WSUP
Water & Sanitation for the Urban Poor

A GUIDE TO NON-REVENUE WATER REDUCTION: HOW TO LIMIT LOSSES, STRENGTHEN COMMERCIAL VIABILITY AND IMPROVE SERVICES

GLOSSARY

Commercial Audit: In the context of NRW reduction programmes, commercial audit refers to the detailed survey of the water utility customers in a specified zone or area. The survey will obtain relevant customer data, water usage and check the status of water services, including function of water meters. The audits can be used to provide advice and guidance to customers on water security and the practice of good water use, limiting waste.

District Metered Area: A district metered area (DMA) is a supply area that is hydraulically isolated in terms of water inflows and outflows, enabling the estimation of water loss within the DMA. DMAs are usually smaller sub-systems within larger operating zones.

Field Audit: These are field surveys in selected parts of the water utility service area to obtain data and information on water delivery status. This includes assessing surface leaks, the status of delivery network and identifying illegal connections.

Infrastructure Leakage Index (ILI): This is an internationally accepted indicator of physical losses developed by the International Water Association, one that takes into account how the network is managed. It is the ratio of the current annual volume of physical losses to minimum achievable annual physical losses. The ILI is computed via the water balance analysis and can be used as a target KPI for NRW management. The lower the ILI the better, and utilities aspire to reduce ILI to under 10 and preferably under 5.

Natural Rate of Rise: There is a permanent tendency in all water distribution networks for physical losses (leakage) to increase with time. The rate of increase will normally be fairly consistent unless the network deteriorates rapidly due to a change in climate or the network reaching the end of its life. This rate is called 'the Natural Rate of Rise' (NRR). Unless the level of resources for the detection and particularly the repair of leaks is sufficient to save an amount of water greater than that lost due to NRR, leakage does not decrease even when resources are employed to locate and repair leaks.

Water Balance: Water balance is the analysis undertaken to compute water losses within a defined service area or zone. This is usually done based on measured water flow data, billed consumption and estimates of commercial losses. It is the method of estimating leakage recommended by the International Water Association (IWA) and is used throughout the world.

World Bank EasyCalc Software: The WB-EasyCalc tool is software designed by Liemberger and Partners to facilitate water balance analysis. WB-EasyCalc was designed in 2006 to help water utilities and consultants properly apply to IWA Water Loss Specialist Group Methodology for water balance analysis and can be used with a wide range of languages. It is free to download from the Liemberger and Partners website (http://www.liemberger.cc/).

CONTENTS

INTRODUCTION

What NRW is and why it matters

This guide has been developed as a resource for water utilities to support implementation of Non-Revenue Water (NRW) reduction programmes. Before detailing the components involved, it is important to understand why NRW reduction is a critical step towards the commercial viability of water utilities, and how it can contribute to improved service provision.

NRW is a key indicator of a utility's operational and financial performance

A high level of water losses is one of the major challenges facing water utilities across the developing world. This includes a) physical losses, due to leaks and theft of water from the system; and b) commercial losses, due to unpaid bills, and water that is unbilled or incorrectly billed because of poor metering or poor customer records. The difference between the amount of water a utility puts into the distribution system and the amount of water billed to consumers is known as 'Non Revenue Water' (NRW).

NRW has a serious effect on the financial viability of water utilities through lost revenue, lost water resources, and increased operational costs. High levels of NRW reduce a utility's capacity to fund necessary expansions of services, especially for low-income consumers. 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.

Small savings in NRW can have a huge positive impact on service provision

The global volume of non-revenue water (NRW) is staggering. It is estimated that each year more than 32 billion m^3 of treated water are lost through leakage from distribution networks (USAID/WBI, 2010). An additional 16 billion m^3 per year is estimated as 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 (ibid). In some developing countries this loss represents 50-60% of water supplied, with a global average estimated at 35% (ibid). Saving just half of this amount would supply water to an additional 100 million people without further investment (see Box 1) (World Bank, 2006).

Successful NRW reduction requires sustained commitment from across the utility

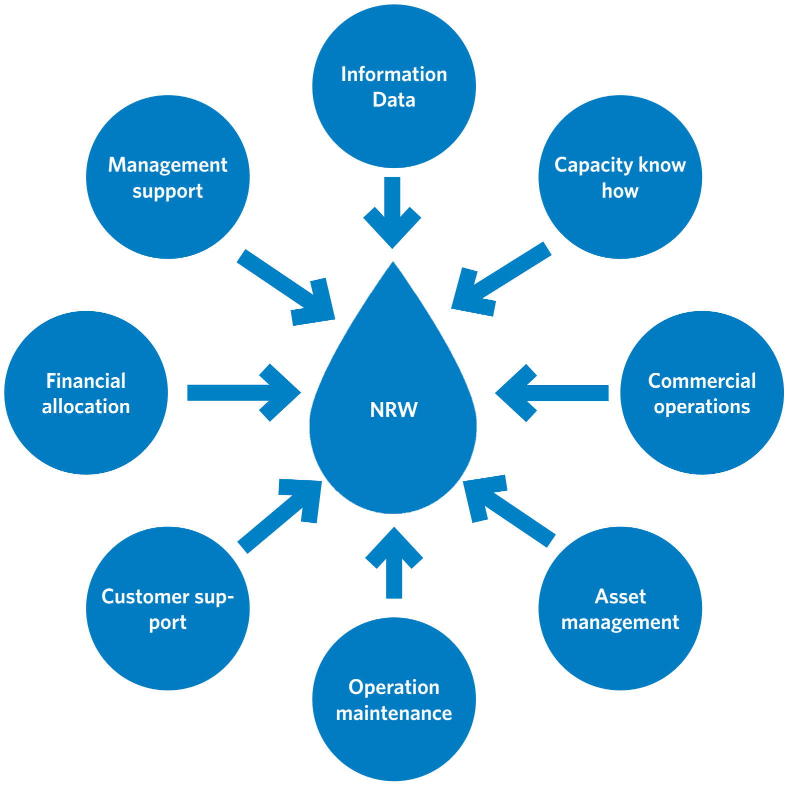
There are a number of complex reasons why utilities struggle to control NRW. These include:

- Failure to understand the problem (magnitude, sources, costs)
- Lack of capacity (insufficient trained staff)
- Inadequate funding to replace infrastructure (e.g. pipes, meters)
- Lack of management commitment
- Weak enabling environment and performance incentives

It is particularly important to understand that NRW management is not a one-off activity: it requires the 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 leads to the failure of reduction programmes. 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). It is not only the management's responsibility, but the responsibility of everyone in the utility.

Insufficient allocation of finance is another cause of weak NRW management and resulting high water losses. From a utility's point of view, not allocating finance to NRW reduction is a short sighted strategy: effective NRW management will lead to increased revenues and profitability for the utility. The inclusion of financial Key Performance Indicators (KPIs) linked to NRW can be used as incentives to seek increased budget allocations for NRW management.

Figure 1: Utility inputs required to implement successful NRW reduction programmes



Box 1: the link between reduced NRW and improved service provision for low-income consumers

Technical support in reducing NRW is a core feature of WSUP's capacity building activities with water utility partners around the world. This support is based on the understanding that NRW programmes not only improve service delivery and enhance profitability: in the long term, such programmes can massively increase a utility's capacity to extend or improve services to the city's low-income areas. A powerful example is the NRW reduction programme implemented over a number years by JIRAMA, the Madagascan national water utility, in the capital city Antananarivo: an estimated 710,000 low-income consumers have benefited from JIRAMA's NRW reduction programme since 2010 (see WSUP Practice Note, 2017). By generating additional revenue that can be channelled towards improving services citywide, NRW reduction programmes are a vital tool for urban utilities in fulfilling their mandate to serve low-income areas of the city.

About this Guide

The guide has been designed to provide systemic guidelines – in the form of a set of procedures described through flowcharts – that can be adopted by utility managers, engineers and operations staff to plan and implement a phased, sustainable NRW programme encompassing the full service area and customer base. The order in which the procedures in the flowcharts are presented does not represent actual order of implementation: in practice, timelines for many of these procedures should be expected to overlap.

The procedures in the flowcharts have been prepared with the assistance of WSUP's NRW Consultant Jo Parker, based on her wide experience on this subject and WSUP's experience in supporting NRW programmes in Madagascar and Mozambique in particular. The procedures reflect the approach described in The Manager's Non Revenue Water Handbook for Africa (USAID/WBI, 2010), which emphasises leakage management, pressure management, commercial management and monitoring and review.

A glossary of the key concepts featured in the Guide is provided on Page 2.

DEVELOPING, FINANCING AND INITIATING AN NRW REDUCTION PROGRAMME

The flowchart in Figure 2 presents the overall framework for developing and initiating a NRW reduction programme. The inclusion of a high level meeting reflects the need to secure buy-in of utility management from the outset. The overall approach presented in Figure 2 can be adapted to suit the current status of the utility's NRW activities and functions; where a utility is already undertaking any of the stated activities, it is recommended that these are reviewed and updated before programme initiation.

It is recommended that any NRW programme include the following components:

- Capacity building and institutional strengthening - including leak detection teams and NRW monitoring and management – in order to ensure the continued efficiency and long term sustainability of programme activities. This may require mobilising specialist support, at least in the initial stages.
- Procurement of NRW equipment and stocks of leak repair material.
- Field audits (Page 11)
- Commercial audits (Page 12)
- Designing and setting up District Metered Areas (DMAs) with metering to collect flow data (Page 14)
- Continuous monitoring and water balance analysis
- Structured programme of active leakage management and pressure management (Page 10)
- Incorporating NRW management within the utility operational strategy, including Key Performance Indicators (KPIs)

Allocating finance

The availability and allocation of finance to initiate and maintain a long term NRW programme is challenging for many utilities. However, contrary to widespread belief, the levels of funding required to initiate and develop a long term NRW programme is a relatively small percentage of a utility operating costs, while the financial returns are usually significant. It is feasible to seek or allocate finance for NRW programme based on an attractive return on investment.

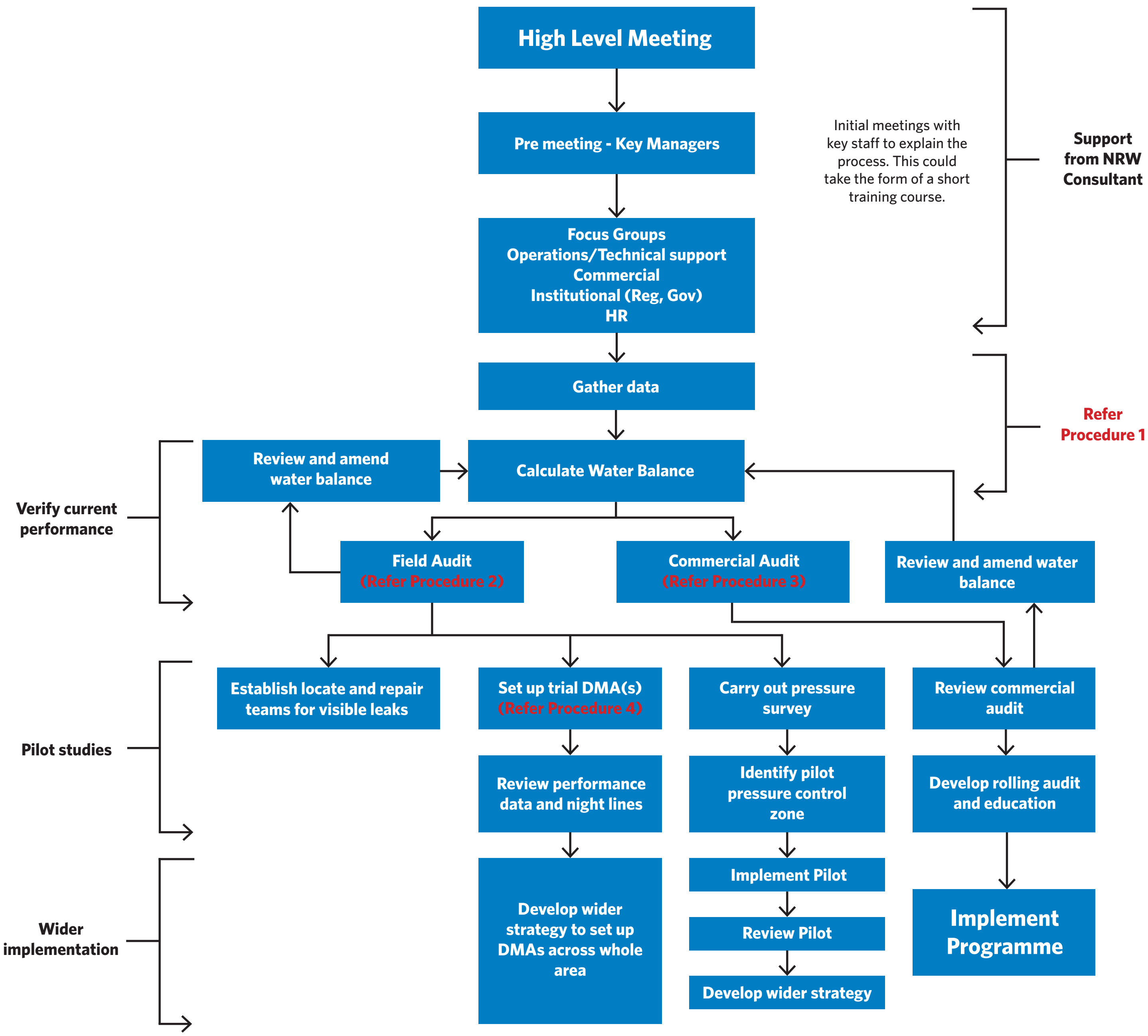
If the level of available funding is initially limited, the utility could adopt a phased approach with an initial set of activities that would lead to quick wins in reducing NRW and justify the allocation of more NRW funding to the subsequent phases. This approach could commence with the following set of activities:

- Field Audits: to identify priority areas or zones for carrying out an initial intensive programme of leakage management (see Page 11)
- Initial, intensive leak detection and management programme (see Page 10)
- Water balance analysis: undertaking water balance analysis for each hydraulic zone is essential to estimating NRW and to plan a NRW management programme. This can be undertaken using the WB EasyCalc software.[1] If flow data is unavailable, these can be approximately estimated with simple assumptions. An initial assessment of NRW and physical losses can then be made to identify critical areas with high losses, and the information fed back to leakage teams for leak detection and management.

The above three activities require very limited budgets and can be expected to yield immediate results of NRW reduction. This will help make the case for further investment in a structured NRW reduction programme of the scope presented in Figure 2.

[1] Software free to download from www.liemberger.cc/WB-EasyCalc.xlsx

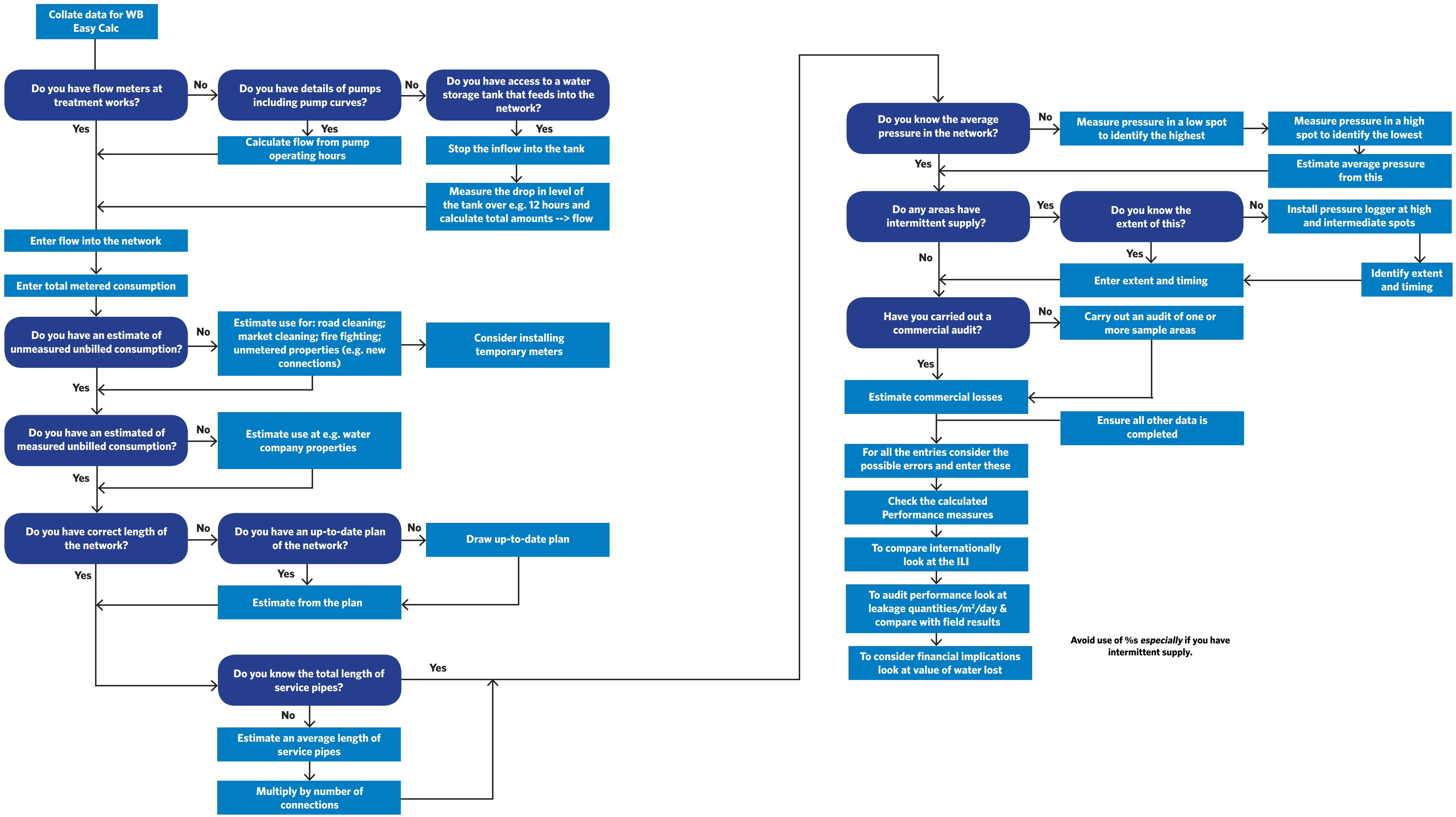
Figure 2: Overall framework for developing and initiating a NRW reduction programme. The framework includes the linked set of procedures that are described in the following sections.



DETERMINING CURRENT NRW PERFORMANCE

The procedure outlined below be used to determine current performance in a District Metered Area (DMA), operating zone or the full service area, using information available and supplemented by field measurements and data. The performance is estimated using World Bank EasyCalc software.

Procedure 1: Determining current performance



SUSTAINED LEAKAGE MANAGEMENT AND CONTROL

Leakage control and management is the most fundamental activity in reducing physical water losses. Effective and sustainable leakage management is best achieved by incorporating it within the operating procedures and linked to specific Key Performance Indicators (KPIs). This requires:

a. Effective institutional structure

b. Setting up Leak Detection Teams

c. Training and capacity development

d. Availability of leak detection equipment (basic and high tech including spares)

e. Stock of materials for leak repairs

f. Logistics including field transport and IT equipment

g. Standardised procedures for leak repairs

Guidelines on leak detection are described in Annex A (adapted from IWA, 2007, USAID/WBI, The Manager's Non-Revenue Water Handbook for Africa, 2010.

Undertaking and managing leak repairs efficiently is a pre-requisite for effective leakage management and control. The utility should assign a high priority to this activity including setting up Standardised Operating Procedures for leak repairs, which will include:

- Health and safety
- Technical guides for types and causes of failure
- Method statements for different categories of repairs (mains, secondary and service pipes etc.)

As noted on Page 4, an initial, intensive programme of leak detection and repairs can be an important early step where finance for a comprehensive NRW programme is initially lacking. This could follow the process outlined below:

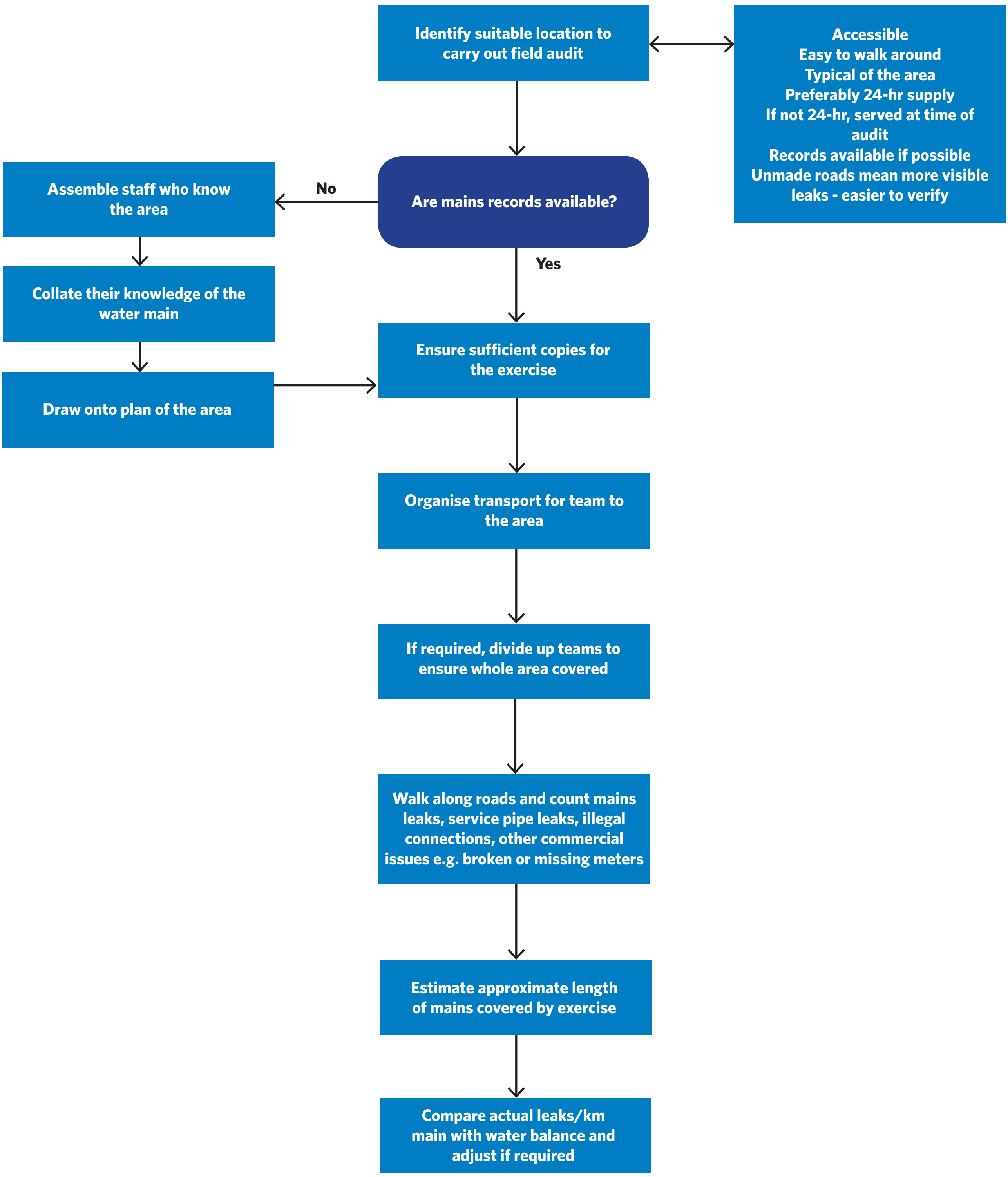
- Assign a manager with overall responsibility for planning and managing an intensive programme of leak detection and repairs (section by section)
- Organise and allocate technical staff for leakage management
- Subject to existing capacity and skills, arrange training for the leakage teams (if required with external expertise)
- Check and update material stocks for leakage repairs (pipes, joints, valves etc.)
- Allocate necessary transport for the teams
- Execute programme and monitor

FIELD AUDITS

The completion of field audits is a critical activity that should be commenced at an early stage in the programme - and repeated during the course of the programme - to assess progress as part of leakage management.

As noted on Page 4, field audits can be a critical step in making the case where finance for a comprehensive NRW reduction programme is initially lacking. Systems with limited NRW management will have a significant number of surface leaks that can be detected and repaired with relatively limited capacity. Field audits undertaken by a team of technicians will lead to prioritising areas or zones for carrying out an initial intensive programme of leakage management. The field audits could be undertaken stage-by-stage with priority assigned to areas or zones which are generally known to have high levels of leakage (for example, due to old assets, illegal connections, extensive secondary and tertiary networks).

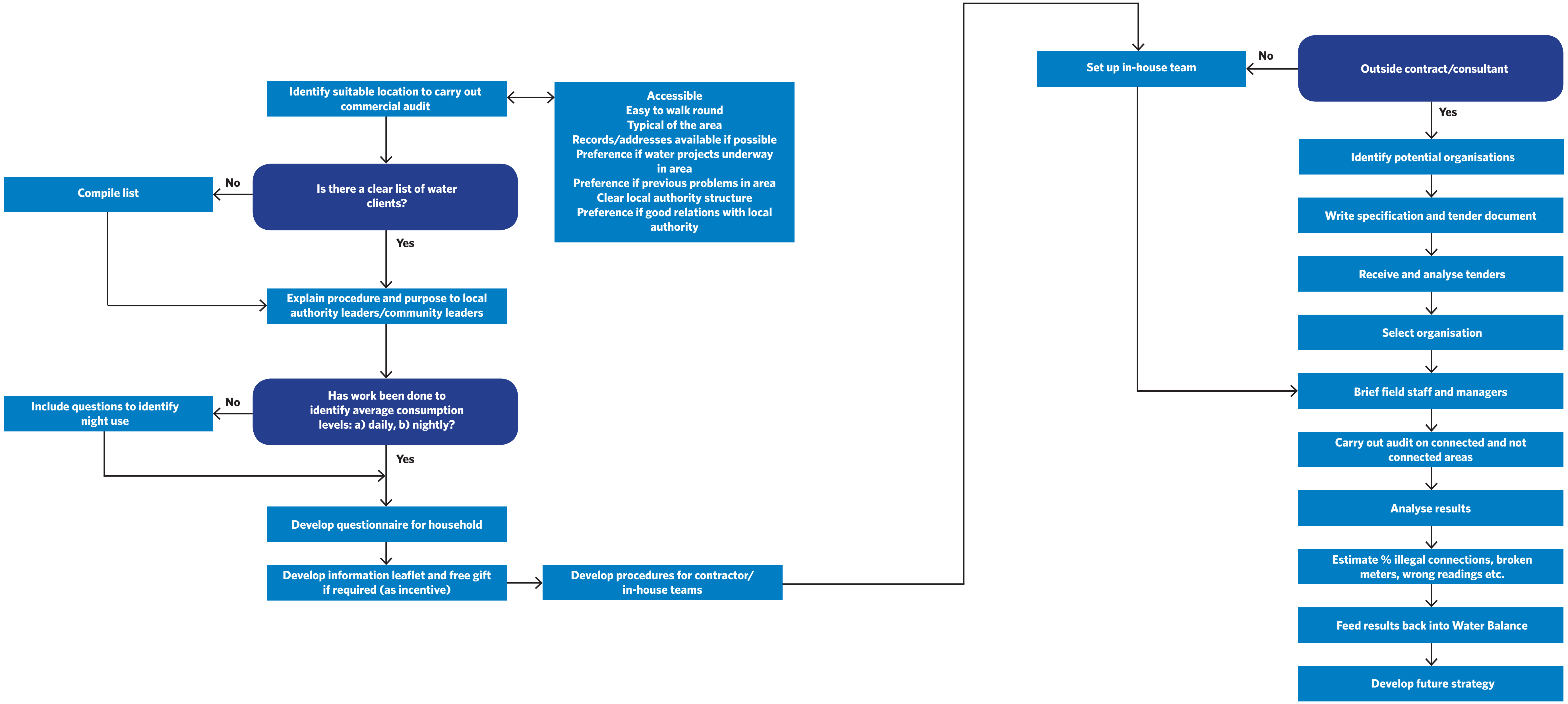
Procedure 2: Conducting field audits



COMMERCIAL AUDITS

Commercial audits can be challenging due to the potentially varied character of commercial losses and the complexities involved in their identification and estimation. However such audits are critical components of any NRW reduction programme: commercial losses are often significant, and have an adverse impact on operational efficiency, the financial viability of the utility and its relationship with the public. Commercial audits should be undertaken in a transparent manner with due stakeholder consultation.

Procedure 3: Conducting commercial audits



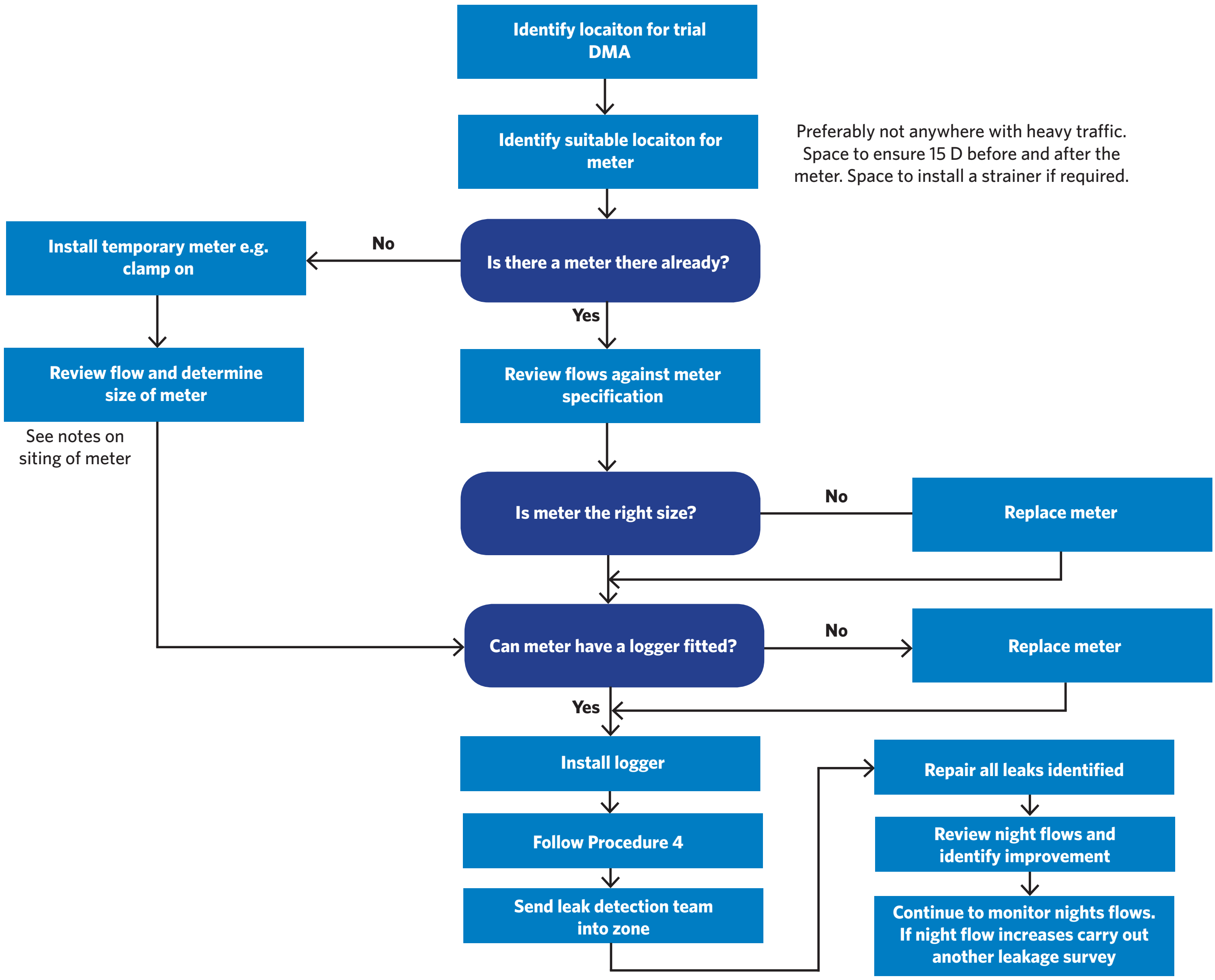
FORMATION OF DISTRICT METERED AREAS (DMAs)

It is recommended that any network is divided into District Metered Areas (DMAs). It is suggested that one or two trial DMAs be set up to carry out the principles in this training guide. The procedure below outlines the process for creating a DMA and undertaking leakage management. While it is not necessary to have an established network model in order to identify a suitable location for a DMA, use of a model can ensure that there will be no further degradation of service caused by the isolation and metering of the chosen part of the network. The location for the trial DMA should where possible include the following criteria:

- Easily isolated from the rest of the network
- At least 500 connections
- No degradation of service when isolated
- Preferably 1 entry point where a meter can be installed; not more than 2 entry points
- Preference should be given to an area with a flow meter already installed

A successful approach that has been adopted in WSUP programmes is to commence longer term NRW management in a selected DMA to better understand the field tasks and water balance estimation and interpretation. This can be gradually replicated to other DMAs or zones over a phased programme of NRW management. A strong example is the NRW programme implemented by JIRAMA in Antananarivo (WSUP Practice Note, 2017).

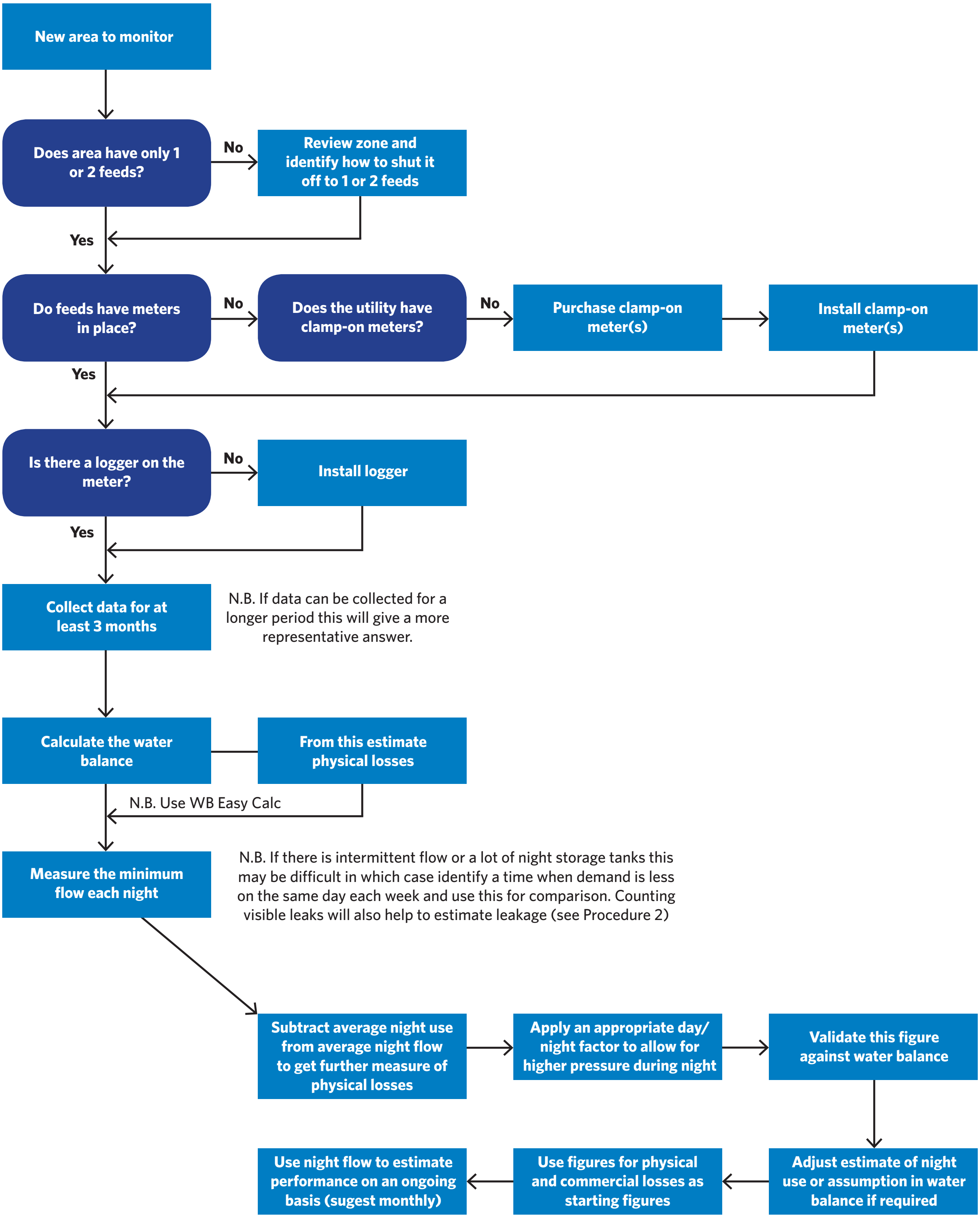
Procedure 4: Setting up DMAs



ESTABLISHING THE STARTING LEVEL OF LEAKAGE IN A DMA OR HYDRAULIC ZONE

The figure below presents a field operational procedure that is undertaken to establish the baseline leakage in a DMA (or hydraulic zone).

Procedure 5: Establishing starting level of leakage in a DMA or hydraulic zone

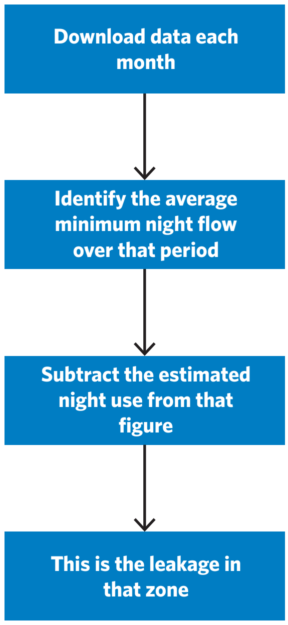


ASSESSING MONTHLY PERFORMANCE

Below is detailed a monthly procedure to monitor and estimate leakage in the DMA or hydraulic zone. It should be seen as part of a set of continuous monitoring and leakage management activities which underpin the NRW programme, enable leakage control and facilitate water loss reduction.

Procedure 6: Assessing monthly performance

It is assumed that a discrete zone has been set up with the minimum of feeds and with all feeds having a suitably sized flow meter and logger.



Validate:
a) Identify the number of leaks found and repaired in that zone, estimate the flow from each leak using the following table (from the NRW Managers Handbook). This should be at least as much as any reduction. If the amount is higher this gives an indication of the Natural Rate of Rise.

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

Source: IWA Water Loss Task Force

b) If there are a large number of visible leaks in the zone (often the case with a lot of unmade up roads) then these can be counted and a flow rate attributed to each leak to give an alternative value of leakage. If it is less than the estimate it is likely there are other non-visible leaks. If it is more the leak flow rate needs adjusting e.g. for lower pressures.

References

International Water Association (2007) Leakage Location and Repair - Guidance Notes.

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

World Bank Institute, USAID (2010) The Manager's Non-Revenue Water Handbook for Africa: A Guide to Understanding Water Losses.

WSUP (2017) Non-Revenue Water Reduction: A Critical Step Towards Commercial Viability. WSUP Practice Note.

Credits:

Written by Baghi Baghirathan and Jo Parker. The procedures described in this Guide reflect the approach detailed in The Manager's Non Revenue Water Handbook for Africa (World Bank Institute and USAID, 2010). Production Coordinator: Madeleine Stottor. Editor: Sam Drabble [Version 1, March 2017].

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ANNEX A: LEAK DETECTION GUIDELINES

1. VISIBLE LEAKAGE

The easiest leakage to identify is visible leakage. This will appear as clear water on the surface and if pipes are pressurised it may well be possible to see water bubbling up to the surface. It is possible that visible leaks have been running for some time and vegetation may indicate the presence of a leak even if there is no water on the surface. The actual location of the leak is not always at the point it comes to the surface, depending on the road surface and topography and this should be verified by the pin pointing methods below.

All staff should be encouraged to identify visible leaks.

2. LEAK DETECTION IN DMAS

2.1 Leak Localising

There are predominately two methods of leak localising i.e. the narrowing down of a leak to a street or section of pipe, Acoustic Noise Logging and Step Testing.

Acoustic loggers are commonly used in a defined area such as a DMA or part of a DMA where potential losses are suspected by the measurement of a minimum night flow. This is an efficient method of localization and can be used in any type of distribution network. The acoustic or noise loggers are installed on pipe fittings by way of a strong magnet and are programmed to listen for leak characteristics. Typically, noise is recorded at one second intervals over a period of two hours during the night, when background noise is likely to be lower. By recording and analysing the intensity and consistency of noise, each logger indicates the likely presence (or absence) of a leak. The noise generated by a leak tends to have a reasonably consistent amplitude or loudness. Loggers placed around part of a network involve the identification of recorded noise from a leak, followed by a comparison of noise amplitude at the different locations to determine the approximate location of a leak or leaks. Acoustic noise logging techniques, however, have limitations in systems that are characterised by the combination of low pressures and long pipe sections of non-metallic pipe preventing good sound propagation.

The technique whereby a leak or leaks are detected by making temporary successive valve closures to reduce the size of a district or sub-district (generally called a Leakage Control Zone) and typically may contain 500 to 1500 connections is often known as Step Testing.

2.2 Leak Location

Leak locating is carried out in DMAs as a result of:

- In sections of a DMA that have high NRW identified as a result of a step test
- Following a report of a leak from customer reports
- In DMAs that have an increase in NRW but a step test has not or cannot be undertaken

In any of the above circumstances the leak detection team should follow up to try and locate or pinpoint any obvious leaks and undertake the leak repair.

2.3 Leak Location Methodology

The Leak Detection Team (LDT) would carry out a 'walk the line' survey observing visible leaks and some soundings to locate and pinpoint easy to find leaks that are creating a loud noise. Part of the training for the Leak Detection Teams will be to locate leaks using a Leak Noise Correlator and this will be used subject to availability.

The LDTs typically operate on a rotating shift, working either days or nights within a DMA to coincide with the hours of supply, gain access to certain premises and minimise health and safety risks to employees when working on busy carriage ways or for personal security reasons. The teams will be directed to work in certain sections of a DMA (when following up on a step test) or a certain street or precise address in other circumstances. Leak locating (which is generally considered to be the location of a leak to within 1 to 2 meters) is made by the use of listening sticks and leak noise correlation and pinpointing through the use of ground microphones.

2.4 Random or Blanket Sounding Surveys

In some DMAs it is not possible to undertake a step test for the following reasons:

- There is a lack of suitable valves
- The DMA is too small (e.g. less than 500 connections)
- The DMA is too large (e.g. greater than 2,000 connections)
- Technical guides for types and causes of failure

In these cases the first stage of leak detection can be a sounding survey with a traditional listening stick, an electronic listening stick or a systematic 'sweep' using acoustic loggers. Leak noise Correlators or ground microphones are then used to pinpoint the exact location of the leak.

This system of routine sounding survey is time-consuming and not very efficient in terms of focusing on areas with potential leaks, because the leakage engineers or technicians are often looking for leaks in sections of the network where they do not exist. However, regular sounding does provide a systematic inspection of part of a system or DMA.

2.5 Leak Detection outside of DMAs

A leak location exercise may be required as a request from a customer alert, a report of low pressure, a report of no water, or it is considered that a particular area has a high level of NRW. The LDT should undertake the initial blanket survey using their basic equipment followed by acoustic noise logging or step testing in the case of a suspected non-visible leak (or leaks) that they are unable to pinpoint.

In the absence of any zoning or DMAs, random or blanket soundings would be an appropriate first stage of localising followed by a pinpointing exercised as described in Section 1.3 above.

3. LEAK DETECTION IN PRIMARY MAINS AND SECONDARY MAINS

The LDTs have the responsibility of trying to locate non-visible leaks on primary and secondary mains (generally mains of >300mm diameter). The request will be made following an audit carried out on a particular section of main where it has been estimated or calculated that there is a high volume of NRW.

The purchase of a dedicated trunk (or larger diameter) mains Correlator and the leasing of the Sahara system will enhance LDTs ability to locate and pinpoint leaks on the primary and secondary mains. These devices should be used on sections of main where a flow audit has indicated that there is a high level of NRW.

4. LEAK DETECTION EQUIPMENT

The types of equipment used in the three stages of leak detection on tertiary mains are:

- Localising - acoustic (noise logger), conventional listening stick and electronic listening stick
- Location - leak noise Correlator, correlating loggers, and listening sticks
- Pinpointing - listening sticks and ground microphones

There are also more expensive leak detection systems that can be used to accurately locate and pinpoint leaks on primary and secondary mains (e.g. Sahara Leak Detection Platform - www.puretechltd.com/technologies-brands/sahara).