirt infiltration due to pipe shutdowns—may cause sediments 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 friction 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.

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. Electronic

(fluidic oscillation) and ultrasonic meters are unaffected by air entrainment but are more expensive.

Intermittent supply should be avoided for a number of reasons, including the negative impact on customer meter accuracy. A phased NRW reduction strategy (zone by zone) does help to eliminate intermittent supplies - and the water balance will take account of intermittent supply in the calculation. See Chapter 7 for information on utilising District Meter Areas to implement a 24-hour supply system.

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 proper meter size for households and businesses. For customers with a high demand, checking the flow pattern and the newly installed meter verifies whether the correct meter size is used.

Problems with low flows can occur when a storage tank, with the water flow 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 be continually low.

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



Sedimentation is a major cause of meter reading inaccuracies.

AFRICAN UTILITY EXPERIENCE: LARGE CUSTOMER METER REPLACEMENT

The City of Tshwane Metropolitan Municipality, South Africa, carried out an audit of large water users and found examples of unmetered connections at fuel terminals, by-passed fire hydrant meters and un-registered connections. Out of 698 connections audited there were 67 unmetered connections and 156 meters that required replacing. Metering the unmetered connections and replacing malfunctioning meters resulted in extra sales of 17300 m³/month, an increased revenue of USD 206,400/year. The payback on cost of the audit was 17 months.

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 should be installed above ground and located where they can be audited easily, including by the meter readers during their regular rounds. 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.



Examining meters regularly enables utilities to detect the need for calibration or replacement, and builds trust with customers.

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 or an *in situ* testing method—comparing volume flow over time against with accurate ‘master meter’. This testing will determine the optimum age at which customer meters should be replaced.



Checking accuracy of a large customer meter.



One of the proprietary in situ large customer meter testers.



In situ small meter testing with meters in series.

Customer Meter Servicing

It is usually cost-effective to service customer meters 50 mm and above on a 6-month to 1-year frequency, depending on the water quality in the area. In addition, analyses of smaller domestic meters within a District Meter Area (DMA) will reveal if the water quality is affecting the meter accuracy. If so, then the utility should carry out meter servicing for all domestic meters in the DMA.

Addressing Meter Tampering

Although water tariffs in Africa are relatively low, people still sometimes tamper with their meters to lower the measured volume. Customers 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 have boiled plastic meters trying to melt the internal plastic parts.

Most reputable meter manufacturers now produce meters that are very tamper-resistant, with non-metallic parts, strong clear

plastic windows, and impenetrable casings. Although these meters may cost a bit more, 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.



The customer has tampered with the meter's moving parts.

5.2.2 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.

Preventing Illegal Connections

Lockable valves help limit illegal connections. The water utility should have the only keys available for the valves. After a customer's water supply has been disconnected for non-payment, and reconnection has not been requested within one week, the utility should visit the property to check whether the customer has made an illegal connection.

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 unauthorized 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 leakage step tests to determine where the missing flow occurs.

Preventing Illegal Use of Fire Hydrants

The only legal use of fire hydrants is for fire fighting. However, people can use them illegally to fill tankers (normally at night) or as water supply connections to construction sites. These flows, which are often high flows over a short period of time, can be detected through flow measurements at DMA meters. These high flows are not only



Water theft can occur from large pipes as well as from household water connections.



A sound customer billing consumption management system reduces NRW that is caused by billing and data handling errors.

incidences of theft of water, but also a detriment to the pipe network and water quality, which affects the service to the customer.

Customer awareness programs should encourage customers to report cases of illegal uses of fire hydrants. Utilities should cooperate with the relevant departments, such as the Road and Transport Department, to identify owners of tankers that steal water, and develop regulations to penalise the water thieves once they are caught.

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. A sample of a typical customer survey form can be found in Annex 4.

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.

AFRICAN UTILITY EXPERIENCE: METER READING PRACTICES

Entebbe water utility carries out spot checks and audits of meter readings, and rotates meter readers every 6 months.

Avoiding Corrupt Meter Readers

Corrupt meter readers can create a large impact on the monthly billed consumption. The same meter reader who walks the same route for an extended period of time may become familiar with the customers and their monthly billed consumption. Corrupt meter readers will record lower meter readings in exchange for a monetary incentive. To reduce this risk, each meter reader should be assigned to a different meter reading route on a regular basis.

5.2.3 METER READING ERRORS

Errors can be easily introduced through negligence, aging meters, or even 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 problems.

These errors are addressed by implementing new systems for meter reading and billing. For example, effective supervision of meter readers, rotating routes, and spot checks will reduce these problems. Meter readers are the frontline of the utility in liaising with customers and their activities have an immediate impact on cash flow. Utilities should therefore invest in capacity building to train and motivate their meter readers.

5.2.4 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 then recorded by hand on a 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.



Spot billing minimizes data handling errors.

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.



Awareness programmes educate customers on NRW and encourage them to report water thefts.

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.

6. IDENTIFYING PHYSICAL LOSSES

6.1 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 Section 2.3, 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 Chapter 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 first and second types of leakage are usually quite visible to either the public or utility staff, so they are easy to detect and are repaired relatively quickly. The third type is more difficult to detect and can therefore lead to a greater volume of physical losses. This chapter describes these three types of losses and solutions for reducing them.



Catastrophic’ mains bursts can cause serious damage

6.2 PHYSICAL LOSS ELEMENTS

6.2.1 LEAKAGE FROM TRANSMISSION AND DISTRIBUTION MAINS

Leakages occurring from transmission and distribution mains are usually large events, sometimes catastrophic, causing damage to highway infrastructure and vehicles. The majority of such bursts are usually not very severe although they cause supply disruptions. Because of their size and visibility, the bursts are reported quickly, and are then repaired or shut off soon afterwards.

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:

$$\text{Total annual volume of leakage from mains} = \text{Number of reported bursts} \times \text{Average leak flow rate} \times \text{Average leak duration}$$

If no detailed data are available, utility managers can use approximate flow rates from Table 6.1. Estimates for background losses and excess losses (current undetected leaks on mains) can then be added.

TABLE 6.1: 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

Background losses are individual events (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 6.2 shows background losses from various components of a network with average infrastructure condition.

TABLE 6.2: CALCULATING BACKGROUND LOSSES

| | | |
|--|------|---|
| Mains | 9.6 | Litres per km of mains per day per metre of pressure |
| Service Connection – main 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 yet detected and repaired under the current leakage control policy

$$\text{Excess Losses} = \text{Physical losses from water balance—known physical loss components}$$

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 re-checked, and, if necessary, corrected. If the value is still negative after re-checking the assumptions this indicates that faulty data were used in the water balance calculation. For example, utility managers may have underestimated system input or overestimated commercial losses, and all the components should be checked.

6.2.2 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.

Monitoring reservoir overflows can be done by placing a plastic bottle in the overflow pipe of each reservoir. The bottles are checked once per month - if they have moved outside of the pipe this indicates a

possible overflow. Monitoring teams can then undertake further investigations using a pressure (depth) transducer and a data logger.



Typically more difficult to detect, service connection leaks result in significant water losses.

6.2.3 LEAKAGE ON SERVICE CONNECTIONS UP TO THE CUSTOMER'S METER

This type of leakage is usually more difficult to detect and results 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.

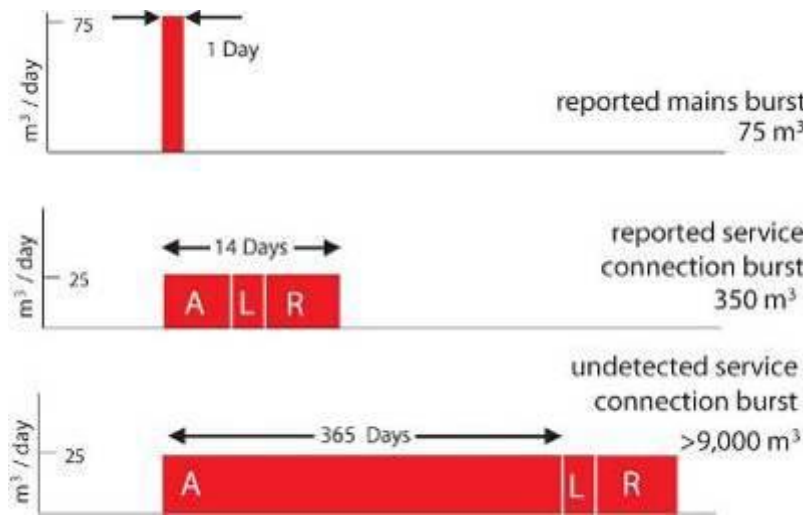
6.3 CHARACTERISTICS OF LEAKAGES

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 (see Figure 6.1, and Section 3.3 for a discussion of the ALR concept).

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.

FIGURE 6.1: LEAK RUN TIME AND VOLUME OF WATER LOSS



General conclusions concerning leakage include:

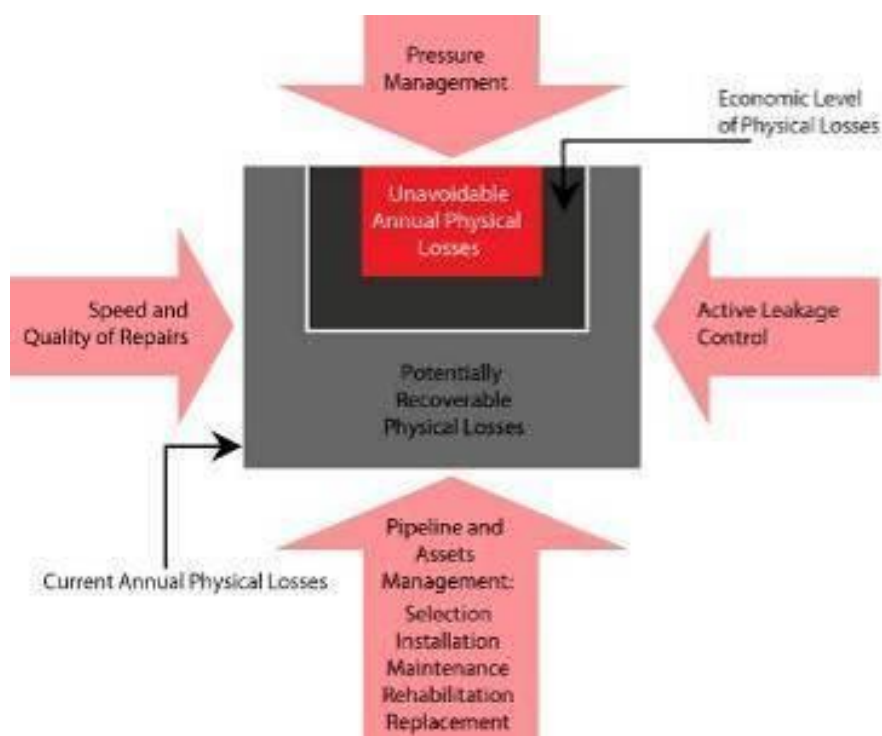
- Most leaks are invisible
- The majority of leaks do not come to the surface
- Managers need to be aware that most leaks are on service connections
- The absence of an active programme to detect invisible leaks is an indication of high levels of leakage

6.4 DEVELOPING A LEAKAGE MANAGEMENT STRATEGY

The four pillars of a leak management strategy include pressure management, repairs, active leakage control, and asset management (Figure 6.2). 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 **C**urrent **A**nnual Volume of **P**hysical **L**osses (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 **M**inimum **A**chievable **A**nnual **P**hysical **L**osses (MAPL), 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 6.2: THE FOUR PILLARS OF A SUCCESSFUL LEAKAGE MANAGEMENT STRATEGY

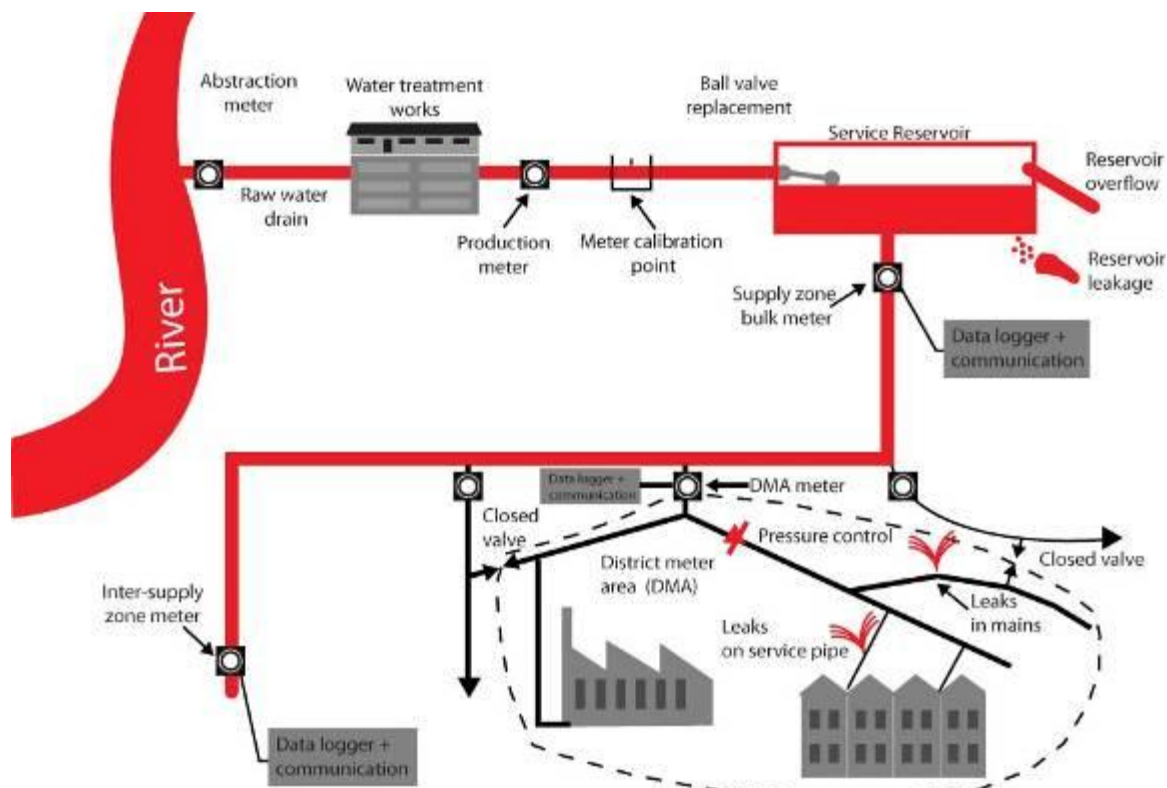


6.4.1 ACTIVE LEAKAGE CONTROL (ALC)

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.

There are many points in a distribution network where leakages can occur and where they are best monitored (Figure 6.3). The DMA concept, and the associated technology and equipment for leakage monitoring, detection, and location, is described in detail in Chapter 7.

FIGURE 6.3: A TYPICAL DISTRIBUTION NETWORK



Flow Metering

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

Leak Localising, Locating, and Pinpointing

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 size and shape of the leak and the pipe material.

For ensuring accuracy the utility has a wealth of acoustic equipment to choose from 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 and maintenance requirements of each tool to maximise their use.

- **Noise loggers**—Noise loggers narrow down areas of a DMA that contain suspected bursts or number of leaks. A cluster of loggers, usually 6, 12, or 18, is deployed in the survey area, with each logger placed on a hydrant, meter, or other surface fitting. Noises that are suspected of being caused by leaks can be confirmed, and the leak is located using other location equipment as described below. Some noise logger systems also incorporate data from multiple points to ‘instantly’ locate leaks.



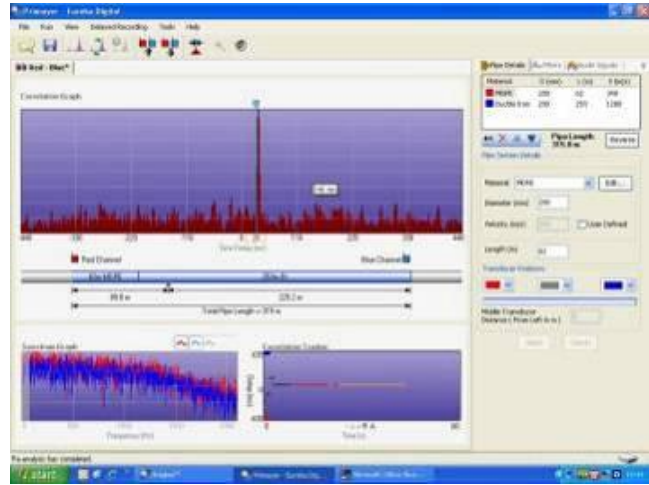
Proper application and maintenance requirements of the equipment needs to be understood.



Noise loggers can be deployed on fittings in the network.

- **Leak noise correlators**—Rather than locating a leak based on the noise level, this instrument uses the velocity of sounds made by the leak as they travel along the pipe wall toward each of two microphones placed on fittings either side of the suspected leak. The effectiveness of this process is dependant on the strength of the leak noise and the sound conductivity of the pipe material. Hydrophones placed in the water column can also enhance the leak sounds in plastic or large pipes and other pipes where the noise conductivity is known to be poor. These hydrophones work by listening to the leak noise travelling through the water, which is a better conductor, than most pipe materials, of sound.

The latest correlator versions, have the capability of frequency selection and filtering, to quickly locate leaks to within 0.5 metres in most sizes of pipe, provided there are sufficient contact points along the line of the main.



An 'advanced' leak noise correlator, showing the correlation peak.



One of the 'low-cost' correlators.

Low-cost basic models are also available—these usually have a single channel radio link and fewer functions. Although they are easier to use, and adequate for most situations, they are disadvantaged when correlating over long distances.

- **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



Using a ground microphone.

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. Utility managers use it to listen to leak sounds on the surface of the highway or on directly exposed pipes and fittings. The sounding stick is a piece of equipment that can be easily made from materials readily available materials, such as a bamboo cane or a reinforcing rod.

The sounding stick is invariably used to confirm a leak site that is first identified by a correlator, and for checking that a leak has been repaired correctly.

Entry-level equipment—for utilities that are about to embark on active leakage control—could consist of a sounding stick and a ground microphone—and maybe a low-cost correlator. Utilities that are intending to implement a policy of regular leakage monitoring, may wish to add an advanced correlator and a set of acoustic noise loggers.

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 correctly.



Using a listening stick.

6.4.2 PRESSURE MANAGEMENT



Low pressure



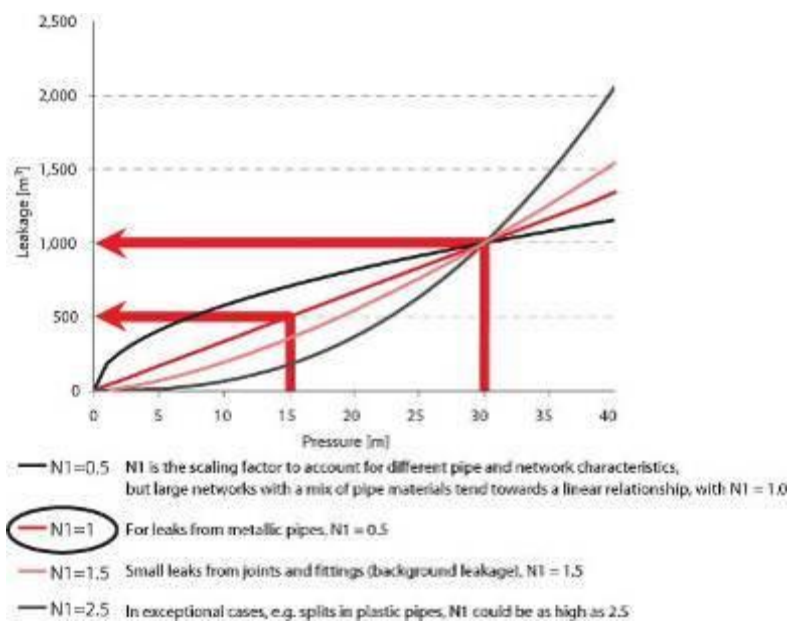
High pressure

Flow rate from the same fractured pipe at low and high pressure.

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

FIGURE 6.4: PRESSURE/LEAKAGE RELATIONSHIP



$N1$ is the scaling factor to account for different pipe and network characteristics, but large networks with a mix of pipe materials tend towards a linear relationship, with $N1 = 1.0$

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

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 or PRV.

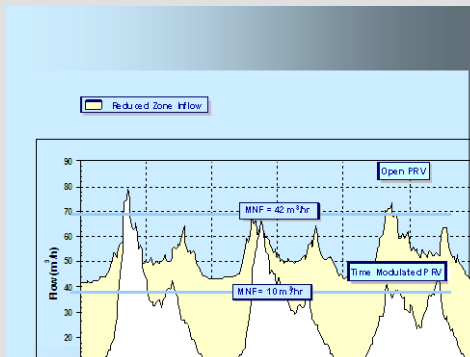
PRVs are instruments that are installed at strategic points in the network to reduce or maintain network pressure at a set level. The valve maintains the pre-set downstream pressure regardless of the upstream pressure or flow-rate fluctuations. PRVs are usually sited within a DMA, next to the flow meter, as shown in the photos below. 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.



PRVs installed in meter chambers.

AFRICAN UTILITY EXPERIENCE: PRESSURE MANAGEMENT

The City of Tshwane Metropolitan Municipality, South Africa, has 800 pressure reducing valves. The summary of results for Mabopane below show the savings and fast payback from one installation. By reducing night flow from 42 m³/hour to 10 m³/hour, the cost saving - at a tariff of 0.5USD/m³—was 109 000 USD/year. The installation cost was 25 000USD, giving a payback of less than 3 months.



| FLOW | Night flow (m ³ /h) | Average flow (m ³ /h) | Annual demand (Ml/year) |
|--------|--------------------------------|----------------------------------|-------------------------|
| Before | 42 | 52 | 455 |
| After | 10 | 27 | 237 |
| Saving | 32 | 25 | 218 |

6.4.3 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 staff
- Good quality of service connections—service connections are often the ‘weakest link’



Leak repairs should be fast, efficient and of good quality materials and workmanship.

6.4.4 ASSET MANAGEMENT

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.

During the decision process, utility managers should ask themselves 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?

AFRICAN UTILITY EXPERIENCE: ASSET MANAGEMENT

The NRW management team in Entebbe, Uganda, has a multi-tiered approach to asset management:

- Pressure management throughout the distribution network by installation of pressure reducing valves
- Routine inspection and servicing of valves and fire hydrants
- Leak 'clustering' - monitoring the network condition by identifying fragile areas of pipework (frequent breaks and repairs). This helps to plan a replacement policy
- Developing a medium term investment plan—rehabilitating worn-out segments of the water distribution network
 - 12.4 Km of worn out pipes were replaced
 - More than 60% of the network is currently less than 5 years old



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 but are usually repaired quickly. Other 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.

Further Reading

Leak Detection Guidance Notes

Developed and published by the IWA Water Loss Task Force, 2007. Available as a free download from the IWA website: www.iwaom.org/wlwf

7. 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. Thus, determining the exact locations of NRW occurrences—and where NRW reduction activities should take place—can 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, such as leaks, reservoir overflows, and illegal connections.

Active NRW Management is only possible using zones, 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.

7.1 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 include:

- 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
- Number of flow meters to measure inflows and outflows (the fewer meters required, the lower the establishment costs)
- 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 pressure and supply hours.

BOX 7.1: NETWORK MODELLING

Network modelling is the process of constructing a computer simulation of a pipe network using specialised computer software. Utility managers then verify the simulation by comparing the simulated flows and pressures with real flow and pressure data recorded onsite. Adjustments are made to the model to ensure that the simulated and the real data correlate, thus creating a calibrated hydraulic network model.

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 also helps to reduce the cost of flow meter 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.

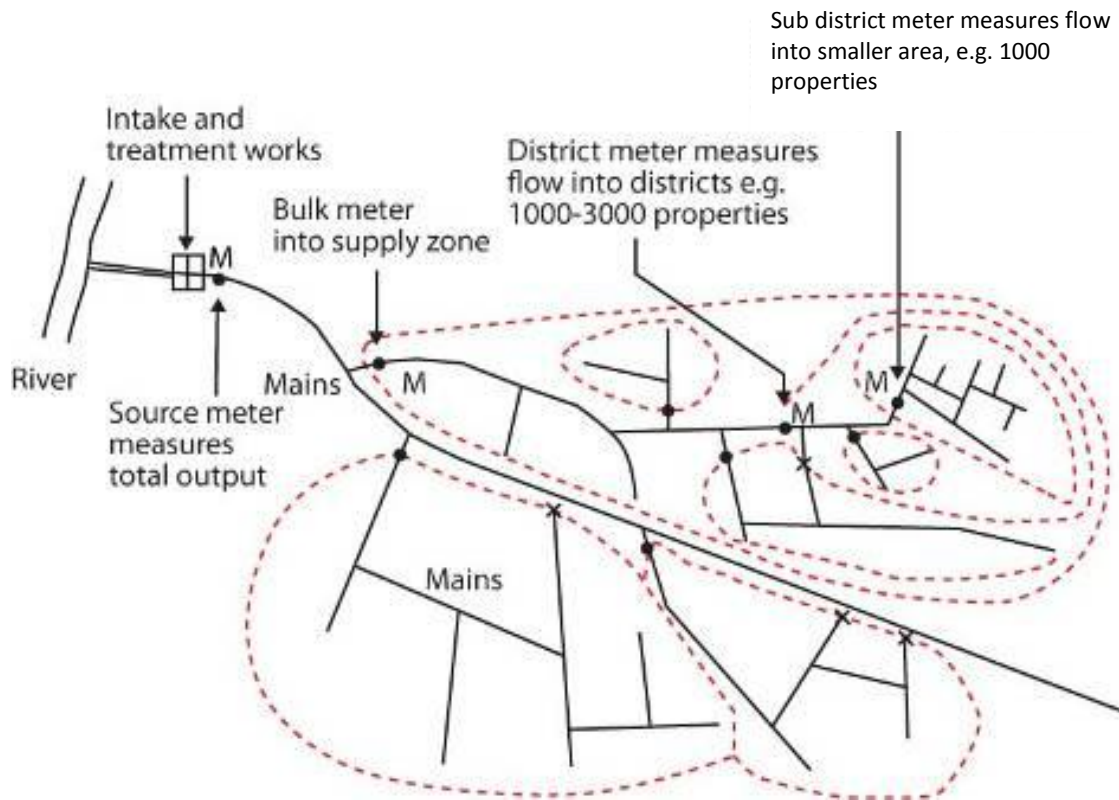
Utility managers will ensure that all pipes into and out of the DMA are either closed or metered by performing an isolation test as follows:

- Close all metered inlets.
- 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.

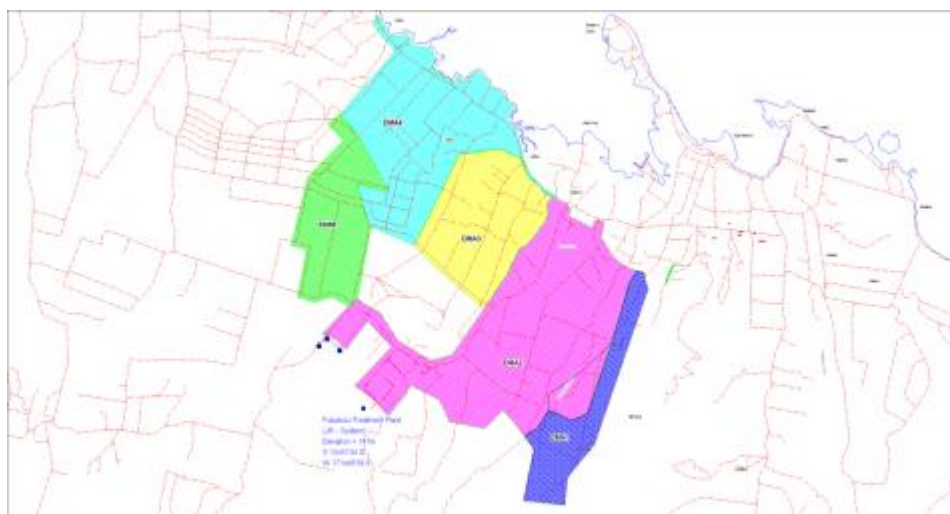
If the budget is limited, the water utility should initially establish larger zones of 5,000 or more connections. It can subsequently subdivide them into DMAs and sub-DMAs of 1,000 or fewer connections for those DMAs with high NRW and long lengths of pipework, as detailed in Figure 7.1.

FIGURE 7.1: TYPICAL DMA LAYOUT



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, and 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



Supply zone schematic showing supply source, DMA meters and boundaries

7.2 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:

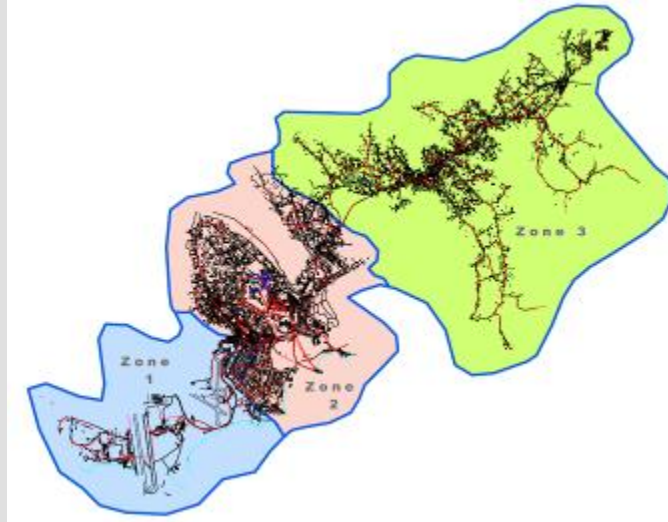
$$\text{DMA NRW} = \text{Total DMA Inflow} - \text{Total DMA Consumption}$$

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.

AFRICAN UTILITY EXPERIENCE: DMA ESTABLISHMENT



The NRW team at Entebbe, Uganda, undertook pilot studies of the distribution network and isolated three discrete DMAs:

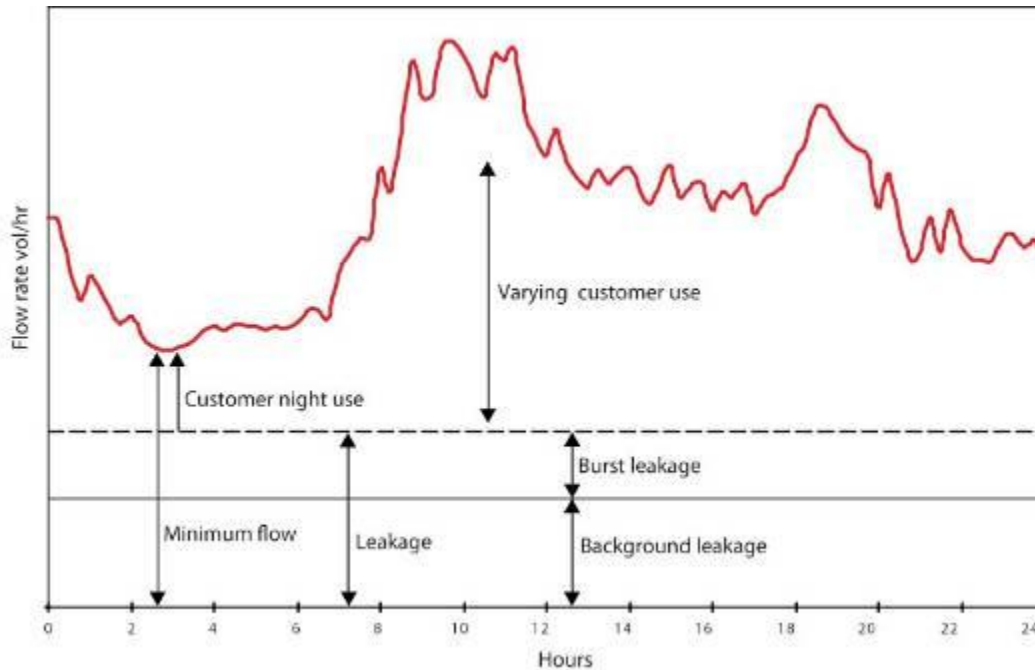
- Each DMA was aligned with the customer billing system - for consistency of monitoring
- A staffing structure was allocated to each DMA—to ensure staff accountability
- DMA leaders were appointed—accountable for the DMA’s management and performance
- Targets were set for each DMA—an incentive mechanism was established to drive performance
- Regular DMA performance monitoring was carried out

7.2.1 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 occurs through holes or cracks in the main pipes or at pipe joints, which will leak water constantly over a 24-hour period. In contrast, leaks from customer connections fluctuate with customer demand throughout the day, with peak demand in the morning and evening, and a minimum demand at night when most customers are asleep and not using water.

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 7.2 shows the flow pattern into a typical DMA with mainly domestic customers.

FIGURE 7.2: TYPICAL 24-HOUR DMA FLOW PROFILE



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.

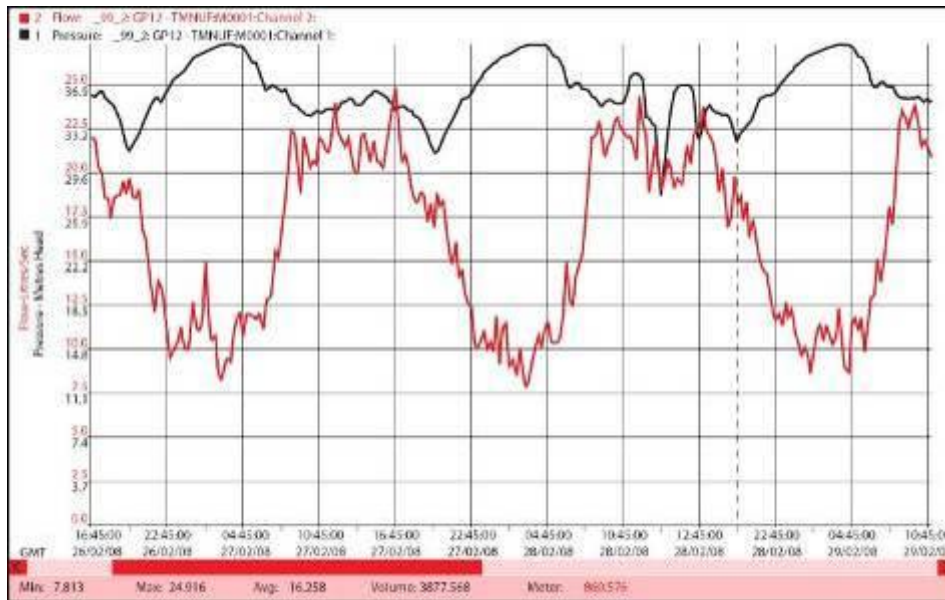
To determine the level of Net Night Flow (NNF) or the portion of night flow directly attribute to leakage, subtract the LNF from the recorded MNF.

$$NNF = MNF - LNF$$

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 headlosses within the system, and thus when the DMA has its lowest inflows, the pressure will be at its highest (Figure 7.3). 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.

Therefore, the NNF or leakage calculated for the minimum night flow period will 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.

FIGURE 7.3: DMA FLOW AND PRESSURE RELATIONSHIP OVER A THREE-DAY PERIOD



7.2.2 DETERMINING COMMERCIAL LOSSES

The level of NRW within a DMA can be calculated by subtracting the recorded consumption from the inflow. Section 7.2.1 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:

$$\text{Commercial loss} = \text{NRW} - \text{NNF}$$

Once utility managers identify the DMAs with significantly high commercial losses, they should investigate 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.

7.3 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 discussed in Chapters 5 and 6 should be implemented.

When DMAs are first established a baseline NNF target for each DMA should be established. This is done by calculating the NNF from the DMA meter readings before and after a sounding survey and fixing leaks. The survey should be a ‘sweep’ of the DMA, sounding on every fitting, and all leaks found should be repaired quickly. The second meter reading will give the baseline NNF target for each DMA, so that when NNF rises the leakage team has a baseline level to aim for in each DMA.



Managers walking the line to monitor the DMA.

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. However, the installation of a data logger to record flows will reveal more detailed data, including the daily NNF, which 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 7.4).

FIGURE 7.4: NNF AGAINST TIME

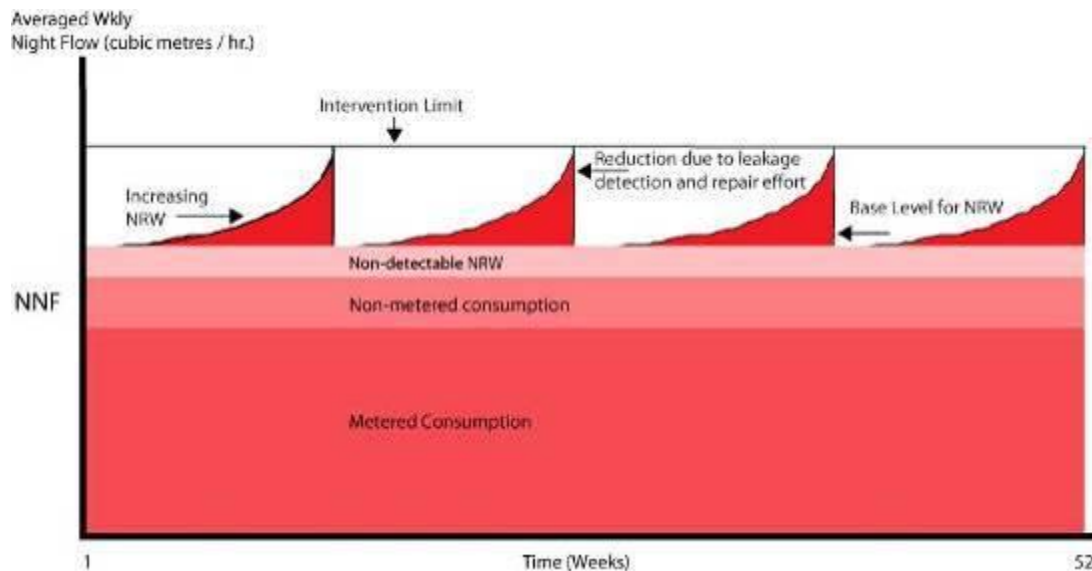
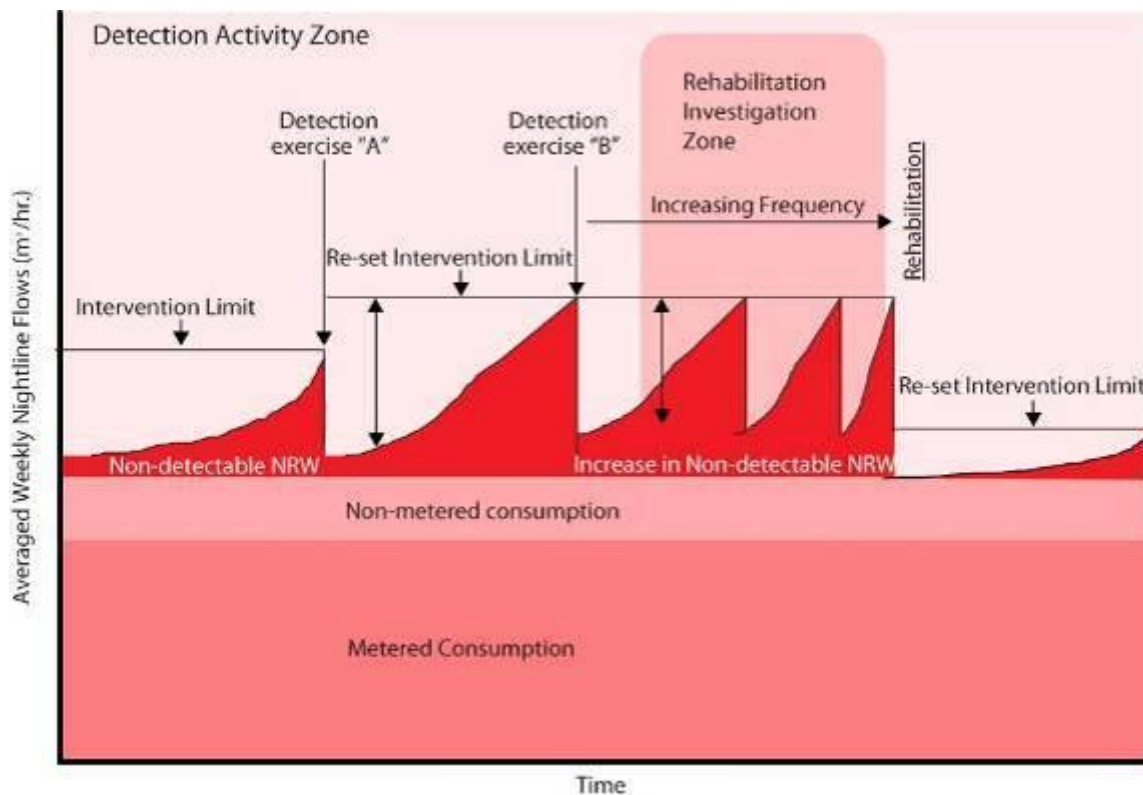


Figure 7.4 shows that the NRW level within the DMA continues to increase, and the rate of increase depends on a number of issues, including pipe network age and condition, system pressures, and the number of illegal connections and tampered meters. For most water utilities, it is inefficient for leakage

detection and customer survey teams to work in the DMA continually. Therefore, the monitoring team should 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 teams have been sent into the DMA, the NRW level can be brought down within two to four weeks. Afterwards, the NRW level should be 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 7.5).

FIGURE 7.5: 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 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 7.5).

7.4 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

7.4.1 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 headlosses 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 headlosses 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. However, the pressure in a gravity system can 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.

7.4.2 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 pipe will be disturbed less, thereby reducing water discolouration. The number of dead-end pipes within the system should be minimised to reduce the number of areas with stagnant water. Where dead-end pipes exist, a regular flushing regime can be implemented to ensure the water is kept fresh.

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.

7.4.3 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 challenging 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.

Further Reading

DMA Guidance Notes

Developed and published by the IWA Water Loss Task Force (2007). Available as a free download from the IWA website: www.iwaom.org/wlwf.

8. MONITORING PERFORMANCE OF NRW MANAGEMENT

NRW is a measure of a utility's efficiency in terms of both operational performance and financial performance. Managers, policymakers, 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.

8.1 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

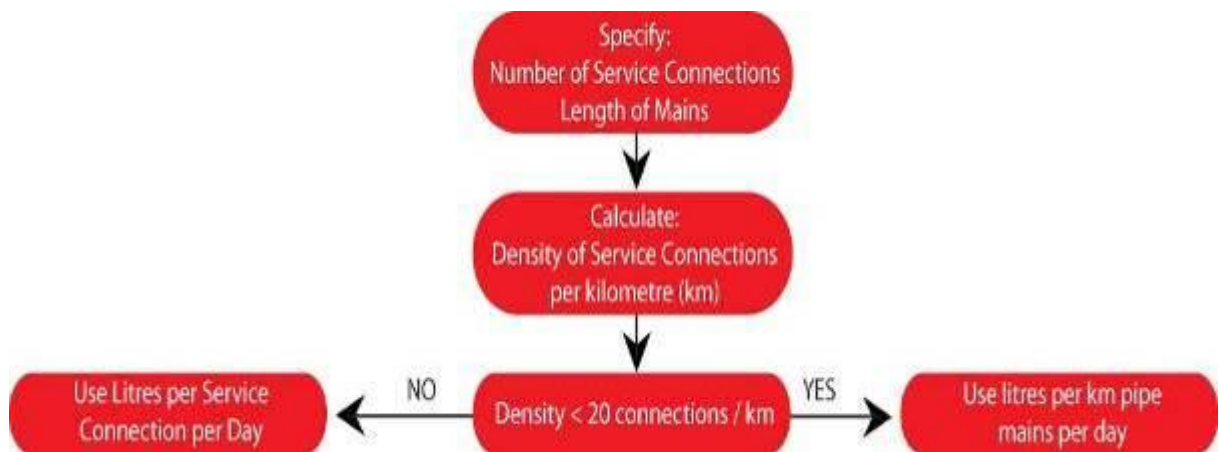
A good NRW PI should be clear and easy to understand and have a rational basis. It should also be easy to calculate using data that the utility gathers regularly. Finally, utilities should include standard performance indicators to measure performance to facilitate comparisons with other utilities. Tools such as decision trees are available for managers to select appropriate performance indicators for their utility's needs and operating context (Figure 8.1).

8.2 PERFORMANCE INDICATORS FOR PHYSICAL LOSSES

8.2.1 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.

FIGURE 8.1: IWA DECISION TREE TO SELECT PERFORMANCE INDICATORS



8.2.2 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)
- Infrastructure Leakage Index (ILI)

Figure 8.1 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*.⁵ 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.

⁵ Alegre H., Hirner W., Baptista J.M. and Parena R. (2000) Performance Indicators for Water Supply Services: IWA Manual of Best Practice. ISBN 900222272.

TABLE 8.1: RECOMMENDED INDICATORS FOR PHYSICAL LOSSES AND NRW

| Function | Level | Code | Performance Indicator | Comments |
|-----------------------------|------------------|-------|---|---|
| Financial: NRW by Volume | 1 (Basic) | Fi 36 | Volume of NRW [% of System Input Volume] | Can be calculated from simple water balance, not too meaningful |
| Operational: Real Losses | 1 (Basic) | Op 24 | [liters/service connection/day] or: [liters/km of mains/day] <i>(only if service connection density is < 20/km)</i> | Best of the simple 'traditional' performance indicators, useful for target setting, limited use for comparisons between systems |
| | | | [liters/service connection/day/m pressure] or: [liters/km of mains/day/m pressure] <i>(only if service connection density is < 20/km)</i> | |
| Operational: Real Losses | 2 (Intermed.) | - | [liters/service connection/day/m pressure] or: [liters/km of mains/day/m pressure] <i>(only if service connection density is < 20/km)</i> | Easy to calculate Indicator if the ILI is not known yet, useful for comparisons between systems |
| | | | [liters/service connection/day/m pressure] or: [liters/km of mains/day/m pressure] <i>(only if service connection density is < 20/km)</i> | |
| Financial: NRW by cost | 3 (Detailed) | Fi 37 | Value of NRW [% of annual cost of running system] | Allows different unit costs for NRW components, good financial indicator |
| Operational: Real Losses | 3 (Detailed) | Op 25 | Infrastructure Leakage Index (ILI) | Ratio of Current Annual Real Losses to Unavoidable Annual Real Losses, most powerful indicator for comparisons between systems |

8.2.3 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%. The ILI can then 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 **C**urrent **A**nnual **V**olume of **P**hysical **L**osses (CAPL) to **M**inimum **A**chievable **A**nnual **P**hysical **L**osses (MAAPL).

$$ILI = CAPL/MAAPL$$

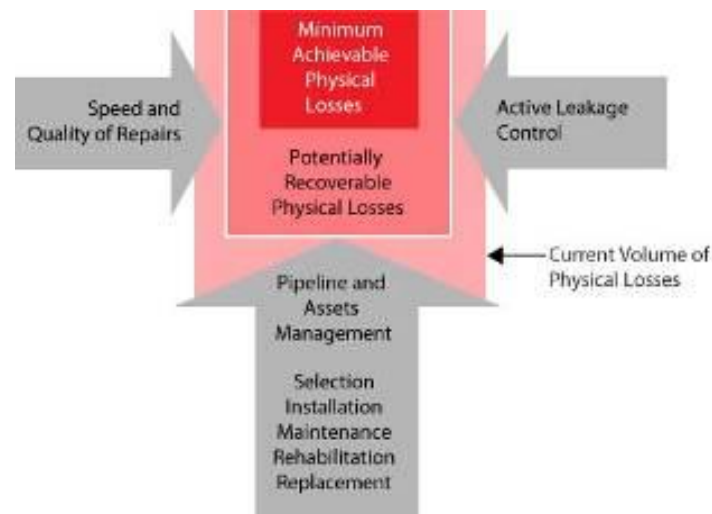
Being a ratio, the ILI has no units and thus facilitates comparisons between utilities and countries that use different measurement units. The complex initial components of the MAAPL formula have been converted to a format using a pre-defined pressure for practical use:

$$MAAPL \text{ (litres/day)} = (18 \times Lm + 0.8 \times Nc + 25 \times Lp) \times P$$

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

Figure 8.2 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 smallest box represents the MAAPL, or the lowest technically achievable volume of physical losses at the current operating pressure.

FIGURE 8.2: 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 (Figure 8.3.)

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.

TABLE 8.2: PHYSICAL LOSS TARGET MATRIX

| Technical Performance Category | | ILI | Physical Losses [Litres/connection/day] (when the system is pressurised) at an average pressure of: | | | | |
|--------------------------------|---|--------|--|---------|---------|---------|----------|
| | | | 10 m | 20 m | 30 m | 40 m | 50 m |
| Developed Countries | A | 1 - 2 | | < 50 | < 75 | < 100 | < 125 |
| | B | 2 - 4 | | 50-100 | 75-150 | 100-200 | 125-250 |
| | C | 4 - 8 | | 100-200 | 150-300 | 200-400 | 250-500 |
| | D | > 8 | | > 200 | > 300 | > 400 | > 500 |
| Developing Countries | A | 1 - 4 | < 50 | < 100 | < 150 | < 200 | < 250 |
| | B | 4 - 8 | 50-100 | 100-200 | 150-300 | 200-400 | 250-500 |
| | C | 8 - 16 | 100-200 | 200-400 | 300-600 | 400-800 | 500-1000 |
| | D | > 16 | > 200 | > 400 | > 600 | > 800 | > 1000 |

Source: World Bank Institute

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.

8.3 PERFORMANCE INDICATORS FOR COMMERCIAL LOSSES

The IWA Water Loss Task Force is also developing a performance indicator for commercial losses similar to the ILI.⁶ 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).

$$\text{Apparent Loss Index (ALI)} = \frac{\text{Apparent loss value}}{5\% \text{ of water sales}}$$

⁶ Apparent Water Loss Control—The Way Forward. WLTF article, Water 21, April 2008.

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

8.4 IMPLEMENTING A MONITORING PROGRAM

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.



Utilities should continuously monitor NRW levels.

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.

Annex 5 contains a ‘self assessment matrix’ for operators to review the status of tasks at each stage of NRW management. This allows the utility to score its operational efficiency on a range from 1 to 5, and from a basic to a high level of NRW management. The utility can move from a lower to a higher level by introducing improvements to NRW management tasks.

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).
- A commonly used performance indicator for commercial losses is the Apparent Loss Index (ALI). Currently, the best commercial loss indicator is to measure it as a percentage of authorised consumption.
- Utility managers must develop and implement monitoring programs to ensure their NRW targets are being met.

9. BUILDING CAPACITY TO MANAGE NRW THROUGH UTILITY-TO-UTILITY TWINNING PARTNERSHIPS: CASE STUDIES

Reducing and managing NRW remains a challenge for many utilities and service providers, especially those in Africa where dwindling water supply, worsening water quality, and aging infrastructure place additional pressure on tackling water losses and improving operational efficiencies. To overcome these challenges, water service providers worldwide have demonstrated the value of ‘twinning’, or focused and sustained exchange between practitioners, in promoting the adoption of improved policies and best practices, and in building human and institutional capacity.

This chapter gives an example of a newly-formed partnership between African utilities, and an example of established twinning partnerships between SE Asian utilities.

BOX 9.1: TWINNING AND WATER OPERATOR PARTNERSHIPS

During the 4th World Water Forum in 2006, the UN Secretary General’s Advisory Board on Water and Sanitation announced the Hashimoto Action Plan, calling for the establishment of a platform to launch and coordinate twinning arrangements or Water Operators Partnerships (WOPs) ‘in order to strengthen the capacities of the public water operators that currently provide over 90 per cent of the water and sanitation services and who are key players for attaining the [Millennium Development Goals] on drinking water supply and sanitation.’

9.1 TWINNING APPROACH

9.1.1 FACILITATING LINKAGES

Through twinning, utility managers and staff learn about best practices and gain practical knowledge through peer-to-peer exchanges, specialised on-the-job training, information exchange, technical assistance, peer review, and technology demonstrations from leading utilities. All partners contribute in-kind or in-cash for twinning activities, such as workshop venues, translation services, and local travel.

In a twinning arrangement, a utility searching for solutions to operational efficiency constraints is paired with another utility that has proven success in addressing similar



Practitioners share best practices and new systems to build capacity and realise tangible improvements for managing NRW.

challenges and is willing to share its knowledge and innovations. The facilitator searches for potential linkages, matches counterpart institutions, and facilitates the initiation, establishment, and implementation of twinning partnerships.

Both partners have to express their priorities to strengthen their capacities in understanding and addressing NRW. To link both partners with other practitioners the facilitator must conduct an assessment of various utilities that have successfully reduced NRW and then determine their interest in participating in a twinning partnership. Once mentor utility partners are identified detailed discussions between the utilities are held to understand the incentives for all parties to commit to a partnership. Site visits to enable the mentor practitioners to become familiar with the partners' operational challenges can also be arranged. Building trust and a working relationship are critical outcomes of the initial introduction.

BOX 9.2: TWINNING PRINCIPLES

- Practitioner-to-practitioner exchange of policies and practical solutions is key.
- Benefits from the twinning partnerships are mutual, but not necessarily equal.
- Twinning partnerships are demand-driven, in line with partner strategies, plans, and interests, and results-oriented, ensuring the adoption of best practices and activities that result in real improvements and tangible outcomes.
- Partners support programmes on a cost-share basis, providing in-kind and funding support for each activity.
- All partnerships operate on a non-profit basis.

9.1.2 UNDERSTANDING PRIORITIES AND SETTING GOALS

To support the partnering approach, the Water and Sanitation Program (WSP) in Africa facilitated a utility self-assessment exercise among selected African water utilities to ascertain their strengths and needs and identify the most promising areas for learning and peer-support under the evolving Water Operators Partnerships (WOPs) platform. The results of the assessment provide a basis for further development of the WOP program in Africa.

The findings, despite the many problems in getting reliable data, broadly confirm the perilous state of the urban water sector in Africa. On average, utilities provide water to only about 65 percent of the population within their respective areas of jurisdiction while sewerage services coverage is only 36 percent. Sewerage coverage generally lags behind water in all regions but it is one of the areas where there is greatest opportunity for collaboration. The findings also show that NRW is a major weakness for most utilities in the sample. In many systems, as much as a third of production is lost due to technical and commercial losses and, on average, utilities in the sample get revenue for only half of the water they produce.

In addition to the NRW challenge, most utilities in the sample are currently struggling to cover even their operating costs. In all regions less than half of the utilities can be considered financially viable and, for many, poor performance on collections seems to be the main problem.

The WOP-Africa programme is managed jointly by the African Water Association (AfWA) and the East and Southern Africa Region-IWA (ESAR-IWA). This is via a three year business plan with major support from the Global WOPs Alliance and the World Bank's Water and Sanitation Programme (WSP). The WOP-Africa programme is building on the work of the former Water Utilities Partnership (WUP) in Africa. WOPs apply a strategy of intense and systematic knowledge-sharing (including peer-support) between water operators as a way of bridging the capacity gaps that exists in many countries.

BOX 9.3: BASIC STEPS IN ESTABLISHING TWINNING PARTNERSHIPS

1. Solicitation—Finding the right partners
2. Assessment—Selecting the right match for each utility
3. Initiation—Introducing partners
4. Establishment—Getting started in working together, including understanding priorities and setting goals
5. Implementation—Working together to achieve results
6. Replication—Disseminating best practices through key networks

9.2 TWINNING ACTIVITIES IN AFRICA

Over the last decade more than thirty countries in Africa have been implementing institutional reforms of urban water and sanitation services. Some have been more successful than others but all provide lessons to be shared in the sector. The trend in the sector has been to bring in non-utility consultants to engage with water and sewerage utilities on specific, short-term projects for institutional capacity building. In common with many such projects worldwide these have not usually yielded sustainable solutions. However, selected utility-to-utility exchanges have been promising and provide an opportunity to scale-up these initiatives within a stronger framework.

The WOP-Africa is built on the premise that well-performing utilities will step forward and emerge as leaders and that the needs of the less well-performing utilities will be met in a professional

and sustainable manner. This framework for WOP-Africa is a culmination of initial activities facilitated by the Water and Sanitation Programme in Africa (WSP-Africa). This is in response to the need of the utilities in Africa to operationalise the WOP-Africa. The utilities in Africa believe that by working together, making use of the immense experience that exists on the continent and sharing these experiences, WOP-Africa is more likely to realize its vision of an Africa with improved water and sanitation services for all.

9.2.1 WATER OPERATOR PARTNERSHIPS (WOPS)

The development of WOPs in Africa has progressed in stages:

- Inter-utility twinning and capacity building
- 'Establishment' workshops to initiate WOPs
- 'Building partnerships' workshops to identify potential twinning projects

Twinning and capacity building had been carried out between utilities prior to the WOP/AfWA activities. Mentor utilities were:

- SDE Senegal (for most West African countries utilities)
- ONEP Morocco (for most west African countries utilities)
- SODECI Cote d'Ivoire (for most West African counties utilities)
- NWSC Kampala (for most East and Central African utilities)
- Rand Water, South Africa (for the southern region)

'Establishment workshops' to initiate the Water Operator Partnership and potential partnerships in Africa were held at Nairobi, Johannesburg and Cotonou between 2006 and 2008. These workshops led to the creation and launch of WOP Africa for the African continent

Three WOP Africa 'Building Partnerships' workshops took place over the period July 2007 to October 2008. These began with the Kampala workshop (July 2007) organized by Uganda's NWSC, aimed at utility managers and sector policymakers from Eastern Africa. It was followed by the Dakar workshop (September 2008) gathering utilities from Western & Central Africa including a contingent of senior managers from six Nigerian utilities. The last workshop was directed at utilities from Southern Africa, as well as at a number of Eastern African utilities, and took place in Maseru (November 2008).

Each workshop gathered about 60 to 100 utility managers and representatives from other sectors and partners. All in all, more than 240 utility managers from more than 80 utilities have been exposed to the WOP concept and have participated in its preparation.

9.2.2 THE KIWASCO MODEL

Utility-to-utility partnerships are at the core of the WOP activities, and a first capacity building WOP-Africa is underway between NWSC in Uganda and Kisumu Water and Sewerage Company (KIWASCO) in Kenya.

At a regional workshop held in Kampala in June 2008, a utility self assessment exercise validated and developed a framework for a utility-to-utility partnership. KIWASCO identified NWSC as a corporation from which it would share its best practices based on strengths and weaknesses. A memorandum of understanding was signed on 23rd December 2008 from which areas of cooperation on core utility operations were laid down. Discussions have been held with the Global WOPs Alliance and UN HABITAT regarding the execution of a short term high impact programme with advisory services/technical assistance from the NWSC External Services unit. Funding has been secured and will be channelled through the African Water Association (AfWA). The project began in May 2009.

The partnering project is addressing:

- HR management policies, procedures and tools
- Labour productivity, rewards and incentives
- Operations effectiveness and contractualization
- Reduction of NRW, detection of leaks and other losses

- Customer care, revenue collection and communication strategies

9.3 TWINNING ACTIVITIES IN ASIA

The United States Agency for International Development’s Environmental Cooperation–Asia (ECO-Asia) programme demonstrates how twinning arrangements helps water utilities meet the challenges of reducing water losses and improving operational efficiencies to support the achievement of the Millennium Development Goals (MDGs) in urban areas. ECO-Asia facilitates linkages between utilities to address specific priority needs, such as NRW management. Utility strengthening through these collaborative arrangements promotes self-reliance and long term sustainability, which in the long run will result in not only improved efficiencies but also expanded service areas and increased revenues.

In 2006-07, ECO-Asia facilitated twinning partnerships between Ranhill Utilities Berhad (Ranhill), a Malaysian utility recognized for effectively reducing and managing NRW, and the Provincial Waterworks Authority (PWA) of Thailand and the Bac Ninh Water Supply and Sewerage Company (WSSC) in Vietnam. The aim was to build their capacities in understanding and tackling NRW. In these twinning arrangements, ECO-Asia promoted the practitioner-to-practitioner exchange of best practices based on Ranhill’s achievements in reducing NRW in Johor, Malaysia.

After initiating linkages between utility partners, ECO-Asia facilitated the development of a programme of activities involving all partners, where Ranhill—the mentoring utility - would share its best practices for managing NRW. Upon concurring to the joint program, all partners signed an agreement to implement the twinning activities to strengthen capacities and achieve the adoption of best practices for managing water losses at PWA and the Bac Ninh WSSC. ECO-Asia continued to facilitate and monitor the programme implementation to better enable integration of practices and policies.

In the Ranhill-PWA-Bac Ninh WSSC partnerships, activities included a series of classroom and on-the-job training workshops and field practices to enable transfer of practical solutions and best practices. Initially, Ranhill trained senior managers and operations staff to better understand NRW and its impact on a utility’s finances and operations. Building on this improved awareness, operations staff next learned how to conduct an internationally-recognised water balance to detect key sources of NRW, followed by further hands-on training on approaches to reduce NRW, such as DMA design and establishment. Key PWA and Bac Ninh WSSC managers also visited Ranhill operations in Johor to advance their understanding of field applications of NRW reduction techniques. In all exchanges, Ranhill shared its solutions and practical lessons gained in effectively managing NRW.

9.3.1 THE BAC NINH MODEL

For the Bac Ninh WSSC, the twinning partnership built the capacity of its staff to improve its operations by strengthening the basic understanding of NRW management and introducing various activities needed to lower NRW. Main results from the partnership with Ranhill include:

- Key staff from both technical and non-technical departments improved their understanding of NRW, especially on identifying the major causes of NRW and developing practical



Experts from Ranhill working hand-in-hand with their counterparts in Bac Ninh, Vietnam, to test DMA operations.

- Solutions necessary to manage them, and on performing a water balance as the critical step in developing an NRW management strategy.
- Technical staff members continue to conduct water balances on discrete service areas and are beginning to attribute inconsistent NRW to inadequate billing and collection processes (i.e. commercial losses).
- Technical staff members have incorporated best practices introduced by Ranhill for establishing DMAs, such as ensuring adequate water pressure and closing all boundary valves, to their current procedures and are testing them on a pilot DMA.
- Key engineers worked with Ranhill to revise its current DMA design to enable improved NRW management following training events.
- As part of the pilot DMA activities, the Bac Ninh WSSC purchased and commissioned critical equipment, such as data loggers and a bulk meter to lower NRW levels, with guidance from Ranhill.

9.4 PROMOTING TWINNING PARTNERSHIPS

Twinning partnerships are practitioner-to-practitioner linkages. Linkages are usually water utility partnerships that explore opportunities to twin water service providers, cities, governments, and financing institutions—with the aim of improving and expanding delivery of water supply and sanitation services.

One example of this is the model provided by ECO-Asia to disseminate, replicate, and strengthen the results of such twinning partnerships, ECO-Asia cooperates with regional Asian networks and platforms on knowledge sharing, training, and networking activities. Partner networks include the International Water Association (IWA), Southeast Asian Water Utilities Network (SEAWUN), South Asia Water Utilities Network (SAWUN), ASEAN Environmentally Sustainable Cities Initiative, Association of Development Financing Institutions in Asia and the Pacific, and CityNet. With its partner networks, ECO-Asia will continue to find opportunities to replicate best practices and innovations and to facilitate new twinning arrangements. Inter-regional cooperation is an effective approach to leveraging local capacity and, at the same time, promoting greater understanding and collaboration in a highly diverse region.

In Africa, a workshop for utilities held in Johannesburg on 24-26 April 2007 brought together 96 water utility executives representing 70 water utilities in 30 African countries. The workshop was a follow-up to the 6-8 December 2006 Capacity Building Workshop organized jointly by UN-DESA and UN-HABITAT in Nairobi, Kenya. The idea of Water Operators Partnerships (WOP) was endorsed by the United Nations Secretary-General's Advisory Board (UNSGAB) on Water and Sanitation in March 2006 as one of its key programs. It is also part of the Hashimoto Action Plan to be implemented by different key stakeholders in the water and sanitation sector including the UN, international organizations, multi-lateral development banks and governments.

The Water Operators Partnership for Africa (WOP-Africa) will build on the work of the Water Utilities Partnership (WUP) and is part of the Global Water Operators Partnership under the leadership of UN-Habitat. The workshop in Johannesburg was historic in that AFWA and ESAR-IWA, the two Water Associations on the continent, had an unprecedented opportunity to come together and strategize on how best to meet the challenge of improving utility performance and achieving the MDGs in water and sanitation for urban Africa. There are a number of operational details that are yet to be determined, but it

is clear that African water utilities are best placed to move forward with this initiative in a participatory and coordinated manner.

Key Messages

- Water service providers worldwide have demonstrated the value of ‘twinning’, or focused and sustained exchange between practitioners, in promoting the adoption of improved policies and best practices, and in building human and institutional capacity.
- In a twinning arrangement, a utility searching for solutions to operational efficiency constraints is paired with another utility that has proven success in addressing similar challenges and is willing to share its knowledge and innovations.
- Twinning activities include peer-to-peer exchanges, specialised on-the-job training, information exchange, technical assistance, peer review, and technology demonstrations.
- The twinning model demonstrates how regional collaboration and sharing of best practices among peers benefit all parties involved, although the benefits vary in form and results.
- To disseminate, replicate, and strengthen the results of such twinning partnerships, ECO-Asia cooperates with regional networks and platforms on knowledge sharing, training, and networking activities.

ANNEX 1: GLOSSARY

MANAGERS' NRW HANDBOOK - GLOSSARY

THE WATER BALANCE

| | | | | |
|---|------------------------|---------------------------------|--|-------------------------|
| System Input Volume (allow for known errors) | Authorized Consumption | Billed Authorized Consumption | Billed Metered Consumption | Revenue Water |
| | | | Billed Unmetered Consumption | |
| | | Unbilled Authorized Consumption | Unbilled Metered Consumption | Non-Revenue Water (NRW) |
| | | | Unbilled Unmetered Consumption | |
| | Water Losses | Commercial Losses | Unauthorized Consumption | |
| | | | Customer Metering Inaccuracies and Data Handling Errors | |
| | | Physical Losses | Leakage on Transmission and/or Distribution Mains | |
| | | | Leakage on Service Connections up to Point of Customer Use | |

WATER BALANCE DEFINITIONS

In the following, all terms used in Figure above are listed in hierarchical order—as one would read the water balance form from left to right. Some of the terms are self-explanatory but are still listed for consistency.

System Input Volume

The volume of treated water input to that part of the water supply system to which the water balance calculation relates.

Authorized Consumption

The volume of metered and/or un-metered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorized to do so by the water supplier, for residential, commercial and industrial purposes. It also includes water exported across operational boundaries.

Authorized consumption may include items such as fire fighting and training, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, frost protection, building water, etc. These may be billed or unbilled, metered or unmetered.

Water Losses

The difference between System Input and Authorized Consumption. Water losses can be considered as a total volume for the whole system, or for partial systems such as transmission or distribution schemes, or individual zones. Water Losses consist of Physical Losses and Commercial Losses (also known as Real Losses and Apparent Losses)

Billed Authorized Consumption

Those components of Authorized Consumption which are billed and produce revenue (also known as Revenue Water). Equal to Billed Metered Consumption plus Billed Unmetered Consumption.

Unbilled Authorized Consumption

Those components of Authorized Consumption which are legitimate but not billed and therefore do not produce revenue. Equal to Unbilled Metered Consumption plus Unbilled Unmetered Consumption.

Commercial Losses

Includes all types of inaccuracies associated with customer metering as well as data handling errors (meter reading and billing), plus unauthorized consumption (theft or illegal use).

Commercial losses are called "Apparent Losses" by the International Water Association and in some countries the misleading term "Non-Technical Losses" is used.

Physical Losses

Physical water losses from the pressurized system and the utility's storage tanks, up to the point of customer use. In metered systems this is the customer meter, in unmetered situations this is the first point of use (stop tap/tap) within the property. Physical losses are called "Real Losses" by the International Water Association and in some countries the misleading term "Technical Losses" is used.

Billed Metered Consumption

All metered consumption which is also billed. This includes all groups of customers such as domestic, commercial, industrial or institutional and also includes water transferred across operational boundaries (water exported) which is metered and billed.

Billed Unmetered Consumption

All billed consumption which is calculated based on estimates or norms but is not metered. This might be a very small component in fully metered systems (for example billing based on estimates for the period a customer meter is out of order) but can be the key consumption component in systems without universal metering. This component might also include water transferred across operational boundaries (water exported) which is unmetered but billed.

Unbilled Metered Consumption

Metered Consumption which is for any reason unbilled. This might for example include metered consumption by the utility itself or water provided to institutions free of charge, including water transferred across operational boundaries (water exported) which is metered but unbilled.

Unbilled Unmetered Consumption

Any kind of Authorized Consumption which 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 which is very often substantially overestimated. Theoretically this might also include water transferred across operational boundaries (water exported) which is unmetered and unbilled—although this is an unlikely case.

Unauthorized Consumption

Any unauthorized use of water. This may include illegal water withdrawal from hydrants (for example for construction purposes), illegal connections, bypasses to consumption meters or meter tampering.

Customer Metering Inaccuracies and Data Handling Errors

Commercial water losses caused by customer meter inaccuracies and data handling errors in the meter reading and billing system.

Leakage on Transmission and/or Distribution Mains

Water lost from leaks and breaks on transmission and distribution pipelines. These might either be small leaks which are still unreported (e.g. leaking joints) or large bursts which were reported and repaired but did obviously leak for a certain period before that.

Leakage and Overflows at Utility's Storage Tanks

Water lost from leaking storage tank structures or overflows of such tanks caused by e.g. operational or technical problems.

Leakage on Service Connections up to point of Customer Metering

Water lost from leaks and breaks of service connections from (and including) the tapping point until the point of customer use. In metered systems this is the customer meter, in unmetered situations this is the first point of use (stop tap/tap) within the property. Leakage on service connections might be reported breaks but will predominately be small leaks which do not surface and which run for long periods (often years).

Revenue Water

Those components of Authorized Consumption which are billed and produce revenue (also known as Billed Authorized Consumption). Equal to Billed Metered Consumption plus Billed Unmetered Consumption.

Non-Revenue Water

Those components of System Input which are not billed and do not produce revenue. Equal to Unbilled Authorized Consumption plus Physical and Commercial Water Losses.

(Unaccounted-for Water)

Because of the widely varying interpretations and definitions of the term 'Unaccounted for Water', it is strongly recommend that this term be no longer used. It is equivalent to 'Water Losses' in the Water Balance diagram

UNDERSTANDING LEAKAGE

Background Leakage

Background leakage (also called background losses) are individual events (small leaks and weeps) that will continue to flow, with flow rates too low to be detected by an active leakage control campaign unless either detected by chance or until they gradually worsen to the point that they can be detected. As the term is nearly untranslatable, it is often referred to as "unavoidable losses". The level of background leakage depends on the overall infrastructure condition, the pipe material(s) and the soil. It is furthermore heavily influenced by pressure (N1=1.5 or even higher).

Bursts

Events with flow rates greater than those of background losses and therefore detectable by standard leak detection techniques. Bursts can be visible or hidden.

Reported Bursts

Reported Bursts are visible leaks that are brought to the attention of the water utility by the general public or the water supply organization's own operatives.

Unreported Bursts

Unreported bursts are those that are located by leak detection teams as part of their normal everyday active leakage control duties. These breaks go undetected without some form of active leakage control.

Active Leakage Control (ALC)

ALC is the policy a water utility implements if it decides to pro-actively search for hidden leaks. ALC in its most basic form consists of regular sounding (e.g. listening to leak noise on fire hydrants, valves and accessible parts of service connections (e.g. stop cock) with listening sticks or electronic devices.

Leak Duration

The length of time for which a leak runs consists of three separate time components - awareness, location and repair time.

Awareness Time

Awareness Time is the average time from the occurrence of a leak until the water utility becomes aware of its existence. The awareness time is influenced by the type of applied ALC policy.

Location Time

For reported bursts, this is the time it takes for the water utility to investigate the report of a leak or break and to correctly locate its position so that a repair can be carried out. For Unreported bursts, depending on

the ALC method used, the location duration may be zero since the burst is detected during the leak detection survey and therefore awareness and location occur simultaneously.

Repair Time

The time it takes the water utility to organize and affect the repair once a leak has been located.

N1 Factor

The N1 Factor is used to calculate pressure/leakage relationships:

Leakage Rate L (Volume/unit time) varies with Pressure^{N1} or $L1/L0 = (P1/P0)^{N1}$

The higher the N1 value, the more sensitive existing leakage flow rates will be to changes in pressures. N1 Factors range between 0.5 (corrosion holes only in metallic systems) and 1.5 with occasional values of up to 2.5. In distribution systems with a mix of pipe materials, N1 values might be in the order of 1 to 1.15. Therefore a linear relationship can be assumed initially until N1 Step Tests are carried out to derive better data.

N1 Step Test

The N1 Step Test is used to determine the N1 value for areas of the distribution network. Inflow to the area as well as pressure at the Average Zone Point are recorded. During the test supply pressure into the area is reduced in a series of steps. This pressure reduction together with the corresponding inflow reduction forms the basis for the calculation of N1.

Pressure Step Test

Equivalent to N1 Step Test.

Average Zone Point (AZP)

The AZP is the point in a certain zone or area of the distribution network which is representative for the average pressure in this particular part of the distribution network.

QUANTIFYING LOSSES

Physical Loss Component Analysis

Determination and quantification of the components of physical losses in order to calculate the expected level of physical losses in a distribution system. The BABE concepts were the first component analysis model.

BABE Concepts

The Bursts And Background Estimates (BABE) concepts were developed by the UK National Leakage Initiative between 1991 and 1993. The concepts were the first to model physical losses objectively, rather than empirically, thus permitting rational planning management and operational control of strategies for their reduction.

Leakage Modeling

Leakage modeling is a methodology to analyze 24h inflow and pressure data of a hydraulically discreet part of the distribution system. Using the N1 pressure:leakage relationship principles and the results of the N1 Step Test the measured inflow can be split into:

- Consumption; and
- Leakage; and further into:
- Background Losses
- Losses from Bursts (= losses which can be recovered)

Equivalent Service Pipe Bursts (ESPBs)

The number of ESPBs is an indication of how many hidden leaks can be expected in a certain part of the distribution network. It is calculated by dividing the volume of excess (or hidden) losses by the volume of water lost through an average service pipe burst.

Hidden Losses (Excess Losses)

Physical loss component analysis is used to determine the part of physical losses which is in "excess" of all other leakage components. The volume of Hidden (Excess) Losses represents the quantity of water lost by "hidden" leaks that are not being detected and repaired with the current leakage control policy.

District Metered Area (DMA)

A discrete zone with a permanent boundary defined by flow meters and/or closed valves.

Night Flow Test (NFT)

Zone inflow and pressure measurement carried out during night hours, usually between 02:00 and 04:00 hours to measure Minimum Night Flow and corresponding Average Zone Night Pressure.

Average Zone Night Pressure (AZNP)

The AZNP is the average pressure during (low consumption) night hours measured at the Average Zone Point.

Minimum Night Flow (MNF)

The Minimum Night Flow (MNF) in urban situations normally occurs during the early morning period, usually between around 02:00 and 04:00 hours. The MNF is the most meaningful piece of data as far as physical loss levels are concerned. During this period, consumption is at a minimum and therefore physical losses are at the maximum percentage of the total flow. The estimation of the physical loss component at Minimum Night Flow is carried out by subtracting an assessed amount of Minimum Night Consumption for each of the customers connected in the zone being studied.

Minimum Night Consumption

Minimum Night Consumption is part of the Minimum Night Flow and is normally composed of three elements:

- Household night use
- Non-household night use
- Exceptional night use

Net Night Flow

Net Night Flow is the difference between Minimum Night Flow and Minimum Night Consumption and is equivalent to Night Leakage

$$[\text{Net Night Flow}] = [\text{Minimum Night Flow}] - [\text{Minimum Night Consumption}]$$

PERFORMANCE INDICATORS

Infrastructure Leakage Index (ILI)

The ILI is a measure of how well a distribution network is managed (maintained, repaired, rehabilitated) for the control of real 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 it facilitates comparisons between countries that use different measurement units (metric, U.S., or imperial).

Minimum Achievable Annual Physical Losses (MAAPL)

Physical Losses cannot be totally eliminated. The volume of Minimum Achievable Annual Physical Losses represent the lowest technically achievable annual volume of Physical Losses for a well-maintained and well-managed system. The standard equation for calculating MAAPL for individual systems was developed and tested by the IWA Water Losses Task Force. It allows for:

- background leakage—small leaks with flow rates too low for sonic detection if non-visible
- reported leaks and breaks—based on average frequencies, typical flow rates, target average durations
- unreported leaks and breaks—based on average frequencies, typical flow rates, target average durations
- pressure/leakage rate relationships (a linear relationship being assumed)

The MAAPL equation requires data on four key system-specific factors:

- Length of mains (all pipelines except service connections)
- Number of service connections
- Length of service connection between property boundary and customer meter. (Note: this is not the same as the total length of the service connection. Losses on the service connection between the tapping point at the main pipeline are included in the allowance per service connection. The additional allowance for length of connections on private land was included to take the longer leak run-times in situations where visible leaks would not be seen by public into account. In most urban situations, if the

customer meter is inside the building, the length of service connection between property boundary and customer meter is obviously nil.)

- Average operating pressure

Minimum Achievable Annual Physical Losses (MAAPL) is called "Unavoidable Annual Real Losses (UARL)" by the International Water Association.

ANNEX 2: LOCATING AND REDUCING UNAUTHORISED CONSUMPTION

At least once a year, the water utility should:

1. Verify Customer Database

During routine meter reading, direct meter readers to confirm:

- Buildings are connected to and receiving water supply.
- Buildings are recorded in the customer account register.
- Size of the service connection or meter.
- Meter serial number is assigned to the customer account.
- Building classification matches service connection or meter size.

2. Review Policies and Procedures

- Review service connection policies and procedures to make sure they do not encourage illegal connections.
- Simplify connection application procedures.

ANNEX 3: STEPS FOR CALCULATING NRW USING THE IWA WATER BALANCE TABLE

| A | B | C | D | E |
|---------------------|------------------------|---------------------------------|---|-------------------|
| System Input Volume | Authorized Consumption | Billed Authorized Consumption | Billed Metered Consumption | Revenue Water |
| | | | Billed Unmetered Consumption | |
| | | Unbilled Authorized Consumption | Unbilled Metered Consumption | Non Revenue Water |
| | | | Unbilled Unmetered Consumption | |
| | Water Losses | Commercial Losses | Unauthorized Consumption | |
| | | | Customer Meter Inaccuracies and Data Handling Errors | |
| | | Physical Losses | Leakage on Transmission and Distribution Mains | |
| | | | Leakage and Overflows from the Utilities Storage Tanks | |
| | | | Leakage on Service Connections up to the Customer Meter | |
| | | | | |

Water balance results in volumes and consumptions in cubic meters per year.

2.3.1 STEP 1—DETERMINE SYSTEM INPUT VOLUME

Identify sources of input (and export) volume:

- Water supplied to the network from own WTW sources
- Water transferred in from adjacent networks
- Water purchased from bulk suppliers
- Water exported from the network

Ensure meter accuracy:

- Establish meter accuracy from manufacturers' manuals (eg +/- 2%)
- Check meter readings using downstream master meter or insertion meter
- Replace or re-calibrate meters as necessary
- Correct System Input Volume for all known errors
- Apply 95% Confidence Limits

If there are any un-metered sources the annual flow should be estimated by using any (or a combination) of the following:

- Temporary flow measurements using portable devices
- Reservoir drop tests
- Analysis of pump curves, pressures and average pumping hours

2.3.2 STEP 2—DETERMINE AUTHORISED CONSUMPTION

Billed Metered Consumption

- Extract consumption of the different consumer categories (e.g. domestic, commercial, industrial) from the utility's billing system
- Analyse the data, paying special attention to very large consumers.
- Process the annual billed metered consumption information taken from the billing system to
 - allow for meter reading time-lag
- Ensure that the billed metered consumption period used in the audit is consistent with the audit period
- Establish meter accuracy from manufacturers' manuals (eg +/- 2%)
- Apply 95% Confidence Limits

Billed Unmetered Consumption

- Extract data from the utility's billing system
- Identify and monitor unmetered domestic customers for a certain period, either by the installation of meters on those non-metered connections or by measuring a small area with a number of unmetered customers (the latter avoids customers changing consumption habits)

Unbilled Metered Consumption

- Establish the volume of unbilled metered consumption in a way similar to that for billed metered consumption

Unbilled Unmetered Consumption

Unbilled unmetered consumption, traditionally including water used by the utility for operational purposes, is often seriously overestimated. This might be caused by simplifications (a certain % of total system input) or deliberate overestimates to ‘reduce’ water losses. Components of unbilled unmetered consumption should be identified and individually estimated, for example:

- Mains flushing: How many times per month? For how long? How much water?
- Fire fighting: Has there been a big fire? How much water was used?

2.3.3 STEP 3—ESTIMATE COMMERCIAL LOSSES

Unauthorised Consumption

It is difficult to provide general guidelines for estimating unauthorized consumption. There is a wide variation of situations and knowledge of the local situation will be most important to estimate this component. Unauthorised consumption can include:

- Illegal connections
- Misuse of fire hydrants and fire fighting systems
- Vandalised or bypassed consumption meters
- Corrupt practices of meter readers
- Open boundary valves to external distribution systems (unknown export of water).

The estimation of unauthorised consumption is always a difficult task and should at least be done in a transparent, component based way so that the assumptions can be easily checked and/or modified later.

Customer Metering Inaccuracies and Data Handling Errors

The extent of customer meter inaccuracies, namely under- or over-registration, has to be established based on tests of a representative sample of meters. The composition of the sample should reflect the various brands and age groups of domestic meters. Tests are done either at the utility’s own test bench, or by specialized contractors. Large customer meters are usually tested on site with a test rig. Based on the results of the accuracy tests, average meter inaccuracy values (as % of metered consumption) will be established for different user groups.

Data handling errors are sometimes a very substantial component of commercial losses. Many billing systems do not reach the expectations of the utilities but problems often remain unrecognised for years. It is possible to detect data handling errors and problems with the billing system by exporting billing data (of say the last 24 months) and analysing it using standard database software.

The detected problems have to be quantified and a best estimate of the annual volume of this component has to be calculated.

2.3.4 STEP 4—CALCULATE PHYSICAL LOSSES

The calculation of real losses in its simplest form is now straightforward:

Physical Losses = Volume of NRW minus Volume of Commercial Losses

This figure is useful for the start of the analysis in order to get a feeling for the expected magnitude of physical losses. However, it always has to be kept in mind that the water balance might have errors—and that the calculated volume of real losses might simply be wrong.

2.3.5 STEP 5—ESTIMATING REAL LOSS COMPONENTS

To accurately split real losses into its components will only be possible with a detailed component analysis. However, a first estimate can be made using a few basic estimates:

Leakage on Transmission and/or Distribution Mains

Bursts on distribution and especially transmission mains are primarily large events—they are visible, reported and normally repaired quickly. By using data from the repair records, the number of leaks on mains repaired during the reporting period (usually 12 months) can be calculated, an average flow rate estimated and the total annual volume of leakage from mains calculated as follows:

NUMBER OF REPORTED BURSTS X AVERAGE LEAK FLOW RATE X AVERAGE LEAK DURATION (SAY 2 DAYS)

A certain provision for background losses and current undetected leaks on mains can then be added.

Leakage and Overflows at Utility's Storage Tanks

Leakage and overflows at storage tanks are usually known and can be quantified. Overflows can be observed and the average duration and flow rate of the events estimated. Leakage of storage tanks can be calculated by making a level drop test with in and outflow valves closed.

Leakage on Service Connections up to Point of Customer Metering

By deducting mains leakage and storage tank leakage from the total volume of real losses, the approximate quantity of service connection leakage can be calculated. This volume of leakage includes reported and repaired service connection leaks as well as hidden (so far unknown) leaks and background losses from service connections.

Step 1: Enter System Input Volume in Column A

Step 2: Enter in Column C: Billed Authorized Consumption

Enter in Column D:

- Billed Water Exported (none exported = 0)
- Billed Metered Consumption
- Billed Un-metered Consumption

Enter in Column E: Revenue Water

(NOTE: Billed Authorized Consumption should equal to the summation of the three Billed components above and. All billed water use is the same as a utility's revenue).

Step 3: Calculate the Volume of Non-Revenue Water (E) as:

System Input Volume (A) - Revenue Water (E).

Step 4: Enter in Column D:

- Unbilled Metered Consumption
- Unbilled Un-metered Consumption

Enter in Column C: Total Unbilled Authorized Consumption

Step 5: In Column C: Add volumes of Billed Authorized Consumption and Unbilled Authorized Consumption

Enter sum in Column B (top) as Authorized Consumption

Step 6: Calculate Water Losses (B) = System Input Volume (A) - Authorized Consumption (B)

Step 7: Assess components of Unauthorized Consumption, and Metering Inaccuracies and Data Handling Errors (D) by best means available through field verification in random service area and by estimation.

Add Unauthorized Consumption and Metering Inaccuracies (D)

Enter sum in Commercial Losses (C)

Step 8: Calculate Physical Losses (C) = Water Losses (B) - Commercial Losses (C).

Step 9: Assess components of Physical Losses (D) by best means available in the field and through desk studies (e.g. night flow analysis, burst frequency/flow rate/duration calculations, modeling etc)

Add components of Physical Losses (D)

Cross-check with volume of Physical Losses (C) as derived from Step 8

This approach yields best results when meters are installed and regularly calibrated. Results will remain approximate to the extent that factors are based on estimates.

ANNEX 4: SAMPLE WATER AUDIT CHECKLIST

OBJECTIVES FOR A WATER AUDIT

- To assess whether the water utility is serving its customers effectively, efficiently and equitably;
- To estimate water losses and their sources; and
- To assess how different groups are connected to piped water and to determine how the utility and informal service providers respond to concerns of different groups.

ANALYSIS

The important aspect of the analysis is to reveal:

- The actual coverage of the community with piped water and 24-hour service.
- The official NRW and the use of NRW.
- Unit cost of water from various sources and the numbers who use.
- Unit consumption of water from various sources and the numbers who use.
- The extent of informal water supplies.

USE OF ANALYSIS

The analysis may be used to:

- Reduce water losses.
- Register and assist water vendors.
- Monitor investment and intervention results and gauge impact over time.

SERVICE AREA

1. Population in City
2. Population in Waterworks Service Area
3. Population Served by Waterworks (Direct)
4. Population Served by Waterworks (Bulk Supply / Indirect)
5. Population Served by House Connection

6. Population Served by Shared Connection
7. Population Served by Standpipe or Community Tank
8. Population Served by Waterworks Tanker

SERVICE DELIVERY—METERING

9. Number of Connections Domestic Metered / Not Metered
10. Number of Standpipes / Community Tank Metered / Not Metered
11. Number of Bulk Connections Metered / Not Metered
12. Number of Non-Domestic Connections Metered / Not Metered
13. Number of Sources of Treated Water for Piped Supply Metered / Not Metered
14. Are all master meters accurate? Yes / No
15. Is there any chance of backflow, bypass or double metering of water? Yes / No
16. Number of Waterworks Tankers / Capacity
17. Are all parks, schools, wastewater treatment plants and government buildings metered? Yes / No
18. Are meter readers motivated to find leaks and trained to do so? Yes / No
19. Are slow or stopped meters identified by the billing department? Yes / No
20. Are both system and customer meters regularly tested and properly sized? Yes / No
21. Are authorised unmetered uses estimated and reported? Yes / No

SERVICE DELIVERY—LEVEL OF SERVICE AND OPERATIONS

22. Proportion of House Connections with 24 hour Supply %
23. Percentage of Service Area with 24 Hour Supply %
24. Production Volume (m³/day)
25. Consumption Volume Domestic (m³ / month)
26. Consumption Volume Non-Domestic (m³/ month)
27. Are comparisons made between water produced and water used, on a regular basis?
28. New Connections Installed in last 12 months (Domestic)
29. New Connection Fee and Terms of Payment (Domestic)
30. Average Household Water Consumption Per Month

31. Average Household Water Bill Per Month
32. Number of People Employed by Waterworks
33. Is the public notified via advertising, to report leaks and bursts? Yes / No
34. Are there any unusual pressure drops in any part of the system or isolated complaints about low pressure? Yes / No
35. Are there high flows occurring during periods when flows should be low? Yes / No
36. Are all valves and backflow preventers between pressure zones working properly? Yes / No
37. Is the telemetry available? Yes / No. If yes, is it accurate? Yes / No
38. Are streams and storm channels routinely checked for unusual flows or possible leaks? Yes / No
39. Once estimated, are non-revenue water figure monitored over time? Yes / No
40. Is the volume of non-revenue water increasing? Yes / No

FINANCIAL PARAMETERS

41. Money Billed Per Month for Domestic Customers
42. Money Billed per Month for Non-Domestic Customers
43. Are there any known major errors or are any corrections used in billing records such as wrong multipliers on meters? Yes / No
44. O&M Expenses Power /Staff/ Other Per Annum
45. Operating Ratio Expenses /Total Billings
46. Accounts Receivables in Equivalent Months Billings
47. Annual Capital Expenditure
48. O&M Cost
49. Capital Cost
50. Lifeline Rate for Poor
51. Cross Subsidy Non-Domestic to Domestic
52. Cross Subsidy City to Town
53. Sources of Capital Works Funding (Central Govt, Local Govt, Donors, Other)
54. Average Household Income Per Month

ANNEX 5: SELF ASSESSMENT MATRIX ON NON-REVENUE WATER

SELF ASSESSMENT MATRIX ON NON-REVENUE WATER

| Level | | | | | | |
|------------------|---|---|--|--|--|---|
| Issues questions | 1 Basic | 2 | 3 | 4 | 5 High | |
| 1 | Water Balance, Flow and Pressure Monitoring, Mapping | | | | | |
| 1.1 | Water Balance | We do not establish a water balance | We have tried to establish a water balance but gave up since we don't know the split in physical and commercial losses | We establish a water balance following our own format | We establish an annual water balance in accordance with the international form | We establish an annual water balance in accordance with the international form and also use 95% confidence limits to indicate accuracy bands. |
| 1.2 | System Input Metering | Most of our system input is not metered | Not all, but > 50% of our system input is metered | Our system input is metered but we are not sure about the accuracy of these (partly old) meters | Our system input is metered with mechanical and/or magnetic flow meters that are rarely calibrated | Our system input is metered with magnetic flow meters that are regularly calibrated |
| 1.3 | Pressure Monitoring | We do not have any pressure recorders installed | We have a few pressure recorders at pumping stations and treatment plants installed | We have a few pressure recorders at pumping stations and treatment plants installed and sporadically measure pressure in the distribution network with pressure gauges | We have a few pressure recorders at pumping station and treatment plants and sporadically measure pressure in the distribution network with pressure loggers | We have permanently installed pressure loggers and continuously monitor pressure in the distribution network |

| | Level | 1 Basic | 2 | 3 | 4 | 5 High |
|------------------|-------------------------------|------------------------------------|--|---|---|---|
| Issues questions | | | | | | |
| 1.4 | Maps/GIS | We do not have maps at all | The maps we have are not updated | We have started to update our maps | Our maps are updated but do not include GIS | We use GIS based on updated maps |
| 2 | Leak Repair Records | | | | | |
| 2.1 | Leak Repair Records | We have no records of leak repairs | The only way to know the number of leaks repaired is to look into the customer complaints book | We keep basic leak repair records that only tell us whether the leak was on a main pipe or a service connection | We keep detailed records that indicate location, pipe diameter, material and type of leak as well date of detection and date and duration of repair | We keep detailed records that indicate location, pipe diameter, material and type of leak as well date of detection and date and duration of repair and have linked this to our GIS |
| 3 | Performance Indicators | | | | | |
| 3.1 | Performance Indicators | The only PI used is % NRW | We have tried to calculate water loss performance indicators | We regularly calculate physical loss performance indicators | We regularly calculate physical and commercial loss performance indicators | We regularly calculate physical and commercial loss performance indicators and publish them in our annual report |
| 4 | Active leakage control | | | | | |
| 4.1 | Active leakage control | We only repair visible leaks. | We have leak detection equipment but we do not use it. | We do leak detection occasionally if there is a specific problem in an area. | We have started to do regular leak surveys. | We cover the network by leakage survey at least once a year. |

| | Level Issues questions | 1 Basic | 2 | 3 | 4 | 5 High |
|----------|--|---|--|---|---|---|
| 4.2 | District Meter Areas (DMAs) | We have no DMAs and have no plans to establish DMAs | We have started to establish the first DMAs | The first DMAs are established and we have already the first results | We have several DMAs and check and analyse inflow data sporadically | We have several DMAs and monitor flow and pressure on a regular basis |
| 4.3 | Leak Repair - Distribution Pipes(Repair Time) | We have no records and therefore don't know how fast our leaks repaired | Our average repair time is more than 7 days | Our average repair time is between 7 and 3 days | Our average repair time is between 3 and 1.5 days | Our average repair time is less than 1.5 days |
| 4.4 | Leak Repair - House Connections | We have no records and therefore don't know how fast our leaks repaired | Our average repair time is more than 14 days | Our average repair time is between 14 and 7 days | Our average repair time is between 7 and 2 days | Our average repair time is less than 2 days |
| 5 | Customer Metering | | | | | |
| 5.1 | Customer Metering | We have no customer metering | Only large customers are metered | We have started with universal customer meters but at present not all customers have meters installed | Nearly all of our customers are metered, except public fountains, stand pies and similar. | 100% of our customers are metered |
| 5.2 | Customer Meter Replacement and Age | We have no reliable information on the age of our customer meters | Many of our customer meters are older than 10 years, we have not yet introduced a regular replacement policy | We only change meters if they are obviously not functioning anymore | We have a meter replacement policy but have not been able to change all meters so some of our customer meters are still older than 10 years | We strictly follow our customer meter replacement policy and replace ALL meters every 5 - 7 years |

| | Level Issues questions | 1 Basic | 2 | 3 | 4 | 5 High |
|-----|---|--|---|---|--|---|
| 5.3 | Customer Meter Class | All customer meters are class B | All customer meters are Class B and C | All customer meters are class C | All customer meters are Class C and D | All customer meters are class D |
| 5.4 | Customer Database | Our customer database has not been updated for a long time | We sporadically update our customer database | We are in the process of updating our customer database | We regularly update our customer database by house to house surveys and checks | We have an updated customer data base that is linked to the GIS. |
| 5.5 | Customer Meter Reading | We have no special system of controlling meter readers | We only rotate meter readers if we are suspicious of inaccuracies | We regularly rotate meter readers | We regularly rotate meter readers and make often spot checks | Our meter readers use handheld meter reading devices |
| 5.6 | Illegal Connections, meter tampering, bypasses | We have not made any assessment and have no program to deal with water theft | We occasionally detect illegal connections | We occasionally detect illegal connections and other forms of fraud | We have a thorough illegal connection detection program | We have a thorough illegal connection detection program and also try to identify bypasses |