Guidelines

for Reducing Water Losses in South African Municipalities

WATER RESEARCH COMMISSION

TT 595/14

GUIDELINES FOR REDUCING WATER LOSSES IN SOUTH AFRICAN MUNICIPALITIES

Report to the

Water Research Commission

by

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FOREWORD

It gives me great pleasure to introduce this report or guide, since it encapsulates more than 20 years of knowledge and experience gained in the application and implementation of water loss control and management by a team and individuals, Dr Ronnie Mckenzie and WRP Pty Ltd, whom I regard and are regarded as world leaders on the subject. The appreciating aspect is that I have been part of this journey from its humble beginning, nurturing and pushing the boundaries of innovation and research.

Thus, it is satisfying to say that this report is unique and different in many ways since it is not purely technical and engineering orientated, but presents the subject from an experiential basis. It has very few formulas and calculations, and was designed and written to capture those lessons and experiences which very rarely get recorded and captured.

The report consolidates many innovative research tools, products and studies which have been generated over the years at the WRC and elsewhere in response to the challenges associated with water loss management, as well as the a number of projects and implementation of water loss management in South Africa. Over this period there have been a number of world firsts which have been achieved in this subject field, to name a few:

- The South African water sector was amongst the first countries in the world to adopt the BABE processes and the IWA standard water balance.
- South Africa was the first to introduce advanced pressure control on a large-scale installation supplying almost 500 000 residents from a single installation.

I am hoping that this report will stimulate and empower both the young and new, experience and knowledgeable. It has been an absolute privilege to have been part of the development of this report and also wish to acknowledge the guidance and inputs of Speedy Moodliar and Simon Scruton from eThekweni Metro, Micheal Singh and Paul Herbst from DWA, Darryl Cassel and Trevor Westman from Tshwane Metro, Keith Baily of Kent Meters, Dave Still, Johan Vorster of Ekurhuleni Metro. My thanks to Dr Ronnie Mckenzie for all the inspiration, innovation and sound knowledge over the years and the sweat put into writing this document.

JN Bhagwan (Jay)

Executive Manager - Water Use and Waste Management
Water Research Commission

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ADD	**Average Daily Demand**
ALC	**Active Leakage Control**
AZP	**Average Zone Pressure**
BABE	**Burst And Background Estimate**
CARL	**Current Annual Real Losses**
CBD	**Central Business District**
DWA	**Department of Water Affairs**
EMM	**Ekurhuleni Metropolitan Municipality**
GPR	**Ground Penetrating Radar**
GPRS	**General Packet Radio Services**
GPS	**Global Positioning System**
GSM	**Groupe Spécial Mobile (Global System for Mobile Communications)**
IBNET	**The International Benchmarking Network for Water & Sanitation Utilities**
ILI	**Infrastructure Leakage Index**
IWA	**International Water Association**
MNF	**Minimum Night Flow**
NRW	**Non-Revenue Water**
PI	**Performance Indicator**
PLC	**Passive Leakage Control**
PPP	**Public Private Partnership**
PRV	**Pressure Reducing Valve**
SMS	**Short Message Service**
UARL	**Unavoidable Annual Real Losses**
uPVC	**Unplasticised Poly Vinyl Chloride**
WC	**Water Conservation**
WDM	**Water Demand Management**
WRC	**Water Research Commission**

1 INTRODUCTION

1.1 Purpose of this book

There are many excellent books and publications on the subject of reducing water losses from municipal water distribution systems. This book does not attempt to replicate or replace any of these previous publications but concentrates on highlighting the key issues in simple and straightforward terms in an attempt to explain what interventions can be undertaken in order to reduce water losses from municipal water supply networks and how best to implement them. The book is based on the extensive practical experience of the authors derived from the implementation of various water demand management (WDM) interventions in over 20 countries.

Saving water and WDM in general is often quite confusing to a municipality wishing to embark on some form of water loss reduction activities. It can be similar to a driver facing the “Magic Roundabout” for the first time – an unusual traffic feature located in the UK (**Figure 1)**. The new driver entering the 5-sided roundabout normally knows where he is and where he wants to get to but the path to his destination is often not clear and can be very confusing.

Figure 1: The "Magic Roundabout"

A municipality considering whether or not to tackle water losses may find it useful to think carefully about the famous quote by Henry Ford (**Figure 2**) which is often quoted by Mr Tim Waldron, Chair of IWA Water Losses Specialist Group when he makes his motivational talks on WDM and water loss reduction.

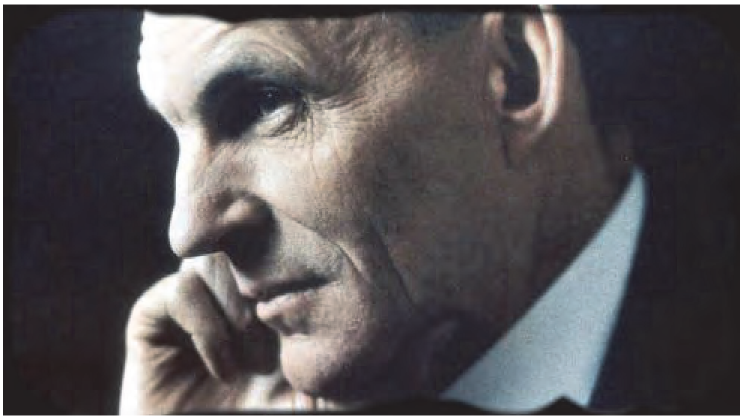
"Whether you think you can or you can't – you are usually right" **Henry Ford**	

Figure 2: Famous quote by Henry Ford

The remainder of this book will try to assist municipalities in understanding how they can reduce water losses from municipal reticulation systems. It is not "Rocket Science" by any means and the results will take time to achieve. Immediate savings cannot be expected and municipalities should rather plan for a 5-year or preferably 10-year programme. The savings will be difficult to achieve, and possibly more difficult to sustain, but one thing is certain **- if no action is taken to reduce water losses, the losses will continue to increase.**

1.2 Water loss reduction interventions

There is no single WDM intervention that will always provide the best savings at the least cost. Every water-supply system is unique in some way and will have its own specific problems that set it apart from other systems. In reality, reducing water losses from municipal water distribution systems is not complicated, but does require a dedicated and methodical approach if real and sustainable savings are to be achieved. It is often similar to detective work where the first step in the process is to identify and understand the problem before trying to solve it. Too often, water loss reduction interventions are introduced which are inappropriate to the problems experienced in the reticulation system. The interventions must be selected to address the most serious problems experienced in a specific area to have any chance of success.

There are a great many different interventions that can help to reduce water losses from municipal reticulation systems as can be seen in **Figure 3**.

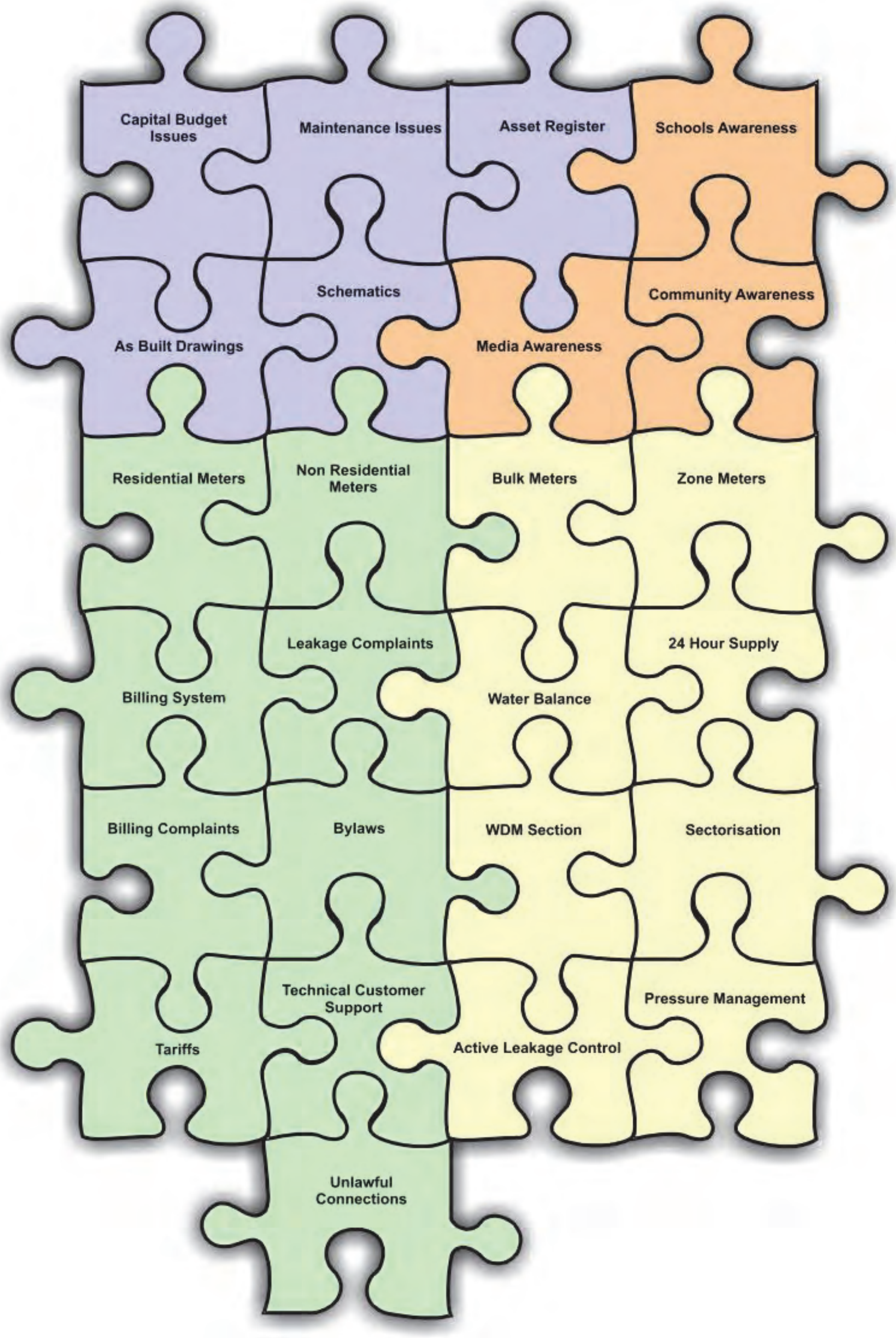


Figure 3: Some possible WDM Interventions and issues

The key issue is to decide which interventions are the most appropriate to a specific area and how best to implement them. The most common mistake made by many municipalities throughout the world is to believe that water loss reduction is achieved through only leak detection and repair. In such cases, large budgets are often used to search for unreported leaks using the latest hi-tech and expensive equipment. If the water losses are due to inaccurate metering or even background leakage, the leak detection activities will yield little or no results. Before embarking on any major water loss reduction intervention it is therefore necessary to spend some time and effort to examine the problems and try to identify the root causes of the water losses. Once the real problem issues have been identified, the solutions are often obvious and the way forward becomes clear.

In the remainder of this book, the following key water loss reduction issues are discussed which are listed in no specific order:

- System schematics
- Leak location and repair
- Pressure management
- Sectorising
- Logging and analysis of minimum night flows
- Bulk management meters
- Bulk consumer meters
- Domestic metering and billing
- Pipe replacement and repair
- Water balance
- Community awareness and education

2 GETTING THE BASICS IN PLACE

2.1 Addressing the obvious

Many municipalities struggle to appreciate the necessity and benefits of dealing with water losses in their reticulation systems. Council officials will often debate at length over a budget allocation of a few thousand Rand when a road leak will run unattended for weeks if not months which can easily run up a bill of hundreds of thousands of Rand. Based on the existing situation in many municipalities, there are a few key issues regarding water loss reduction that need no explanation or detailed analyses which are basically nothing more than common sense. Unfortunately they require a budget and real effort from the municipality often involving excavation of pipelines and repair where necessary. Until these basic issues have been addressed, there is relatively little benefit to be gained by introducing some of the more expensive and sophisticated measures, such as pre-paid metering and automatic meter reading, for example.

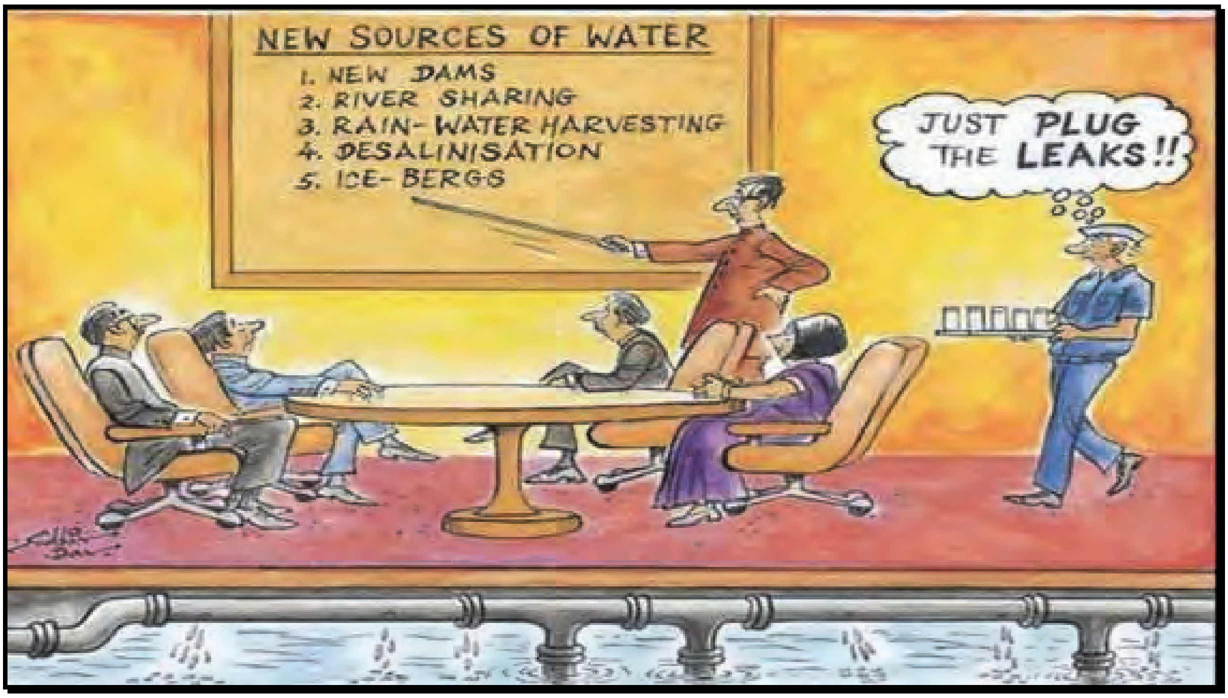


Figure 4: Fix the obvious! (Courtesy World Bank: Water and Sanitation Sector)

The key basic issues should be addressed before any municipality considers implementing any of the more sophisticated and expensive interventions. Addressing the basics correctly will always be cost-effective and should be considered as a pre-requisite for future water loss reduction interventions.

2.2 Network schematics

Before any work can be considered in a water-supply network it is important to understand the basic layout of the network. Some water utilities and municipalities have already developed comprehensive CAD drawings which show every pipe and valve in the system which are very useful, however, they are normally too complicated and detailed for the purpose of gaining a basic understanding of how the system operates.

In order to understand how a particular system operates, it is recommended that one of the first tasks undertaken is to develop a high level system schematic. Such a schematic is shown in **Figure 5** for the water supply to a small town. As can be seen, the schematic is not drawn to scale and is designed specifically to show the key components in the system including master meters, reservoirs, purification plants etc.

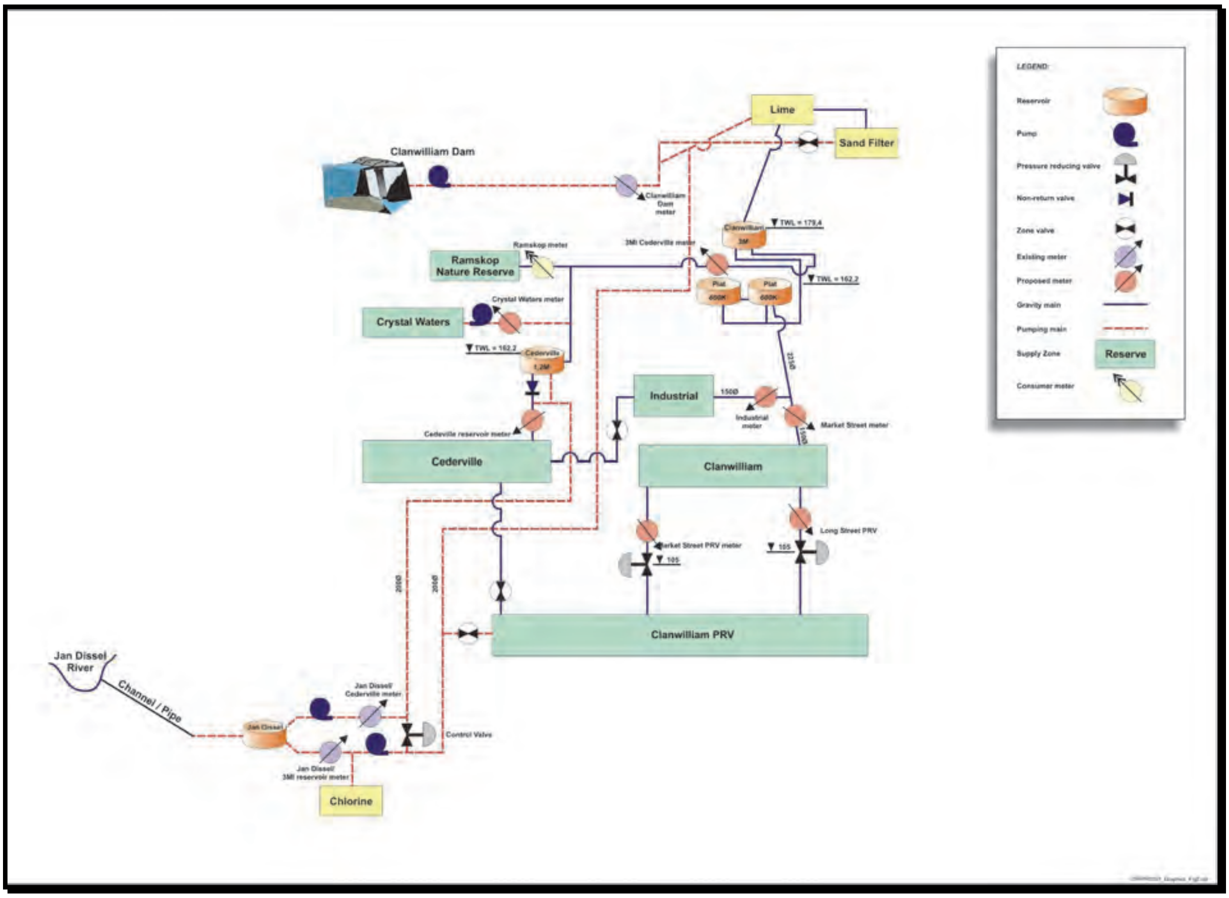


Figure 5: Typical high level system schematic

The schematic in **Figure 5** is a relatively simple system and in the case of larger towns, the schematic may become more complicated as shown in **Figure 6.** In some cases, it may be necessary to split the schematic into various components in which case, there can be a high level schematic together with several more detailed schematics.

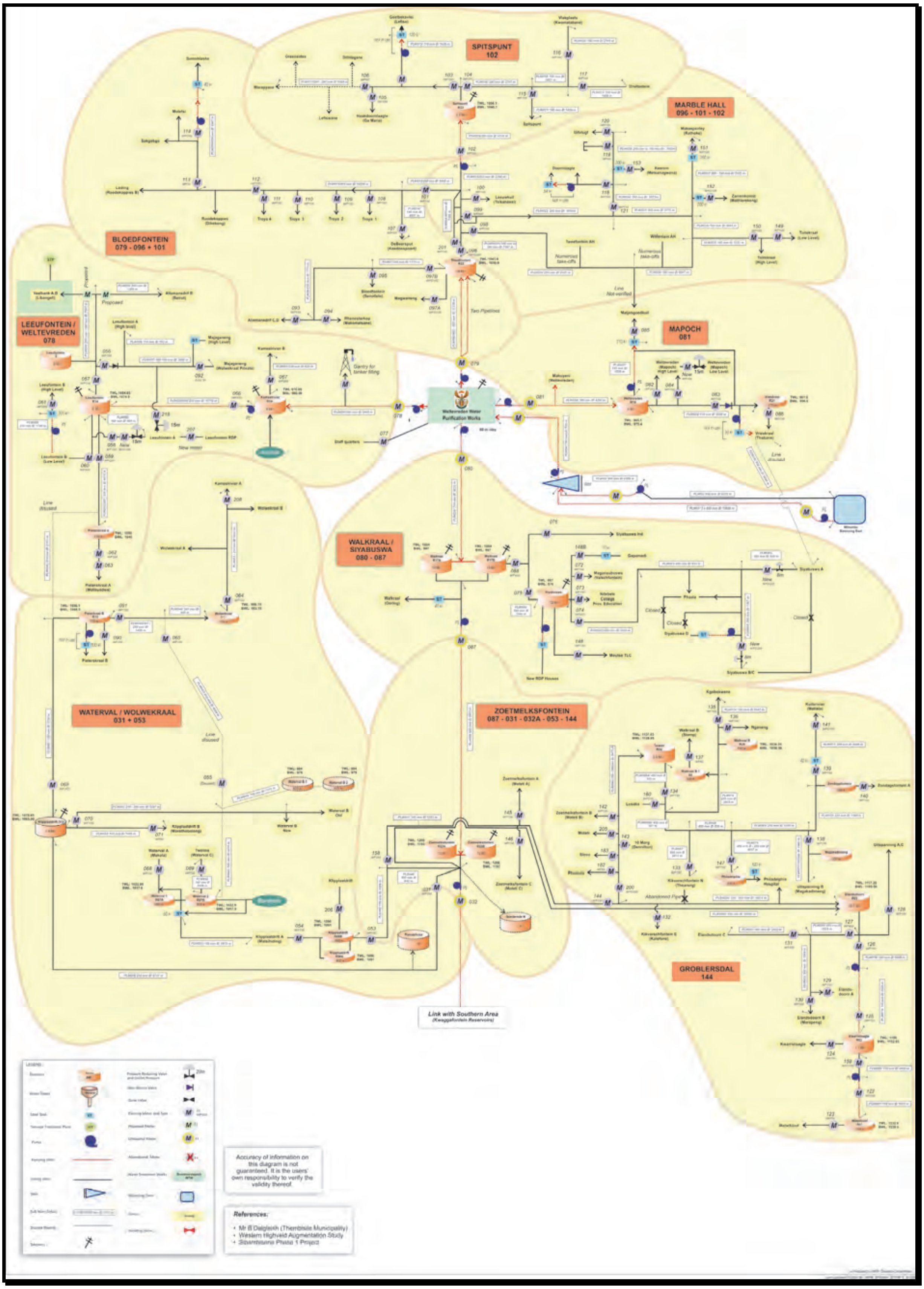


Figure 6: A more complicated high level schematic

2.3 Leak location and repair

Identifying and repairing leaks is often what most people think of when addressing water losses. While in some areas it can be very important, in other areas it is not the main problem. Throwing big budgets at leak location and repair may be futile if the underlying problem is high water pressure or a network which is no longer viable. It is, however, a very useful intervention for municipalities spending big budgets very quickly and those offering the leak detection equipment and services like this to be the first and often only water loss reduction activity undertaken by the municipalities.

Repairing visible and reported leaks (preferably within 24 hours of being reported) is without doubt one of the most obvious and basic interventions that should be implemented as a top priority. The repair of such leaks needs no financial justification or preliminary assessment to determine if it is worthwhile. It is the most obvious and cost-effective measure that any municipality can undertake and will always be worthwhile. No municipality can expect its customers to save water and pay for services if the municipality allows visible leaks to run for weeks or months without being repaired. Repairing visible leaks is the most basic and obvious water loss reduction intervention that can be implemented.

Spending time and effort searching for unreported leaks (those below the ground that are not visible) with some form of leak detection equipment is referred to as active leakage control (ALC). This may or may not be cost effective depending upon the level of leakage in a specific area. If an area is known to have high leakage (the area will have high minimum night flow) and the network is known to be in a poor condition, it may be worthwhile and cost effective to send in a team of leak locators to identify unreported leaks. It must always be noted that all visible leaks should be repaired before any leak location activities are undertaken to search for new and unreported leaks. It should also be noted that the equipment used to identify the unreported leaks need not be the most expensive or most sophisticated. In most cases, a well-trained experienced leak detector with a basic listening rod will often find more leaks than a poorly-trained leak locator with the most expensive equipment. **Figure 7** shows some leak location equipment in action.

Figure 7: Leak location using sounding equipment

2.4 Pressure management

Pressure management is one of the most important WDM interventions that should be considered when attempting to drive down water losses. Leakage is driven by pressure and, while it must be acknowledged that pressure management is not the answer in every case, it is often one of the most cost-effective measures to reduce leakage and wastage that can be considered. Many municipal water-supply systems in South Africa are operated at unusually high pressures and, as a result, pressure management is often one of the most important WDM interventions that can be implemented.

Pressure management can take many forms ranging from the basic fixed outlet pressure control to some form of more sophisticated hydraulic or electronic control which is often referred to as “smart control” or “advanced pressure control”.

South Africa was one of the first countries in the world to adopt the principles of advanced pressure control initially developed in the UK for the UK water industry back in the early

1990s. The techniques used in the UK were first presented in South Africa in 1997 and following a series of small pilot projects, the full-scale Johannesburg Pressure Management Project was completed in 1999 involving the design and commissioning of almost 50 advanced pressure control installations. Around the same time, both Cape Town and Drakenstein municipality recognised the benefits of pressure management and introduced measures to lower pressures in their water supply systems. Cape Town currently boasts the lowest level of non-revenue water (around 20%) for any Metro in the country while Drakenstein now has one of the lowest levels of non-revenue water for any municipality in the country (around 11%). Pressure management is a key component of the water demand management interventions that have been implemented in both cases.

Following the success of the Johannesburg project, one of the most ambitious pressure management projects undertaken anywhere in the world was designed and commissioned in 2001 in Khayelitsha for the City of Cape Town (see **Section 12.4.1** for details). At the time, this was the largest installation of its type in the world and was the forerunner to the even larger installation located in Emfuleni Local Municipality – both of which have received national and international recognition.

The most recent large-scale advanced pressure management installation in South Africa was commissioned in Mitchells Plain for the City of Cape Town in November 2008 and was the 3rd large-scale pressure management installation of its type to be constructed in South Africa (Meyer, Wright & Engelbrecht, 2009). Each of these three installations controls the supply of water to approximately 500 000 residents from a single supply. It is interesting to note that South Africa is one of the few countries in the world where such installations are viable due to the nature of the water-supply systems and the relatively high service levels.

Water-supply systems worldwide are generally designed to provide water to consumers at some agreed level of service, which is often defined as a minimum level of pressure at the critical point which is the point of lowest pressure in the system. In addition, there may be certain fire-flow requirements which can override the normal consumer requirements. The systems are designed to accommodate these pressure and flow requirements during the period of peak demand which would normally occur at some specific time of the day and during a particular month in the year. In other words, the systems are designed to provide the appropriate supply volumes and pressure during a very short period in the year and for the remainder of the time the systems tend to operate at pressures significantly higher than required. Even within the same system, there will be areas of high pressure due to topography and/or distance from the supply point with the result that many parts of a supply area will operate at pressures significantly higher than required in order to ensure that there is sufficient pressure at the one critical point.

Managing water pressures in a supply area is not a simple issue, and there are a great many items to consider. The common factor in every system is the fact that leakage is driven by pressure and, if the pressure is increased, the leakage will also increase.

In order to reduce leakage through pressure management it is necessary to reduce the water pressure without compromising the level of service with regard to the consumers and fire-fighting. As mentioned previously, most systems are designed to provide a certain minimum level of service in the system during the peak demand period as shown in **Figure 8**. If the water pressure in a system can be reduced, even, for a short period during times of low demand, the water leakage from the system will be reduced. In this example it is assumed that a minimum pressure of 20m is required.

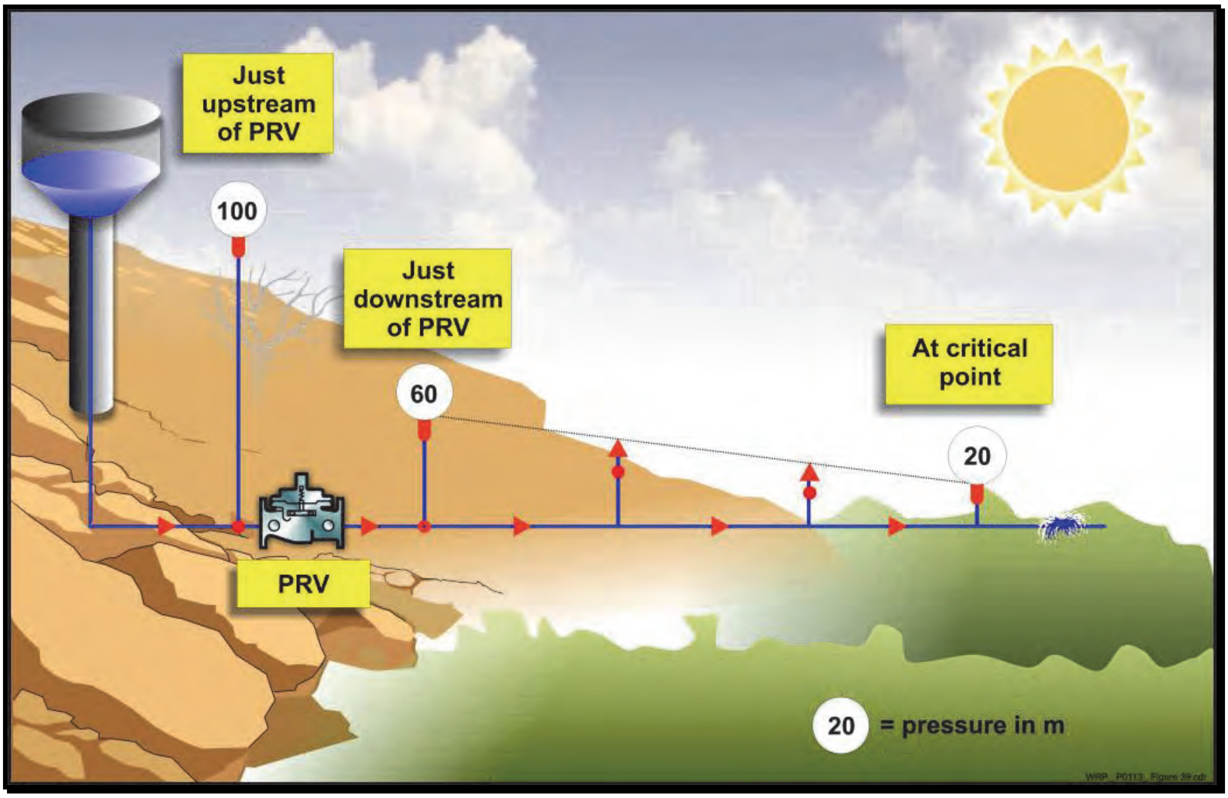


Figure 8: Typical pressure during peak demand periods

During the off-peak periods, which tend to much greater than the peak periods, the system operates at a water pressure which is significantly higher than necessary as shown in **Figure 9.** In effect, there are long periods when there is significant scope for pressure reduction and this is the basis on which the pressure management interventions are designed.

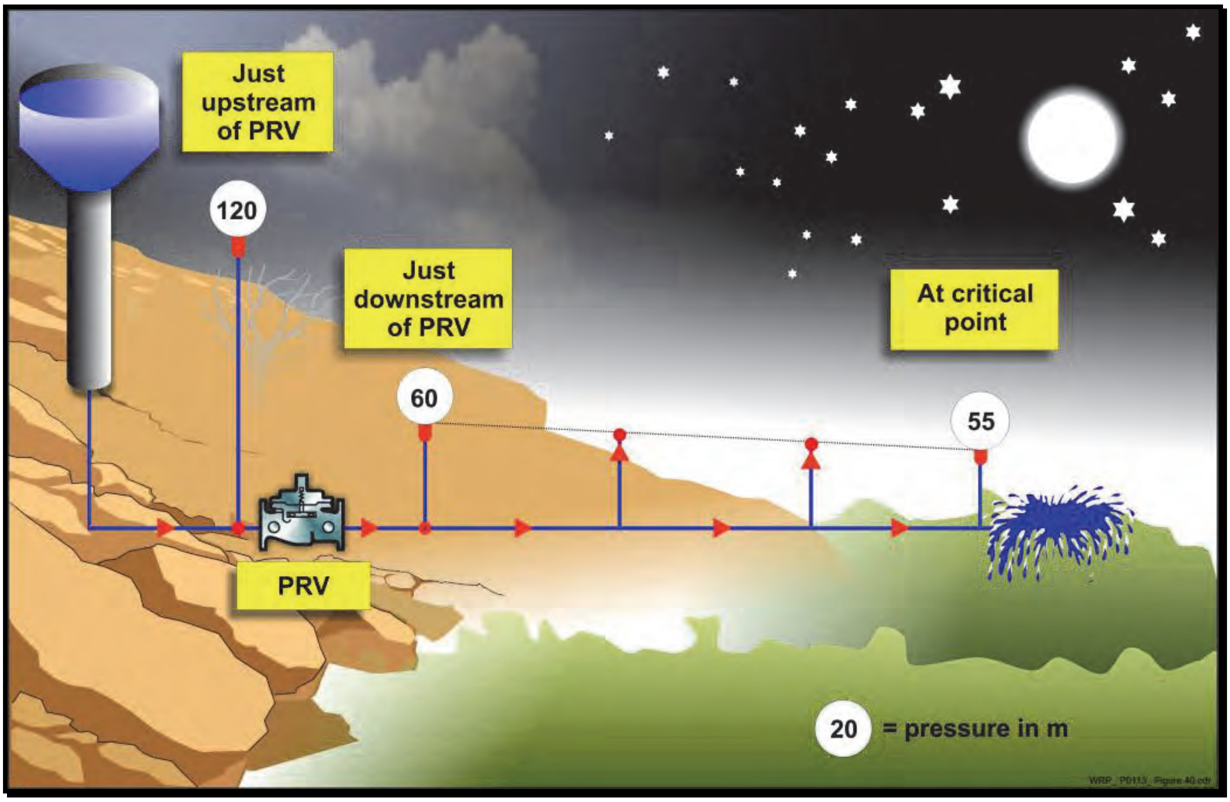


Figure 9: Typical pressure during off-peak periods

Reducing the water pressure in a system can be achieved in many ways ranging from simple fixed outlet control valves to a variety of electronic or hydraulic controllers. Over the past 15 years, many new control devices have been developed, each of which offers greater sophistication and intelligence than previous devices. Smart controllers have become even smarter, with several of the latest devices incorporating artificial intelligence and feedback loops.

Without detracting from the latest advances in pressure management, it is critically important for water-supply managers not to lose focus of the real problem issues as no piece of equipment, hydraulic or electronic, can replace the need for a properly designed, well managed and well maintained network. Ensuring that boundary valves are closed or open on a regular basis as per the network design is of greater importance than any pressure controller, which in any event will not operate properly when a pressure management zone has been compromised by unauthorised opening or closing of boundary valves.

South Africa is one of the most progressive countries in the world with regard to the use and implementation of many forms of advanced pressure control. Since the first large-scale project was implemented by the City of Johannesburg in 1998, many other cities throughout the country have found out for themselves the benefits that can be achieved through some form of pressure management. It is important to realise that it is not always necessary or appropriate to use the most sophisticated or expensive electronic or hydraulic controllers and the “appropriate technology” to suit a specific situation may often result in the use of the most basic (and robust) equipment. The selection of the most appropriate form of pressure control will ultimately be based on many factors including, cost, technical expertise within the water utility, technical backup for the equipment, topography, leakage levels as well as main source of leakage. It is therefore important for the water-supply manager to carefully select the most appropriate pressure management equipment for each zone to provide a sustainable and effective solution.

Pressure management can produce huge savings, but the key to success rests not with the valves or the associated high-tech “add-ons” but rather with sorting out the pressure zones and making sure that they remain discreet. Most of the savings achieved through pressure management originate from the basic fixed outlet pressure reducing valve and the additional benefits to be achieved from some form of advanced control are often exaggerated. The most serious problem facing municipalities in South Africa is ensuring that the pressure zones are operating properly and have not been compromised through an unauthorised opening or closing of valves. Unfortunately sorting out the zones is often tedious and thankless work which attracts little attention and is rarely the sort of material that makes a good conference paper. It is, however, the key to any successful pressure management installation.

It must always be remembered that pressure management does not eliminate leaks or repair any existing leaks. All leaks in the network before the introduction of pressure management remain as leaks after the pressure management installation has been commissioned. The benefits of pressure management are mainly through the fact that the leaks will run at a lower rate at any time where pressure has been lowered as can be seen in **Figure 10** and **Figure 11**.

Figure 10: Underground leak running at low pressure (Ken Brothers)

Figure 11: Underground leak running at high pressure (Ken Brothers)

In addition, the lower pressure regime will lower the rate at which new leaks develop and in many cases the incidence of new bursts can be reduced significantly – sometimes 90% or even more. The financial benefits of the reduction in new bursts and prolonging the life of the reticulation system are rarely included in the financial analyses despite the fact that they dominate the financial viability of most pressure management projects.Pressure management will usually provide very attractive pay-back on the initial investment.

Further details of the different forms of advanced pressure control are discussed in **Section 12 (Appendix I).**

2.5 Sectorising

Sectorising is simply the process of cutting a big area into smaller more manageable areas which allows the water manager to identify problem areas. The process of sectorising is well known as a critical element of any water loss reduction programme. The International Water Association's (IWA's) recommendations on a maximum zone size of approximately 2 000 connections has been embraced throughout the world to the extent that this is often considered a pre-requisite to any other WDM intervention. Unfortunately while it is recognised that sectorising is very important, it is equally important to recognise that sectorising is only a means to an end and not the end itself. What is often overlooked when considering the sectorising of a large system is the fact that every new sector created must be maintained indefinitely if it is to remain effective. The costs and effort required to maintain new zones is often neglected. These costs are rarely added to the operational budgets of the municipality with the result that any zones created tend to be breached soon after establishment. The lack of commitment to the maintenance of zones is one of the most common and serious issues facing many water utilities. It is therefore often better to concentrate on a smaller number of larger zones that can be properly maintained rather than too many small zones that are not maintained.

It should also be noted that in areas where small zones have not been established, it is still possible to use the concept of sectorising to identify problem areas, albeit on a temporary basis usually referred to as step testing (see **Section 9.4 in Appendix F**). Through the use of step-testing it is possible to identify the key problem areas despite the fact that there may be few if any permanent zones. Step-testing is the process of closing internal boundary valves in order to isolate or cut-off portions of the network. By simultaneously monitoring the nightflow during the sectorising process, small zones of high leakage can be identified. This is not a new concept by any means, but appears to be largely neglected by many water utility managers who have forgotten that this is one of the most useful tools for identifying and reducing water losses from reticulation systems.

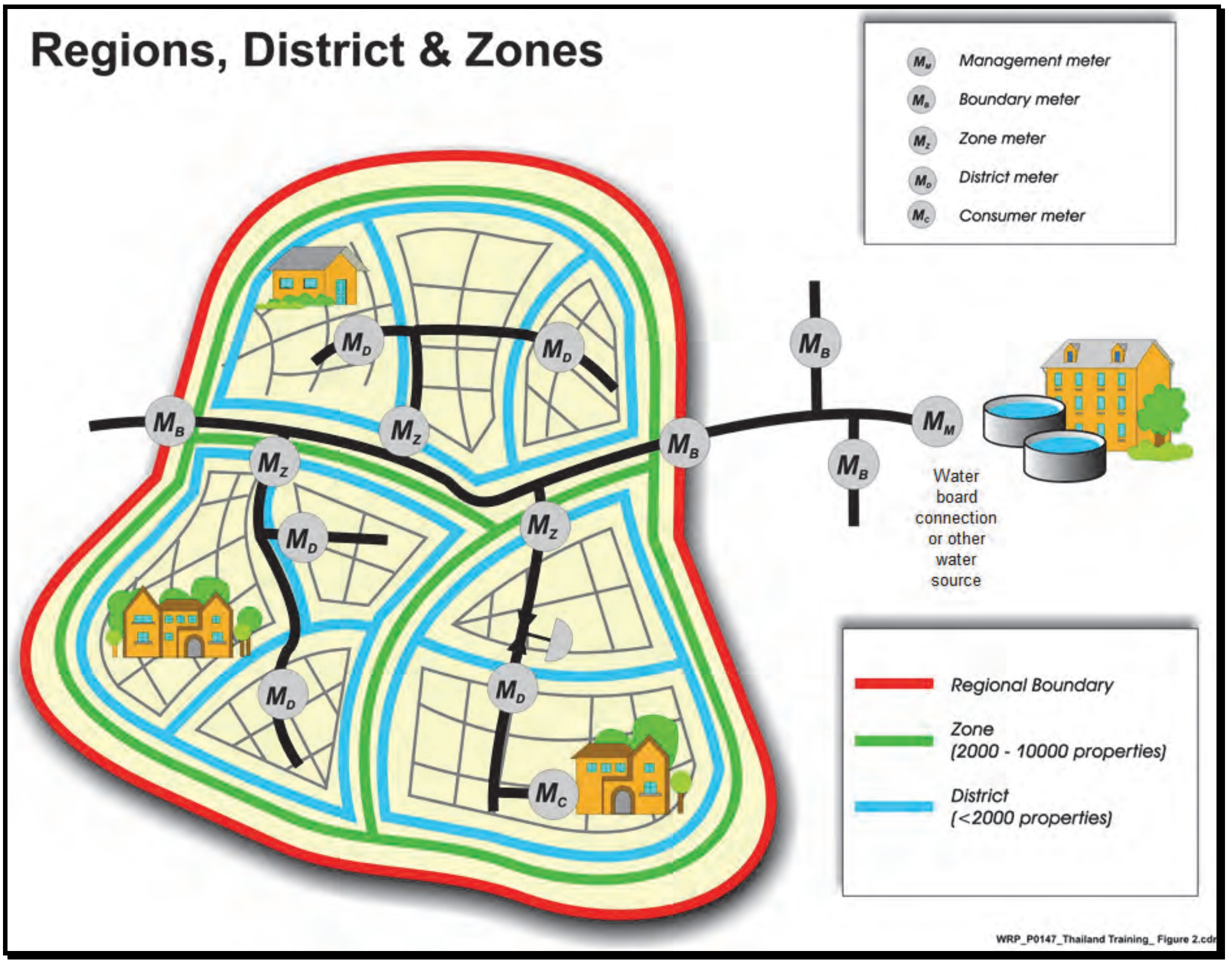


Figure 12: The concept of sectorising

Splitting a large area into smaller zones will not reduce water losses at all. It will simply enable the water losses in each zone to be monitored and measured after which appropriate action can be taken if required to tackle the water losses if they are considered to be excessive and in need of some form of action.

2.6 Logging and analysis of minimum night flow

The logging of pressures and flows in a water reticulation system is a bit like a doctor measuring the pulse and blood pressure of a patient to see how healthy he or she is. This monitoring process is effectively the intervention that supports the sectorising process as discussed in the previous section. After zones have been established, the flows and pressures can be monitored in order to identify specific problem areas. So much can be determined from the examination of the logging results that it is surprising how few municipalities in South Africa have a logger let alone understand how to interpret the logging results. With the advent of the Internet and availability of GSM and GPRS communications, it is now, not only possible, but highly cost-effective to use loggers which automatically transmit the data directly to some receiving platform where the results are immediately available to anyone with a smart phone or other mobile device. The full benefits of “live” data acquisition, analysis and display have yet to be fully realised in South Africa and the interpretation of the logging results is discussed in more detail in **Appendix C**.

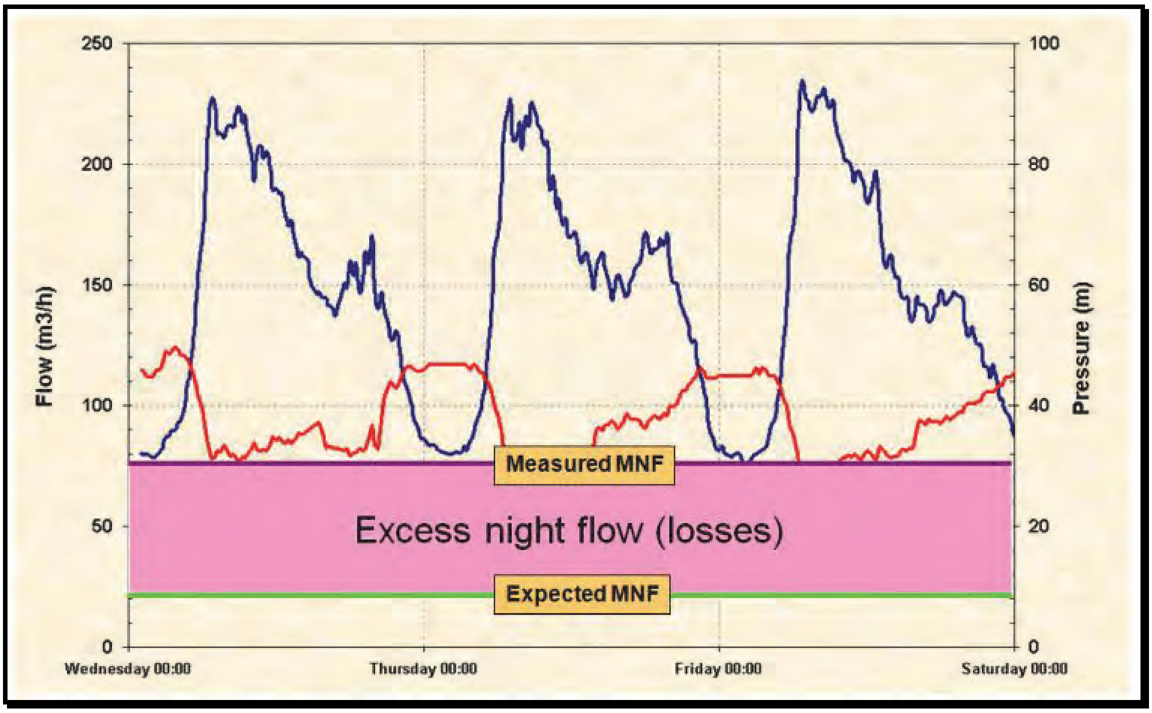


Figure 13: Example of a basic flow and pressure logging

2.7 Bulk management meters

Bulk management meters are sometimes considered to be an unnecessary luxury by water reticulation managers who don’t appreciate the need to continually monitor the pressures and flows throughout their networks. Such meters are not used to generate accounts to anyone, but are specifically to help the water supply managers to monitor and understand what is happening in the water supply network. Bulk management meters are therefore essential for the proper operation and management of any reliable and well managed water supply system. A typical example is shown in **Figure 14**.

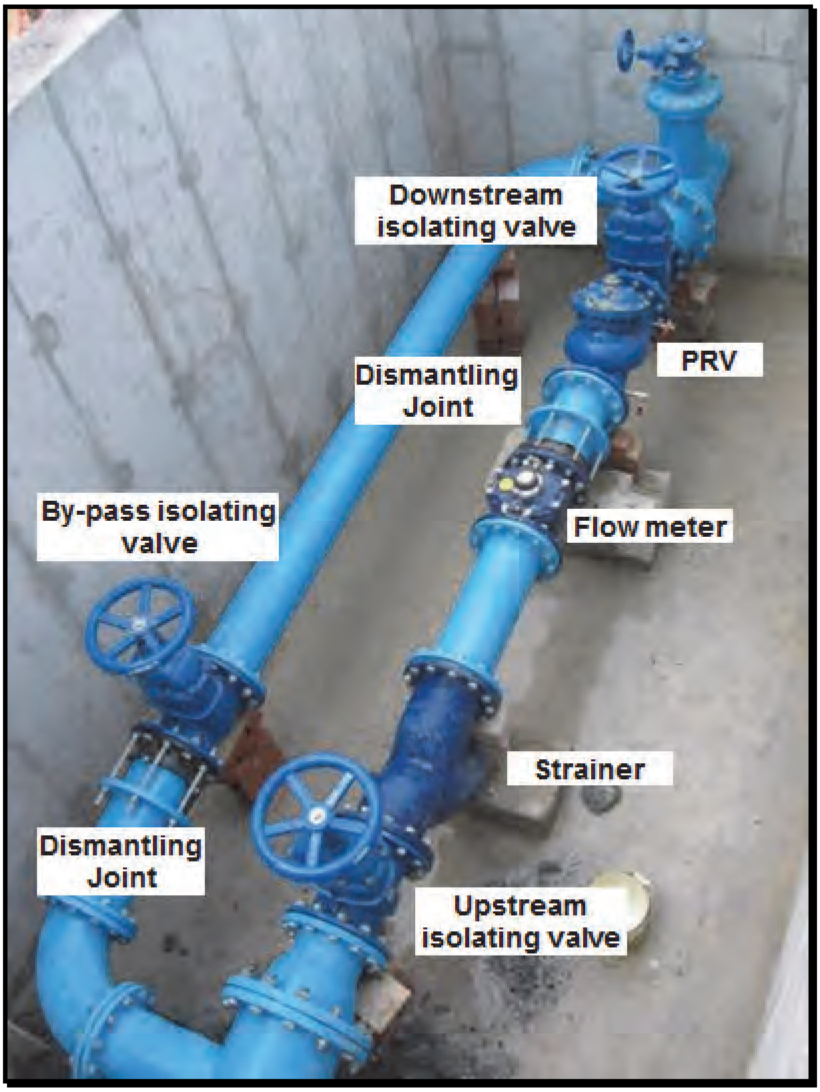


Figure 14: Typical bulk management meter in PRV chamber

Ideally, bulk management meters should be installed at the entrance to every zone in the system (see **Figure 15**) and such meters are effectively part of the overall sectorising process as discussed previously. The old saying that "…***to measure is to know*** " cannot be over emphasised and it is the bulk meters throughout the water-supply system which are used to measure and quantify both water supplied to an area as well as the level of leakage in a specific area. Such bulk meters are an essential component of any efficient management process and they should be properly maintained and used to help identify problems which can then be rectified. Ideally there should always be an option for measuring the water pressure at the same time as the flow into an area is measured. Knowing both pressure and flow helps to explain some of the problems which regularly occur. Once again, it is important that the water supply manager is able to understand the flow and pressure logging results and this is discussed in more detail in **Appendix C**.

Figure 15: Some bulk meters in Johannesburg

2.8 Bulk consumer meters

Industrial customers demand and expect a reliable water supply from their water service provider. No company in the world will invest billions on a new manufacturing facility if the water supply is likely to be unreliable. Industries pay their water accounts and do not expect to receive free water, but do expect a very reliable supply that they can count on in their industrial processes. Most municipalities charge an “industrial water tariff”, which is usually higher than the domestic tariffs. In addition, they often charge a higher sewage tariff due to the fact that the industrial effluent can be problematic from a water quality perspective.

Since industries tend to use large quantities of water, often through a single connection, and also pay fully for their water use at a relatively high tariff, they often represent a very significant component of the water supplier’s total annual water income. It is for this reason that industrial water users should receive some level of “special attention” by the municipality to ensure that they are properly metered and properly billed. This is one of the most important issues that a water supplier should address when dealing with the “commercial losses” component of its water balance. To highlight this issue, a project recently undertaken by Ekurhuleni Metropolitan municipality (EMM) is discussed in detail in **Appendix F**. Since the problems relating to the accurate metering and billing of large consumers are not limited to Ekurhuleni Metropolitan municipality, there is enormous scope for the replication of this project throughout large and small Metros and municipalities in South Africa. In many municipalities, the metering and billing of large consumers is poor, with numerous meters buried or broken or old and many un-metered connections. In light of the savings achieved through this initiative undertaken by Ekurhuleni Metropolitan municipality it is anticipated that savings can be achieved in other municipalities.

Consumers who use a significant volume of water each month and are metered through a bulk meter are very important customers to the water supplier. The bulk consumer meters for such customers can effectively be considered as the cash registers for the municipality. The metering of large consumers is therefore of critical importance to the water supplier as it is a key element of their revenue stream and the revenue generated from a small number of large industrial consumers can often exceed the remaining revenue generated from the residential customers. It is much easier to monitor, bill and control the water supplied to a small number of bulk customers compared to a large number of smaller domestic water users.

Figure 16: Typical bulk industrial meter in Ekurhuleni

2.9 Domestic metering and billing

The metering and billing of domestic consumers should not present problems to municipalities since water is needed by everyone and Government is asking all users to pay for their services. Unfortunately the payment issue is a serious problem in many areas and it will not be solved overnight. If residents can be encouraged to pay for the water they use, many of the existing problems faced by many municipalities will soon disappear. Currently, there appears to be insufficient political support to enforce payment and the issue of non-payment is likely to remain a problem throughout South Africa for years to come. Non-payment is often accompanied by excessive domestic water use and a vicious cycle is established where high water consumption leads to high water bills that cannot be paid since many of the consumers are unemployed and cannot afford to pay high water accounts. Once a customer has taken the decision that they will not pay for their water use, there is no incentive for them to use water efficiently and so in such cases the levels of leakage and general wastage become significant. With low payment levels, the municipality will eventually become bankrupt or have to reduce the funds spent operating and maintaining the water supply system which will deteriorate over time and leakage levels will continue to increase. The level of service delivery will therefore decrease, visible leaks will become more common and the image of the municipality will be damaged. Residents experiencing the poor service levels will not be willing to pay their water accounts and thus the cycle continues in a downward spiral as shown in **Figure 17**.

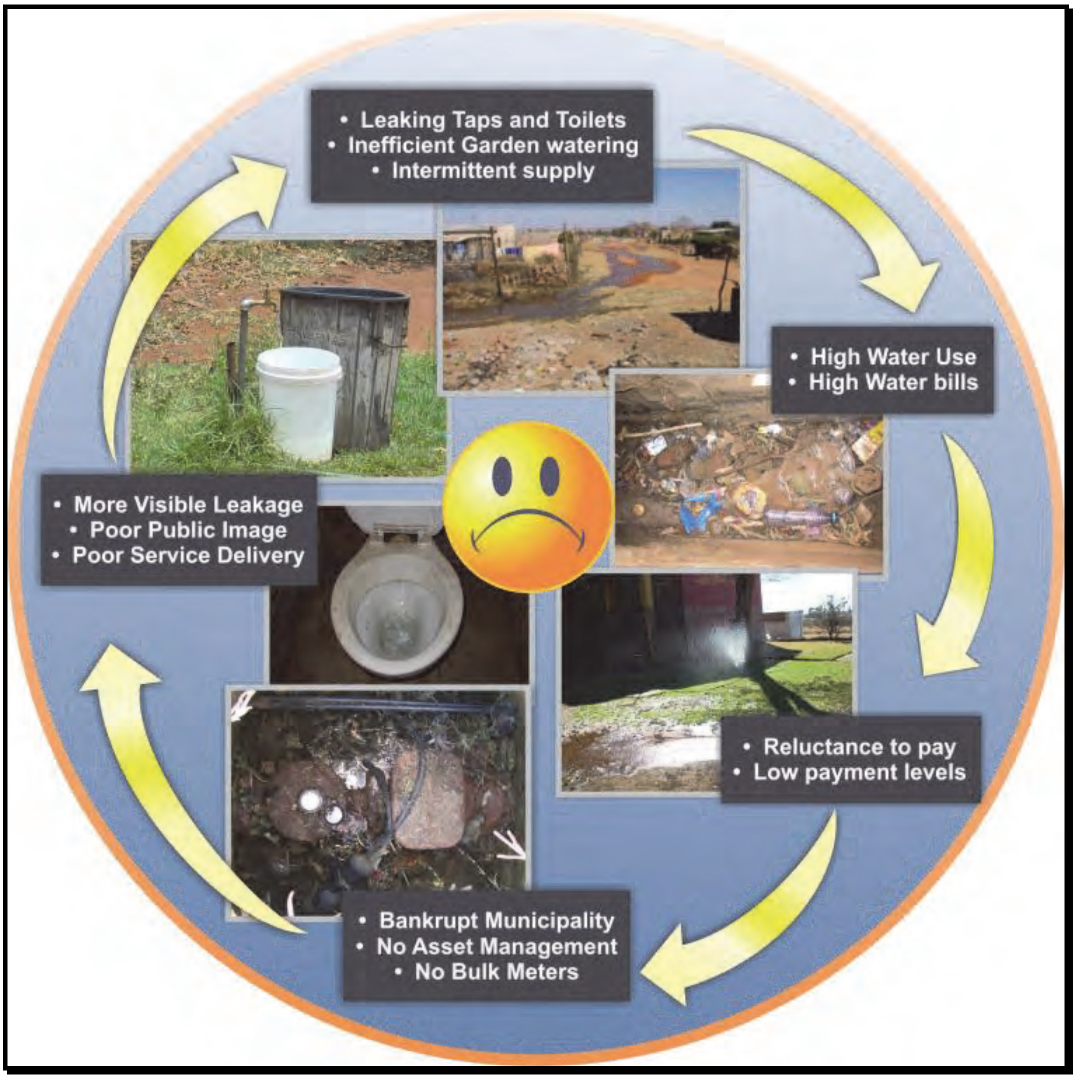


Figure 17: The vicious cycle

One final word of caution when considering the issue of domestic metering and billing concerns the recent trends in the use of smart metering, which has been very successful in some parts of the world. Such metering often eliminates the need for meter readers and, through the use of electronic meters and/or meter reading devices, will also eliminate many of the meter and billing inaccuracies. If implemented properly, this technology offers great potential for improved metering and billing but there are a number of important issues to be considered before embarking on the use of such equipment.

The most important and critical issue which often appears to be overlooked is the need to engage with the community in advance and secure a commitment from the consumers that they are willing to accept the new system and pay their water accounts. If this is not fully resolved before such metering systems are implemented they will fail completely. In many cases, the reasons for withholding payment are linked to other underlying issues such as poor levels of water supply or very high levels of household leakage. If these are the reasons for poor payment levels, no new smart metering system will help and it will in fact simply aggravate an already dire situation. In such cases, the underlying supply problems must be addressed before any new metering system can be implemented.

Another consideration concerns the relatively high initial cost of the equipment as well as the potential loss of employment opportunities for existing meter readers. In many water-supply systems throughout South Africa, there is already insufficient budget to maintain and repair the network in order to provide a reliable and safe water supply. In such cases, it may be considered unacceptable by the customers to spend many hundreds of millions on new meters despite the expectations that the new systems will solve the billing and cost recovery problems. On the issue of meter readers, there is already such high unemployment in most parts of South Africa that any job losses will be very unpopular. Any proposal to introduce sophisticated technology; often imported from overseas, which may eliminate job opportunities in areas experiencing high levels of unemployment must therefore be very carefully considered.

2.10 Pipe replacement and repair

When to repair and when to replace is a question that many water distribution managers struggle to resolve. Pipe replacement is often the most expensive water loss reduction intervention that can be implemented. At some point in the life of a pipeline, however, the repair of the pipe becomes impractical (see **Figure 18** which is a genuine section of pipe as it was removed from the ground) and the only solution is to either reline or replace the pipe – both of which are extremely expensive options. There are currently two main schools of thought when it comes to pipe replacement in South Africa. One approach that was implemented in the eThekwini Metro was the “blanket replacement” approach where all pipes of a certain type and or age were replaced. In this case, it was decided to replace all of the asbestos cement pipes in the network. This was a massive undertaking involving pipe replacement of mains at an estimated cost of almost R1 billion.

Figure 18: A case where pipe replacement is clearly appropriate

An alternative approach to “blanket replacement” has been introduced in Tshwane Metro in which certain types and age of pipes are replaced according to the incidence of burst pipes as recorded and monitored on the municipality’s management information system. This approach involves the replacement of pipes as they deteriorate to a level where the occurrence of new leaks becomes so high that the pipes are effectively no longer suitable for use. This approach requires the collection and analysis of all burst information which is part of a sophisticated GIS/MIS system. Such information and statistics on pipe bursts is invaluable when used to determine whether or not it is time to replace a section of pipe and is one of the factors contributing to the lower than average leakage experienced in Tshwane Metro.

Both of the above mentioned approaches are supported by the respective water managers who operate and manage large water reticulation systems. In cases where funding is a major constraint, then the option of selective replacement will most likely be the appropriate route to follow since there will simply be insufficient funds available to complete a full replacement of some pipe type.

Great care should be taken when considering any large-scale pipe replacement project and it is recommended that some form of pilot area should be tested before embarking on any full scale project. Numerous pipe replacement projects have been undertaken where the leakage has in fact increased after long lengths of pipework have been replaced. Pipe replacement is the most expensive water loss reduction intervention in most cases and it should be considered as the action of last resort after other options including pressure management and leak repair have been exhausted.

2.11 Co-operation between technical and financial departments in municipalities

One of the most serious problems facing many municipalities in South Africa with regard to water loss control is the divide between the technical and financial departments within the municipalities. In most cases, the technical managers who are responsible for the supply of water to all customers of the municipality have little control over the billing of the water sold to the customers or the use of the funds recovered to sustain the water supply system. Too often, the sale of water is seen as a “cash-cow” to the municipality and much of the income generated from water sales is used to fund other “more important” matters. As a result of this practice, there has been a general lack of re-investment in water-supply systems throughout South Africa, which eventually results in a poor level of service to the customers. Burst pipes cause water shortages and water quality problems and in extreme cases will eventually lead to intermittent supply.

It is essential that water-supply managers appreciate the need to reinvest large amounts of capital in maintaining the water-supply infrastructure. A figure of 2% of the replacement cost of the water-supply system annually is required to maintain a 50-year replacement cycle. That is the norm for a properly managed water supply system operating at an average water pressure of around 50m. Unfortunately if the financial department is not working closely with the technical department, the 2% needed to maintain the system will rarely be allocated and the system will gradually deteriorate. Many municipalities do not even know the replacement value of their water-supply infrastructure, and have little or no idea how much they should be allocating to maintenance. It is usually safe to assume that the budget allocated for maintenance is well below what is needed. In a recent assessment undertaken in Australia, it was established that the annual budget required to cover the depreciation of assets for the water supply infrastructure for a selection of Australian and New Zealand municipalities was between 25% and 45% of the annual operating budget for the whole of the water department. (See **Figure 19** courtesy Tim Waldron). In other words, the 2% of the replacement value of the water-supply infrastructure needed just to maintain the status quo represents almost half the total budget allocated to the water-supply department. In South Africa, there has been such a long period of under-investment in many water-supply systems that even 2% of the replacement cost may not be sufficient to adequately maintain the water-supply systems due to the backlog that has developed. It may therefore be necessary to provide a larger budget for several years to address the maintenance backlog after which the 2% should be sufficient.

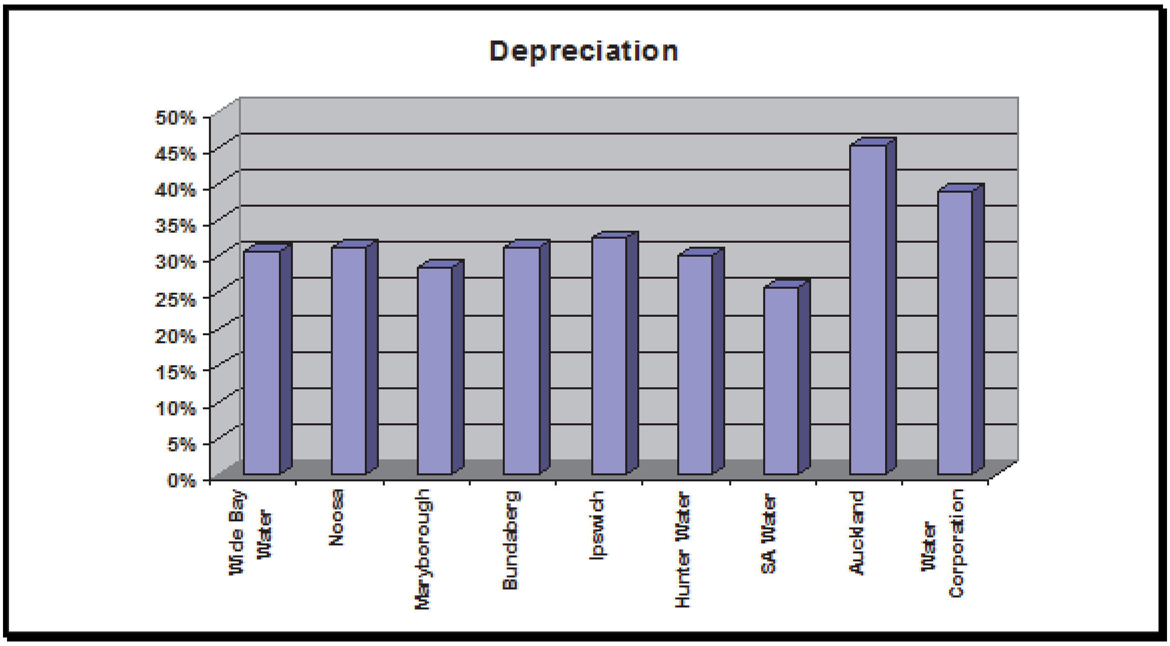


Figure 19: Annual budgets allocated for depreciation of water assets.

2.12 Basic water balance

The South African Water Research Commission (WRC) has been providing support to municipalities to address leakage and wastage from their potable reticulation systems since the early 1990s. South Africa was one of the first countries outside of the UK to fully recognise the benefits of adopting the Burst and Background Estimate (BABE) methodology, which was initially developed by the UK water Industry when the major water suppliers in England and Wales were privatised in the early 1990s. The aspect of non-revenue water (NRW) measurement and benchmarking has been one of those important interventions which the WRC has being pursuing and developing over the years. Complementing this, the WRC has supported the development of various models to assist water suppliers in understanding and ultimately reducing their leakage. These included the SANFLOW night - flow analysis model (WRC, 1999, The PRESMAC pressure management model (WRC,

2001) the ECONOLEAK active leakage control model (WRC, 2002) and finally the AQUALITE water balance model, which is used to assess the levels of NRW based on the IWA Water Balance. All of the models are discussed in more detail in **Appendix D**.

Unavoidable annual real losses

An interesting and important concept that was recently developed (Lambert et. al., 1999) concerns the level of physical leakage (real losses) in a system that theoretically cannot be avoided. It is widely accepted that no system can ever be completely free from leakage no matter how new or well managed. The concept of unavoidable annual real losses (UARL) is now one of the most useful and important concepts used in component based leakage management. Effectively, it is a simple concept based on the fact that no system can be entirely free from leakage and that every system will have some level of leakage which cannot be reduced any further. Even a new reticulation system with no use will have some level of leakage, although it may be relatively small. The minimum level of leakage for a system is the lowest level of leakage that can be achieved for the given system based on the following assumptions:

- The system is in top physical condition and is well-maintained;
- All reported leaks are repaired quickly and effectively;
- Active leakage control is practised to reduce losses from unreported leaks.

Considerable work was undertaken to assess the minimum level of leakage for water distribution systems (Lambert et. al., 1999) and, after careful analyses of many systems throughout the world a relatively simple and straightforward equation was developed. The standard form of the equation is as follows:

$$\mathbf{UARL = (18 * Lm + 0.80 * Nc + 25\ Lp) * P}$$

Where:

UARL	=	Unavoidable annual real losses (/d);
Lm	=	Length of mains (km);
Nc	=	Number of service connections (main to meter);
P	=	Average operating pressure at average zone point (m);
Lp	=	Length of underground pipe from street edge to customer meter (km).

The basic equation is based on an average length of pipe from the water main to the customer meter of 10m. The third term (the Lp term) is therefore only used in cases where the customer meter is located in excess of 10m from the water main. In countries such as South Africa where the customer meter is located at the street edge, the equation can therefore be simplified to the following:

$$\mathbf{UARL = (18 * Lm + 0.80 * Nc) * P}$$

To show how easily the UARL can be calculated for a system a simple example can be used. If a system has 114km of mains, 3 920 service connections all located at the street property boundary edge and an average operating pressure of 50m, the UARL can be calculated in the following manner:

UARL	=	(18 * 114 + 0.80 * 3920 + 25 * 0) * 50 Litres/day
	=	102 600 + 156 800 litres/day
	=	259 400 litres/day
	=	259.4 m^3/day
	=	94 681 m^3/year
	=	66 litres/connection/day

Performance Indicators including the ILI

Selecting an appropriate performance indicator to quantify and monitor leakage from a water network is often a contentious issue as there are several schools of thought in this regard. What is generally accepted by everyone around the world is that percentages should not be used as they can be extremely unreliable and will often give the completely wrong picture. This statement can be explained using a very simple example. In a water-supply system which is supplied with 150 million m^3/annum, the leakage is known to be 50 million m^3/annum and the water use is 100 million m^3/annum. The leakage in this case is ± 33.3%. A drought occurs and the municipal manager is tasked with reducing the water use in the area and he implements water restrictions resulting in the water use dropping from 100 million m^3/annum to 50 million m^3/annum. The total water entering the system is now 50 million m^3/annum consumption and 50 million m^3/annum leakage. The percentage leakage has now increased to 50% despite the fact that in reality the leakage has remained the same. This simple example demonstrates the danger of using percentages when discussing leakage. Despite general agreement internationally on why percentages must not be used; they remain the indicator of choice in most parts of the world. If it is accepted that percentages will always be used, they should always be accompanied by some form of warning and if possible, one of the other more reliable indicators should also be included.

There are several other performance indicators which each provide a different "picture" of the leakage from the system being analysed. They are often helpful in providing a better picture of the leakage levels rather than simply accepting the usual percentage. The three recommended performance indicators are discussed below.

The most basic indicator is expressing the losses in litres/service connection/day or m^3/km mains/day. If a system has more than 20 service connections per kilometre, it is recommended that litres/service connection/day be used. In more rural systems with less than 20 connections per kilometre, it is recommended that m^3/km mains /day be used.

A more sophisticated and involved indicator can be used in cases where the average system pressure is taken into account. This "intermediate" performance indicator (PI) is basically similar to the basic version discussed above for systems with more than 20 connections per kilometre of mains. The losses are expressed in terms of litres/service connection/day/metre of pressure. This PI takes the average system pressure into consideration, but does not allow for the actual density of connections and average length of private un-metered supply pipe.

Finally if there is information on the length of mains, the number of service connections and the system pressure then a more "detailed" PI called the ILI can be used. The Infrastructure Leakage Index (ILI) is now widely used throughout the world as an indicator of physical leakage from a water-supply system. It is a single number which is dimensionless and is the ratio of the current annual real losses to the unavoidable annual real losses (as mentioned in the previous section). Full details of the ILI calculation are provided in the original paper by Lambert (1999). It is a very useful indicator which should be used whenever possible. A value of 1.0 suggests that the actual leakage is equal to the minimum level of leakage that can in theory be achieved in the specific zone. If the ILI is 10.0 then it suggests that the actual leakage is 10 time higher than it could be. Once the ILI exceeds 10 or 20 it becomes rather academic as the purpose of the indicator is to highlight whether or not the zone has a leakage problem. Any value of 10 or above usually suggests that there is a very serious leakage problem and the actual number becomes less important.

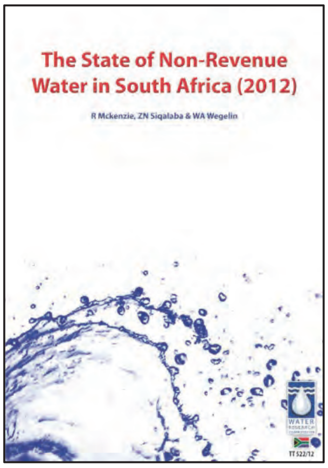
Details of various NRW assessments

Four NRW assessments have been published by the WRC in the last 20 years. The initial NRW assessment, undertaken in 1999, eventually used only 20 datasets which were considered to be of an acceptable quality from a potential set of approximately 600 water suppliers. The assessment suggested that the average NRW for the 20 water suppliers was in the order of 25%, with an average ILI value of 6.0. Most of the acceptable datasets were provided from the larger municipalities, which were the only water suppliers at this time who collected the appropriate base data and meter readings. As a result of this initial assessment, the WRC commissioned a follow-up assessment in 2005.

In the 2005 assessment (WRC, 2005) information from 60 water suppliers was obtained from which 30 acceptable datasets were identified representing just under 50% of the total municipal water supplied in South Africa. In this assessment, the percentage NRW was not calculated due to the IWA recommendations on avoiding the use of percentages when dealing with NRW. Unfortunately, most of the municipalities and politicians wishing to use the results insisted that the percentages were included in all future reports. As a result they were again included although it is recommended that other performance indicators such as the ILI are also used. The ILI, which provides an indication of the physical leakage (not the overall NRW), was however calculated for the 30 municipalities and an average value of 6.3 was derived. Once again, the value of the assessment was clear to the WRC as well as the Government which commissioned a third assessment to be undertaken.

The third assessment was undertaken in 2007 (WRC, 2007) and involved 100 datasets from which 62 were included in the final assessment, representing almost 60% of the total municipal water use in South Africa. In this assessment many of the smaller municipalities were included and the NRW was estimated to be 36%, with an average ILI of 7.6. The percentage NRW was again included in the assessment despite the fact that it was accepted that percentages can be very misleading. Some of the high level committees were uncomfortable with the use of the ILI and other recommended performance indicators with the result that percentages were used albeit with a “health warning” to highlight that they can be misleading in certain cases.

The 2012 NRW assessment



Following the success of the 2007 assessment in raising the issue of NRW to a national platform where it was discussed at length by Government, a 4th assessment was undertaken between 2010 and 2012, the results of which were officially released in March 2013 (WRC, 2012). This assessment is the most comprehensive and detailed assessment of NRW undertaken in South Africa and involved water balance information from more than 130 municipalities. The project was supported not only by the WRC but also the Department of Water Affairs.

The data gathered from 132 of the possible 237 municipalities supplying water to more than 40 million residents represents over 75% of the total volume of municipal water supply in South Africa. The results indicate that the current level of NRW estimated for the country as a whole is almost 37% with an average infrastructure leakage index (ILI), which is an indicator of the physical leakage, of 6.8.

The NRW figure for South Africa is similar to the estimated world average of 36.6% but is considered high in comparison to other developed countries but low when compared to other developing countries. Once again, it must be stressed that percentages can be misleading and the values provided in **Figure 20** should therefore be used with caution. The ILI of 6.8 is considered to provide a realistic indicator of physical leakage for the South African systems and it is interesting to note that the various estimates of ILI over the past 12 years have all been between 6 and 8. Again, this would be considered high for most developed countries but low for most developing countries, and highlights the fact that levels of physical leakage are generally high in South Africa.

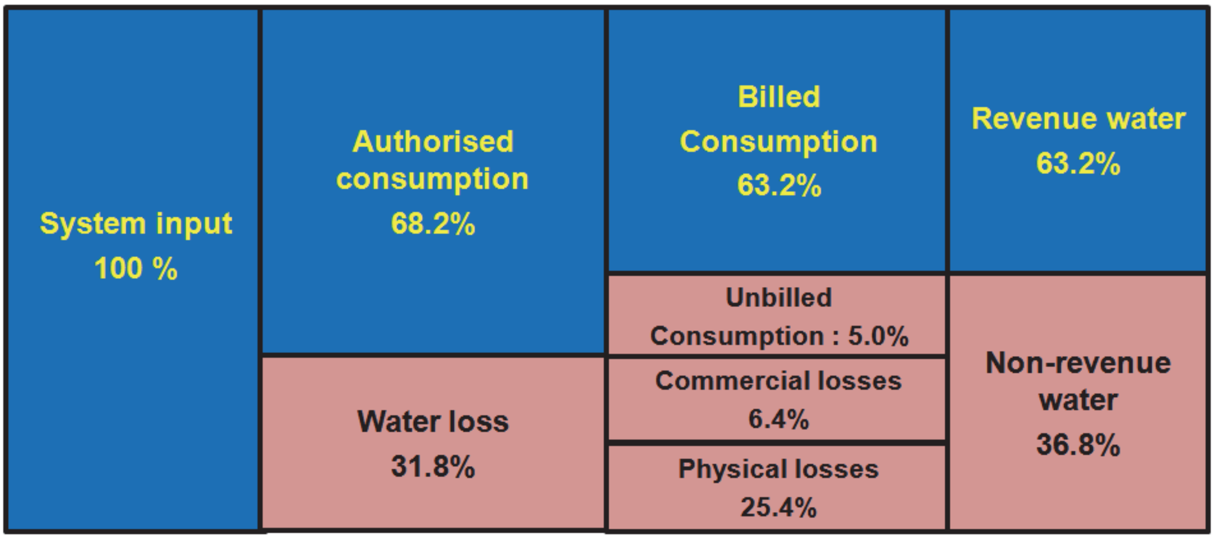


Figure 20: National water balance for SA from WRC Report (WRC, 2012)

It should also be noted that in South Africa, every water supplier is categorised according to the size of the population supplied and whether the area is urban or rural. The results from the breakdown into the different categories are provided in **Table 1**.

Table 1: NRW figures for South African municipalities (2012)

Category	Population	Input (m^3/a)	NRW (m^3/a)	Revenue Water (m^3/a)	l/c/d
A	17 420 512	1 849 091 117	634 192 022	1 214 899 095	291
B1	7 756 187	683 667 320	282 585 164	401 082 156	241
B2	3 882 070	325 623 095	99 407 207	226 215 889	230
Urban Total	**29 058 769**	**2 858 381 532**	**1 016 184 393**	**1 842 197 140**	**269**
B3	3 845 279	230 642 568	85 229 869	145 412 699	164
B4	4 245 736	101 138 956	73 334 514	27 804 442	65
Rural Total	**8 091 015**	**331 781 524**	**158 564 383**	**173 217 141**	**112**
National Total	**37 149 784**	**3 190 163 056**	**1 174 784 776**	**2 015 414 281**	**235**
Extrapolated	**49 988 373**	**4 292 650 981**	**1 580 730 012**	**2 711 920 969**	**235**

The figures provided in **Table 1** are based on an estimated total urban and rural consumption of approximately 4 292million m^3/annum, which was considered to be realistic for the country as a whole and this figure was used in the calculations to generate the extrapolated values provided in the last row of the table.

The latest NRW study undertaken for the WRC and DWA represents a major advance in the understanding and assessment of water losses from municipal water supply systems in South Africa. It is the most comprehensive assessment yet undertaken and despite the many problems experienced with data collection from many of the smaller municipalities, it was possible to gather information for more than 75% of the water supplied in South Africa. The overall NRW for South Africa is estimated to be 1 580million m^3/annum, which is approximately one third of the total water supplied. Conservatively, this represents an annual loss of over R7 billion based on an average bulk water tariff of approximately R5/m^3.

The average ILI value for all of the South African municipalities of 6.8 is in line with the world average. This figure would be above average (i.e. bad) when compared to most developed countries and well below average (i.e. good) when compared to most developing countries. Effectively, the ILI value of 6.8 tends to support the perception created from the percentage non-revenue water figures for South Africa (36.8%) where there is clearly a high level of wastage or water losses in the country and considerable scope for improvement.

It should be noted that the figures are based on the Standard IWA Water Balance in which the “Revenue Water” figures provided by the financial departments are assumed to be correct. In South Africa, however, there can be a significant component of revenue water which is never paid for by the consumers. Preliminary estimates of this component suggest that if this is taken into account, the level of NRW may increase by up to 10%. Investigations are continuing to try and quantify this element with greater certainty so that future assessments can provide a more complete and accurate water balance.

2.13 Community awareness and education

This item has deliberately been left to the end, not because it is the least important of the interventions discussed, but because it is the most important. Too often, well designed and implemented technical interventions fail miserably purely due to the fact that the community they serve are not included in the overall process with the result that they do not “buy-into” the project. In extreme cases, the community representatives may go out of their way to ensure that some technically sound project fails. Proper consultation with the community is therefore an essential element of any technical WDM intervention (see **Figure 21**) and is discussed in **Appendix H**.

Figure 21: Discussing WDM intervention with local residents

It is unfortunate that community awareness and education activities are difficult to monitor with regard to the cost of the activities compared to the savings achieved which are often impossible to quantify. As it is therefore difficult to develop a cost-benefit analysis for the proposed activities, they are often not supported at the political level where funds are allocated. It is therefore necessary to incorporate the costs associated with the community awareness and education activities as part of every technical intervention when undertaking the cost-benefit calculation for the technical intervention.

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Water Research Commission, 2005	Benchmarking of Leakage from Water Reticulation Systems in South Africa.	Report TT 244/05 to the South African Water Research Commission by Mckenzie, R and Seago, C,	ISBN: 1-77005-282-8.
Water Research Commission, 2007	An Assessment of Non-Revenue Water in South Africa.	Report TT 300/07 to the South African Water Research Commission by Mckenzie, R and Seago, C,	ISBN 978-1-77005-529-2
Water Research Commission, 2009	AQUALITE Water Audit Model: User Guide.	Report TT 315/07 to the South African Water Research Commission by Mckenzie, R.	ISBN: 978-1-77005-599-5
Water Research Commission, 2010	Municipal WDM Balanced Scorecard: User Guide	Report TT 523/12 to the South African Water Research Commission by Mckenzie, R.	ISBN: 978-1-4312-0271-3
Water Research Commission, 2013	The State of Non-Revenue Water in South Africa	Report TT 522/12 to the South African Water Research Commission by Mckenzie, R Wegelin, W and Siqalaba, Z.	ISBN: 978-1-4312-0263-8

Authors	Title	Publisher	Reference
Water Resources Group 2030	Managing Water Use in Scarce Environments: A catalogue of case studies	Published by the 2030 Water Resources Group	
Wegelin W, & Mckenzie, RS.,(2005)	Sebokeng/Evaton Pressure Leakage Reduction: Public Private Partnership.	Proceedings from the International Water Association Specialist Conference: Leakage 2005, Halifax, Nova Scotia, Canada. pp 382-391. 12 - 14 September 2005.	
Water Services Association of Australia	Water Reticulation Code of Australia: WSA 03-1999	Available from Water Services Association of Australia Inc, 469 Latrobe Street, Melbourne, Victoria 3000, Australia	ISBN 1 87060 8862 1
Vickers, A	Handbook of Water Use and Conservation	Available from WaterPlow Press, PO Box 2475, Amherst, MA 01004-2475, USA. www.waterplowpress.com	ISBN 1-931579-07-5

3.2 Some useful websites

Organisation or Company	Web Site	Details of Site
American Water Works Association	www.awwa.org	American based web site with details of useful publications and information on all aspects of water supply including considerable information and publications on water conservation.
Aqualoc	www.aqualoc.net/mainframe.html	Australian based company providing flow restricting devices for taps.
Con-Serv	www.con-serv.com.au	Australian based company providing flow restricting devices for taps and low flow shower heads.
Caroma	www.caroma.com.au	Australian based company providing low flow showerheads and dual flush toilets.
Delrama Ltd	www.delrana.com.au	Australian based company providing low flow showerheads.
Department of Water Affairs and Forestry (South Africa)	www.dwaf.co.za	Useful site: can download the SA Water Services Act (No. 108 of 1997) and National Water Act (No. 36 of 1998).
Environment Agency (United Kingdom)	www.environment-agency.gov.uk/savewater	Useful web site containing many articles and reports, many of which can be downloaded free of charge. Also provides access to the “Demand Management

Organisation or Company	Web Site	Details of Site
		Bulletin" which is extremely useful and informative to anyone considering WDM initiatives.
Enviroloo Ltd	www.eloo.co.za	South African based company involved with the manufacture and distribution of waterless toilets.
Ecosan Pty Ltd	www.jojo.co.za	South African based company involved with the manufacture and distribution of waterless toilets.
Flexispray Ltd	www.flexispray.com	Australian based company providing low flow showerheads.
Gem Flow Ltd	www.jemaustralia.com.au/index.html	Australian based company providing flow restricting devices for taps.
Interbath Ltd	www.interbath.com	Australian based company providing low flow showerheads.
Queensland Government Environmental Protection Agency	www.epa.qld.gov.au	Web site with large quantity of useful information on many aspects of the environment including considerable material on water conservation.
Rand Water	www.randwater.co.za	Largest supplier of potable water in Africa and joint sponsor of this manual
RST Water Saving Systems Pty Ltd	www.rst.co.za	Details of low flow shower heads
Save-a-Flush Pty Ltd	www.save-a-flush.co.uk	UK based company specialising in the manufacture and distribution of toilet displacement devices.
South African Water Research Commission	www.wrc.org.za	Government research organisation responsible for the development and distribution of many products to assist water suppliers in all aspects of water resource management, WDM and water quality issues.
South African Department of Water Affairs and Forestry	www.dwaf.co.za	Web site containing information on many issues related to WDM including the government's policy document as well as various water acts etc.
Technolog Ltd.	www.technolog.co.uk	UK based company specialising in pressure management controllers, loggers and remote logging equipment.
United Nations Centre for Human Settlements	www.un-urbanwater.net www.unchs.org	
Waterless Advantage Pty Ltd	www.rotaloo.com	South African based company involved with the manufacture and distribution of waterless urinals
	www.wsaa.asn.au	Australian based web site providing information and publications on various water supply and WDM related issues.

Organisation or Company	Web Site	Details of Site
Water Services Association of Australia	www.ratings.wsaa.asn.au	Australian based web site providing details of the Water Conservation 5A Rating and Labelling Scheme managed by the WSAA.
2030 Water Resources Group	www.waterscarcitysolutions.org	USA based NGO
WRP Pty Ltd	www.wrp.co.za	South African based consultant specialising in Water Conservation and WDM plus training in all aspects of WDM

4 APPENDIX A: BURST AND BACKGROUND LEAKAGE

4.1 Understanding leakage

Before embarking on any major WDM initiative, it is first necessary to understand the problem to ensure that the interventions being proposed are appropriate and cost effective. With regard to physical leakage (often referred to as real losses), there are 3 main sources of leakage namely:

- Background leakage
- Burst leakage on mains and connections
- Internal plumbing leakage inside the properties

It is important to understand the differences between the three main sources of leakage to ensure that the proposed interventions will address the problem and provide real savings.

4.1.1 Background leakage

Background leaks are basically very small leaks that tend to run unnoticed, sometimes for years and may not create any problems until they eventually grow into larger leaks at which point they are called bursts. Every water-supply system will have some level of background leakage and it is impossible to completely eliminate such leakage as the leaks are so small (see **Figure 22**) that they are virtually impossible to detect. Even if the background leaks could somehow be detected, it would not be cost effective to repair them since the costs involved would be magnitudes higher than the value of the water that would be saved. It is, however, important to appreciate that such leakage will always exist in every water reticulation network and that although each leak may in itself be very small; if the system has many hundreds or thousands of such leaks they can sometimes represent a significant loss of water to the municipality.

Although background leakage can never be eliminated completely, it can be controlled to some extent through pressure management or as a last resort by pipe replacement. Replacing the pipes is usually the most expensive option to be considered and should generally be considered as a last resort.

Figure 22: Typical background leak

4.1.2 Burst leakage

Most leaks tend to start off as small background leaks which grow over time until they are large enough to be considered as burst leaks. The normally accepted definition of burst leakage is that they are over 250 litres/hr which was initially selected because this was the typical level at which such leaks could be detected using normal leak detection equipment. With more modern equipment, however, it is possible to identify leaks which are less than 250 litres/hr and so the actual limit at which a leak is considered to become a burst has become a rather academic point. Basically burst leakage can be thought off as any leak that is large enough to be detected and economically viable to detect and repair. As the value of water increases, the limit at which a background leak becomes a burst leak may well reduce since it will become cost effective to search for and repair smaller leaks.

Burst leakage occurs on both mains and connections. Such leaks on mains tend to be spectacular and can range in size from below 2 m^3/hr to more than 1 000 m^3/hr although the average mains leak is likely to be between 2 m^3/hr to 4 m^3/hr.

4.1.3 Internal plumbing leakage

In most countries around the world, internal plumbing leakage is the problem of the householder and not the water utility. In South Africa, however, this is not the case due to Free Basic Water and the fact that municipalities will not cut off water to households, particularly in medium- to low-income areas. In such areas, the internal plumbing leakage can often be high and in extreme cases may dominate the water use in the area. For this reason, internal plumbing leakage is one of the key problems facing municipalities throughout the country.

Normal household water use in a medium-sized property with a garden and some grass that is occasionally watered should be around 30 m^3/month. In cases of smaller properties without any garden watering, the monthly consumption tends to average at around 12 m^3/month. In cases where internal plumbing leakage is a problem, the average figure can increase to above 50 m^3/month with some individual properties using more than 200 m^3/month. These figures are rough estimates which are provided to give some idea of how much water a specific area should be using every month and it is surprising to find that the 12 m^3/month ties in very well with the water used in similar sized properties in Sao Paulo in Brazil (personal communication Francisco Paracampos: SABESP).

4.2 Where is the leakage?

Identifying burst leakage is usually quite simple and straightforward, especially if the leaks come to the surface where they can be easily spotted by visual inspection. If the leaks do not surface, it is more difficult to quantify the level of leakage in the area and to know if the main source of leakage is background leakage, burst leakage or internal plumbing leakage. Many municipalities struggle to identify the main source of leakage and can waste money on actions that are neither needed nor cost effective. It is very important to know the main source of leakage before trying to fix it and to assist in this dilemma there are a few simple checks that can be undertaken.

The water supply to a typical household is shown in **Figure 23** from which it can be seen that there is a water main connected to a household supply pipe which in turn supplies the pipes inside the property. Various fittings are connected to the water supply pipes inside the house and there are some connections from the basins, baths, showers and toilets to the sewer network which take way the dirty or leaking water.

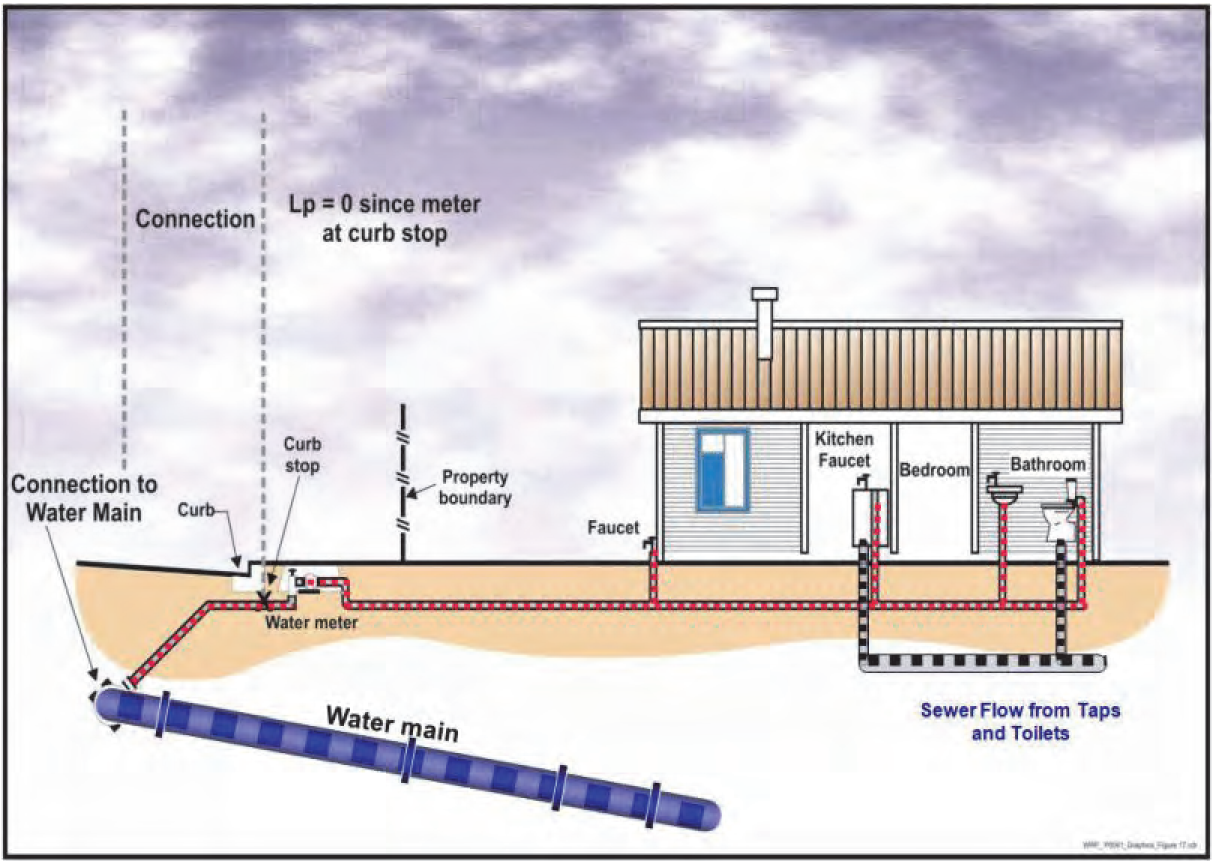


Figure 23: Typical Household pipework

When identifying the source of the leakage, the following issues should be considered:

- Most burst leakage will find its way into the stormwater system and/or a natural stream or river. This applies to both large mains bursts and the more common connection bursts on the connection pipe between the main and the consumer meter. It is often useful to monitor any unusual flow of water in a stormwater sewer or culvert/stream, particularly during the dry season when there should be little or no flow of water at that time.
- Burst leakage on the connection pipe after the consumer meter is on private property and will often cause a wet patch on the private property which can run undetected for many months if it is not causing any inconvenience. This leakage tends to run into the soil and may not find its way into either the sewer or stormwater system. Such leaks are difficult to detect and the only means of detection is through inspection of the water meter at the property which will run continuously, even when the customer is not using any water – checking the meters at night-time is an excellent way of picking up such leakage, however, the leak may be inside the property (plumbing leakage) or on the connection pipe.

- Internal plumbing leakage will usually result in high sewer flows. In areas where internal plumbing leakage is a serious problem, the sewer flows will be very high at night -time and the sewage entering the treatment plant at night may be crystal clear in cases of extreme plumbing leakage. This is a serious issue in parts of South Africa where the internal plumbing fittings are sub-standard and payment levels for water are very low.
- Background leakage is difficult to quantify and is normally determined from the analyses of the minimum night flow (see **Section 5.2** in **Appendix B**). Such leakage rarely enters either the sewers or stormwater since the individual leaks are so small. The leakage usually disappears into the surrounding soil.

4.3 Active and passive leakage control

Passive leakage control (PLC) is the process of repairing leaks once they have been reported while active leakage control (ALC) is the more complicated process of investigating an area in order to identify leaks that have not been reported. Internationally ALC is considered to be one of the most important interventions of water loss control and is a multi-billion dollar business worldwide. Many companies manufacture and sell leak location equipment designed specifically to find leaks that are not obvious from visual inspection. Such leaks can run undetected for months if not years in some cases and the volumes of water lost through such leaks can be enormous. Many international presenters start their presentations by explaining that 90% of all leaks do not appear on the surface and thereby suggest that ALC is essential in all cases. While this figure of 90% may be appropriate in some parts of the world, it is not the case in most parts of Southern Africa. To understand why some leaks come to the surface and others remain below ground and effectively invisible from surface inspection, it is necessary to consider several factors. The most important factor is possibly the depth at which the pipe has been buried. If the pipe has been laid 2m below the ground surface, there is less chance of a leak surfacing compared to a pipe that is buried only 1m below the surface. In many countries, particularly in the northern hemisphere, pipes are laid 2m or more below the surface in order to escape the effects of the frost and long winters where temperatures can remain below freezing for months at a time. In most developing countries, such extreme low temperatures are uncommon and pipes tend to be laid at only 1m below the surface and sometimes even less. It is therefore to be expected that leaks will tend to come to the surface in countries where the pipes are close to the surface. Other considerations are of course, the soil type as well as the average system operating pressure. If the water pressure is high, there will be greater chance of a leak surfacing than in cases where the system pressures are very low. In South Africa, the system pressures are high and the pipes are shallow with the result that more leaks reach the surface and can be identified from visual inspection. Another important consideration concerns areas which are at or near sea level with the result that the groundwater is close to the surface. In such areas, even if a leak will come to the surface, it may be confused with normal groundwater and therefore be difficult to detect from visual inspection.

From several case studies undertaken in South Africa, it appears that in most areas, the leaks do in fact come to the surface and are therefore visible. Obviously some leaks will not come to the surface and the only way of identifying these leaks is to search for them using some form of leak location equipment. The actual split between leaks that are visible on the surface and other leaks that are not visible is a debatable point and will vary from area to area. It is the view of the author that in South Africa the split is likely to be more towards visible leaks unless the area is dolomitic in which case, the leaks will not surface in most cases.

Undertaking ALC does not solve the problem, and in all cases the municipality must still ensure that all leaks reported or detected are repaired quickly and effectively. A municipality that has a proper and efficient PLC process in place can drive leakage down to acceptable levels while a municipality undertaking ALC on a regular basis but does not repair the leaks quickly or properly may have a serious leakage problem.

At the very least, a municipality should ensure that all visible and reported leaks are repaired quickly (target should be within 24 hours) and effectively. ALC is cost effective in some cases, but should not be undertaken in a "blanket fashion" but rather in a "targeted fashion" where specific problem areas are first identified (e.g. minimum night flow analyses) after which they should be prioritised for investigation and finally investigated when appropriate. There are far too many cases where municipalities buy expensive leak location equipment that gathers dust in some office or store room – especially at financial year end when budgets must be used or lost. If money must be spent, then rather buy some loggers or meters to monitor or measure what is going on in the system and only purchase leak location equipment if it is to be used.

4.4 Implementing active leakage control

As mentioned previously, ALC is the proactive approach of sending leak detection and repair teams into areas to search for and repair **unreported bursts**. The procedure for active leakage control normally involves a series of steps which include, but is not limited to, the following:

- Administration and set-up costs
- Manpower inspection costs
- Supervision costs
- Mains repair costs
- Connection repair costs
- Various other small costs

Passive leakage control, as the name implies, involves the passive approach of waiting for leaks to be reported after which the leak repair teams are dispatched to locate and repair **reported bursts**. This approach is considerably cheaper to operate and manage compared to the approach of active leakage control. It can, however, also result in many unreported bursts running for many months, if not years, before they grow to such an extent that they are finally reported. Reports of relatively large leaks running undetected for many years are common in most water utilities.

While PLC is clearly not ideal from the viewpoint of reducing leakage, the key issue is to determine whether it is more cost effective to use teams of plumbers to detect and repair leaks or simply to react to customer complaints when the leaks become so large that they are reported. This is effectively the question answered by the ECONOLEAK Model which attempts to provide an indication of how often the leak detection and repair teams should visit a particular water supply system. In some instances, it is cost effective to investigate a system every 6 months, while in other instances it may not be cost effective to carry out such investigations more frequently than every two years. The ECONOLEAK model considers active leakage control intervals at every 6, 12 and 24 months which should be sufficient for most systems in South Africa. If it is found that the model suggests implementing active leakage control at some interval outside the 6- to 24-month range, then there is likely to be some other factor dominating the calculation such as the cost of water which may be outside the normal range.

4.5 Duration of reported and unreported bursts

A key issue to be considered when addressing leakage concerns the length of time over which a leak will run. Obviously, reported bursts are identified and repaired much quicker than the unreported bursts, but in both instances there is a clearly defined period over which the leak will run. Unfortunately, relatively few municipalities in South Africa collect and process the data that are necessary to estimate the average running time of the various leaks. For this reason, the default values suggested in the UK can always be used as a starting point for any municipality wishing to develop its own active leakage control strategy. In summary, the running time for any particular leak can be considered as the sum of three components namely:

- Awareness
- Location
- Repair

The awareness time for a leak will depend upon the size of the leak, its visibility to the public and its impact on water users in the system. A serious leak that is highly visible and causes low water pressures to certain consumers will be brought to the attention of the water supplier within hours. A smaller leak, however, that causes no real problems and perhaps runs directly into a stormwater drain may run undetected for several days, months or even years. If no form of active leakage control is practised by the water supplier, such leaks can run indefinitely or until they become sufficiently large to draw some attention. The awareness time for a leak can vary considerably from system to system, and will also depend upon how diligent the consumers are with regard to reporting leaks.

It is important to understand the issue of awareness, location and repair of leaks as it is generally assumed that large leaks will result in greater wastage than small leaks. For this reason, the repair of small leaks is often given a low priority. In many cases, however, this is not the case and the overall leakage from a small leak can exceed the water lost from a large leak. Consider a typical mains leak which will normally run at approximately 3 m^3/hr or 72 m^3/day as shown in **Figure 24**. This type of leak is normally highly visible and often causes low pressure problems to some consumers. As a result of the inconvenience caused, the leak is reported within a few hours and repaired as a priority in less than a day. This type of leak will typically run for approximately 1.1 days and result in leakage of ± 80 m^3.

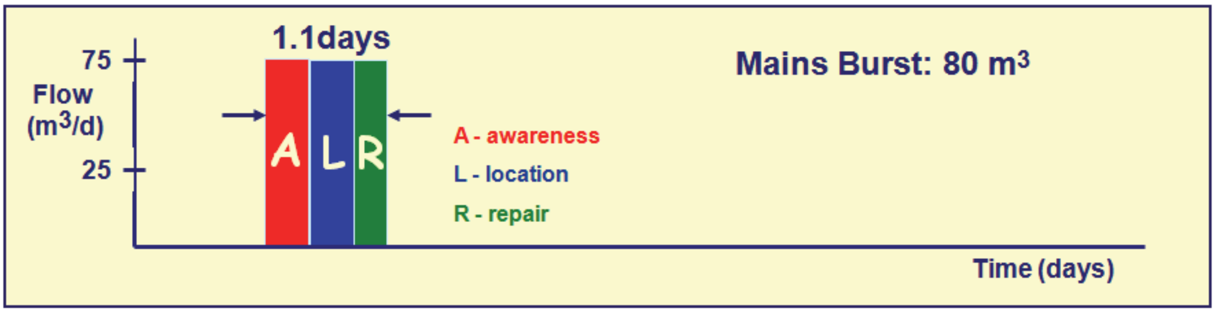


Figure 24: Typical duration and loss through a mains leak

Figure 25: Typical mains burst

If, however, a relatively small leak develops on a connection pipe, which is by far the most common type of leak in all water reticulation systems, it will run at approximately 25 m^3/day which is considerably less than the mains leak. In view of the fact that the leak may not cause such widespread disruption as the mains leak, it is not considered to be a high priority. It may also take a few days for the customer to notice the problem, after which it may take several more days before the water supplier has sent out a team to find the leak and assess the situation. Furthermore, it may then take a few more days to dig up the water pipe and repair the leak. In total, it takes an average of 16 days from the time a connection leak occurs until it is repaired. This type of leak will typically result in losses of 400 m^3 as shown in **Figure 26**.

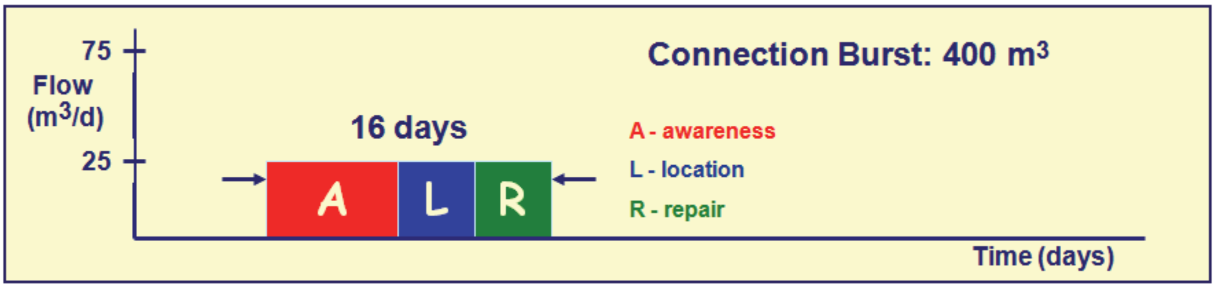


Figure 26: Typical duration and loss through a connection leak

Figure 27: Typical connection leak before the meter

If the leak occurs on the consumer's property after the meter, the situation can be even worse from a leakage viewpoint. In such cases as shown in **Figure 28**, the consumer may not pick up the leak for several weeks or even months. After identifying the leak, the location and repair may also take many days or weeks to complete, with the result that such leaks normally run for approximately 46 days. The water lost through such a leak will average out to approximately 1 050 m^3 as shown in **Figure 29.**

It is important to realise that the water lost through burst leakage is dependent on the awareness, location and repair times for the water supplier and the performance of different water suppliers can vary significantly, depending upon where they place their priorities.

Figure 28: Property leak after the meter (Courtesy Niel Meyer)

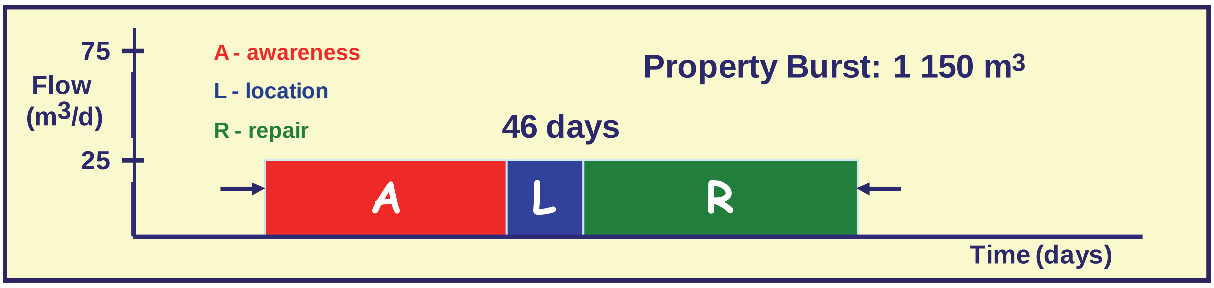


Figure 29: Typical duration and loss from a property leak

In the UK, many water companies decided to repair leaks on customer's properties free-of-charge rather than leave such leakage to the customer. Part of this strategy was based on the fact that many customers are not metered individually and such leaks result in a loss to the water company. In cases where the customer is charged for the water, the water supplier may decide that such leakage is not a priority issue since the water is being paid for and the water company is not losing any revenue as a result of the leak. In South Africa the situation is probably somewhere between the two extremes in that many water suppliers supply water to customers who either have no meters or pay a fixed tariff each month. In such cases, the water supplier may decide that it is in its best interests to locate and repair all leaks on the customer's property. In other cases, the water supplier may decide that such repairs will be the customer's problem.

4.6 Addressing visible leaks

Visible leaks need no explanation and there is no excuse for not fixing them as a matter of priority. Municipalities that want to spend money on smart metering or expensive infrastructure cannot justify such expense if they do not first address visible leaks. Before considering any other intervention, the repair of visible leaks is without question one of the most cost-effective interventions that can be undertaken. On a cautionary note, however, it should be noted that by repairing all visible leaks, the system pressure will increase which, in turn, will encourage new bursts to occur. The losses through existing bursts will also increase as they will flow at a faster rate. If the underlying problem is due to excessive water pressure, then the pressure issue should be addressed simultaneously with the leak repairs. If the pressure is not managed, then the leaks will simply re-appears somewhere else in the network, and the overall leakage will simply revert back to its previous levels.

5 APPENDIX B: LOGGING AND MINIMUM NIGHT FLOW ANALYSIS

5.1 Importance of logging

Logging of pressures and flows is one of the most important aspects of any WDM programme and one that is generally neglected if not ignored completely. In recent years, with the advent of GSM and GPRS based loggers it is now possible to capture and transmit logging information with relative ease. Such information, if used properly, can help water managers to manage their water distribution systems effectively and efficiently, and they can often identify problems before they become major crises.

There is no substitute for reliable “real-time” flow and pressure information and where available, it will facilitate the analysis of minimum night flows which was the original foundation of any proper WDM programme. Over the years, more effort seems to have been placed on high-tech electronic solutions and software which eliminates the need to visit the site or to get one’s hands dirty. Recording and analysing minimum night flows has, in fact, become less common as the new technology and software models eliminate the need for any such analyses. In reality, many water reticulation managers have lost the ability to properly manage their systems in many parts of South Africa and there is a real need to move back to the basics and start using logging results to monitor the water reticulation systems and to find problems. Reliable logging information provides a manager with real-time data on what is really happening in the system as opposed to what the hydraulic models say should be happening. In many instances, the modelled flows and pressures bear little resemblance to what is being measured on the ground. Such discrepancies are not a reflection on the software models that are used to design the reticulation systems since the results from such models are only as reliable as the information on which they are based. When the model results and reality diverge, the problem is most likely due to operational issues such as valves which are closed when they should be open or vice versa.

In the remainder of this section, the value of real-time flow and pressure logging information will be discussed to highlight some of the common issues that will be found in most water reticulation systems.

5.2 Interpretation of minimum night flows

This section explains how the minimum night flow in an area can be used to identify the possible leakage in an area as well as to help identify some of the more common operational problems. Before proceeding to interpret various logging results, it is useful to recap on the basic methodology for assessing the level of leakage in a zone from the analysis of the measured minimum night flow. This is fully discussed in the original SANFLOW User Guide (WRC, 2001) and is not repeated in detail below. A basic summary of the approach is, however, provided to highlight the ease with which the minimum night flow can be assessed.

The measurement of background night flows is one of the most important actions that can be taken to identify leakage problems. It is often possible to identify many problem issues by simply looking at the minimum night flow. The minimum night flow is usually found to occur sometim**e between midnight and 4 am when the consumption in the network is at its lowest.** **Figure 30** provides a typical plot of the flow entering a zone metered area.

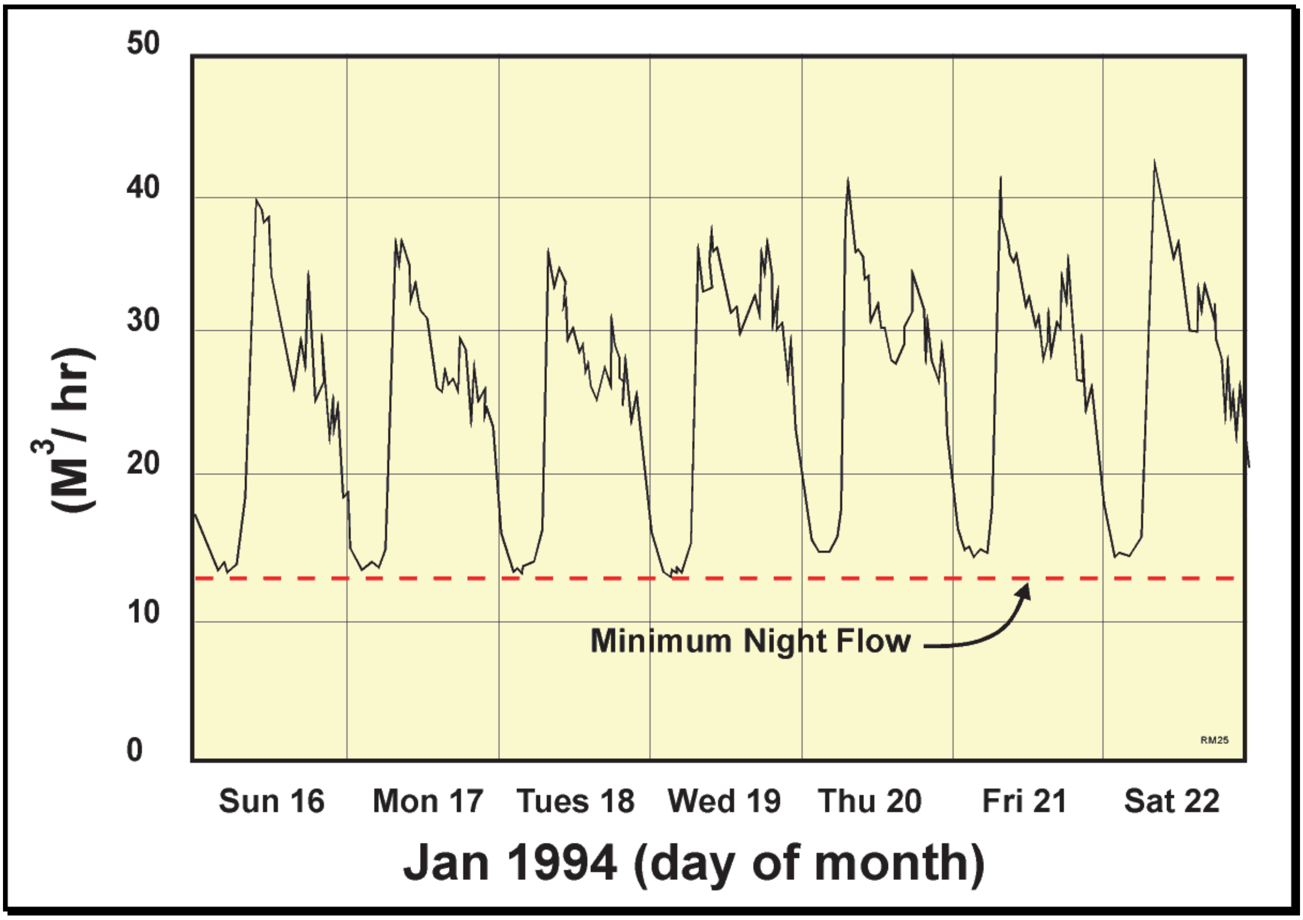


Figure 30: Typical flow logging for zone showing minimum night flow

Having logged a zone meter in order to establish the minimum night flow, it is then necessary to figure out what it all means. The key issue is to establish whether or not the zone has a problem or if it is healthy and has no problems. In order to achieve this objective, a very simple and pragmatic approach was developed using the Burst and Background Estimate (BABE) methodology whuch was originally developed by the UK water industry to assist managers in identifying and controlling leakage. In this approach, the minimum night flow is considered to consist of three main components namely :

- Normal legitimate night use
- Background losses
- Burst pipes

This breakdown is shown in **Figure 31** from which it can be seen that the normal use and background losses have been further divided into smaller components each of which can be estimated using some simple and basic assumptions that tend to be surprisingly close to what is found in the field. The bottom line is that the normal night use and background leakage can be estimated for any specific zone, and the burst leakage is the unknown variable that must be determined. After logging the flow into a zone for a few days or weeks, the component of night flow due to bursts can be determined by simply subtracting the background leakage and normal night use from the measured minimum night flow.

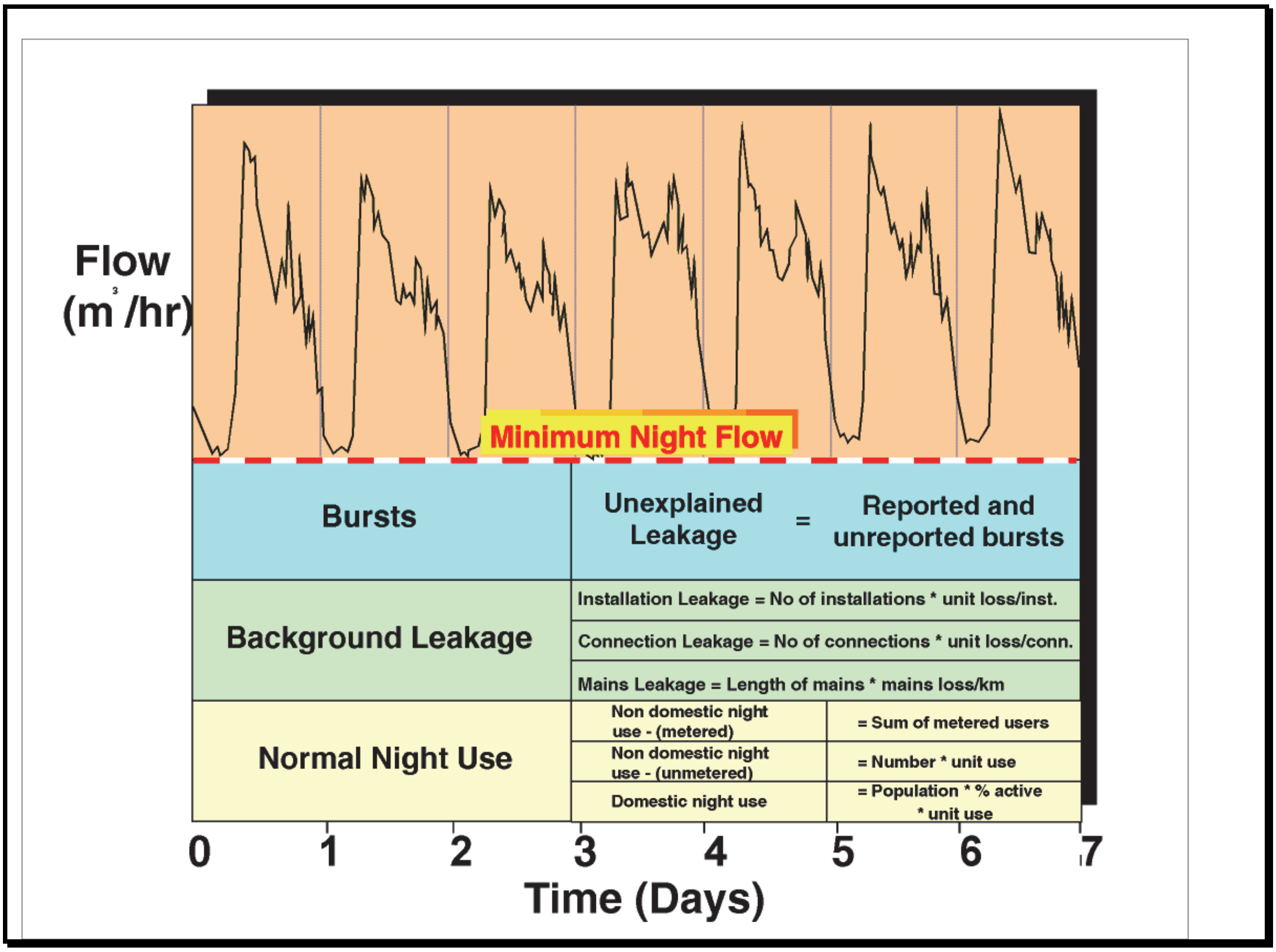


Figure 31: Interpretation of the minimum night flow

5.2.1 Normal night use

The expected legitimate water use in a zone cannot be measured accurately every evening since it comprises a large number of small users – sometimes more than 2 000. It is impractical to try and measure the use for each small user during the period of the minimum night flow analysis. Instead, the expected normal night use is estimated based on certain norms and variables that have been refined over the years through practical research around the world.

For the purpose of the analysis of the minimum night flow, the expected normal night use is split into three components namely:

- Normal domestic night use – mainly toilet flushing
- Small non-domestic night use such as hotels and garages etc.
- Larger users such as hospitals or factories etc. (recorded individually)

5.2.2 Normal domestic night use

Normal domestic night use represents the water used during the night in a household and is predominantly due to toilet use. Use of water for making coffee or tea represents a very small portion of the overall household use and is effectively ignored. In some areas of South Africa, garden watering or the filling of swimming pools may be of importance; however, in most cases such water use is minimal between the hours of 00:00 and 04:00 when the night-flow monitoring is undertaken.

Experience in various parts of the world has shown that approximately 6% of the population are active during each hour and that the water used per toilet flush is in the order of 10 litres. The normal household night use is therefore easily estimated from the product of the active population and the average use per hour.

Normal night use = 6% of population * 10 litres per hour

This may seem over simplistic which is true, however, it usually provides a reasonable estimate of what to expect in an area and will most likely err slightly on the high side. It should be noted that in areas with high internal plumbing losses, the water being "used" at night in the households will be much higher than the estimated normal night use. If this is the case, the analysis of the minimum night flow will suggest very high burst leakage – much of which will in fact be internal household leakage. The purpose of the analysis is to identify if something is wrong and if the assessment shows that there is very high burst leakage, then it must first be checked if in fact the leakage is burst leakage or a combination of burst leakage and household leakage. Checking the sewer flows will often provide an indication of the household leakage.

5.2.3 Small non-domestic night use

The small non-domestic night use is more difficult to evaluate and depends, to a large extent, on the type of businesses (if any) operating in the zone. The assessment is not ideally suited for industrial areas or residential areas which have a high component of industrial use at night. Although each small non-domestic user is metered individually it is again impractical to record each of the meters during the night flow exercise. Instead, the users are lumped into various categories and a typical night use is assumed for the group. For example, there may be several all-night garages or all-night cafes where the unit use is relatively small although when added together the total use may be significant. A range of typical night use values for various different commercial enterprises has been produced based on extensive studies undertaken overseas and some guidelines are provided in the SANFLOW user-guide.

5.2.4 Large non-domestic users

In some zone metered areas, it is often found that there may be one or more large water consumers whose consumption can have a significant influence on the night flow analysis. In such cases it is necessary to meter such consumers individually to determine how much water has been used during the night flow exercise. Only one or two such consumers would reside within a specific zone and therefore they can easily be checked during the night to assess exactly how much water they consume during the period of minimum night flow. Consumers falling into this category would include airports, large hotels, breweries, swimming pools, etc.

5.2.5 Background leakage

Background leakage is the cumulative leakage from all relatively small leaks in the reticulation system. Such leaks occur from valves, joints, hydrants, stop-taps, meters, dripping taps, toilet cisterns, roof tanks etc. Individually such leaks are generally uneconomic to find and repair with the result that background leakage is accepted as a fact of life in all water reticulation systems within certain limits.

In general, background leakage can be split into three main components namely:

- Background leakage from each km of mains
- Background leakage from each connection
- Background leakage from each property

5.2.6 Background leakage from mains

There will always be some background leakage from any distribution system, some of which occurs from the water mains. Small leaks often occur at the pipe joints or from small cracks or holes in the pipes and the magnitude of the leakage is dependent upon the condition of the infrastructure and of course the operating pressure. For the purpose of the assessment of the minimum night flow, all leakage parameters used in the calculation are based on a standard operating pressure of 50m. When assessing the expected level of background leakage from systems operating above or below this pressure, the calculated background leakage must simply be adjusted upwards if the pressure is greater than 50m and adjusted downwards if it is operating below 50m. The adjustment for pressure is fully discussed in the SANFLOW User Guide and is not repeated in this report. Typical background leakage rates for normal diameter water mains suggest average values of around 40 litres/km of mains per hour. A new pipeline may have lower leakage, sometimes even below 20 litres/km /hr while older pipelines can have much higher leakage rates of 100 litres/km /hr or even higher.

5.2.7 Background leakage from connections

Poor workmanship coupled with general wear and tear often results in leaks from pipe connections. In general, we usually work on the basis of one pipe connection to each property although in many systems a single connection can sometimes be used to supply multiple properties. This issue has been discussed and debated at many venues and in the view of the author, it is appropriate to assume that the number of connections or “equivalent connections” is equal to the number of properties except in cases of apartments where the actual number of connections should be used. Connection leakage is considered as the leakage occurring from the connection at the water main to the water meter at the property or to the property boundary in cases where no meters exist. In most water distribution systems, the connection losses are often the major source of loss from the system. For most purposes, a value of 3 litres per property per hour can be used which will provide a reasonable estimate of the expected background property leakage.

5.2.8 Background leakage from properties

The third and final component of background leakage used in the calculation reflects the property leakage for each property after the consumer meter – as opposed to the previous component, which relates to leakage on the connection pipe before the customer meter. This component is intended to allow for some leakage on the pipe from the meter to the property and also some leakage inside the property. Under normal circumstances, an allowance of 1 litre/property per hours is appropriate.

A common criticism of this component-based methodology is often raised concerning areas where the most significant source of leakage is from the plumbing fixtures inside the properties. This has been mentioned previously but as it is such an important issue it deserves further explanation.

In South Africa, household leakage is often the most serious leakage issue in the zone and the household leakage can dominate the whole water balance and therefore also the minimum night flow. In such cases, the household leakage will not be close to 1 litre/property per hour but may be several hundred litres per property per hour. In such cases, all of the other components of the minimum night flow analysis are irrelevant and the analysis with suggest that there is a huge burst problem. On closer examination, it will be found that there is no sign of such high burst leakage and from experience, the individual looking at the analysis results will often be able to confirm that the problem is most likely inside the properties. In reality, this is not a difficult issue to identify and in cases where household leakage is found to be the problem, it will usually be so significant and clear cut that there is no question about where the problem lies.

5.2.9 Calculation of unexplained bursts

Having measured or estimated the various components of normal night use and background night use, the two figures are added together and then subtracted from the measured minimum night flow. The difference is the unexplained losses that are attributable to either unreported bursts or to errors in the assumptions made during the calculation.

To demonstrate the analysis of a minimum night flow using the Burst and Background Estimate procedures, it is easier to make use of a simple example. In this example a case will be used where the average zone night pressure is at 50m which is the base pressure where no pressure correction factors are required. The basic information required for the calculation is provided in **Table 2**

Table 2: Basic information needed for MNF analysis

Description	Value
Length of mains	9 300 m
Number of connections	600
Number of properties	672
Estimated population	3 000
Average zone night pressure (AZNP)	50 m
Measured minimum night flow (MNF)	14.4 m^3/h
Background losses from mains	40 l/km/h
Background losses from connections	3 l/connection/h
Background losses from properties	1 l/connection /h
% of population active during night flow exercise	6%
Quantity of water used in toilet cistern	10 l
Number of small non-domestic users	30
Average use for small non-domestic users	50 l/h
Use by large non-domestic users	1.2 m^3/h

Table 2 also includes the various default parameters that are normally used to calculate the background leakage and the normal night use as mentioned previously. Having established the default loss parameters it is now possible to estimate both the normal night use and the background leakage. The respective calculations are provided in

Table 3 and **Table 4.**

Table 3: Estimate of normal night use

Description	Calculation	Value
Domestic night use	3 000 @ 6%/h @ 10 l	1.8 m^3/h
Small non-domestic use	30 @ 50 l/h	1.5 m^3/h
Large non-domestic use	1 @1.2 m^3/h	1.2 m^3/h
Total normal night use		**4.5 m3/h**

Table 4: Estimate of background leakage

Description	Calculation	Value
Mains losses	9.3 km @ 40 l/km/h	0.37 m^3/h
Connection losses	600 @ 3 l/connection/h	1.80 m^3/h
Property losses	672 @ 1 l/property/h	0.67 m^3/h
Total background leakage at 50 m pressure		**2.84 m^3/h**

Pressure correction factor	$(50/50)^{1.5}$	1.00
Total background leakage at 50 m pressure		**2.84 m^3/h**

It should be noted that a pressure correction factor is indicated in the above table. In the case of this example the operating pressure is known to be 50m, which is considered to be the standard pressure. At standard pressure, no pressure corrections are required and it can be seen that the pressure correction factor is calculated to be 1.0 (i.e. no change). The topic of pressure correction is discussed in the SANFLOW User Guide (WRC, 2001).

Now that the two main night time water use components have been estimated, it is possible to calculate the difference between the measured minimum night flow and the expected legitimate night time use.

Table 5 provides the calculation that identifies the level of unexplained leakage in the given zone metered area.

Table 5: Estimate of burst leakage

Description	Value
Expected background leakage	2.84 m^3/h
Expected normal night use	4.50 m^3/h
Total expected night use	**7.34 m^3/h**
Measured minimum night flow	14.40 m^3/h
Unaccounted-for leakage (14.40 – 7.34)	**7.06 m^3/h**

As can be seen from the table, it is estimated that in this example the unexplained leakage is in the order of 7 m^3/h. The remainder of this Annexure is devoted to the interpretation of various real logging results to demonstrate the value of such information.

5.3 Calculation of unavoidable annual real losses (UARL)

The procedure to estimate the unavoidable annual real losses (UARL) was developed by Lambert during the period of the International Water Association's Task Force on Water Losses. The methodology is described in a paper in AQUA (Lambert et. al., 1999) and basically involves estimating the unavoidable losses for three components of infrastructure, namely:

- Transmission and distribution mains (excluding service connections);

- Service connections, mains to street/property boundary;
- Private underground pipe between street/property boundary and customer meter.

In South Africa, the third of these components can normally be ignored since customer meters are located close to the edge of the street.

The parameters used in the calculation of the losses are indicated in **Table 6**. From this table it can be seen that the one variable common to all elements is pressure. This is also the one variable that is normally excluded from most commonly used leakage performance indicators such as percentage, leakage per connection per year and leakage per km of mains per year, etc.

Each of the elements in **Table 6** can be allocated a value appropriate to infrastructure in good condition, operated in accordance with best practice, based on the analysis of data from numerous systems throughout the world. The results are provided in **Table 7**.

The parameter values indicated in **Table 7** include data for minimum background loss rates and typical burst frequencies for infrastructure in good condition, and for typical average flow rates of bursts and background leakage at 50m pressure. The average duration assumed for reported bursts is based on best practice worldwide. The average duration for unreported bursts is based on intensive active leakage control, approximating to night flow measurements once per month on highly sectorised water distribution systems.

Table 6: Parameters required for calculation of UARL

Component of Infrastructure	Background Losses	Reported Bursts	Unreported bursts
Mains	Length Pressure Minimum loss rate/km*	Number/year Pressure Average flow rate* Average duration	Number/year Pressure Average flow rate Average duration
Service connections to street/property line	Number Pressure Minimum loss rate/conn*	Number/year Pressure Average flow rate* Average duration	Number/year Pressure Average flow rate Average duration
Service connections after street/property line	Length Pressure Minimum loss rate/km*	Number/year Pressure Average flow rate* Average duration	Number/year Pressure Average flow rate Average duration

These flow rates are initially specified at 50m pressure

Table 7: Parameter values used to calculate UARL

Component of Infrastructure	Background Losses	Reported Bursts	Unreported Bursts
Mains	20 * ℓ/km.h	0.124 bursts /km.yr at 12 m^3/h per burst* average duration of 3 days	0.006 bursts /km.yr at 6 m^3/h per burst* average duration of 50 days
Service connections to street/property line	1.25* ℓ/conn.h	2.25/1000 connections.yr at 1.6 m^3/h per burst* average duration of 8 days	0.75/1000 conn.yr at 1.6 m^3/h per burst* average duration of 100 days
Unmetered service connections after street/property line	0.50*ℓ/conn.h per 15m length	1.5/1000 connections.yr at 1.6 m^3/h per burst* average duration of 9 days	0.50/1000 conn.yr at 1.6 m^3/h per burst* average duration of 101 days

**** These flow rates are initially specified at 50m pressure***

Assuming a simplified linear relationship between leakage rate and pressure, the components of UARL can be expressed in modular form, for ease of calculation, as shown in **Table 8**. Sensitivity testing shows that differences in assumptions for parameters used in the 'Bursts' components have relatively little influence on the 'Total UARL' values in the 5th column of **Table 8**.

Table 8: Calculated components of UARL

Component of Infrastructure	Background Losses	Reported Bursts	Unreported Bursts	Total UARL	Units
Mains	9.6	5.8	2.6	18	l/km mains/day per m of pressure
Service connections to street/property line	0.60	.04	0.16	0.8	l/connection/day / m of pressure
Unmetered Service connections after street/property line	16.0	1.9	7.1	25	l/km underground pipe/day/metre of pressure

NOTE: the UARL losses from Unmetered Service Connections after the street/property line can be ignored in the South African context, as all customers are metered and these meters are located close to the street/property line. The losses from the service connections (main to meter) tend to dominate *the calculation of UARL in most parts of South Africa, except at low density of connections (less than 20 per km of mains)***.**

Based on the figures provided in **Table 8**, the calculation of the UARL can be expressed as follows:

$$\textbf{UARL} = (18 * Lm + 0.80 * Nc + 25 * Lp) * P$$

Where:

UARL	=	Unavoidable annual real losses (ℓ/day)
Lm	=	Length of mains (km)
Nc	=	Number of service connections (main to meter)
Lp	=	Length of unmetered underground pipe from street edge to customer meters (km)
P	=	Average operating pressure at average zone point (metres)

Example: A system has 114 km of mains, 3 920 service connections all located at the street property boundary edge and an average operating pressure of 50 m.

UARL	=	(18 * 114 + 0.80 * 3920 + 25 * 0) * 50 ℓ/day
	=	102 600 + 156 800 ℓ/day
	=	259 400 ℓ/day
	=	259.4 m^3/day
	=	94 681 m^3/year
	=	66 litres/connection/day

5.4 Calculating average zone pressure

As pressure is a key parameter in modelling and understanding leakage, it is worthwhile to adopt a systematic approach to its calculation. The procedure is as follows:

- For each individual zone or sector, calculate the weighted average ground level;
- Near the centre of the zone, identify a convenient pressure measurement point which has the same weighted average ground level – this is known as the average zone point (AZP);

- Measure the pressure at the average zone point, and use this as the surrogate average pressure for the Zone.

AZP pressures should be calculated as average 24-hour values; night pressures at the AZP point are known as AZNPs (average zone night pressures).

For relatively small sectors with well-sized mains in good condition, with reliable information on average zone inlet pressure at a single inlet point, preliminary estimates of average pressure can be made as follows:

- Measure or estimate the average pressure at the Inlet Point to the zone or sector, and estimate the average zone pressure, taking into account the difference in datum levels between the Inlet Point and the AZP point, assuming no frictional loss.

To obtain average pressure for aggregations of zones, calculate the weighted average value of pressure using (preferably) number of service connections in each zone.

If a network analysis model is not available, the approach used in **Section 5.5** should be followed. If a network analysis model is available, follow the approach in **Section 5.6**.

5.5 Average zone pressures where no models exist

5.5.1 Calculate weighted average ground level for each sector

Split the distribution system conceptually into sectors defined by pressure management zones or district metered areas; break the system down into the smallest areas for which average pressures may be required.

Next, for each sector, superimpose a plan of the distribution system over a contour map, preferably with 2-metre intervals. Allocate to each contour band one of the following infrastructure parameters (parameters are in order of preference):

- Number of service connections;
- Number of hydrants;
- Length of mains.

Whichever infrastructure parameter is selected, the weighted average ground level can then be calculated as shown in **Table 9.**

Table 9: Example calculation of weighted ground level

Contour Band (m)			Number of Service Connections	Contour Band Mid Point * Number of Connections
Lower Limit	Upper Limit	Mid-Band		
2.0	4.0	3.0	18	54
4.0	6.0	5.0	43	215
6.0	8.0	7.0	40	280
8.0	10.0	9.0	41	369
10.0	12.0	11.0	63	693
12.0	14.0	13.0	70	910
14.0	16.0	15.0	41	615
16.0	18.0	17.0	18	306
18.0	20.0	19.0	12	228
20.0	22.0	21.0	8	168
22.0	24.0	23.0	3	69
24.0	26.0	25.0	0	0
Totals			**357**	**3907**

Weighted Average Ground Level = 3907 / 357 = 10.9 m

5.5.2 Measure or calculate average zone pressure

Obtain the average pressure at the Average Zone Point in the following manner:

- Measurements over a period of one year;
- Preliminary estimate based on average inlet pressure adjusted for difference in ground levels between inlet point and AZP.

Example: In the sector data in **Table 9**, the average inlet pressure at a service reservoir is 1.5m below the overflow level (which is 65m above sea level).

- The average inlet pressure is (65.0 – 1.5) = 63.5m above sea level;
- The ground level at the AZP point is 10.9m above sea level;
- The average zone pressure is therefore estimated as (63.5 – 10.9) = 43.6m.

5.5.3 Calculate weighted average pressure for aggregation of zones

The weighted average pressure for sectors of a distribution system, consisting of aggregations of individual zones with different average pressures, is obtained by calculating a weighted average for all the zones. If possible, the number of service connections should be used as the weighting parameter (if not available, use length of mains or number of hydrants). An example calculation is shown in **Table 10**.

Table 10: Example calculation of weighted ground level

Area Reference	Number of Service Connections	Average Zone Pressure	Number of service Connections * AZP
A	420	55.5	23 310
B	527	59.1	31 146
C	443	69.1	30 611
D	1352	73.3	99 102
E	225	64.1	14 423
F	837	42.0	35 154
G	1109	63.7	70 643
H	499	56.3	28 094
I	1520	57.0	86 640
	6932		**419 122**

Weighted average pressure for the whole area = 419,122/6932 = 60.5 m

5.6 Calculating average zone pressure where a model exists

Because each node of a network analysis model will normally have a number of properties, a datum ground level, and an average pressure value, it is relatively easy to calculate the weighted average pressure for all the nodes in the model (or any defined part of it).

It is worthwhile, however, to ensure that a weighted average ground level and an AZP point are defined for each zone/sector, as these will occasionally be required for test measurement.

6 APPENDIX C: LIVE LOGGING OF BULK METERS

In the previous section, the value of logging pressures and flows was discussed in which many examples were provided to highlight specific problems that can be identified through the accurate interpretation of the logging results. Most of these logging results are recorded at bulk management meters. Such management meters are not used to generate revenue for the municipality but are used to help in the management of the reticulation system. In order for bulk management meters to be useful, they must be properly designed and must record the flows accurately. Most management meters are located inside a meter chamber which records the flow entering a specific area. The issue of sectorising has already been discussed to highlight the need for proper zones to be established so that the bulk management meters can be used to monitor the minimum night flow entering an area from which the leakage can be estimated.

Bulk management meters are not only used to analyse the minimum night flow, however, they are also used to monitor the day-to-day operation of a zone. Through the availability of low cost GSM and GPRS based loggers, it is now possible to identify problems almost immediately as they occur. The Internet has opened up a new medium for monitoring system flows, and water managers can now examine what is going on in their system from virtually anywhere that has access to Internet communication. This includes smart phones, iPads and other similar devices.

The value of such information is best explained through the use of some real examples which have been taken from the City of Tshwane's real-time logging database.

Figure 32 provides a graph taken directly from the City of Tshwane's real-time logging system, which shows the flow recorded at the New Eersterus PRV installation, which contains both a meter and a PRV. The flow at the meter indicates that a serious leak of approximately 30 m^3/hr has developed between the 14th and 15th of December 2012. This leak was identified by the municipality within a day and took a further 2 days to find and one day to repair. It was an interesting leak in that it occurred in an area of open ground where a construction vehicle had accidently knocked over a hydrant which had broken and was leaking into the open ground. No damage had been caused and there was no evidence of this leak from the nearby road as the water was flowing directly into a small stream. Without the monitoring system in place, this leak would not have been identified for weeks if not months. After finding the source of the leak, it was quickly repaired and the minimum night flow returned to the levels prior to 14 December.

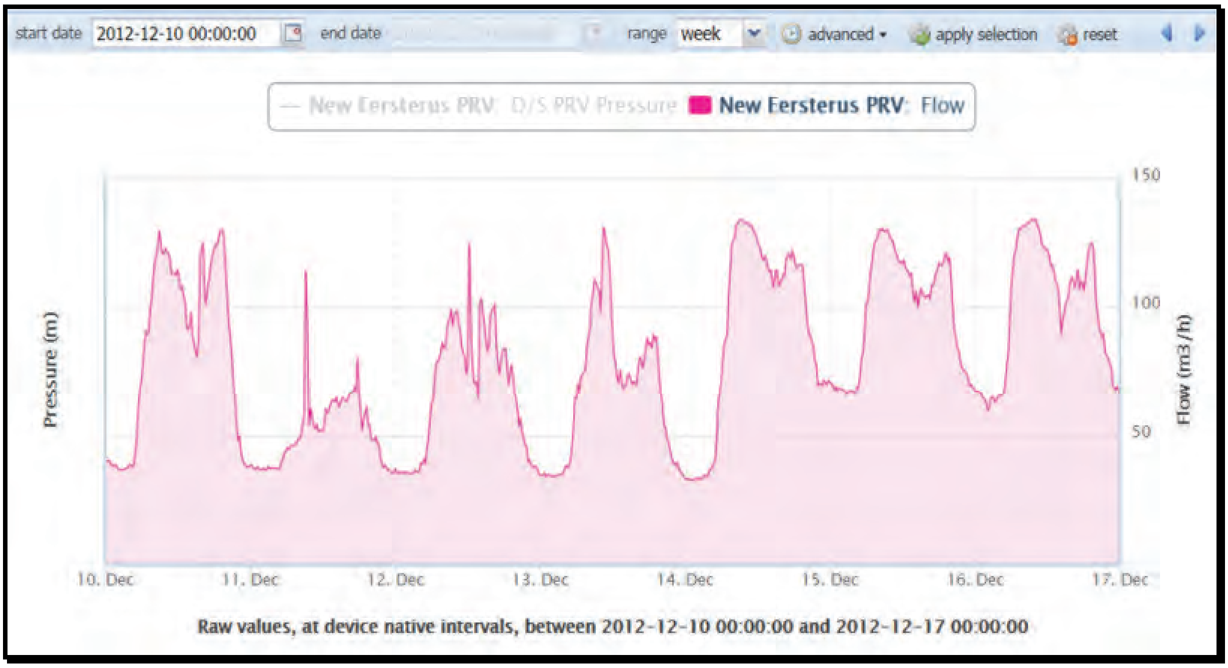


Figure 32: Zone with sudden rise in leakage (courtesy City of Tshwane)

The second example, also from the City of Tshwane shows a leak of 40 m^3/hr that developed between 4th and 5th April 2012 near the Nellmapius area as can be seen in **Figure 33**. In this case, the leak was identified from the real-time logging system and took almost a week to find the leak and complete the repair. It is important to appreciate that not all leaks create problems or are immediately visible.

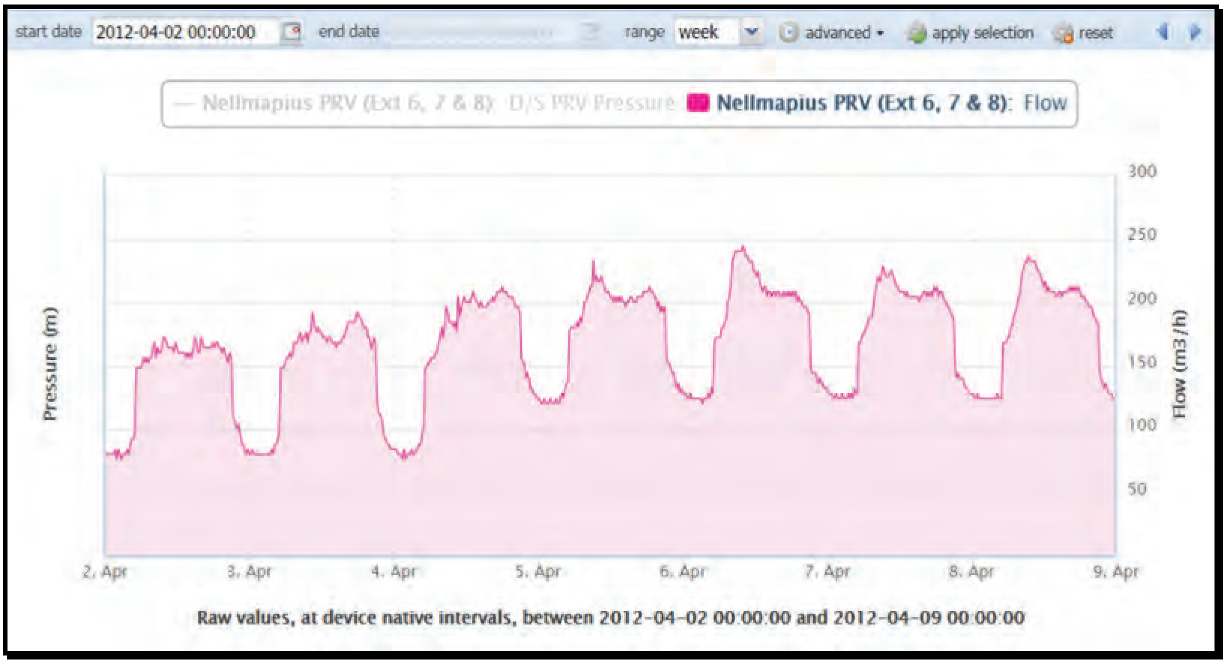


Figure 33: Zone with significant leakage (courtesy City of Tshwane)

This specific leak was caused by the end cap on a 150mm-diameter pipe being damaged by a contractor once again in an area of open field where the water from the leak ran into a stream. The contractor did not inform the municipality of the damage caused to the pipe and it would have run indefinitely had the municipality not been actively monitoring the flow into the area.

The third example shown in **Figure 34** was identified through an alarm from the logger as soon as the leak occurred. As can be seen this was an enormous leak of around 1 000 m^3/hr from a 300mm-diameter pipe which had completely failed at high pressure.

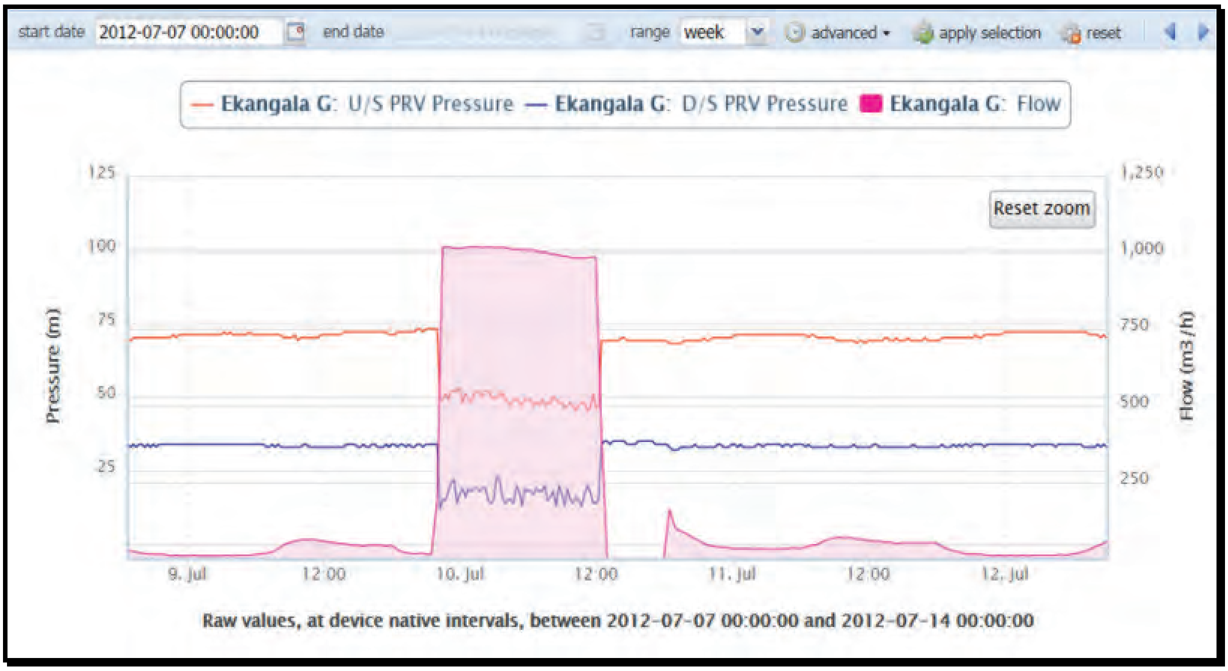


Figure 34: Massive leak and subsequent repair (courtesy City of Tshwane)

Managers at the City of Tshwane were in contact with the office personnel at the Ekangala local depot within minutes of the leak occurring. It was a difficult leak to isolate and repair but was repaired within hours of it occurring. This leak did cause serious damage to the surrounding area and would have been identified with or without the real-time monitoring system. The system does, however, provide a record of the leak from which the volume of water lost and time taken to find and repair the leak can be established.

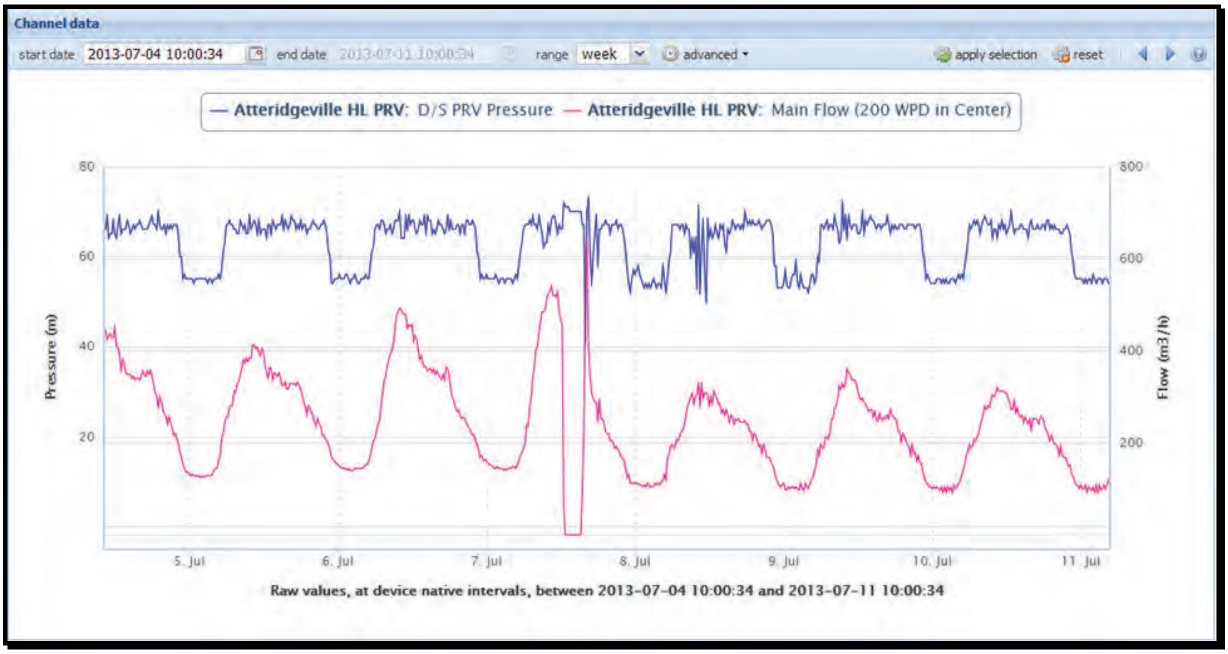


Figure 35: Leak and repair in Attridgeville (courtesy City of Tshwane)

The graph shown in **Figure 35** highlights a leak that had been running for some time and was repaired on 7 July after which the minimum night flow dropped by about 50m^3/hr. This is a very sizeable leak, but had not been reported and was eventually identified and repaired by Tshwane Water Department. It is important to appreciate that it is not only small leaks but also large leaks that can remain undetected for many days, weeks, months or even years.

The logging result from another project where real-time logging has proved very beneficial and highly cost effective is shown in **Figure 36**. This logging result may at first glance seem very complicated, but is in fact the flow and pressure logging into a large industrial factory. The results clearly highlight the impact of tank filling where a pump switches on and off throughout the day which, in turn, creates large pressure variations throughout the network in the vicinity of the factory. Such fluctuations should be discouraged where possible through the introduction of a more consistent supply regime.

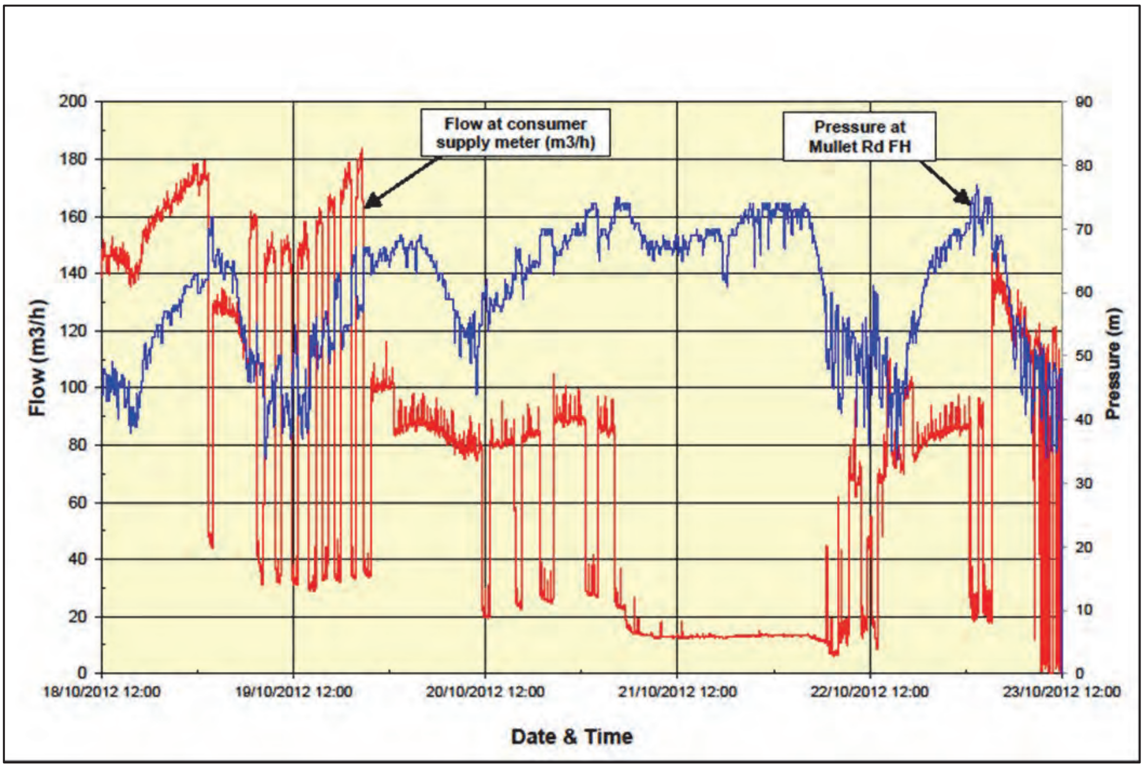


Figure 36: Logging result from large industry (courtesy Ekurhuleni Metro)

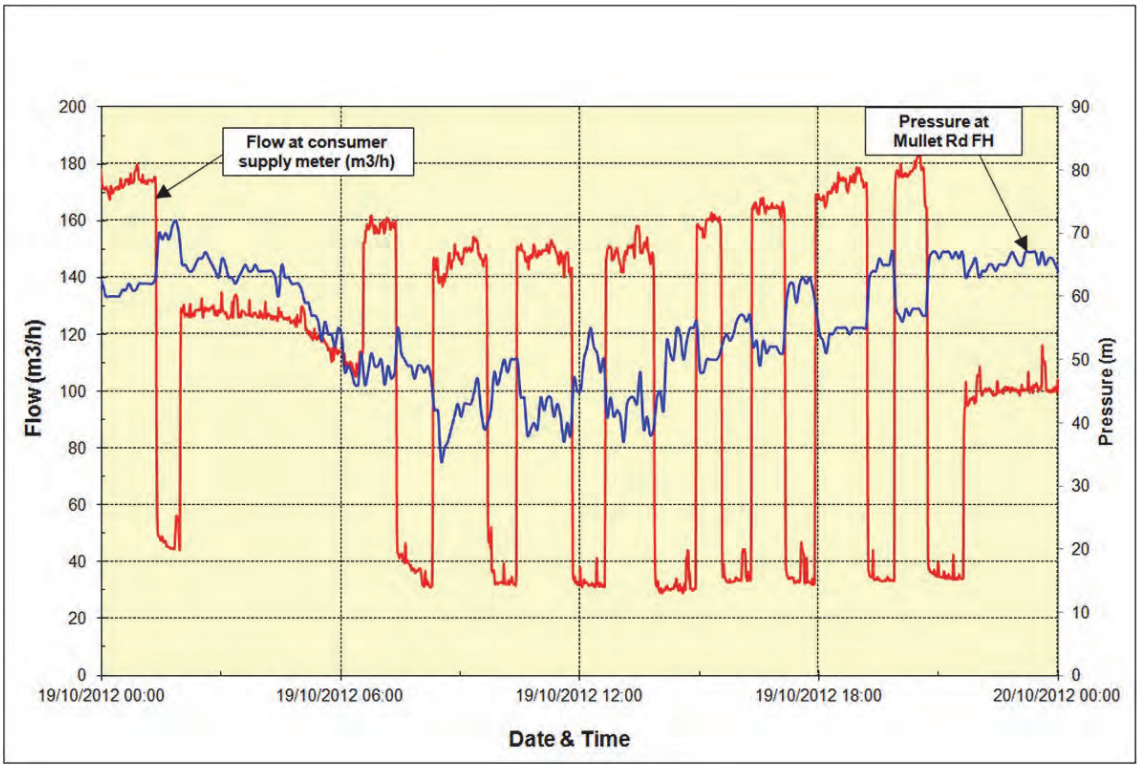


Figure 37: Detailed logging result from large industry (courtesy Ekurhuleni Metro)

The graph shown in **Figure 38** provides an example of a relatively small leak which had been running inside a townhouse complex for many months. The residents of the complex had approached the municipality for assistance regarding their monthly water bill which had been slowly increasing over a period of two years. After installing the logger at the water meter to the complex, it was clear that there was a serious leak on the system of almost 15m^3/hr.

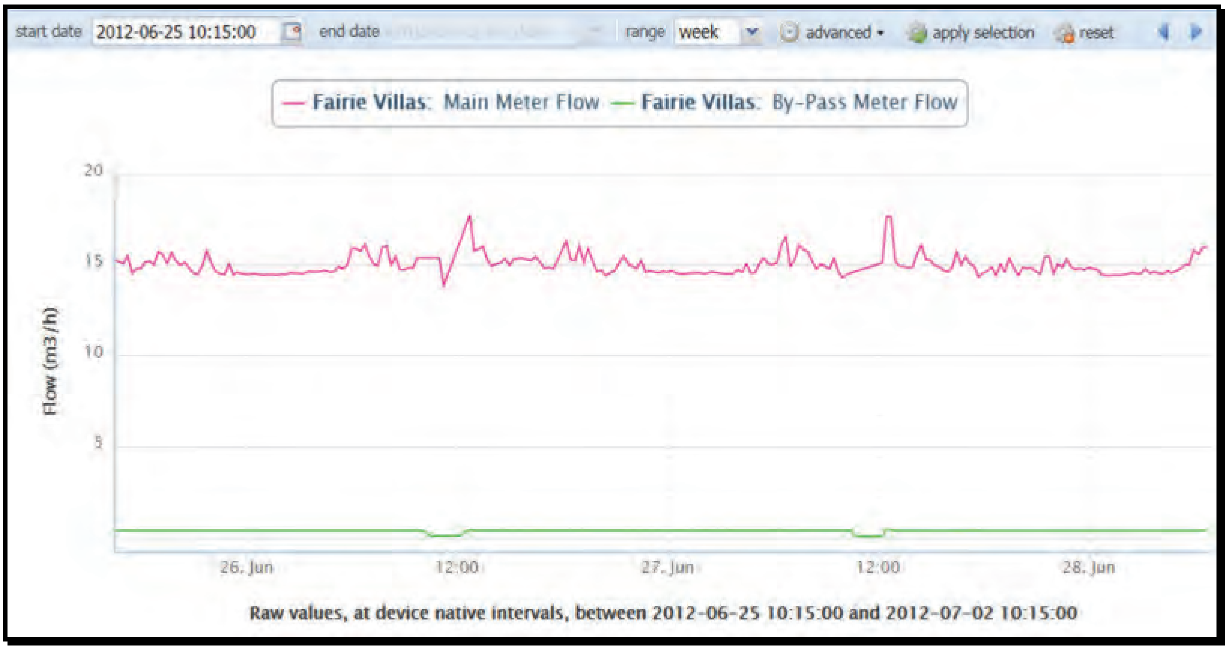


Figure 38: Example of leak in townhouse complex (courtesy City of Tshwane)

Within a weekthe leak had been found and repaired and the water consumption dropped back to normal levels with a minimum night flow of only 0.3 m^3/hr as can be seen in **Figure 39**.

This particular example highlights the benefits for such logging on bulk meters into large consumers – in this case a townhouse complex with approximately 50 properties. It can be seen that there are two flow records on each graph – one shown in pink and the other in green. This is typical of a combination meter where there are two water meters in a single housing and therefore the logger must record both meters. The pink flow record represents the flow through the main meter while the green line represents the flow through the low-flow by-pass meter. In **Figure 38**, it can be seen that virtually the full flow passes through the main meter which is due to the large leak. In **Figure 39**, it can be seen that the low-flow by-pass mater is again functioning properly and taking up much of the flow during periods of lower demand.

Another nice example demonstrating the value of continuous monitoring of the bulk water use into an industrial facility is shown in

Figure 40**,** which clearly highlights a leak running at approximately 2m^3/hr. Without continuous monitoring, the industrial user would simply have received an abnormally large water account and would not have realised the extent of the leak which is quite clear from the graph. This leak represents a loss or rather an additional expense of almost R17 000 per month to the industrial user based on the current industrial water tariff of R12/m^3 as applicable in the supply area.

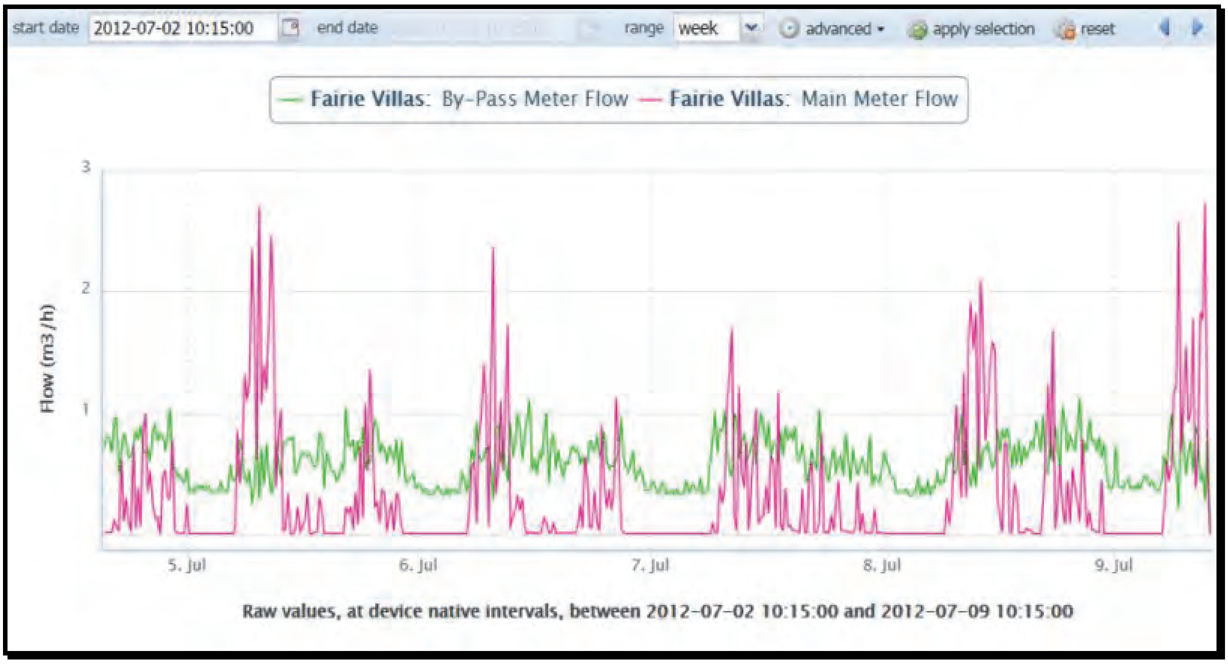


Figure 39: Post repair graph for townhouse complex (courtesy City of Tshwane)

Figure 40: Bulk consumer leak (courtesy Ekurhuleni Metro)

7 APPENDIX D: DESIGN OF PRV AND METER INSTALLATIONS

7.1 Introduction

When designing a PRV or meter installation, there are certain key issues that must always be considered and many others that will simply help to create an installation that will be easy to operate and maintain in future. Unfortunately the general practice in many parts of South Africa is to award tenders for the design, construction and commissioning of an installation based on price, which invariably leads to a poor design and, in some cases, designs which are simply not functional.

Although this section is aimed mainly at the design of bulk management meter installations, it is often worthwhile to consider whether or not a PRV may be used to control the pressure in the zone at some point in future. If such pressure management is a possibility, then it can often be worthwhile to design the installation in such a manner that it can accommodate a PRV in future. This will obviously have certain financial implications since the installation will be larger and therefore more expensive; however, it will be much cheaper than building a 2nd installation at a later date and trying to cut in a new PRV. If the pipework is already designed to allow for the future installation of a PRV, it will be a relatively simple operation to install the PRV when necessary.

When designing any installation, whether it is for a meter or a PRV, or both, there are a few items to consider namely:

- What type of meter will be used;
- Will a PRV be installed either as part of the installation or later;
- What type of isolating valves will be used;
- Is a by-pass required?
- Are air-valves required?
- Are thrust blocks required?
- Should the chamber be watertight or not?
- Are strainers required?

7.2 Basic dimensions of the chamber

When designing a meter or PRV chamber it is important to allow sufficient space inside the chamber to assemble the various components and to allow for maintenance. Ideally, headroom of over 1.8m should be provided to allow those servicing the fittings or monitoring the installation to stand upright. In addition, there should always be sufficient clearance between the walls and floors from the pipework to allow the use of a spanner without hitting the chamber. In cases where a strainer is used, care should be taken to ensure that the strainer itself can be replaced. Many chambers exist where the strainer is almost tight against the floor which creates problems when it must be cleaned or replaced. As a general rule of thumb, it is recommended that there is clearance of at least 300mm in each direction from any part of the pipework to the walls or floor of the chamber. Where possible the chamber should protrude above the surrounding ground to prevent water flowing into the chamber during a storm. Ventilation should be provided to prevent the build-up of potentially toxic gasses at the bottom of the chamber as these can be lethal and in some cases such gases have no smell. Unfortunately, providing ventilation ducts in some parts of South Africa creates unwanted access to the chamber and some municipalities tend to seal the chambers completely with thick concrete slabs. In such cases, care must be taken when entering the chamber to ensure that there are no toxic gasses, and the maintenance team should always involve more than one person.

7.3 Management meters

When selecting the appropriate meters for a new installation, every water-supply manager will have their own preference based on their experience and knowledge of their system. There is no simple answer to this question, and what is appropriate for some installations may well not be appropriate for others. A full and very comprehensive description of flow metering is provided in the WRC publication by Van Zyl (2011) and such detail is not repeated in this chapter. A few practical issues, however, are discussed which are worth noting based on practical experience gained from the assessment of various meter and PRV installations from many parts of the world. When selecting the type of meters to use, several issues must be considered described in more detail below.

Magnetic flow meters tend to be more accurate than mechanical meters although they are generally more expensive especially on the smaller sized meters below 300mm. On the larger sizes, the magnetic flow meters can become cheaper than large mechanical meters, and in many networks there is often a combination of mechanical meters on the smaller pipes and magnetic flow meters on the larger pipes. There are various requirements regarding the length of straight pipe before and after each type of meter and the supplier will provide details of these requirements for each meter. On paper, there is often little doubt that magnetic flow meters are the better option, even when dealing with some of the smaller sizes. The reality of the situation, however, is often quite different due to the fact that the magnetic flow meters use some form of power supply – either mains or battery operated. In both cases, the power supply can be vandalised or stolen. In South Africa and many other parts of the world, the issues of theft and vandalism sometimes result in the use of mechanical meters just to ensure that there is some form of metering in place.

Mechanical meters are more susceptible to water quality problems and a strainer is always recommended which should be placed before the meter. The meter must always be placed after the strainer and before the PRV (if any). The length of straight pipe before and after the meter should be sized in accordance with the meter manufacturer's recommendations and the meter should be placed horizontally unless the meter manufacturer specifies otherwise. Mechanical meters will slow down with age and become less accurate with the result that they must be replaced or re-calibrated at regular intervals – often every few years. In cases where a network has been drained and the water supply is re-instated, great care must be taken to recharge the system slowly or there is a risk that the sudden supply of water to the empty network will damage the mechanical meter. Magnetic flow meters are less sensitive to such issues although they can be at risk from lightning strikes which have little effect on the mechanical meters.

7.4 Strainers

Strainers are often seen as a nuisance as they can become blocked with dirt and stones and must then be opened up and cleaned. For this reason, many water suppliers prefer not to include them in their installations because they just create problems. Unfortunately, **they are essential** and should be included in any meter or PRV installation to trap dirt and foreign objects that have managed to get into the pipework.

The strainer is effectively a protection device to prevent the meter and/or PRV from being damaged should a stone or foreign object get into the pipeline.

Figure 41: Typical strainer before a PRV

In the case of a magnetic flow meter, a strainer may not be necessary since there are no moving parts that can be damaged by foreign objects. If there is any possibility of installing a PRV downstream of the meter, however, it is always advisable to include a strainer in the installation. There are a number of different designs of strainers and the size of hole in the mesh should be carefully considered. If it is too small, it may create too much resistance to the flow of water in the pipe and in extreme cases can be ripped out of the body of the strainer fitting and itself become a foreign object – see **Figure 42**. If the holes in the strainer are too large, they may allow small stones to pass through the strainer which are large enough to cause damage to the downstream valves and or meters. A properly sized and designed strainer will provide the protection required without compromising the flow through the installation. Sometimes, the strainers will catch only small pieces of rust and pipe lining while in other cases they may catch some serious stones which would cause significant damage to the downstream valves and meters as shown in **Figure 43**.

Figure 42: Damaged strainer due to small hole diameter and very high flows

Figure 43: Some rocks caught by strainer

Where possible, strainers should be fitted with quick-fit pressure measurement couplings (see **Figure 44)** front and back to allow the pressure drop through the strainer to be checked during normal maintenance procedures. If the strainer is blocked, there will be a significant pressure drop through the strainer which should then be opened up and thoroughly cleaned. The installation shown in **Figure 44** also shows that the strainer must be a sufficient distance from the floor of the chamber to enable the strainer to be extracted for cleaning in such cases where the strainer must be removed from the bottom.

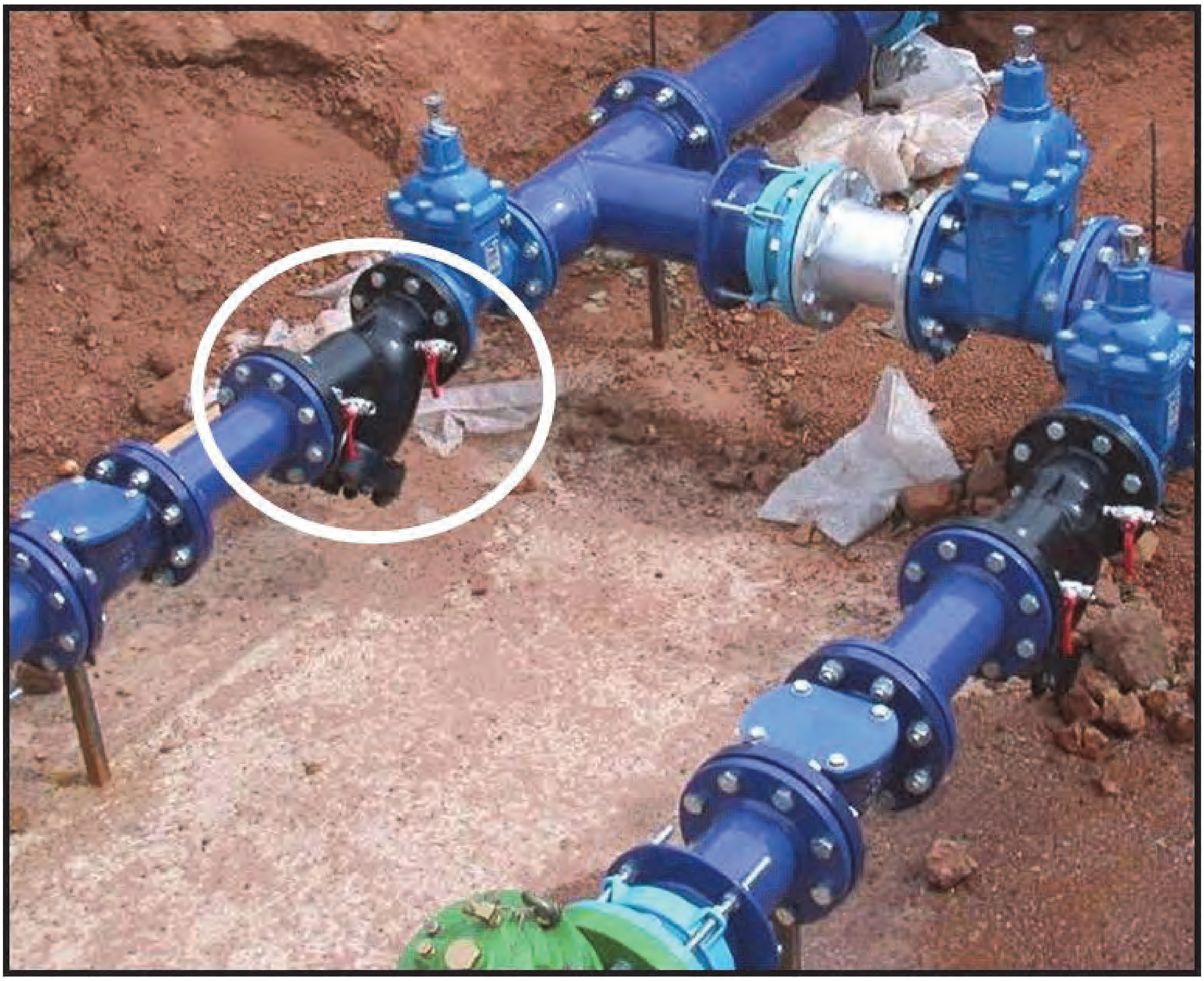


Figure 44: Typical strainer in PRV chamber under construction

7.5 Air valves

Air in pipelines can create serious problems and if there are no air valves in the pipeline, it can lead to a serious burst pipe and in other cases where the pipeline is being drained; it can lead to the collapse of the pipeline if it experiences significant negative pressure. A typical air-valve installation is shown in **Figure 45,** which shows the air-valve located above the collector pipe. It should be noted that the collector pipe is simply a section of larger diameter pipe sitting below the air-valve, which allows greater opportunity for any air in the pipeline to be captured. Without this section of larger diameter pipe, the air may be swept past the air-valve and will build up somewhere downstream of the valve and eventually create a burst pipe. Air-valves should always be open and the small gate valve shown just below the air-valve should only be closed to service the air-valve. Air-valves are an essential component of any reticulation system and must be in good working order at all times.

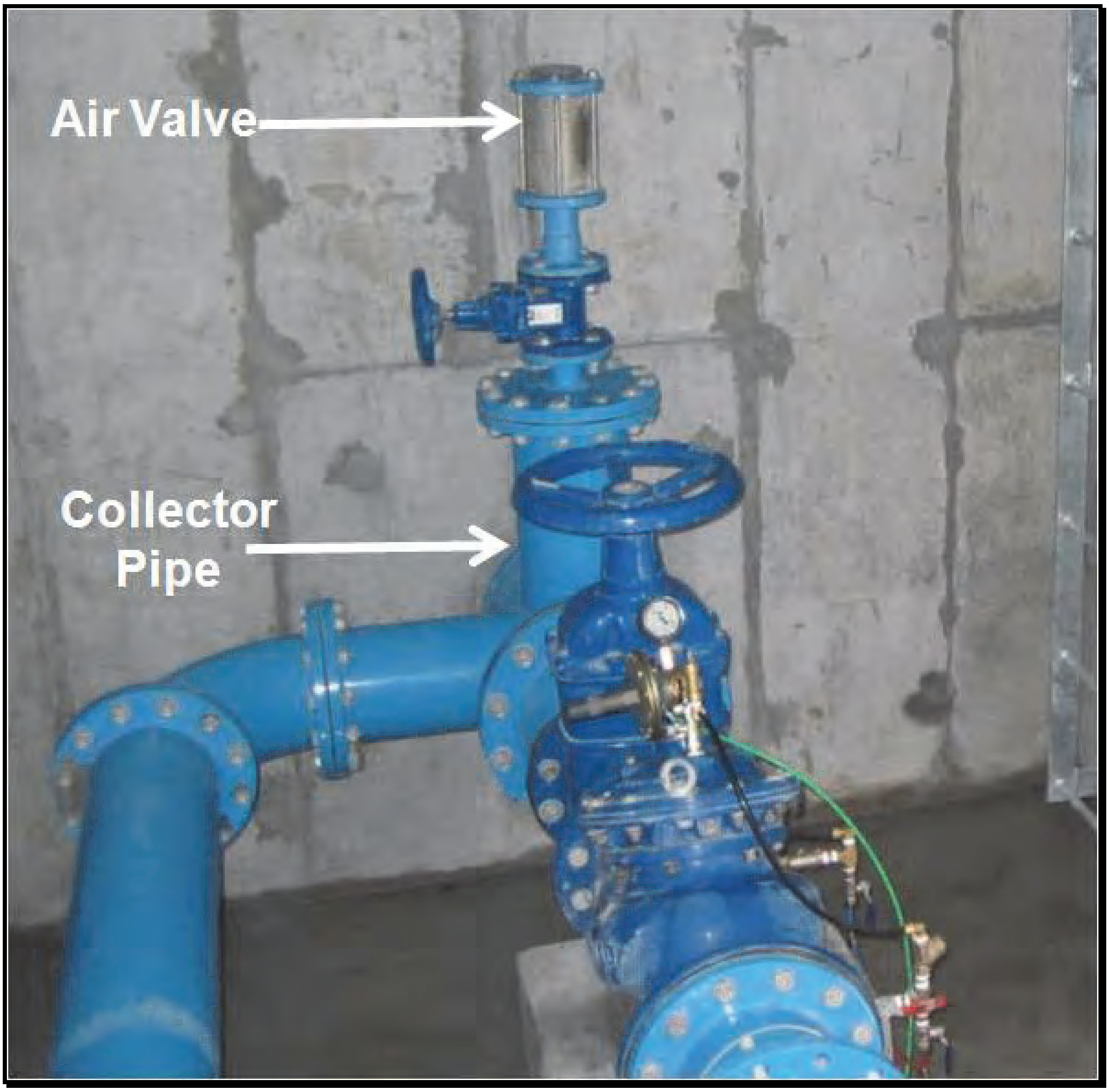


Figure 45: Typical air-valve and collector pipe

7.6 Pressure relief valves

Pressure relief valves are sometimes used in installations to protect against the failure of the main PRV. In the event that the main PRV fails, the pressure into a zone would normally increase and may cause serious damage. As protection against such failure, it is sometimes useful to include a pressure relief valve, which allows the excess pressure to dissipate at the installation before entering the network. There are a number of different design approaches to this as shown in **Figure 46** and **Figure 47.**

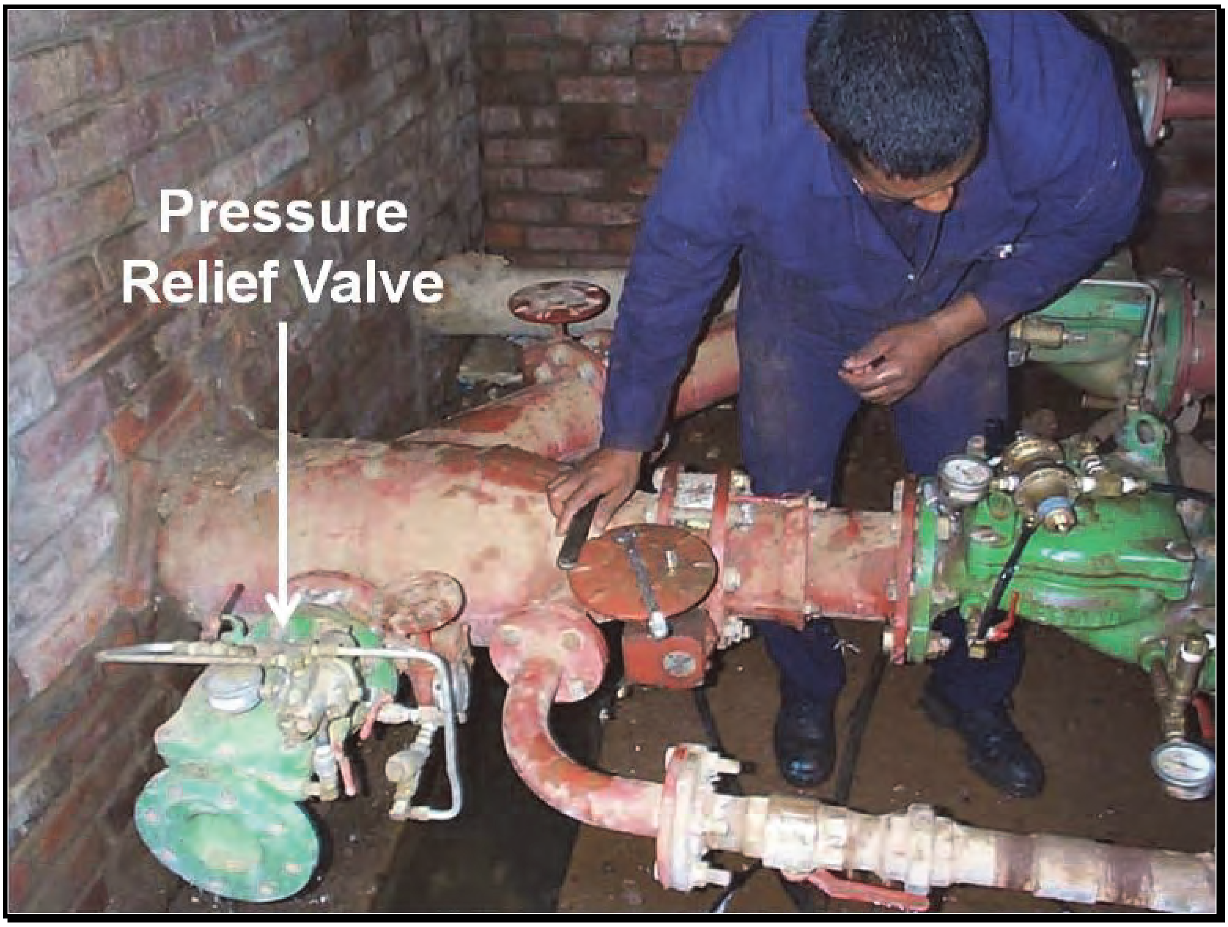


Figure 46: Typical pressure relief valve (without surface release)

Figure 46 is not an ideal example since if the main PRV should fail; the emergency pressure relief valve will open up and immediately flood the chamber. On the positive side, it will prevent full system pressure from entering the zone and once the chamber has flooded, the water will start to appear above surface and will be reported by someone as a major leak.

The example in **Figure 47** is a better design in that the emergency pressure relief valve has been connected to a pipe which will take the water to the surface. In the event of a failure, the pressure relief valve will open up, and there will be a serious flow of water above ground that will also appear to most observers as a major leak. In both cases the pressure relief valve protects the downstream pipework in the event of the main PRV installation failing.

Figure 47: Pressure relief valve with surface outlet (courtesy City of Tshwane)

7.7 By-passes

Whether or not to include a by-pass is often a question of budget as well as the preference of the municipality. A by-pass is used to re-direct the water around the main installation in the event of maintenance being undertaken on the main installation or a leak developing somewhere on the main pipework. If a by-pass is not provided, the supply into the zone must be cut off whenever maintenance is provided. In some cases this is not a problem and the occasional shut-off may not be a problem. In other cases, it may not be acceptable to cut off the water supply into the area due to certain key water users such as a hospital or some large industry. A by-pass is often used in these cases to provide a continuous supply even in the event of maintenance being undertaken on the installation. **Figure 48** shows a typical small installation where it was not considered necessary to include a by-pass.

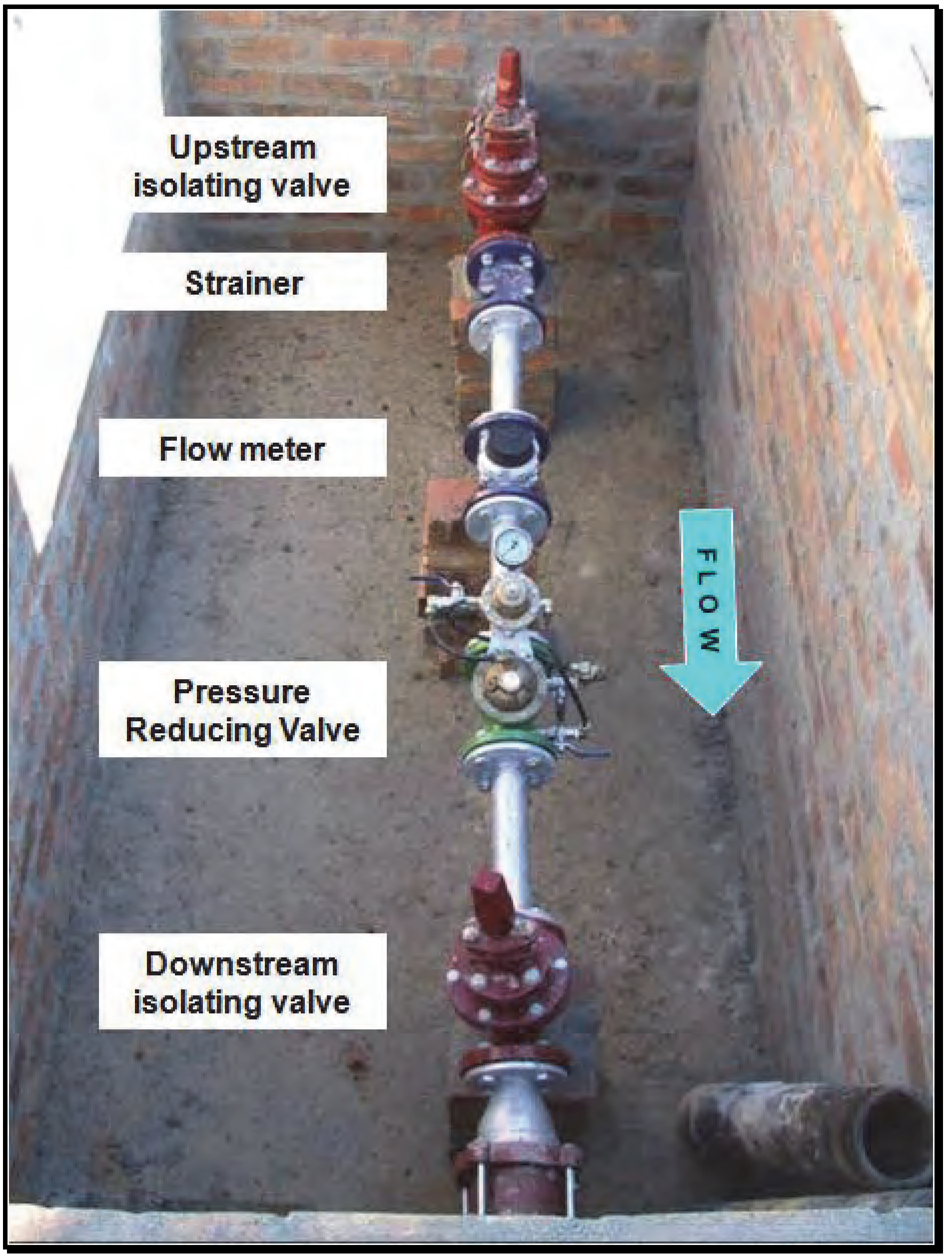


Figure 48: Small installation without by-pass

Figure 49 shows a typical design for a PRV installation which includes a service by-pass. Once again, there are many possible design options and much depends upon the available budget as the client's requirements. In the case of a PRV installation which has a service by-pass (as opposed to a low-flow by-pass), some clients will insist that the by-pass is fitted with its own PRV and meter despite the fact that the by-pass will only ever be used for an hour or two every year. In cases, where the by-pass does not have its own PRV, care must be taken to ensure that full system pressure does not enter the zone during scheduled maintenance. Normally, the by-pass is significantly smaller in diameter than the main supply pipe, which will help to reduce the pressure into the zone during the maintenance work. If necessary, the flow through the by-pass can be throttled to some extent by only partially opening the gate valve on the by-pass. Using a gate valve to throttle flow is very poor practice and is not recommended; however, in an emergency it is preferable to supplying full pressure into a zone which could create bigger problems.

7.8 Puddle flanges

Another important aspect of the design shown in **Figure 49** is the use of the two "Puddle Flanges" which secure the pipework to the chamber walls and eliminate the need for thrust blocks in the chamber. This design is often used in cases where the chamber is constructed of reinforced concrete and would not be recommended in cases where brickwork is used. The puddle flanges provide a solid restraint for the pipework within the chamber which effectively eliminates the need for any thrust blocks inside the chamber since the whole chamber effectively becomes a large thrust block. For the pipework to move the whole chamber will have to move, and this form of construction is ideally suited to large installations.

In addition, the installation shown in **Figure 49** makes use of two dismantling joints, one on the main pipework just after the meter and the other on the by-pass. Such joints are not favoured by all municipalities, and it is important to ensure that they are strong enough to handle the upstream pressures. This is discussed further later in this section.

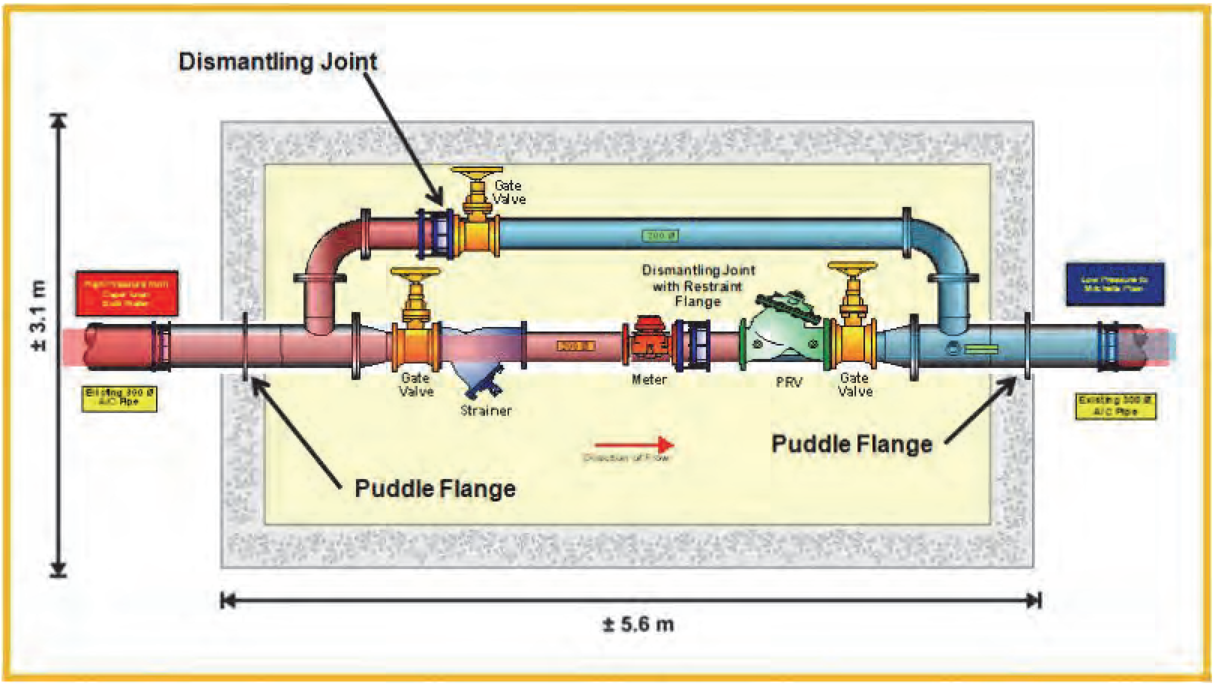


Figure 49: Typical PRV installation with service by-pass

The actual installation as built from **Figure 49** is shown in **Figure 50.** Due to the use of the puddle flanges the whole installation is effectively rigid and does not require any further thrust blocks. The installation will be completed by the inclusion of the missing air valve which has yet to be added and the various temporary supports will be replaced by permanent concrete blocks to provide basic support.

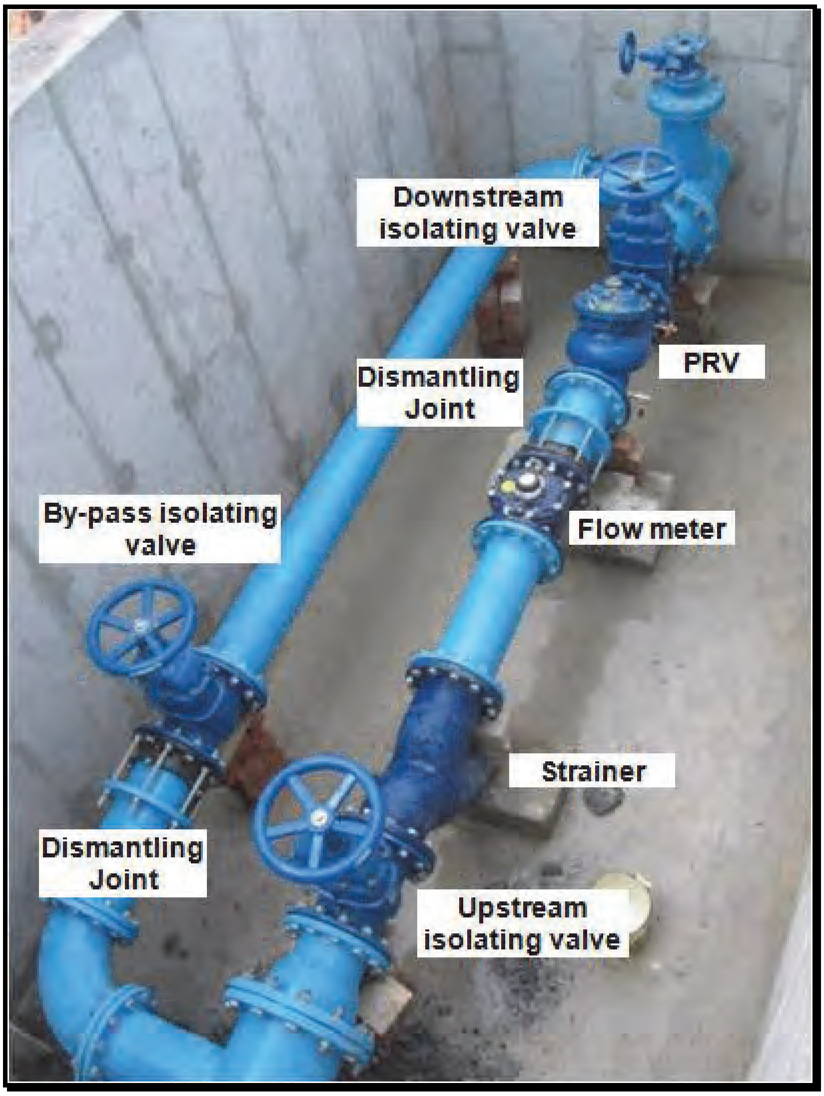


Figure 50: Actual installation shown in previous figure

In some cases, it may not be possible or desirable to have the main pipework in line with the existing pipework, and the installation itself can be constructed on what would normally be considered the by-pass while the main line actually becomes the bypass. Such an installation is shown in **Figure 51,** which was designed to the municipality's requirements where they wanted to ensure that the main line could be re-instated sometime in future if needed without creating any additional head loss. This type of installation may be useful in cases where the future growth in the area is unknown and there is a possibility that sometime in the future, the full system pressure may be needed. Had the installation been based on the previous design shown in **Figure 49**, there would have been some head loss through the installation, even if the PRV was fully opened or removed completely due to the various restrictions in the pipework.

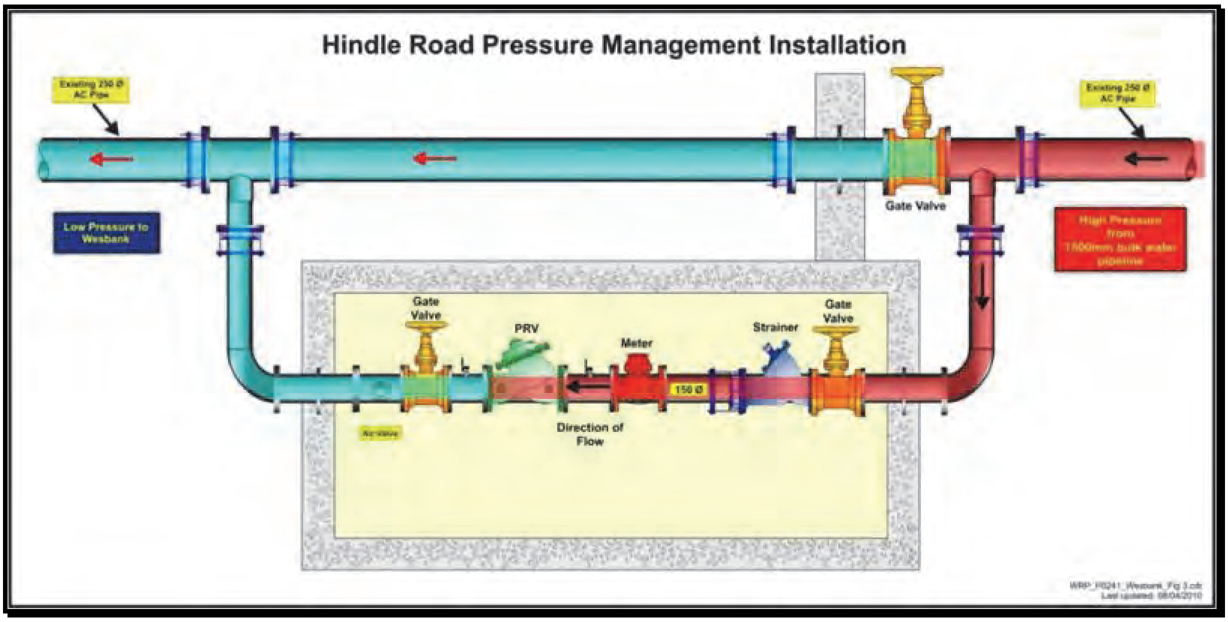


Figure 51: Alternative design where main line remains intact

7.9 Dismantling joints

Dismantling joints are usually included in most installations to enable the components of the installation to be removed where necessary for replacement or maintenance purposes. Some clients do not like to use dismantling joints in such installations due to the possibility of the joint failing under extreme pressure conditions. In some parts of Johannesburg for example, the dismantling joints have been replaced by sections of welded pipe. In such cases, the pipe must be physically cut if any component is to be replaced after which the cut section must be re-welded. This is a very secure approach but does require the use of cutting and welding equipment when any components are being replaced. If a dismantling joint is used and it is not installed properly, then any small movement can result in the pipework jumping out of the joint and creating a serious leak in the chamber. To prevent this from happening, it is recommended that all dismantling joints used in such installations should be fully restrained as shown in **Figure 52** and not simply the basic joints. **Figure 52** shows a typical dismantling joint installed in a high pressure PRV installation. As can be seen, the connecting pipework has been designed with a welded flange which is bolted to the flange of the strainer once the coupling has been tightened. Once all of the restraining bolts have been tightened, this joint cannot move and there is little possibility of any problems while allowing for the installation to be dismantled in future if necessary.

Figure 52: Flange adaptor with restrained dismantling joint (bolts not tightened)

While the restrained couplings are an acceptable design in any high pressure installation, the unrestrained couplings as shown in **Figure 53** can create problems and should not be used. The example shown in the figure is in an area that experiences very high pressures and the by-pass has no other form of restraint at either end. When the water is directed through the by-pass, the pipework can move as the pressure attempts to push the joint open. If the joint has been poorly fitted, there is real danger that it can open up suddenly – often with serious and potentially lethal consequences. It is therefore recommended that all dismantling joints used in high pressure installations should be fully restrained. In cases where the municipality opts to use the cut and weld approach, it is important to ensure that the weld inside the pipe does not rust as it will eventually become an area of weakness which can ultimately fail. Unfortunately, it is very difficult to prevent rusting of the joint inside the pipe and such joints will sometimes give problems.

Figure 53: installation with unrestrained coupling on by-pass

8 APPENDIX E: COST OF LEAKAGE

There is often little or even no appreciation of the value of water being lost through leakage. Before discussing how to get the basics under control it is perhaps useful to highlight the true value of water that is lost through visible leaks.

A few real examples are provided where logging results were used to confirm the actual volumes of water lost. For the purpose of this section a simplistic approach to the value or cost of water has been used, which it is acknowledged is not always applicable. The value of the water lost through the leak has been based on a unit cost of R5/m^3 which is a realistic 2013 bulk water cost in many parts of South Africa. It is however, less than half the normal commercial rate charged by most municipalities.

Figure 54: Large mains leak on 600mm-diameter main at 260m pressure

Value of water lost =	**± 200m^3/hr * ± 3hrs * R5 /m^3**	**= ± R 3 000**

The first leak shown in **Figure 54** is from a high-pressure, large-diameter transmission main, which was running at a pressure of ± 260m. This specific leak had a very high flow rate of ± 200m^3/hr and created a huge water feature which was obvious to all nearby residents. It was immediately reported to the water authorities and the pipeline was closed within 3 hours to allow the repair to be undertaken. Despite the fact that this leak was very large and created an impressive spectacle which was documented in the local newspapers, the value of the water lost through the leak was a modest R3 000.

Figure 55: Leak on 600mm-diameter main at pressure of 230m (courtesy N Meyer)

Value of water lost =	**± 300m^3/hr * ± 4hrs * R5 /m^3**	**= ± R 6 000**

The leak shown in **Figure 55** is from the same high pressure 600mm-diameter transmission main running at a pressure of ± 200m. This specific leak was caused by a construction team which damaged the top of the pipe with an excavator. This leak was measured from the logging results to be at a flow rate of ± 300m^3/hr and it was stopped within 4 hours and subsequently repaired.

Figure 56: Leak on 110mm-diameter uPVC main at ± 60m pressure

Value of water lost =	**± 20m^3/hr * ± 3hrs * R5 /m^3**	**= ± R 300**

The leak shown in **Figure 56** is from a medium-sized water main of 110mm diameter on a plastic uPVC pipe. This leak was highly visible and was immediately reported to the water supplier who reacted quickly to address the problem. The leak was repaired within 3 hours and the total volume of water lost was only ± 60m^3. Such leaks are often easily identified on the flow logging results for an area in cases where continuous logging is being maintained. Such logging results are useful in assessing both the magnitude of the leak as well as the total running time associated with the water loss.

Figure 57: Mains leak on 315mm-diameter uPVC pipe at ± 50m pressure

Value of water lost =	**± 40m^3/hr * ± 6hrs * R5 /m^3**	**= ± R 1 200**

The leak shown in **Figure 57** is from a larger water main of 315mm-diameter on a plastic uPVC pipe. The pressure within the reticulation system at this point was ± 50m, and it was estimated that the flow rate was ± 40m^3/hr. Due to the fact that this leak occurred in the early hours of the morning it was not reported for over 3 hours and as such ran for just over 6 hours before being repaired. The water lost is valued at approximately R1 200.

This example clearly highlights the importance of reporting and repairing leaks as quickly as possible. Just a 3-hour delay can result in the cost of the water losses doubling and if leaks are allowed to run for days, months or years, the financial consequences can be dramatic as the following examples will show.

Figure 58: Small connection leak on 25mm-diameter uPVC pipe at ± 50m pressure

Value of water lost =	**± 1m^3/hr * ± 3 months * R5 /m^3**	**= ± R 11 000**

The leak shown in **Figure 58** is from a 25mm-diameter uPVC connection pipe just before the meter. The pressure within the reticulation system at this point was ± 50m. This leak had a lower flow rate of only ± 1m^3/hr, but was not reported by the home owner and ran unchecked for more than 3 months. Although the flow from this leak is relatively small compared to those shown previously, the total volume of water lost through the leak far exceeds that from any of the previous examples. This once again highlights the significance of the "run-time" of the leak and the need to encourage all water users to report all leaks to the water supplier. The water supplier, in turn, must ensure that systems are in place to facilitate the reporting of all leaks and of greater importance to make sure that all reported leaks are repaired quickly and effectively. It is normal practice for a water supplier to have a target time of 24 hours within which to repair all reported leaks. If it is found that the average repair time is greater than 24 hours, it suggests that additional resources in the form of personnel and equipment may be required.

Figure 59: Hidden connection pipe burst on 25mm uPVC pipe at ± 60m pressure

Value of water lost =	**± 0.5m^3/hr * ± 3 years * R5 /m^3**	**= ± R66 000**

The leak shown in **Figure 59** is a real example of a 25mm-diameter uPVC connection pipe which was found to be leaking directly into a storm-water catch-pit. The pressure within the reticulation system at this point was ± 60m, and it was estimated that this leak had a flow rate of ± 0.5m^3/hr. Although the leak was relatively small, it was estimated by the water supplier that this leak had been running for more than 3 years.

This example once again highlights the importance of the leak "run-time" since despite the fact that the leak was the smallest of all leaks discussed in this section, the total volume of water lost through this leak was by far the highest. In this case, the water supplier did not undertake active leakage control measures at regular intervals and, therefore, such leaks could theoretically run indefinitely since they were not causing any visual flooding and the home owner was unconcerned about a slight drop in water pressure.

Figure 60: Leak on 63mm-diameter pipe that resulted in a R3.5 million loss

The final example presented is another real example of a leak detected during the auditing of an industrial area in Gauteng. In this particular case, the industrial premises had a connection which was metered; however, the meter had been buried for years and was not captured on the billing system. The 63mm-diameter uPVC connection pipe to a small block with two toilets had been damaged as shown in **Figure 60** and was leaking at a measured rate (as logged) of 25m^3/hr as can be seen in **Figure 61**. The volume recorded on the water meter which was 3 years old stood at over 600 000m^3 with a cost to the municipality of over R3 million. Had this water been sold to the industrial user, the cost would have been in excess of R6 million.

It was highly unfortunate that this leak flowed directly into a sewer as shown in **Figure 61** and therefore created no damage or visible water feature with the result that it remained undetected for over 3 years. If the municipality had not undertaken water audits on all of its industrial consumers, this leak would most likely still be running.

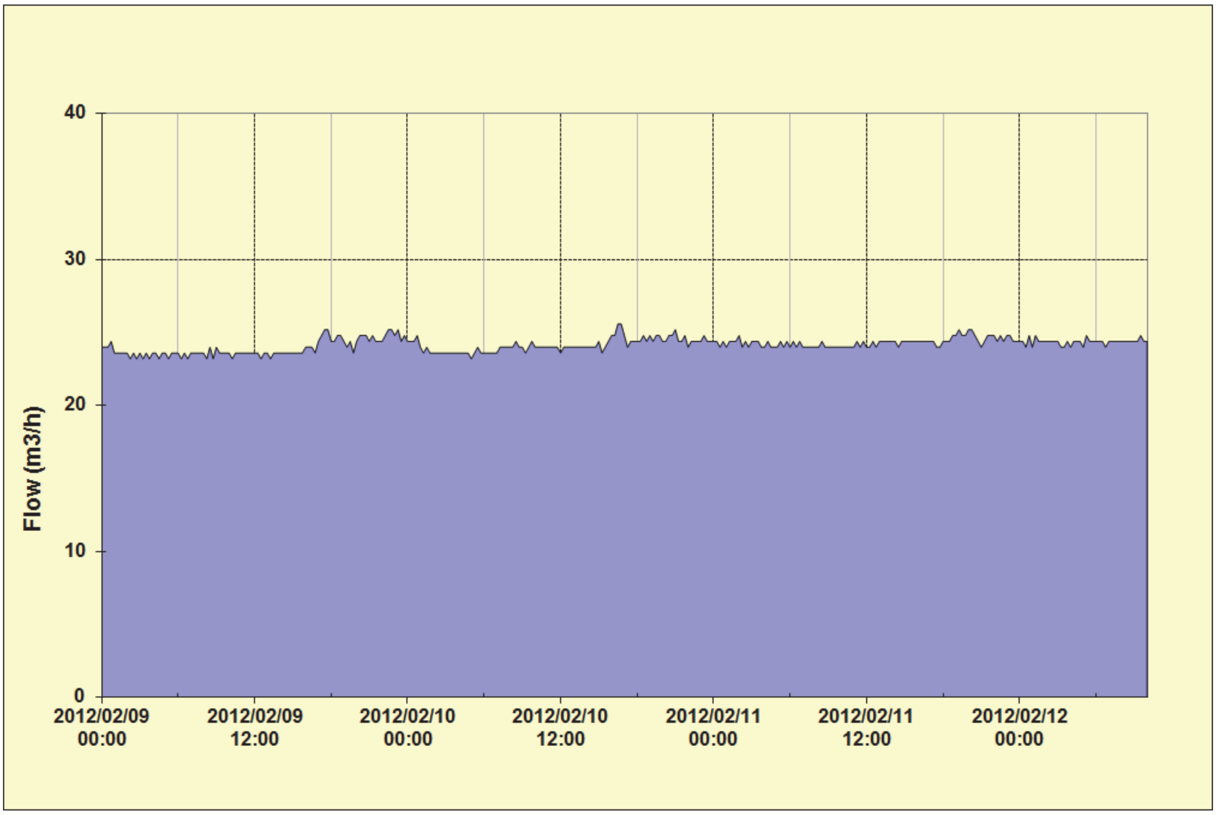


Figure 61: Leak on 50mm uPVC supply before repair

Figure 62: Leak on 63mm uPVC pipe flowing into stormwater manhole

The logging results after the repair of this specific leak are shown in **Figure 63,** which clearly highlights the significance of what was a relatively large leak that ran for a very long period of time. The direct cost of the water to the municipality was in excess of R3 million over a 3-year period. In summary, it is essential that municipalities deal with leakage in their systems and appreciate the value of the water that can be lost through even a small leak which is left unattended for months if not years. This is one of the most important and basic duties of all water providers – fix the visible leaks quickly even if they are considered to be small. A small leak running for a long period will almost certainly result in greater losses than a very large leak which is fixed within 24 hours.

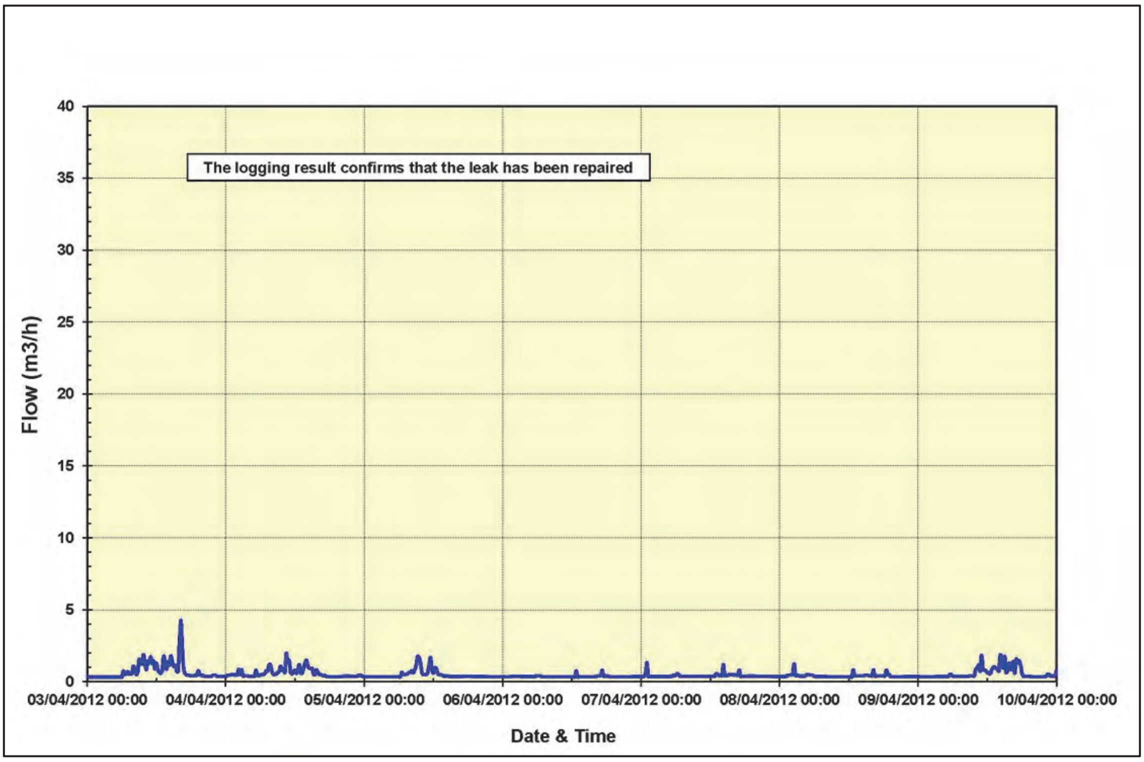


Figure 63: Logging results on 50 mm uPVC supply after repair

Value of water lost =	**± 24m^3/hr * ± 3 years * R5 /m^3**	**= ±R3 000 000**

It should be noted that the above calculation is based on the cost of water to the municipality and not the cost of water to the consumer, which would have been more than double if the sewage charge is also included.

9 APPENDIX F: VARIOUS FORMS OF ACTIVE LEAKAGE CONTROL

Active leakage control (ALC) is a multi-billion dollar industry worldwide and there are many large companies that specialise in developing and manufacturing various types of equipment to find leaks. Despite the claims of the various manufacturers, there is no "silver bullet" for leak location and no single piece of equipment that will find all the leaks in a particular reticulation system. In all cases, the most important factor is the skill of the operator. A skilful operator using the least expensive listening rod will find more leaks than a poor operator using the most expensive and sophisticated equipment available. There are so many new devices now available that it is impossible to try and describe them all in this book. In order to provide a broad overview of active leakage control, the following items will be discussed:

- Eyes and ears
- Listening rods
- Leak-noise correlators
- Step testing
- Ground penetrating radar
- Noise loggers
- Latest hi-tech equipment

A short description of each method is provided in the remainder of this section.

9.1 Eyes and ears

Before buying any leak location equipment, the first action that should be taken to address physical leakage is to visit the area and simply drive or walk around the area to gain a feeling of what is going on. If leakage is a serious problem, it will usually be quite evident unless it is inside the properties. Just walking down a few streets in an area will usually provide a good indication of whether or not it is necessary to purchase leak location equipment. In many leak reduction projects reviewed by the author, the purchase of leak location equipment is often one of the first items on the agenda and it can involve some very expensive equipment. In many of the projects, the equipment is purchased and never used. There are many cupboards and store rooms full of unused leak location equipment, much of which has been purchased at financial year end as a means of utilising an agreed budget. While, the purchase of leak location equipment is not necessarily to be frowned upon, it is important that the appropriate equipment is purchased and that it is used to find leaks.

If the initial visual inspection highlights a large number of clearly visible leaks which are running without being repaired, rather fix them first and only after the obvious leaks have been eliminated, should effort be placed on looking for leaks that have not come to the surface. In this regard, many WDM specialists from around the world continually quote the "fact" that 90% of leaks do not come to the surface and suggest that if you can see 10 on the surface, then there are another 90 that are hidden and finding them will require some leak location equipment. While this breakdown of visible and invisible leaks may be appropriate in some parts of the world, it is not appropriate in most parts of South Africa. Dolomitic areas may be the exception, but in general, the split between visible leaks and invisible leaks is not 10 to 90 and in many cases appears to be virtually the opposite. This observation will draw considerable criticism especially from those selling leak location equipment. The only way of determining the split is to undertake a pilot study in a small area before embarking on a city-wide leak location exercise. If the pilot project demonstrates that it is worthwhile searching for the hidden leaks then a full-scale leak location exercise can be initiated based on real information. To proceed with a full-scale project before checking the facts, may waste valuable resources.

In all cases, identifying and repairing the clearly visible leaks is always worthwhile, and should be the first action undertaken in any WDM programme. It should always be borne in mind that fixing leaks in a reticulation system will result in the system pressure increasing which, in turn, will push up the leakage through any existing leaks and cause new leaks to form. Any large-scale leak location and repair project should therefore be undertaken together with some form of pressure management where the system pressures can be reduced if necessary as the leaks are repaired. If the pressure is not managed properly, the system leakage will quickly revert to pre-leak repair levels and no benefit will have been gained.

9.2 Sounding (listening sticks and geophones)

Leaks make a noise as the water escapes through a hole or crack in the pipes, and it is this noise that leak detections teams search for in order to find the leaks. Some leaks make a loud noise which is relatively easy to find while others make only a slight noise which is not easy to find. The noise from the leak travels through the pipeline and can be picked up nearby using some form of listening device. On metal pipes the noise can sometimes be heard over 100m away while on plastic pipes it may disappear within a few meters, and cannot be picked up unless the observer is right on top of the leak. Large leaks often make less noise than smaller leaks and therefore the noise may not always reflect the magnitude of the leak creating it.

Before entering an area to search for leaks, it is first advisable to undertake some form of assessment to help identify areas where leaks are likely to occur. Monitoring the minimum night flow is an excellent approach as it tends to provide the real picture of what is going on in an area and can be used to quantify the likely leakage that will be found in the area. Similarly, "Step Testing" is also an excellent approach for identifying specific areas within a zone which have a leakage problem. Only after it has been established that there is a potential leakage problem in an area, should the "Sounding" exercise be undertaken. Sounding (see also **Section 2.5**) of a water distribution system is undertaken using a listening stick (**Figure 64**), which is placed against all valves and hydrants to detect noise emitting from possible leaks. The listening stick can be a simple "stick" with no smart electronic technology behind it or it can be a highly sophisticated electronic device that has many useful features to help the Leak Locator to find and pin-point the leaks. This approach will not identify the position of the leak but will normally indicate if there is a leak on a certain section of pipe.

Figure 64: Basic Listening Rod

Figure 65: Amplified Listening Rod

A Geophone (**Figure 65**) is an amplified listening rod, which comprises a very sensitive microphone, an amplifier and headphones. Water leaks are detected by listening for noises made in pipelines caused by water escaping through the wall of the pipe. Usually there are two types of microphone. The first is a wand-type microphone (or listening stick as shown in **Figure 65**) to permit contact with fittings such as valves and hydrants. The second type is a more sophisticated (and expensive) ground microphone, which is moved along the ground or road surface on top of the line of the pipe and is shown in **Figure 66**. The leak is pinpointed at the position of greatest noise intensity as detected by the ground microphone.

Figure 66: Full ground microphone kit

A simple Listening rod (**Figure 64**) with no electronics can cost as little as R1 000 or even less, depending on the make and quality. An "Amplified Listening Rod" can vary significantly in price, depending on the quality and the features provided. A high-quality unit without any special features will generally cost around R10 000 (**Figure 65**) and a more sophisticated unit with noise filters and extra "bells and whistles" can cost up to R20 000 (**Figure 66**). The units are designed to "pinpoint" leaks as the unit is moved over the pipeline and the position of maximum noise will generally indicate the position of the leak (**Figure 67**).

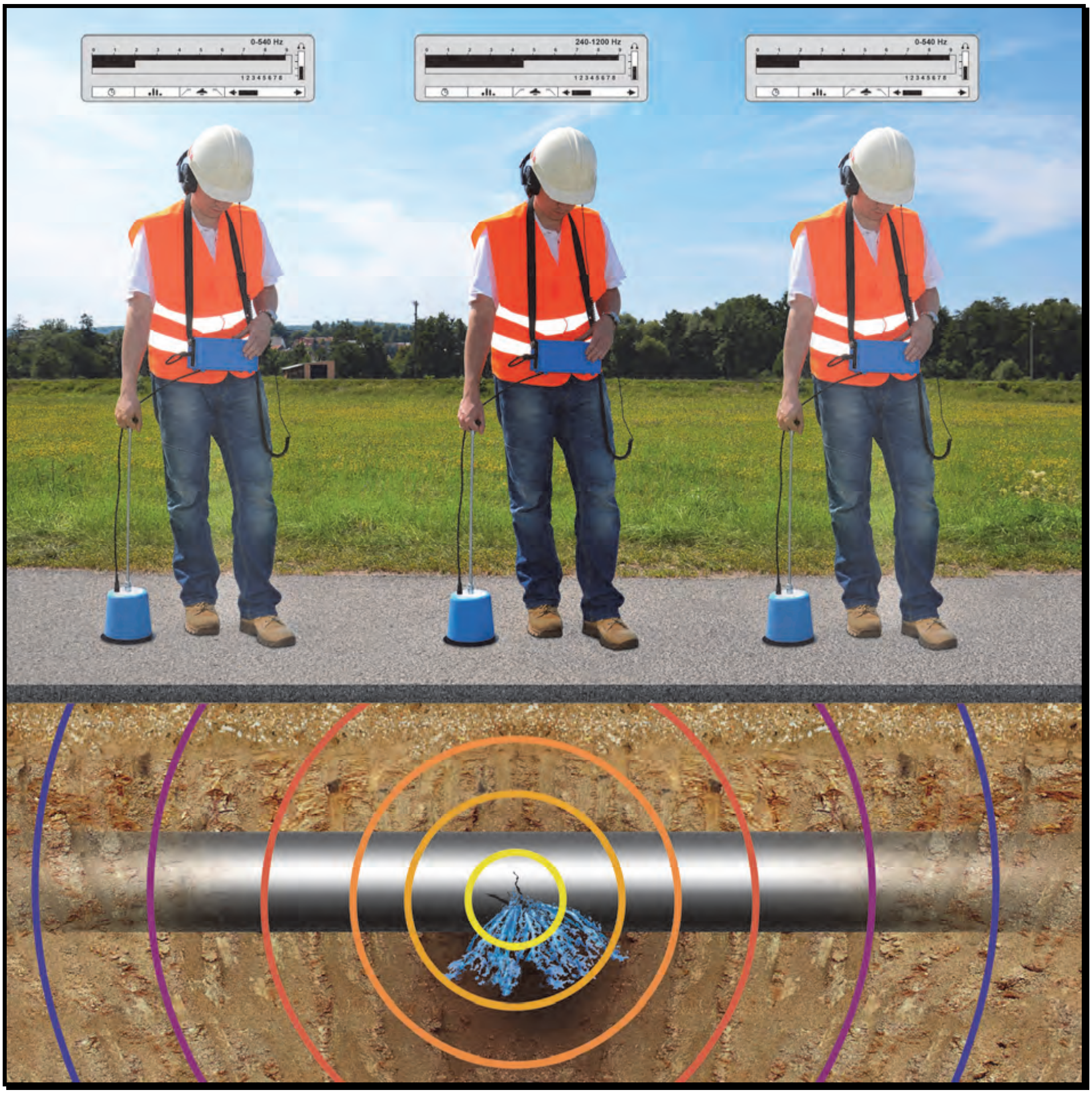


Figure 67: Finding leak with sounding rod

9.3 Leak noise correlation

A leak noise correlator (**Figure 68**) is a device that can locate (pinpoint) the position of a leak to within a few centimetres by measuring, at two different locations on the pipe, the noise that arrives at these points having travelled along the pipe from the leak. Microphones or transducers are placed in contact with the pipeline (usually at fittings) on either side of the leak. During the correlation scan, the leak noise will reach the closer transducer first and the signal is progressively delayed until the more remote transducer receives a similar leak noise. The time delay, the difference between the times that the leak noise reaches the two transducers, is measured, and the accurate position of the leak can be computed as shown in **Figure 69**. The leak noise correlator is used after the initial sweep has identified a suspected leak along a specific part of the main.

Figure 68: Leak noise correlator (courtesy Seba)

Figure 69: Theory of leak noise correlation (courtesy Seba)

9.4 Step testing

Step testing is an indirect method of locating leaks that involves the measurement of water flow in discrete areas. The flow in each discrete section is measured during the period of minimum night flow, when the water used by the consumers should be low. Sections of the zone are eliminated by closing the isolating valves while the minimum night flow is recorded continuously. If there is a substantial drop in the minimum night flow when a particular section of the zone is cut off, it suggests that there is a leakage problem in that area. The approach is shown in **Figure 70**, which indicates four steps from which it can be seen that there is a noticeable drop with steps 2 and 4 suggesting possible leakage in these areas.

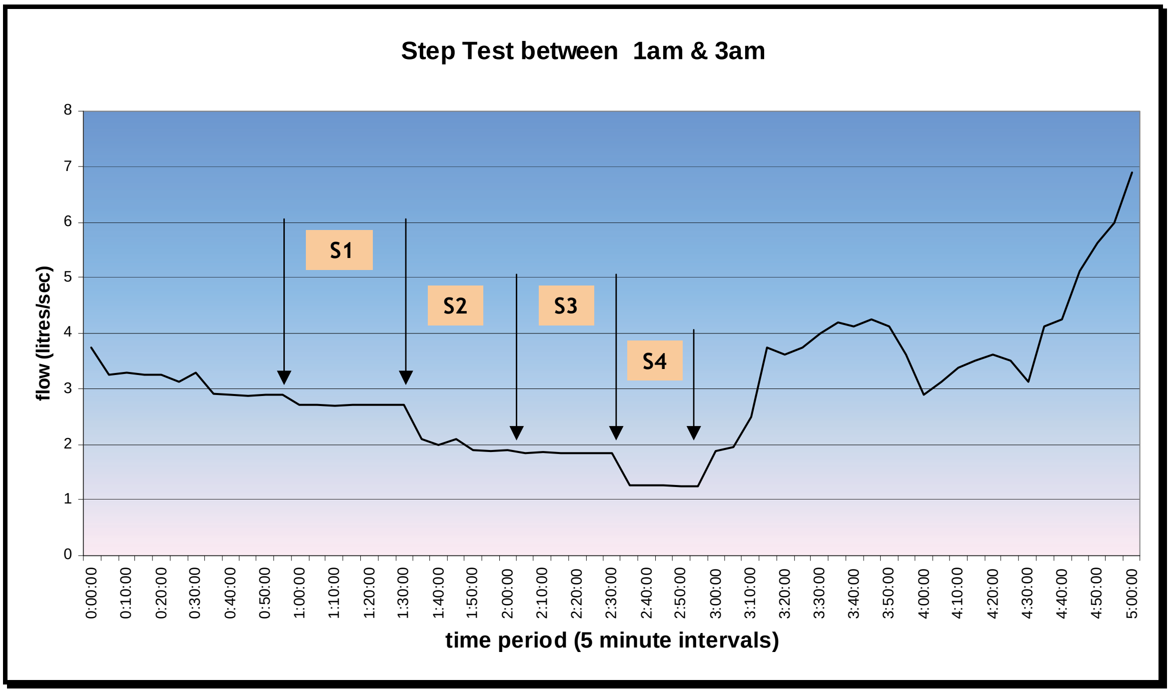


Figure 70: Results from a typical step-test (courtesy Tim Waldron)

The concept of step testing is not restricted to actual exercises where sections of a network are taken out of service specifically to identify leakage. The concept can also be applied to any activity taking place within a zone where some section of the network is taken out of service even in cases where the activity is during normal demand periods. For example, **Figure 71** provides the logging details for the inflow to a large industrial area in Ekurhuleni. A short section of pipe (about 200m) was isolated by closing two internal valves to allow the installation of a new water meter to a single industrial user during peak demand periods. It was only several days later, that the project manager for the construction noticed that there had been a sudden and highly significant drop of almost 350m^3/hr into the area during the "shut-off" to the factory. On further investigation, it was found that the water used by the factory was generally not more than 5 m^3/hr and that the remaining 345m^3/hr could not be explained. It was traced back to an enormous leak on the specific section of pipeline that had been isolated and by replacing this section of pipe, the leakage of 345m^3/hr was eliminated.

This is a classic example demonstrating the concept of "step-testing" without actually undertaking an official step testing investigation during the period of minimum night flow. It is clearly worthwhile checking the impact of closing any part of a network on the flow into the network and it need not always be undertaken at night-time when the demand is at its lowest.

If accurate logging results are available, it is often possible to identify individual leaks on small sections of pipeline in cases where "shut-offs" are being undertaken for other reasons. It is therefore an excellent form of leak detection if the inflow to an area is logged continuously whenever any maintenance is being undertaken since the results can be analysed in the same manner as those from an official "Step-Test". Obviously this form of "unofficial step testing" may not pick up small leaks as the influence of the leaks will often be masked by changes in the consumption, particularly in industrial areas where pumps can be switched on and off suddenly resulting in significant variations. It is, however, always worth checking as in some instances, the logging results can highlight significant leakage.

Figure 71: Typical "shut-off" for industrial consumer

9.5 Ground penetrating radar

Ground penetrating radar (**Figure 72**) operates on the principal of emitting a radar pulse through an antenna into the ground. This pulse is reflected back from the various interfaces in the ground. By moving an antenna slowly over the surface, a picture is built up of what is below the surface (**Figure 73**). The picture can be viewed on a monitor whilst scanning is in progress. The data can be recorded on tape for further analysis and record purposes. Water in the ground is particularly reflective to radar, which thus enables radar to be used to locate water in the ground. Further investigative work is then required to determine if the water is groundwater or leakage from pipelines.

Figure 72: Ground Penetrating Radar

Figure 73 shows the image of a leak discovered by acoustic methods and confirmed by GPR. The additional water in the ground is very reflective to radar and shows up as the brighter blue and purple areas, with the main at the top, apparently rising and falling due to the compressed scale of the image.

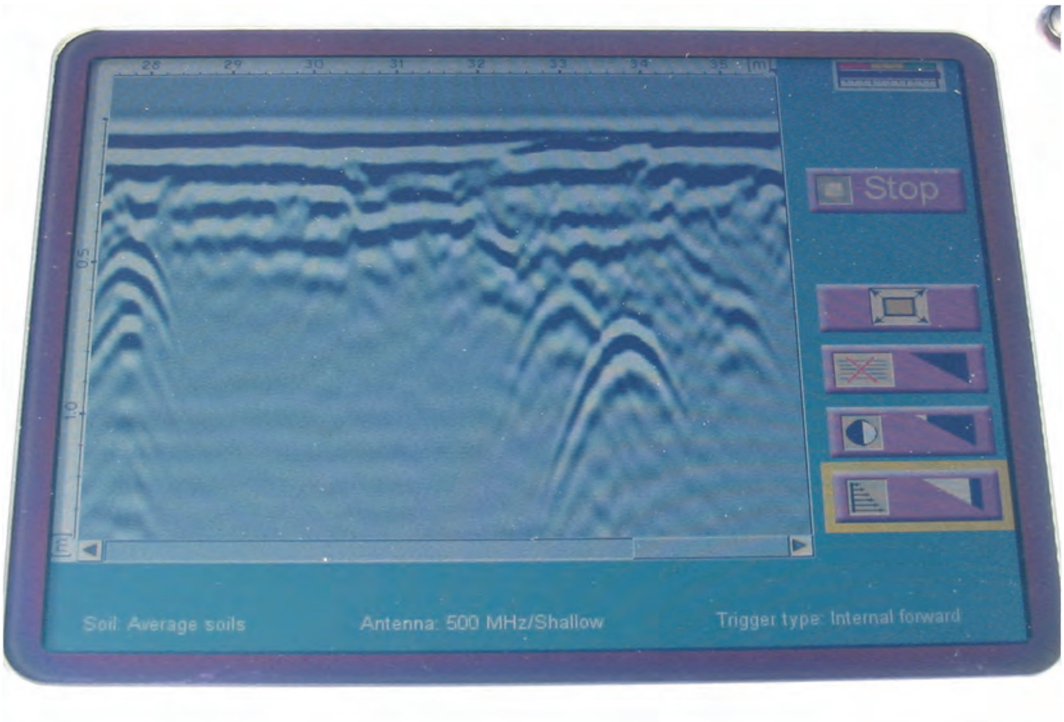


Figure 73: Typical GPR Image

9.6 Noise loggers

Noise loggers are a relatively new and innovative technology that is rapidly being accepted by many large water suppliers. The basic approach involves attaching (magnetic) the self-contained noise logging devices (see **Figure 74**) to various hydrants and valves throughout the water distribution system. The units each record any leakage noise during a pre-determined period and the information can be captured remotely from a vehicle equipped with a receiver. In this manner the information from all of the noise loggers can be captured quickly and efficiently by one technician. After the information has been captured, it is processed using accompanying software, which provides an indication of the likelihood of a leak in the vicinity of each noise logger. Noise loggers are not used for pinpointing leaks, but rather for identifying areas where a leak is likely to be found. The location of the leak must again be determined using a correlator or amplified Listening Rod (Geophone).

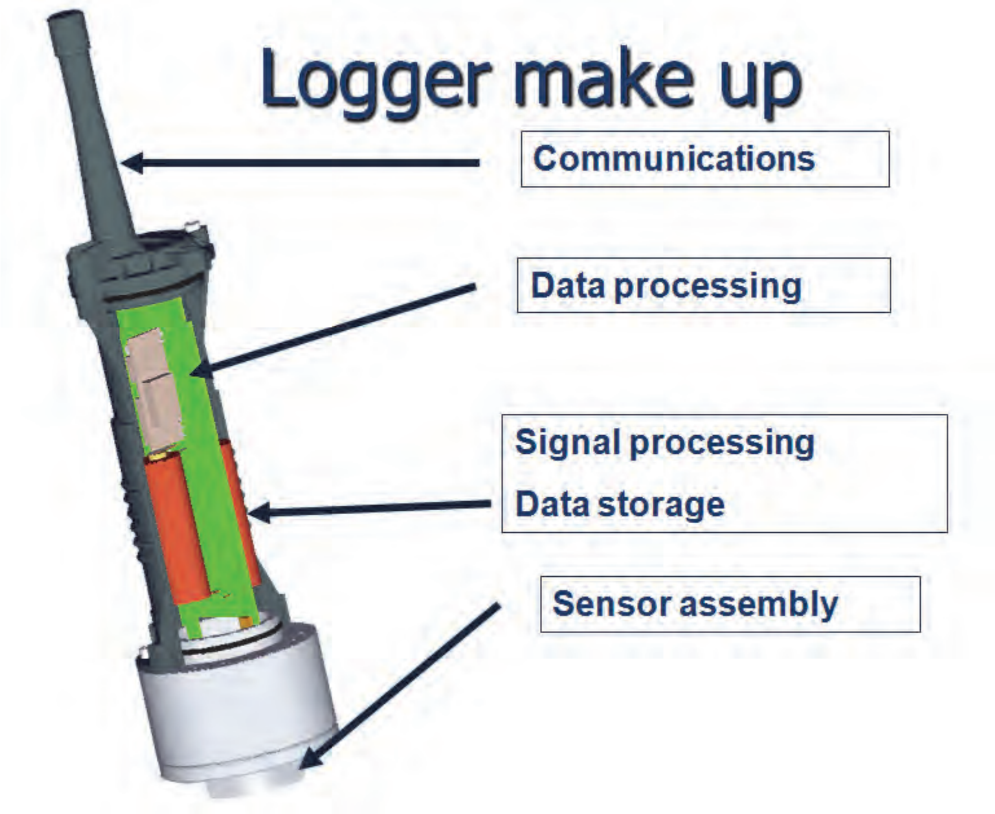


Figure 74: Noise logger (Courtesy S Hamilton)

In most situations, it is found that there is no single technique, which will find all leaks in a system and the personnel using the equipment are often more important that the equipment being used. The most effective approach for leak detection is often to make use of a combination of techniques. In most cases, this will involve a broad sweep of the area using sounding, GPR, step testing and sometimes noise loggers which are used in sets (see **Figure 75**. After the initial sweep is completed, the leak noise correlator and/or the ground microphone are the best techniques for pin-pointing the leaks.

Figure 75: Typical set of Noise Loggers

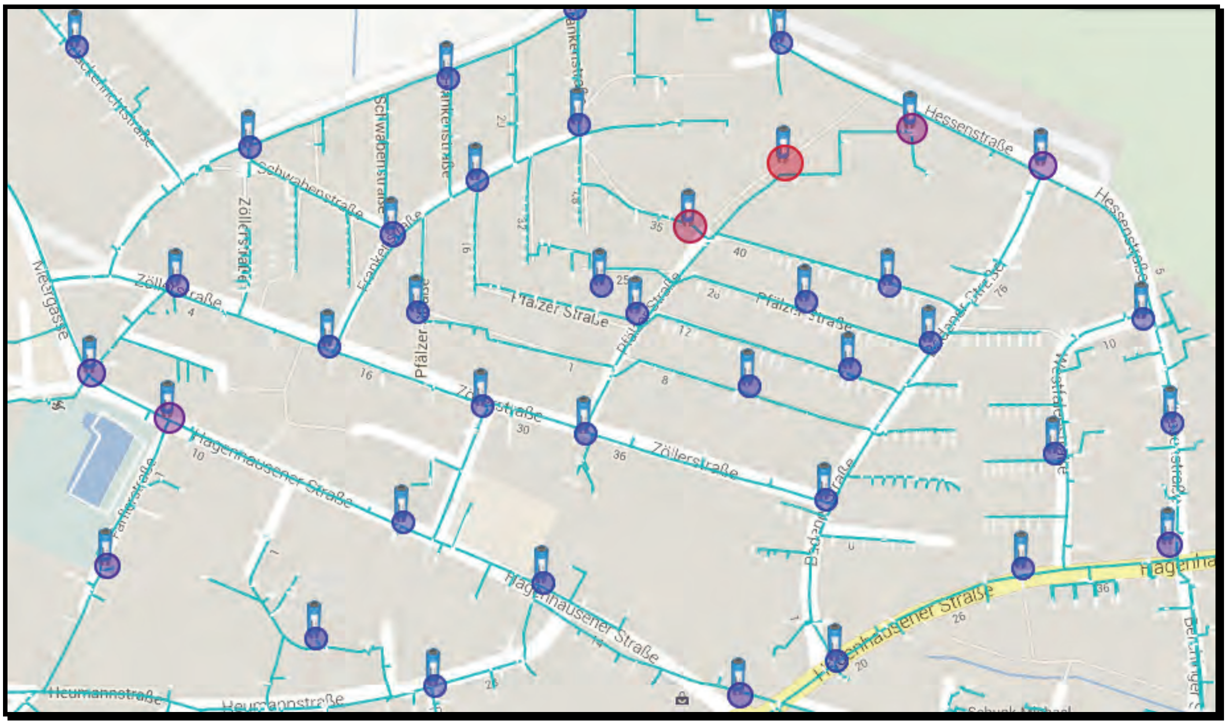


Figure 76: Possible permanent installation of noise loggers (Courtesy: Seba)

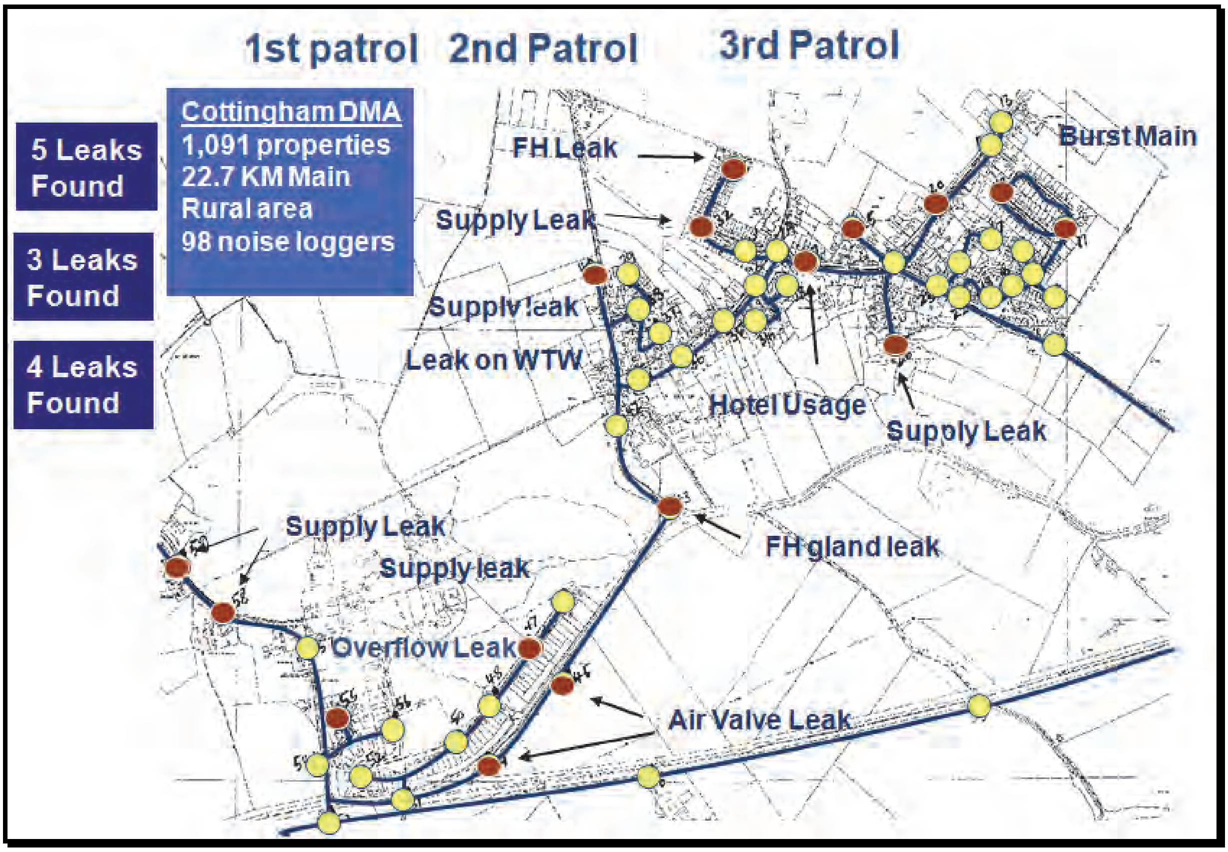


Figure 77: Typical employment of noise loggers (Courtesy S Hamilton)

Leak detection should not be regarded as a "once-off" exercise. Different size leaks emit different noise intensities. Small leaks generally emit a higher intensity of noise and are generally picked up first. Larger leaks may still be present. Once initial leak repairs have been undertaken, the area should be tested again to ensure that larger leaks have not been overlooked.

The best approach for undertaking a leak detection exercise, especially in a central business district (CBD) area, is to make use of a combination of techniques. Some methods are better suited for a rough first time sweep of an area, while others can be used to pin-point the exact location of leaks.

9.7 Other advanced techniques

New leak detection techniques are continuously being developed to meet the needs of this multi-billion dollar industry. The problems are becoming more difficult to solve through the greater use of plastic pipes which do not transmit the noise from the leak to the same extent as metal pipes. To overcome this problem, a number of relatively new products have been introduced into the growing leak detection market. While it is not possible to discuss every new product, a few of the more popular are mentioned below.

9.7.1 Smart Ball

The smart ball, as the name suggests, is basically an electronic device which is encased in a protective wire ball which folds down into a small cylinder for the purpose of inserting and recovering from the pipeline. This device is inserted into a fully pressurised pipeline through a special fitting which is attached to a fire hydrant. Once inside the pipeline, the wire frame pops open to form a protective ball around the electronics and it rolls down the pipeline being pulled along by the flow of water. The device records its position as it moves along the pipeline and also records any noise it picks up along the way. Basically it identifies leaks as it passes them in the pipeline. At the end of the section of pipeline being examined, the ball is recovered using a net which is once again inserted through a valve or fire hydrant and the unit is pulled up in a similar manner to which it was inserted. Once recovered, the unit is interrogated from which the locations of any leaks picked up on route are identified.

SmartBall is a free-swimming data acquisition system suitable for detecting leaks in fluid pipelines. The system consists of the following components:

- An aluminium sphere containing and acoustic sensor and other sensors, acoustic transponder, data processor, memory device and batteries. The sphere is enclosed in an open-cell foam ball. The purpose of the ball is two-fold:

- To ensure that the device travels silently through the pipeline, minimising apparatus noise and maximizing acoustic sensitivity.
- To allow the overall diameter of the device to be optimised for pipe diameter, in-line valve clearances, flow velocities and maximum pipe grade (slope).
- Above-ground tracking devices (SmartBall Receivers and acoustic sensors) which are used to track the progress of the ball through the pipe, by monitoring acoustic transmissions from the ball, with timing referenced to a GPS clock.
- Pressurised insertion equipment (see **Figure 78)**
- Pressurised retrieval equipment consisting of a net assembly and in-pipe video camera (see **Figure 79**)

Figure 78: Smart Ball insertion equipment (courtesy S Hamilton)

The current version of the SmartBall can operate for up to 15 hours in a water pipeline, depending on water temperature. The maximum length of pipeline that can be surveyed is determined by the flow rate in the line. For instance, with a flow rate of 1 m/s and a maximum operating life of 12 hours, the SmartBall can survey up to approximately 40km.

The size of leak that can be detected is determined to some extent by the ambient noise frequency range and level within the pipe; however it is generally less than 0.5 l/min. The type of leak (weeping joint, pinhole) is not relevant. The on-board instrumentation allows the velocity of the ball at all points along the survey route to be calculated during post-processing.

The on-board instrumentation allows the velocity of the ball at all points along the survey route to be calculated during post-processing. Thus, the location of any leaks can also be located. Because a cumulative error can occur using this method, the fact that the exact time that the ball passes the SmartBall receiver stations is known can be used to reduce this error. Hence, the leak location accuracy is a function (within 0.5%) of the distance between receiver locations.

Figure 79: Smart Ball Retrieval equipment (Courtesy S Hamilton)

This device has received both good and bad reviews and, like every leak detection device, has its uses and its limitations.

9.7.2 Sahara and JD7 systems

The Sahara and JD7 systems are both very similar and involve the use of a small camera/microphone mounted at the end of a probe which is inserted into a pipeline on a long "umbilical cable". The probe is pulled along the pipeline by a small parachute which is pulled downstream by the flow of water in the pipeline. This form of leak location is relatively expensive and is best suited to work in relatively straight pipelines where deployments of up to 2km from a single insertion point are possible; other constraints may restrict the length that can be surveyed from each insertion point. Careful planning of the work will maximise the distance that can be surveyed.

The Sahara and JD7 systems are deployed through a tapping made into the pipe (which must have a minimum internal bore of 50mm). Typically these insertion points may be air-valve connections, insertion flow meter tappings or special insertion points which have been created specifically for the purpose of leak location using such equipment.

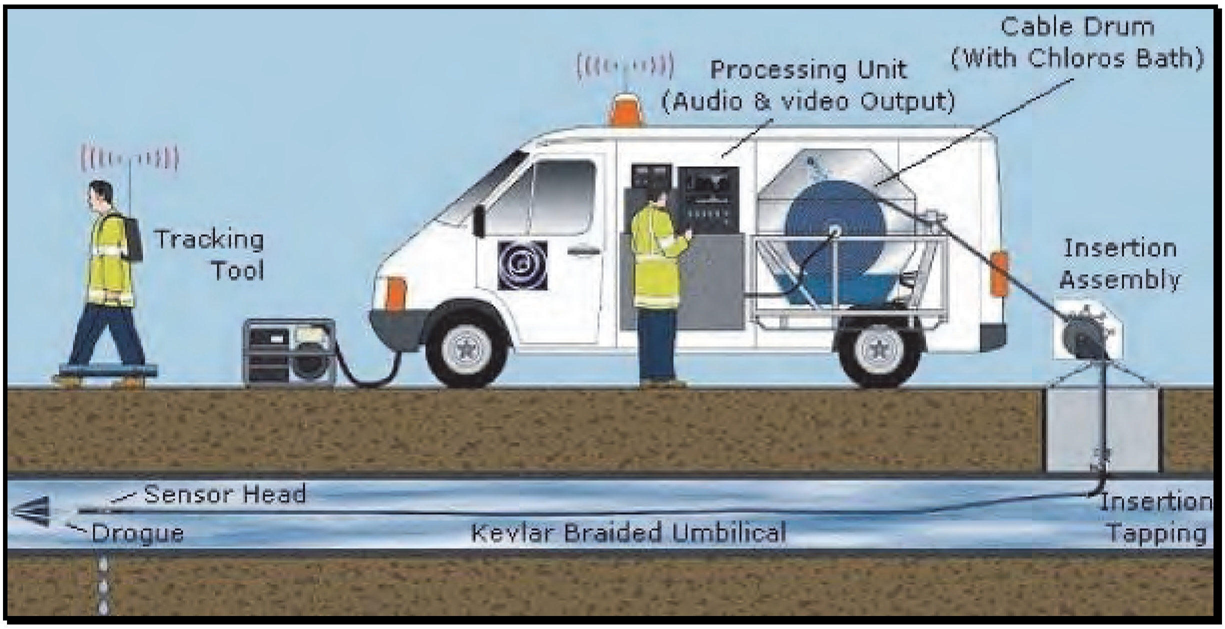


Figure 80: Concept of Sahara and JD7 leak location systems

Since the equipment is inserted into the pipeline, care must be taken over sterilisation of the equipment and, in particular, the cable to prevent any possible contamination. The systems are designed to be used on live (pressurised) water mains with no disruption to customers.

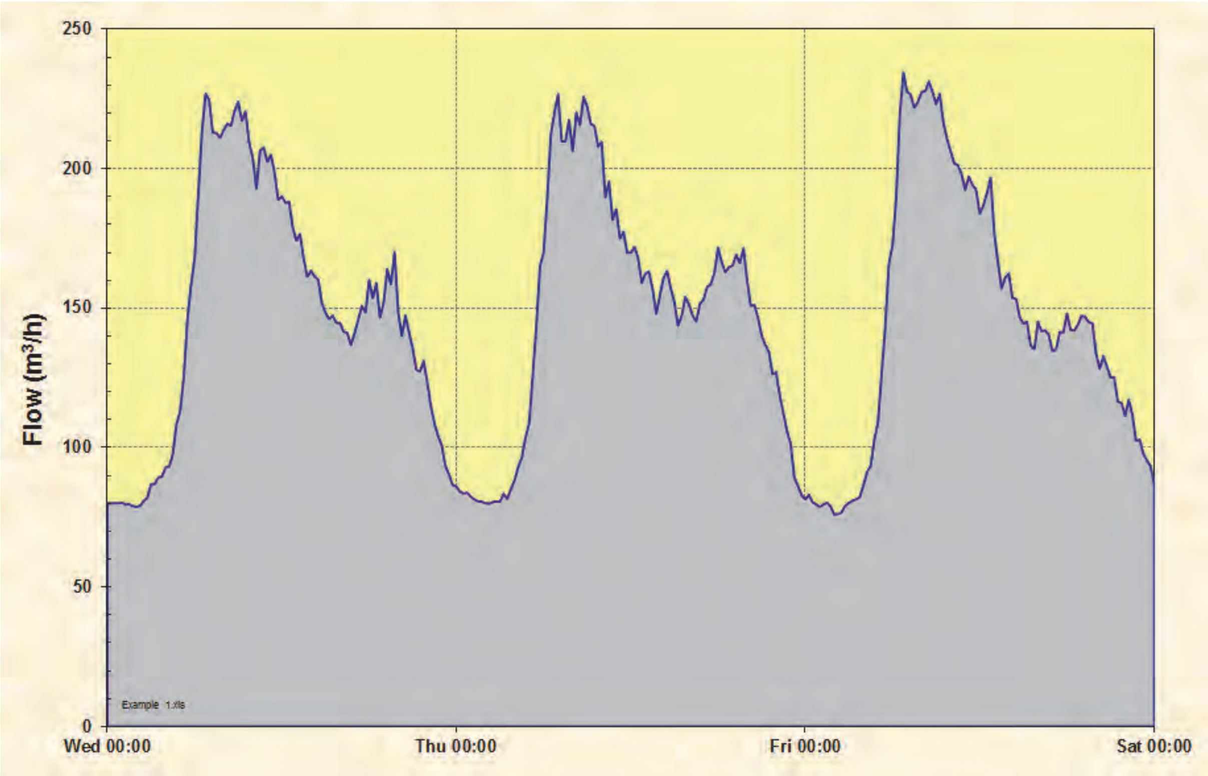
Each survey team will consist of several operators who must be qualified to work within confined spaces and understand the equipment.

The equipment inserted into the main is made from materials that are suitable for use in contact with drinking water – schedule and relevant certification appended. All equipment is sterilised before insertion into the live main.

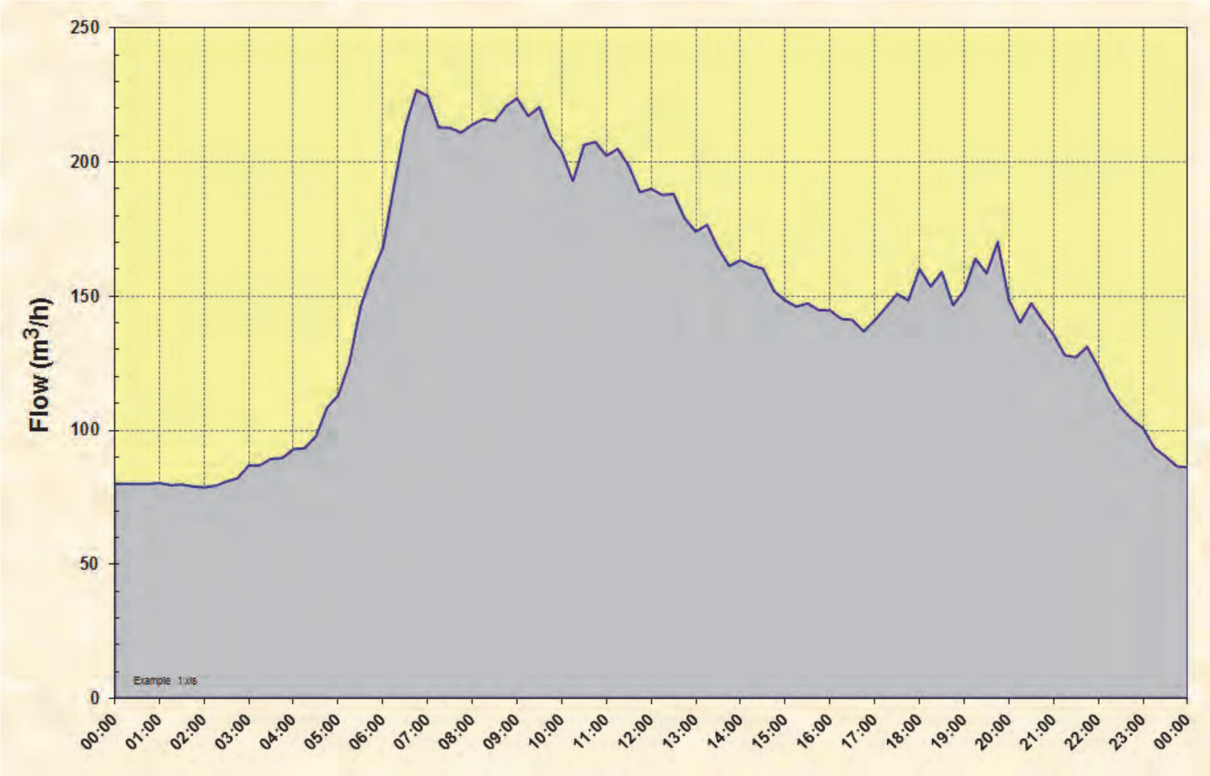
10 APPENDIX G: UNDERSTANDING LOGGING RESULTS

The following logging results are provided to highlight the value of logging the flow and/or pressure into a zone metered area. Understanding and interpreting the results is a skill that is developed over time with practice and often allows the water manager to pick up problems before they become more serious.

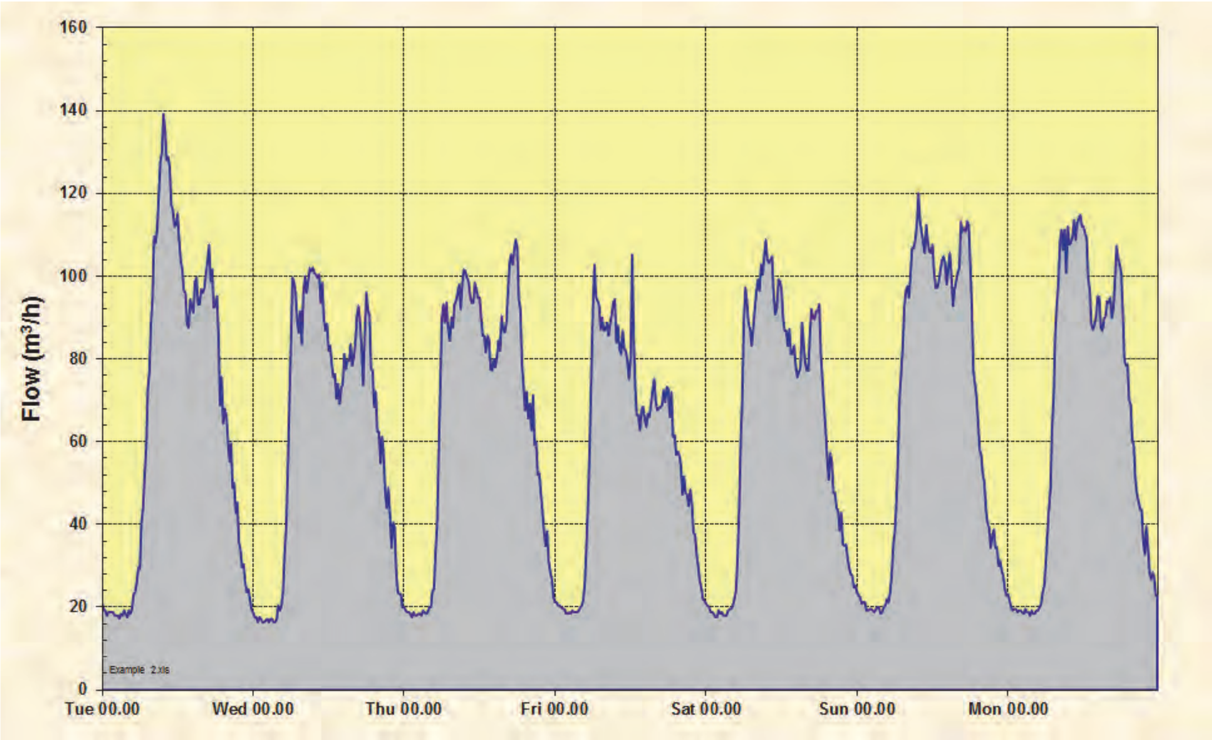
Description:	**Interpretation:**
The graph shows the pressure recorded at the critical point in a zone over a 3-day recording period.	The zone exhibits a stable pressure profile with continuous 24-hour supply. The pressure pattern is typical of a residential zone with maximum pressure at night and minimum during the day. Max pressure is 50m and minimum pressure is around 30m. The maximum daily pressure appears to decrease as the week progresses which can often indicate a supply from a large reservoir which fills at weekends and gradually drops during week. There is no obvious pressure problem in this zone.



Description:	Interpretation:
The graph shows the flow into a zone over a 3-day recording period.	The graph shows a stable supply pattern indicating continuous 24-hour supply. The graph suggests a typical demand pattern for a residential area with a morning and early evening peak. The minimum night flow (MNF) is around 80 m^3/hr. The average daily flow (ADD) is around 150 m^3/hr. The ratio of MNF to ADD is approximately 53% which without a detailed analysis of the MNF suggests high leakage. This zone has a serious leakage problem.



Description:	**Interpretation:**
The graph shows the flow into a zone over a 1-day recording period. This is in fact the same zone as used in previous example and is being presented to demonstrate that even a 1-day logging over 24-hours can be useful.	The graph shows a stable supply pattern indicating continuous 24-hour supply. The graph suggests a typical demand pattern for a residential area with a morning and early evening peak. The minimum night flow (MNF) is around $80m^3$/hr. The average daily flow (ADD) is around $150m^3$/hr. The ratio of MNF to ADD is approximately 53% which without a detailed analysis of the MNF suggests high leakage. This zone has a serious leakage problem.



Description:	**Interpretation:**
The graph shows the flow into a zone over an 8-day recording period.	The graph shows a stable supply pattern indicating continuous 24-hour supply. The graph suggests a typical demand pattern for a residential area with a morning and early evening peak. The minimum night flow (MNF) is around 18m^3/hr. The average daily flow (ADD) is around 70m^3/hr. The ratio of MNF to ADD is approximately 25% which without a detailed analysis of the MNF suggests that there is substantial leakage, however, it is not particularly high and it is likely that there are other areas with a more serious problem. This zone has some leakage but it is not serious.

11 APPENDIX H: SOFTWARE AVAILABLE FROM THE WRC

11.1 Introduction

In order to support government legislation and encourage efficient use of the available water resources in South Africa, the Water Research Commission (WRC) has initiated and supported numerous projects over the past 15 years. Although some very comprehensive and sophisticated software is already available both internationally and locally, it is often out of reach of many of the smaller municipalities who cannot afford to purchase such packages. The WRC has therefore concentrated on providing low cost software solutions to assist water suppliers in understanding and managing their non-revenue water.

The new models are all based on the Burst and Background Estimate (BABE) methodology, which was first developed for the UK Water Industry in the early 1990’s. The BABE philosophy has since been accepted and adopted in many parts of the world as it provides a simple and pragmatic approach to the very complex and often confusing problem of leakage from water distribution systems. The approach was so successful that it is now recommended by many international water associations as the most systematic and pragmatic approach to leakage management.

The BABE approach was first introduced to South Africa in 1994 through a series of courses and seminars presented countrywide at the request of the WRC. The methodology and concepts have since been widely accepted by most water suppliers throughout the country and through the efforts and initiatives of the WRC, South Africa is now regarded as one of the key players in this field worldwide.

In the development of the BABE techniques, it was agreed that the following four principal issues concerning leakage management (see **Figure 81**) should be addressed:

- Logging and analysis of minimum night flows;
- Economics of leakage and leakage control;
- Pressure management;
- Benchmarking of leakage and auditing of non-revenue water

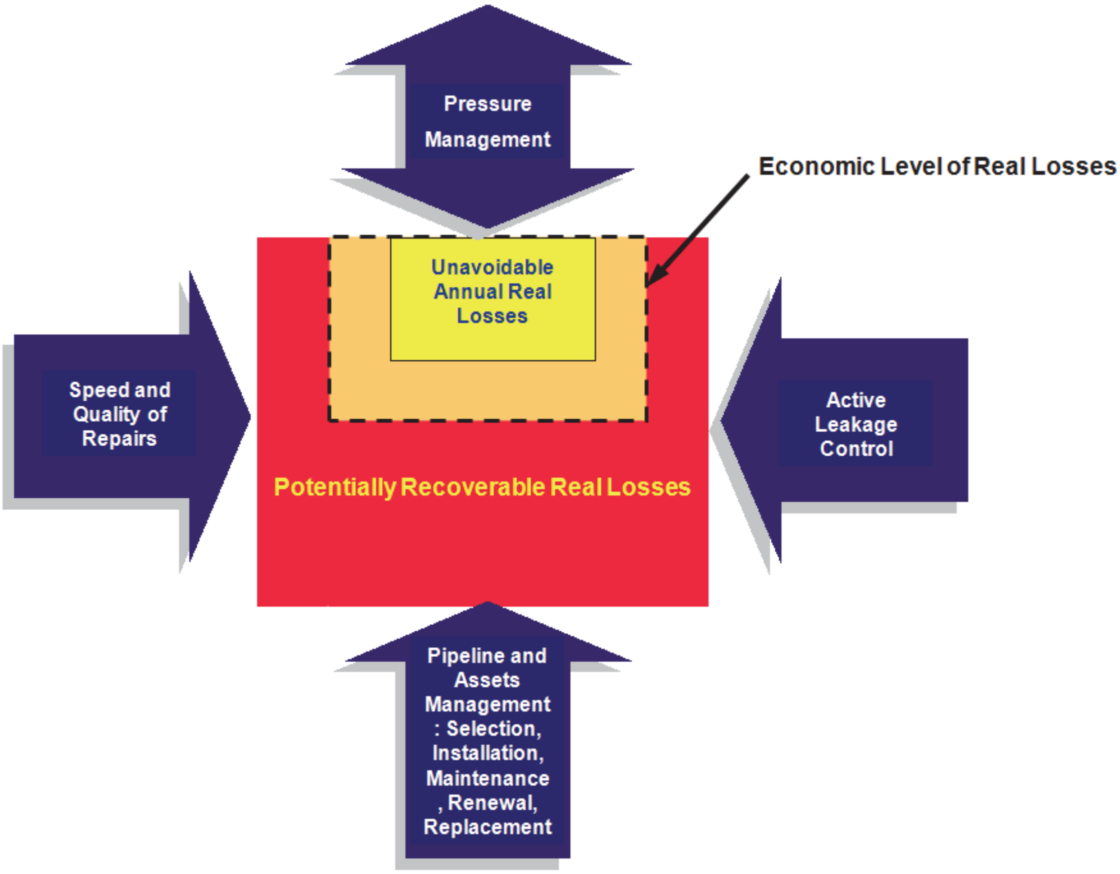


Figure 81: Four key considerations for managing physical leakage

In order to address the four key components of the BABE methodology, four models were developed over a period of approximately four years as shown in **Figure 82** and described in **Table 11**.Each model is a small self-contained program which addresses one specific issue. It was decided to adopt this simple and straightforward approach in order to avoid confusion and allow water suppliers to use one or all of the models as they consider appropriate.

Figure 82: Four models originally developed by the WRC

All four models are available through the WRC and details of the models are provided in **Table 11** for reference purposes. The models were all developed with support from Mr Lambert who also developed many of the original models for the UK water industry although they have been customised to some extent for use in South Africa. They are accompanied by detailed user manuals which provide background to the theory as well as tips on how to use the models. The software and accompanying manuals can be obtained directly from the WRC web site on www.wrc.org.za.

Table 11: Details of BABE Model documentation

Model	Details	ISBN Reference	WRC Reference	Released
SANFLOW	Model designed to provide an indication of the unexpected detectable leakage in a zone from the analysis of the minimum night flow.	1 86845 490 8	TT 109/99	1999 & 2009
PRESMAC	Model designed to estimate the potential for pressure management in a pressure zone based on logged flow and pressures over a	1 86845 772 2	TT 152/01	2001 & 2009

	representative 24-hour period.			
BENCHLEAK	Model designed to establish the components of non-revenue water in a water utility or zone metered area and associated performance indicators based on the latest IWA Task Force recommendations.	1 86845 773 7	TT 159/01	2001 superseded
ECONOLEAK	Model to evaluate the most appropriate frequency for undertaking active leakage control	1 86845 832 6	TT 169/02	2002
AQUALITE	Updated version of model designed to establish the components of non-revenue water in a water utility or zone metered area and associated performance indicators based on the latest IWA Task Force recommendations. Replaces Benchleak.	978-1-77005-599-5	TT 315/07	2009
WDM SCORECARD	A basic scorecard based model used to develop a first order WDM strategy for a municipality quickly and effectively.	978-1-4312-0271-3	TT 523/12	2010
The State of Non-Revenue Water in South Africa	A comprehensive report on the state of NRW throughout South Africa based on over 130 water balance assessments using the standard IWA methodology.	978-1-4312-0263-8	TT 522/12	2013

The four main BABE models developed through the WRC, shown in **Figure 82,** include the original BENCHLEAK water balance model, which was initially developed as a simple Excel spreadsheet and has now been superseded by the AQUALITE Model. The SANFLOW model used to analyse minimum night flows was one of the WRC's most popular downloads due to its ease of use and simple design. This model has recently been upgraded and the new version is already available of the WRC website. The original PRESMAC pressure management model has also been improved and provides a few additional features which were not available on the original version. AQUALITE, SANFLOW and PRESMAC are full DELPHI packages.

The underlying approach of the WRC is to promote good governance of water, and it is recognised that promoting the BABE methodology is of great help in this regard. Many of the BABE developments in South Africa are based to some extent on the previous work completed in the UK through the numerous initiatives undertaken by several key specialists working for the UK water industry. Although the models have been customised for use in South Africa, they are generally applicable for use in most water supply systems throughout the world with the possible exception of certain very low pressure systems that experience long periods of intermittent supply as experienced in some parts of Asia. The WRC decided at an early stage that any software developed to support leakage reduction in the municipal environment would be distributed free of charge to any municipality wishing to use the BABE techniques.

Since the WRC models were initially developed, many new models have been introduced to the water industry throughout the world either as commercial packages or as free packages developed by various organisations as their contribution to the industry. In South Africa, the WRC has continued to support the concept of free software in the WDM field and in this regard, most of the original models have now been upgraded to ensure that they remain useful and relevant in the current environment where WDM is becoming one of the key issues being addressed by virtually all water service providers worldwide. The WRC software is freely available not only to South African users but to any individuals or organisations throughout the world.

11.2 The water audit model (AQUALITE)

The BENCHLEAK model developed in South Africa was the first Excel-based water audit model to be developed in the world, and was based on the original Word document by Allan Lambert who also assisted in the design of the various South African models to ensure that they are in line with the International Water Association's guidelines for "best practice". Through the efforts of the WRC, South African water utilities now have free access to the full range of BABE software. The BENCHLEAK model also helped to promote the concepts of the Infrastructure Leakage Index (ILI) throughout southern Africa and, in turn, led to a large scale study of ILI values for over 130 systems countrywide as discussed in **Section 2.12**.

The water audit and benchmarking model was one of the first models developed by the WRC and was released as BENCHMARK in 2000 although the final documentation was only released two years later in 2002 (WRC, 2002). This simple Excel based model was used for several years in South Africa and many other countries to assess the overall water balance of water utilities based in the standard International Water Association water balance. Many other similar models have since been developed, some of which are sold commercially while most are provided freely to users. In 2007, the WRC commissioned the development of AQUALITE (**Figure 83**) which is effectively a Delphi based version of the original model incorporating a few additional features which were not included in the earlier Excel-based model. The additional features include:

- Ability to toggle between 7 different unit sets
- Splitting mains into bulk and transmission to allow different pressure and time of pressurisation to be modelled;
- Ability to specify error bounds in cases where users have knowledge of data accuracy;
- Selection of specific performance indicators in accordance with density of connections;
- Ability to supply base data at greater level of accuracy where available through tables.

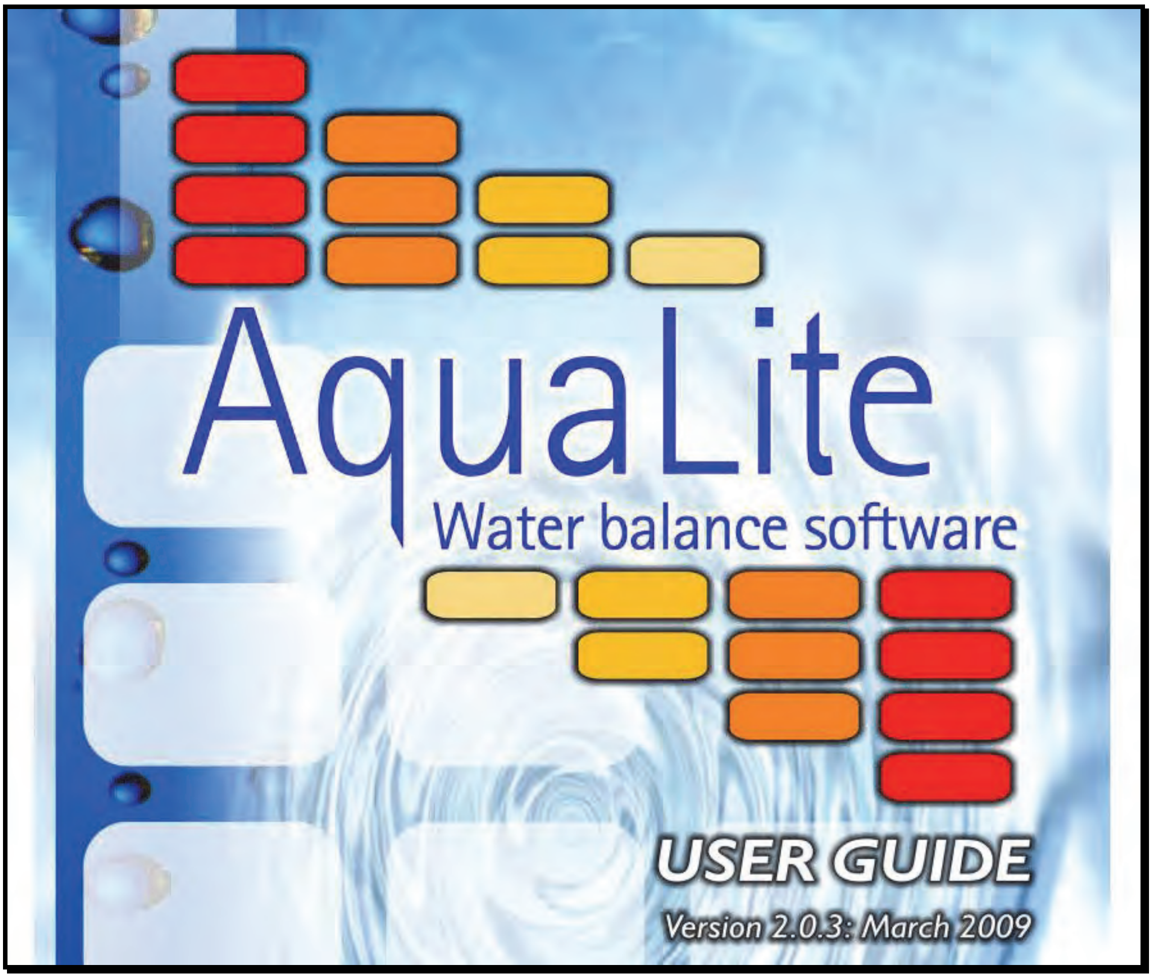


Figure 83: Updated version of water balance and benchmarking model

11.3 Analysis of minimum night flows (SANFLOW)

The analysis of minimum night flows was undertaken using the SANFLOW model (WRC, 1999) which was one of the first models developed and also included a full description of the BABE methodology. The model is used to assess the level of excess leakage in a discrete zone from the analysis of the minimum night flow using the standard BABE methodology which is fully described in the accompanying documentation.

This model has been one of the most popular of all WRC models to date and was originally developed in Delphi. The success of the model was due in part to the simplicity of use and it has remained unchanged for almost 10 years before being upgraded in 2008 (**Figure 84**). The new version contains virtually no new features and is effectively a face-lift which allows the model to operate under the various new operating systems which created certain conflicts with colour schemes etc. The revised version should operate properly on any new Microsoft operating system and is available freely from the WRC website (www.wrc.org.za).

The analysis of minimum night flow is discussed in more detail in **Section 5 (Appendix B)** and a full discussion on how to interpret the results is provided through a series of annotated examples of real logging results.

Measurement of minimum night flow into a zone-metered area is possibly one of the simplest and most valuable actions that a water supplier can take in order to identify whether or not they have a serious leakage problem.

The analysis of background night flows is a simple exercise and the new SANFLOW model provides a quick and effective aid to water suppliers in this regard. The program was designed specifically to assist water suppliers in identifying likely problem areas with respect to leakage and conversely also those areas that do not have a serious leakage problem. The development of the new model was initiated and supported by the WRC and was officially released in August 1999.

The model is based directly on the BABE principals as set out by the UK Water Industry (1994) and is written in DELPHI for the Windows operating system. The SANFLOW Model includes several additional features which are not currently available on any of the overseas versions. In particular, it includes the ability to undertake sensitivity analyses based on basic risk management principals in order to provide a likely distribution for the number of bursts in a zone (or district). This feature enables the user to set an upper and lower limit on each parameter used in the model. The selection of the parameter values has often been criticised as too subjective, with the result that different users may obtain different results from the same initial data. By using the sensitivity analysis feature of the model, this potential problem can be addressed.

The most important difference between SANFLOW and its UK counterparts is the fact that SANFLOW is not based on an EXCEL spreadsheet. Instead it is a full Windows application based on the Borland DELPHI package and therefore requires no additional software on the user's computer. The UK-based products generally require the user to have EXCEL available to run the leakage programs.

The second main difference between SANFLOW and the UK programs is that SANFLOW has been designed in such a way that it is extremely simple to use, and all of the detailed calculations are hidden from the main screen. The main screen therefore provides a clear and concise overview of the leakage in a particular zone. Details for any of the calculated values can be viewed by simply selecting the variable from the main task bar.

A third and possibly the most useful difference between the models is the incorporation of a sensitivity analysis in SANFLOW. In all of the previous commercial versions of the BABE models, there was always a concern regarding the selection of certain process parameters or variables that could influence the overall leakage predictions. To establish if such variables had an important influence on the results, the user would normally have to change each variable individually and re-run the program. In the case of SANFLOW, a new feature has been added that allows the user to view (graphically) the significance of changing the various process parameters either individually or simultaneously. This feature adds a new dimension of reliability to the results from the model and addresses perhaps the most common criticism of the basic BABE approach.

In summary, the SANFLOW model is based to a large degree on research and work undertaken in the UK. It started at the point where the UK research left off in 1996 and has taken the development to a new level of presentation and reliability.

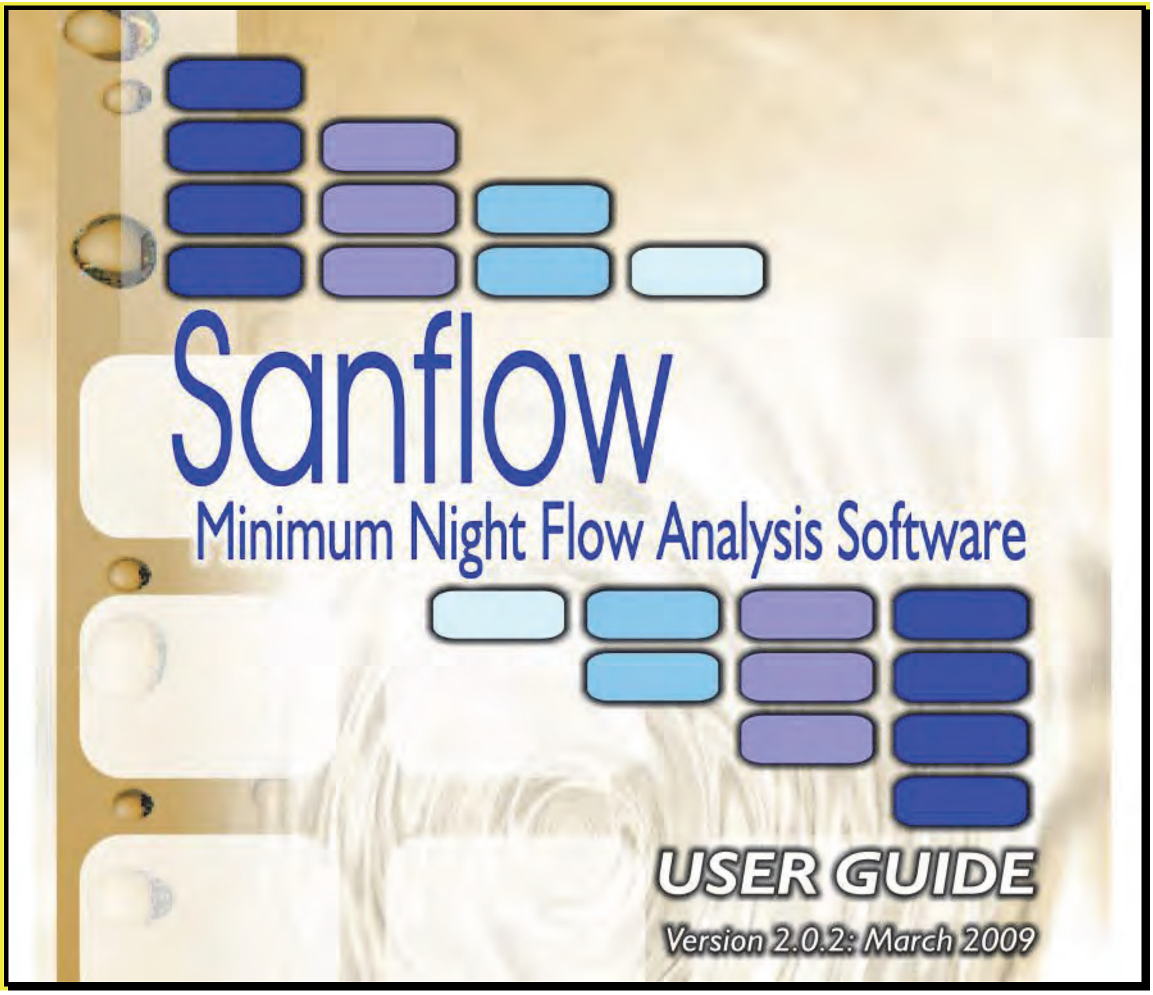


Figure 84: Updated version of night flow analysis model

11.4 Pressure management model (PRESMAC)

The original PRESMAC model was developed in 2001 (WRC, 2001) and was designed to provide an initial estimate of the likely savings that could be achieved in an area through some form of pressure management. The original model was developed in Delphi and allowed the user to analyse fixed outlet and time modulated pressure control. The revised version of PRESMAC (**Figure 85**) includes the flow modulated pressure control option which was not available in the original model, while most other features are common to both. The new version is available from the WRC web site (www.wrc.org.za).

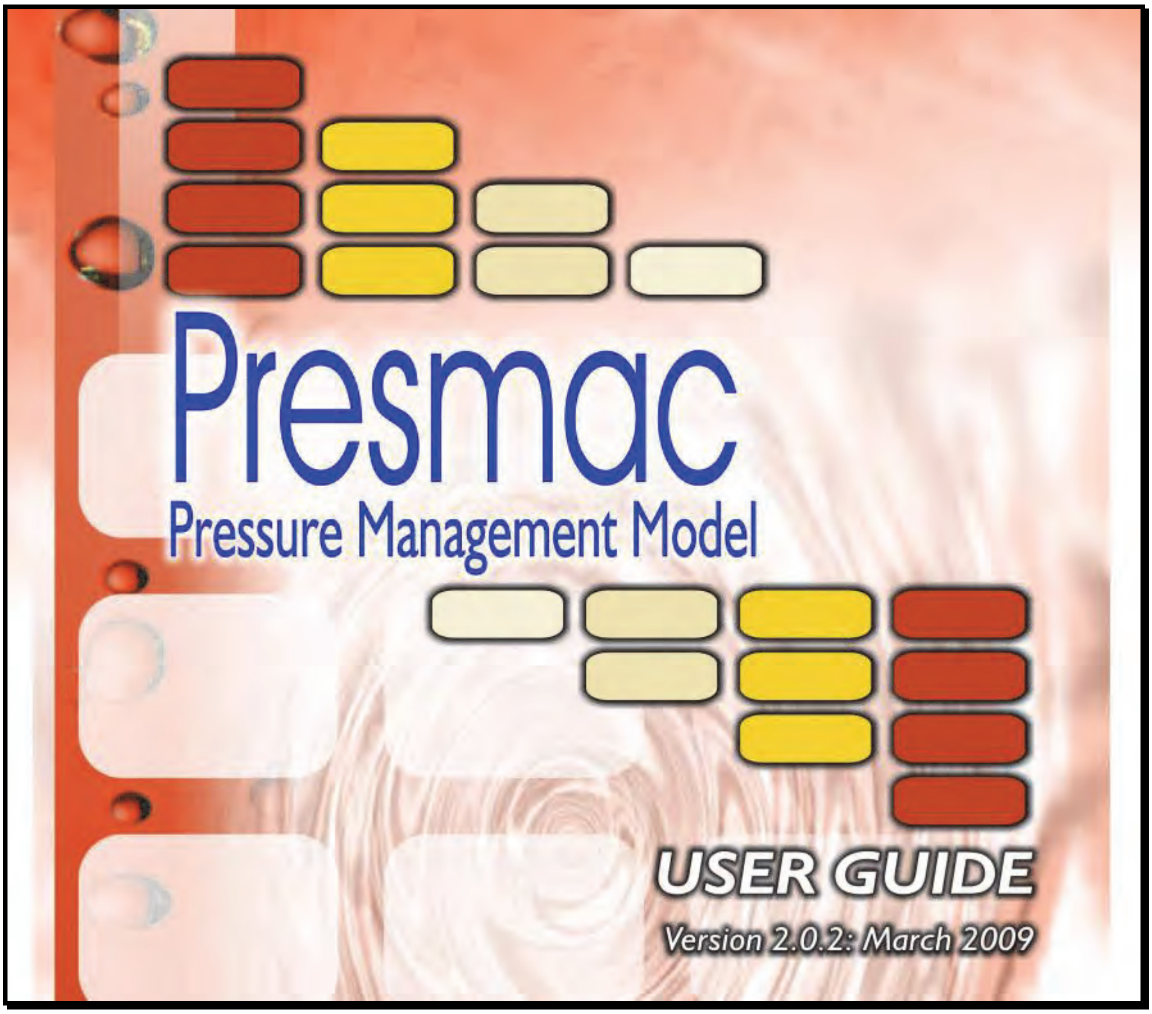


Figure 85: Updated version of pressure management model

There has been considerable debate over the past 10 years concerning the accuracy of the predicted savings from any of the numerous models available which claim to be able to predict the savings that can be achieved through different forms of pressure management, including the various time and flow modulated options as discussed in **Section 12**

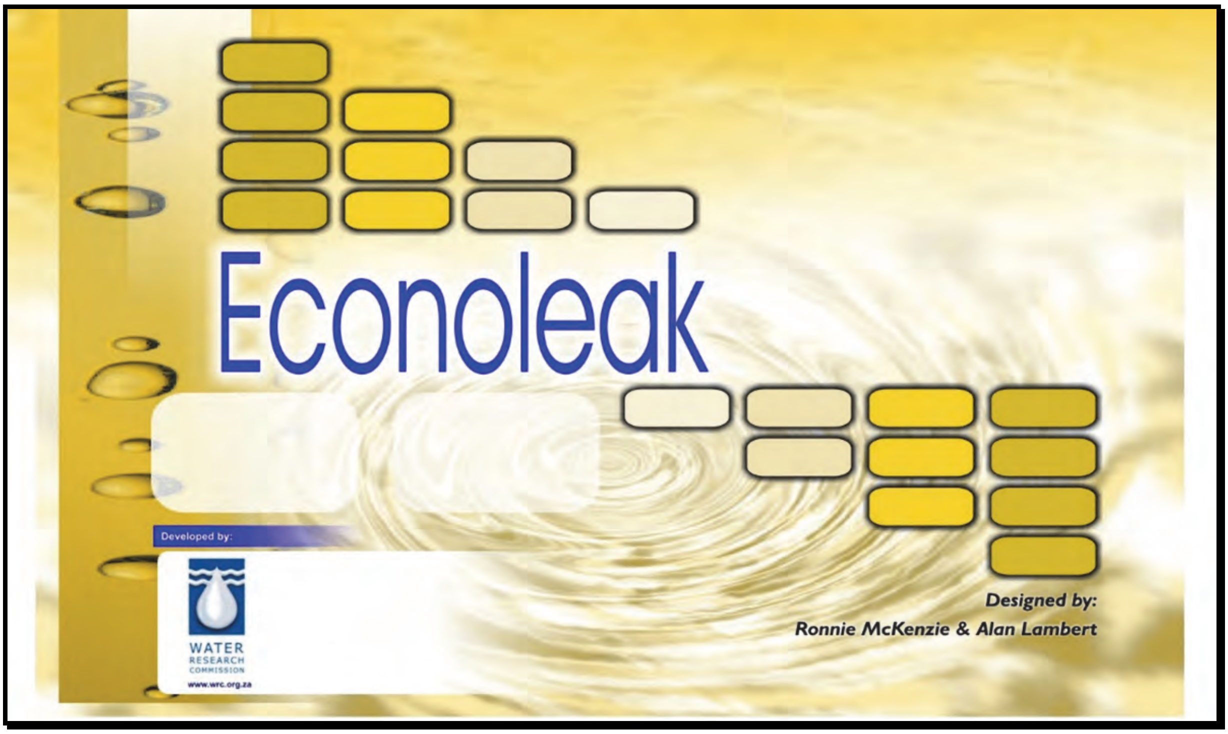
(Appendix I). The approach used in PRESMAC is relatively simple, and does not incorporate a full hydraulic reticulation model which many other vendors provide: normally on a commercial basis. In practice, however, it is usually found that the results from PRESMAC are of sufficient accuracy to establish whether or not pressure management is viable and the predicted savings are normally within the error margins expected. In most cases, it is found that the actual savings achieved, cannot be predicted with greater accuracy due to a wide range of factors that are excluded from any available model such as quality of workmanship when laying the reticulation. The model does not include the savings that result from the reduced number of new burst pipes which can be highly significant and it also excludes the financial benefits resulting from the extended life-span of the reticulation system. This latter item can in many instances dominate the economics of the pressure management initiatives but it is also the most difficult item to quantify with any level of confidence. By excluding some of the benefits from the assessment, the results will err on the conservative side.

The PRESMAC pressure management model is used to assess the likely savings (in monitory terms) of various pressure reduction options (fixed outlet and time –modulated PRV's) in a selected zone metered area. The analysis is undertaken in a relatively simple and pragmatic manner based on the general BABE concepts. This approach allows the user of the program to gauge the potential for pressure management very quickly and effectively without requiring a full detailed pipe network analysis. Although the methodology is based on a number of simplifications and assumptions, in practice the predicted savings are generally within 10% to 20% of those actually achieved.

11.5 ECONOLEAK

The ECONOLEAK model is not designed to address the economic issues associated with all of the various types of leakage-reduction activities mentioned above. Instead, it is aimed specifically at determining when a water supplier should invest in active leakage control for a specific zone metered area. The model will assist water suppliers in gaining a better understanding of the main factors influencing the economics of leakage control, and will enable them to identify the most cost-effective methods of reducing their system leakages.

In order to use the ECONOLEAK Model, the user must supply considerable factual system data relating to the frequency of burst pipes in the system and the associated costs of repair. Such information is often difficult to obtain and in many cases the water supplier is unable to provide even the most basic leakage data. While this is clearly a problem in the short term, it does create an awareness of what information is required to undertake an economic analysis of leakage control. This in turn, should encourage water suppliers to start capturing and processing the necessary data so that they may be able to carry out some form of economic analysis in future. In this regard, the model is very useful in creating awareness of the key information that all water suppliers should be capturing and monitoring on a continuous basis.



It should be noted that ECONOLEAK (WRC, 2002) has not been upgraded. This model was developed to assess the economic level of active leakage control and remains in its current form. Since the model was first released, there have been numerous new developments aimed at establishing the economic level of leakage most of which tend to again address only the aspects of active leakage control.

11.6 WDM scorecard for developing initial WDM strategy

Before any WDM intervention is implemented, it is normal practice to undertake an investigation of the area in question in order to assess the key problems and to propose a strategy to address the critical issues. The resulting WDM strategy usually includes recommendations of a range of interventions designed to address the main problems in order to reduce losses and/or the consumptive use. To assist municipalities in developing a basic first order WDM strategy, the WRC has developed a simple model using a standard scorecard as shown in **Figure 86**.

Figure 86: Municipal WDM Scorecard available from WRC

Balanced Scorecards have been used for many years to assess and monitor complex situations which involve a wide range of functions many of which cannot be assessed or quantified in a normal manner. It is ideally suited to multi-disciplinary activities such as the operation and management of a water utility for example. In such an organisation there may be various technical issues that must be assessed and monitored as well as different human resources and financial activities etc., all of which are important in their own right but cannot be compared or measured directly with each other. It is therefore difficult to evaluate and measure the overall performance of the utility without resorting to some form of Balanced Scorecard approach.

In 2002 a highly simplified version of the Balanced Scorecard methodology was adopted in South Africa to evaluate the many aspects of a WDM strategy for a large water supplier. The methodology was modified over several years into a simple spreadsheet comprising 25 key issues each of which carried different weightings in accordance with their perceived importance. The approach was found to be very useful and was subsequently modified and customised to evaluate the WDM situation in South Africa as well as in several other countries around the world. It was found to be very helpful in developing a quick and pragmatic WDM strategy for a water supply authority and the respective Clients using this approach also found the process extremely helpful since they were involved directly with the evaluation and scoring of each item.

The methodology is far from complicated and is very simple and straightforward to use. It is extremely flexible and can be modified to suit a specific application or client or even be colour coded if this is considered easier to understand. Many variations of the methodology have already been applied, and the items included in the scorecard can be reduced or increased where appropriate. From the analysis of more than 300 municipalities it has been found that between 20 and 40 items is generally more than sufficient to capture the key elements needed by a specific water supplier to develop a practical WDM strategy. When more items are included, it tends to become a more academic exercise with the subsequent risk of losing focus on the key problem issues to be addressed.

11.7 Summary

When using any of the BABE models it should be remembered that the underlying basis of the methodology as developed by the UK Water Industry is an empirical assessment of various sample datasets obtained from different water utilities throughout the world. The ILI, for example, is based on only 26 different data sets as analysed originally by Allan Lambert, who then selected the four most important variables which he considered to be appropriate to explain physical leakage from a reticulation system (pressure, number of connections, length of mains and length of underground connection pipe). If the same analysis was repeated today based on the many thousands of available datasets, the results and parameters selected may be quite different from those originally selected. It is therefore not an exact science by any means, and those using the BABE Methodology must always be aware that it has its limitations and should not be taken to a level of complexity that ignores the underlying assumptions. The overall methodology is designed to help water supply managers understand their systems and to identify the key issues that influence leakage.

Municipal Scorecard for Assessing the Potential for WC/WDM Efforts in Municipalities

August 2010, Version 2.3

water affairs
Department: Water Affairs
REPUBLIC OF SOUTH AFRICA

WATER RESEARCH COMMISSION

Basic Information

Name of Municipality/ Water Service Provider: ______________________

Additional details (if required): ______________________ Assessment Year: __________

Contact Details

Scorecard completed by

Name: ______________________ E-mail: ______________________

Tel: ______________________ Fax: ______________________

1. Development of Standard Water Balance	Score
WSA has developed reliable water balance and results indicate UAW/NRW at less than 20%	4
WSA has developed reliable water balance and results indicate UAW/NRW at 20% to 40%	3
WSA has developed reliable water balance and results indicate UAW/NRW at more than 40%	2
WSA has no water balance but is currently developing one	1
WSA has no water balance	0

2. Pressurised Supply to all consumers 100% of time	Score
WSA maintains a pressurised supply to all areas within the water distribution network all of the time at a minimum of 20m pressure	4
WSA maintains a pressurised supply to all areas within the water distribution network however pressure drops below 10m in certain areas	3
Small isolated sections of the network experience intermittent supply	2
Many sections of the network experience intermittent supply	1
The entire network experiences intermittent supply	0

3. Residential Metering System	Score
More than 98% of all connections are metered and billed.	4
75% and 98% of all connections are metered and billed	3
50 -75% of connections are metered and billed	2
Less than 50% of connections are metered and billed	1
No metering takes place	0

4. Non Residential Meters (Commercial, Industrial and Institutional)	Score
More than 98% of all non-residential connections, including fire supply connections, are metered and billed based on metered use	4
75% to 98% of all non-residential connections, including fire supply connections, are metered and billed based on metered use	3
50 - 75% of non-residential connections, including fire supply connections, are metered and billed based on metered use	2
Less than 50% of non residential connections, including fire supply connections, are metered and billed based on metered use	1
No non-residential metering takes place	0

5. Effective Billing System & Informative Billing	Score
WSA produces informative billing to all customers based on meter readings	4
WSA produces informative billing to most customers based on meter readings	3
WSA produces informative billing to only some customers based on meter readings	2
WSA has an uninformative billing system in place	1
WSA has no billing system in place	0

6. Network (Leakage) Complaints System	Score
Efficient reporting system in place (90% of reported leaks are repaired within 24 hours)	4
Efficient reporting system in place (90% of reported leaks are repaired within 48 hours)	3
Leakage reporting system in place although response times need to be improved	2
Leakage reporting system in place but few if any field response teams available to undertake repairs	1
No leakage reporting system in place and no plans to create one	0

7. Billing and Metering Complaint System	Score
Efficient reporting system for metering and billing problems in place (90% dealt within 14 days)	4
Efficient reporting system for metering and billing problems in place (90% dealt with within one month)	3
Metering and billing problem reporting system in place response times need to be improved	2
Metering and billing problem reporting system in place but very poor response time with many problems never resolved	1
No Metering and billing problem reporting system in place	0

8. Asset Register for water Reticulation System	Score
WSA has a comprehensive and accurate asset register in place which is available digitally	4
WSA has a partially completed accurate asset register in place	3
WSA has a poor asset register in place	2
WSA is in the process of developing an asset register	1
WSA has no asset register in place and no immediate intention of generating one	0

9. Asset Managemeknt - Capital Works	Score
2% or more of the value of the water network is invested annually into new capital works related to the existing infrastructure	4
1% - 2% of the value of the water network is invested annually into new capital works related to the existing infrastructure	3
Less than 1% of the value of the water network is invested annually into new capital works related to the existing infrastructure	2
No estimate of asset value of water supply system is available but WSA feels that sufficient budget is spent on new Capital Works	1
No estimate of asset value of water supply system is available and WSA feels that insufficient budget is spent on new Capital Works	0

10. Asset Management - Operations and Maintenance	Score
2% or more of the value of the water network is invested annually into the maintenance of the existing infrastructure	4
1% - 2% of the value of the water network is invested annually into the maintenance of the existing infrastructure	3
Less than 1% of the value of the water network is invested annually into the maintenance of the existing infrastructure	2
No estimate of asset value of water supply system is available but WSA feels that sufficient budget is spent on operations and maintenance	1
No estimate of asset value of water supply system is available but WSA feels that insufficient budget is spent on operations and maintenance	0

11. Dedicated WDM Support	Score
Efficient WDM Section in place with sufficient resources	4
WDM section in place requires some resources and capacity building	3
WDM section in place. Major resources and capacity building required	2
No WDM section currently in place, although it is in process of being created	1
No WDM Section and no intention to create WDM section	0

12. Active Leakage Control	Score
Active leakage detection and repair undertaken continuously with average sweep time of 12 months or less	4
Active leakage detection and repair undertaken continuously with average sweep time of 48 months or less	3
Active leakage detection and repair is undertaken on an add-hoc basis	2
No active leakage is currently undertaken, however, the WSA intends to initiate such measures	1
No active leakage detection is undertaken and the WSA has no intention to conduct such measures	0

13. Effective Sectorisation	Score
Reticulation network has been sectorised and is checked regularly to maintain discrete zones	4
Reticulation network has been sectorised but is not checked regularly to ensure discrete zones	3
Only portions of the reticulation network have been sectorised	2
Few if any zones have been created but plans are in place to sectorise the system	1
No sectorisation has been undertaken and no plans are in place to implement such measures	0

14. Effective Bulk Meter Management	Score
All bulk water sources to the WSA are metered by the WSA using some form of check metering(either permanent or temporary)	4
All bulk water sources to the WSA are metered by the Bulk water supplier or by the WSA	3
Few bulk water meters are operational	2
No Bulk Metering in place, however, WSA has plans to install bulk meters	1
No Bulk metering in place and no plans for such meters have been made	0

15. Effective Zone Meter Management and Assessment of minimum	Score
All inlet points to discrete zones are metered and accurate with Minimum Night Flows logged and analysed on a regular basis	4
All inlet points to discrete zones are metered and accurate but no Minimum Night Flow analyses are undertaken	3
All inlet points to discrete zones are metered but many are broken or considered to be inaccurate	2
Zone inputs are currently not metered although the WSA has planned to install meters on all zone inlets	1
No accurate zone metering is in place and there are no plans to introduce such measures	0

16. Pressure Management and Maintenance of Pressure Reducing Valves	Score
Reticulation is comprehensively sectorised into pressure zones which are all discrete. All PRV's are maintained under maintenance schedule	4
Reticulation is comprehensively sectorised into pressure zones which are all discrete. PRV's are only maintained when problems become apparent	3
Reticulation is sectorised in pressure zones but the zones are not verified and little or no maintenance is undertaken on the PRV's	2
WSA intend to introduce pressure zones and the use of PRV's to manage system pressures	1
No Discrete pressure zones and no PRV maintenance	0

17. As-built Drawings of Bulk and Reticulation Infrastructure	Score
Accurate as-built drawings for all reticulation are available digitally	4
As-built drawings available digitally for the majority of the network and available in hard copy for the remainder of the network	3
A mixture of digital and hard copy as-built drawings available for the majority of the network but many problems are known to exist with the data quality	2
Only some hard copy as-built drawings are available for portions of the network	1
No as-built drawings available	0

18. Schematic Layout of Water Infrastructure	Score
An up-to date and detailed schematic of the whole bulk reticulation network is available	4
A detailed schematic of the bulk reticulation network is available but is known to be outdated and/or inaccurate	3
Only a rough schematic of the bulk reticulation network is available which is known to be inaccurate and/or outdated	2
No schematic of the bulk reticulation is available although the WSA is planning to develop such a schematic	1
No schematic of the bulk reticulation is available and the WSA has no plans to develop such a schematic	0

19. Regulations and By-laws	Score
Regulations and By- laws are in place which address WDM issues and some form of enforcement is undertaken	4
Regulations and By-laws are in place which address WDM issues but are not enforced	3
Regulations and By-laws are in place but do not address WDM issues	2
There are no By-laws in place but SA is intending to introduce such measures	1
There are no By-laws in place and WSA has no plans to introduce them	0

20. Tariffs	Score
WSA has rising block tariffs in place that encourage water use efficiency	4
WSA has rising block tariffs in place but they do not encourage water use efficiency sufficiently	3
WSA has single water tariff in place	2
WSA has a declining block tariff in place	1
WSA does not know what tariff structure is in place	0

21. Technical Support to Customers	Score
The WSA actively engages with customers and offers technical support on WDM to both domestic as well as commercial/industrial customers	4
The WSA offers technical support on WDM to large consumers on a pro-active basis	3
The WSA only offers technical support on WDM on a reactive basis	2
The WSA currently offers no technical support but plans to introduce a support mechanism	1
The WSA has no plans to offer technical support on WDM measures to any customer	0

22. Removal of Unlawful Connections	Score
The WSA actively monitors and removes all unlawful connections	4
The WSA selectively monitors and removes unlawful connections	3
The WSA monitors unlawful connections but has no policy for removal	2
The WSA plans to introduce measures to tackle unlawful connections	1
The WSA has no plans to deal with unlawful connections	0

23. Community Awareness and Education Programmes	Score
WSA is actively involved in conducting workshops on water conservation within the communities with a dedicated team	4
WSA is involved in conducting workshops on water conservation within the communities however no dedicated team exists	3
WSA has very little involvement with workshops on water conservation within the communities	2
WSA currently does not conduct workshops on water conservation within the communities, however these interventions are proposed	1
WSA currently does not conduct workshops on water conservation within the communities	0

24. Schools Awareness and Education Programmes	Score
WSA is actively involved in conducting workshops on water conservation within the schools with a dedicated team	4
WSA is involved in conducting workshops on water conservation within the schools however no dedicated team exists	3
WSA has very little involvement with workshops on water conservation within the schools	2
WSA currently does not conduct workshops on water conservation within the schools, however these interventions are proposed	1
WSA currently does not conduct workshops on water conservation within the schools	0

25. Newspaper & radio articles plus posters and leaflets for distribution	Score
WSA runs regular adds in newspapers and/or radio and has library of posters and leaflets for public distribution	4
WSA runs occasional adds in newspapers and/or radio and has library of posters and leaflets for public distribution	3
WSA has library of posters and leaflets for public distribution but does not advertise in newspapers or radio	2
WSA has some leaflets and/or posters and intends to strengthen its capacity to promote WC/WDM in the community	1
WSA does not advertise in newspapers or radio and has no posters or leaflets on WC/WDM	0

"The purpose of the Municipal Scorecard for the assessment of Water supply systems is to ascertain the Status quo of these systems and evaluate the potential for Water Conservation / Water Demand Management (WC/WDM) measures to be implemented in these systems. The scorecard is designed to enable the Regulator (Department of Water Affairs) to assess the current situation regarding losses and levels of wastage in all water supply systems countrywide. The initiative will provide the mechanism whereby the DWA can identify areas where WC/WDM is not being addressed properly to ensure that appropriate measures are taken to encourage efficient use of water and the elimination of wastage. The scorecard is based on a number of key issues which all water service providers must address as part of normal management. The Scorecard will also identify areas of expertise and best practice which can be used to help other areas which are experiencing problems. The following table provides the items included in the Scorecard."

Name of Municipality/ Water Service Provider: ____________________

Item No.	Description	Points
1.	*Development of Standard Water Balance*	
2.	*Pressurised supply to all consumers 100% of time*	
3.	*Residential Metering System*	
4.	*Non Residential Meters (Commercial, Industrial and Institutional)*	
5.	*Effective Billing System & Informative Billing*	
6.	*Network (Leakage) Complaints System*	
7.	*Billing and Metering Complaints System*	
8.	*Asset Register of Water Reticulation System*	
9.	*Asset Management - Capital Works*	
10.	*Asset Management - Operations and Maintenance*	
11.	*Dedicated WDM support*	
12.	*Active Leakage Control*	
13.	*Effective Sectorisation*	
14.	*Effective Bulk Meter Management*	
15.	*Effective Zone Meter Management and Assessment of Minimum Night Flows*	
16.	*Pressure Management and Maintenance of Pressure Reducing Valves*	
17.	*As-Built Drawings of Bulk and Reticulation Infrastructure*	
18.	*Schematic Layout of Water Infrastructure*	
19.	*Regulations and By-Laws*	
20.	*Tariffs*	
21.	*Technical Support to Customers*	
22.	*Removal of Unlawful Connections*	
23.	*Community Awareness and Education Programmes*	
24.	*Schools Awareness and Education Programmes*	
25.	*Newspaper & radio articles plus posters and leaflets for distribution*	

Total: ____

12 APPENDIX I: PRINCIPLES OF PRESSURE MANAGEMENT

12.1 Importance of pressure management

As mentioned previously in the main text, one of the most important WDM interventions that should be considered when developing a comprehensive WDM strategy for an area is pressure management. While it must be acknowledged that pressure management is not the answer in every case, it is often one of the most cost-effective measures to reduce leakage and wastage that can be considered. South African water-supply systems tend to be operated at relatively high pressures and, in some cases, the pressures experienced in the distribution system exceed 150m, which is well in excess of the normal design pressure of 50m. In many parts of South Africa, pressure management is therefore one of the most important WDM interventions, and is often one of the first WDM interventions to be implemented.

There are a number of different options available when considering pressure management ranging from a basic pressure reducing valve (PRV) to several different forms of "advanced pressure control" which require some form of additional electronic or hydraulic control device. While the use of such controllers can reduce leakage rates and the incidence of new bursts significantly, care should be exercised when considering their use. Despite some of the claims being made regularly in the media concerning the huge savings that have been achieved in specific circumstances, the use of such equipment will not work at all if the basics regarding the pressure zone are not in place. In other words, it is essential to ensure that the pressure zone under investigation is operating properly as a discrete pressure zone. If not, then no form of advanced pressure controls, no-matter how "smart" or sophisticated, will function properly.

From experience, the most important issue when trying to introduce any form of pressure management is ensuring that the zone being considered is discrete and remains discrete. Only then can any form of pressure management be considered. Installing and operating controllers is the easy part of this intervention while establishing a proper pressure zone is often the most difficult and time consuming part of the work. If the zones are not discrete and are interlinked in any way, then pressure management is unlikely to function properly and should not even be considered until the underlying zone problems have been resolved.

12.2 Concepts of pressure management

Water-supply systems worldwide are generally designed to provide water to consumers at some agreed level of service, which is often defined as a minimum level of pressure at the critical point, which is the point of lowest pressure in the system. In addition, there may be certain fire-flow requirements which can override the normal consumer requirements. The systems are designed to accommodate these pressure and flow requirements during the period of peak demand, which would normally occur at some specific time of the day and during a particular month in the year. In other words, the systems are designed to provide the appropriate supply during a very short period in the year and for the remainder of the time the systems tend to operate at pressures significantly higher than required. Even within the same system, there will be areas of high pressure due to topography and/or distance from the supply point with the result that many parts of a supply area will operate at pressures significantly higher than required in order to ensure that there is sufficient pressure at the one critical point.

Managing water pressures in a supply area is not a simple issue and there are a great many items to consider. The common factor in every system is the fact that leakage is driven by pressure and if the pressure is increased, the leakage will also increase. If the water pressure in a system can be reduced, even for a short period during times of low demand, the water leakage from the system will be reduced.

Many theories have been postulated to explain the pressure-leakage relationships in a municipal water-supply system with the FAVAD (fixed area variable area) being the most widely accepted approach. Contrary to popular belief worldwide, the origin of the FAVAD theory can be traced back to a paper by Ledochowski (1956), who completed his research in Johannesburg. It is therefore very fitting that Johannesburg should have been the first city to implement advanced pressure control on a relatively large scale in South Africa back in 1998.

In summary, the relationship between pressure and leakage will conform to a square-root relationship in cases where the size of the leakage path (i.e. hole) remains constant during the change in pressure. This is the typical situation when the leak is a small hole in an iron or steel pipe (i.e. a fixed area leak) in which case doubling pressure will result in approximately a 41% increase in leakage. In the case of leaks from plastic pipes or from cracks in asbestos cement pipes, the surface area of the leakage path does not remain constant when the pressure changes and such leaks will often open up to create a larger hole through which the water can leak. Such leaks are referred to as variable area leaks and if the pressure is doubled, the leakage will increase more than from a fixed area leak. In some cases, the leakage will increase by as much as 8 times the original level.

In order to reduce leakage through pressure management it is necessary to reduce the water pressure without compromising the level of service with regard to the consumers and fire-fighting. As mentioned previously, most systems are designed to provide a certain minimum level of service in the system during the peak demand period.

In most systems, there tends to be a mixture of fixed area and variable area leaks, and the split will depend on the proportion of steel/iron pipes to plastic/asbestos pipes. Many papers have been presented on this topic in which formulae are provided to predict the impact of changes in pressure on leakage. From the author's experience, it is often found that certain other factors play a more critical role in the pressure-leakage relationship. For example, it has been found in many parts of South Africa that the quality of workmanship when laying the pipes is one of the most important factors influencing the leakage. Two similar systems next to each other can have significantly different leakage characteristics simply because one system was laid properly with adequate site supervision while the other system was laid by a poorly qualified contractor with poor supervision. In such cases, there is no adequate theory to explain the different responses to changes in pressure.

In order to reduce leakage through pressure management it is necessary to reduce the water pressure without compromising the level of service with regard to the consumers and fire-fighting. As mentioned previously, most systems are designed to provide a certain minimum level of service (around 20m) in the system during the peak demand period.

During the off-peak periods, which tend to much greater than the peak periods, the system operates at a water pressure which is significantly higher than necessary. In effect, there are long periods when there is significant scope for pressure reduction and this is the basis on which the pressure management interventions are designed.

Reducing the water pressure in a system can be achieved in a number of ways each of which has advantages and disadvantages. The following techniques are discussed:

- Fixed outlet pressure control
- Time-modulated pressure control
- Flow modulated pressure control
- Closed loop and hybrid control

Fixed outlet pressure control involves the use of a device, normally a pressure reducing valve (PRV) which is used to control the maximum pressure entering a zone as can be seen in **Figure 87**. This is possibly the simplest and most straightforward form of pressure management as it involves the use of a PRV with no additional equipment. The advantages of this form of pressure control are:

- It is relatively simple to install as it requires only a PRV
- Cost is relatively low as it involves no electronic equipment
- Maintenance and operation is relatively simple

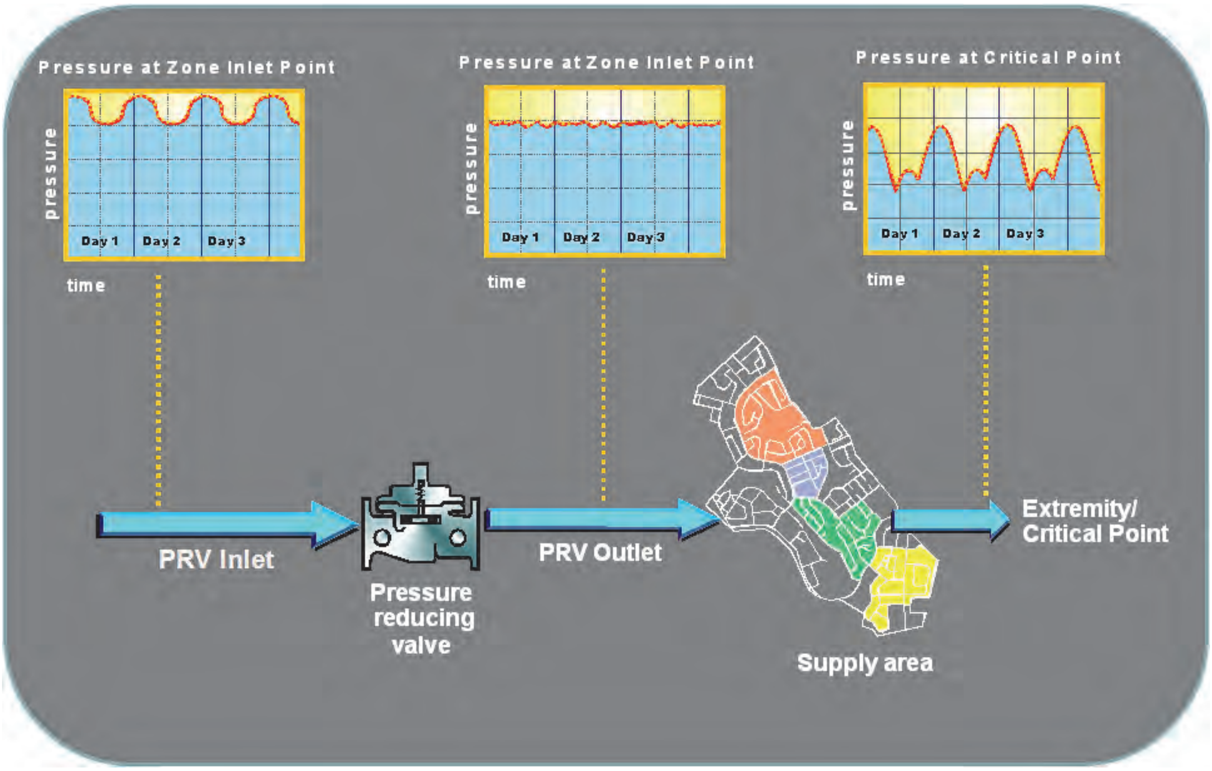


Figure 87: Fixed outlet pressure control

The only disadvantage is that the system does not have the flexibility to adjust the water pressures at different times of the day, with the result that the maximum possible savings cannot be achieved. In many instances, fixed outlet pressure control is the preferred option due to the capacity of the maintenance teams who may not be able to operate and maintain the additional equipment required when using some form of advanced pressure control.

The time-modulated pressure management option is shown in **Figure 88** and is effectively the same as the fixed-outlet system with an additional device which can provide a further reduction in pressure during off-peak periods. This form of pressure control is useful in areas where water pressures build up during the off-peak periods – typically during the night when most of the consumers are asleep. The main advantages of this option are:

- The controller provides greater flexibility by allowing pressures to be reduced at specific times of the day, resulting in greater savings
- The electronic controller is relatively inexpensive
- The controller is relatively easy to set up and operate
- The installation does not require a flow meter as the controller connects directly to the pilot on the PRV

The main disadvantage of time-modulated control is that it does not react to the demand for water and this can be a problem if a fire breaks out requiring full pressure for fire-fighting. This problem can be overcome to some extent through the installation of a flow meter. In addition, the time-modulated option is more expensive than the fixed outlet option and does require a higher level of expertise to operate and maintain the installations.

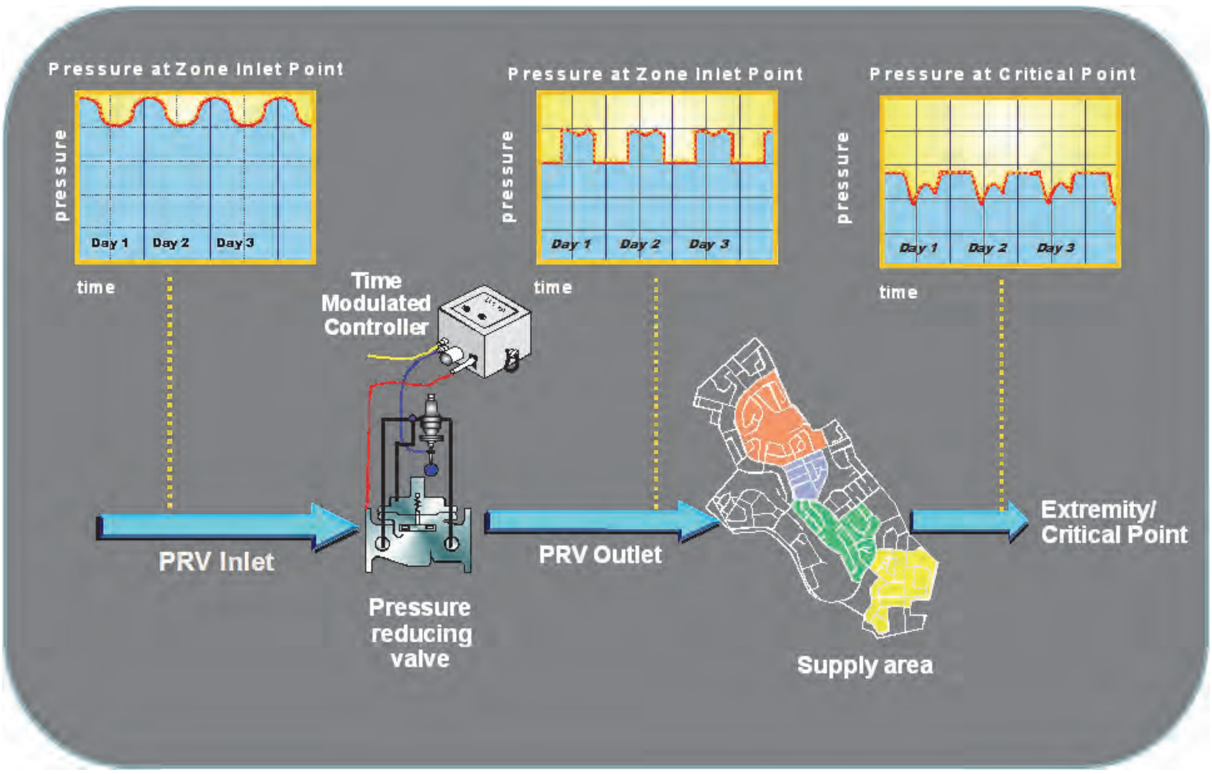


Figure 88: Time control

A typical time-control installation is shown in **Figure 89** from which it can be seen that the controller is only connected to the pressure reducing valve via three coloured plastic pipes (red, green and blue). The fourth cable which is connected to the meter is an optional cable that is simply used to log the flow going through the installation but has no influence on the controller.The controller itself is a simple device which is easily set up using the two selection buttons on the front panel to set up the time for switching between the high and low pressure settings. A simple round knob-like dial on the bottom of the controller is used to control the low pressure setting while the high pressure setting is fixed by the pilot on the pressure reducing valve. Should the controller fail for any reason, the PRV will revert to the outlet pressure setting as controlled by the pilot of the PRV. It should be noted that there are many similar controllers available in the market and they all have slightly different features.

Figure 89: Typical PRV with time-control (photo Niel Meyer)

Flow modulated pressure control as shown in **Figure 90** provides even greater control and flexibility than the time-modulated option. It will normally provide greater savings than either of the two previously mentioned options but this greater flexibility (and savings) comes at a price. The electronic controller is more expensive and it requires a properly-sized meter in addition to the PRV. It may not always be cost effective to use the flow modulated option and careful consideration should be given to the specific application before selecting flow-modulated control. One key advantage is that the flow modulated option will not hamper the water supply in the case of a fire but the additional savings achieved may be offset against the extra cost of the controller and need for a meter. In addition, there are more components in a flow modulated installation and there will be failures from time to time. The reduction in savings during such component failures is an issue to consider.

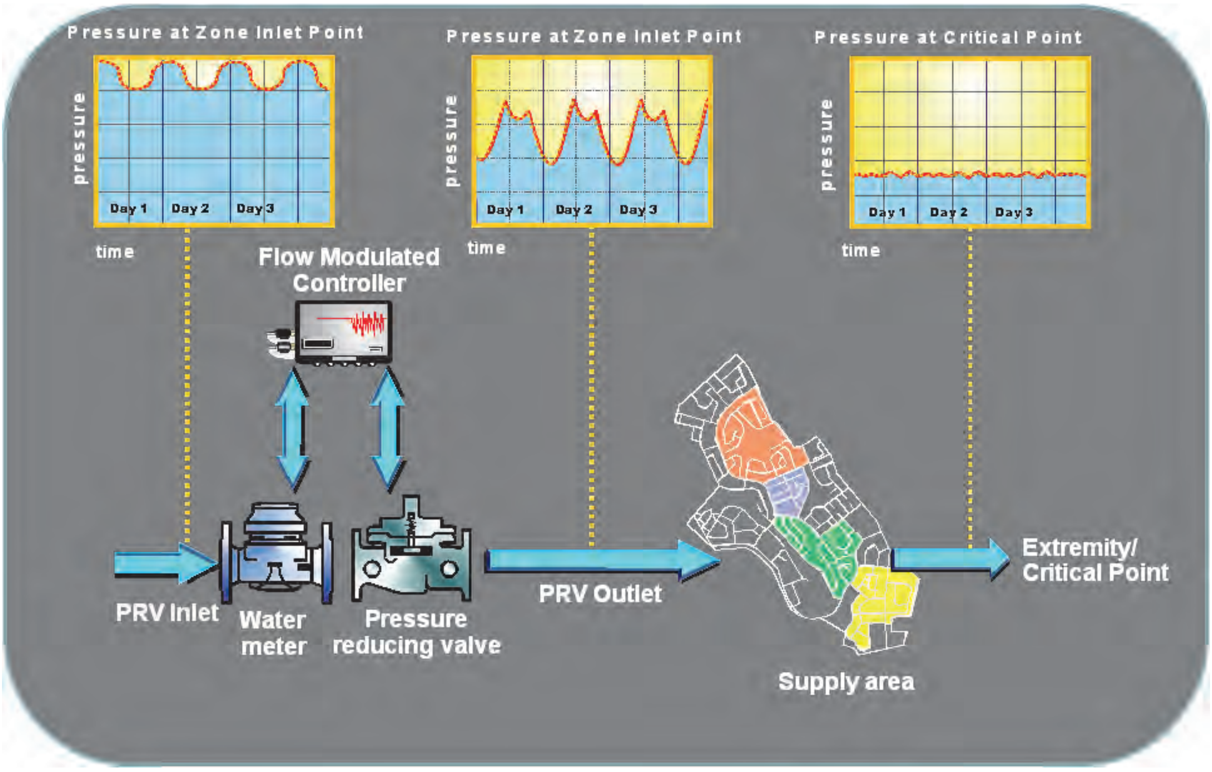


Figure 90: Flow modulated pressure control

A typical example of flow modulated pressure control is shown in **Figure 91** from which it can be seen that the downstream pressure profile closely mimics the flow through the installation.

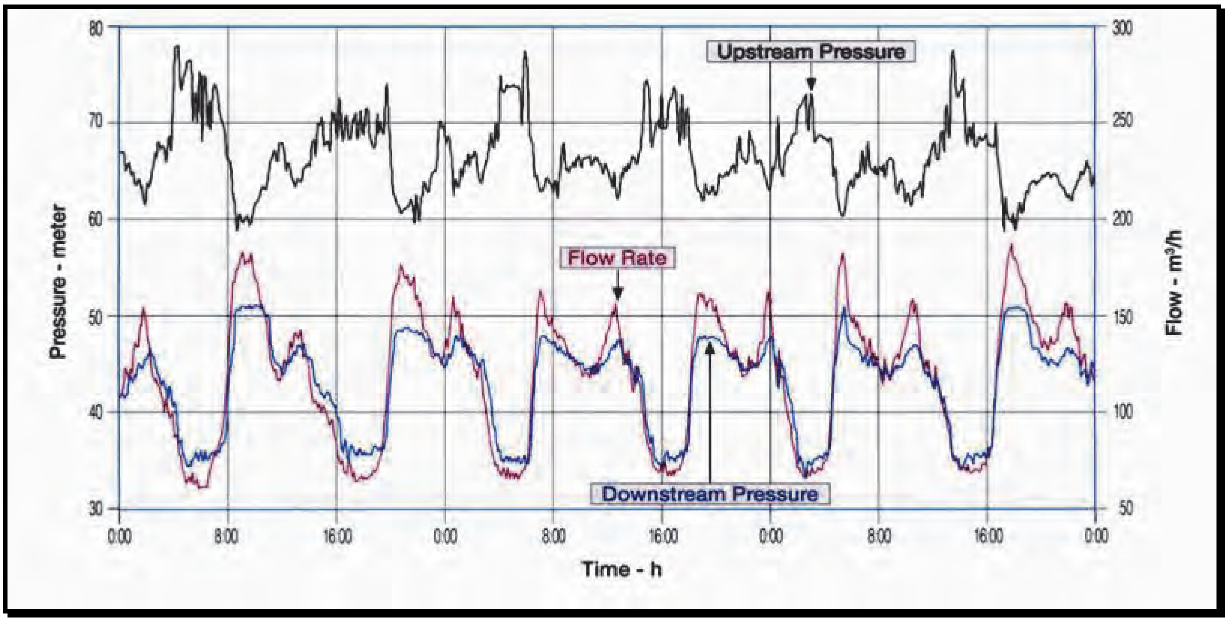


Figure 91: Flow modulated pressure control

This form of pressure control has various advantages over the simpler time-control or fixed outlet control in that it provides greater flexibility and will generally achieve greater savings than the simpler forms of control – usually an additional 10% to 20%. It also helps to address any concerns regarding the fire-fighting flow requirements in the respect that in the case of a fire, the controller will open up if required to maintain the necessary system pressure to support the increased flow. The increased flexibility does, however, come at a cost, which includes not only the increased cost of the controller itself but also the need for a flow meter to drive the controller. The flow meter must be properly sized and fully functional together with a working reed-switch to connect the flow meter to the controller. In addition, the controller may require the use of a computer or hand-held device to set up the pressure and flow profile. It is therefore a more complicated process, and one that now includes several other components, all of which can malfunction and therefore represent potential problem issues when using such control. In certain circumstances where the potential savings warrant such control and the client has the technical capacity to operate and maintain the equipment, it can be a viable option. In other cases, it may be too sophisticated and without proper maintenance it will not be sustainable, in which cases a simpler and more robust solution should be considered.

Figure 92 shows a typical set-up for a flow modulated controller in which the key items necessary to achieve flow control are indicated.

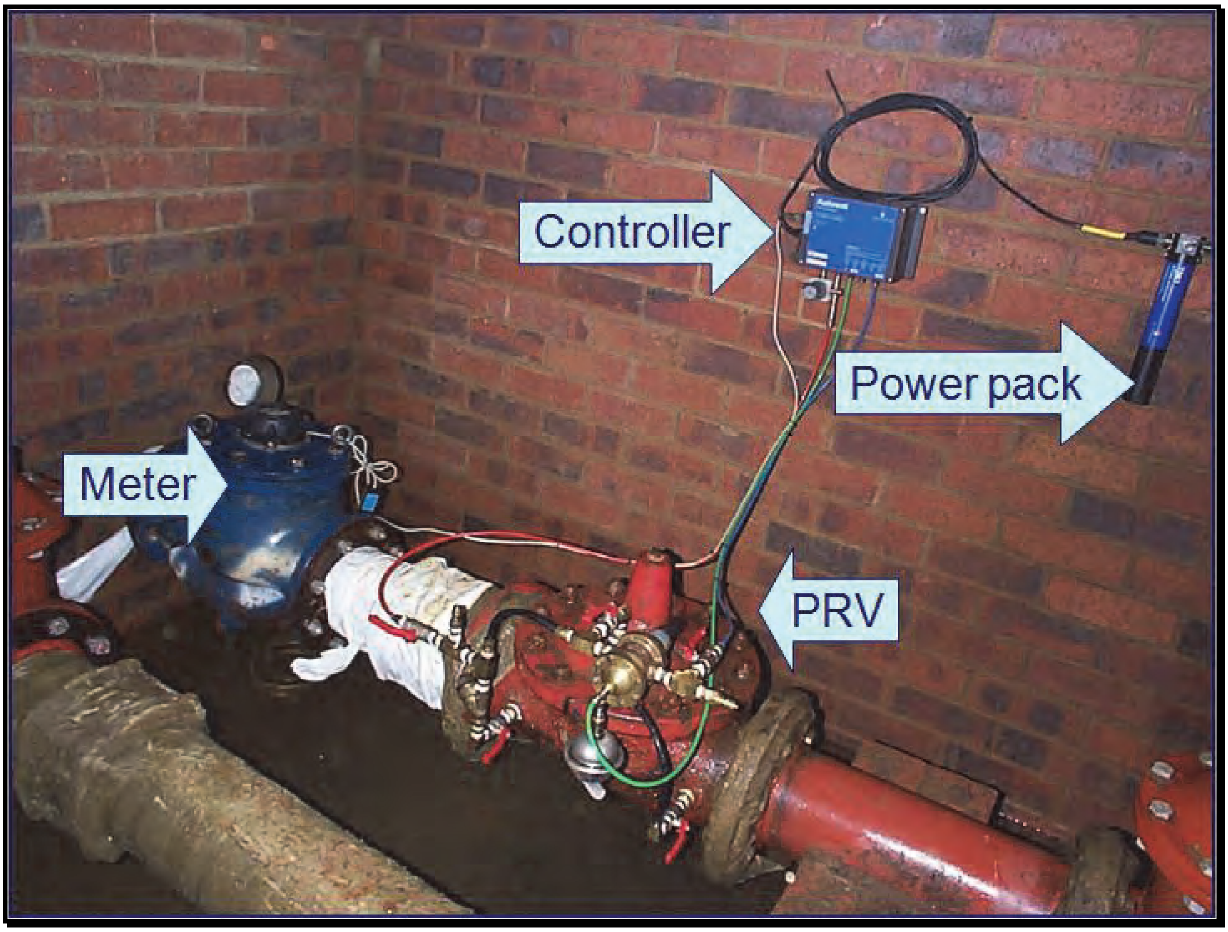


Figure 92: Typical flow modulated controller installation

In most cases, flow modulated pressure control is as sophisticated as most water utilities will consider. In many instances, the use of flow modulated control is beyond the human resource skills base of the water utility and, as a result, time-modulated control or basic fixed outlet pressure control is the preferred and most appropriate option. In recent years, however, several more advanced “closed-loop” and “self-learning” systems have been implemented in various parts of the world which claim even greater savings than those achieved from flow control with claims of an extra 2% to 10% over standard flow control. In these more advanced installations, a pressure sensor at the critical point is generally used to monitor the pressure and provide some form of feedback to the controller at pre-defined intervals. The feedback to the controller can be on a real-time basis, in which case it will normally update the controller on the pressure status at the critical point every 15 minutes or so. In other cases, it will record a full day of pressure information before transmitting the data to the controller which will then adjust the pressure profile for the following day. These forms of pressure control as shown in **Figure 93** and **Figure 94** can provide the near ultimate level of control and therefore also the maximum savings that can be achieved.

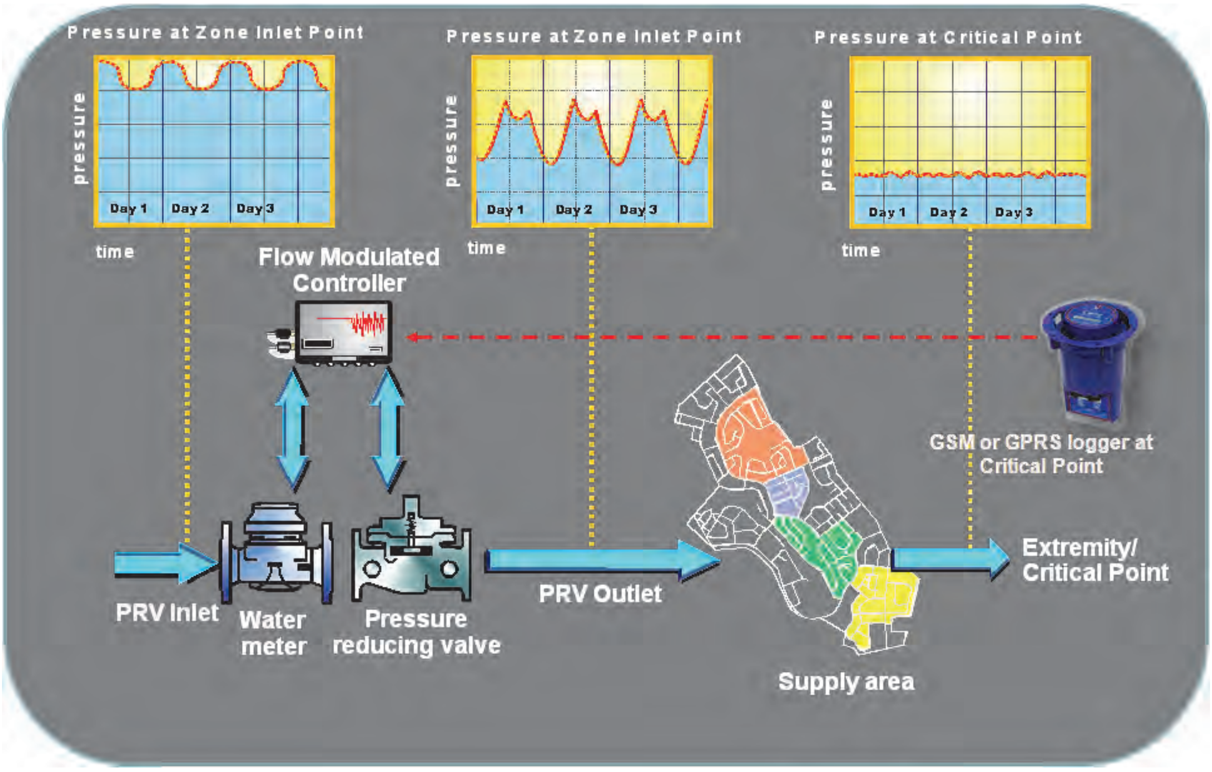


Figure 93: Closed loop pressure control

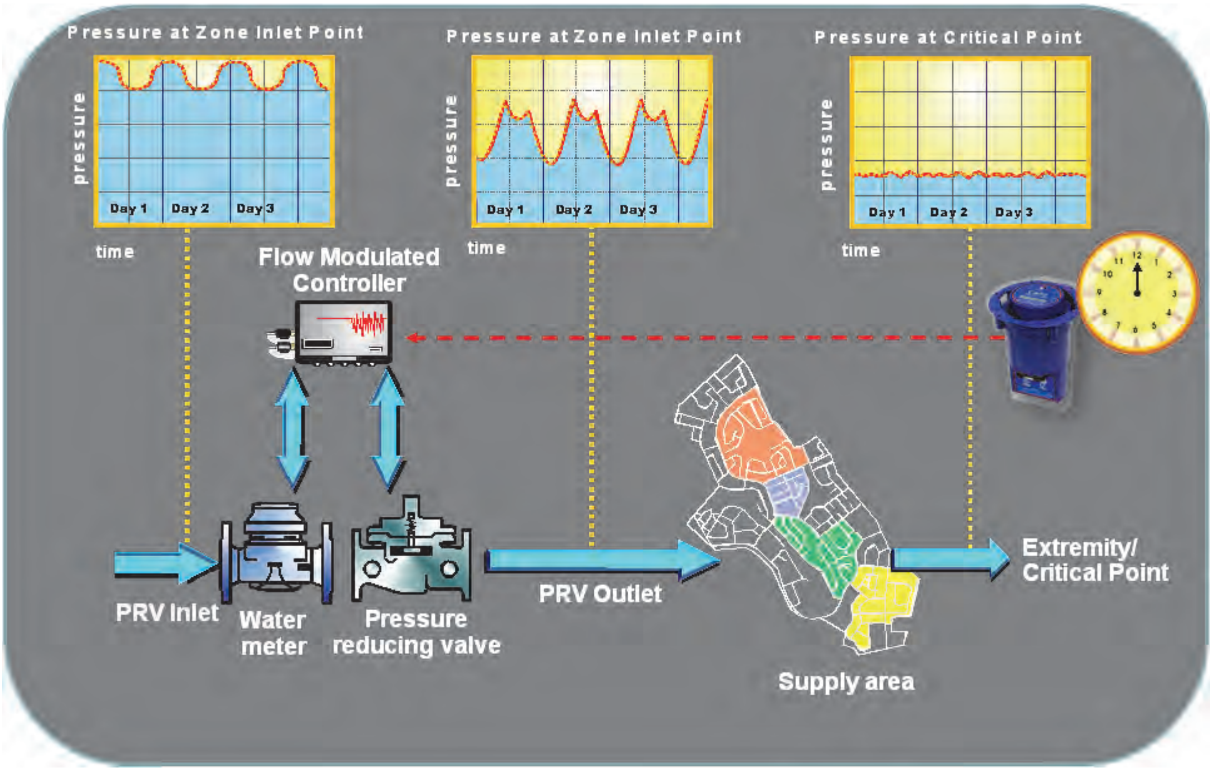


Figure 94: Advanced closed loop pressure control

Once again, both approaches have certain advantages and disadvantages, which should always be taken into account when trying to establish the most appropriate form of pressure control for a specific application. Any additional savings will come at a cost both in monetary terms and also the technical expertise needed to support the long-term sustainability of the equipment and the possibility of component failure which will happen at some time as well as the battery life for the units in cases where they are battery powered.

It should be noted that there are numerous other forms of pressure control which can be considered when trying to reduce losses from a water distribution system. Several excellent hydraulic controllers are also available in addition to a number of simpler devices based on a basic orifice plate. No matter what approach is selected, if the water pressure in an area can be reduced for even a short period, there will be a reduction in leakage, a reduction in the number of new burst pipes and the useful life of the reticulation system will be extended to some degree.

12.3 When to use pressure controllers

In recent years there has been considerable debate regarding the use of electronic controllers on pressure reducing valves. The most common question being asked is "when is it appropriate to use a controller and if so, what type of controller". Unfortunately there is no clear cut answer to this question, and each installation and pressure zone must be examined carefully after which the various options can be compared and a final decision taken. It is important to look beyond the hype and spin of some suppliers who promote the use of controllers in virtually every case when in reality, many situations do not warrant the use of anything more than a standard pressure reducing valve. Based on the results achieved from over 400 pressure management installations, it appears that the largest saving achieved from a pressure management installation is usually from the basic fixed outlet pressure control, which simply involves a pressure reducing valve and associated pilot. In most cases, this will provide around 60% to 70% of the ultimate savings that can be achieved and, in some cases, even more. Obviously the benefits will vary from case to case and will depend on the characteristics of the pressure zone in question. Adding some form of time-control can often give a further 10% to 20%, again depending on the characteristics of the zone. A flow controller will bring up the ultimate savings to between 90% and 95% of the ultimate savings and some form of closed-loop or self-learning control will provide the remainder. Any claims that a controller is directly responsible for generating 60% of the savings or more are usually over optimistic and tend to include both the benefits of the fixed outlet control and the controller.

In summary, if a zone experiences large pressure fluctuations at the critical point between peak demand and off-peak demand periods, there will often be scope for additional savings through the use of a controller. In other cases, where a system does not experience major pressure fluctuations at the critical point between the peak and off-peak periods, there will be little benefit achieved through the use of a controller unless the client is willing to accept a different critical point pressure at night compared to that required during the day.

To highlight the above issue, the Eerste River Case Study from the City of Cape Town provides an excellent case study where a controller is not necessary. The Eerste River water-supply system initially experienced very high water pressures in excess of 80m, resulting in high water losses through infrastructure leaks and a high incidence of burst pipes.The level of leakage at the start of the project before any form of pressure management was introduced can be seen in **Figure 95** which indicates an average daily flow of 265 m^3/hr and a minimum night flow of around 158 m^3/hr. The ratio of MNF to ADD (often used as a rough indicator of leakage levels) of 60% was very high and suggested very high levels of leakage in the area – a target value of around 20% would normally be considered acceptable. As a result of the high water pressure, the zone experienced approximately 240 bursts per annum before any form of pressure control was introduced. This naturally had major cost implications as well as service delivery implications.

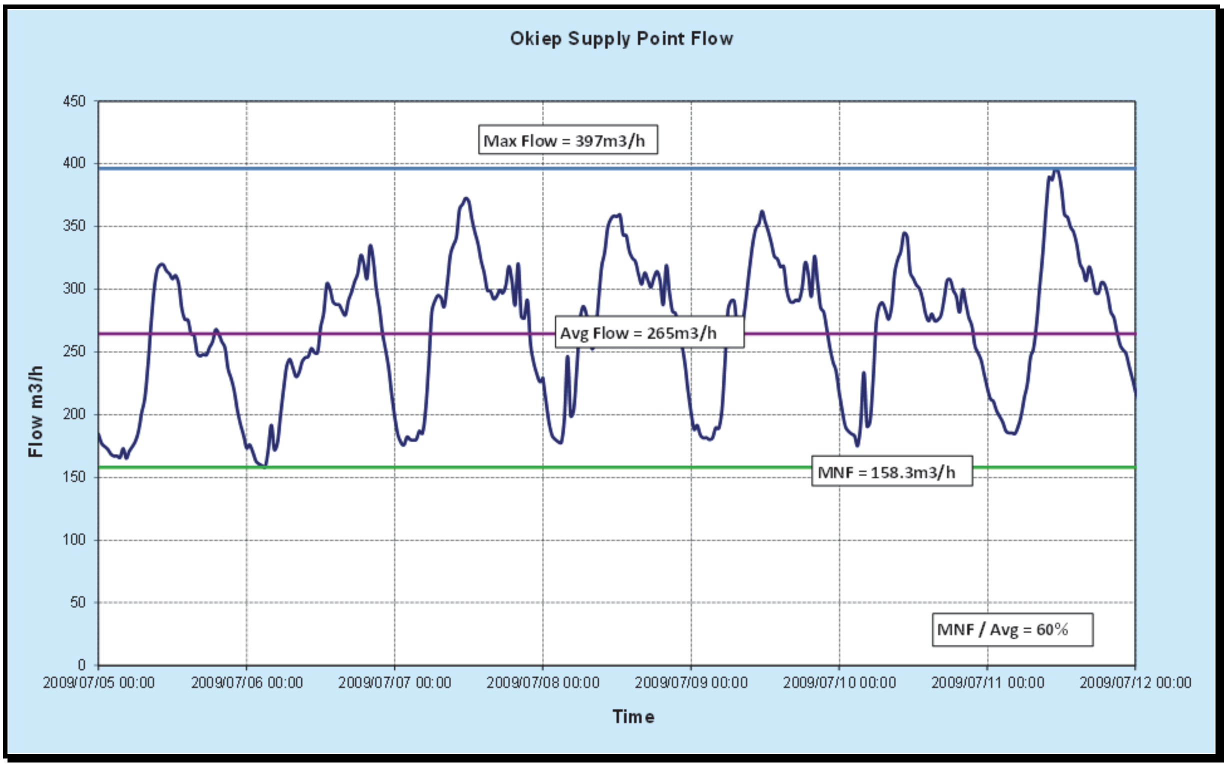


Figure 95: Original flows into Eerste River

To address this problem, the City of Cape Town commissioned the design and implementation of a single pressure management installation on the main supply pipeline into the area. Before introducing the pressure management, it was first necessary to sectorise the area and eliminate all bottle-necks caused by open or closed valves which first had to be identified. This is often the most difficult and time-consuming part of any pressure management initiative and only after the zone has been properly sectorised can the pressure be reduced.

The area involved is shown in **Figure 96** and the PRV installation involved a single chamber housing a 250mm-diameter valve. The initial pressures in the area are shown in **Figure 97,** which highlights that the pressures at both the inlet and critical point were very high, with critical point pressures of between 60m and 80m. In such an area, there is clearly significant scope for some form of pressure management and the main PRV installation was completed in 2009. It is also important to note that in this specific case, the variation in pressure at the critical point between peak and off-peak demand periods was relatively small. This is unusual as it indicates that the reticulation network is under relatively little stress during the peak demand periods, and often indicates that the area has yet to achieve its full developed demand.

Before even considering the use of a controller, it is good practise to set up and monitor the effect of the basic PRV based on fixed outlet pressure control. In this case the pressure at the outlet of the PRV was reduced from over 80m to approximately 47m. The selection of the downstream pressure at 47m was based on the client's request that the pressure at the critical point should not drop below 35m and this can be seen in **Figure 99** which highlights that the critical point pressure has effectively stabilised at between 38m and 35m, which is an unusually tight pressure band to find at a critical point from normal fixed outlet pressure control.

The net result of this reduction in pressure is shown in **Figure 100** where the reduced water consumption is highlighted by the area shown in blue. As can be seen in **Figure 100,** the savings are highly significant and clearly demonstrate the benefits that can be achieved from standard fixed outlet pressure control. The MNF dropped from 158 m^3/hr to 47 m^3/hr and there was still considerable scope for further pressure reduction since a minimum critical point pressure of 20m is usually sufficient.

A summary of the initial savings generated through fixed outlet control at the Eerste River pressure management installation is provided in **Table 12.** The value of the water savings is based on the estimated cost of water production of R6.20/m^3.

Table 12: Eerste River pressure management project savings

Area	Savings (m^3/day)	Savings (m^3/year)	Value Savings / year @ R6.20/m^3	Implementation Cost	Payback Period
Eerste River	3 288	1 200 120	R 7 440 744	R 2 000 000	0.3 years

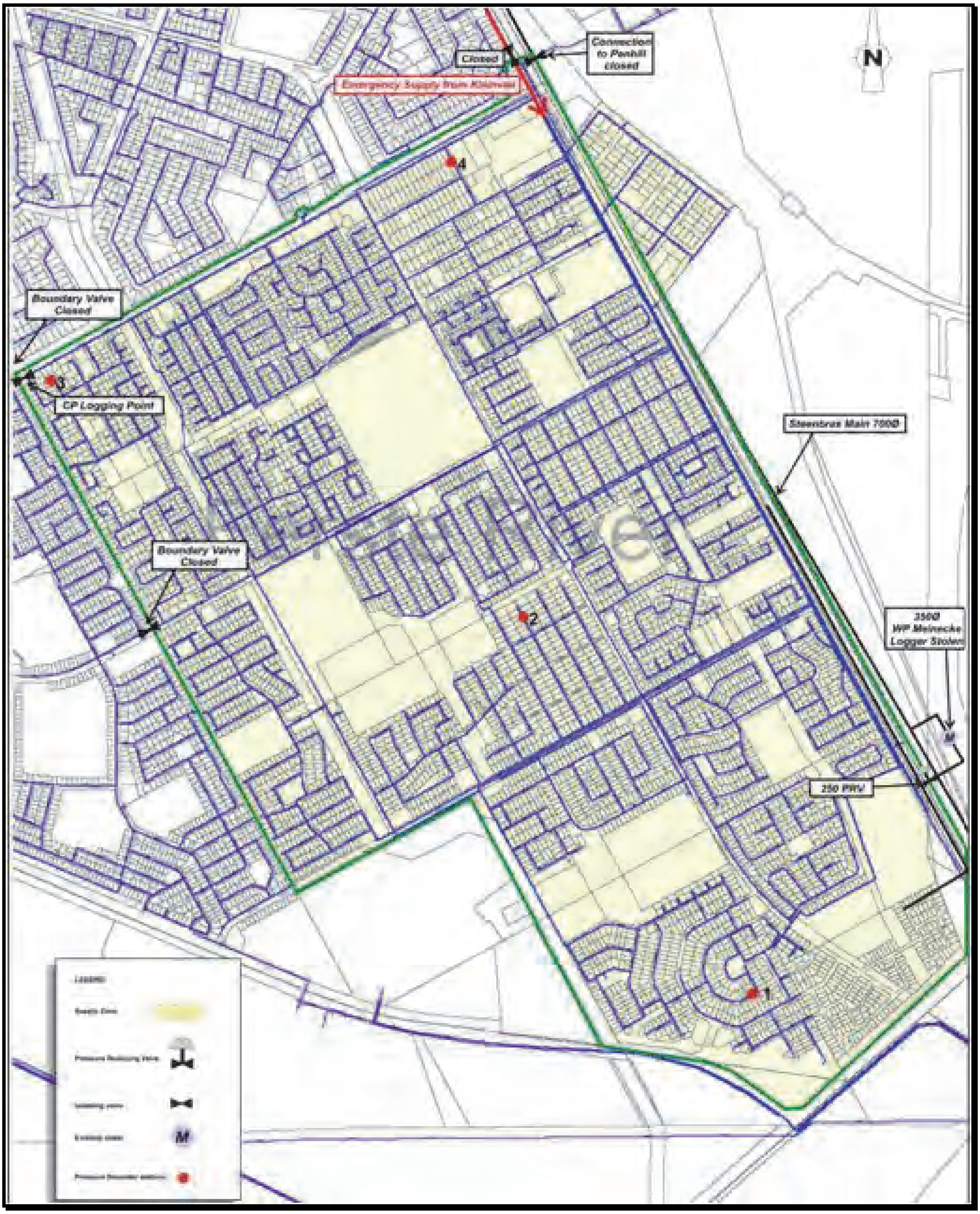


Figure 96: Map of the Eerste River pressure management zone

As can be seen from the figures provided in **Table 12**, the payback for this specific installation was around 4 months based on the initial savings. The use of fixed outlet pressure control in this area resulted in a reduction of more than 70% based on the minimum night flow dropping from 158m^3/hr to 47m^3/hr. The total water use in the zone reduced from 266m^3/hr to 129m^3/hr representing a reduction of approximately 50% as can be seen in **Figure 100**. In addition, the average number of burst pipes per annum was reduced from over 240 per annum to less than 24 per annum following the initial intervention – a drop of approximately 90%.

Returning to the initial question of whether or not to use a controller, the answer lies in **Figure 99** which shows the new pressure at the critical point. This figure clearly highlights that there remains scope for further pressure reduction in the area based on a normal minimum pressure of 20m. What is very interesting, however, is the fact that the pressure variation at the critical point is unusually low at only ± 5m and there is relatively little additional benefit to be gained from advanced pressure control.

In order to establish the additional benefits of further pressure control in this area, the client subsequently tested the impact of reducing the fixed outlet pressure to 27m with an additional drop to 4m (using a highly sophisticated electronic controller) for approximately 6 to 8 hours each night. Dropping the pressure to 27m is easily achieved by simply adjusting the pilot on the main PRV while the additional drop at night is achieved using some form of advanced pressure control. Based on the published results, the overall water use dropped to an average of 127m^3/hr, the minimum night flow dropped to 32m^3/hr and the number of new burst pipes dropped to around 9 per annum. Clearly the introduction of more advanced pressure control does result in additional savings and it is simply a matter of deciding if the additional savings are sufficient to motivate the additional expense and associated maintenance. As always, there are two views on this and ultimately it is the decision of the client.

One further comment regarding the application of pressure management which was conveyed by the water demand manager at one of the largest Metros in South Africa concerns the number of complaints received from consumers in a specific area. When assessing the financial viability of pressure reduction, it is also important to monitor customer complaints as they can often influence how low the pressure can be taken. In many cases, the financial models will suggest that water pressure can still be reduced while the water supplier will decide to accept a higher pressure regime to minimise customer complaints. The issue of pressure management will therefore often come down to some form of subjective decision and trade-off between savings and complaints.

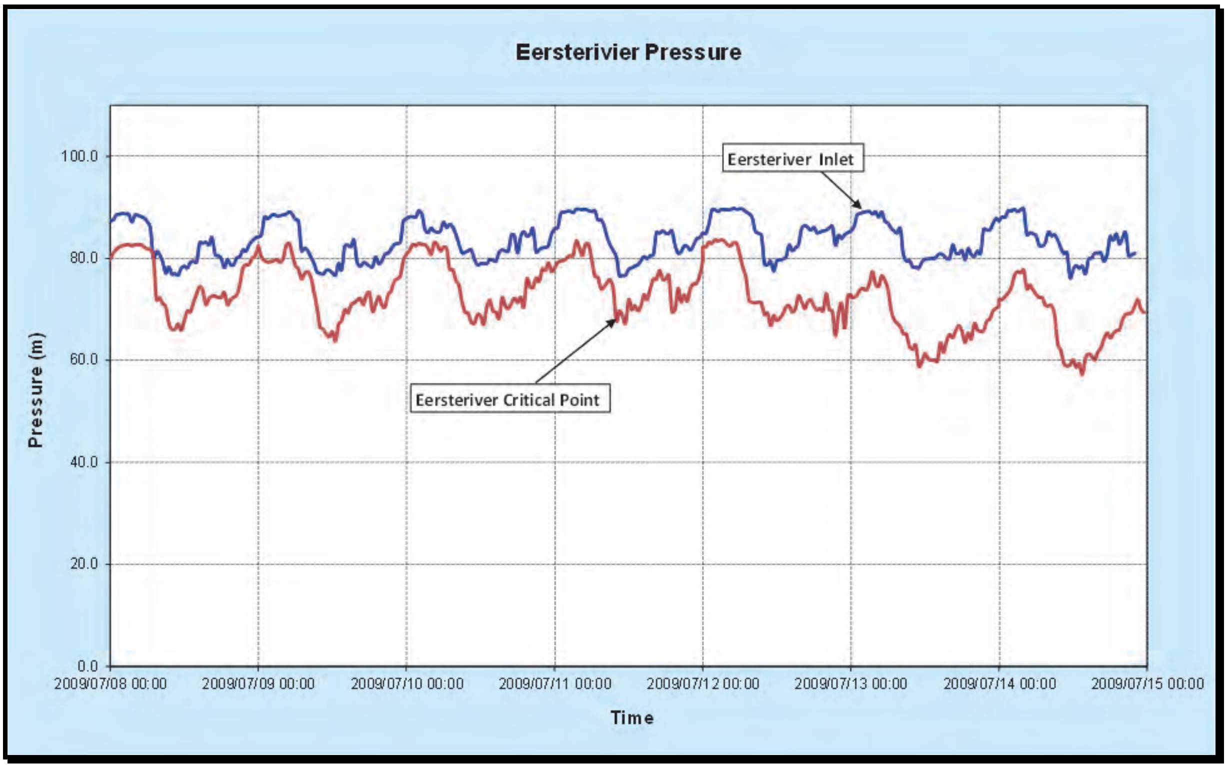


Figure 97: Original pressure in Eerste River

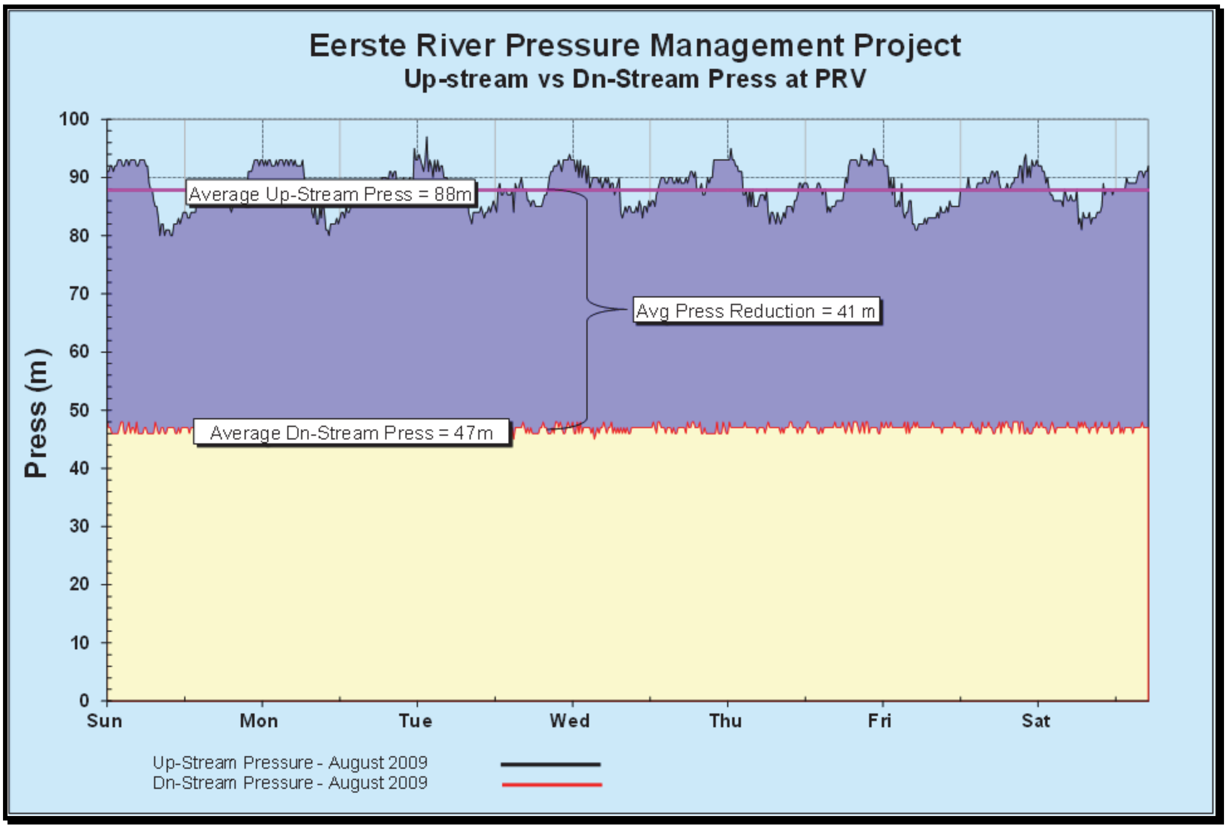


Figure 98: Pressures after implementation of fixed outlet pressure control

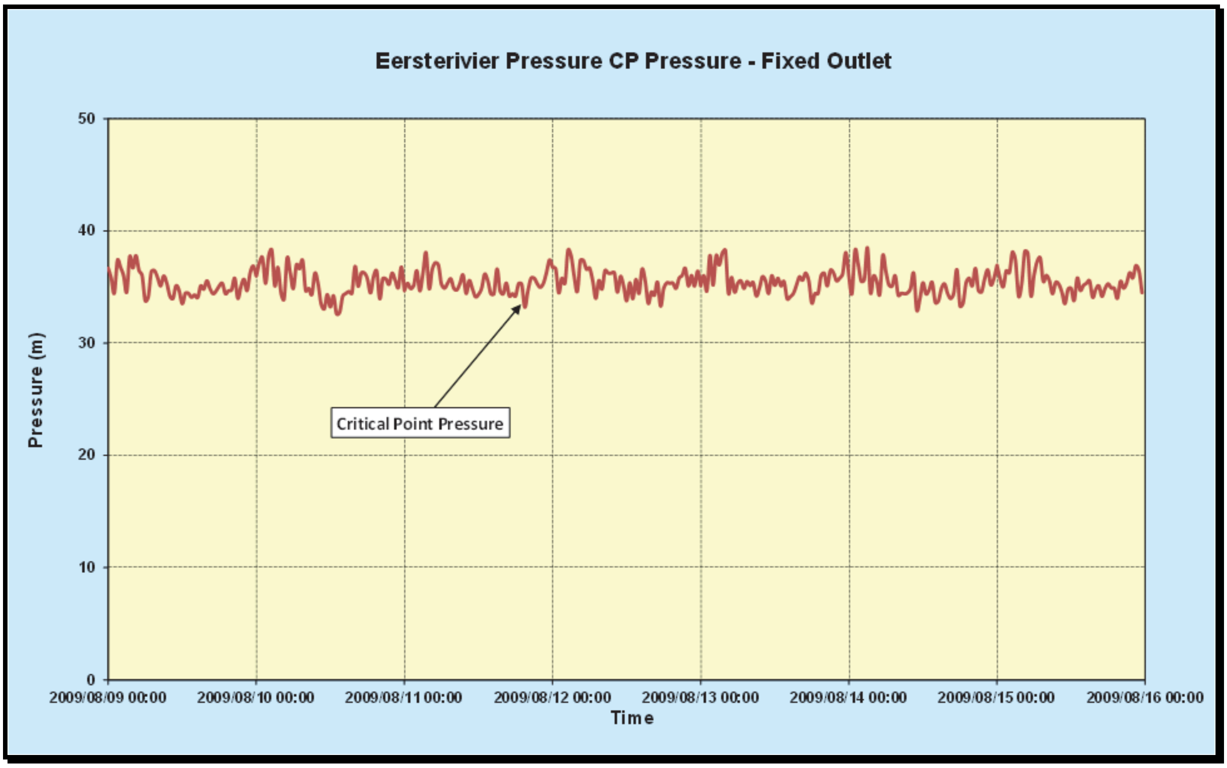


Figure 99: Critical point pressure after fixed outlet pressure control

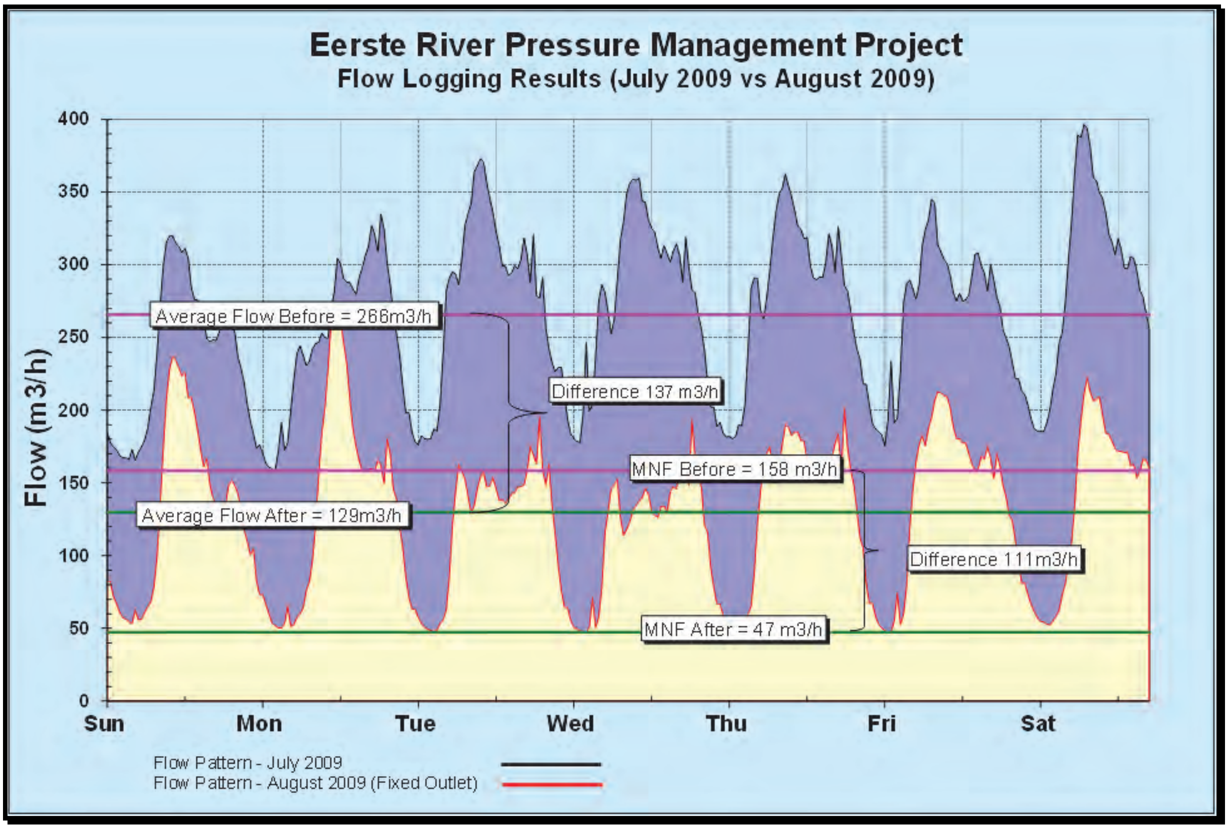


Figure 100: Flow savings from fixed outlet pressure control

The previous example from Eerste River demonstrated a zone where significant savings could be achieved through the implementation of pressure management although there was little if any additional benefit to be gained through the use of advanced pressure control due to the fact that the pressure at the critical point was already stable through the use of a normal fixed outlet PRV. In this second example, another zone is used to highlight a case where there is scope for advanced pressure control. The example is again from the City of Cape Town in an area called Langa as shown in **Figure 101**.

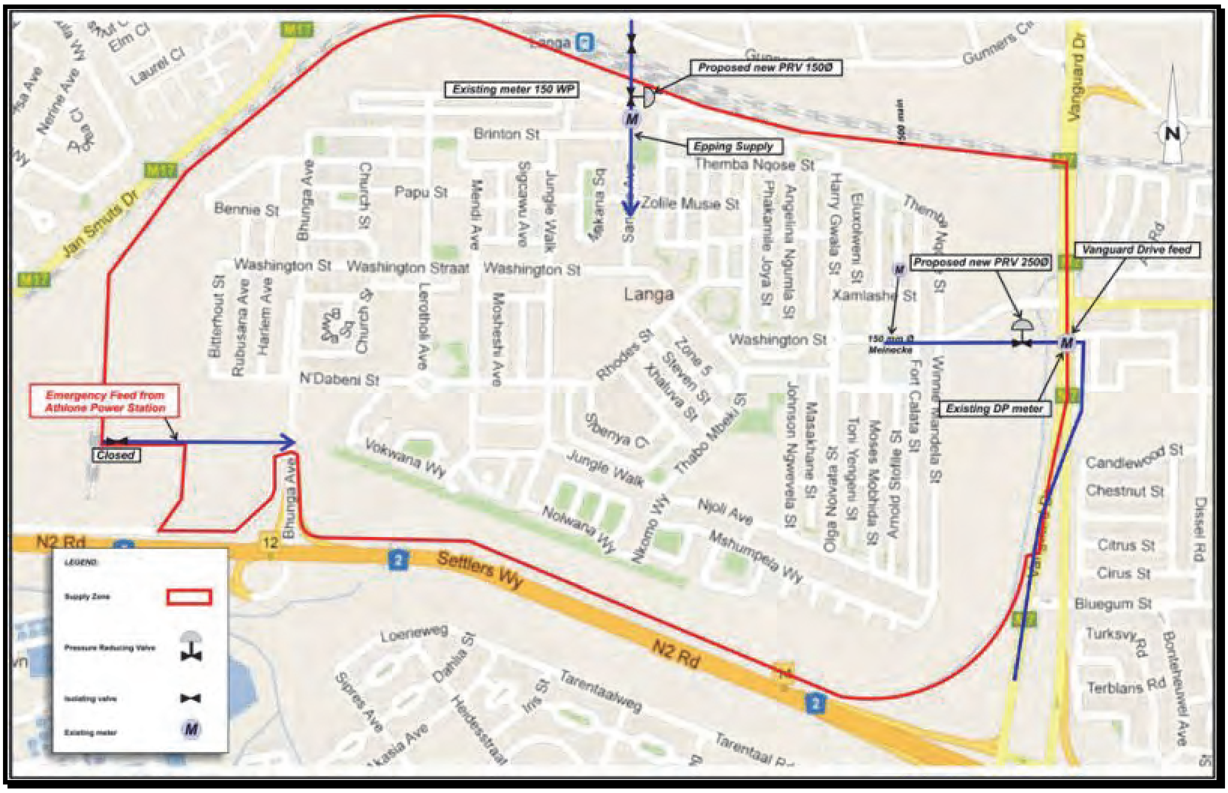


Figure 101: Location plan for Langa

The zone is not particularly large but makes an interesting case study due to the fact that the pressure at the critical point is highly variable unlike the previous example where there was very little difference between peak demand pressure and off-peak pressure. The inlet pressure, PRV outlet pressure and flow profile for Langa are shown in **Figure 102** in which it can be seen that the PRV has been set to provide a fixed outlet pressure of around 52m and the valve is indeed providing a stable and continuous pressure into the zone. he resulting pressure at the critical point is shown in **Figure 103** which clearly highlights a significant pressure variation between peak conditions and off-peak conditions. Such a pressure variation is often observed in pressure zones and is a function of the characteristics of the reticulation system and the system demand. If the demand is high relative to the capacity of the water mains, then at peak demand conditions the friction losses will be high and as a result, the system pressure at the critical point will be significantly lower than that provided into the zone at the PRV. During off-peak conditions, there is little demand and therefore the friction losses are also low with the result that the pressure at the critical point is at or near the zone inlet pressure. This is clearly reflected in **Figure 103**.

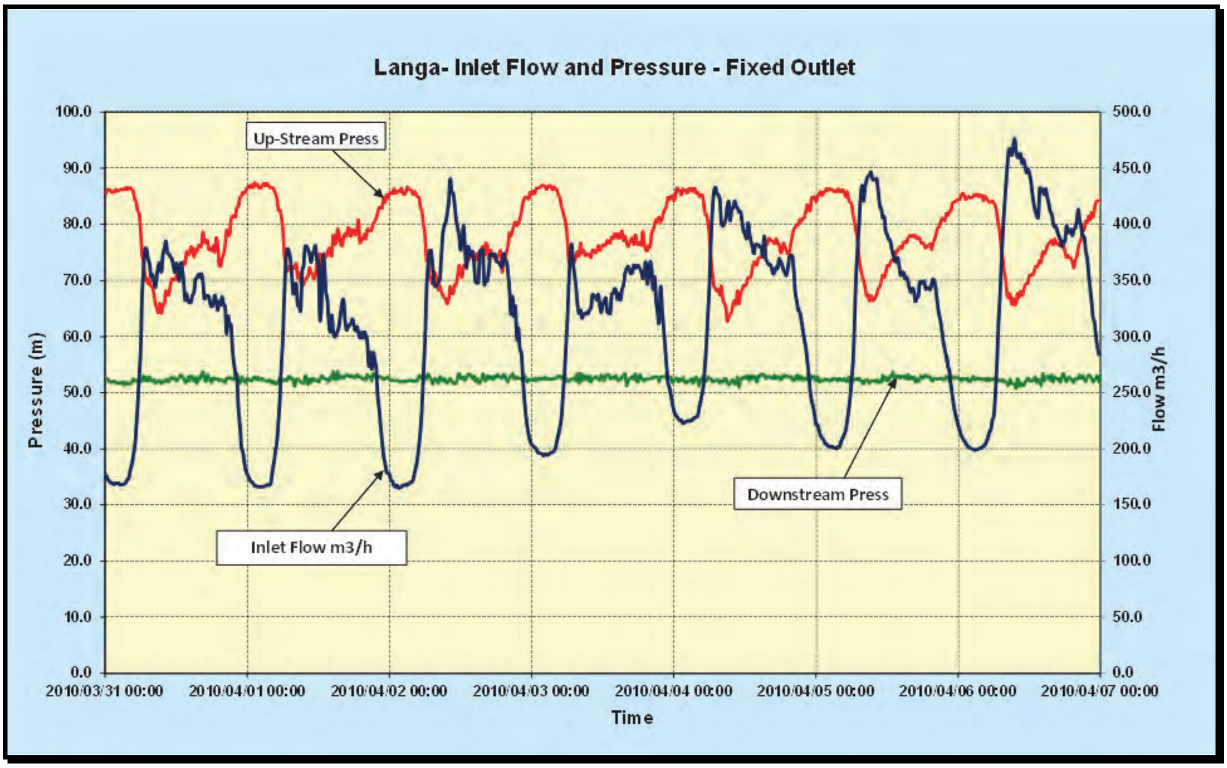


Figure 102: Inlet and PRV outlet pressure into Langa

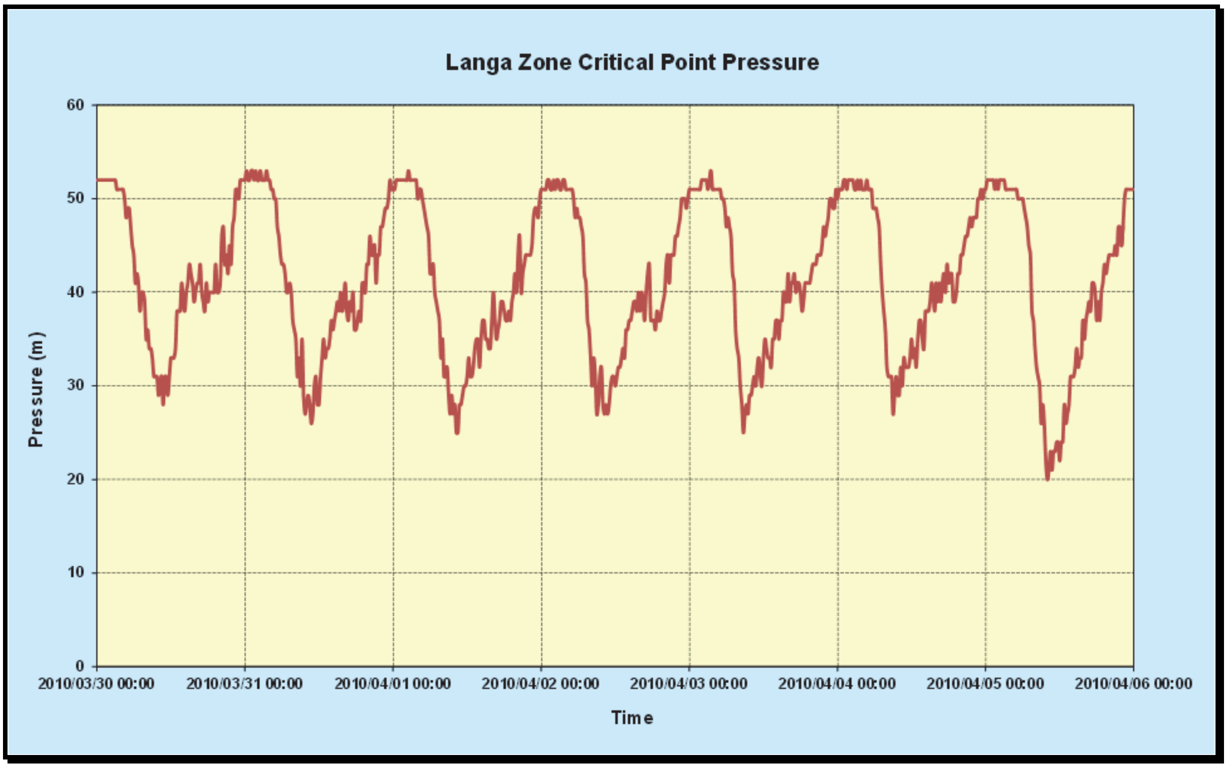


Figure 103: Pressure at the critical point in Langa

Zones with such a high pressure variation at the critical point are often ideal candidate zones for some form of advanced pressure control. As always, the question is to select the most appropriate form of pressure control to suit the zone and the needs of the municipality. In this particular case, it was decided to use basic time-control as a first step to assess the savings that could be achieved through a simple and relatively inexpensive controller. The resulting pressure entering the zone is shown in **Figure 104** while the resulting pressure at the critical point is shown in **Figure 105**.

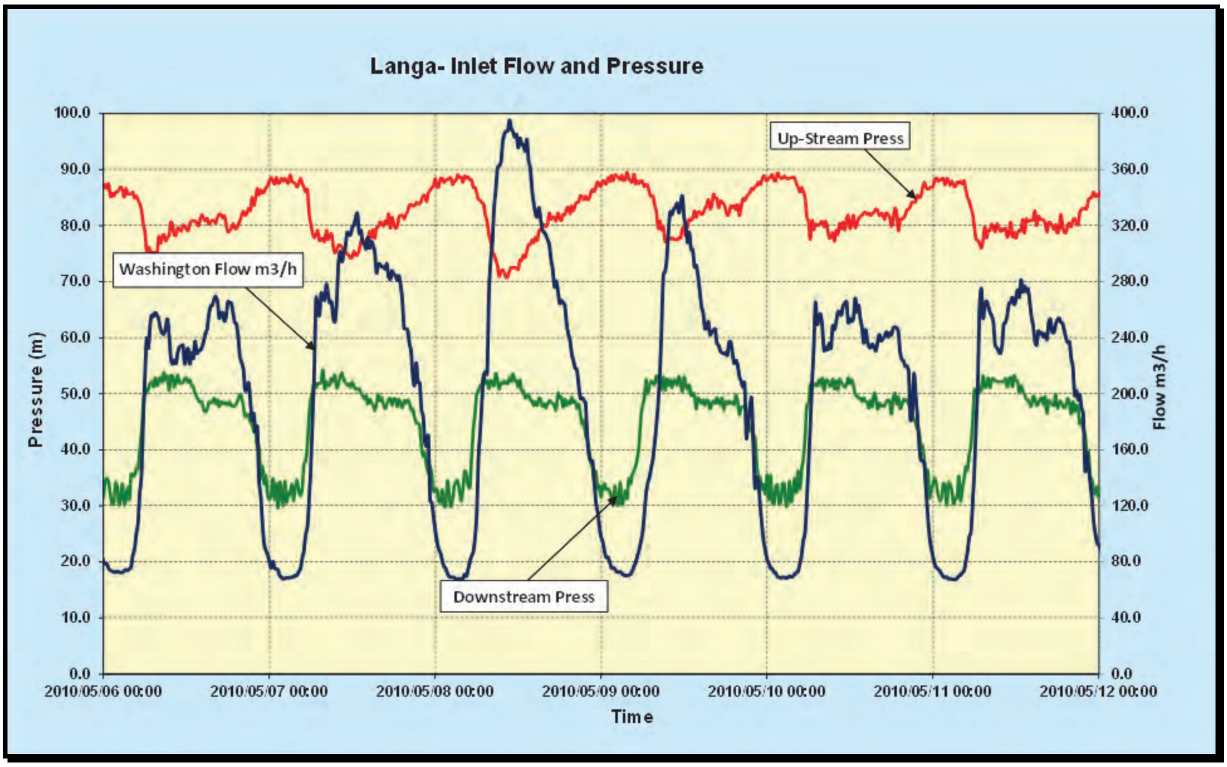


Figure 104: Advanced pressure control using time control

From **Figure 105** it can be seen that the pressure variation at the critical point has been reduced significantly from the original situation as shown previously in **Figure 103**. The leakage in the area has also been significantly reduced from around 200m^3/hr when using the fixed outlet PRV to around 80m^3/hr when lowering the night-time pressure from 52m^3/hr to around 30m^3/hr. As can be seen in this example, the savings based on the minimum night flow analysis were very significant and in addition, there was a marked reduction in new burst pipes.

The pressure variation at the critical point is not yet stable and indicates a variation of around 10m to 15m which can be improved through the use of a more sophisticated (and expensive) pressure controller. The use of some form of flow control can be viable in this example and would most likely provide further savings of between 10% and 20%, however, after discussions with the client it was agreed to use the basic time control for a period and to review the situation after the residents had become used to the lower pressures in the area. Unlike the previous example, the Langa zone clearly demonstrates that the additional control provided by an electronic controller is worthwhile.

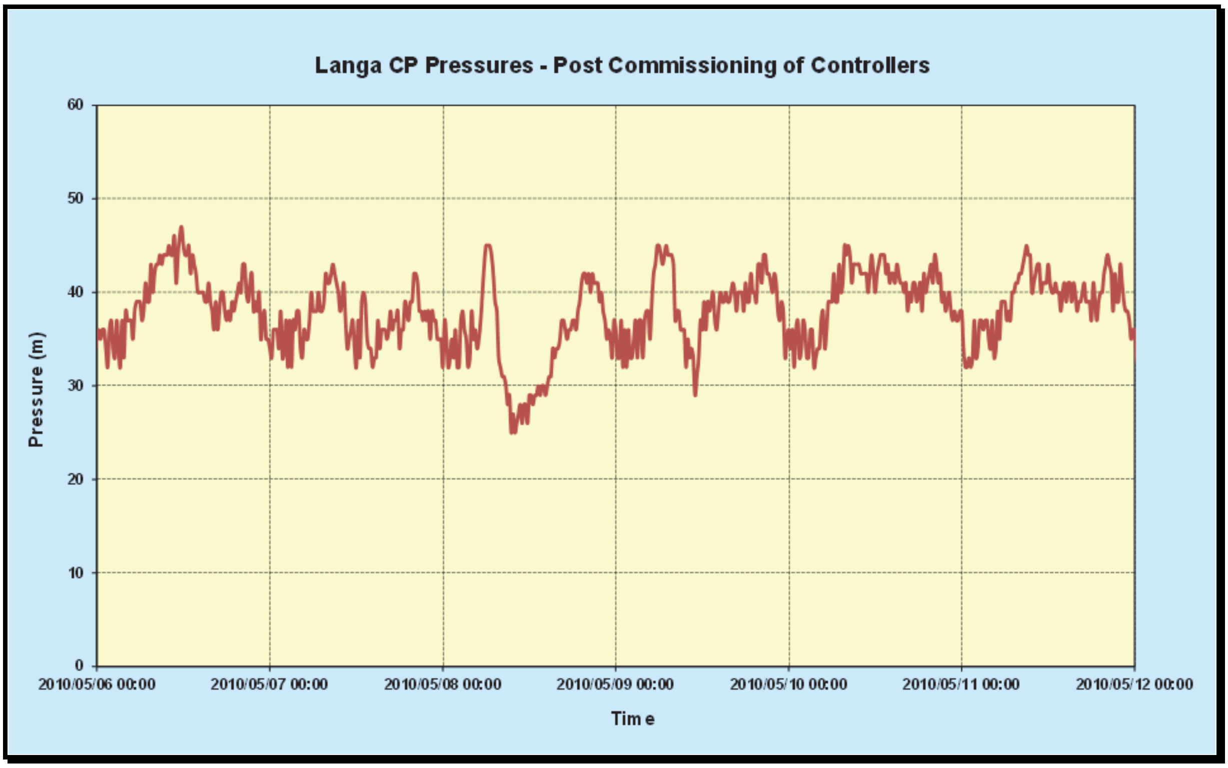


Figure 105: Critical point pressure using time control

12.4 Some large advanced pressure management installations

There are several hundred advanced pressure control installations in South Africa including at least three of the largest installations of their type in the world. While many of the smaller installations are of significance and of interest for a variety of reasons, the three largest installations are discussed below since they have helped to create awareness both locally and internationally of the benefits that can be achieved through advanced pressure control. The three large installations discussed below include, Khayelitsha, Sebokeng and Mitchells Plain – all three of which are fully functioning are at the time of writing this report were 12, 8 and 4 years old respectively. Each of these installations is noteworthy for various reasons as discussed below.

12.4.1 Khayelitsha: City of Cape Town - 2001

Khayelitsha is one of the largest townships in South Africa. The township is located approximately 20km from Cape Town on the Cape Flats, which is a large flat sandy area at or near sea level. There are approximately 43 000 serviced sites, with both internal water supply and waterborne sewage while there are a further 27 000 low-cost housing units which are supplied from communal standpipes supporting a population of approximately 450 000.

At the beginning of 2000 the water supplied to Khayelitsha was measured to be almost 22 million m^3/a. The level of leakage was estimated from the night -time water use to be almost three-quarters of the water supplied to the area. The minimum night flow was measured to be in excess of 1 600m^3/hr which is sufficient to fill an Olympic sized swimming pool every hour.

The main source of the leakage was identified as the household plumbing fittings which have been badly damaged through constant exposure to a relatively high pressures which could exceed 80m at some times. Such leakage resulted in very high water consumption in most properties and high levels of non-payment since the customers could not afford to pay for new taps and toilet fittings let alone the high water bills.

The Khayelitsha Pressure Management Project was commissioned in 2000 to improve the level of service to the Khayelitsha community by reducing the excessive water pressure and pressure fluctuations in the reticulation system. The layout of the installation is provided in **Figure 106**.

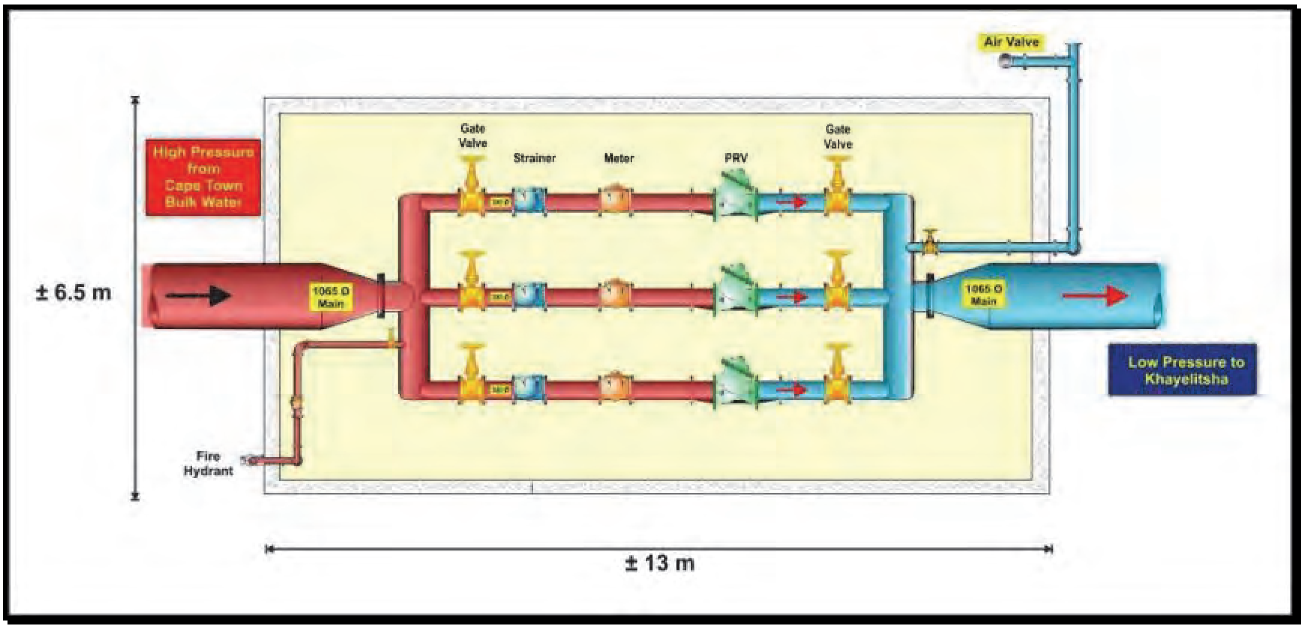


Figure 106: Schematic layout of Khayelitsha installation

The average daily flow was reduced from 2 500m^3/hr to 1500 m^3/hr representing an annual saving of 9 million m^3/hr or approximately 40% of the original water use. The minimum night flow was reduced from 1 600m^3/hr to 750m^3/hr. The number of burst pipes reduced significantly although these savings were not taken into account in the overall cost benefit analysis. Local labour was used throughout the project and the community support was a key factor in the successful implementation of the project which was implemented without any incidences of theft or vandalism. The community awareness process was designed and implemented by the City of Cape Town using its own personnel in parallel with the project implementation.

A summary of the actual savings achieved from the first two years of operation is provided in **Table 1** (Mckenzie, Mostert & Wegelin, 2003). It should be noted that the latest estimates of savings achieved from the installation made by the City of Cape Town suggest savings of 9 million m^3/a, with a financial saving of R54 million per year (± $6 million/a) (Meyer, Wright and Engelbrecht, 2009).

The completed installation is shown in **Figure 107** and **Figure 108**.

Table 13: Summary of Khayelitsha savings for initial 2 year period

Description	Basis of calculation	Volume saved	Value of saving (R million)
Direct water savings in 2002	Based on R3.09/ m^3	9 million m^3	27.8
Direct water saving in 2003	Based on R3.49/ m^3	9 million m^3	31.4
Delay to infrastructure – 2 years	7% of R35 million/yr		4.9
Maintenance and replacement	R250 000 per year		-0.5
Total saving over 2 year period			**63.6**

Figure 107: Khayelitsha pressure management installation

Figure 108: External view of the Khayelitsha pressure management installation

12.4.2 Sebokeng: Emfuleni Local Municipality – 2005

Emfuleni Local Municipality is located to the south of Johannesburg in the industrial heartland of South Africa. The municipality supplies water to approximately 1.2 million residents of which 450 000 are located in the Sebokeng and Evaton areas. The areas are predominantly low-income residential areas, with approximately 70 000 household connections, each of which is supplied with an individual water supply as well as waterborne sewage. The combination of low income coupled with high unemployment has resulted in a general deterioration of the internal plumbing fittings over a period of many years. This has caused high levels of leakage, which is characterised by a minimum night flow in the order of 2 800 m^3/hr. This is one of the highest minimum night flows recorded anywhere in the world, and represents almost two Olympic-sized swimming pools of water every hour during a period when demand for water should be minimal. It was estimated that the wastage in the area before the project was commissioned was in the order of 80% of the water supplied to the area. In turn this represented an annual water bill of approximately R120 million per year (±$12 million).

In 2004, the municipality commissioned one of the largest advanced pressure management installations in the world as the first phase of a long-term strategy to reduce wastage in the area. The project involved no financial input from the municipality and even the initial capital costs were provided in total by the project team. The project was, effectively, a small-scale Public Private Partnership (PPP) involving a simple risk-reward model details of which are provided in **Figure 109** (Mckenzie and Wegelin, 2005).

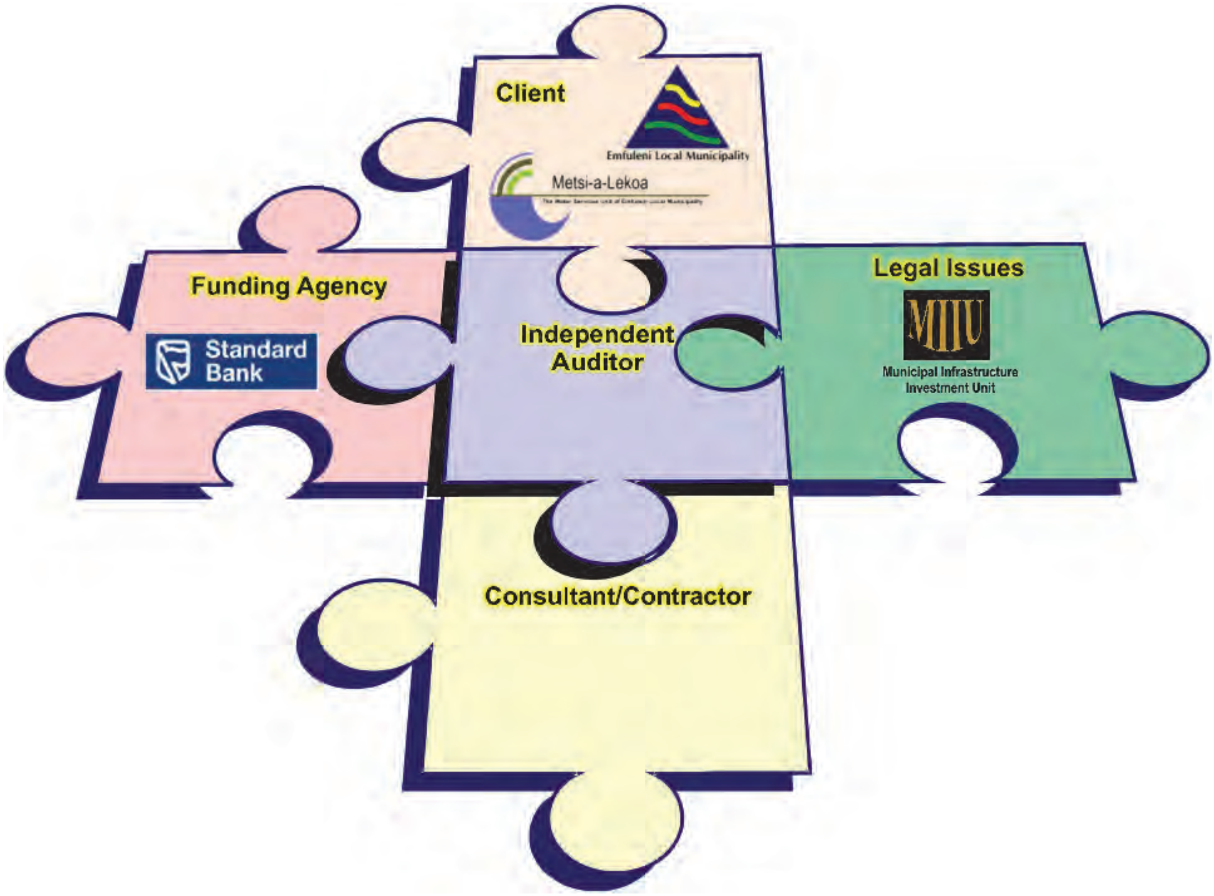


Figure 109: Organisation framework for Sebokeng PPP

The installation itself is shown in **Figure 110** and is interesting for a number of reasons.

- The installation includes a manifold section at each end with 5 branch pipes connecting the two manifolds.
- The middle pipe section has no PRV or meter and is used to recharge the downstream network which may have emptied after a shutdown. If the supply pipes with meters are used to re-charge the network, there is a risk of damaging the meters in cases where mechanical meters are used. The original mechanical meters have now been replaced with Magnetic Flow meters to eliminate the meter problem,
- Butterfly valves are used in both manifolds to provide flexibility, both in allowing the pressure to be equalised between the two supply pipes which enter the chamber at different pressures due to their different pipe diameters and it allows the downstream pressure to be equalised if required. They also provide the opportunity to include the central pipe either to supply Sebokeng or Evaton should this be necessary as they grow in future.

- All valves on the 5 supply pipes are resilient seal valves and not butterfly valves since they tend to provide a better seal in cases where valves are being opened and closed regularly
- Air valves are located on both manifolds and an enlarged collector tube is used to ensure that the air is in fact able to escape from the pipework. This is easier to see on **Figure 111**.

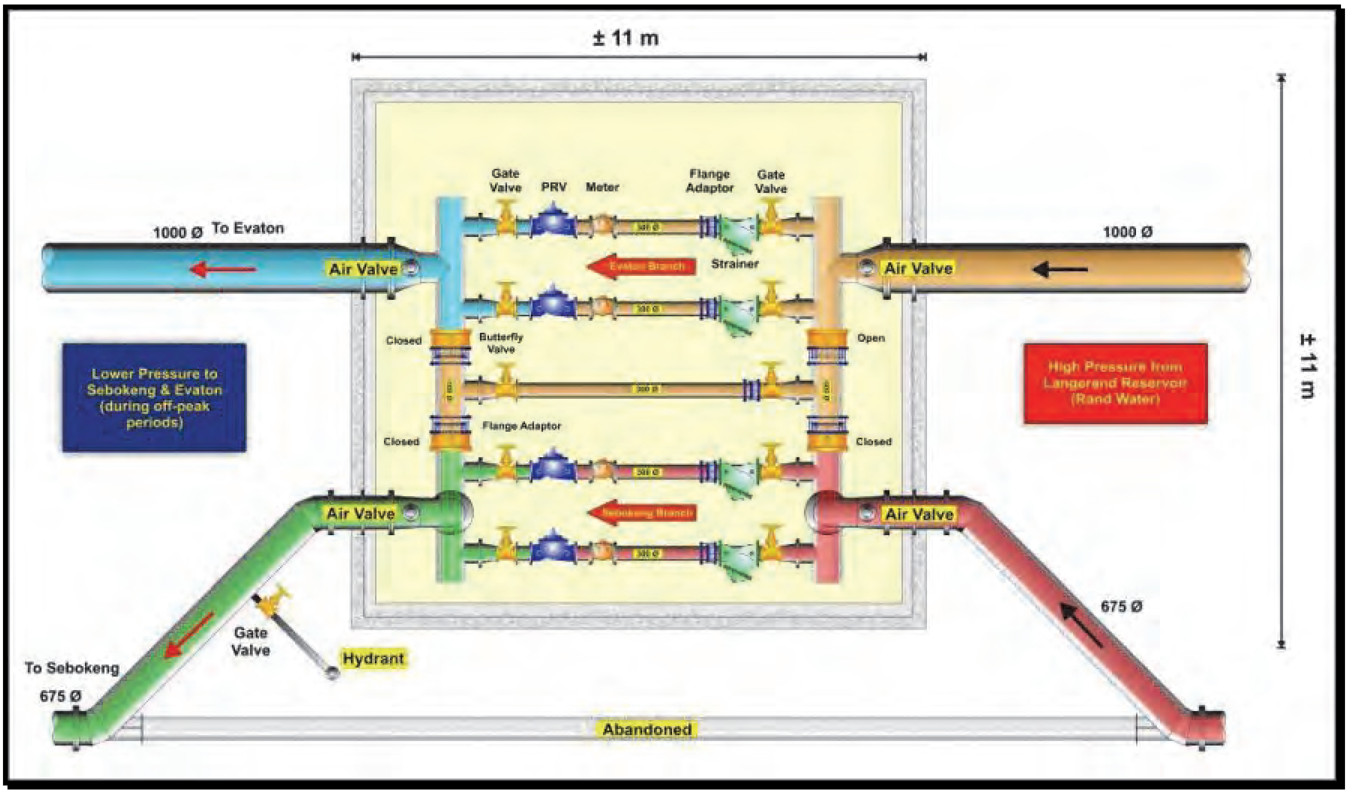


Figure 110: Schematic layout of Sebokeng installation

Figure 111: Sebokeng/Evaton pressure management installation

The savings achieved in the first 30 months of operation of the installation exceeded all expectations of both the project team as well as the municipality and are the most obvious benefits to accrue from the project. After operating and managing the installation for several years, several other benefits also became apparent which were not initially anticipated. In particular the following benefits have been achieved:

- Defer upgrading of infrastructure
- Identification of bottlenecks in the system and problem infrastructure
- Identification of bulk meter errors
- Catalyst for funding
- Improved municipality status
- Creation of national WDM fund
- Catalyst for other WDM interventions
- Sustainability of savings

The project represents a significant advancement in PPPs, and clearly demonstrates that small-scale partnerships can be viable despite the general view that this type of project is confined to large-scale initiatives due to the effort and expense in developing the PPP type of contract. While the Sebokeng and Evaton PPP is clearly one of the most successful small scale PPPs to be completed in South Africa, the real benefits of the project are only now materialising four years after the project was commissioned. Both the project team and the municipality are very happy with the outcome of the project and are continuing to work together to build on the initial success. While the financial savings generated exceed all initial expectations, the hidden and often less tangible benefits greatly outweigh the obvious and tangible benefits.

The actual savings achieved are summarised in **Table 14** and also depicted graphically in **Figure 112**. As can be seen from **Figure 112**, the water supplied to the area at the start of 2010 is almost the same as it was at the start of 2001, which clearly highlights the true level of savings that have been achieved.

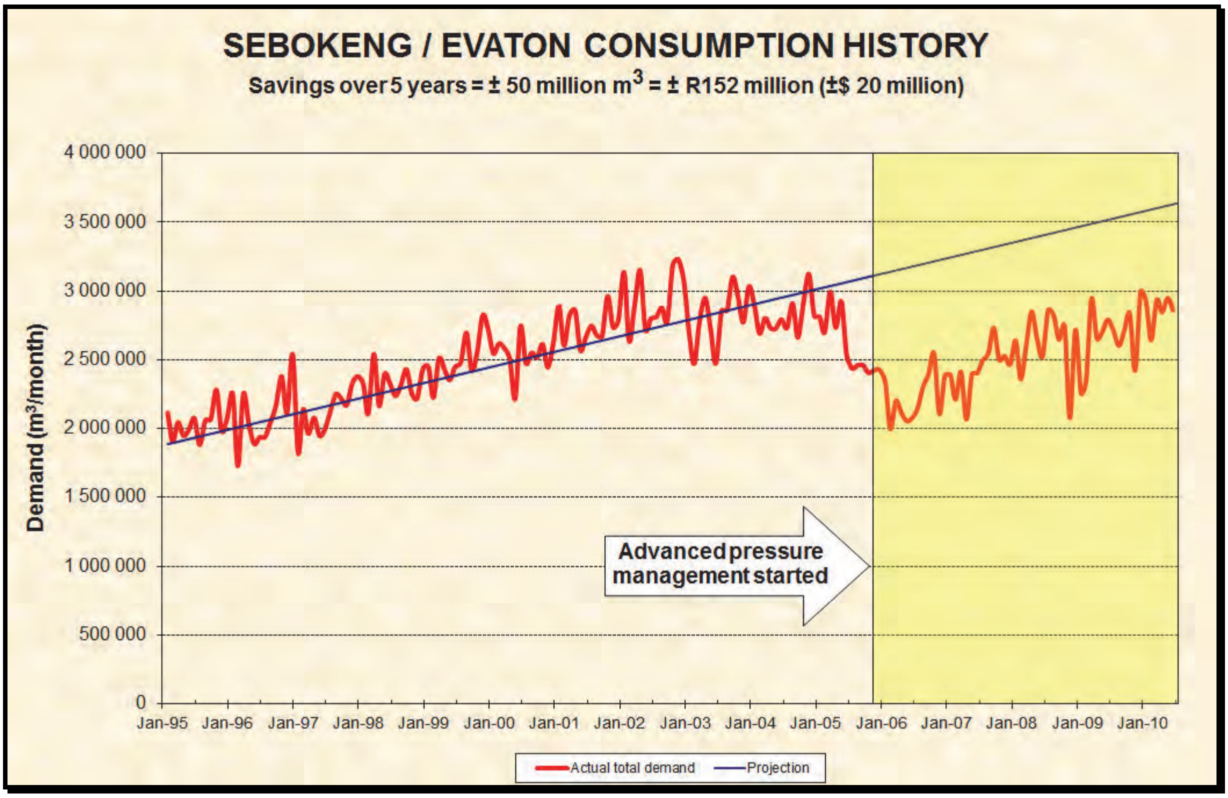


Figure 112: Water consumption in Sebokeng and Evaton areas for a 13 year period

Table 14: Summary of Sebokeng savings for first 60 months of operation

Year	Water Use		Saving		
	Expected	Actual	m3	Rands	US$
Months 1 to 6	18,721,000	14,614,000	4,107,000	11,499,600	1,691,118
Months 7 to 12	18,751,000	12,785,930	5,965,070	16,702,196	2,456,205
Months 13 to 18	19,403,000	13,886,451	5,516,549	16,218,654	2,316,951
Months 19 to 24	19,423,000	13,877,370	5,545,630	16,304,152	2,329,165
Mopnths 25 to 30	20,086,000	15,269,040	4,816,960	14,788,067	2,112,581
Months 31 to 36	20,206,000	15,633,153	4,572,847	14,038,640	2,005,520
Months 37 to 42	20,769,000	15,870,850	4,898,150	15,918,988	1,768,776
Months 42 to 48	20,766,000	15,692,825	5,073,175	16,487,819	1,831,980
Months 49 to 54	21,452,000	16,479,970	4,972,030	16,159,098	1,901,070
Months 55 to 60	21,438,000	16,874,423	4,563,577	14,831,624	1,744,897
Total Months 1 to 60	201,015,000	150,984,012	50,030,988	152,948,838	20,158,263

The completed Sebokeng/Evaton pressure management installation is shown in **Figure 111** and **Figure 113**.

Figure 113: External view of the Sebokeng pressure management installation

12.4.3 Mitchells Plain: City of Cape Town – November 2008

In order to meet the growing water demands within the City of Cape Town's supply area, several large and expensive water transfer schemes have been commissioned in addition to the ongoing water demand management interventions. One of the most significant water loss reduction activities involves the use of advanced pressure management. Since the City of Cape Town receives its most of its water via the Blackheath Water Purification Plant which stores the bulk water in a large reservoir at an elevation of approximately 110m above sea level, many low lying areas are supplied at very high pressures leading to high levels of leakage. This is particularly evident in the low lying and relatively flat sandy areas referred to as the Cape Flats. Such areas are therefore ideally suited to pressure management which has, in turn, resulted in the city embarking on several large scale pressure management projects.

In 2008, however, the city decided to commission its second major pressure management installation in the Mitchell's Plain area, which supports a similar population to Khayelitsha. This project was commissioned in October 2008 and details of the installation are provided in **Figure 114** and **Figure 115**. The projected water savings based on the initial flow logging results indicate that it will save approximately 2.4 million m^3/a with a value of R14 million resulting in a pay-back of less than 6 months.

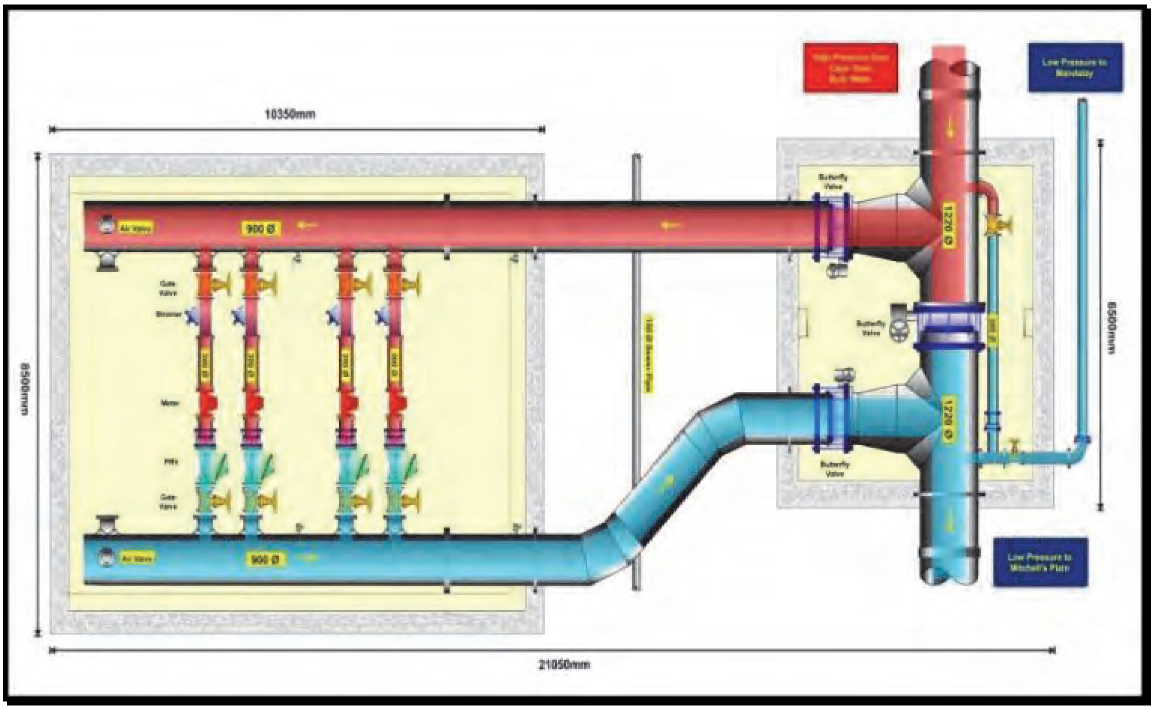


Figure 114: Schematic layout of the Mitchells Plain installation

Figure 115: Mitchells Plain pressure management installation

The initial savings from the Mitchells Plain installation are shown in **Figure 116** (Engelbrecht, et. al, 2009)

In order to promote the installation and emphasise the importance of water demand management in the community, the installation was painted by local artists in such a manner that it sends a strong message to all passers-by as can be seen in **Figure 117**.

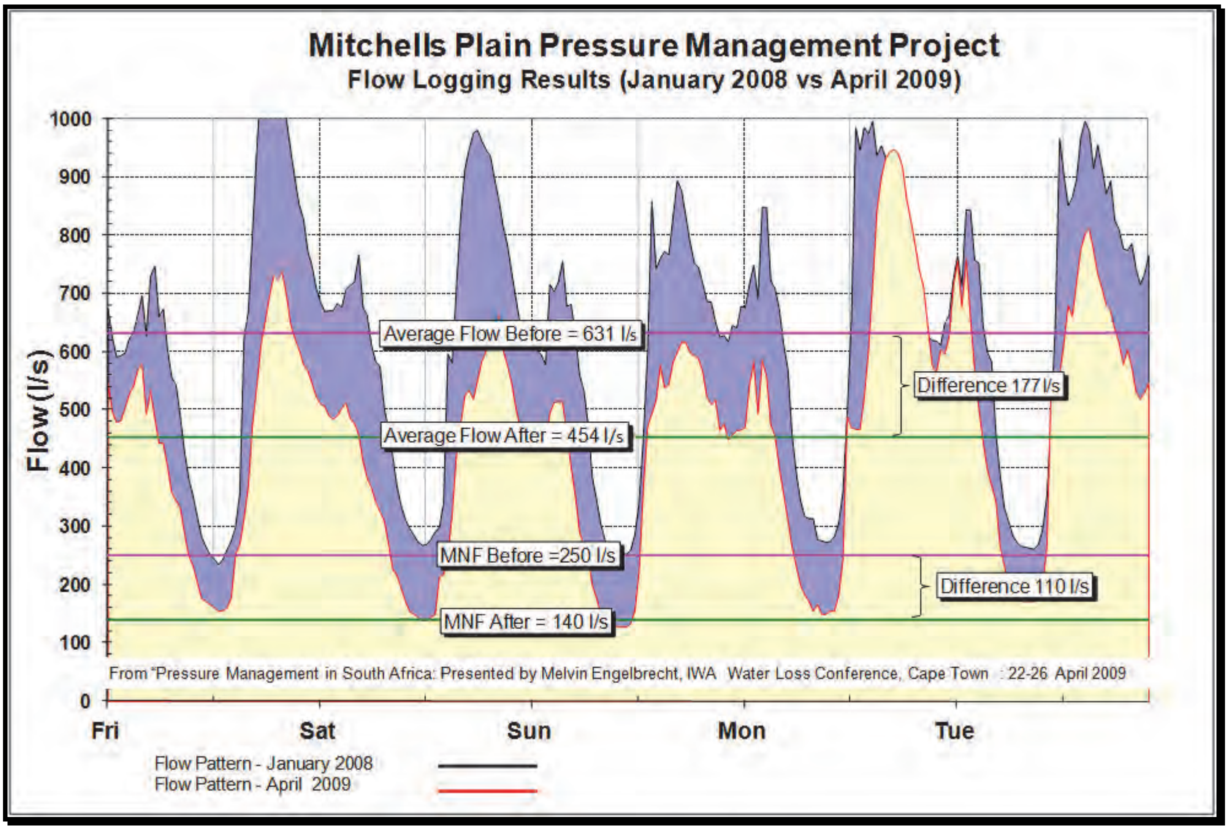


Figure 116: Initial savings from the Mitchells Plain pressure management installation

Figure 117: External view of the Mitchells Plain installation

12.5 Conclusions

Based on the results from the three case studies, it is clear that pressure management is highly effective in many parts of South Africa and that it can be implemented successfully on a large scale in certain areas. While it must always be remembered that pressure management is normally only the first phase of a larger water demand management strategy, it can often provide very significant savings in a short period of time. Pressure management also has many secondary benefits that are often overlooked, including extending the useful life of the water reticulation system as well as reducing new bursts. Such a benefits can often far outweigh the initial benefits as calculated from the water savings but will only become apparent many years down the line.

South Africa was one of the first countries to recognise the benefits that can be derived from advanced pressure control, and currently lays claim to three of the largest advanced pressure control installations in the world. The Khayelitsha and Sebokeng installations in particular have received considerable recognition from various water utilities and funding agencies throughout the world, and have often been used to highlight "world best practice" in the field of water conservation in action.

Finally, it must always be remembered that the most difficult and time-consuming part of any large pressure management installation is usually related to the sectorising and operation of the pressure management zone. If the basic groundwork has not been completed properly, no pressure management installation will function properly. Unfortunately this is often overlooked as is the regular maintenance needed to ensure that pressure zones have not been compromised by the unauthorised opening of boundary valves or the closure of internal reticulation isolating valves. These issues are critical and many well designed pressure management installations are not functioning due to problems within the zone. No amount of electronic equipment or sophisticated software will overcome the efforts of a local plumber focused on opening boundary valves. The best option is to introduce some form of monitoring system that will pick up such problems soon after they occur. The monitoring and maintenance of the zones is a continuous process and should always be part of any overall pressure management strategy.

The City of Cape Town is one of the most progressive municipalities in South Africa with respect to pressure management and together with the City of Johannesburg; they have been implementing various forms of advanced pressure control since 2000. A summary of their key projects was presented by Engelbrecht at the international IWA Water Losses Conference, held in Cape Town in 2009 and is provided in **Figure 118**. The figures provided refer to only four of the numerous pressure management projects that have been implemented in the Greater Cape Town area but they clearly highlight the significance of the savings that are being achieved by such WDM interventions. Although some of the figures cannot be directly compared with each other without taking inflation and interest into account, it is very clear that the pay-back for the pressure management activities is well under a year and in any municipality, such interventions will be cost effective.

Area	Water Savings (million m³/yr)	Cost (R)	Savings @R6.20/ m³ (R/ year)
Khayelitsha	9 million m³/yr	2.7 mill (2001)	R 55 million/yr
Mfuleni	0.4 million m³/yr	1.5 mill (2007)	R 2.5 million/yr
Gugulethu	1.6 million m³/yr	1.5 mill (2008)	R 10 million/yr
Mitchells Plain	2.4 million m³/yr	7.7 mill (2009)	R 15 million/yr
Total	13.4 mill m³/year	13.4 mill	R83 mill/yr

From "Pressure Management in South Africa: Presented by Melvin Engelbrecht, IWA Water Loss Conference, Cape Town : 22-26 April 2009

Figure 118: Savings from selected pressure management projects in Cape Town

12.6 A final word on pressure management

Pressure management is clearly one of the most important issues when trying to minimise water losses from a reticulation system. The benefits of lowering water pressures are numerous and in many cases it is difficult to accurately quantify the long term "hidden" benefits such as extending the useful life of the network. Various models are available to undertake cost-benefit analyses which are very helpful in determining whether or not pressure management is likely to be viable in a specific situation. It is recommended that such a cost-benefit assessment is undertaken before finalising whether or not to implement pressure management. The models will also help identify which form of pressure control is likely to provide the best returns on investment.

In many cases the decision regarding which form of pressure control to use, will not only rest with the results from the cost-benefit analysis, but also the preferences of the reticulation managers. The reticulation managers must be comfortable that they can manage and maintain any pressure management valves and controllers used in the network. Experience has shown that the success of a pressure management installation ultimately depends upon the expertise of the operational personnel and their ability to maintain the various components used in the installation.

13 APPENDIX J: EKURHULENI BULK METER MANAGEMENT PROJECT

13.1 Introduction

The Ekurhuleni Metropolitan Municipality (EMM) houses some of the largest industrial areas in the South Africa. It also houses many other bulk water users such as academic and medical institutions, large residential complexes, large retail complexes and municipal facilities. The focus areas for the work undertaken on this project were limited to bulk consumers in Springs, Germiston, Benoni and Edenvale as indicated in **Figure 119.** Most of the water connections to the bulk consumers in these areas were constructed many years ago and have not been replaced or upgraded since installation. As a result, numerous below-ground meters are no longer operational and some have been buried for years and do not appear on the billing system. A large number of the meter chambers have been filled with debris and there are no records of fire supply connections to some bulk consumers which are therefore not metered. Over several decades, some of these “mislaid’ connections have inadvertently or deliberately been used to supply domestic and, in some instances, process water. Some fire reticulation systems have developed leaks, but without metering of the fire connection in place, these leaks have gone un-noticed for years. As a result, the status of the metering infrastructure to many of the large consumers has been poor and subsequently it has been difficult for Ekurhuleni metropolitan municipality to bill these consumers accurately for their water consumption.

Ekurhuleni metropolitan municipality has in the past provided new connections to large consumers as and when requested. This has led to a situation where a large consumer may have up to 20 connections to a single industrial site. The municipality is then required to maintain and read all of these supplies which invariably lead to mistakes. In many cases meters are simply not included in the billing process. This results in high levels of “commercial losses” in these heavily industrialised areas. These “losses” represent water that may be used for legitimate purposes, but is not being recorded in the billing system and therefore bypasses the accounting systems completely. As a result of such losses, the municipality loses many hundreds of millions in unclaimed revenues annually. If it is assumed that the commercial and physical losses are of similar magnitude in Ekurhuleni metropolitan municipality, it is estimated that the value of the commercial losses based on the current industrial water tariff of approximately R10/m^3 is in the order of R700 million annually. It is this component of the water losses that Ekurhuleni metropolitan municipality is targeting through the bulk meter audits of all large industrial users since the return on the project costs will generally be between 6 and 24 months.

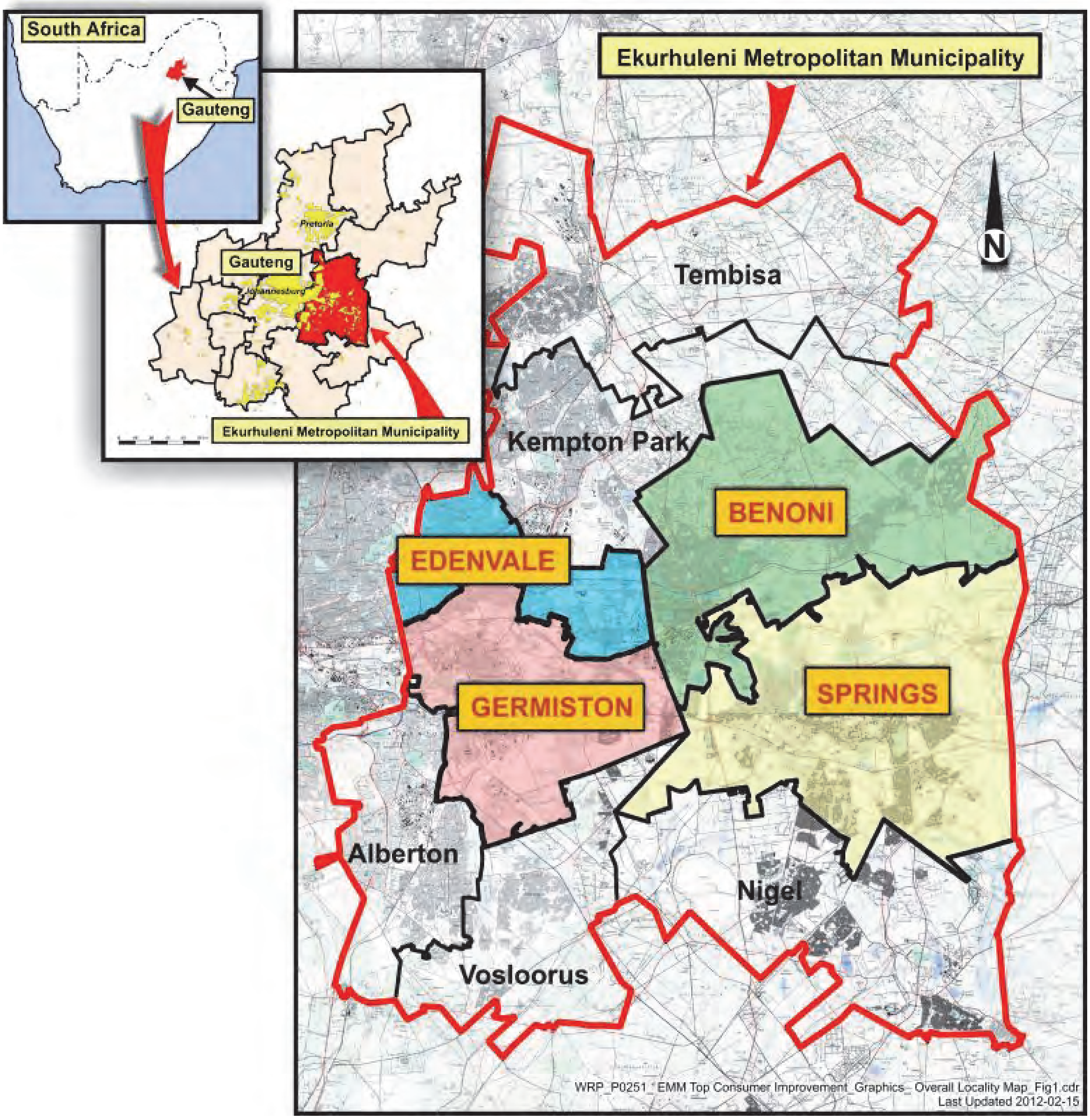


Figure 119: Ekurhuleni Location Plan

As new connections have been made to the water distribution networks, the hydraulic capacity of the distribution system is slowly decreasing, which can have an adverse influence on fire-fighting systems which were originally designed on the basis of the previous capacity of the reticulation network. As part of the project, Ekurhuleni metropolitan municipality has conducted drawdown tests on the municipal network to determine the capacity of the network at each of the large consumers investigated. This provides both the council and the consumer with a good understanding of what the fire flow capabilities of the municipal network are. In many cases, the consumer may be required to improve fire-fighting capacity on site and can no longer rely completely on the municipal system. This can have serious and costly implications to certain large users, which may be required to provide both on-site storage and booster pumps to support their fire-fighting systems for insurance purposes.

The accurate measurement of water supplied to all large industries is essential to enable the Ekurhuleni metropolitan municipality to measure all water used and to charge correctly for the water services provided. To this end Ekurhuleni metropolitan municipality, launched a project to assess and replace where necessary the water connections to its largest 500 industrial customers. This initial project is expected to be extended to cover over 25 000 industrial customers and, when completed, will be one of the largest bulk metering projects to be undertaken in Africa.

The project was funded by the Ekurhuleni metropolitan municipality in a phased approach where the savings generated in one year are used to motivate the expenditure for further bulk meter replacements in the following year. The savings related to this initiative are achieved through a decrease in non-revenue water and an increase in revenue for the municipality through improving metering and billing to consumers. It is anticipated that once the large consumers are accurately metered for their consumption, efforts will be made by the consumer to reduce water losses and operate more efficiently. This has been experienced at a number of consumers where leakages on internal reticulation have been repaired following the meter consolidation exercise. In addition to the decrease in non-revenue water, Ekurhuleni metropolitan municipality has experienced an increase in revenue through the location and accurate reading of buried and lost meters which previously supplied consumers. Based on the initial results achieved for over 500 industrial customers, the total increase revenue from the project is expected to exceed R44 million/ year which conservatively indicates a pay-back of between 6 and 12 months.

This project has provided clear evidence that tackling the bulk metered consumers is one of the most significant and cost-effective interventions that can be undertaken in Ekurhuleni metropolitan municipality, and serves as an example of what can be achieved in many other municipalities in South Africa. As a result of the success of the project, the approach is to be extended to all bulk water users throughout the Ekurhuleni metropolitan municipality area of supply and is likely to continue for many years.

13.2 Objectives of the project

The key objective of the project was to reduce non-revenue water and specifically the commercial losses, by addressing metering problems at the top 500 consumers within EMM. Water connections to many of these bulk consumers had been constructed years, and in some cases decades ago, and had never been replaced or upgraded since they were installed. As a result, numerous of the existing below ground meters were no longer operational and some had been buried for years with the result that the meter chambers have become full of debris which must be removed before the meters can again be included in the billing process. Some of the typical problems encountered in the investigations are shown in **Figure 120** to **Figure 123**.

Figure 120: Buried and broken meters

Figure 121: Cleaning rubbish from chamber

Figure 122: Meter buried in ground

Figure 123: Non-functional and old meter

Another key issue that is relevant in many parts of South Africa concerns the fire connections which were previously never metered. As a result, there are many thousands of unmetered fire connections throughout most parts of South Africa – as can be seen in **Figure 124**. Over time, some of these connections have inadvertently (or deliberately – see **Figure 125)** been tapped into for domestic or process water supply, with the result that such water use is not recorded and is therefore part of the “commercial losses”. Many industries that are using water through unmetered fire connections are completely unaware that they are doing so illegally, and are very happy when such use is identified and brought to their attention. Others may not be so happy and in such cases, they generally know what is going on with their water supply. In both cases, the problems must be addressed and corrected so that all water being used by every industry is properly measured and properly billed. Many of the older unmetered fire reticulation systems have developed leaks over a period of years, and without proper metering in place, these leaks remain undetected and can often result in significant water losses. In the case of Ekurhuleni, the situation was aggravated by the fact that the current Metro comprises a number of previously autonomous municipalities, each of which had its own system for managing the metering and billing and in some cases; the systems used were totally inadequate. When the various municipalities were combined into a single Metro, many records and management systems were either lost or discarded resulting in some level of confusion and lack of consistency between the areas. In general, the quality of the bulk metering and associated billing was and the municipality eventually decided to address this problem through a large scale bulk meter management and replacement programme involving the top 500 consumers. It should be noted that Ekurhuleni is the most industrialised Metro in South Africa and has over 25 000 industrial consumers. The “Top 500 Project” was the initial phase of a much larger and longer term plan to address the metering and billing problems in all 25 000 bulk consumers.

Figure 124: Example of an Un-metered fire connection

Figure 125: Example of illegal connection to un-metred fire supply by consumer

13.3 Methodology

In view of the repetitive nature of the work involved with the project, a systematic and methodical approach was developed which involved a large database application and associated report generator. This greatly improved the efficiency of the process and the work was eventually completed well within budget and programme. The project was undertaken in the following eight steps:

- Identification of top 500 consumers
- Initial field audit
- Zero pressure test
- Drawdown test
- Design of consolidated supply
- Construction of new pipework and meter chamber
- Commissioning of the new installation
- Courtesy visit and delivery of “Installation Report” to the customer

13.3.1 Identification of top 500 consumers

The first task was to identify the large consumers and consumers who have multiple feeds and un-metered connections. Consumers with metering or billing problems were also identified by the municipality who prepared a list of top consumers which was passed on to the project team for investigation.

13.3.2 Initial field audit

Ekurhuleni metropolitan municipality had previously provided new water connections to large consumers as and when they were requested. This created a situation where a single industrial consumer could have up to 20 connections to a single property, each of which had its own meter. This creates problems for the municipality, which is then required to maintain and read all of these metered supplies for a single consumer invariably leading to problems with either the meter reading or the associated billing processes. In many instances, meters would “get lost” and no record of them would exist on the systems resulting in very high commercial losses. To address this issue, it was therefore necessary to identify all supplies into a specific consumer and to consolidate them into a single metered supply where possible. The initial field audit was the first step in this process.

The field audit involved locating and capturing all information relating to the consumer's water supply and water infrastructure on the property. An assessment was also made of the consumer's water demand in terms of fire-fighting, industrial and domestic demand. Effective communication was maintained with the consumer throughout the process to inform them of the purpose of the project and the benefits associated with the project. This improved the relationship between the consumer and Ekurhuleni metropolitan municipality as the consumer was generally impressed and pleased to see that action was being taken by the Metro. In most instances the consumer was happy to have accurate metering a billing of their water consumption in order that proper budgeting could be performed even in cases where the interventions eventually resulted in higher water accounts. All information collected during the field audit investigations was captured on a new database developed specifically for the project, which facilitated the generation of Audit Reports quickly and effectively.

13.3.3 Zero pressure test

Once the audit had been completed, a zero pressure test was undertaken at each consumer to check that there were no other supply connections that had not been identified. The test involved isolating each of the identified supplies while simultaneously monitoring the water pressure inside the property. If any part of the water reticulation system inside the property remained pressurised during the zero test, it indicated that there was one or more additional connections to the main reticulation system that had not been identified and closed. In such cases, further investigations were undertaken, often involving the use of metal detectors and other locating equipment to try and find the missing supplies. The process was repeated until a successful shutdown could be achieved. Another form specifically developed for capturing details of the zero pressure test was completed for each consumer and an aerial photograph illustrating all metered and un-metered connections to the property was prepared as illustrated in **Figure 126.** It is important to recognise that in cases where a zero pressure test could not be achieved, it also implies that the consumer is unable to isolate their system in case of an emergency such as a burst pipe. When the process has been completed, all consumers are able to isolate their water supply and are provided with a detailed report providing information on all of the supply pipes and isolating valves etc. This type of information is very valuable to every industrial consumer and the consumers expressed their full support for the efforts.

Figure 126: Illustration of Metered and un-metered connections to a single property

13.3.4 Drawdown test

Drawdown tests were conducted at fire hydrants on the municipal network as shown in **Figure 127** and **Figure 128** to determine the hydraulic capacity within the municipal system and provide a good indication of the potential within the municipal supply system to provide water for fire-fighting purposes. Results from the drawdown tests were then used to support the consolidated meter sizing where each consumer would be supplied through a single metered connection. The tests were implemented by installing a pressure logger on the municipal main and monitoring the pressure in the main when a nearby fire hydrant is opened fully. The consumers were also informed in cases where the municipal network did not have sufficient capacity to provide water for fire-fighting purposes. Photographs of the drawdown test being conducted are included in and typical graphics achieved from the tests are included in **Figure 129.**

Figure 127: Typical drawdown test

Figure 128: Typical drawdown test

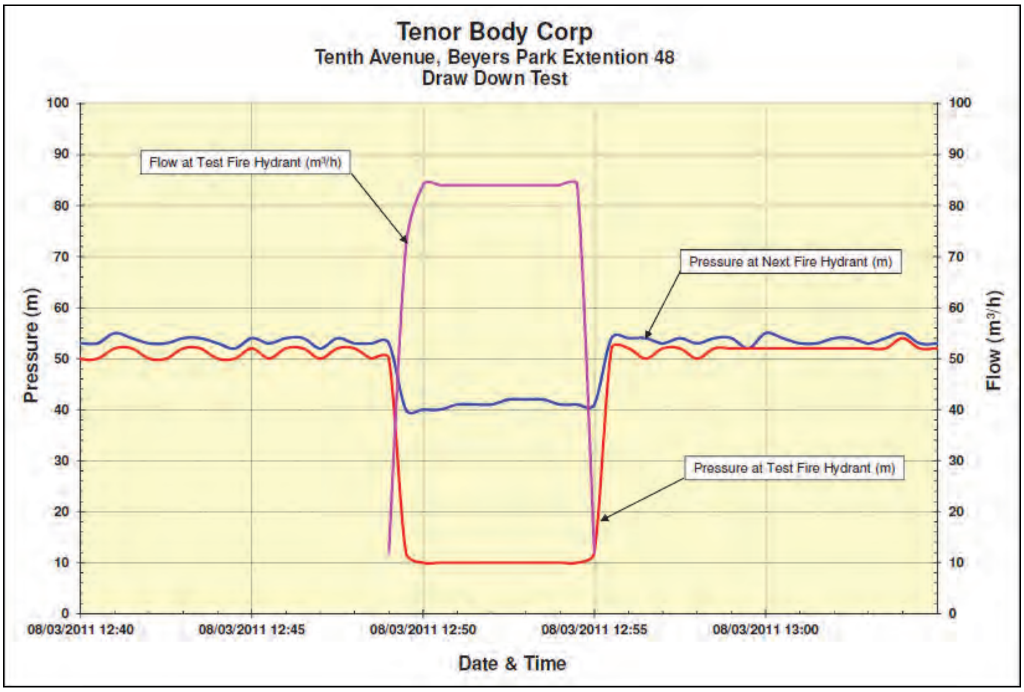


Figure 129: Logging results from a drawdown test

13.3.5 Design consolidated supply

The appropriate water meter was selected based on a detailed assessment allowing for domestic, industrial and fire demands. The assessment took any on-site storage into consideration as well as the presence of booster pumps or absence thereof. Once the demand had been calculated, a suitably sized meter capable of delivering that demand was selected. In some instances it was found that the water-supply network could not deliver the maximum demand required by the consumer. In such cases, the consumer was informed of the potential supply problems so that they could be addressed through an additional connection or some on-site storage etc. Once again, the consumer was very happy to support the process.

All the information collected as well as a recommendation on the work required to implement the consolidation of metered and un-metered connections to the consumer was collated into a design report, which was submitted to council for approval. The design allowed for a single connection to each property wherever possible although in some cases additional connections were allowed. The designs involved cutting and capping all additional connections so that only the one or two "official" connections remained.

13.3.6 Construction

Once the designs had been approved, a contractor was appointed by the municipality for implementation. The consumer was informed of the construction activities through a letter providing details of the work to be undertaken and regarding any possible interruptions to the water supply to ensure that any inconvenience would be minimal.

In many instances it was necessary to isolate the municipal mains in order to achieve a shutdown for the new meter to be installed and the removed connections to be isolated at the municipal main. Dummy shutdowns were performed prior to the main shutdown date to confirm that the mains could indeed be isolated and to confirm which other consumers would be affected by the water outages. All affected consumers were then informed seven days in advance of the impending shutdowns and where necessary water tankers were arranged to provide water to consumers.

The construction process was documented through photographs especially of the old meters to capture any final readings as well as details of any new meters. Typical photographs of the construction process are included in **Figure 131** to **Figure** 135**.**

Figure 130: Typical metered and unmetered supplies

Figure 131: Preparing meter pipework

Figure 132: Consolidating supplies

Figure 133: Capping of old connection

Figure 134: Connections consolidated

Figure 135: Complete meter installation

13.3.7 Commissioning

On completion of the construction, the project team inspected the site accompanied by the consumer to confirm that all water infrastructure was re-pressurised. The consumer was requested to sign a “Consumer Acceptance Form” for the work undertaken on their premises. A completion report was prepared for each site detailing all work undertaken and submitted to council as a formal record of all work undertaken at each large consumer. Full details of all meters removed together with serial numbers and meter readings were captured in the completion reports. Details of all new meters installed with serial numbers and meter readings were also documented. “As-built” drawings were prepared for all properties where sufficient work was undertaken to require an as-built drawing.

13.3.8 Courtesy visit and full report

A final courtesy visit was made several months after the installation had been completed and a copy of the final report was presented to the consumer. The process involved the following;

- Assessing the correctness of metering & billing information on consumers account;
- Determining if the consumer had any complaints or concerns;
- Assessing the correct operation of the new meters;
- Repeat drawdown test to confirm all water supplied passed through meter installation;
- Cleaning the strainer on the meter installation if needed as shown in **Figure 136** and **Figure 137**.

Figure 136: Blocked strainer

Figure 137: Clean strainer

13.4 Summary of results

The project was funded entirely by Ekurhuleni metropolitan municipality at a total cost of around R20 million. The municipality benefited from the reduction of “commercial losses” which appeared as additional water sales to most of the consumers. In some instances, the increases in “billed consumption” were more than expected due to the location of buried meters which were ultimately brought into the consolidated supplies. Based on the metered and billed consumption during the first year after completion of the project, it was estimated that the increase in billed consumption to the municipality was in the order of R43 million/year. This represents a pay-back on the original investment of approximately 6 months.

This project led directly to the creation of approximately 20 full-time jobs for a period of two years, creating more than 4 500 man-days of employment.

In addition to the decrease in non-revenue water and job creation achieved through this project, a number of additional benefits were achieved which are worthy of mention, namely:

- The number of consumer meters requiring reading and maintenance was greatly reduced.
- The relationship between council and their bulk consumers was greatly improved.
- Council has a full report for each large consumer indicating their water demand, all supply points, “as-built” drawings, and detailed photographs of all key customer water connections.
- The hydraulic condition of the network was assessed and council now has information on where improvements / enhancements are required.
- A better understanding of the location and condition of network isolating valves was established. All buried network valves were located and housed in proper valve boxes.
- Consumers can now isolate their water supply in case of an emergency, which was not previously possible in the majority of cases.
- Consumers were encouraged to repair leakage on their properties and operate more efficiently since they now know how much water they are actually consuming.
- Consumers are now able to accurately budget for their water use expenses.

14 APPENDIX K: DRAKENSTEIN MUNICIPALITY WDM PROGRAMME

14.1 Background

Drakenstein municipality is located in the Western Cape (see **Figure 138**) and includes Paarl and many of the small towns adjacent to Paarl. In 1999 the municipality faced a major water crisis due to the annual growth in water demand of 3.5% and a high level of NRW which stood at over 33%. Drakenstein municipality is a relatively small municipality with a total population in the region of 225 000, of which approximately 140 000 reside in the main town of Paarl.

Figure 138: Drakenstein municipality locality map

As a result of the impending water demand crisis in 1999, the municipality decided to take action and implement measures to reduce its water consumption with particular emphasis on reducing wastage. This took the form of a comprehensive WDM programme which had six goals namely:

- Reducing the high percentage of non-revenue water;
- Reducing the high static water pressures;
- Reducing the high average daily demand;
- Increasing the total revenue collected by the municipality;

- Providing a more constant and efficient service to consumers;
- Conserving water which was becoming increasingly scarce.

Approximately 10% of the water used by Drakenstein municipality is derived from its own raw water sources, with the remaining 90% purchased as potable water from the City of Cape Town. The high level of NRW provided a major opportunity to decrease the municipality's water bill and at the same time reduce wastage. Interventions were wide-ranging although the introduction of advanced pressure management throughout the system provided the backbone to the overall water demand management programme. Over a period of approximately 14 years, Drakenstein municipality has significantly reduced its overall water consumption and greatly reduced the wastage. This reduction in demand has been achieved against a backdrop of increasing population and general growth within the municipality. This case study remains one of the best examples of what can be achieved through a dedicated team of water managers simply doing their jobs properly. Through their efforts, they have achieved a reduction in NRW from 33% in 1999 to 12% in July 2013. This clearly demonstrates that **"...it can be done**"!

14.2 How the savings were achieved

This case study is one of the few case studies where accurate data have been recorded over the period of the whole water saving initiative. Records have been taken since the water saving initiative was introduced in 1999, which provides a comprehensive and reliable assessment of water consumption and the associated levels of non-revenue water over a 14-year implementation period. Water demand management is not an exact science and it cannot be implemented overnight. If it is implemented properly by dedicated and conscientious personnel who take a long-term view of the problem issues then great savings can be achieved.

In the case of Drakenstein municipality, there was no single "magic intervention" that resulted in the huge savings achieved over the 14-year period. Instead, the combined efforts of a great many smaller interventions were eventually successful. It is for this reason that the Drakenstein municipality case study is considered so relevant and has been included in this publication. If it can succeed in Drakenstein municipality then a similar approach can also succeed elsewhere.

To achieve the savings, numerous actions were taken which were all part and parcel of normal proper water supply management practices. The manager of the system, Mr Andre Kowalewski, was instrumental in achieving the savings and, while he does not attribute the success to any one specific action, he was willing to share his views on certain key issues that he feels were of particular importance. The key issues identified by Mr Kowalewski are discussed below:

14.2.1 Metering and block tariff structure

By the end of the project all properties had been metered and new block tariff structure introduced. A rising block tariff structure was used to charge consumers for all water used. The tariff structure was designed to provide the initial consumption at a heavily subsidised rate, with the high volume users paying significantly more in order to discourage water use and at the same time subsidise the low volume users.

14.2.2 Public awareness and water savings devices

Significant efforts were undertaken to educate the consumers on how to use water efficiently and, at the same time, create general awareness on the scarcity of water in the region. Various interventions were implemented inside the consumer properties to reduce wastage and water use, including basic plumbing repairs as well as the introduction of certain water saving devices. The project enjoyed a high level of support within the community due in part to the job creation through the use of labour-based construction methods using only local labour in conjunction with extensive stakeholder consultation.

14.2.3 Real-time flow and pressure monitoring

One of the key components of the Drakenstein municipality WDM programme is the real-time monitoring of pressures and flows at various points in the reticulation system. Mr Kowalewski has installed real-time GSM/GPRS loggers at over 30 points in the system These are checked on a daily basis to ensure that the network is operating as intended. A typical pressure logging installation is shown in **Figure 139** and a graph of the flow and pressure logging results for one specific zone are provided in **Figure 140**. The logging results have proved invaluable in picking up problems at an early stage in their development before they become critical. The system forms the backbone of Drakenstein municipality’s preventative maintenance programme.

Figure 139: Typical pressure logging point in Drakenstein (Courtesy A Kowalewski)

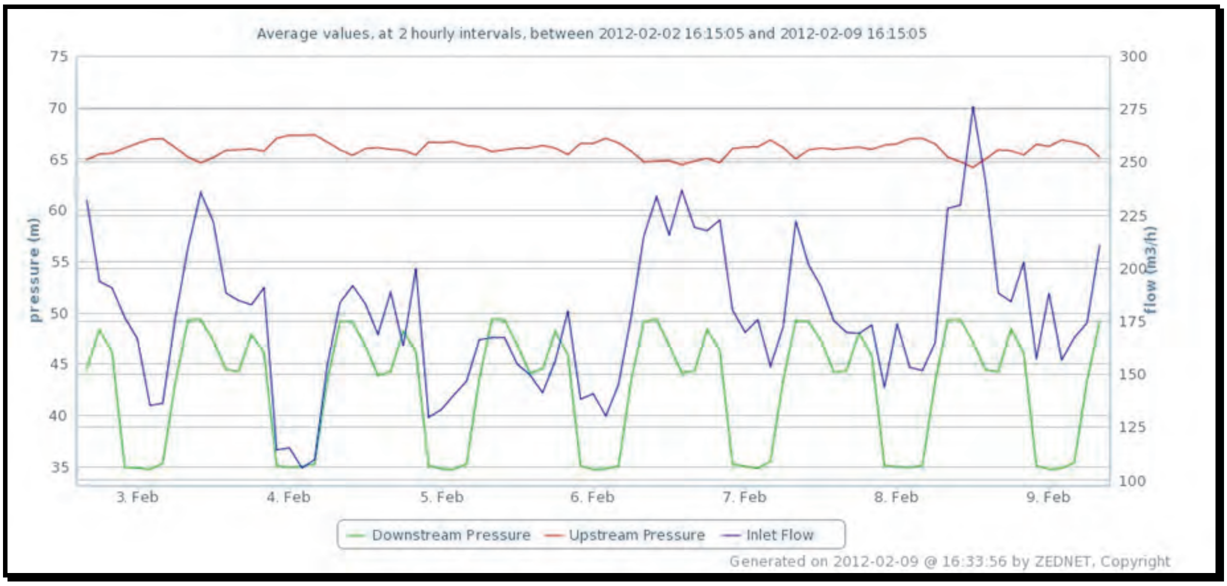


Figure 140: Real-time flow and pressure monitoring in Drakenstein (Courtesy A Kowalewski)

14.2.4 Refurbishment and leakage repair

One of the key interventions of the water loss reduction programme was the identification of water leaks on the reticulation system, and a policy to repair all known leaks within an hour where possible. This rather ambitious target for repairing known and reported leaks has helped to reduce physical leakage in the system to one of the lowest in South Africa. In cases where pipes had to be replaced, only high-quality pipes were used and, in many cases, stainless steel fittings were used which greatly reduce future pipe bursts.

14.2.5 Advanced pressure management

Advanced pressure management was first introduced into South Africa from the UK in the late 1990s after the world's first electronic pressure controllers were developed for the British Gas industry and later modified to suit the water industry. While the City of Johannesburg was the first major city in South Africa to recognise the benefits of advanced pressure management, Drakenstein municipality was one of the first to test the approach in the Cape (at same time as City of Cape Town). Drakenstein municipality approved and commissioned seven relatively large advanced pressure reduction installations ranging from 100mm diameter to 300mm, each fitted with flow modulated electronic controllers (see **Figure 141**). The cost of the pressure management installations (i.e. valves, pipework, chambers, and controllers) was approximately R3 million (± $0.5 mil), which was paid back through the savings within 5 months. Advanced pressure management remains one of the key focus areas for Drakenstein municipality and is considered an essential element of its overall WDM programme. It is often possible to judge the quality of management and workmanship in a municipality from the quality and cleanliness of the valve chambers within the reticulation system. The example in **Figure 141** is an excellent case in point which shows a clean, bone dry and well maintained PRV installation where there is clearly attention to detail. Items worthy of note are the air valve, stainless steel "specials", and the protective waxed tape used to protect the dismantling joint from corrosion. The use of a flow modulated controller with all pipework and fittings neatly positioned is also worthy of comment. This is an excellent installation, and one which would not be out of place in any of the world's best managed water utilities. It is certainly not the type of installation that is being promoted in many municipalities in South Africa where the overriding consideration is not the fitness for purpose or long-term sustainability, but the price.

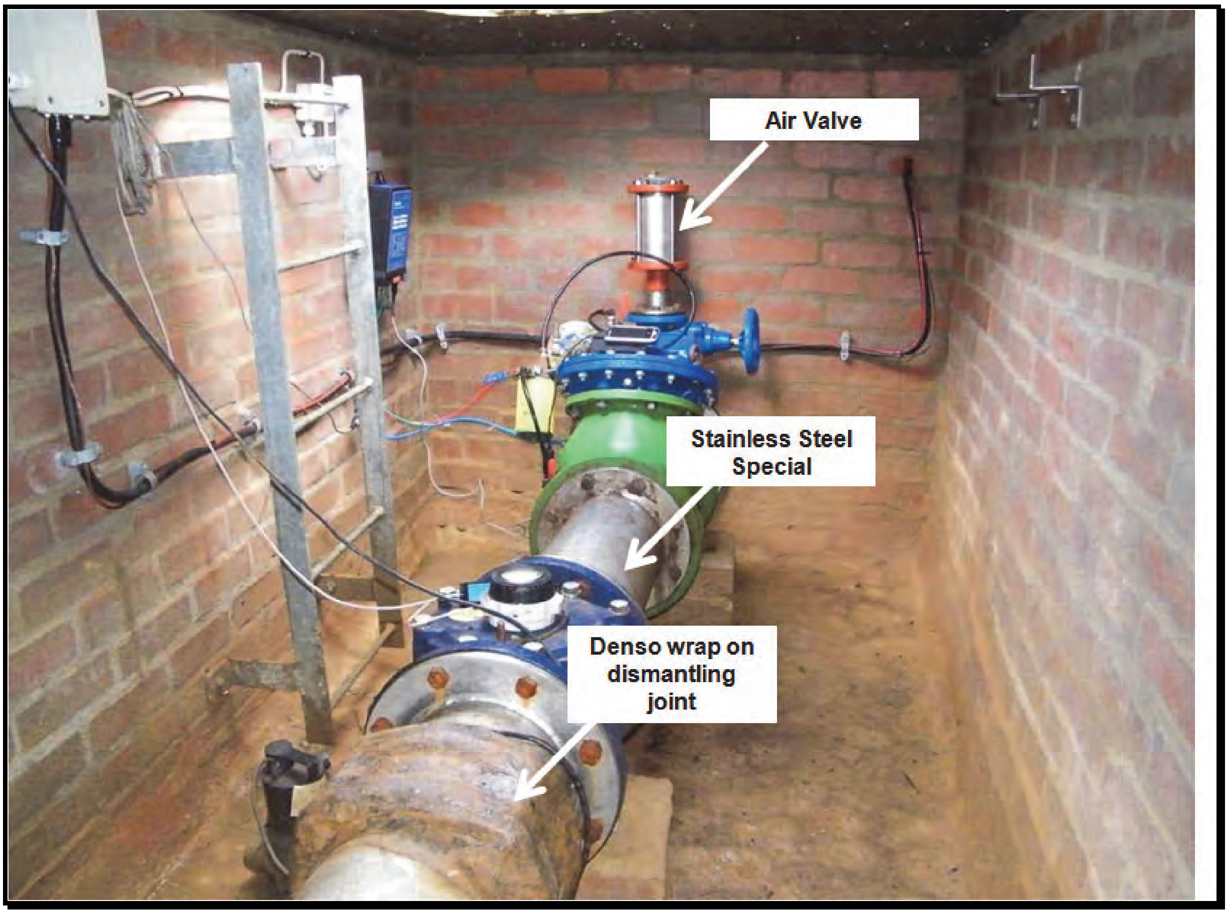


Figure 141: Advanced pressure management installation in Drakenstein municipality

14.2.6 Hydraulic modelling

A locally developed pipe network hydraulic model based on the well-known EPANET model was used to identify areas of high pressure and to assist in sectorising the whole network into discrete pressure management zones. Real-time data logging was used to monitor the zones and pick up any unauthorised zone valve operations which, in turn, compromise the pressure management activities.

14.3 Conclusions

The key goals of the water demand management strategy were met in full and the results achieved by this project have earned Drakenstein municipality numerous national and international awards for water use efficiency. The unacceptably high level of NRW was reduced from over 33% in 1999 to just 12% over a period of 14 years as shown in **Figure 142**.

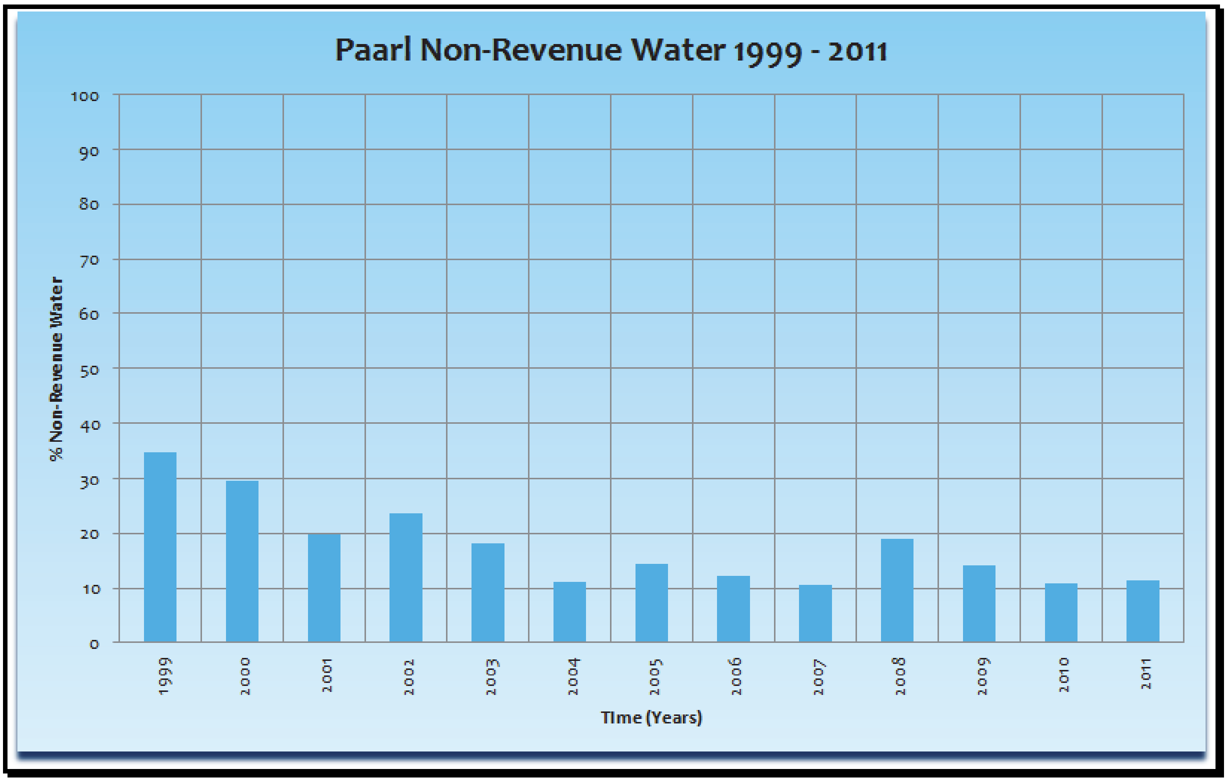


Figure 142: Results of the NRW assessment for Paarl (Courtesy A Kowalewski)

The municipality currently boasts one of the best managed water supplies in South Africa, and one of the lowest levels of NRW in the country. Despite selling less water to its consumers, a combination of the new block tariff structure and the fact that the municipality was buying significantly less water from the City of Cape Town, resulted in a significant gain in net revenue which greatly outweighed the costs of the various interventions. The value of water savings over the 14-year period amounted to more than R700 million.

The most impressive and significant statistic is the reduction in annual water use from 17.8Mm^3/a in 1999 to 11.3Mm^3/a in 2012 ensuring that the final goal of water conservation was fulfilled. The true impact of the WDM interventions is best shown when the long-term water demand for the main town of Paarl is analysed as shown in **Figure 143**. The water demands shown in this figure do not reflect the total demands for the whole of Drakenstein municipality since the boundaries have changed over the past 50 to 60 years. For this reason, only the demands for Paarl have been shown in the graph since the figures over the 50-year period are consistent and not influenced by the boundary changes. The actual savings for Paarl compared to the expected water demands are shown in **Figure 144** which is self-explanatory.

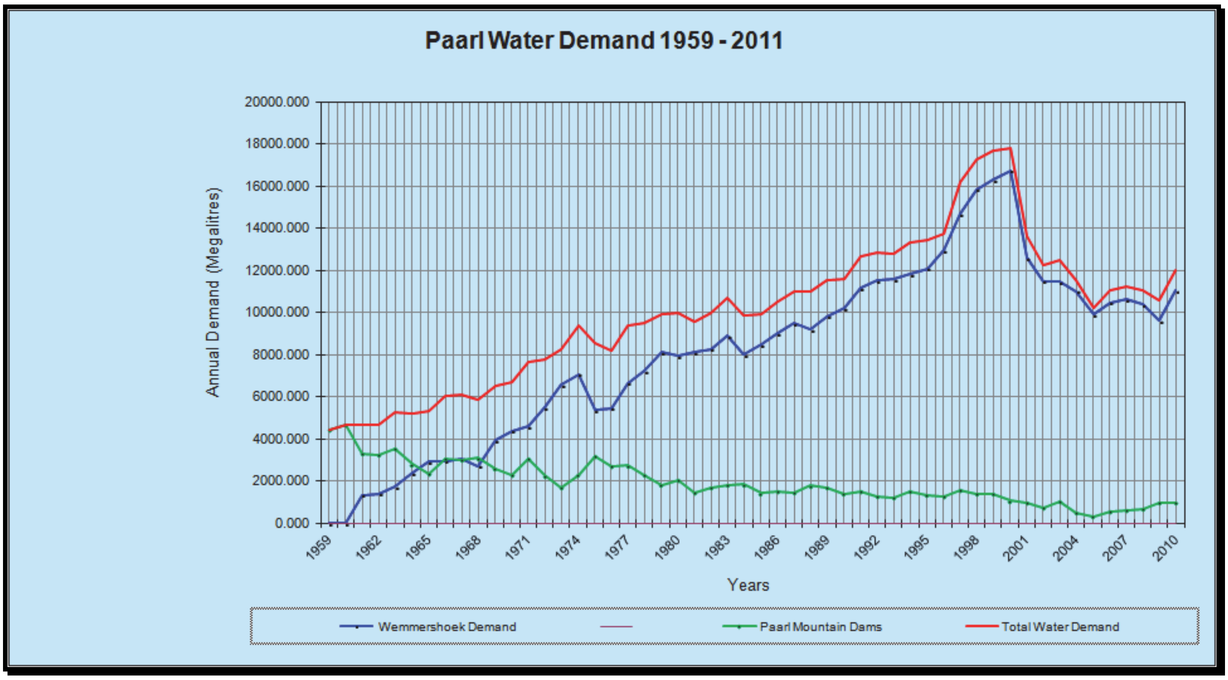


Figure 143: Historical water demand for Paarl (Courtesy A Kowalewski)

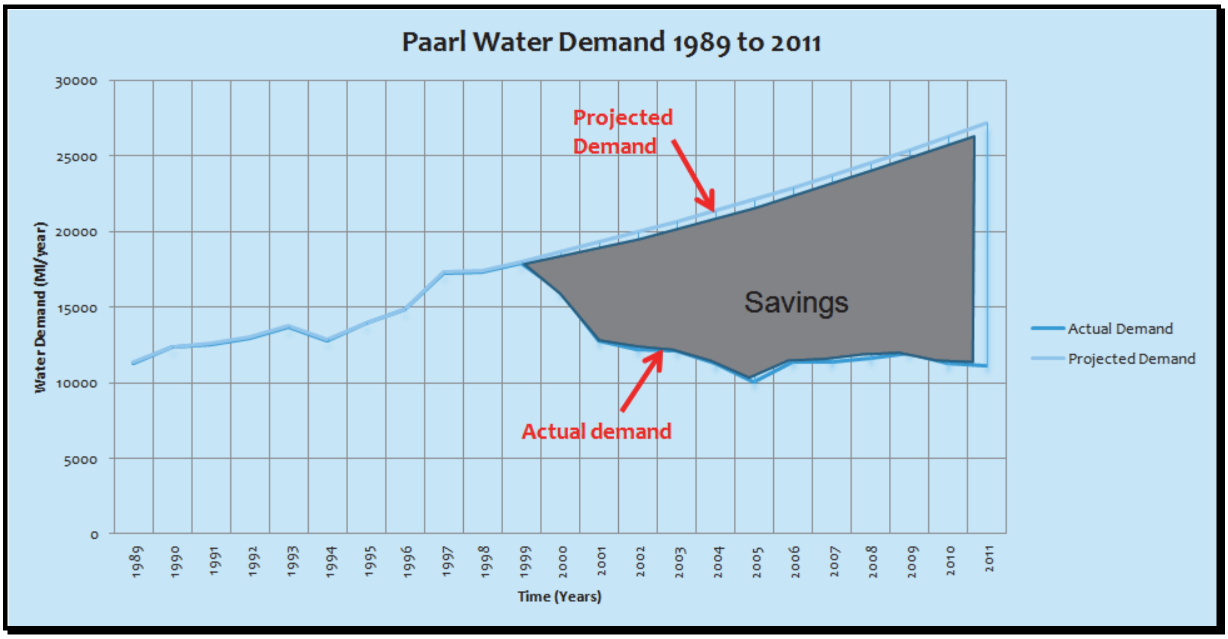


Figure 144: Reduction in water demand due to WDM activities (Courtesy A Kowalewski)

The success of the project is to a very large extent due to the enthusiasm and professionalism of several key individuals within the Drakenstein municipal water department together with the full support from the municipal managers and the relevant political decision makers.

The key challenges faced by the technical personnel tasked with implementing the various interventions included obtaining funding, vandalism of infrastructure as well as sustaining buy-in from Council and municipal management. Another critical challenge related to the scarcity of competent technical staff and retaining them in a very competitive market. With respect to the pressure management interventions, the main challenges included the selection of the different pressure management zones and maintaining their integrity. The issue of which controllers (if any) to be used in the operation of the pressure management installations is insignificant when compared to the issue of maintaining the zone integrity which was achieved to a large extent by the use of continuous GSM or GPRS based pressure and flow logging at various strategic points throughout the reticulation.

15 APPENDIX L: COMMUNITY AWARENESS AND EDUCATION

15.1 Introduction

For many years, community awareness and education has been considered the ugly, useless step child of water demand management. It has been the nice thing to do near the end of the financial year in order to spend the remaining unspent budgets, left over from lack of implementation on operations and maintenance or meter installations amongst many performance areas. A variety of arguments have been posited for the prevalence of this mindset particularly amongst technical professionals in the water sector. The most common of these have been the lack of tangible or observable water loss reduction as a result of community awareness as well as the general absence of proper monitoring and evaluation techniques, necessary to highlight the need for community awareness and to support or substantiate increased investment into this pillar of WC/WDM. The arguments put forward are logical, reasonable, and worthy of consideration; and do indeed highlight a number of short comings in the manner in which community awareness has been implemented in the past. Whilst valid, it is however also a reality that the South African society and consumer base is one which demands to be informed and involved in decision making. This is a critical expression of the present democratic era whose boundaries the citizens are constantly pushing in order to restore the "power to the people" on all frontiers so to speak; and as a means of keeping all tiers of Government accountable to the citizens, for all actions taken on their behalf. Communication has thus become the pivot key to sustainable development in which people, who are at the centre of societal transformation, take ownership of development and the maintenance thereof. This was never more pertinent than when it comes to water, one of the most basic resources, which is responsible for current and future prosperity in its varying forms.

This chapter thus aims to address some of the perceptions noted above and elucidates some of the challenges pertaining to the implementation of community awareness and education. This chapter will further deal with the varying mediums of communication, and outline what is required for successful community engagement on water conservation in future.

The implementation of community awareness is by no means for the faint hearted. The perception that public engagement, fondly known to technocrats as the "soft issues," is a secondary consideration after other more important interventions is not only deceptive but also very dangerous. The case of what can be called Soweto vs City of Johannesburg in dispute over prepaid meters and their constitutionality or lack thereof and the sufficiency of the 6Kl free basic allocation is another classic example of the harm that can be caused by a break in communication. There was nothing soft or easy about this case; nor dealing with angry citizens after the prepaid meters had been installed without complete buy-in and support from the residents. There are many other examples where costly investments have been made by municipalities with good intentions in order to increase cost recovery and water use control and, in turn, improve maintenance of infrastructure and service delivery. Many have been thwarted before completion and set the municipalities back years before they can recover from the problems and resume efficient provision of services. These interventions are often well intentioned and well substantiated by the conditions of the municipalities, which can vary from old dilapidated infrastructure which must be refurbished, huge water losses with no means to recover the costs of service provision or mere shortage of resources which necessitate restrictions. All these reasons for undertaking specific technical interventions are valid however, if the consumers do not know nor understand these reasons, such interventions can merely come across as yet another thing the municipalities are doing to make life difficult for consumers or to increase the cost of living. Proper consumer engagement is therefore crucial in mitigating some of the difficulties mentioned and whilst not an easy task, the rewards can be substantial.

It is important to acknowledge that not all water loss or service delivery problems can be rectified through technical interventions. **Figure 145** depicts a community problem in which crime has made a significant contribution to water losses in the area. The picture was taken in a neighbourhood where many brass taps had been stolen over one night resulting in substantial water losses. This case was not the first of its kind in this community and surrounding areas. The immediate problem could be solved through replacing the taps however the root is a community issue which must be dealt with by the community. The reality is that the community has allowed a scrap-yard to exist which purchases stolen goods. What was most astounding about this case is that the community members had knowledge of the perpetrators, and could pinpoint where the taps had been sold. Through engagement with the community policing forums in the area, the taps were located (see **Figure 146**) and refitted. What is crucial is that through community engagement and making people aware and more cognisant of the issues, they in turn can assist in rectifying the problems in partnership with the municipalities as illustrated by this case study. The ostrich mentality of ignoring problems and hoping they will go away will not suffice in the context of increasing water scarcity and service challenges in South Africa. Even under conditions of imperfect service delivery, engaging consumers and obtaining their cooperation whilst other issues are being dealt with is a prudent and, in the long term, a more cost-effective and sustainable manner of achieving the desired results.

Figure 145: Impact of stolen taps on community

Figure 146: recovery of stolen taps by community support

Municipalities are unique and comprise unique communities with a specific history, socio-economic conditions and political landscape. Within this context there is no one size fits all intervention. Lessons can be taken from municipalities which have successfully implemented water loss reduction initiatives however; the application of the methodologies will differ. Before implementation can commence, it is crucial for the implementer to ask a number of questions which are as follows:

- **Why?**

It is important to establish the purpose of the community engagement which must be undertaken. Is it geared at informing people regarding certain events, is it to educate the consumers or is it to involve them in a specific decision making process, to get their inputs or feedback? The "why" will inform the "how" of your intervention, in other words what form of engagement will take place and what medium of communication will be utilised.

- **What?**

The next step will be to establish the message to be disseminated to the consumers. If the goal of the engagement is specifically education and awareness then it must be clear what the key messages will be. The idea is to focus on a few key issues and make that the overall theme of the education and awareness. The messages must also be grounded on proper research. The implementer must not simply assume the topic of engagement; the messages must be based on the reality of the community. There is no point telling consumers to save water in an area where consumers are not getting water. A more appropriate topic may be exploring other avenues of obtaining and storing water such as rainwater harvesting.

- **Who?**

The "what" of the intervention discussed above will inform the "who". Once the pertinent messages have been established, the target audience for the message must be established which will, in turn, also determine how the message will be disseminated. It is crucial to be familiar with the demographics in an area such as prominent languages and ethnic cultures in an area, literacy levels, levels of employment and which segment of the population is most acutely affected by the topic of education. For instance, there is no point handing out simply handing out pamphlets with lots of writing on them if a large portion of the target audience is illiterate. Knowing the target audience will assist in tailoring existing material or creating new material to suite the situation.

- **How?**

Based on the target audience, the implementer can now determine how the message will be disseminated. There are several methods which are commonly used for education and awareness purposes, which are described below.

15.2 Importance of community awareness and education

As a point of departure, it is vital to understand why community awareness is necessary, specifically in the context of WC/WDM as a key strategy for non-revenue water reduction. In recent years WC/WDM has taken centre stage in the fight against the ever increasing scarcity of South Africa's most precious natural resource. High levels of water losses coupled with low levels of payment for services and poor quality infrastructure have ushered in an era of intense debate regarding how best to preserve this resource to aid future development. Whilst South Africa is world renowned for strategic planning and policy development, the implementation of water demand management remains the foremost challenge in improving the delivery of services to the ±5 million South African citizens who remain without a basic consistent supply of water and sanitary facilities. Some of the key challenges in terms of implementation rest with the transfer and development of skills within the water sector and the integration of community education and involvement in decision making, which are essential in developing relevant strategies that address the most pertinent issues. It is no longer adequate, proper nor effective for professionals to develop strategies based on assumptions and scientific calculations in the obscurity of their offices. The current economic climate demands a move towards cost-effective problem solving which requires proper needs assessments to be conducted and strategies which address the relevant issues to avoid unnecessary duplication of efforts.

Numerous papers have been written worldwide which assess and advocate various water demand management interventions that play a significant role in decreasing water losses; however few, if any, present a holistic perspective or take into account the importance of active community participation in the successful implementation of sustainable water demand management. Lack of community support has proven to be one of the key factors in the slow and inefficient delivery of services often comprising the vandalism of much needed infrastructure and essential measurement tools, as well as a general disregard for the manner in which water is utilised. This leads to the failure of many potentially successful water demand management projects.

Having explored the importance of community engagement in WC/WDM the objectives for this engagement must be clear. Communicating is not undertaken merely for communicating's sake but to achieve certain end results. The following are considered to be some of the key reasons why it is critical to communicate and educate the communities regarding water conservation:

- **Creating an informed public on efficient water use**

It has often been said that knowledge is power, the premise being that education enables informed decision making and hopefully better choices regarding the subject of information. Understanding is a potent motivator of human behaviour (Fiske, 2004) and making sure that people are informed regarding efficient water use can play a critical role in the acculturation of communities. By communicating efficient water use, the old culture of bad practices comes into contact with the new efficient culture which catalyses the process of migration from one culture to the next. This of course is not an overnight process, however as the saying goes, the journey of a thousand miles is commenced with a single step.

- **Establishing partnerships between the community and the municipality**

One of the observed tragedies when it comes to the manner in which municipalities engage with communities, is the gaping hole of the "us and them" dichotomy which is often left un-bridged. Municipalities make large investments into installing smart devices to monitor and control water use and bill consumers, whilst communities invest time and energy into burning tires, placing large stones on the roads and creating imaginative placards; all aimed at cursing the municipalities for lack of service delivery. Although both parties have a unique and in many cases justified perspective on service delivery issues and what is required to effect change, more appropriate solutions which do not involve unnecessary expenditure or destruction of sorely needed infrastructure could be possible if a partnership is forged between the communities and municipalities. Communities are a valuable on-the-ground resource for municipalities which can be utilised to improve the state of the infrastructure through reporting of leakage for example, which is a form of passive leak detection. Education and awareness can thus help to establish such a partnership which must be enforced through continuous engagement. As with any relationship, this partnership must be nurtured and strengthened. Hit-and-run, once-off programmes will not be effective in achieving this, as such programmes can start to foster mistrust and scepticism if communities feel that they are engaged and exploited as a means to an end.

- **Promoting the municipality and its activities in the community**

As mentioned previously, one of the key outcomes of the engagement between the municipalities and communities is to not only transmit information to people which is the purpose of education and awareness, but also community participation which is geared at involving communities in decision making processes. WC/WDM by its very nature makes room for both forms of community engagement. Education is vital in helping people to understand the activities and projects the municipalities are implementing to reduce water losses but involvement in decision making is also vital so that the projects do just remain the municipalities but become integrated into the lives of those they are meant to benefit. Classic cases depicting this kind of engagement are the Emfuleni and Khayelitsha pressure management installations where schools competitions were organised to allow the community to select a suitable design for the chamber. In the case of the Khayelitsha installation the original design shown in **Figure 147** was replaced about 10 years later with the design shown in **Figure 148.**

By painting the chambers and drawing attention to them, they become a recognised land-mark to the communities they serve and by involving the communities in the design, they tend not to be vandalised. In the case of the large Sebokeng installation shown in **Figure 149**, the design was part of a schools competition where the pupil providing the winning design received a small prize as did the school where the pupil was based (see **Figure 150**). These two award-winning installations have been running for 9 years and 12 years respectively, and have never been vandalised in any way by community members.

Figure 147: Initial Khayelitsha installation shortly after completion

Figure 148: Khayelitsha installation after "face-lift) (courtesy City of Cape Town)

Figure 149: The Sebokeng installation showing winning design

Figure 150: Prize giving for the Sebokeng Installation design

- **Promoting and enforcing water wise behaviour**

The only manner in which the prevailing inefficient water use practices can be altered is through disseminating the correct information. Regulations 509 of 2001 pertaining to WC/WDM specify that municipalities have a responsibility to educate consumers in respect of effective water use. The promotion of water efficient use must precede enforcement of municipal bylaws in order for consumers to understand the rules of engagement however; promotion alone is limited in effectiveness if not followed by enforcement. The proverbial carrot must be countered by a stick in order to for tangible water loss reduction to be realised. In many municipalities, the availability of human resources to enforce bylaws as well as the institutional knowledge to do so has posed a huge challenge and a serious impediment to the municipalities complying with the regulations. This element is however crucial as without consequence, water conservation will remain in the realm of social responsibility as opposed to being seen as a responsibility and obligation every citizen must undertake.

- **Encouraging ownership of water loss reduction and infrastructure**

Last but not least of the long-term objectives of demand management is ensuring that consumers take responsibility for water conservation and the infrastructure installed by the municipality. The water services which are provided are for the consumers, they are the direct beneficiaries of the infrastructure and as such; should play a role in reporting faults and directing municipal resources to where they are required. Communities are a valuable asset and possess local knowledge which can at times supplement or cover over limited institutional memory of municipal personnel. It is common knowledge that staff turnover in many municipalities around the country is very high which at times can pose difficulties in terms of locating and operating infrastructure for emergencies or routine maintenance. The participation of consumers is especially vital in such cases in order to mitigate system failure through timely identification of problems.

15.3 Door to door education and awareness

This method is particularly useful in cases where the levels of literacy in an area are low or a large segment of the populations has limitations in mobility either due to age or availability and economic affordability of transportation. This method is also a fantastic vehicle for employment creation and community upliftment. Identifying and utilising people from the affected community to implement the programme is a good way of obtaining community cooperation, and assists in building trust between the community and the municipality. It also means that the existing knowledge and skills in the community are effectively utilised. This approach has been used successfully in many municipalities including Emfuleni, Randfontein as depicted in **Figure 151** and **Figure 152**. Door-to-door education and awareness also increases the visibility of the municipality in the community, which can raise consumer confidence and also present an easy channel through which to communicate issues to the municipality. Utilising this approach has also got many other added benefits, including visual leak detection through the people that are already on the ground moving from house to house. It is generally very cost-effective as transport fees are usually not necessary if the programmes are ward based.

Figure 151: Community education and awareness in Emfuleni

Figure 152: Community education and awareness in Randfontein

15.4 Public meetings and workshops

Public meetings, gatherings or organised workshops where whole communities are invited are another avenue for disseminating information. This method is particularly useful in informing and educating large groups of people at once, which may be necessary depending on the urgency of the information which must be disseminated. Usually these gatherings are seen as events by the community which helps to create the necessary publicity and in interest in the programme to trigger greater participation from community members. This avenue or method of communication should, however, be used with care depending on the sensitivity of the context. The topics of discussion must be made clear from the outset to avoid making the meetings a venting session for a host of other community issues. Nevertheless, this method is a very useful tool in community education and awareness and generally if conducted properly, communities can be receptive and responsive in helping to drive water conservation. Despite popular belief, communities are willing and able to participate in municipal activities, and there is an observed increasing interest in engaging on water issues due to the importance of the resources as depicted in **Figure 153** and **Figure** 154 showing the attendance of water conservation workshops undertaken in Evaton, one of the townships located in Emfuleni municipality.

Figure 153: Public meetings in Sebokeng

Figure 154: Public meetings in Evaton

15.5 Pamphlets and posters and billboards

The use of pamphlets, posters and billboards is common in education and awareness campaigns and very effective when utilised appropriately. In the development of such material, care must be taken that the information is presented in a manner which is comprehensible to the target audience. This includes using the appropriate languages and making sure that the writing is simple, clear, uncluttered, precise and minimal. Using pictorial illustrations is often very helpful in communicating the message and helping people to relate to the information presented.

Municipalities wishing to implement community must be realistic regarding the timeframes in which they expect to see results. Building relationships with communities is not an overnight exercise. It requires commitment and persistence. It is important to note that community awareness interventions are not intended as short-term, “hit-and-run” initiatives but rather as long-term strategies to address water losses. Wasteful habits that have been entrenched over years and decades will require a relentless process of re-acculturation to alter.

Implementers should also be mindful of what is happening in the municipality before commencing with such programmes. It is not helpful, for example; to begin a community awareness programme right before national or local elections as this is often misconstrued as a ploy to garner votes for certain political parties. It is thus crucial that such interventions are appropriately timed and given sufficient time to properly monitor the process.

15.6 Schools awareness and leak reduction

Schools have been found to be an essential avenue for the promotion of water conservation as significant consumers and contributors to the demand for water. Instilling good values and habits at the foundation developmental stage is invaluable as the future leaders will get a good head start in practicing wise water use behaviours and teach them to others. Young learners are also a particularly receptive target for WC/WDM education and awareness as they would not have accumulated the inefficient habits practiced by adults over years of entrenchment. Based on schools programmes undertaken previously, some of the key challenges and issues facing schools with regards to WC/WDM are as follows:

- **High levels of leakage**

Water loss through leakage appears to be a serious problem for schools particularly those found in township settlements as shown in **Figure 155**, **Figure 156**, **Figure 157**, and **Figure 158**. A number of the schools visited on previous programmes exhibited high levels of visible leakage. Maintenance of internal plumbing fittings appears to be a challenge due to ongoing vandalism and theft of water fittings, insufficient funding, and poor workmanship by the plumbers that are obtained to undertake repairs in many of the schools. What appeared to be the most significant source of water losses were the toilets some of which were leaking profusely over long periods. In this respect the schools expressed their desire for greater support and guidance from both the municipalities and the District Department of Education to address these challenges. It is, however, important to note that in many municipalities, a large portion of the schools are section 21 schools, which are allocated with a maintenance budget utilised at their own discretion. Many schools complain that the budget is not sufficient to address all the maintenance needs however; the majority of leaks found in the schools do not require huge capital expenditure. In most cases, simply replacing the tap and toilet washers suffices.

Figure 155: Leaking toilet in school

Figure 156: Vandalised toilet in school

Figure 157:Leaking tap in school

Figure 158: Leaking toilet fitting in school

Automatic flushing urinals also pose a serious problem in terms of water losses as shown in **Figure 159** and **Figure 160**. The presence of these urinals usually results in high water bills even during school holidays as they continue to flush regardless of actual use.

Figure 159: Automatic flushing urinal in school

Figure 160: leaking urinal in school

- **Inaccurate and billing and broken meters**

Billing and metering is a contentious issue in many municipalities and if not conducted properly, negatively affects the willingness of consumers to pay for services. Before the commencement of the assessments undertaken in schools in previous programmes, one years' consumption data was requested from the municipalities for all the schools participating in the programmes. It soon became apparent that most of the billing was based on estimates and not actual meter readings which was a matter of great concern for the schools. The meter investigations which formed part of the assessment confirmed this finding with the meters generally being in very poor condition or illegible (see **Figure 161** and **Figure 162**). The schools representatives present at the discussion sessions mentioned that the meters had been reported to the municipalities however no response was received. These inaccuracies in the billing of schools and the lack of response to meter complaints will be to the detriment of many municipalities in future if left to continue unabated. In order to improve the communication between the schools and the municipalities, and to ensure effective cost recovery; municipal response to reported problems must improve.

Figure 161: Leaking school meter

Figure 162: Illegible school meter

- **Poor response and communication with the municipality**

As mentioned previously, communication between the municipalities and the schools has been perceived to be generally lacking. The lack of responsiveness or rather protracted response to billing related queries has also contributed to the tension existing between the schools and numerous municipalities. Constant fruitless referrals were noted to be time consuming and disheartening for the schools resulting in further lack of confidence in the municipalities. A coherent support structure is required from the municipalities to assist the schools in resolving billing matters.

- **Relatively low levels of water conservation awareness**

Based on the scores attained in the score card assessments undertaken in numerous schools, it is evident that more intensive water conservation and awareness education is required to reduce the water losses and to change the inefficient consumption patterns in some of the schools. General observations made during the course of the assessments included the following:

- Irrigation of school gardens during the midday heat using potable water
- Leaks that were left unattended for long periods of time
- Very limited rainwater harvesting
- School management with no knowledge of the location of the school meter
- Frequent occurrence of internal plumbing leakage due to vandalism

- General wastage of water by learners (see **Figure 163)**
- Poor hygiene conditions (see **Figure 164**)

Figure 163: Inefficient water use by learners

Figure 164: Unhygienic conditions in schools

In general, it has been observed that water conservation is a culture which must be cultivated in the schools. The state of the schools often reflects the leadership of the schools and the participation of the whole school community including principals, educators, learners and school governing bodies and parents. Whilst some schools display inefficient water use and poor hygiene conditions others existing within the same socio economic conditions exhibit exemplary practices a seen in **Figure 165** and **Figure 166**, and it comes down to the efforts and leadership of the parents, educators and school management where the same message is communicated to learners at school and at home.

Figure 165: Water wise mural at school

Figure 166: Efficient drip irrigation

Despite the seemingly dire picture painted by the challenges outlined above, it must be noted that there are many schools which are implementing admirable water conservation strategies, including keeping buckets of water in the classrooms to increase monitoring during teaching time, use of boreholes for irrigation of food gardens used for feeding schemes, rainwater harvesting and self-initiated water conservation workshops on spring days when children would habitually play with water to celebrate the day. These have been some of the outcomes of the schools WC/WDM campaigns implemented previously and illustrate the value of engagement with schools. It is, however, recommended that such programmes should not focus only on the learners. Water conservation is a whole school effort, and can only be sustained through the participation of every player. The participation of the Department of Education is also invaluable. More recently, it has been found that in certain regions, the Department of Education has established a system where schools are obligated to provide their own meter readings on a monthly basis. This is a very positive in raising the profile of water management in this sector, and has significantly raised the awareness of decision makers in the schools, who now take greater cognisance of the consumption patterns in the schools.

In undertaking schools awareness campaigns, the following should be considered:

1) **Whole school participation:**

Each segment of the school community has a crucial role to play in water conservation, and as such should not be left behind. As mentioned previously, the focus should not only remain on the learners not taking away from the fact that they are critical component. Huge benefit can be derived from engaging with the principals and governing bodies as the school management structures which set the rules and drive WC/WDM. The general assistants who deal with maintenance issues on a daily basis should not be omitted from such campaigns. One of the observations mentioned is that of the leakage which is left unattended for long periods of time. Most of the leakage does not require highly technical expertise and can be conducted by the general assistants if basic training is provided. Future campaigns could perhaps provide such training to reduce the persistence of basic leakage. Educators are the custodians of knowledge and how that knowledge is communicated in the classroom. Focussing on the learners alone limits the opportunities for building a culture of water conservation. It is thus crucial that the educators are provided with the knowledge and tools to continue the acculturation process.

2) **Schools competitions**:

Schools competitions have been found to be very effective motivators of water conservation in schools. They allow both learners and educators to engage vigorously with the water conservation issues and to compare their performance against that of other schools which in itself creates greater awareness.

15.7 Use of media in creating awareness

The media is powerful tool for driving public participation as well as education and awareness. It engages a variety of senses and if utilised well, can allow the public to interact with projects and with municipalities and provide feedback on their concerns and issues. The numerous forms of engagement mentioned previously primarily target individuals which are at home during the day and thus greatly impact on the peak demand periods, however, in water conservation and demand management related campaigns, it is just as critical that household owners which are paying for water services also be reached. This segment of the population is typically at work during the day, and forms the very important tax base which contributes to the economic viability of the country. Door-to-door education and awareness or workshops held during the day cannot reach this target market, therefore other mediums of communication must be considered. In this respect, local community radio stations can be used to target the working population. This type of media is widely accessible to most people, and covers the all bases in terms of literacy levels because no reading is required. Local newspapers can also be used to reach the working population, and are a popular and affordable means of communication both for the target consumers and implementing agents.

One of the most potent and effective forms of communication is visual. When educating consumers on water conservation, it has been observed that people respond very positively to mediums such as powerpoint presentations where pictures are shown of the behaviours which must be altered. It also makes the topic more relatable for consumers when they can visualise the topics of discussion. Television is thus a very effective medium for disseminating information as it combines both visual and auditory mediums of communication. The Department of Water Affairs advertisement on the “War on Leaks” campaign is a great illustration of the impact of television media. The advertisement had to be removed shortly after it was released due to the influx of callers reporting internal leaks to

DWA. This is however a very expensive form of communication and often beyond the reach of the day-to-day campaigns undertaken by municipalities. Billboards are regularly utilised to a similar effect and are a more economical medium to use.

Irrespective of the mediums used to communicate, it is important that the message be clear and uncluttered. Due to the fact the media is such a powerful tool for communication, it also has the potential to create confusion and the message can be distorted if not formulated properly. It thus crucial to the keep the messages short, concise, clear and to the point.

The educational material, particularly for written media, must be easily understood. The idea is to keep the language simple and un-convoluted to ensure that the messages are received loud and clear.

WC/WDM is a very wide field which involves a multitude of topics ranging from rainwater harvesting to pressure management. In education and awareness it is crucial to focus the themes or topics for the awareness, based on the crucial issues identified in the community in order to aid assimilation of the information. The “more the merrier” approach does not apply in this instance. Consumers must be left with a few key messages to process at any one time. The education and awareness can therefore be themed and undertaken in phases where the messages can be changed periodically.

15.8 Role of politicians and councillors

The role of the political representatives of any community in water conservation and demand management projects cannot be stressed enough. Many a project has seen success or failure on the basis of the participation of councillors and ward committee members and their support or opposition to programmes. Ward councillors and tribal authorities are often the gatekeepers to communities as elected or cultural representatives and should be the starting point in gaining entry to any community. Communities also look up to these individuals as the example and expression of democracy and their right to choose and participate in the affairs of the land. It is thus crucial that these individuals are engaged and involved at the commencement of any community based programme to avoid costly and unnecessary project delays.

This component has proven to be particularly challenging for most municipalities as often, there is a tug of war between making popular decisions which lean towards everything for free for all and the unpopular but difficult decisions which are required to ensure that water services are sustainable. This may include increase of water tariffs, implementation of pressure management, which reduces the water pressures at certain times, or perhaps implementation of restrictions, such as hose pipe bans in areas which are struggling with the availability of water resources. The fact is that these difficult decisions can be made and successfully implemented with proper consultation, strong leadership from the political and tribal authorities and purposeful efforts towards common objectives. This has been demonstrated time and time again in municipalities in the Eastern Cape, such as Nelson Mandela Bay and Beaufort West in the Western Cape amongst many, which have been plagued by droughts and water shortages. It is therefore crucial that political and traditional leaders play their part in WC/WDM programmes. Increased training and capacity building for these leaders is sorely required to improve their understanding of the water issues and to support their decision making. Only what is known can be managed and improved on and the same applies to the decision makers in municipalities.

15.9 Monitoring and evaluation

One of the main concerns related to education and awareness has frequently been how these initiatives can be monitored and evaluated. It is important to remember that communication is not a one way stream of information. It depends on a cycle of input and feedback. In this regard, undertaking Knowledge Attitudes and Perception (KAP) Surveys can be a useful tool. Although not without their flaws, if they are undertaken prior to the commencement of a community awareness programme at the mid period of implementation and at the conclusion of the programme; they can provide very valuable feedback regarding the effectiveness of the programme and how the communities feel about the initiative.

In cases where an area is discrete and fitted with a bulk meter, it becomes technically possible to monitor the impact of the interventions through the bulk meters, provided there are no other interventions being undertaken at the same time. **Figure 167** shows the consumption patterns in such an area, where a community awareness programme was implemented in the absence of other technical interventions. Through community awareness conducted over a 12 month period, there was a reduction of $6m^3/h$ in the minimum night flow as residents began to fix their internal plumbing leakage.

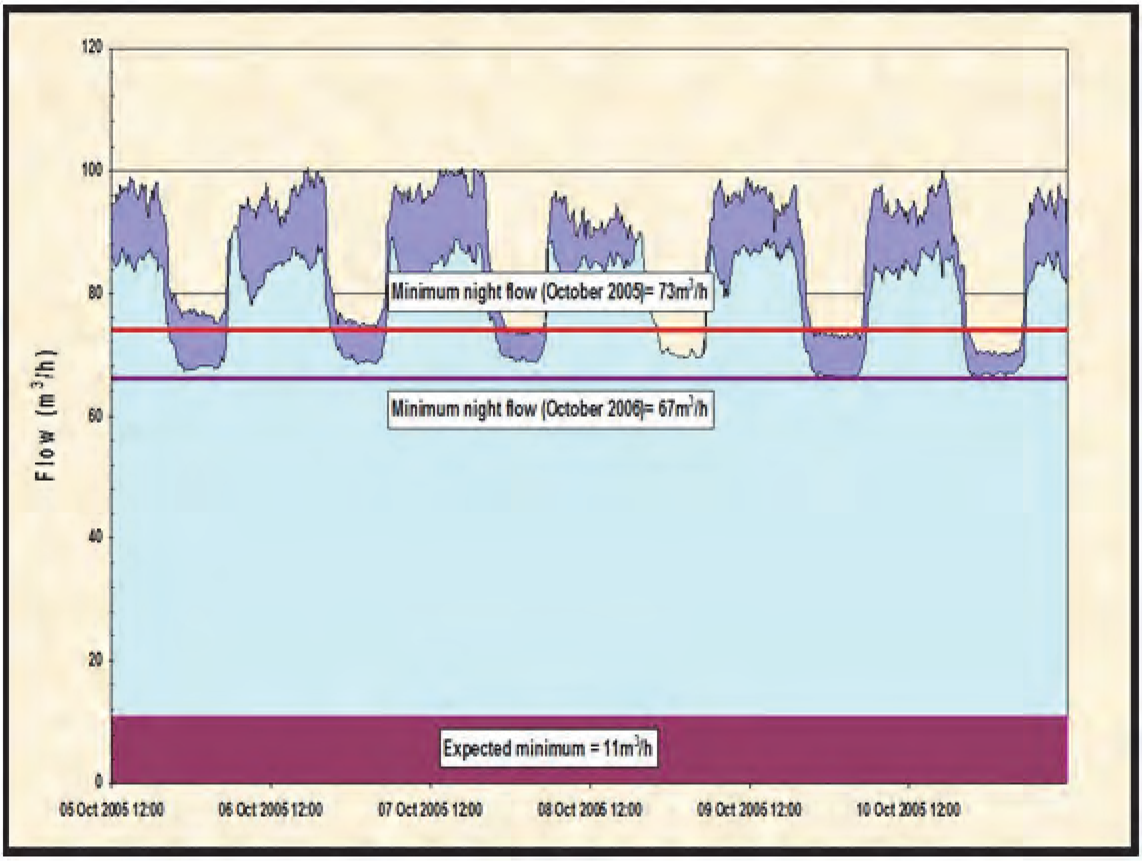


Figure 167: Graph of consumption in a discrete zone

Like a cake which is baked with a pinch of salt to bring out the sweetness; the main benefit of community awareness programmes is to enhance and assist with the sustainability of technical interventions. Their true value lies in opening the channels of communication between communities and municipalities, building a culture of ownership of municipal projects and thus protecting costly investments in infrastructure. It is indeed very difficult to quantify the potential savings which can be made through such interventions however, the benefits are often acknowledged retrospectively when damage control is conducted on projects which have been terminated due to lack of engagement. Following the example set by municipalities such as City of Cape Town and Emfuleni municipality amongst many municipalities, community awareness has assisted in protecting big pressure management installations as well as the identification over 15 000 water related problems over a one year period through ward based water conservation warriors conducting visual leak detection.

15.10 Lessons learnt

Capacity retention

A key challenge in many of the municipalities is how to retain the capacity developed during the implementation of water projects. The projects are implemented as short-term solutions with little thought for their continuance in the future. Should the status quo remain unchanged, little progress will be made in improving the delivery of services and furthermore the same problems will continue to persist. Money spent on perpetual training programmes can be more effectively utilised to retain the individuals already trained and directed to the implementation and operation of other water demand management measures that are required to minimise the water losses.

Vision and leadership

Retaining capacity without clear vision and leadership can prove fruitless. The resources developed through water conservation education and training must be utilised for their intended purpose and for this to take place proper guidance and continuous monitoring and evaluation from the municipality leadership is required. If this can be achieved, there is no reason why lack of capacity should remain an obstacle to service delivery.

Consistency and sustained effort

Both training and capacity building and community awareness programmes share one common vital condition for success; they both require consistent and sustained effort. So often momentum is built up during the implementation period of the projects only to be deflated in a matter of a few months when the implementing agents leave the system. This is a concern because unlike technical programmes, initiatives that involve people cannot be easily rectified or recommissioned. An extensive investment of time is required to open the channels of communication between communities and municipalities, but more importantly they require a degree of trust and goodwill between the two parties for the re-acculturation process to take place. The culture of short term hit and run interventions undermines open communication and the process of establishing efficient water use practices. If these interventions are undertaken in such a manner, the communities cannot be expected to display any persevering changes in behaviour. Words must be supported by visible action with the municipalities taking an exemplary stand in this regard. Likewise, building capacity requires mentorship and consistent effort to establish the experience necessary for continued successful implementation of water demand management initiatives.

Communities

Demand management is often conceptualised as a model comprising a wide range of technical interventions requiring sophisticated methods and equipment. Communities are an essential resource for the municipality notwithstanding the fact that 80% of the implementation of demand management takes place at grass roots, in individual homes where the consumers must adapt their water use practices to promote economic efficiency and sustainability of the resource. They must be taken on board and provided with the necessary skills to take ownership for their progress.

Communication

The provision of clear realistic information is essential to healthy communication between municipalities and communities. Particularly when it comes to the provision of basic services such as water which is often a fairly sensitive issue, unrealistic promises of free services and short delivery times are neither helpful nor sustainable. Effective demand management requires the provision of consistent, realistic and honest information to consumers that allows them to make informed decisions.

16 APPENDIX M: HOUSEHOLD WATER USE (APPARENT LOSSES)

The previous section highlighted the importance of dealing with visible leaks which are generally obvious and are often reported within hours of occurring. A slightly less obvious but nonetheless important issue concerns water leakage on actual residential properties. In many countries, such leakage is ignored by the water supplier since it is the problem of the customer who is metered and billed for any water passing through their water meter. In South Africa, however, this is not always the case and sometimes household leakage after the customer meter becomes the problem of the municipality where payment for services does not occur. To understand this issue it is important to have a reasonable understanding of how much water is used by a typical household. Obviously the water use in a household can be influenced by a number of factors including:

- Size of the property
- Number of people living in the property
- Gardens and/or swimming pools
- High or low income area
- Water pressure and 24-hour supply

Although there is no hard and fast rule regarding domestic water use, the following numbers are “Ronnie’s Rule of Thumb” and can be helpful as a rough guide to what water use one can expect from certain properties:

- Small- to medium-sized houses in low- to middle-income areas without large gardens or pools – typical water use is $10m^3$/month to $15m^3$/month
- Larger properties in medium- to high-income areas with some garden irrigation but no pools – typical water use $20m^3$/month to $30m^3$/month
- Larger properties with significant garden irrigation and/or pool use – typical water use of $50m^3$/month to $100m^3$/month

While these numbers are clearly not universally applicable, they often provide a realistic estimate of residential water use in many areas assuming that there is little or no internal household leakage. In cases where there is household leakage, the monthly water use can increase significantly and is particularly problematic in areas with low levels of payment. A typical example of such an area is shown in **Figure 168**.

Figure 168: Garden watering in peri-urban area with low payment levels

In the above pictured area, the average monthly water use increased from the expected $10m^3$/month on average to more than $60m^3$/month due to the fact that there is virtually no payment for water use which in turn encourages wasteful practices such as unchecked garden irrigation. If proper water accounts were being generated and the customers were paying for the water they use, the average consumption would drop to expected levels.

This issue is clearly highlighted in **Figure 169** which shows a house in a middle to high income area which has a monthly water consumption of only $15m^3$/month. The low monthly water consumption is due mainly to the absence of any garden irrigation together with full payment for all water used.

Figure 169: House in middle- to high-income area with low water consumption

The low water use for the house shown in **Figure 169** dispels the myth that water use in larger houses with many bathrooms etc. will always be higher than smaller houses in lower income areas. The water use is not always a function of the size of property or the number of bathrooms, and is often influenced by the condition of the internal plumbing fittings and the owner's appreciation of the value and scarcity of water.

Another interesting example to highlight typical domestic water use is provided in **Figure 170** which shows two houses in a middle-income area which have normal sized families living in the same lifestyle.

Figure 170: Two houses in same area with different water consumption (Z Siqalaba)

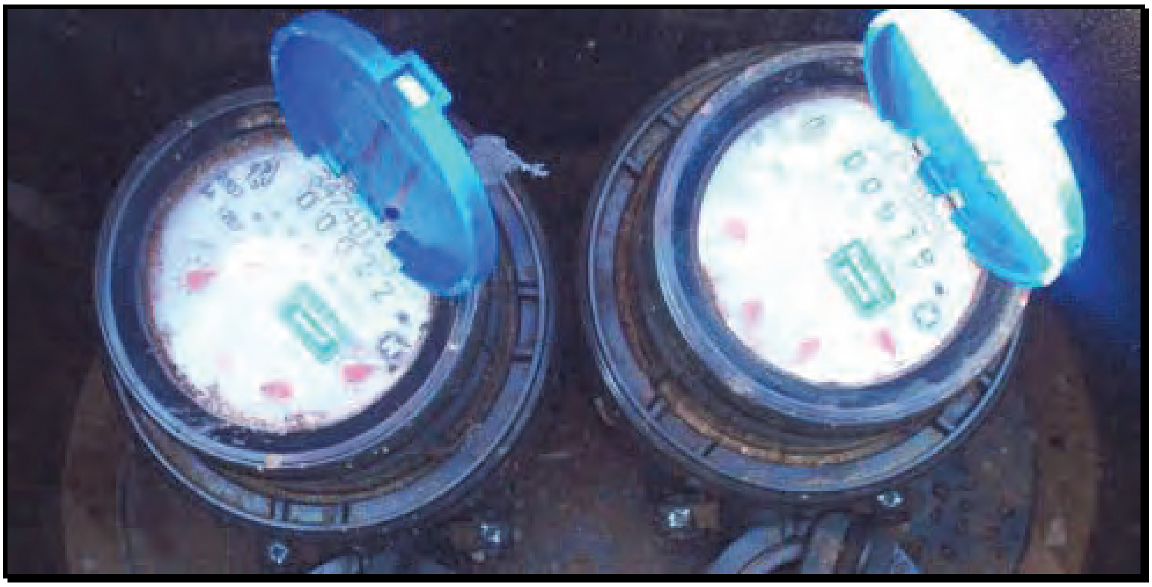


Figure 171: Water meter readings for the two properties in previous figure (Z Siqalaba)

New water meters were installed for all properties in the zone in which the two houses shown in **Figure 170** are located. The meters at all houses were read for the first time after approximately 3 months and the actual meter readings are shown in **Figure 171**. The house on the left had used $42m^3$ in the 3-month period which is in line with expectations. The house on the right, however, had used over 600m^3 in the same period (i.e. over 200m^3/month) which is clearly well outside the expected range of monthly water use. In this area it was found that 80% of the properties used less than 15m^3/month while the remaining 20% used more than the combined water use of the other 80% of properties. Many properties were found to be using in excess of 100m^3/month and in virtually all cases the excessive water use was caused by some form of internal plumbing leak. In the case of the property using over 200m^3/month, the problem was traced to a leaking tap at the rear of the property as shown in **Figure 172**. In this case, the owner was not paying for water and found it easier and cheaper to simply attach a hosepipe to the tap rather than replace the washer. In effect, the water service provider was covering the cost of more than R1 000 per month because the owner was unwilling to pay for a 20 cent washer.

Figure 172: Leaking tap "repair" at one property (courtesy Zama Siqalaba)

The key message from this example is that in some cases it is important to monitor the domestic water use especially in areas where residents may not be paying for the water used or are paying on a fixed rate tariff. In such cases there is often little or no incentive for residents to save water and this often leads to irresponsible and unacceptable water use. Such problems require both technical support as well as education and awareness. By undertaking a simple check of the average monthly water use in an area, it is possible to identify whether or not there is a leakage problem after which action can be taken if necessary.

17 APPENDIX N: SECTORISING

17.1 General

Sectorising is basically the process of splitting a larger water reticulation system into smaller more manageable “chunks”, which provide greater control over what is happening in the system. The aim of sectorising is to create small zones which are easier to manage than large zones. The smaller the zone, the more control the water manager has over what happens in the area, however, with every benefit comes some problem and in the case of zones, the biggest issue is the maintenance of the zone. Setting up new zones is a time consuming and often expensive process. Each zone must be discrete for it to operate as a zone and will normally involve a number of valves, inlet supplies and sometimes outlets to an adjacent zone. If any of the boundary valves are opened or closed by mistake (sometimes on purpose) the zone can be compromised and will no longer act as a zone. By far, the biggest problem issue facing water suppliers throughout the world is the continual breaching of zones within the system – often by officials from the water supplier. Very few water suppliers have any system in place to monitor and manage their zones properly and without such monitoring, the supplier is often unaware that the zone has been compromised and is no longer functioning properly.

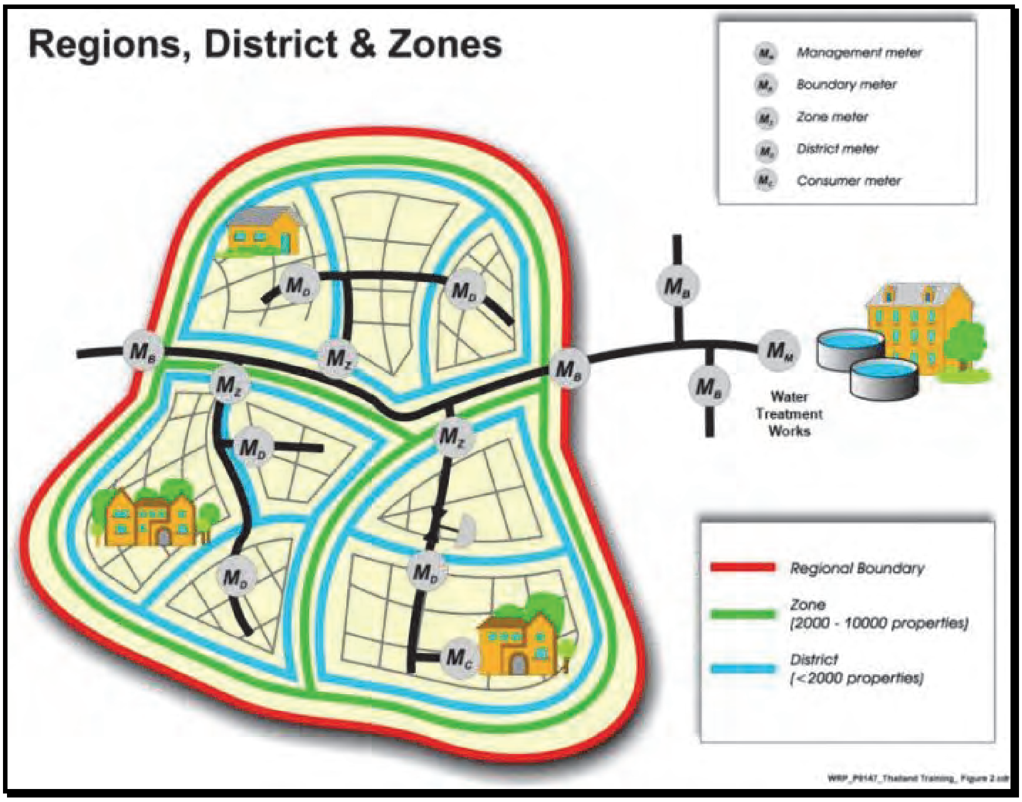


Figure 173: Typical zone and district layout

Sectorising a water reticulation system is one of the most important and useful aspects of any WDM plan. Before undertaking any form of sectorising, however, it must always be remembered that creating a new zone with proper meters and monitoring equipment can be expensive, and every zone requires some element of maintenance which will continue indefinitely. The advantages of numerous small zones must always be weighed up against the establishment costs and the ongoing maintenance costs. It is sometimes not appropriate to create too many small zones when one or two larger zones are all that is needed. If a zone does not have a serious leakage problem and has a relatively uniform pressure distribution, then there may be little benefit in cutting it up into smaller pieces – each of which should ideally have its own meter and monitoring equipment. It is therefore recommended, that when sectorising a new area, a few large zones should initially be created and monitored. If leakage is found to be a serious problem or the pressure profile warrants a smaller zone, then the larger zone should be cut up into smaller sections. If no leakage problem is evident and pressure is not an issue, then the large zone can remain since there will be no real benefit from creating smaller zones and in fact they will just add to the costs of running the system. This concept is highlighted in **Figure 174** and **Figure 175** which show the original and final sectorising layout for Halifax in Canada. Initially only two large zones were established to manage pressure and leakage. After several years, the large zones were cut up into 8 smaller zones to help manage the pressure and leakage. This phased approach to sectorising is often the best approach as it gives the water supplier time to assess whether or not it is really worthwhile cutting into small areas.

When establishing zones in an area, there are a few general rules of thumb that can be considered namely:

- Zones should be homogeneous where possible and avoid mixed residential with industrial.
- Zones should be established to help manage leakage and water use in the system and not simply because some book or manual has indicated that they are necessary and that they should not be larger than 2 000 customers.
- Sectorising should commence at the outskirts of an area and gradually work back towards the central business district.
- It is often not possible to sectorise the Central Business District due to the number of cross-boundary connections and hidden pipes etc. The CBD is often left as an unsectorised area as it is often not possible or cost effective to achieve proper sectorising of such areas.

- Sectorising should try to follow the boundaries created by roads, rivers railways etc. If such features are used to guide the sectors, they tend to be easier to operate and maintain.

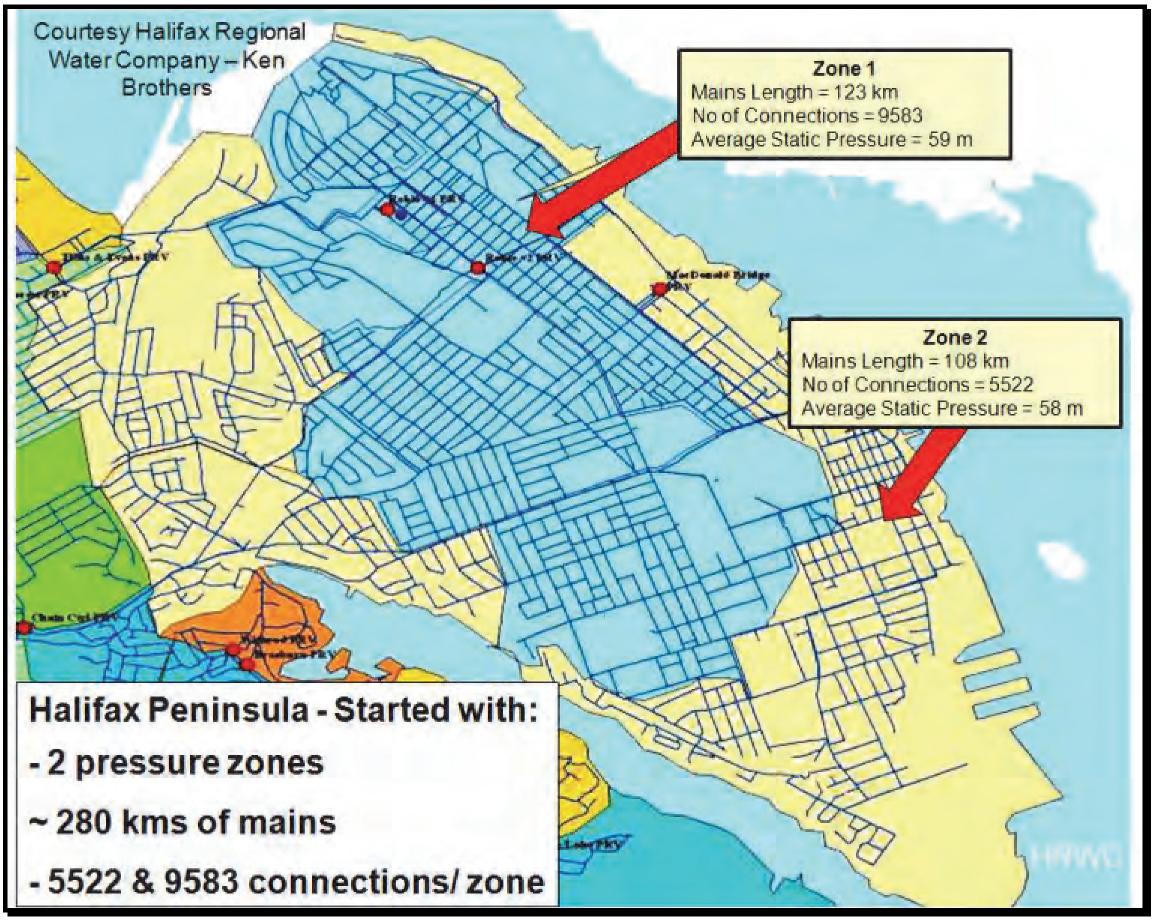


Figure 174: Initial sectorising of Halifax (courtesy Ken Brothers)

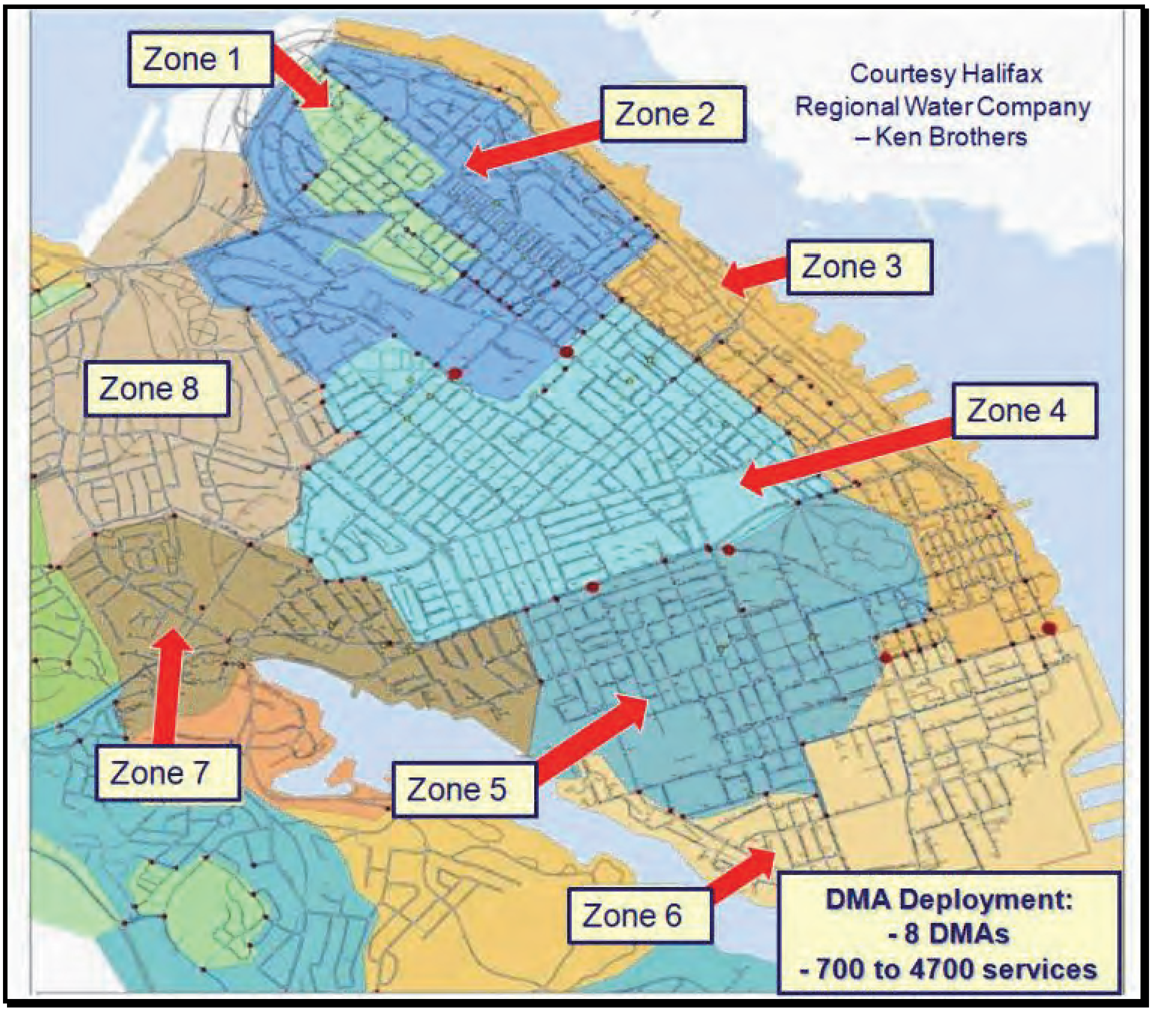


Figure 175: Final sectorising for Halifax (courtesy Ken Brothers)

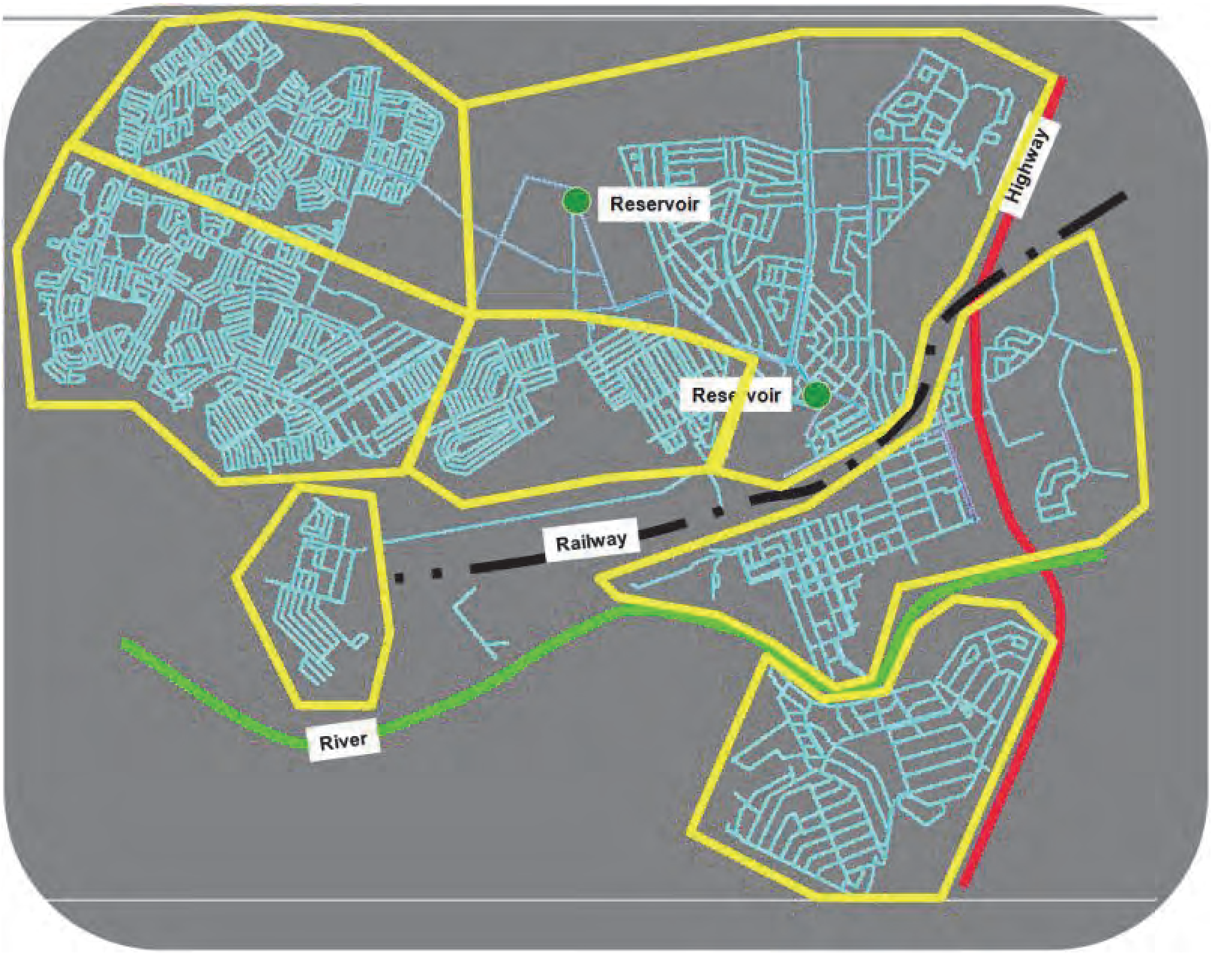


Figure 176: Typical sectorising following roads, rivers and railways

Boundary valves remain the most common problem issue facing water suppliers who are trying to manage zones in their system. A simple example of such a problem is shown in **Figure 177**. It can be seen that the water supply to "Point A" is a short distance from the inlet point and as such the pressure is likely to be close to the inlet pressure assuming the elevations are similar. As a result of a fire in the zone close to "Point A" 5 internal zone valves are closed in order to isolate the area in the vicinity of the leak in order to effect a repair as shown in **Figure 178**. The leak is repaired late at night and the repair team are particularly lazy and only open one of the 5 vales which they closed in order to restore water to all residents. As a result, the water must travel a longer path through the network in order to reach "Point A" as shown in **Figure 179**. There are now 4 internal network valves which are closed that should be open resulting in low pressure problems in the vicinity of "Point A". Consumers in the area complain about low pressures and the easiest solution is to increase the system pressure at the inlet rather than try to find closed valves in the network which does take considerable time and effort. This is the typical situation facing most water suppliers who do not check regularly for closed network valves or open boundary valves

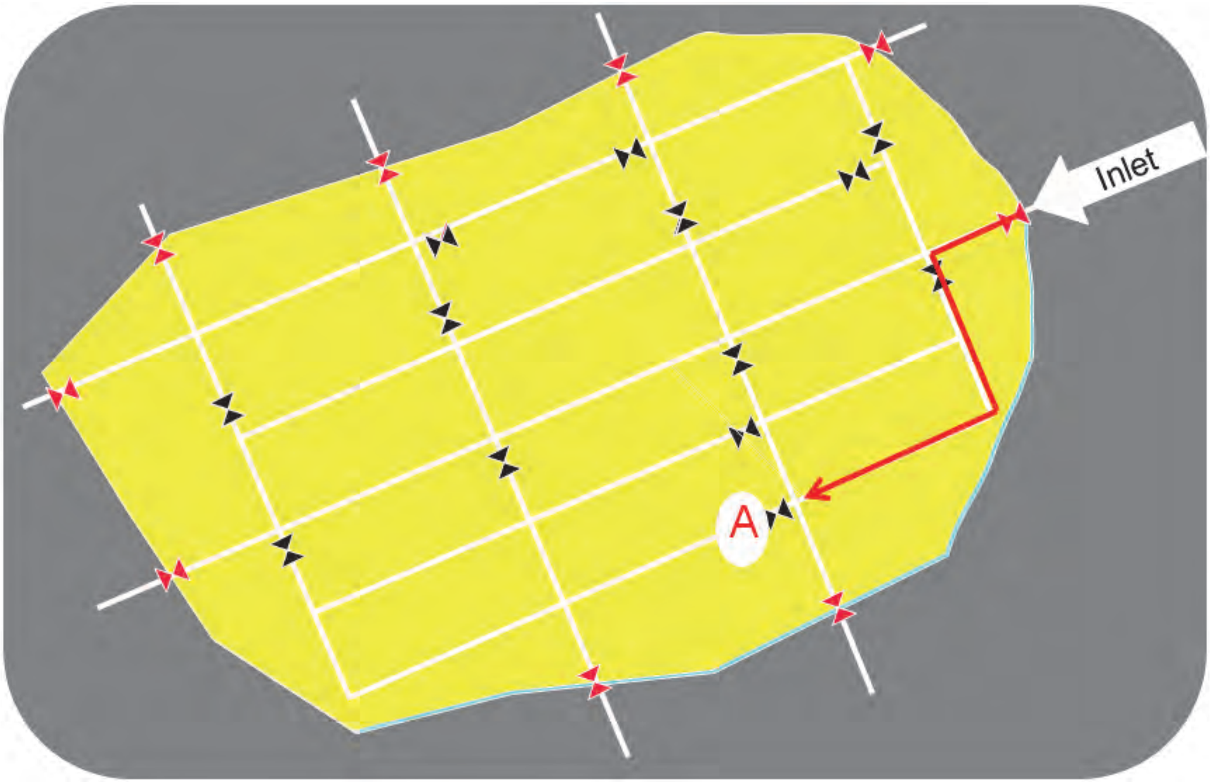


Figure 177: Sectorised zone showing flow path of supply to Point A

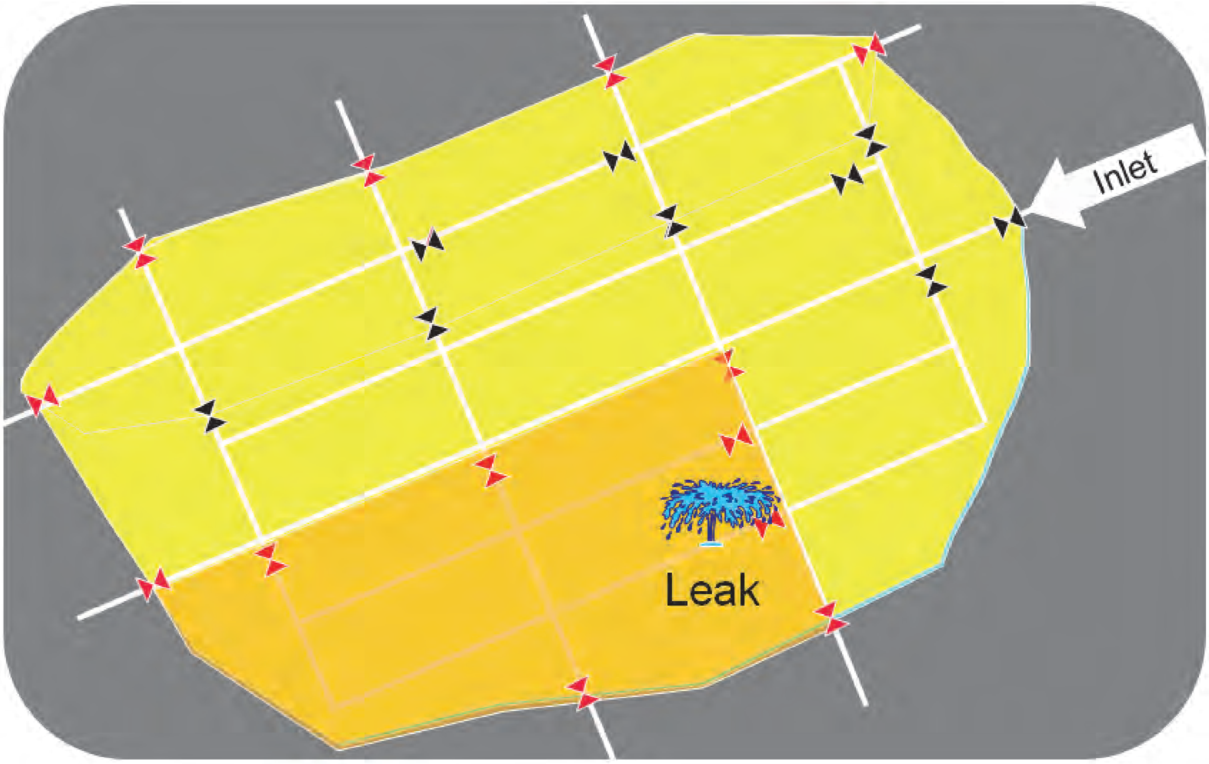


Figure 178: Leak near Point A showing valves closed for repair

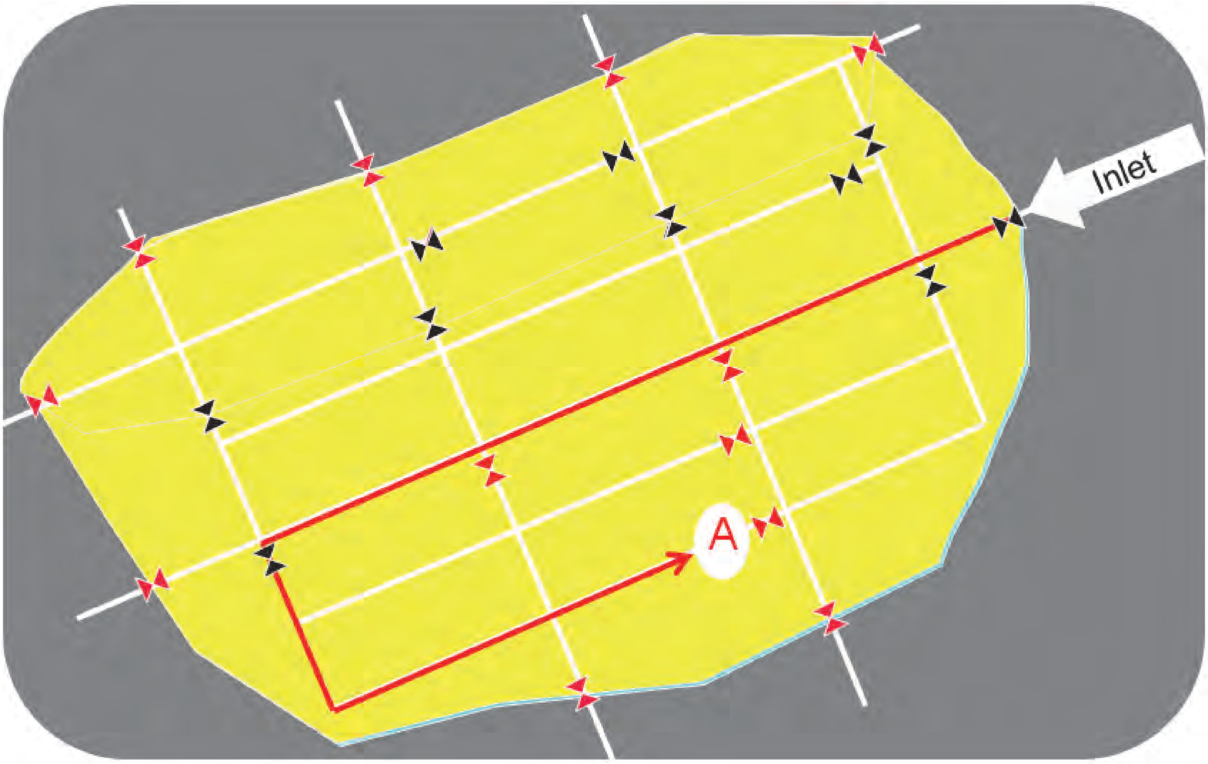


Figure 179: Flow path to Point A after leak repair

Another potentially more serious problem involves the unauthorised opening of boundary valves between adjacent pressure zones. **Figure 181** shows the original pressure profile for the two adjacent zones which are on a steep incline. A PRV has been installed halfway down the hill to prevent the pressure in the lower zone from increasing above 60m and the two zones are operating properly as long as the boundary valves remain closed. As soon as one or other of the boundary valves is opened, the lower zone is breached and immediately receives the full system pressure which raises the pressure at the lowest point from 60m to 120m as shown in **Figure 181**. Such a pressure increase will increase leakage rates in the lower zone significantly and result in a higher incidence of new burst pipes.

There are a number of ways of addressing the potential problems caused by unauthorised opening of boundary valves. The most drastic is to cut and cap the cross boundary connections but most water suppliers do not favour this option as it hampers the possibility of using the cross boundary connection to supply the zone in case of an emergency. Another option is to close the valve and fill the box with sand and place a thin layer of cement over the sand. If anyone opens the valve, they will have to break the screed and anyone checking the valve will see that it has been tampered with. Another approach as shown in **Figure 182** is to have the pipes cut and fire hydrants placed at both sides of the zone. If the zones must be connected in the case of an emergency, they can be joined by using some temporary connection as shown in the figure. It is not an ideal solution but is functional.

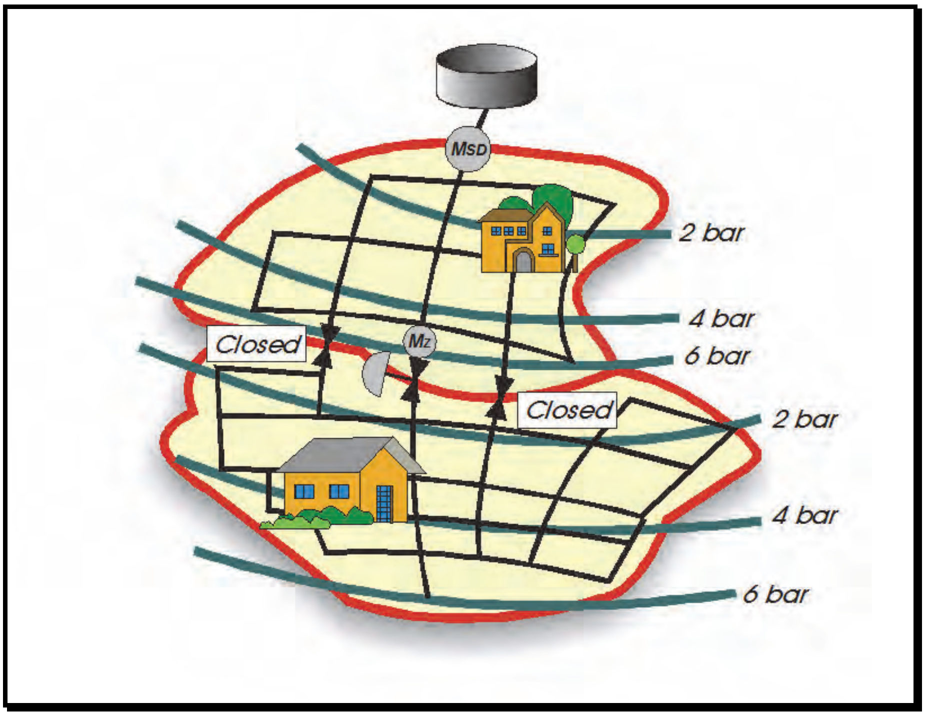


Figure 180: Pressure profile after re-establishment of zones

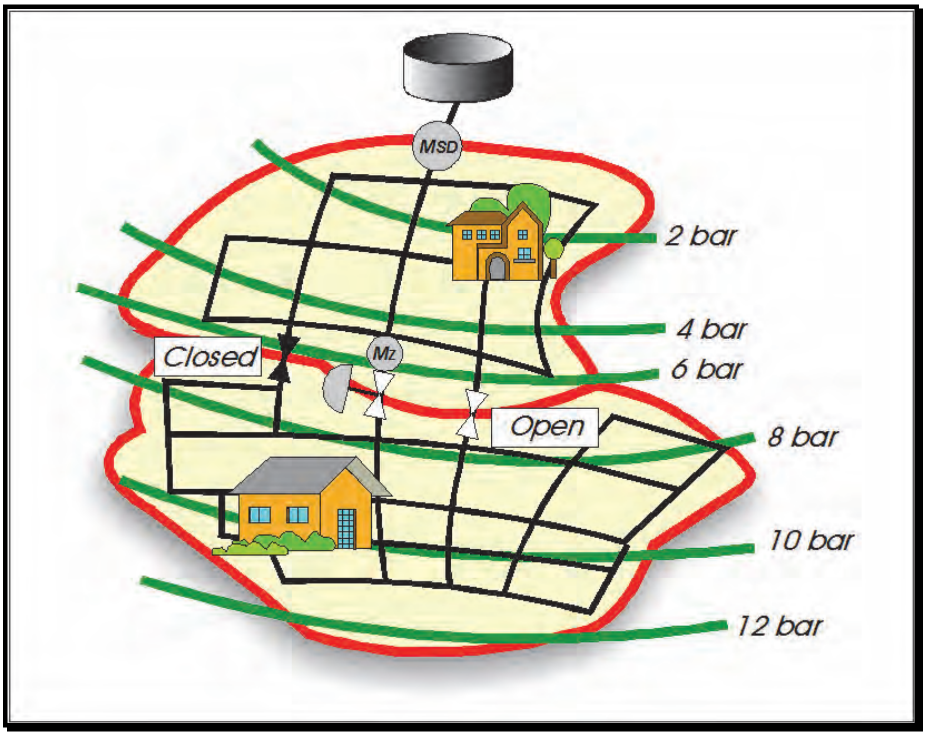


Figure 181: Opening boundary valve between two pressure zones

Figure 182: Approach used to identify cross boundary connections

17.2 Checking zone discreteness

As highlighted in the examples above, sectorising is an extremely important issue to all water suppliers and checking that the zones are discrete is part of the operation and maintenance of the zones. Such checking can be undertaken through regular filed inspections where someone visits each valve in the system and ensures that it is open if it is a normal internal network valve and closed if it is an important boundary valve. An alternative approach is to install pressure loggers at specific points in the system which can monitor the system pressures and send alarms should the pressure move outside of the specified range.

A pressure drop test can be undertaken in which the supply to the zone is shut off and the pressure is monitored at the critical point in the zone to ensure that it drops to zero. A typical example of this is shown in **Figure 1823** which shows a successful pressure drop test.

Figure 184 and **Figure 185** show the results from logging at two points which are in different pressure zones. As can be seen, the pressures tend to follow each other closely suggesting that the zones are not discrete. **Figure 186** shows an example where the same test has been undertaken, however, on this occasion the zone pressures do not match and the logging results suggest that the two zones are not connected to each other and are therefore discrete.

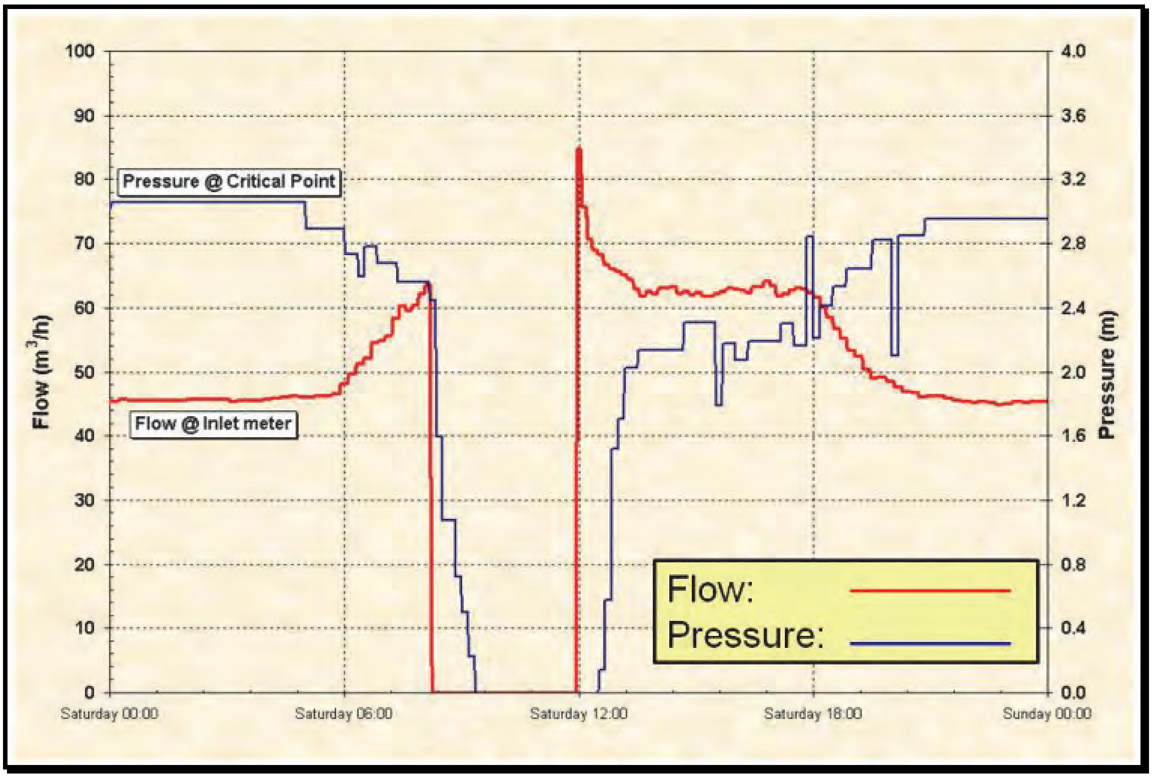


Figure 183: Results of successful pressure drop test

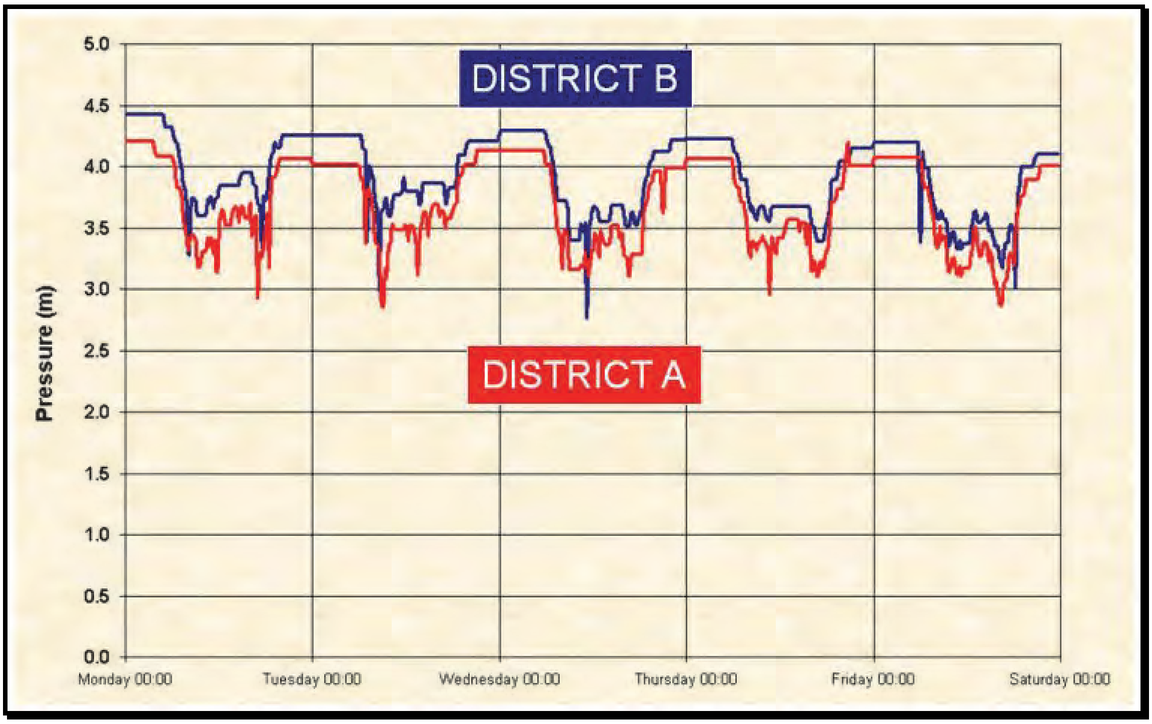


Figure 184: Example where both zones are connected

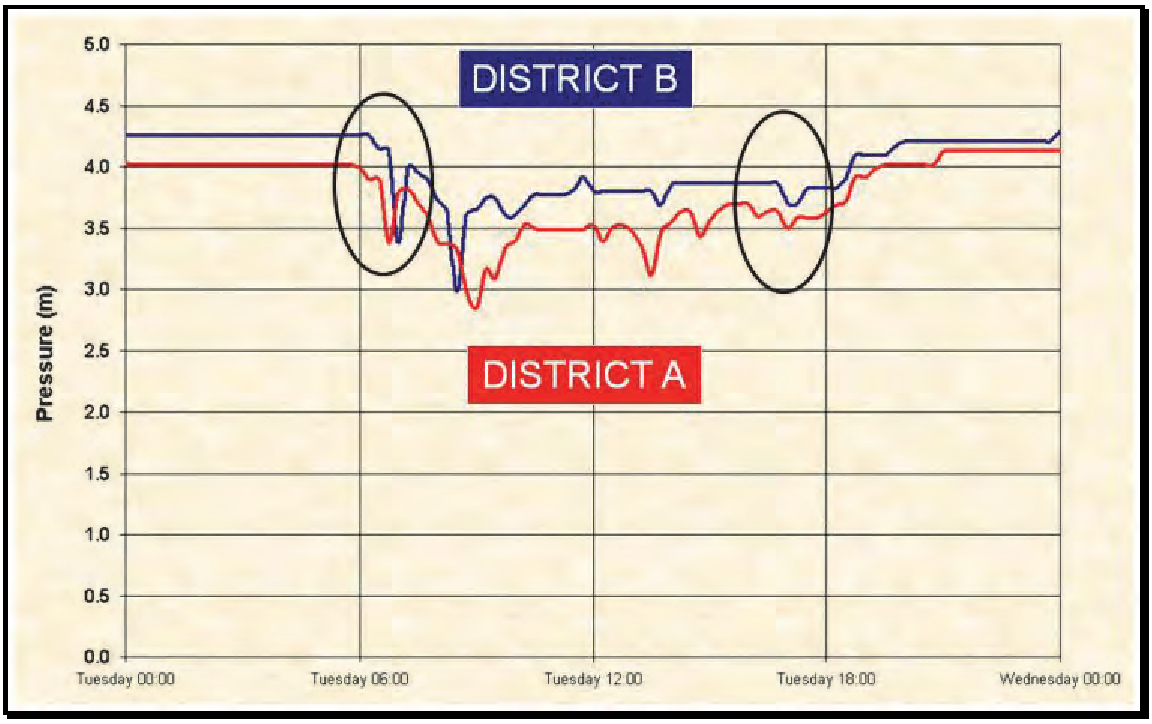


Figure 185: Example where both zones are connected

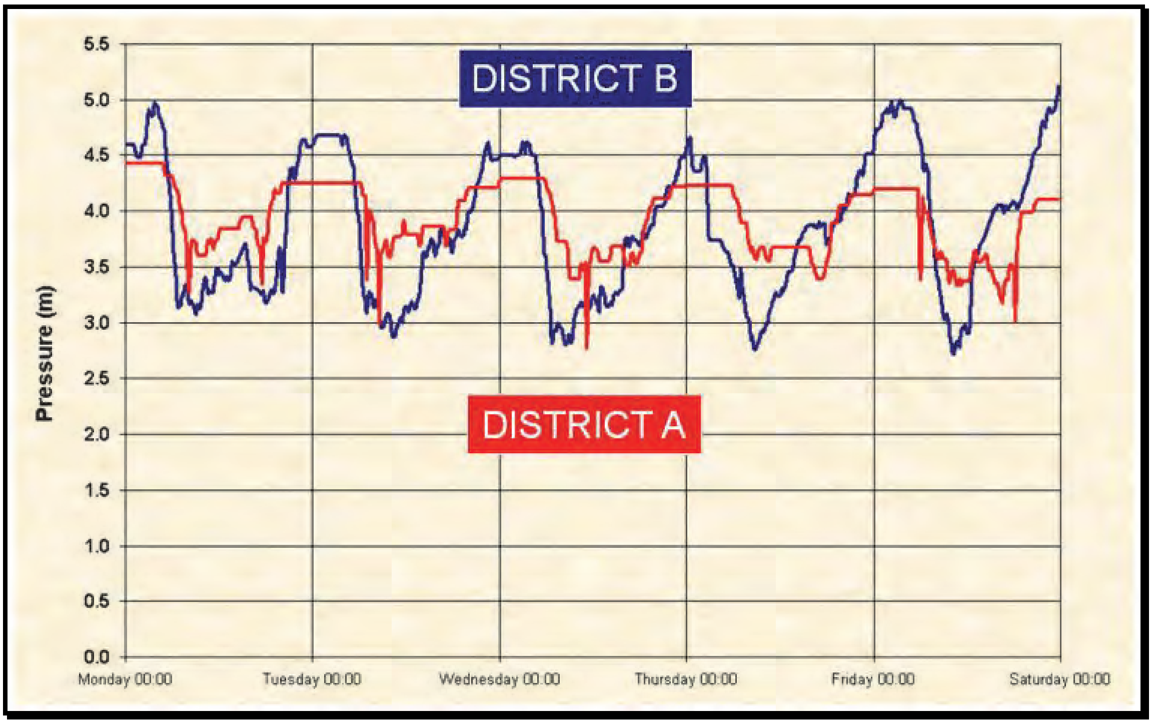


Figure 186: Example where the zones are discrete

17.3 Tips and traps on sectorising

This section provides some simple tips and traps for sectorising based on the combined experience of many WDM specialists including 3 of the former chairmen from the IWA Water Losses Specialist Group. Based on their combined knowledge the following tips are recommended:

- Although the British water industry and more recently the International Water Association have recommended that water distribution systems should be split into sectors of around 2 000 connections, this should not be considered as a hard and fast rule. In many cases, it is often better to initially establish a fewer number of large zones rather than a large number of small zones due to the establishment costs of setting up each zone as well as the ongoing maintenance costs.
- The introduction of large diameter magnetic flow meters with high levels of accuracy allows larger zones to be used which are still capable of picking up medium sized leaks. With such metering, it is often possible to adopt larger zones than those previously recommended.
- Always provide budget for ongoing maintenance of zones as they must continually be monitored and checked for discreteness at regular intervals.
- When sectorising an area, start at the outside and pick off the obvious zones first and gradually work towards the middle which is often the central business district.
- Connections between adjacent zones should be clearly marked to ensure that the cross-boundary connections are closed. If possible, such connections should be cut and capped to reduce the possibility of accidental (often deliberate) opening which compromises both zones.
- Zones should preferably not extend across obvious boundaries such as major roads, railways, rivers and certain geological features such as deep valleys and steep hills.
- The key purpose of sectorising is to help manage leakage and smaller zones will help to identify areas of high leakage. If budget is a problem, the leakage can be identified through the normal process of step-testing in which temporary zones are established through the closure of boundary valves which under normal operating conditions will remain open. Sectorising is therefore not the only method that can be used to identify areas of high leakage.