Specialist Group
Efficient Operation and Management
Water Loss Task Force

International Water Association

Leak Location and Repair

Guidance Notes

March 2007
Version 1

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Acknowledgements

The authors would like to acknowledge the help and support of members of the IWA Water Loss Task Force, who have made many constructive comments on the content and layout of the Guidance Notes. We particularly thank the members of the Leak Detection Practices, Techniques and Repair Team and the Publications, Conference and Communications Team who have supplied content and comment and facilitated publication

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1. FOREWORD

The Water Loss Task Force (WLTF) is part of the International Water Association's Specialist Group on Efficient Operation and Management of Urban Water Distribution Systems. The vision of the WLTF is to *"provide leadership in the field of Water Loss Management through effective and sustainable international best practices"*.

The mission of the WLTF is accomplished by:
its strong international membership,
the dedication and commitment of its members, and
the participation of the many research scientists and professionals in testing, verifying and challenging current and proposed techniques and practices.

It is evident that water is a limited resource in many parts of the world, a situation that has highlighted, amongst other things, the need to reduce leakage from urban water distribution systems to levels that are considered economically acceptable. We firmly believe that Water Loss Management is of fundamental importance to improving the efficiency of many water networks all over the world in order to ensure long-term environmental and societal sustainability.

The WLTF is continuously building and expanding on current and new areas, such as:
Utility Benchmarking and Performance Indicators,
District Metered Areas and Pressure Management,
Real and Apparent Losses,
Leak Detection and Repair,
Economic Level of Leakage,
Active Leakage Control,
Training and certification.

The practices promoted by the WLTF are well documented in articles, conference proceedings, software, manuals and text books. The WLTF will continue expanding Water Loss Management strategies and developing new research initiatives which can be universally applied.

Within the above context the WLTF has developed the Leak Location and Repair Guidance Notes, a comprehensive document which is intended as an introduction to leakage practitioners to the process of identification, location and repair of leaks. For unreported leaks, this is more widely known as Active Leakage Control. It is part of a series of Guidance Notes prepared by the IWA Water Loss Task Force to cover all aspects of losses from water distribution networks.

These Guidance Notes are the result of endless hours of hard work by many dedicated people in an effort to put together a comprehensive document which is aimed at staff with little or no experience in leak detection and location techniques and practices. It has drawn on the experience of international leakage experts to pull together the key best practice essentials and to outline technical understanding behind this vital activity.

Furthering knowledge and promoting best practices internationally in the field of Water Loss Management is of the utmost importance to the WLTF. To this end it was decided that this document is made freely available to anyone who wishes to use it. The Guidance Notes can be downloaded free of charge from the web site of the Water Loss Task Force (www.iwaom.org/wltf).

Bambos Charalambous
Chair,
Water Loss Task Force,
March 2007

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2. INTRODUCTION

2.1 Purpose of the Manual

These Guidance Notes are intended as an introduction to leakage practitioners to the process of identification, location and repair of leaks. For unreported leaks, this is more widely known as Active Leakage Control. It is part of a series of guidance notes prepared by the IWA Water Loss Task Force to cover all aspects of losses from water distribution networks.

2.2 Readership

These Guidance Notes are aimed at staff with little or no experience of leak detection and location techniques and practices. It has drawn on the experience of international leakage engineers to pull together the key best practice essentials and outline technical understanding behind this vital activity. The Guidance Notes should be seen as a starting point and the influence of local variations must always be considered as local experience is gained.

2.3 Control of Water Loss

The control of water losses has been an activity associated with water distribution since some of the earliest systems were built. The Romans were aware that a good proportion of the water put into supply did not reach its intended destination.

Sextus Julius Frontinus the Water Commissioner to Rome in AD 97 used a crude measuring device to assess losses in the system. Although illegal connections were commonplace it was apparent that water loss through leakage (real losses in IWA terminology) was a serious problem, similar to many of the distribution systems around the world in the 21st century, almost 2,000 years later.

The fight for the reduction and control of losses is never ending but fortunately, for today's water distribution engineers, a range of good equipment and techniques has been developed to assist him or her to tackle the four basic leakage management activities. These activities are pressure management, Active Leakage Control (ALC), pipe materials management and speed and quality of repairs. These activities are shown diagrammatically in Figure 1. This document essentially focuses on Active Leakage Control or leak detection practices and techniques.

The reduction of water loss by means of leakage control is vital in today's world and many utilities have developed a strategy to reduce losses to an economic or acceptable level. In Figure 1, the large rectangular box represents the Current Annual Real

Losses in a distribution system. The smaller box represents the Unavoidable Annual Real Losses (UARL) which consists:
undetectable small hidden leaks (background leakage)
volumes lost from moderate numbers of reported and unreported leaks with well-managed short run-times, for well-maintained infrastructure in reasonably good condition

These strategies have inevitably included Active Leakage Control. Active Leakage Control can best be described as a proactive strategy to reduce water loss by the detection and pinpointing of non-visible leaks using highly trained engineers and technicians with specialized equipment followed by a prompt and good quality repair of these leaks. Best practice also includes the prompt repair of visible leaks.

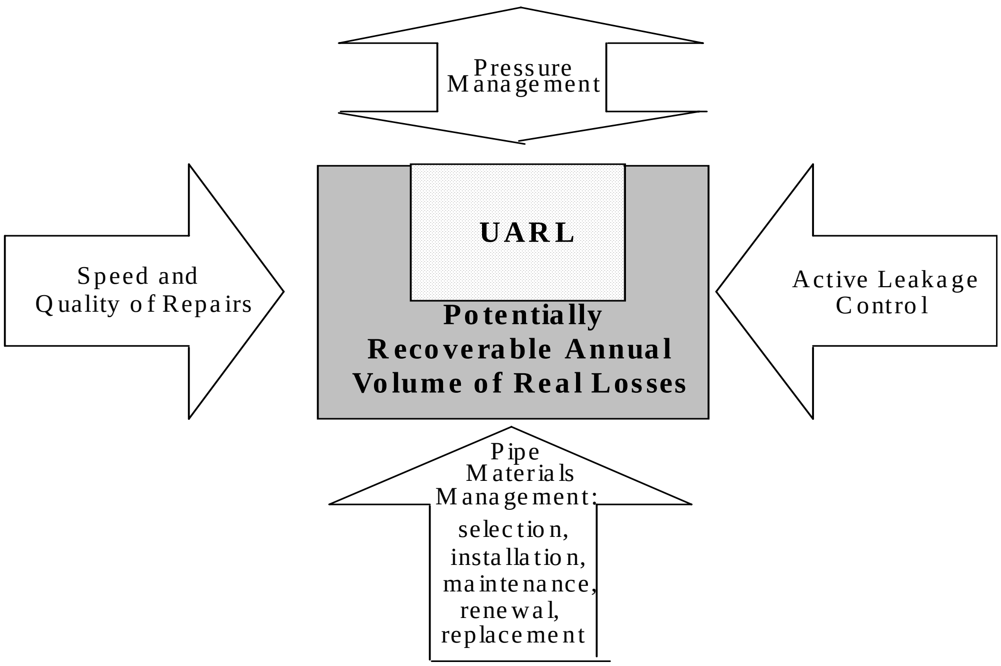


Figure 1: The Four Basic Leakage Management Techniques

2.4 Items Covered by these Guidance Notes

The objective of these Guidance Notes is to outline the factors that influence leakage and to fully describe the methods of modern leakage management practices and techniques.

Predominately the techniques described are those used in a distribution network. Often slightly different techniques and equipment are required to locate leaks on transmission or trunk mains.

3. FACTORS THAT INFLUENCE LEAKAGE

3.1 Introduction

Before examining the equipment and techniques used by leakage engineers and technicians let us consider the main factors that influence leakage:
Infrastructure condition
Pressure
Service connections - number, ownership and location of customer meters
Length of mains
Annual number of new leaks (reported and unreported) on mains
Annual number of new leaks (reported and unreported) on service connections
Average run-times of reported and unreported leaks

The frequency at which new bursts and leaks occur depends upon the overall condition of the infrastructure and how well the pressures in the distribution system are managed. Dependent upon the specific ground type there will always be a proportion of leaks and bursts that do not appear on the surface i.e. non-visible or unreported leaks and these need to be detected.

3.2 Components of Real Losses or Leakage

Real losses or leakage are made up of three components

- **Reported leaks and breaks**
  - Typically high flow rates, short run-time notified to the water utility by customers etc
- **Unreported leaks and breaks**
  - Typically moderate flow rates, long run-time located by active leakage control
- **Background leakage** (mostly at joints and fittings)
  - flow rates too small to be detected if hidden generally < 250 litres/hour, (1 gpm), but run continuously

Reported leaks are usually:

- Phoned in by the public
- Visible
- Found following complaints of low pressure or no supply
- Observed by meter readers and maintenance teams

Unreported leaks are usually:

- Non-visible
- Found by Active leakage Control

3.3 Flow Rates of Leaks and Bursts

Depending upon the type of leak, the fitting on which it is occurring and the pressure in the system bursts and leaks will have different typical flow rates.
Typical flow rates used in a study in the U.S.A. in 2002, for detectable leaks from service pipes and mains at 50m pressure are shown in figures 2 and 3.

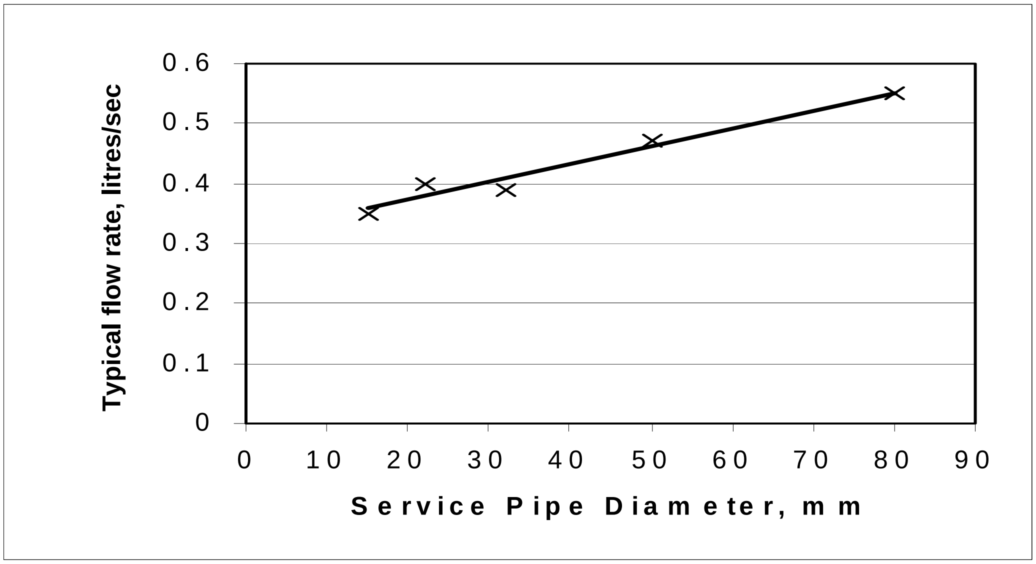


Figure 2: Typical service pipe connection burst at 50 m pressure

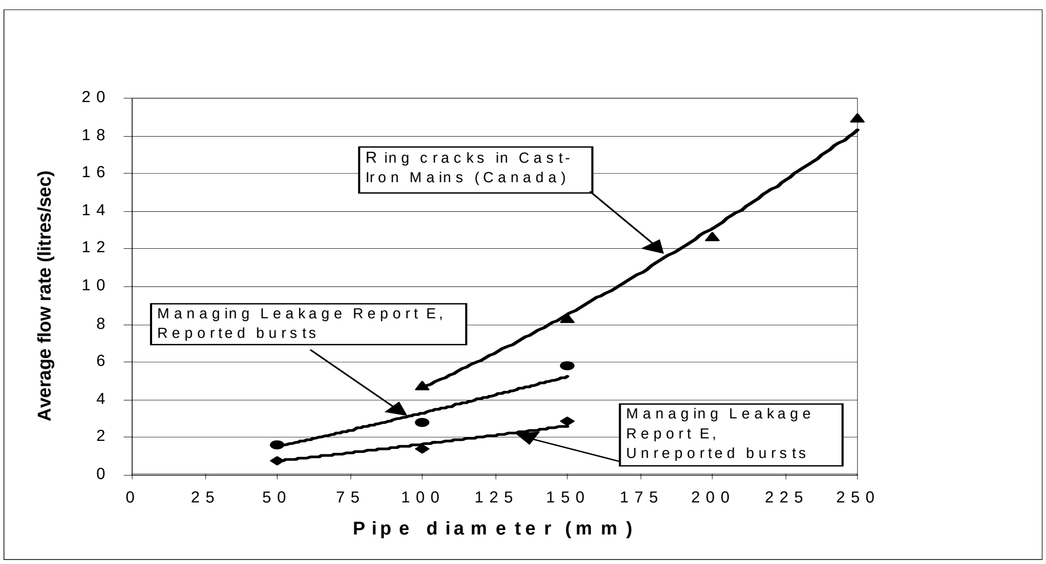


Figure 3: Examples of mains burst flow at 50 m pressure

3.4 Volumes of Water Lost from Leaks and Bursts

Time also makes a difference – the longer a leak runs the greater volume of water that is lost. Figure 4 shows the three key factors in the amount of water that is lost from an individual leak or burst - awareness time (A), location time (L) and repair time (R).

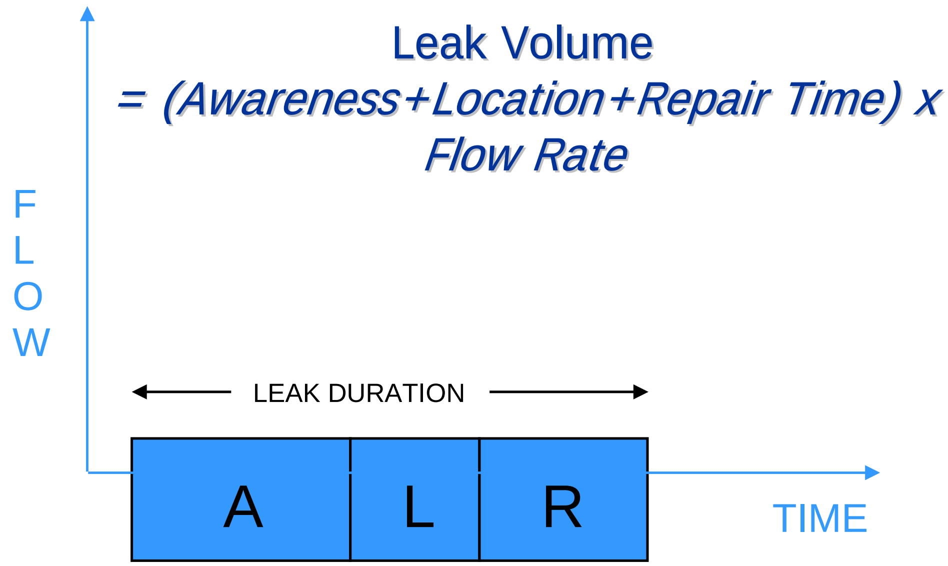
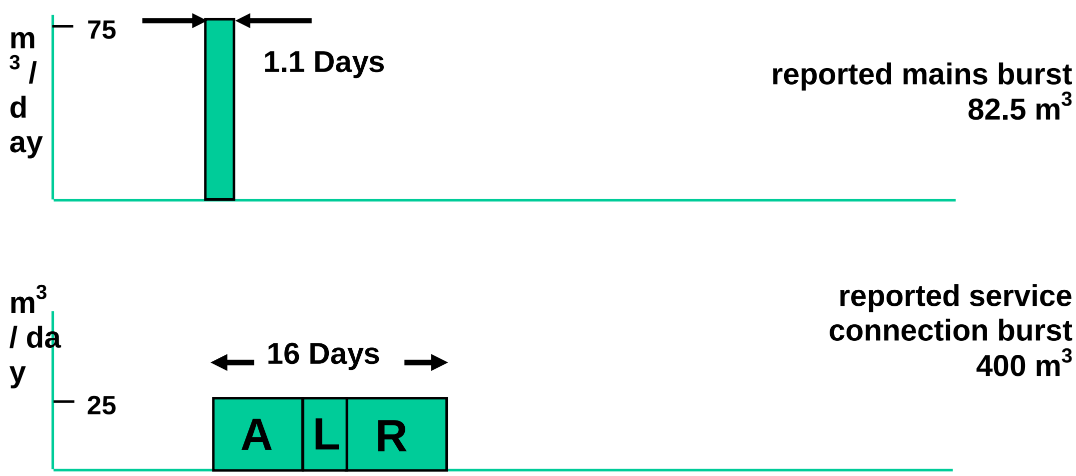


Figure 4: Leak Duration and Volume

Bursts with high flow rates do not produce the largest volumes of real losses or leakage as the run time is the key factor. Figure 5 shows typical run times (from a 1994 U.K. a study) for a reported mains burst, a reported service connection burst and an unreported service connection burst



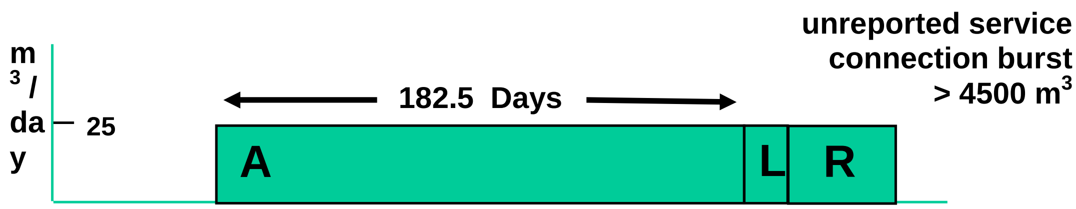


Figure 5: Run times of bursts on service pipes and mains

3.5 Where do Most Real Losses Occur?

It is often assumed that the largest volume of real losses or leakage arises from large visible mains bursts because of their high flow rates as shown in Figure 6.

Figure 6: A dramatic burst

However, component analysis shows that in most well managed systems reported mains bursts account for less than 10% of the annual real losses volume. The largest components of real losses are consistently shown to occur:

- from background leakage
- from long-running unreported leaks and bursts
- from long-running reported leaks which the water utility does not bother to repair

From a practical point of view it is the unreported or non-visible leaks and bursts that most utilities need to locate and repair. If the leaks and bursts are non-visible then there is a degree of difficulty in precisely pinpointing their location in order to repair them. So, what is it that can lead the leakage technician to locate them? Nearly all leaks create some noise and, therefore, if he or she can precisely detect the location of the noise then the leak can be found and repaired.

4. LEAKAGE MONITORING

4.1 Introduction

For many years leakage engineers or technicians would carry out regular house-to-house surveys across the distribution system looking for the evidence of leaks from buried pipes or customer connections. The method relied upon a wooden listening stick which, when placed on the main or fittings such as valves and hydrants, allowed the inspector to listen for the sound of escaping water from a water distribution system. The leak noise was transmitted from the fitting to the engineer's ear via the listening stick similar to a doctor listening to a heartbeat through a stethoscope. Identifying the leak position using this traditional technique was a reasonably low cost operation but the success rate was moderate on metallic pipes with many "dry holes" or incorrectly sited excavations for suspected leaks on non-metallic pipelines such as asbestos cement. Figure 7 shows a leakage engineer locating leaks with a traditional listening stick

The above system of routine sounding was time consuming and not very efficient with the waste (leakage) inspectors often looking for leaks in areas where they did not exist. In the 1980s leak detection gave way to two activities, leakage monitoring and control, these techniques are fully described in this chapter.

Figure 7: A leakage engineer locating a leak using a traditional listening stick.

4.2 Leakage Monitoring Principles

The technique of leakage monitoring requires the installation of flow meters at strategic points throughout a distribution system, each meter recording flows (and often pressures) into a discrete sector or district which has a defined and permanent boundary. Such a district is termed a District Meter Area (DMA) (in the UK style housing infrastructure would cover between 500 and 3000 connections)

The design of a leakage monitoring system has one main aim:

- To divide the distribution network into a number of sectors or DMAs, with the minimum number of meters (to improve accuracy of MNF), so that the night flows into each district can be regularly or continuously monitored, enabling non-visible bursts and leaks to be identified and located more efficiently.

Figure 8 shows typical water distribution system sub-divided into sectors or District Meter Areas (DMAs).

4.3 IWA WLTF DMA Guidance Notes.

It is recommended that the reader refers to the IWA WLTF DMA Guidance Notes (Version 1 published February 2007) for comprehensive detail on the philosophy and practice concerning leakage monitoring.

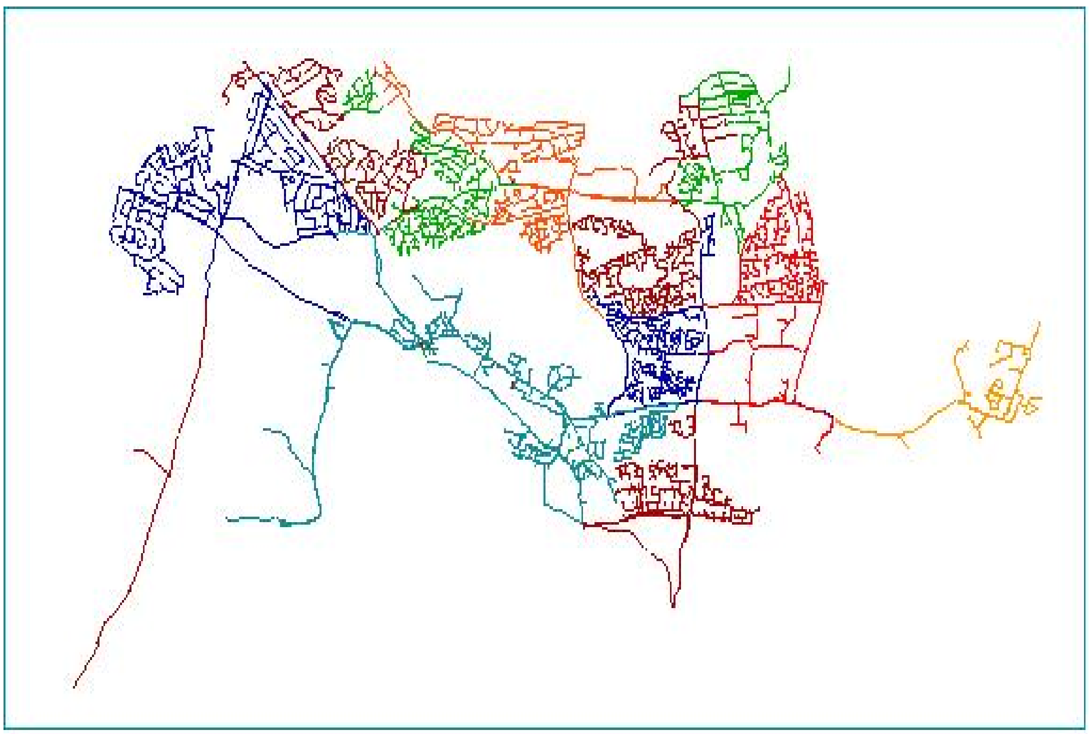


Figure 8: A typical distribution system divided into DMAs

4.4 Leakage Control

Night flow data from DMAs provides the information that enables the prioritization of the leak location effort. This effort is divided into two separate activities, leak localising and leak location. Leak localizing is the 'narrowing down' of a leak or leaks to a section of a pipe network. Leak localizing can be undertaken as a routine survey of the network or part of the network, e.g. every six months or annually, it can also be carried out in targeted areas e.g. DMAs with high night flows or those that have reached a target 'entry' level ***(reference to DMA Guidance Notes)***. Leak location is the identification of the position of the leak and is often referred to as 'pinpointing'.

5. LEAK DETECTION

5.1 Introduction

The act of Leak Detection is the 'narrowing down' or localising of a leak or leaks to a section of pipework in a distribution system (refer to the terminology in Section 12).

In many water distribution systems flows are measured and monitored to DMAs or zones and it is the observation of higher than normal flows (often night flows) that prompts the leakage engineer to organize a leak detection exercise in a particular part of the network.

In the instance where flows are not measured or monitored water loss can be controlled by undertaking regular or random leak detection surveys.

There are several techniques to detect where leakage is occurring in a distribution system:

- The sub-division of DMAs into smaller areas by temporarily closing off valves or by installing sub-meters.
- A traditional step test (or a variation of this techniques)
- The use of acoustic loggers as a survey tool
- Sounding surveys

All of the above techniques are detailed in the following sections.

5.2 Sub-Division of DMAs by Internal Valving (Step testing techniques).

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. The valves are closed for a short duration whilst simultaneously measurements of the rate of flow are being made. The resultant reduction in flow rate following the closure of a particular valve indicates the total leakage plus legitimate night consumption in that section of the distribution system. If the resultant reduction is greater than anticipated, taking into account the number and type of customers in the section isolated, then it is an indication of a leak.

Step tests are generally undertaken during the period of minimum night flow (often between 02.00 a.m. and 04.00 a.m.). Carrying out such a test at this time avoids causing supply problems to the majority of customers.

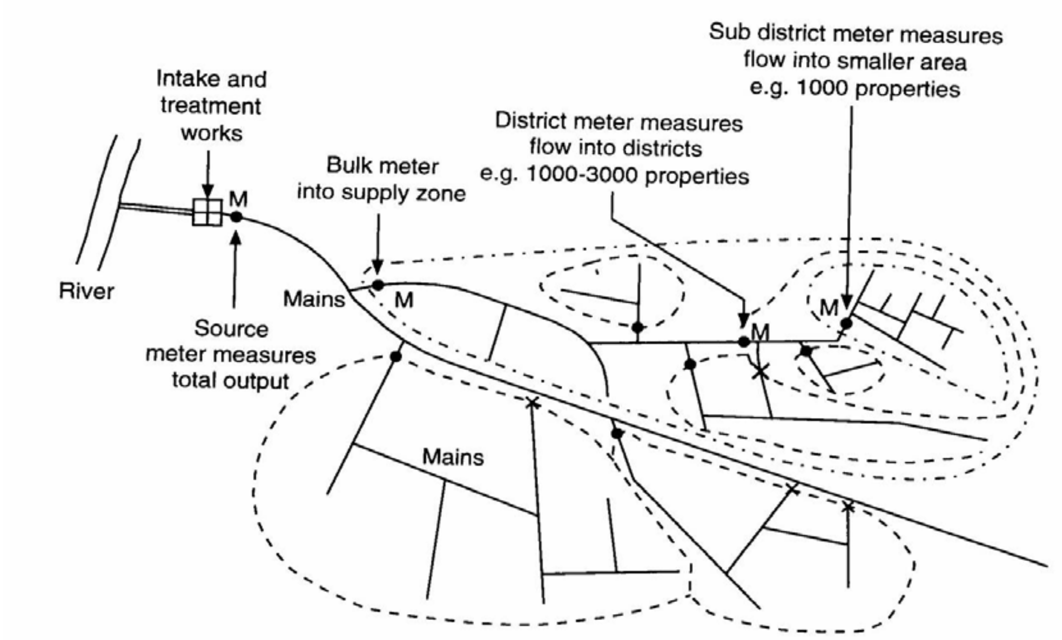


Figure 9: Layout of Districts and Sub-districts

A step test needs to be carefully planned in order that it can be carried out during the period of minimum night flow. Therefore, the number of valves that need to be operated needs to be carefully considered. The size of the individual steps does depend on the size of the Leakage Control Zone. In an urban zone of 1500 connections a step size of approximately 150 connections. In practical terms it is advisable not to have fewer than 10 steps but this may be determined by the location of existing valves.

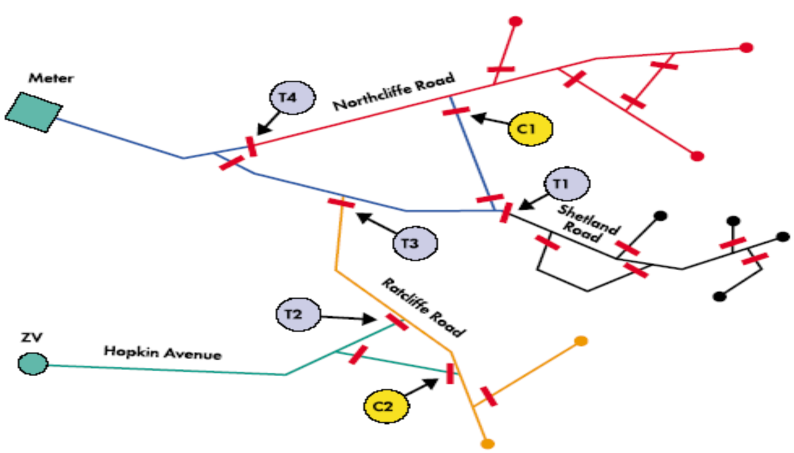


Figure 10: A typical step test plan

There are two main methods of carrying out a step test:

1. The isolation method
2. The close and open method

5.2.1 The Isolation Method

This method involves the successive closing of valves starting from the furthest point from the meter resulting in less of the zone being supplied by the meter. The sequence of closing valves is progressively carried out working back to the meter where the flow should drop to zero.

Whilst potential leaks are identified by this method there is one major disadvantage and that is that the system is de-pressurised for some time and this can cause backsiphonage or the risk of infiltration of ground water.

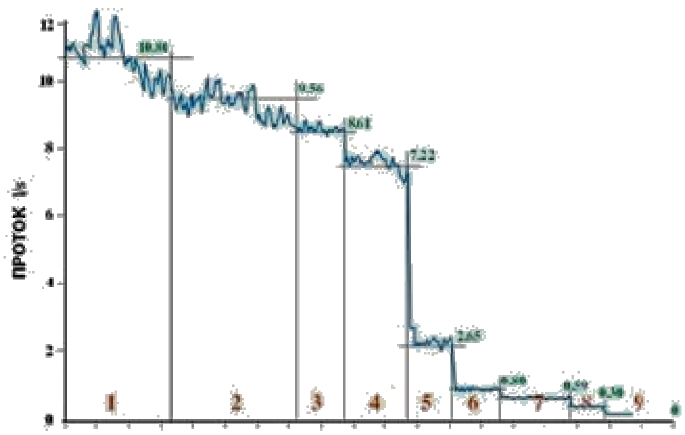


Figure 11: The reducing flow pattern of a step test

5.2.2 The Close and Open Method

This method involves closing valves to isolate each individual step and once the reduction of flow has been recorded the valves are reopened. This method does avoid parts of the system being without water for a period of time but does have the disadvantage that the reduction in flow rate from some steps can include flow from previous steps recharging, thus making interpretation more difficult.

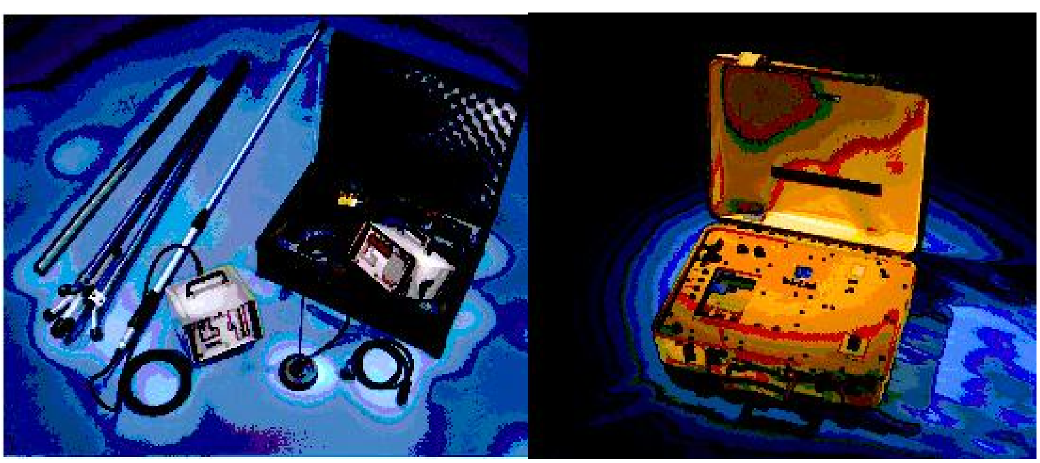


Figure 12: Step Testing Equipment

5.3 Characteristics of the Noise of Leaking Water

Water leaking from a pressurised main emits sound over a range of frequencies and in most cases produces what can be describes as a 'hissing' sound. Each individual leak produces its own specific distribution of noise frequencies and it will depend upon such factors of the type and size of leak, pipe material, pressure and nature of the ground into which the water is escaping. The leak noise will travel through the wall of the pipe at a velocity which is dependent upon both the characteristics of the pipe material and the water. This sound can also travel through the ground surrounding the pipe. As the sound travels away from the leak the frequencies may change due to cavities in the ground or other buried pipes and cables. It should be stated however, that not all leaks produce a detectable sound and different techniques need to be employed.

5.4 Acoustic Logging (also known as Noise Logging)

Leak detection or leak localising by means of the step test began to be replaced by acoustic logging during the 1990s. The advantage of this method is that it does not require night work and the shutting down of various parts of the distribution system and can pick up sounds not auditable to the human ear. Also acoustic logging can be particularly useful in areas where night work is considered dangerous. Many water companies have a policy of developing and operating DMAs combined with pressure management as the main activities at the heart of their real losses (leakage) reduction programmes and in the 21st century acoustic logging is becoming the first-line response by practitioners to a rise in the night flow rate into a DMA. The acoustic logger that has been manufactured in the early 2000s overcame some of the difficulties of earlier models i.e. longer battery life (up to 10 years), smaller in size, more lightweight and that will fit into the smallest of chambers. They are often purchased in portable cases of up to 15 loggers and are easily deployed.

Many practitioners consider that the use of acoustic loggers has made leak detection more efficient and thus, reduced the cost of leak reduction. However, there are occasions when a step test is appropriate e.g. the locating of a leak that is creating little or no sound or solving the location of an unknown user of water.

5.4.1 Principles of Acoustic Logging

The acoustic logger detects a signal from the transmission of a leak noise through the pipeline either as a pressure wave through the water or conducted through the wall of the pipe itself. Similar to the leak noise correlator, acoustic loggers incorporate an accelerometer sensor and are suitable for the majority of situations and are easily used by placing them on a fitting such as a sluice valve or fire hydrant.

Figure 13: An acoustic logger and its mode of use.

5.4.2 The Application of Acoustic Loggers in the Distribution System

Acoustic loggers are commonly used in a defined area such as a DMA or part of a DMA (Leakage Control Zone) where potential losses are suspected by the measurement of a minimum night flow. This is an efficient method of leak detection or localization and can be used in any type of distribution network. The precise detection of a leak, or leaks, allows the teams using leak location devices to accurately pinpoint the leak at the excavation site for the remedial repair to be carried out.

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. Acoustic loggers can either be permanently located in the network or they can be deployed at certain points for a user definable period, often two nights. Figure 13 shows an acoustic logger and its mode of use. 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. Figure 14 shows typical logger placements in a distribution system. For increased flexibility of use the current generations of noise loggers also have an SMS capability

Figure 14: Acoustic logger placement in the distribution system

5.4.3 Identification of a Potential Leak

A good leak noise will produce a steady concentrated sound typically a high peak with a narrow spread.

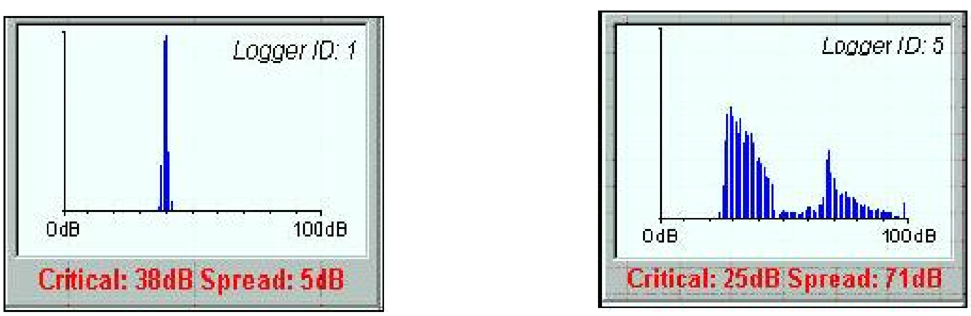


Figure 15: A printout from an acoustic logger indicating a potential leak

General wide spreads with no definite peaks are normal when no leaks are present.

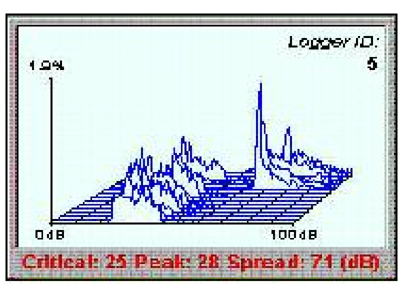


Figure 16: A print out from an acoustic logger indicating no leak

5.5 Regular or Random Sounding

In the absence of Zoning or DMAs 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 often looking for leaks in sections of the network where they do not exist. However, regular sounding does provide a systematic inspection of the system.

6. EXISTING LEAK LOCATION TECHNIQUES

6.1 Introduction

The monitoring of flows into zones or DMAs followed by the analysis of night flows allows the leakage engineer to determine whether there has been an increase in leakage in a particular zone or DMA. Leak Detection or localizing by means of a step test or acoustic logging survey enables the leakage engineer to narrow down the location of the leak or burst to an individual road or length of main.

The next activity for the leakage engineer is to precisely locate or pinpoint the position of the leak and mark the point clearly on the ground surface where the repair teams will have to excavate. There are several methods that can be utilized to pinpoint the leak or burst and as new pieces of equipment are developed techniques change and evolve. It is also true that some pieces of leak location equipment work better on some distribution systems rather than others. None of the methods that will be described below are totally infallible and the skill, motivation/experience of the leakage engineer in the pinpointing of a leak cannot be underestimated. All the methods that are described in this manual depend upon the leak making a noise with the exception of ground radar and a technique that uses gas to trace the leak.

6.2 Direct Sounding

The most common method for determining the position of a leak is by direct sounding. The leakage engineer listens for the characteristic sound of the leak by placing a listening device onto a fitting such as a sluice valve, hydrant or stopcock

6.3 Surface or Indirect Sounding

Surface or indirect sounding is a method whereby acoustic listening is made on the surface directly above the line of the pipe to determine the location of the maximum sound intensity. The maximum sound is often directly above the leak and is a method to verify the pinpointing using another technique.

6.4 Equipment used for Sounding

There are several pieces of equipment used for detecting the sound created by a leak or burst. There are two traditional types of instrument used for the location of leaks, the stethoscope or listening stick and an electronic amplifier and detector. In the last twenty years the leak noise correlator has developed to become the most common method of pinpointing leaks. Recent times have seen the introduction of some new and innovative techniques and are described in Section 8 of this manual. Figure 17 shows the development of leak location equipment over the past 150 years.

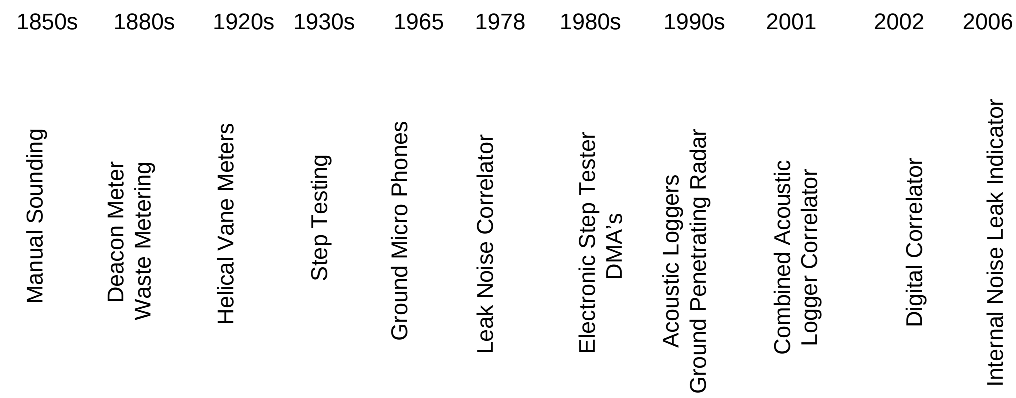


Figure 17: Leakage Detection and Location Technology Timeline

6.5 Stethoscope or Listening Stick

A stethoscope or listening stick has for many years been a cheap but robust and reliable acoustic instrument. On most occasions it is the first piece of equipment the leakage technician uses in their quest to locate a leak. Listening sticks are available in various shapes and sizes and can be made from different woods or metals. This device is very simple to use - one end is placed upon a fitting such as a sluice valve or stopcock and the other end placed against the ear. The leak noise is transferred from the fitting to the ear. Some listening sticks can be acquired in a telescopic form so that they can be conveniently carried or can be used for sounding on top of valve keys. Stethoscopes can be used for either direct or indirect sounding.

6.6 Electronic Leak Locators

This is the electronic version of the listening stick and these systems generally consist of a microphone, amplifier and a combination of frequency filters. The output from the amplifier interfaces with a hand held display unit and headphones. The modern systems usually come with a tripod foot attachment for use on hard surfaces, a hand probe attachment for use in soft ground or for direct use on a fitting. Thus, this piece of equipment can be used for either direct or indirect acoustic leak sounding.

Both the basic listening stick and the electronic version are still widely used by the majority of leakage engineers for:

- Regular or random surveys on a system or part of a system such as a DMA, sounding on all fittings
- Sounding survey just on valves and hydrants
- Confirmation of the position of a leak found by other instruments e.g. leak noise correlator or ground microphone

6.7 The Ground Microphone

Ground Microphones can be used as a leak location tool in both direct and indirect listening mode. It can be used for locating leaks by fixing it onto a fitting, such as a sluice valve, or it can be used on the ground surface directly above the pipeline. In this indirect sounding survey technique the ground microphone is moved along the surface with the operator noting the changes in sound amplification as the microphone nears the position of the leak.

Figure 18: Leakage Engineer using a Ground Microphone

An advanced form of ground microphone was developed and brought to the market place in 2003. This piece of equipment consists of a number of sensors incorporated into what the manufacturers describe as a “Magic Carpet”. This device is available in two versions, a 1.7 metre long carpet with 8 sensors and a 3 metre carpet with 16 sensors.

This piece of equipment has been used to confirm that exact position of a leak that has already been located by leak noise correlator.

6.8 Leak Noise Correlation

6.8.1 Principles of Leak Noise Correlation

Similar to the traditional sonic equipment the correlator relies upon the noise generated by a leak on a buried pipeline. However, the fundamental difference is that with the leak noise correlation process the sound is picked up by sensors deployed at two locations e.g. placed on two fittings such as sluice valves on the pipeline either side of the suspected leak. This noise, in the form of a small vibration, travels away from the leak in both directions through the wall of the pipe. The leak noise journeys along the pipe at a constant velocity, which depends upon the diameter and material of the pipe. The leak noise arrives at the sensor closes to the leak first. The time difference between the two arrival times, combined with the knowledge of the pipe type and length (between the position of the sensors), enables the leak position to be calculated by the correlator. Depending upon the local conditions the accuracy of pinpointing the leak can be within a few centimetres.

It is also possible to correlate the sound of the leak travelling through the water within the pipe by connecting Hydrophones to hydrants or similar fittings, which listen directly to the water. In this instance the noise is conducted through the water as a pressure wave and can lead to more accurate results.

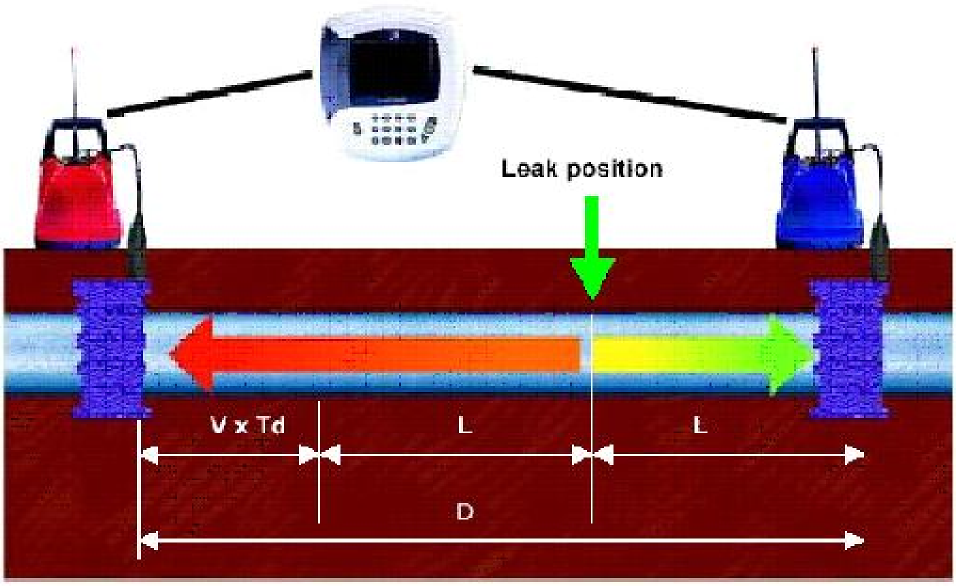


Figure 19: The Principle of Leak Noise Correlation

The first leak noise correlator was developed by the UK Water Research Centre and introduced in the late 1970s. Whilst the correlator was effective it was also very large, had a limited range, required cable for connection to the sensors and had to be housed in a large vehicle or caravan. The first correlator is pictured in Figure 20 together with a late 1990's hand held correlator.

Figure 20: Leak Noise Correlator of the 1970s

The development of the leak noise correlator resulted in a dramatic improvement to the leak location activity. In the 1980s the correlator advanced with the introduction of radio links which gave much easier deployment and the leak location process was much faster. During the 1980s and 1990s the leak signal was continuously amplified and filtered, its resolution reduced for transmission, and then an analogue signal continuously transmitted with as much radio-frequency power as permitted. This approach is essentially unchanged today in analogue correlators.

Thus, during the past 20 or so years the correlator developed from being the size of a large safe that took two men half a day to find a leak to a device that almost fitted into the palm of your hand and leaks were pinpointed in minutes (rather than hours).

6.8.2 The Digital Correlator

The first digital correlator was developed by Flow Metrix Inc. in the late 1990s and was introduced to the market place early in the 21st century. The digital correlator offers the following advantages over its analogue predecessor:

- Superior leak location performance on all pipe materials (especially plastic) and sizes
- Quicker and easier to use, especially for less experienced operators
- Advanced signal processing techniques
- No interference or data loss in digital radio transmissions

Figure 21: Shows the modern correlator in use

Correlators have also moved on many fold from the one pictured above and now include simultaneous multi-correlation systems. These are described more fully in Chapter 7 New and Emerging Technology

6.8.3 Use of the Leak Noise Correlator

The leak noise correlator whether it is either an analogue or digital type can be used in two modes:

- It can be used as a leak detection tool by the operator carrying out a street by street survey to localising a leak to a particular section of pipeline
- As a pinpointing tool following a leak detection exercise

In small DMAs some practitioners consider that it is just as efficient to undertake a correlator survey as it is to carry out a leak localising exercise using acoustic loggers and then pinpointing.

The current types of instrument can be operated by one man but many utilities tend to have two or even three man leakage teams. Figure 19 shows the principles of correlation and simply in the pinpointing of a suspected leak the two microphones are attached to a pipe fitting such as sluice valve either side of the suspected leak. The operator then carries out a correlation run and the machine calculates the position of the leak based upon the calculation shown in figure 22.

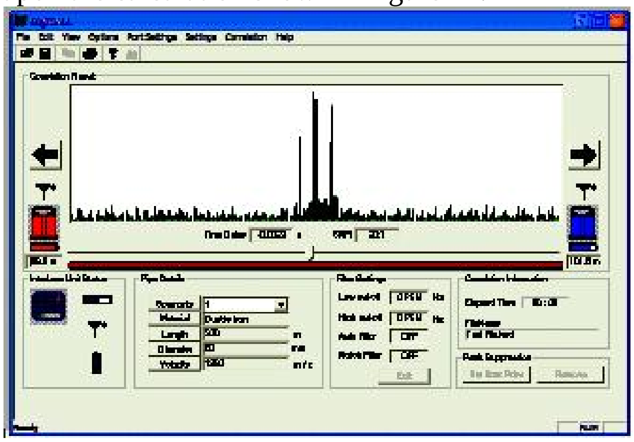


Figure 22: A typical display of the leak position from a correlator

There is quite a range of correlators currently on the market and have a range of sophistication and a corresponding range of costs. There is a version of correlator that has a built in GPS (global positioning system) and this links to GIS (a database of the pipe network) incorporated into the machine. Simply by clicking on the position of the sensors on the map, the correct distances between both the sensors as well as the sound velocity will automatically used for correlation. This means that there is no need to measure the distances with a measuring wheel or enter the material and diameter of the pipe under investigation.

Figure 23: The modern sophisticated correlator has built in mapping system

6.9 The Digital Correlating Logger

In the first year of the 21st century a combined acoustic logger and leak noise correlator was developed. This recently developed device combines the process of acoustic or noise logging and leak noise correlation (pinpointing the location of the leak) into one operation. This results in improved efficiency and a subsequent reduction in operational costs. This system has the advantage of reducing the wait time between identification of a leak noise and pinpointing of the leak thus reducing the run time for the leak and possibly the cost of repair.

The placement of the loggers is planned using a mapping system and are then taken out into the system (often within a DMA) and typically placed approximately 150 metres apart or less. The loggers generally operate overnight and the sound is recorded over three separate periods to ensure that customer usage and leakage is separated. The leak noise data is saved onto a hard disk and correlated to determine the position of a leak (or leaks). The leak noise files can be downloaded, either manually or by radio (with an aerial mounted to the patrol vehicle) and then multiple correlation scenarios may be run from the office PC. Once the leak has been pin-pointed in the office, a detection technician may be sent to verify an exact leakage location. Often correlations performed from the office can be within one metre of the leak position.

Figure 24: The Digital Correlating Logger

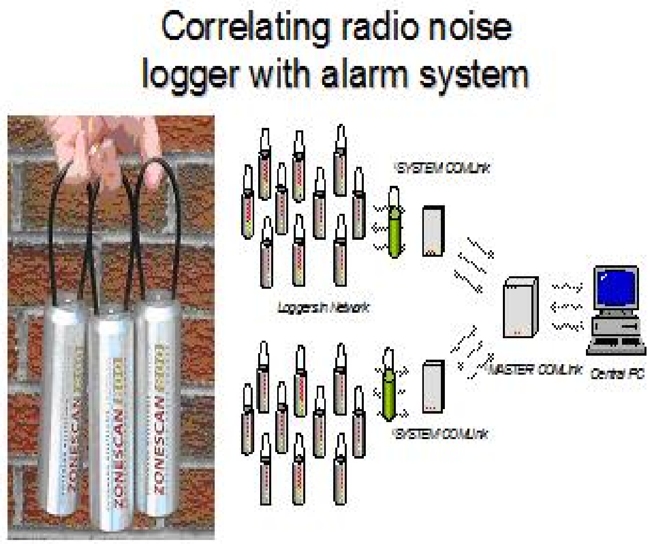


Figure 25: Correlating Radio Noise Logger with Alarm System

6.10 Non – Acoustic Techniques

6.10.1 Ground Penetrating Radar (GPR)

There are occasions when a leak does creates very little or no sound the location of which can render even the most sophisticated leak noise correlator ineffective. There may be other reasons that correlation could be made difficult to locate a leak or leaks and that could be a street or highway that contains several water mains or simply the noise created by pumps or pressure reducing valves.

An alternative method of locating a leak, although expensive is the GPR method. This is a device that has been developed in recent years and has primarily been used for the location and surveying of pipes, cables and other buried objects. Water leaks can be found through the observation of disturbed ground or cavities around the pipe.

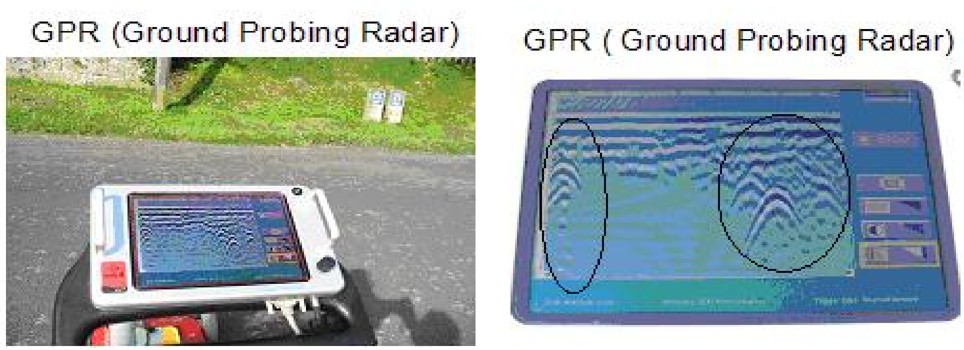


Figure 26: Leak Location using Ground Penetrating Radar

6.10.2 Tracer Gas

Gas injection and tracing techniques for the location of leaks are not so commonly used as they were 20 years ago. This is mainly because of the advancement of acoustic techniques.

However, for leaks on low pressure mains, especially non-metallic or on house connections and other small diameter pipes, especially non-metallic pipes can often be found by using gas injection and tracing techniques. The leak is located by filling the pipe with tracer gas mainly industrial Hydrogen (approximately 95% Nitrogen and 5% Hydrogen or Helium) that escapes at the point of the leak and is detected accurately with a "sniffing" probe on the surface. The tracer gas has the ability to rapidly penetrate all materials – Hydrogen being the smallest and lightest element (Helium the second). One main advantage of this technique is the speed of tracing with the gas dissipating through the soil above the pipeline very quickly, with more solid surfaces such as concrete the process is slower.

This method of leak location is considered by many practitioners to be very specialized and will call in an expert contractor to carry out the work.

6.10.3 Infrared Thermography

In America the first trials are being carried out into infrared inspection of underground leaks. The principle is that the water from the leak is of a different temperature than the surrounding ground and a thermographic camera can sometimes see this temperature discrepancy.

6.11 Leak Location on Trunk on Transmission Mains

Transmission or trunk mains are large diameter pipes (generally larger than 300mm diameter) and in many networks are either used to carry water from source, treatment works and service reservoirs. They are also used to transfer water from service reservoirs to the main distribution system.

If a transmission main bursts or a major defect occurs on a fitting such as an air valve or washout they are often visible and therefore reported and repaired. Lesser leaks that may occur in a joint may go undetected and could run for a long time. Leak location on transmission mains can be more difficult and expensive than the normal distribution system. It is recommended that a certain amount of analytical work is undertaken before carrying out a leak location exercise i.e. is the configuration of the transmission system understood, have meters been verified are there any apparent losses?

Once the above questions have been answered and the indications are that there are leaks on the transmission system then there are several options available to the leakage engineer.

6.11.1 Walking and Sounding

In many instances leaks do occur on washouts, air valves and other fittings. It is often that by initially walking the line of the transmission main and inspecting and sounding on fittings that leaks may be located.

6.11.2 Leak Noise Correlators

Some of the advanced (and most expensive) correlators have been used very successfully on transmission mains but it can be the distance between fittings that can be the limiting factor. The installation of correlation points can help address the distance problem.

6.11.3 In-pipe Acoustic Technology

With this system a sensor head or probe is inserted into a pressurized transmission main through a 50mm diameter tapping point. The flow of water carries the probe through the pipe and leaks are located by analyzing the acoustic signals that are generated by leaks in the pipe wall or joints. Once a suspected leak has been located the probe can be stopped at the position of the leak. It is possible to survey 2 km per insertion. The 'Sahara' system is an example of this technology and is shown below.

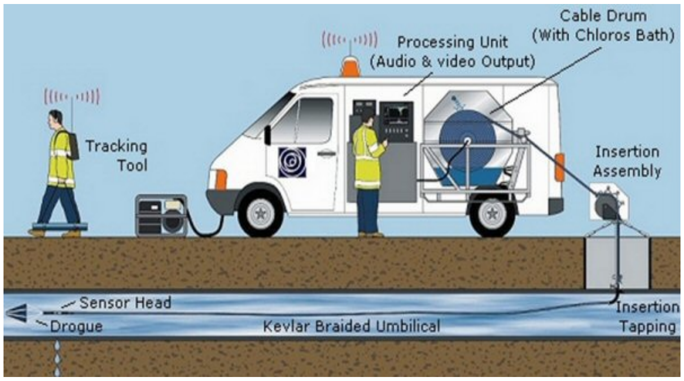


Figure 27: An example of In-pipe Acoustic Technology

6.11.4 Other Transmission Main Leak Location Methods

There are several other methods that can be used to locate a leak in a transmission main and these are:

- Ground penetrating radar
- Step testing
- Pressure testing
- Aerial photography
- Comparison in flora and ground conditions

7. LEAK DETECTION ACCCESORIES

7.1 Introduction

In addition to the leak detection and location equipment that has been described in Sections 4 and 5 the leakage technician also requires some accessories to enable him or her to carry out their work efficiently. For example there is always a requirement to locate precisely the position of a water main or a service connection or locate the cover of sluice valve chamber that has inadvertently been covered over during road resurfacing work.

7.2 Mains and Service Locating and Tracing Tool

These devices which are essentially signal generators (transmitters) and are placed above the pipeline (but not in contact with it). A signal is induced into the water in metallic pipes and a detection head picks up the signal. The standard Cat & Genny or Pipe Locator works in two main ways. One is through direct induction – where the Genny connected to the metallic pipe at a stop cock or valve and also to earth via a rod and earth wire. The other method is indirect induction where the Genny is laid in line and on the ground top of the main. Then the Cat is swept over the expected location of the pipe, when the detected signal is strongest that is the location of the pipe.

Figure 28: Mains Tracing Exercise

8. NEW AND EMERGING LEAK LOCATION TECHNIQUES

8.1 Introduction

The pace of the development of new technology has accelerated in the last ten to fifteen years as the goal of many water utilities around the world to reduce water loss has become a priority. One problem with detailing with new and emerging leak location technologies is that they are evolving rapidly and the equipment mentioned in this section could be out of date within 12 months and therefore details must be regularly updated.

There are many drivers that make a manufacturer constantly strive for the ideal and perfect leak location equipment and the key components of these are depicted in the diagram below.

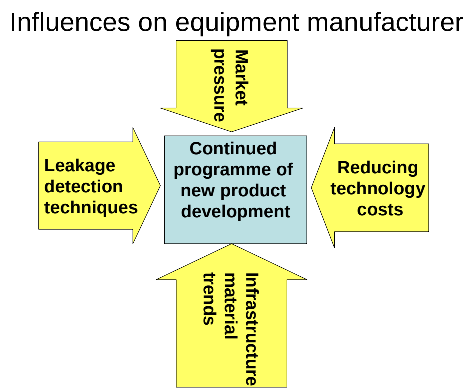


Figure 29: Influences on manufacturers

The results from this pressure enforces the manufacturer to take note and to continuously move forward to try to achieve a tool that will find all leaks first time and every time without any room for error. This is of course not available in this present time and realistically appears to be a long way off.

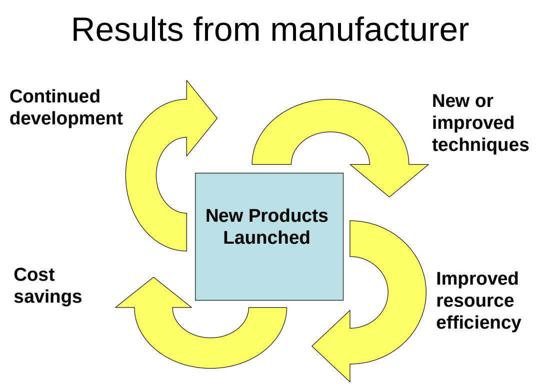


Figure 30: results from manufacturer

New equipment for the location of leaks does not just stay with the correlator manufacturers but covers many areas some of which are shown below, however it must be noted that this chapter does not cover all equipment that is currently available.

Prior to any losses being calculated the flows have to be measured, this has moved forward from the days of mechanical turbine meters and now includes such equipment as full bore electromagnetic meters, strap-on ultrasonic flow meter, electromagnetic insertion probes (some of which now also incorporate a data logger) to noise acoustic flow meters that estimate flows through a sluice valve dependent upon the noise generated from the passing water.

8.2 Leak Noise Correlators

Correlators have advanced rapidly in the last two or three years and now include simultaneous multi-correlation systems, cordless accelerometer radio link systems and PDA based units. Most of these systems also come in either a 2 box or a 3 box system the latter giving an advantage of finding the difficult leak. Due to the increased processing power of computers today many velocities can be used for the correlation calculations. This reduces the chance of error because due to the selection of one velocity or pipe material and improves the confidence of the correlation.

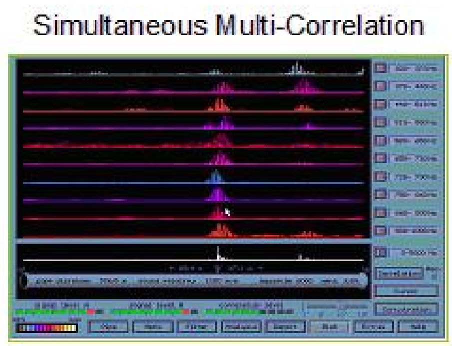


Figure 31: Simultaneous multi-correlation screen

Figure 31: PDA based Correlator

8.3 Specialist Leak Locator for Plastic Pipes

The location of leaks on non-metallic has always been more difficult because there is lower sound propagation along the wall of the pipe especially on plastic pipes. A new instrument has been developed to solve this problem. The ‘Leak Finder’ has been developed in Sweden where there is a high proportion of plastic pipe (this is true of many distribution systems worldwide). This device listens to the leak sound travelling through the water and can be detected by using hydrophones connected to fire hydrants.

8.4 Internal Noise/Leak Indictors

This is now seen as the approach that will locate the smallest of leaks.

The Sahara system was the first of this location method and was first used in the early to mid 1990's and still is to this day with much success.

Many other methods are now being developed which used the process of a noise recorder being deployed into the water within the pipe using the velocity of the water to carry the equipment along. However, this equipment some now smaller than a cricket or tennis ball still has to be inserted into the water main by a safe and suitable method and also has to be retrieved by a similar event. The device travels along the pipe listening and when a noise is heard is transmitted to sensors strategically placed along the route of the main to receive the data. These units are also used to ascertain the water quality and chemical constitute of the water.

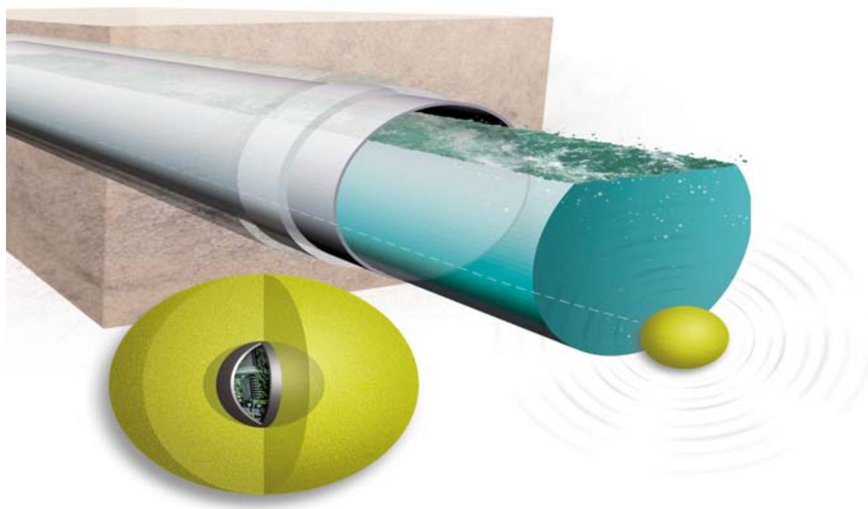


Figure 33: Internal Noise/leak Indictors

8.5 Permanently Installed Acoustic Leak Monitoring at Customer Metering Point

These systems are installed and are part of the fixture of the service pipe. This device listens for when a constant noise is heard and informs the provider with an alarm that would initiate an investigation.

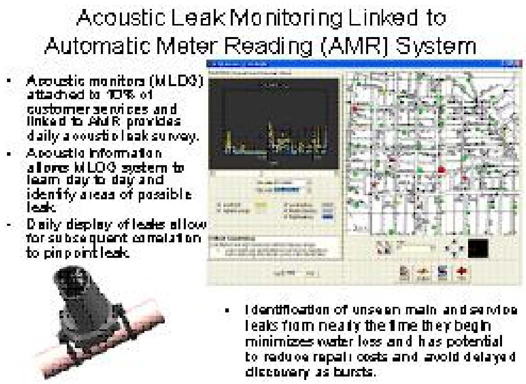


Figure 34: Acoustic Leak Monitoring Linked to Automatic Meter Reading System

This has been further developed so the water main itself can locate its own leaks and pass this information back to a control room that would initiate a repair.

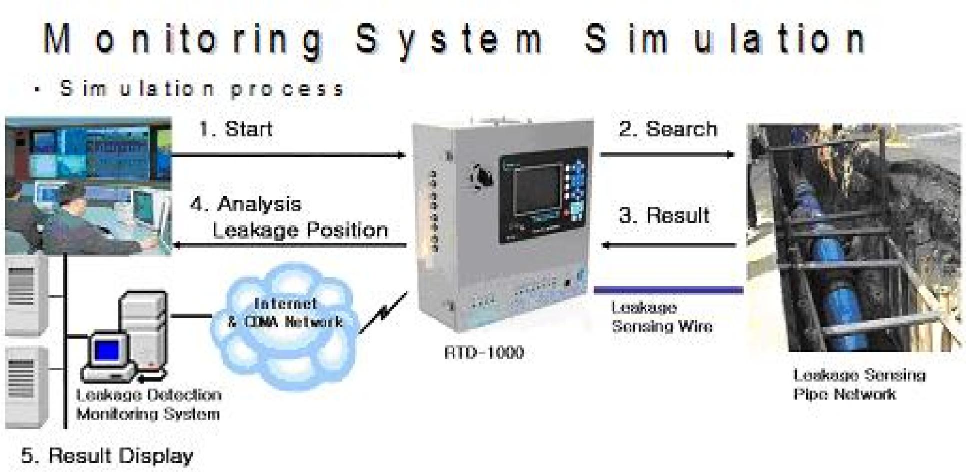


Figure 35: Monitoring System Simulation

9. PRESSURE MANAGEMENT

9.1 Introduction

The purpose of these Guidance Notes is essentially to detail activities concerning active leakage control and the speed and repair of leaks. However, it is considered that as active pressure management is the foundation of an effective leakage reduction and control policy and reference should be made to this subject because of its importance.

9.2 The Work of the IWA's Water Loss Task Force – Pressure Management Team

The IWA's Water Loss Task Force includes a Pressure Management Team and their objectives are:

1. To identify and gather information and case studies on both successful and unsuccessful pressure management projects, analyze and formalize the results and report conclusions.

2. Monitor and promote further research and testing of both existing and new methodologies for analysis and implementation of pressure management.

3. Creation of an international database of said cases for distribution to IWA members.

4. Forward suitable papers and presentations to the Communications, Conference and Publications Team.

The team continues to produce good work and their currently areas of work are prediction methods for:

a. Calculating N1 – Pressure and leak flow relationships
b. Calculating N2 – Pressure and burst/break frequency relationships
c. Calculating N3 – Pressure and consumption relationships

It is perhaps appropriate outline the benefits of pressure management. The reduction of excess pressures (and excess pressure variation) and surges will reduce:

- The number of new leaks and bursts and repair costs.
- The flow rates of all existing leaks.
- 'Background' (undetectable) leakage (unavoidable losses).
- Pressure-dependent consumption
- Help to defer mains and service pipe replacement (increases asset quality)

A 1% reduction in pressure will reduce your current rate by between 0.55 and 1.5% and that most importantly, effective pressure management ensures full benefits from active leakage control.

Outputs from the IWA WLTF Pressure Management Team will be publiscised on the IWA's website from time to time.

10. REPAIR OF LEAKS

10.1 Introduction

A key component in water loss management is the speed and quality of reticulation repairs. This is commonly referred to as one of the 'four pillars of leakage control'. This chapter covers the types of leaks encountered in different water supply networks, how specific leak types are repaired and the techniques used in carrying out repairs.

Leakage can occur due to corrosion in mains and service pipes that are metallic. This corrosion is caused by aging pipes, chemicals in the water and soil make up. Another type of leak that occurs on metallic pipe is cracks and splits. These occur due to ground movement, increases in water pressure (sometimes after nearby repairs), vehicular traffic and ageing. A leak caused by a crack or split will have significantly greater leakage than a leak caused by corrosion. Leaks on fittings such as hydrants and valves are visually identifiable most of the time. Competent repair teams should have appropriate equipment and training to deal with the leaks on their particular system.

Non-metallic water main leaks are similar in leakage nature as the above metallic pipes. However they are harder to pick up with leak detection equipment due to the low conductivity of sound. Corrosion generally doesn't occur in non-metallic mains; but it is not unusual to encounter faulty products that lead to the mains splitting. Also with a non-metallic main; other contractors working on underground services are able to easily damage the pipe leading to large leaks caused by excavators and the like.
With PVC mains the ground movement can cause the pipes to easily crack and often lead to damaged joints.

Figure 36: Typical Repair of a leaking Joint

Once the leak is pin-pointed and repair crews are made aware of the location – the repairs can be carried out. A lot of the time the discretion of the repair crew is used to determine what and how the repairs will be carried out.

Repair teams will usually assess the site and determine the pipe layout and necessary valves that need to be shut off. Once this is completed they are able to start excavation of the leakage location. Dependent on the seriousness of the leak; the pipe may be cut out where it is damaged and replaced or a stainless steel 'wrap-around bandage' can be placed over the leakage point. Some water suppliers prefer the later as it reduces the health risks that could occur when the pipe is cut and left open.

With service pipe leaks there are various methods of repair depending on the network set up. One method is to dig up where the service meets the main (tapping band connection or ferrule), and turn off the water supply to the property by the main tap. Another way is to gain access to the service pipe and temporarily clamp the pipe or freeze it. Repairs are then carried out; or using their discretion the team or water utility may decide it would be more economical in the long term to replace the whole service pipe.

It is very important after a leakage repair to re-scan the areas for other leaks, which may have been masked by the now repaired leak.

Often the cost of a leak is only measured in volume wasted and price of repair. Other factors to be considered include:

- administration,
- traffic management
- customer disruption
- reputation of the water company
- cost of repeat repairs (e.g. on same service pipe)
- addition storage required
- increased treatment costs
- increased pumping costs
- drain on natural resources

11. TRAINING

11.1 Introduction

The need for a sustainable and competently trained workforce is central to the success of any organization. In respect of leakage management and in particular detection and location this is especially true.

In many water utilities the training is the responsibility of the leakage control managers, often in conjunction with training providers to provide appropriate training to staff. In some countries where a leakage reduction scheme has been let to consultants or contractors often a training requirement is specified in the tender documents and it is part of the contract. In many cases when new equipment is procured most manufacturers of leak detection and location equipment provide a day or several days training on the use of the equipment that has been purchased.

A training course on leakage management should comprise classroom sessions as well as ‘on the job’ training in the field. Section 10.2 below outlines a leakage management training course that covers an overview of facts about water and distribution systems.

11.2 Typical Programme for a Leakage Management Training Course

The programme outlined below is designed for practitioners and variation is provided by alternating classroom and field sessions.

Module 1: Facts About Water:

i. The water cycle
ii. The composition of water
iii. Principal characteristics of pressure
iv. Understanding a basic water distribution system
v. Calculating and comparing the capacity of pipelines

Module 2: Pipe Location

Practical training using pipe locators.

Module 3: Network Hydraulics:

i. Common terminology and units of measurement
ii. Flow – velocity relationship
iii. Using the formula
    1. Flows in pipes
    2. Velocity in pipes
iv. Understanding friction losses in pipes
v. Hydraulic gradient
vi. Flow and pressure relationship
vii. Pumps and pumping
viii. Introduction to hydraulic modelling

Module 4: Valve operations and ground microphone use

Practical training in correct valve movement and ground microphones.

Module 5*: *Pressure Management:

i. Why manage pressure
ii. Relationships between flow and pressure
iii. Pressure management design
    1. Standard terminology
    2. Design steps for pressure reduction
    3. Understanding Critical and Average Zone Points
i. Pressure reducing/sustaining valves
ii. PRV sizing software
iii. PRV types (e.g. globe design versus turbine design
iv. PRV controllers

Module 6*: *Leak Detection Techniques

i. Step test design and implementation
ii. Acoustic (noise) logging techniques

***Module 7*: *Data Collection*:**

i. Background to logging
ii. Applications
iii. Pressure
iv. Flow
v. Noise
vi. Sensors and pulse generators for flow and pressure
vii. Recording information
viii. Pressure transducers
ix. Interpretation / understanding of results

Module 8*: *Use of Data Loggers

Practical training on programming and installation of pressure/flow loggers.

Module 9*: *Leak Location Techniques

i. Direct and indirect sounding
ii. Leak noise correlation **-** the basics of correlation
iii. Leak noise correlation – advanced correlation

Module 10: Leak noise correlators

Practical training using a leak noise correlator.

Module 11: Digital Correlating Loggers

Combining leak detection and leak location into one activity

Module 12*: *Metering:

i. Meter types/performance/accuracy
ii. Meter selection and sizing
iii. Design and installation
iv. Calibration

Module 13*: *Installation of meters

Practical training on insertion probe meters.

Module 14*: *Data analysis and Economic Level of Leakage (ELL):

i. Introduction
ii. Glossary of terms
iii. Leakage economics
    1. Units costs
    2. Economic formula
    3. Capital deferment
iv. Benefits of leakage management
v. Resource management
vi. Leakage performance indicators (LPIs)

12. GLOSSARY

Active Leakage Control (ALC). The proactive process whereby unreported leaks are detected and repaired. This contrasts to Passive Leakage Control.

Acoustic Logger. An electronic device to record levels of noise created by a leak at predetermined time intervals may include correlating acoustic loggers

Awareness Time. The time between the occurrence of an unreported leak and the water undertaking becoming aware of its existence.

Background Leakage. The component of leakage that is not affected by ALC. This usually consists of very small (and mostly) undetectable leaks.

Burst. A failure of a water main or service pipe leading to leakage. In this publication the term is interchangeable with leak.

District Meter Area (DMA). A small discrete metered area within the distribution network. The term Distribution monitoring Area is also used to describe the same thing.

Ground Microphone. A device placed on the ground which amplifies the sound created by a leak to facilitate its location.

Leak. See Burst.

Leak Detection. This is the process of 'narrowing down' or localisation of a leak or leaks to a particular section of a pipe network.

Leak Location. Is the identification of the position of a leak (pinpointing) prior to excavation and repair.
Note: leak location surveys can be undertaken with or without prior leak detection activity.

Leak Noise Correlator. An electronic device for matching the sound frequency spectrum from two different locations for the purpose of locating or pinpointing leaks.

Leakage Control Zone. Can be a DMA or more often a sub-part of a DMA which is established for the specific purpose of implementing a leak detection exercise.

Real Losses. Physical water losses from the pressurised distribution system, up to the point of measurement of customer use. The volume lost through all types of leaks, bursts and overflows (from service reservoirs or storage tanks) depends upon the frequencies, flow rates, and average duration of individual leak

Step Test. A method of leak detection whereby successive valve closures are made to reduce the size of the Leakage Control Zone temporarily whilst simultaneous measures of rate of flow are being made.

Sounding – direct. A method of locating leaks in which a trained leakage engineer listens to the characteristic sound of a leak by placing a listening device e.g. listening stick or leak noise correlator onto a fitting such as a sluice valve, hydrant or stopcock.

Sounding – Indirect. A method of locating a leak but with the listening device in contact with the ground surface e.g. a ground microphone.

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14. CASE STUDIES

It was considered that these Guidance Notes would be incomplete without some case studies. Three recent case studies from different parts of the world have been included and they are as follows:

- Sandakan, Malaysia – 2003 to 2005
- Thessaloniki, Greece – 2004 to 2005
- Calgary, Canada - 2006

The three case studies are in the form of papers that have been written and presented by members of the Leak Detection Practices, Techniques and Repair Team. These case studies do not just concentrate on leak detection and location but also include assessment of water loss, strategy development, implementation and the meeting of targets.

The Sandakan case study, written by Richard Pilcher describes how the volume of water loss was calculated and how a strategy was developed for the project. The case study also covers the stages of DMA and Pressure Management design and implementation to the finding and fixing activities.

The second case study, Thessaloniki, written by David Field provides a good example of a tactical leakage management project based on the successful use of acoustic logging and correlation. The study describes the first stages of a leakage reduction exercise in an urban area.

The third case study, written by Stuart Hamilton and his team describes how innovative leak location techniques were applied in a difficult situation in Calgary. The case study explains the techniques used and the application of the IWA's recommended leakage Performance Indicator the Infrastructure Leakage Index (ILI).

Case Study No 1 – Sandakan Malaysia

Richard Pilcher
Principal Operations Engineer, Halcrow Group, Snodland, Kent UK.
(e-mail:pilcherr@halcrow.com)

Sandakan is the second city in the Malaysian state of Sabah situated in the north east of Borneo Island. Sandakan has a population of approximately 450,000, of which quite a number are non-registered immigrants. Most of the activity in Sandakan centres on the docks and wharves where local produce such as rattan, timber, rubber, copra and palm oil is exported or transported to other parts of Malaysia.

The State of Sabah has had one of the highest levels of Non-Revenue Water (NRW) in Malaysia and in the 1990s the level was calculated at almost 60% of system input volume. In 1997 a NRW reduction contract was let to a company named Patterson Candy (at that time Patterson Candy was part of Thames Water) and their objective was to design and implement District Meter Zones and reduce physical losses by 25%. The term District Meter Zone is widely used in Malaysia, but is effectively the same as the term District Meter Area (DMA).

The result of this project was that in Sandakan 31 DMZs were designed and implemented (that covered approximately one third of the Sandakan distribution system); and a 3 man leakage team was trained. Unfortunately for Sandakan this contract did not result in the reduction of water loss to alleviate the water shortage. The water shortage in Sandakan has been brought about by a combination of a rapidly increasing population, high water loss and lack of funding to construct a new water treatment plant.

In the spring of 2003 Jabatan Air Sabah (Sabah Water Board) let another NRW reduction contract, which was aimed at reducing real or physical losses from two directions: improving and expanding the current active leakage control activities and replacing the mains with the highest burst frequencies. This contract was over a period of 30 months and was undertaken by Halcrow Water Services in partnership with a Malaysian Company, Salcon Engineering. In July 2005 the project was being brought to a successful conclusion and Stage 2 was being considered which will concentrate on the reduction of apparent or commercial losses.

The Sandakan Water Supply and Distribution System

The city of Sandakan receives its water from three sources. The major source is a treatment plant that takes its water from Sabah's longest river, the Kinabatangan, and this plant is located some 70km from the city. This source provides approximately 65Mld additionally two borehole sources close to Sandakan produce 8 and 7 Mld respectively.

It is estimated that there is a current shortfall of water of 30% and the true demand is in the order of 115 Mld. Jabatan Air Sabah have plans for a new water treatment plant that should be operational by 2008/09.

The Sandakan transmission main and distribution system totals almost 600km of pipe work and has approximately 36,000 service connections. A particular feature of the Sandakan system is the 70km of single 900mm diameter transmission main linking the main source of water, the Kinabatangan Water Treatment Plant, and the town of Sandakan. In recent years, this pipe has become a problem in terms of both physical losses and non-physical losses (mainly theft of water).

The Sandakan distribution system like many others in Malaysia has a predominance of Asbestos Cement pipe much of which is close to reaching the end of its useful life. The result of which is that the system suffers from a high burst frequency.

The Sandakan water balance was calculated just prior to the commencement of the project (for the year 2002 and is shown in Figure 1) and it was determined that the total NRW was 14947 Ml/Annum (55% system input volume). Of the total NRW, the physical losses were estimated at 77% and the non-physical losses at 23%. The level of unauthorised use i.e. illegal connections and theft of water accounts for approximately 20% of the total NRW.

The IWA's recommended performance indicator for water loss, the Infrastructure Leakage Index (ILI) was calculated to be 30. The ILI is defined as the ratio between the Current Annual Real Losses (CARL) to Unavoidable Annual Real Losses (UARL).

<table>
<tr><td rowspan="7">System Input
27,719
100%</td><td rowspan="4">Authorised Consumption
12779
46%</td><td rowspan="2">Billed Authorised Cons.
12772
45%</td><td>Billed Metered Cons. 12772
45%</td><td rowspan="2">Revenue Water
12772
45%</td></tr>
<tr><td>Billed Unmetered Cons.
0%</td></tr>
<tr><td rowspan="2">Unbilled Authorised Cons.
7
1%</td><td>Unbilled Metered Cons.
0%</td><td rowspan="5">Non-Revenue Water
14947
55%</td></tr>
<tr><td>Unbilled Unmetered Cons.
7 1%</td></tr>
<tr><td rowspan="3">Water Losses
14940
54%</td><td rowspan="2">Apparent (Commercial) Losses
3283
12%</td><td>Unauthorised Use (theft)
2772 10%</td></tr>
<tr><td>Metering Inaccuracies
511 2%</td></tr>
<tr><td colspan="2">Real (Physical) Losses
11657
42%</td></tr>
</table>

Figure 1. The 2002 Annual Water Balance for Sandakan (all units Ml/Annum)

Where do the largest components of physical losses occur?

The high level of real or physical losses in the Sandakan system can be attributed to three main causes:

- A high incidence of burst mains and service pipes leaks
- A water resource shortfall of approximately 30%
- Variations in pressure.

Similar to the majority of systems in Malaysia Sandakan has a high burst frequency in its mains. This can be attributed to the fact that asbestos cement pipes contributes to in excess of 50% of the pipe material in Malaysia. Burst frequencies in Sandakan are in the order of 185/100km mains/annum compared with the UK figure of 15/100km mains/annum.

Figure 3. Photos of Burst Mains and Illegal Service Connections

Mains burst rates from locations around the world are shown in Figure 2. The number of leaks occurring on service pipes is also high with approximately 9/1000 connections as compared to that of the UK that has 6/1000 connections. Burst flow rates are higher from mains than service pipes and with the great number of burst mains it is evident that, in Sandakan, water loss from mains is greater than that from service connections.

The current water shortage in Sandakan results in some rationing being carried out, with certain areas being regularly shut off for a whole day. Systems that are subject to intermittent supplies generally suffer from a higher burst frequency due the pressure cycling caused by emptying and recharging the mains and this is the case in parts of the Sandakan system. The problem is exacerbated by the theft of water and increased in leakage due to the tampering of pipes and fittings.

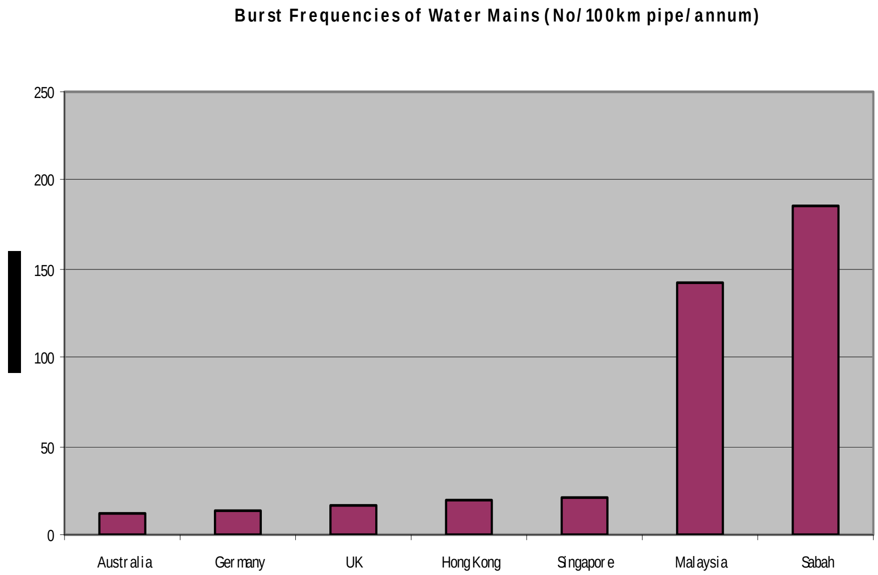

Figure 2. Burst frequencies from different locations worldwide

Developing a Water Loss Reduction Strategy for Sandakan

Once the losses had been assessed and the situation in Sandakan understood, a strategy was developed. Although there are several important stages to a water loss management strategy there is no standard approach and, as in Sandakan, it had to be tailor made to suit the local conditions. It was decided to tackle the problem in two stages.

The target for Stage 1 (to be completed by August 2005) is to reduce Real Losses by 5,500 Mega litres/annum (15Mld), this will result in a level of NRW of 30% thus achieving the target set by the Malaysian Federal Government. In practical terms the rationing will be greatly reduced and Jabatan Air Sabah will have an increase in revenue as each cubic metre of water that can be saved can be sold. In many water distribution systems, losses can be reduced to an acceptable level by the introduction of an active leakage control programme, i.e. proactively ‘finding and fixing’ leaks but, in Sandakan, parts of the infrastructure were in such poor condition that some pipes were in need of replacement. Therefore the problem of water loss had to be tackled from two directions – leak location and repair, and selective pipe replacement. The Sandakan Strategy included the following activities:

- Updating the existing records system
- Construction and verification of a hydraulic model
- Re-establish 31 existing District meter Zones (DMZs)
- Develop and implement DMZs to cover 75% of the system
- Increase manpower in the leakage section
- Specify and procure leakage equipment
- Identify scope for pressure management
- Reduce physical losses by 15Mld
- Identify the mains that require replacement
- Develop a mains replacement programme

- Executing the mains replacement scheme

Increasing the Manpower Level of the Leakage Section

There was one existing leakage team in Sandakan and this team has been seconded to the consultants for the duration of the project. The purpose of this action is to help focus the effort and introduce further training. Two additional teams have been recruited and trained in order to accelerate the leakage reduction effort.

Specify and Procure Leakage Control Equipment

The existing leakage team had been provided with equipment under the previous contract but some of this is now outdated or has fallen into disrepair. The contract provided for the provision of:

- Flow and pressure data loggers
- New computers
- Listening sticks
- Leak Noise Correlators
- Acoustic loggers

Increasing the Manpower Level of the Leakage Section

The existing Jabatan Air Sabah leakage was seconded to the consultants for the duration of the project. Two further teams were recruited during 2003 and training was provided on all aspects of leak location.

Specification and Procurement of Leakage Control Equipment

All necessary equipment for leakage control equipment was specified and agreed with Jabatan Air early in the contract and was procured by the time the new leakage control teams had been recruited. Classroom and in the field training on the use of the equipment was carried out by the manufacturer and Halcrow Water Services. It was important to purchase the equipment from a supplier who could provide a good after sales service.

Leak Location and the Reduction of Physical Losses

During the course of the project approximately 2,100 leaks have been located and repaired. Under the terms of the contract all water saved has to be recorded and reported to Jabatan Air Sabah. A methodology was devised whereby the water saved through active leakage control and mains replacement would be identified.

At the end of June 2005, physical losses have been reduced by almost 17.5Mld against the target of 15Mld. 11Mld have been saved through active leakage control and 6.5Mld by replacement of mains. It is anticipated that by the end of the contract in August 2005 the water saved will be approximately 18 Mld.

The reduction of physical losses has been calculated using the ‘top down’ approach and the ‘bottom up’ using DMZ data.

Conclusions

The Sandakan situation is a very good example of a transmission and distribution system that is under great stress because of the combination of the shortage of water, high incidence of bursts and leaks on mains and service pipes and further exacerbated by the theft of water and tampering with the pipes and fittings. The operational staff have a very difficult task in trying to provide the customers with a reasonable water supply. This object of this project was to try and alleviate the problem by the reduction of physical losses by almost 18Mld through enhanced leakage reduction techniques and the replacement of approximately 20% of the infrastructure that was in poorest condition.

Good results have been achieved on this project by the application of:

- international best practice in the assessment of losses and development of a tailor made strategy
- active leakage control using the latest techniques and practices
- appropriate training of local staff

The author would like to thank Jabatan Air Sabah for their assistance in the preparation of this paper and for their permission in allowing him to present it.

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Case Study No 2 Thessaloniki Greece

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Example of Tactical Leakage Management project based on Acoustic Noise logging and Correlation.[i]

Introduction

This paper describes the first stages of a large-scale leak detection project that covers the whole of the water supply network of Thessaloniki. The project was commissioned by the pertinent authority, EYATh, after the implementation of a 3-month pilot project. The anticipated project duration was one-year. The application would take place through the successive sweeps of the network's billing zones with the deployment of acoustic loggers and subsequent localisation of leaks with a noise correlator and additional acoustic equipment.

The direct aim of this project was the reduction of leakage and consequent saving of water for the supply of the city. Indirectly, however, and more importantly, the project aimed at auditing the effectiveness of acoustic survey methods for leakage detection in a large-scale application for the whole network. Furthermore, it aimed at examining the efficiency of the proposed methodology that was chosen during the 3-month pilot study, under longer-term application.

Equipment Used

The acoustic leak location equipment employed for this project belonged to EYATH and consisted of:

- 200 last generation acoustic loggers
- 1 receiver unit, to download data from the loggers
- 1 communication unit, to set and deactivate loggers
- 1 analogue correlator with 2 sensor units
- 1 ground microphone
- 4 listening sticks

This was backed up by a series of assisting tools and instruments, the necessary software and supporting office infrastructure.

Field work was executed by a team of Greek engineers and technicians with the support of UK experts.

Summary of works

During the first six months of the project's application, approximately 450km of pipeline, comprising 31% of the total network, was surveyed covering 9 billing zones and an area of app. 12.2km^2. A total of 2379 loggers were deployed on an average spacing of 185m. During downloading, 689 loggers produced a leak indication. It should be pointed out however, that the number of leak indications does not correspond to an equal number of possible leak locations, as a single source of noise in the pipeline might be recorded by a number of neighbouring loggers.

After treatment of the data and identification of the possible leak locations, on site confirmation and accurate localisation was conducted. Each of the identified leaks was investigated again within a few days to secure the correctness of the findings. In a few cases, night sounding with the use of the ground microphone was employed in order to accurately pinpoint difficult leaks.

Results, analysis & comments

A total of 177 leaks were identified in the first six months of the project. At the time of writing 70% of these leaks had been excavated and repaired. In the vast majority of the cases, the leak was discovered within 1m of the marked excavation spot. In two cases the leak was discovered 5m away from the marked spot, owing to different pipe layout than that appearing on the network plans. In two other cases, it was found out that the noise was caused by water flowing through a defective valve, which was subsequently replaced. There was only one dry hole, i.e. a case where no leak was discovered where expected.

The overall performance of the method was remarkable with an almost 100% success achieved. The following table presents the results per billing zone including information on the network size and characteristics, as well as a breakdown of the located leaks in different types.

	Kalamaria	Triandria	Evangelistria	Saranta Eklisies	Toumba	Ntepo	Harilaou	City Centre*	Neapoli	Total
Length of mains (km)	61	16.3	12.1	3.7	130.5	56.7	73.4	35.0	60.4	**449.1**
Covered surface (km^2)	2.62	0.36	0.46	0.05	2.72	1.34	1.86	1.25	1.27	**12.2**
Network valves	294	169	75	19	952	560	736	-	388	**3193**
% A/C mains	78.7	35.1	50.4	11.8	65.5	40.4	79.4	-	49.0	**63.3**
% Metallic mains	15.2	54.2	48.5	88.2	32.2	35.0	18.1	-	47.6	**30.7**
% Plastic mains	6.2	10.7	1.1	0.0	2.2	24.7	2.5	-	3.4	**6.0**
Deployed loggers	272	81	40	17	654	352	393	140	427	**2379**
m per logger	224.3	201.2	301.3	217.6	199.5	161.1	186.8	-	141.5	**185.2**
No. of valves per logger	1.1	2.1	1.9	1.1	1.5	1.6	1.9	-	0.9	**1.4**
Leak indications	78	23	23	13	198	106	81	55	112	**689**
Confirmed leaks	16	13	5	3	38	36	27	7	32	**177**
Defective valves	-	1	-	-	1	-	-	-	-	**2**
Dry holes	1[*3]	-	-	-	-	-	-	-	-	**1**
Leaks on distribution mains	2	4	2	3	13	12	9	6	18	**69**
Leaks on service pipes	5	6	-	-	16	13	6	1	6	**53**
Leaks on network valves	5	2	-	-	3	6	8	-	6	**30**
Leaks on service valves	3	-	2	-	3	4	4	-	2	**18**
Other leaks	-	-	1	-	2	1	-	-	-	**4**

Only specific problematic zones of the city centre were surveyed

References

G. KAZANTZIS[1*], V. IOSIFIDIS[2], K. ANAGNOSTOPOULOS[3], K. ANGELIDIS[3]
"Application of acoustic survey methods for leakage detection and reduction in complex water supply networks with no area flow metering." Paper presented to IAHR in Thessaloniki 2003

New Leakage Detection Techniques using various Performance Indicators

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Key Words: ALC; Performance Indicators; CARL; UARL; ILI

Abstract

City of Calgary - Water Services instigated a leakage study of certain parts of the city to estimate the time period to compete a survey of Calgary. This paper explains the technique used and the findings from the study.

The paper shows that regardless of the level of water losses reported from using any of the IWA Performance Indicators, it is still possible to perform Active Leakage Control (ALC) and develop new techniques to increase water loss savings.

Some of the findings from this study are as follows:

- The correlation between a numeric value and the size of water loss is in part determined by the analysis of the data sets and the number of confirmed leaks. In assessing the impact of these leaks on the surrounding infrastructure fitments, indications within the Calgary distribution system are that the numeric value of 45 (using the Gutermann Aqua Scope 3 - AS3) and above is the ‘trigger’ for conducting additional investigation on metallic mains and surrounding infrastructure. It should be noted that whenever a survey such as this is to be considered an acoustic calibration exercise should be completed.

- The propagation of sound values (using the AS3) on the non-metallic material mains and infrastructure appear to much less to that of metallic, therefore without the addition of supplementary data sets taken from confirmed leak types on this material type the methodology established cannot be substantially supported.

- This technique has proved successful and more investigation is required to obtain a generic footprint for non metallic pipe-work. This shows that some form of ALC can be performed with success from an unskilled operator with minimum training.

Introduction

Hydrosave was commissioned by City of Calgary - Water Services to assist with the development of a bespoke leakage detection methodology anticipated to complement the existing detection resources with the addition of a robust procedure, which if proven successful could be utilised by an unskilled operative in order to successfully identify potential areas of loss from the below ground infrastructure.

These potential 'areas of interest' (AOI) could then be recorded and passed to a skilled operator for further investigation and the confirmation of leak position carried out with the assistance of specialist acoustic equipment.

This paper presents the findings of the survey undertaken by Hydrosave in association with City of Calgary - Water Services during 1st – 5th May and 9th – 23rd June 2006.

The real losses currently being estimated from its below ground assets in Calgary are recorded as a percentage of volumetric input, this is currently estimated as being some 12 per cent of the total water into supply. No calculation of the ILI has been completed for the city as a whole but has been for smaller temporary DMA's, and these results are provided later in this paper.

Although 'percentage of volume input' is the method currently being used by City of Calgary - Water Services to measure the real losses, it is important to note that the authors do not support the use of the 'percentage of volume input' as the sole PI for real losses but rather as one of several PIs that should be used collectively

The City of Calgary - Water Services also does not agree with "percentage of water input" being the sole PI for water loss, and will be undergoing a full IWA water audit in late 2007 and 2008.

The following PIs are suggested as being more reliable PI:

- litres/service connection day or L/km/day (if service connections density is > 20);
- ILI

Survey Scope

The survey scope was to develop a robust methodology utilising an acoustic listening device based upon a leak noise value represented by a numeric reading and where possible obtain an acoustic "footprint" for the supply area. The equipment of choice chosen for this purpose was the Aqua Scope AS3 manufactured and supplied by Gutermann Limited the reason being it displays a numerical reading for the acoustic noise heard. The data captured during the process was analysed to identify the correlation between the numeric value and material type and, where possible, substantiated with recorded values taken from known leak positions. Survey times were also monitored and measured so that an approximate estimate of manpower, projected timescales and geographical coverage could be ascertained.

The survey methodology itself and subsequent data collection and assessment were aligned with the International Water Association's (IWA) & American Water Works Association (AWWA) principles and practices

Survey Team

The project survey team consisted of personnel from both Hydrosave and City of Calgary - Water Services whose skills were complementary in the significant identification of the project outcomes.

Survey Areas

The water supply network coverage within the chosen areas for the development of the methodology is approximately 120 square kilometres. These areas are sub-divided into city districts that are represented by a variety of topographic and demographic property types. Each district incorporates about 30 square kilometres of water supply network and integrates a proportionate mix of both material and fitment types. The network is generally constructed on a generic grid-based design with a singular strategic supplying main. In some instances the areas are independently fitted with localised pressure management facilities.

Four districts in total were chosen which concentrated principally upon the residential areas:

- Lake View;
- Glenmore;
- Bowness;
- Spy Hill.

The real losses for these survey areas were unknown as flow monitoring by area is currently limited, however flow data was gathered 12 months prior to the survey.

Fitments, pipe-work and service valves within these areas are mostly accessible and in some instances situated within unmade access routes sited toward the rear of properties. Above ground fire hydrants are generally positioned within the carriageway and are clearly visible with servicing valves installed controlling the fire hydrants.

Analysing the DMAs

One of the main goals of establishing a DMA is to answer the first question of water management, "Where is the water coming from?" and "Where is it going to?" Once the DMA is isolated and the flow meter(s) installed, this question can be answered. The second is answered by monitoring the incoming flow and calculating the losses.

Snapshot ILI and basic cost analysis in Bowness

With the zone closed in the following was losses was recorded

UARL = 12m^3/hour
CARL =50m^3/hour

If all leaks are located then 38m^3/hour can be saved equating to an annual loss of 332.8 ML with a dollar value of $29,880 (based on $90/ML). Based on this information, a leakage survey should be cost effective however other factors also have to be considered.

CARL/UARL = ILI
50/12 = 4.1
Bowness ILI = 4.1

Snapshot ILI & basic cost analysis in Lakeview

With the zone closed in the following was losses was recorded

UARL = 1.5m^3/hour
CARL = 10m^3/hour

If all leaks are located then 8.5m^3/hour can be saved equating to an annual loss of 74.5 ML with a dollar value of $6,700 (based on $90/ML). Based on this information, a leakage survey would not be cost effective however other factors also have to be.

CARL/UARL = ILI
10/1.5 = 6.3
Lakeview ILI = 6.6

This area was considered to small for the ILI calculation to be valid.

Based on this information it may not be worth while at this time to perform a leak survey of the area. The average cost for a repair is $8,000. If it was a single leak, it would pay for itself in a little over a year, however if the losses are coming from multiple small leaks, the cost may be prohibitive. This area has higher real losses than desired for such a small area, but the cost for multiple repairs may not be economically justified.

Equipment

The acoustic equipment utilised during the survey (Gutermann AS3) was selected by City of Calgary - Water Services and the methodology was to be developed using this brand of equipment.

Methodology - General Principle

The primary survey methodology was to incorporate the sounding of all available fitments. A secondary survey option was also identified which concentrated on the use of fire hydrants and fire hydrant controlling valves only.

Each survey option was completed under comparable circumstances by a two-man team comprising a team leader and an assistant with the data collection process defined by the following categories:

- Asset type;
- Asset number;
- Numeric reading;
- Material type;
- Geographical reference.

The primary survey option was completed by the sounding of every available fitment with the AS3. In some instances access to below ground servicing valves was partially obstructed and could only be made by the breaking and removal of the compacted debris around the proximity of the valve chamber and cover.

The secondary survey option was to concentrate on the sounding of the fire hydrant and fire hydrant controlling valve in order to determine if a correlation between the two methods could be obtained and if the survey option was successful in identifying high volume losses.

In both instances the survey equipment was configured with filters off, a volume setting of 75% of the total and held directly to the fitment surface for a minimum period of at least 20 seconds. No headphones were used and numerical values taken only, this was so no sound interpretation was taken into account from an experienced leakage engineer.

The numerical representation of generated system noise was captured from the digital indicator on the AS3 and duly recorded. In all instances the lowest numerical reading captured by the equipment was used.

Numerical Clustering

On the completion of each sub-division, the representative numerical data captured for each fitment surveyed would be overlaid onto a network schematic plan detailing asset position, size, type and distinct reference code. From this process a numerical footprint of the sub-division was obtained and an associated assessment completed. This highlighted any obvious numerical values in close proximity of the defined "intervention denominator" associated around a singular geographical point. See Fig. 1.

Prior to any further analysis, each high reading point was evaluated against an asset location. This was done as the asset may be in the location of a known noise, for example a pressure reducing valve or main incoming supply valve. See table 2.

Each AOI would initially involve the re-capture of the numerical value recorded on the fitment at least 2 hours later or the following day at a different time within the day in case the value was that of domestic draw-off. Should the numerical values be comparable with those initially captured then a more robust leak location process should be instigated with the utilisation of standard leak noise correlation processes and above ground acoustic listening techniques.

The AOIs may only then be removed from the schedule by the confirmation of leak position or quantification of the numerical value as legitimate consumption.

The overall numerical value data range captured throughout the project is presented at table 1

Primary survey – All fittings sounded	
Total numerical range	Material type

25 - 43	PVC
26 - 70	Cast Iron
27 - 60	Ductile Iron

Table 1: All Fitments Survey Results

Valve type	Valve number	Reading	Material type	Map ref No	
MV	5085	38	PVC	32	Close to incoming supply
FHV	5022	33	CI	32	
MV	5064	50	CI	32	Incoming supply
MV	5060	57	CI	32	Incoming supply
FHV	5018	37	PVC	32	Close to incoming supply
MV	2585	39	CI	32	
FH	2505	57	CI	32	Burst Service at ferrule
MV	2552	58	CI	32	Burst Service at ferrule
MV	2553	60	YDI	32	Burst Service at ferrule
MV	2564	46	YDI	32	Burst Service at ferrule
FH	2517	37	CI	32	
FHV	2517	36	CI	32	
FH	2510	40	CI	32	Close to PRV location
FHV	2510	40	CI	32	Close to PRV location
MV	2526	47	CI	32	Close to PRV Location
MV	5005	59	CI	32	PRV Chamber
MV	2567	40	CI	32	Close to PRV location
MV	2536	40	CI	32	Close to PRV Location
MV	2555	35	CI	32	
MV	2554	35	CI	32	
MV	2541	27	PVC	32	
MV	2589	28	PVC	32	

Table 2: Numeric readings and findings

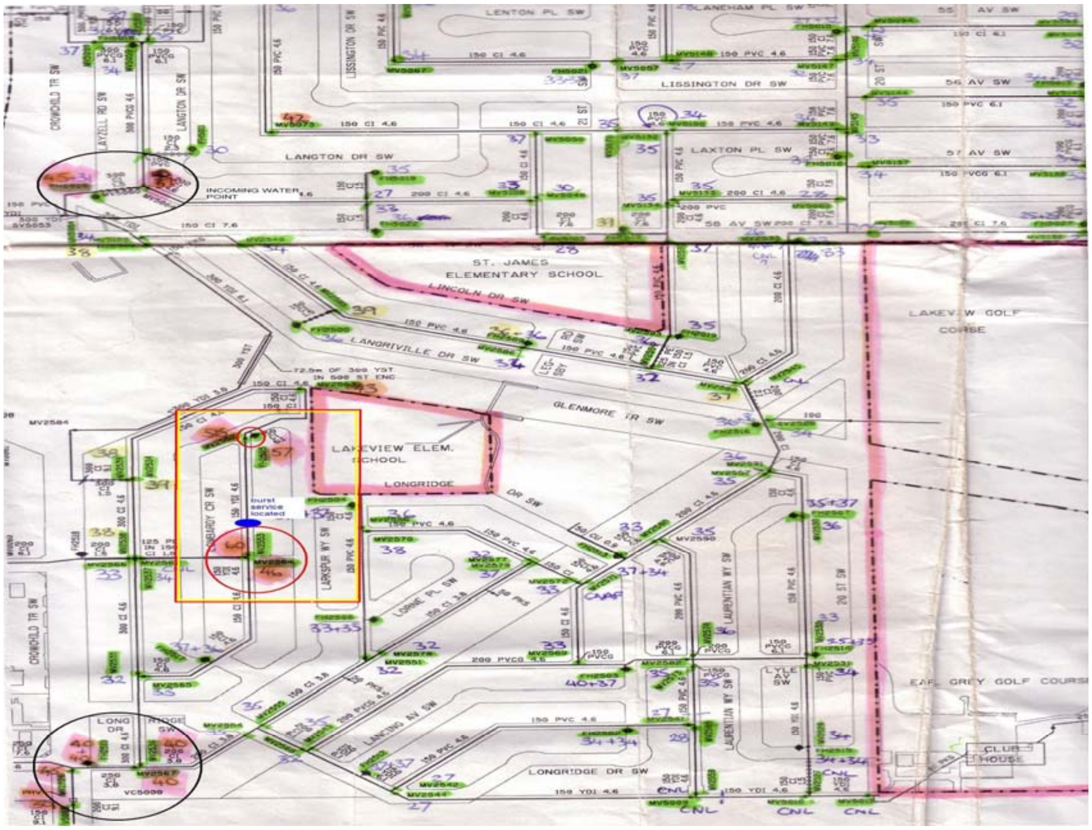


Figure 1:-Noise Clustering

Intervention Denominators

The numeric data captured was generally found to be proportional across all material and fitting types particularly where no leaks were present. In places where several leaks were located, a significant increase in the numerical value was recorded. This increase in the numerical value can not indicate the size of the leak recorded for a known type of pipe material without further assessment of data captured from known losses.

In an attempt to validate the numeric values captured and establish a leak noise threshold by material type, a simulation of a known loss was replicated from the operation of a fire hydrant and the impact of the surrounding numeric values recorded on all valve types situated in close proximity.

Firstly a simulation of a known loss was replicated from the operation of a fire hydrant and the measurement of the subsequent impact of this upon surrounding numeric values recorded on all available valve types situated within a close proximity, the results of which are presented within table 3.

Asset Type	Material Type	Distance From Source (m)	Numeric Value (1)	Numeric Value (2)	Numeric Value (3)
Sluice Valve	Cast Iron	57	34	35	39
Sluice Valve	Cast Iron	57	31	37	39
Sluice Valve	Cast Iron	51	37	36	49
Fire Hydrant	Cast Iron	0	42	78	82
Sluice Valve	Cast Iron	38	31	39	61
Sluice Valve	Cast Iron	43	35	38	69
Sluice Valve	PVC	43	36	32	38

Table 3: Numerical values obtained during test

(1) Reading captured prior to test
(2) Reading captured during test at 0.2 litres per second
(3) Reading captured during test at 1.0 litres per second

From the above it was found that the amount of induced losses had little impact on the numeric values recorded on fitments directly situated on the non metallic pipe. Only those fitments situated on the metallic pipe recorded any “uplift” in numeric activity which was found to be both distance and flow proportionate.

Below are numeric values recorded during this exercise and any singular point identified by a numeric clustering greater than 40 (after calibration of the acoustic noise propagation in this area) was initially highlighted as an AOI and duly scheduled for further investigation, the outcome of which has been summarised below in table 4.

Area Reference	Numerical Profile Range	Investigative Outcome
Bowness	40 - 59	PRV location no leaks found
Bowness	37 - 57	Incoming supply no leaks found
Bowness	46 - 60	Burst service pipe at ferrule connection
Glenmore	56 & 69 & 70	3no leaking service valves found

Table 4: Area of interest summary

Completion of the investigative outcomes identified a number of leaks, the predominant being from a numeric clustering of between 46-60 over a 200m distance. These leaks arose from a combined failure of a copper service pipe and associated ferrule connection situated at a cast iron main. Following excavation and visual confirmation prior to repair, the loss was estimated at some 3 litres per second.

The remaining leaks identified were found to be general losses from service valves, predominantly due to the erosion of packing material from around the operating gland or the general corrosion to the body and bolt sets.

It should be noted that the area of interest for service valve leaks were generated by a singular numeric valve of between 56 –70, dissipation of the numeric value to the surrounding fitments was extremely low with little or no clustering. It is assumed that service valve leak types may only be highlighted by a singular point of interest only.

Unfortunately the impact on the numeric values obtained from the confirmed leak position did not incorporate a proportional or representative amount of plastic pipe material within the immediate peripheral vicinity. Therefore additional information should be obtained before a definite conclusion can be drawn.

In considering the relationship between numerical value and material type it is suggested that the following intervention denominators at table 5 be considered.

Pipe Material	Numeric Intervention Denominator Value
PVC	40
Cast Iron	45
Ductile Iron	45

Table 5: Numerical intervention denominators

Survey Cycle

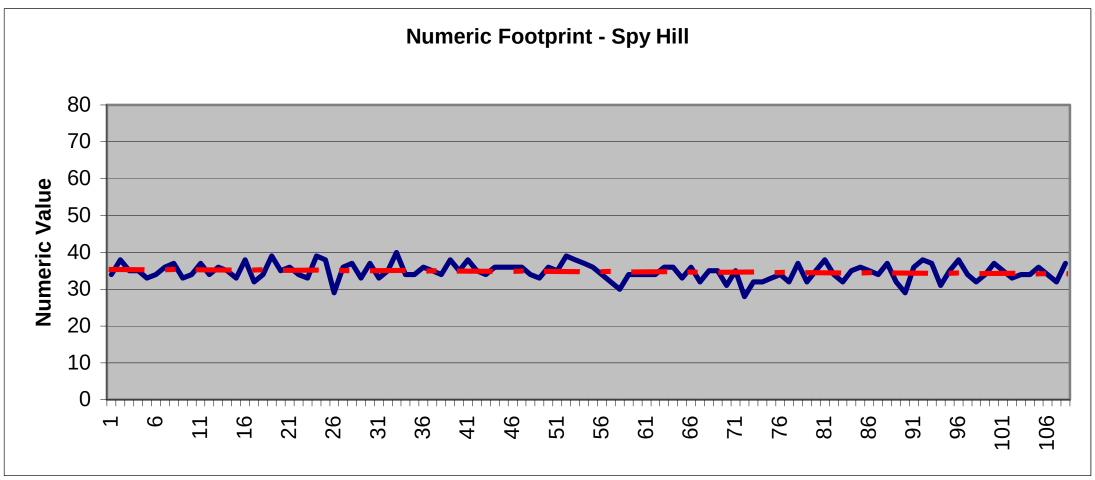
The survey cycle was completed in accordance with the two methodologies outlined in the section above. As previously mentioned, the survey areas comprised a variety of topographical, social and economic property types thus allowing a realistic productivity ratio to be ascertained. From the data obtained it can be reasonably concluded that: -

- In carrying out an all fitment survey, an average timescale between fitments of 5.51 minutes can be expected;
- In carrying out a fire hydrant & controlling valve survey only an average timescale between fitments of 5.0 minutes can be expected.
- Average daily distance listening on all fittings was 5.8km/ day
- Average daily distance listening on fire hydrants only was 14.2km/day
- It must be noted that coverage of mains length listening on fire hydrants only was 230% greater than doing that of all fittings.

(Timescales may vary dependent upon local climatic conditions)

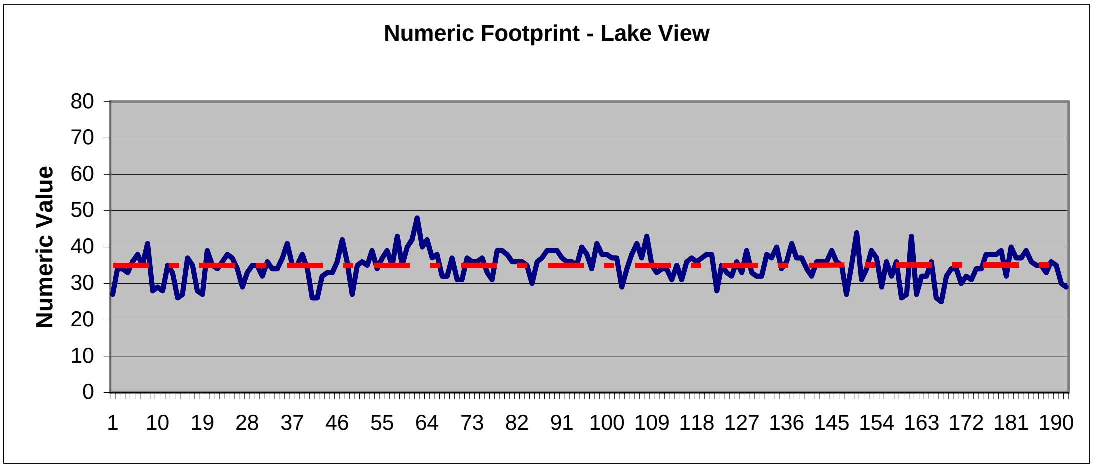
Numeric Footprints

In analysing the numeric data sets recorded during the survey it is possible to build a graphical representation of each district meter area. Each representation may then be considered as a numeric footprint of the water supply characteristics and utilised as a reference point when carrying out any future survey, especially if any significant time period has elapsed.

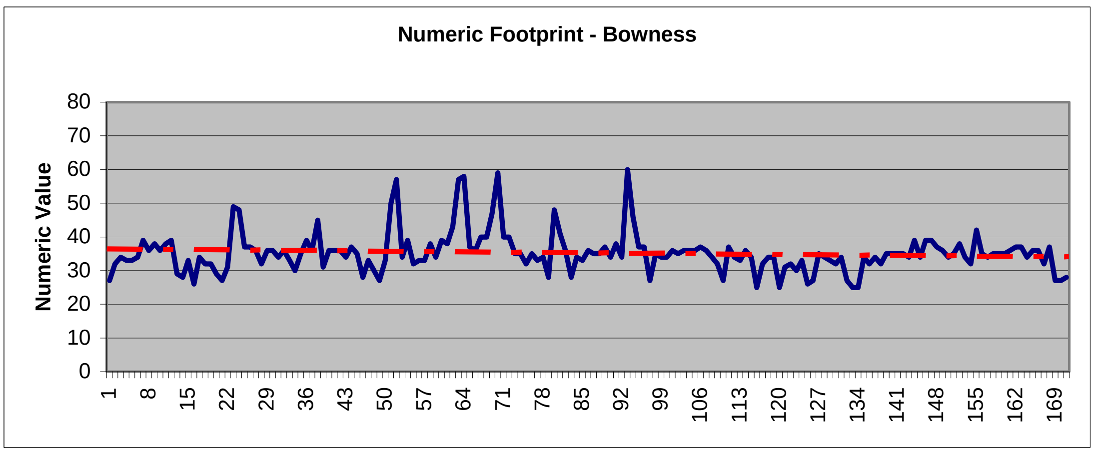


Gr

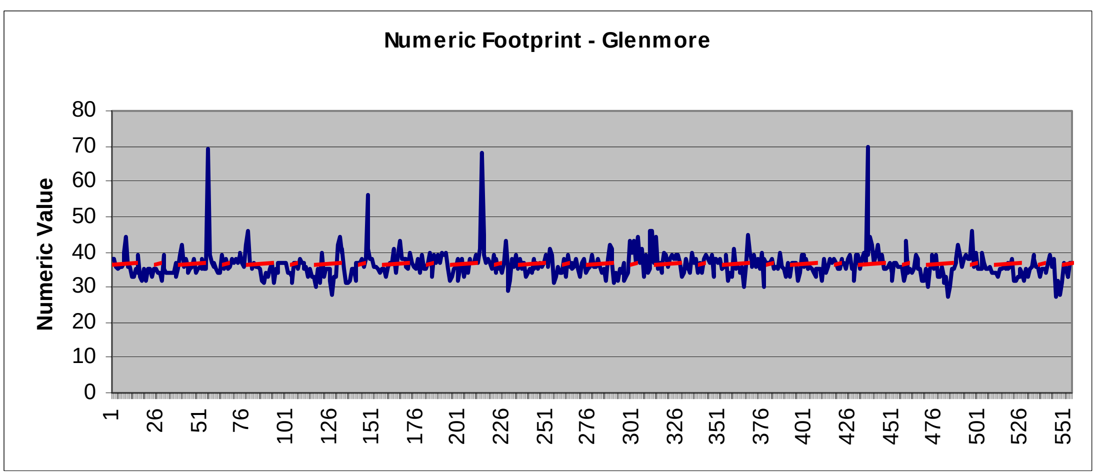
Graph 1: Numeric footprint – Spy Hill



Graph 2: Numeric footprint – Lake View

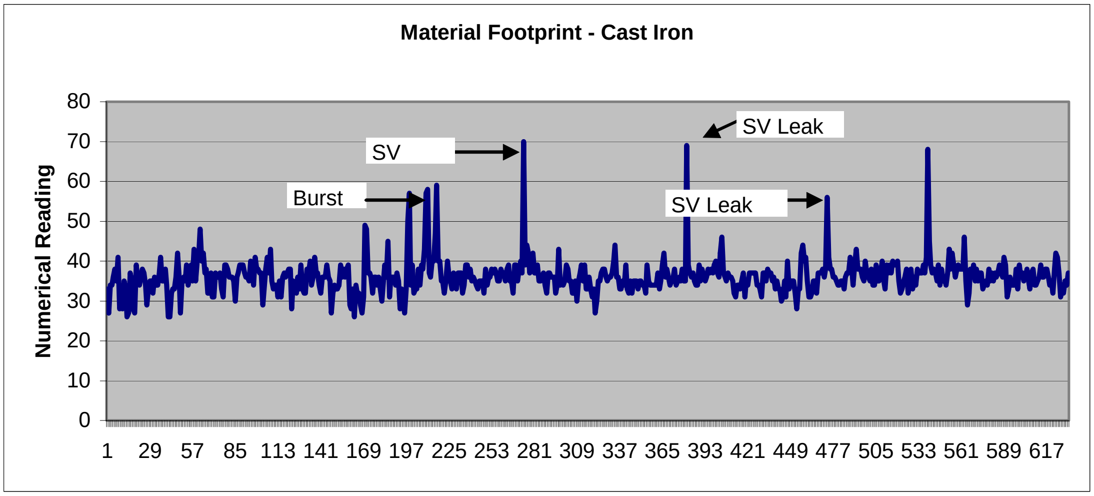


Graph 3: Numeric footprint – Bowness

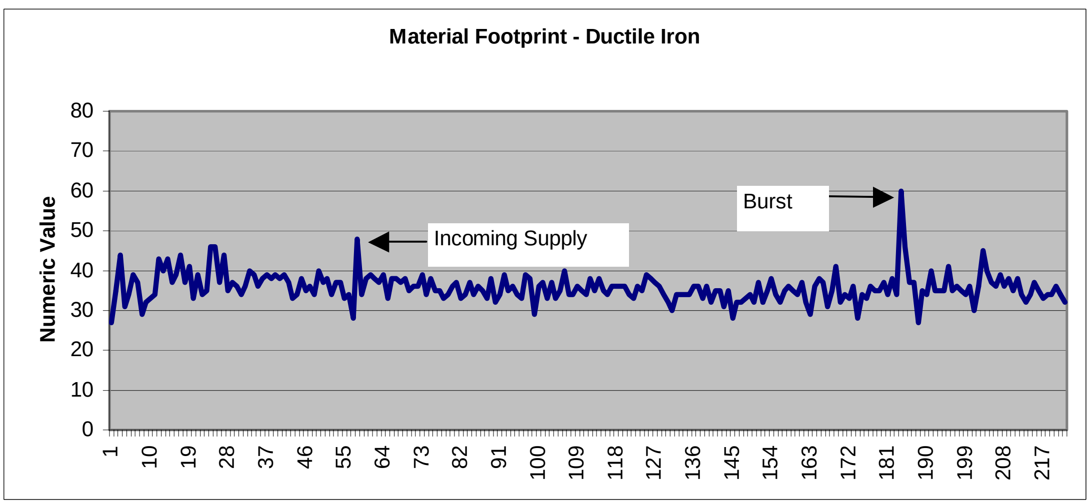


Graph 4: Numeric footprint – Glenmore

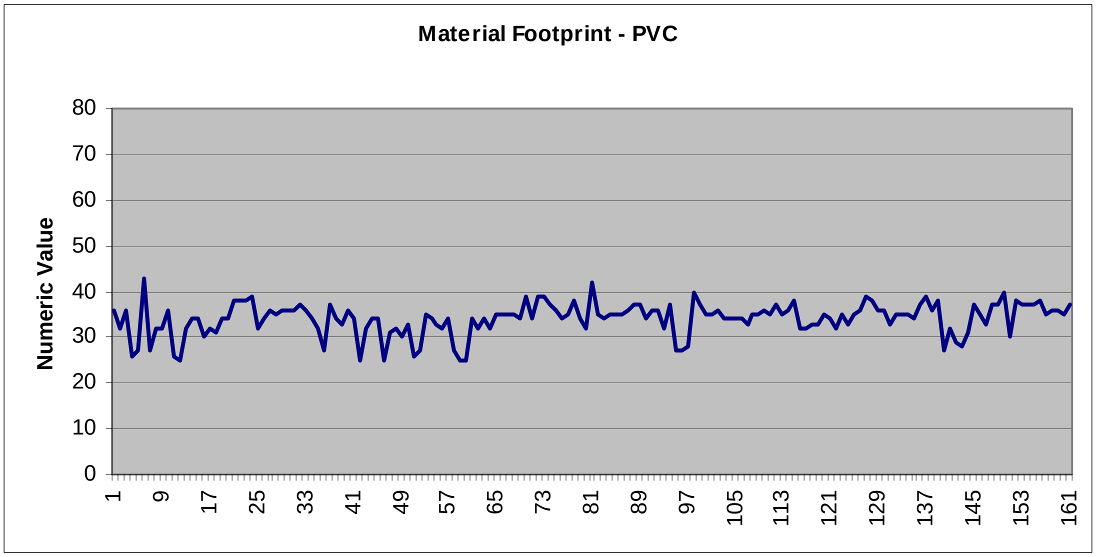
On the whole it was found that the footprint for most supply mains situated within the survey areas and constructed of a metallic composite such as Cast or Ductile Iron recorded a comparable numeric value. This was the case for both normal operating circumstances and where a leak noise was generated. However the footprint obtained for non-metallic composites such as PVC was recorded at a consistently lower numeric value; this can be anticipated due to the inherent low dispersal of sound through non-metallic composites.



Graph 5: Numeric footprint – Cast Iron



Graph 6: Numeric footprint – Ductile Iron



Graph 7: Numeric footprint – Non Metallic

Conclusions

From the data sets obtained from completing the survey, the following conclusions have been made:

- There is a correlation between a numeric value, size of water leak and the pressure within the area.

- A calibration exercise should be carried out in each area to establish the acoustic noise transmittal properties and the intervention number.

- The propagation of sound values (using the AS3) on the non-metallic material mains and infrastructure appear to be much less to that of metallic mains. Therefore without the addition of supplementary data sets taken from confirmed leak types on this material type, the methodology established cannot be substantially supported.

- Although the secondary survey option may be useful in identifying a catastrophic failure within a survey cycle, the primary survey option to incorporate all fitments is suggested as perhaps a more robust method for inclusion into a routine pro-active control plan.

- Above ground fire hydrants were found to be generally susceptible to additional ambient and surrounding noise levels.

- Fire hydrants, where water is replaced by air, gave a lower numeric value as the noise transfer was reliant totally on the wall material of the main. It is therefore considered that noise transferral is greatly enhanced when a main is pressurised with water and that sounding should only be carried out on fittings that are connected to a pressurised main.

- Variation in local climatic conditions could in some instances impact on the numeric recordings obtained. In the case of high background noise, a numeric reading offset should be applied to compensate for the “uplift” in ambient conditions around the equipment.

- When carrying out an all fitments survey option, an average timescale between fitments of 5.51 minutes per fitting for each two-man team may be anticipated under average conditions.

- When carrying out a fire hydrant only survey option, an average timescale between fitments of 5.0 minutes per fitting for each two-man team may be anticipated under average conditions.

- Average daily distance listening on all fittings was 5.8km/day

- Average daily distance listening on fire hydrants only was 14.2km/day

- This technique has proved successful and more investigation is required to obtain a generic footprint for non metallic pipe-work. This shows that some form of ALC can be performed with success from an unskilled operator with minimum training

References

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