MANAGEMENT OF NON-REVENUE WATER:

A CASE STUDY OF THE WATER SUPPLY IN ACCRA, GHANA

by

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Dedication:

This MSc Research Project is specially dedicated to

GOD ALMIGHTY for His Mercies Love and Protection

and

my wife (Mrs.Agnes Adu Yeboah) and My Children

(Miriam Frema Yeboah and Peterkin Adu Yeboah)

Certificate of Authorship

I certify that:

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Chapter One

1.0 Introduction

Water constitutes about two-thirds of the whole earth surface yet it is woefully limited in its availability as a freshwater to man. The emphasis is on freshwater resources since it is freshwater resources that are used for consumption, agricultural and industrial purposes. According to Hu (2006:12), freshwater constitutes only about 2.76 percent of the total water available on earth. And even with this, it is only less than one per cent which is readily available to be accessed and used by man. The table 1.1 below shows water in its various forms, their percentage of the total and their rates of renewal.

Table 1.1 various forms of water and their recharge/renewable times.
Source: Shaw (1994: 3)

	Volume(10^6 km^3)	%	Rate of recharge/Renewal(years)
Oceans	13730	94.2	3000
Groundwater	60	4.13	5000
Ice sheets/Glaciers	24	1.65	8000
Surface water on land	0.28	0.019	7
Soil Mixture	0.08	0.0055	1
Rivers	0.0012	0.00008	0.013(11 days)
Atmospheric vapour	0.014	0.00096	0.027(10 days)

There is already startling reports of the situation of the world's freshwater resource availability and its accessibility to man. It was expected that the total water use in the

world would rise to 5000 km^3 per year in 2000. This is against the previous figure of 4130km^3 per year in 1990 (Aswathanarayana 2001:47). It is already known that about one-fifth of the world's population lack access to potable drinking water and that about eighty countries, which constitute about forty per cent of the world's population are already in serious water crisis situation (Aswathanarayana 2001:47).

The importance of freshwater resource to man's survival on earth can not be over emphasised. It permeates through all aspects of man's life on earth. From its use as drinking water, for food production, for washing (as means of maintaining healthy life and dignity), for the generation of energy, as means of transport, for the production of industrial products to the maintenance of the integrity and sustainability of the earth's ecological systems, are all factors that can not be denied of the fact that water indeed is life. (World Water Assessment Programme of UN, 2003:5). The human body constitutes about fifty to sixty-five per cent of water and water is the most important need of the human body only next to air (Thornton 2002:2).

In spite of the importance of the freshwater resource to man's survival on earth, the resource throughout the world is fast depleting. Various factors account for the fast depletion of the freshwater resource. These factors include; population growth, increase agricultural irrigation, pollution, overexploitation, denuding of water catchments areas, urbanisation, and industrialisation (Butler and Memon 2006:180, Aswathanarayana 2001; 48,). As the population increases, the demand for water in all aspects of life also increases. It is estimated that water use has been increasing twice as fast as population growth in the 21st century and that the global water use rose from 1000 km^3 per year in 1940 to 4130 km^3 per year in 1990 (Aswathanarayana 2001:47), and as stated earlier, it was further expected that this would rise to 5000 km^3 per year in 2000 (Aswathanarayana 2001:47).

In the past man's attitude towards water as a free natural resource and subsequently the way and manner water resources were managed did not make things better but rather contributed to the limitation of freshwater resource available to man. According to Thornton (2002:27), water is often undervalued in most parts of the world (literally and emotionally). Not only was water considered as a free natural gift, but also it was seen as 'endless' resource that is always available (World Water Assessment Programme of UN 2003:5).According to Thornton (2002:2), water was seen in the past as an infinite

commodity and this led to the ignorance of issues like ***water loss*** in the management of water utilities in most countries. Whilst water, and for that matter freshwater resource is free natural resource to man, its availability to man at any particular point in time, place and space is limited hence, the necessity for what is called water management (Baumann et. al. 1997:2).Table 1.1 above shows that, for example when groundwater resource is polluted in any given place, it will take at least 5000 years for it to be renewed at that place.

As stated in the Dublin principle number one, (UN. 1992), “freshwater is finite and vulnerable resource….” Whilst the World’s population keep increasing, freshwater resource remains finite. Again, Dublin principle number four (UN. 1992), declares freshwater resource as having economic value and therefore have to be seen as economic good. But as stated earlier, freshwater resource was seen in the past as an endless free natural resource. This led to wastage, over consumption and mismanagement of this important natural resource. As an economic good, freshwater resource can not be wasted since some how its use must be paid for in one way or the other. Moreover as a finite and vulnerable resource, freshwater can not always be available in the quality and quantity as expected if measures are not taken to ensure its protection.

Apart from man’s activities and attitude towards freshwater resource, which as said earlier, tend to impact negatively on the resource and thereby limit its availability to man, there is also the issue of natural disasters as flooding, droughts and climate change which again may have serious negative consequences on freshwater resources. These natural occurrences further reduce the availability of freshwater resource to man. Man may have little or no control over these natural occurrences that affect freshwater resources, especially climatic changes.

Perhaps the most important aspect of the whole issue is not about the quantity of freshwater resource available on earth, but rather the management and the protection of the resource is the crucial issue that need to be considered seriously.
Sometimes, the issue is not about non availability of freshwater resources but it is about the management of the available water resources in a particular place.

Even though freshwater resource accounts for only 2.5% of the whole water resource on earth, this amount is quite huge enough to cater for the needs of the current population as well as future ones. As stated earlier, it is the ability to manage and protect the resource that is what is needed. It is utmost important that prudent and efficient measures are taken to ensure effective and efficient use of the available freshwater resources. It should be noted that water can not be created or manufactured and therefore the option left to man is the efficient management of the available freshwater resources.

There is also the issue of ***COST.*** There is a huge cost in the management and service delivery of fresh water to satisfy the various uses of freshwater. This cost comprises human resource, capital investment and infrastructural development, including water resource development. The main reason for the huge cost involved in the management and water service delivery is as noted earlier, water (freshwater) is not always available in the quantity and the quality needed. Then again is the issue of timing. Water is not always available at the time it matters most at any particular place. For, example, water would not normally be at the household level at the time it is needed. It is even possible that water would not readily be available to whole city at all times all year round. This means that measures must be put in place to ensure that freshwater availability is assured as much as feasible to users even if not at the needed quantity and quality at all times. This process of ensuring the availability of freshwater to users at the time, place, quantity and quality needed is what is termed as water management (Baumann et. al., 1997:2). Governments and organisations all over the World are committing huge amount of resources into water management.

The implication of all these factors is the need for prudent and efficient measures to be taken in the use and management of freshwater resources. This would not only ensure the continual availability of the resource but also ensure the efficient use of resources in water management and thereby reduce the cost involved in the management of water service delivery. In line with these objectives, during the last few decades, experts in the sector have propounded various management strategies that would ensure both the **efficient** use and **sustainability** of the resource. Some of these strategies are; Integrated Water Resource Management, Water Demand Management, Cost Recovery, Demand Driven Approach in the provision of water and sanitation services, Public Private Participation (PPP), and

Community Involvement. The current research is on Non-Revenue Water (NRW) management, which is a component of the broader topic of Water Demand Management.

Water loss which is a major component of non-revenue water has been one of the major challenges in water utility management all over the world and it is even more challenging and serious in developing countries. In most developing countries, first the needed resource for the development of infrastructure for the provision of adequate good quality water for continues supply to consumers are lacking. This is aggravated by the fact that there is lack of technological expertise and equipment to adequately deal with water loss in most water utilities which further reduces the availability of adequate good quality water to consumers (Thornton 2002:2). According to Arlosoroff, (1999), as cited in Butler and Memon (eds.), (2006:192), and United Nations Environmental Programme's International Environmental Technology Centre (UNEP-IETC 1999:195), water losses in most cities of developing countries are assuming an alarming proportions of about forty per cent to sixty per cent of the total water supply and the city of Accra is no exception. It is therefore hoped that the current research would go a long way of contributing to the search for more efficient, effective and practical way of dealing with the problem.

1.1 Problem statement

The water supply system in Accra and its surrounding areas is beset with a number of problems. According to Sarpong and Mensah (2006:24-25), among these problems are; low coverage, low service level, high non-revenue water, high rate of cut-offs (some areas get supply once or twice a week with still others getting no water for weeks) and intermittent water supply. There are also frequent pipelines bursts (as a result of the pipelines been very old, some laid as far back as1930s) and leakages which also affect the quality of the water supplied. TECHNEAU (2007) describes the cut-offs situation in Accra as lasting for days, weeks and even months depending on where one lives within the metropolis. The non-revenue water is as high as 51% (Aqua Vitens Rand, 2007).
The Minister for Water Resources, acknowledging the water crisis in Accra said "it's about ageing infrastructure, lack of investment and waste" (IRIN, 2008).

Accra, like most commercial cities in West Africa is faced with rapid population growth as a result of rural-urban migration due to economic imbalances between the rural areas and the urban centres. According to the 2000 Ghana population census, as asserted by Sarpong and Mensah (2006:26), Accra metropolis has population growth rate of 4.5 per cent per annum and has a population more than twice the population of the second largest city, Kumasi.

This population growth has its attendant effect of high water demand in Accra. Currently, the water demand in Accra and its environs is estimated at 430,000 m^3 per day, whilst the two water treatment plants serving the area have a total capacity of 350, 000m^3 per day (Sarpong and Mensah, 2006:22).

Perhaps the most important factor one has to appreciate of all these problems is the fact that the economic resources available to the government in terms of finance to adequately provide the needed infrastructure for supply to meet demand is regrettably non-existent. A case study conducted by 'Technology Enabled Universal Access to Safe Water (TECHNEAU) on Accra water sector (27th May – 2nd June, 2007), revealed that, Accra lacks potable water. The study also revealed that the lack of potable water was not necessarily as a result of lack of water resources, but was as a result of the inability of the utility provider to meet the needs of the growing population.

It is therefore the view of this researcher that there is the urgent need to tackle the water situation in Accra for two major reasons:

- For the existing infrastructure to be able to adequately serve the needs of the current population and also to be able to cater for the growing population of the future; and
- To prevent the current situation from escalating into catastrophic levels which will have serious adverse health implications on the inhabitants.

Under the current situation it appears the most feasible option to tackle the water situation in Accra and its environs for both short to medium terms, until such time that resources would be available for more infrastructural development to augment the current level of supply is prudent measures to ensure efficient management of the existing water service infrastructure since it is obvious that new infrastructural development for the expansion of

the current capacity to augment supply to meet demand is not likely to take place in the foreseeable immediate future.

1.2 Aim

The aim of this research work is to investigate the non-revenue water levels in the water service delivery in Accra and to assess the management practices being adopted to manage non-revenue water in Accra and then to come out with some recommendations that would help improve the current strategies.

1.3 Research Objective

The objective of the current research work is to try to come up with some recommendations that would help improve the non-revenue water levels in the water utility in Accra, Ghana, for ultimate improvement in water service delivery in Accra and its environs.

1.4 SCOPE

The scope of this research work focuses on the water service delivery in Accra with particular reference to management strategies adopted for efficient water service delivery in Accra and its environs with emphasis on management of non-revenue water.

Consequently, the research work will try to assess the current levels of non-revenue water, the strategies being adopted by the management of the water utility to deal with non-revenue water and the effectiveness or otherwise of these strategies. In doing so, focus would be directed on assessing the extent to which the management of the water system are managing non-revenue water based on internationally accepted approach.

Even though there are numerous problems facing the water delivery system in Accra, the current research would be limited to the area of non revenue water and the strategies that are being adopted to improve the situation. This is partly due to the limited time and resources available for the current research work. And again, the researcher is of the view that the multi-faceted problems of the water supply system in Accra should best be tackled by addressing the issues on specific context without crumbling and bulking the entire situation together. In this way the actual problems would be able to be identified and dealt with more effectively.

Since Accra and Tema metropolis are served by the same water utility, the issues that would be treated in this research work would refer to the two areas. For this reason the phrase “Accra and its environs” would be replaced by “Accra-Tema Metropolitan Area” (ATMA) for the rest of the research work.

1.5 Research Questions

In order to keep focus and direct the research activities of this research work, the following research questions are formulated:

PRIMARY RESAERCH QUESTION;

How can the non revenue water levels in Accra and its environs be improved with the aim of ensuring efficiency and improved water services delivery?

II. SECONDARY RESEARCH QUESTIONS;

1. What is the existing situation and the management strategies to deal with non-revenue water in Accra?
2. To what extent has non revenue water affected the overall performance of the water utility in Accra?
3. How can the current strategies be improved?

Chapter Two: Literature Review

2.0 Introduction

To start with, it became necessary to review the existing literature to get a better view of the main issues involving non revenue water. It was obvious from the on set that there was no official documentation on non revenue water for the water utility of Accra and its environs. It was therefore necessary to gather general views on the issue in order to be able to access the situation in Accra more scientifically in line with agreed international principles.

2.1 Components and Definitions of Non-Revenue Water (NRW)

In order to come to better understanding and set the framework for in-depth research into the current topic, it was necessary to find out the various components and their definitions as they relate to the topic. Various literatures were identified. But the one which seemed to have dealt with the issue of non revenue water to a greater extent in recent times and to which most writers and researchers kept referring to was the document which has been developed by the International Water Association (IWA) Water Loss Task Forces for concepts and methodologies for quantifying and definitions of the components of non revenue water. Most of the following definitions are therefore quoted from this document.

According to the International Water Association (IWA) Task Force on Water Loss, (IWA, 2003), Non Revenue Water (NRW), is “the difference between System Input Volume and Billed Authorised Consumption”. According to the task force, system input is “the annual input to a defined part of the water supply system” and billed authorised consumption, according to the task force is “billed metered consumption including water exported and

billed unmetered consumption”. These definitions and others are shown in figure 2.1 below.

<table>
<tr><td rowspan="9">System Input Volume</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Metered Consumption (including water exported)</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Non-metered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-Revenue Water</td></tr>
<tr><td>Unbilled Non-metered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Metering Inaccuracies</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and/or Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Utility’s Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to Customers’ Meters</td></tr>
</table>

Figure 2.1: The IWA best practice standard water balance.

Source: McIntosh (2003).

The World Bank Group (December, 2006) and its affiliate partners (Water and Sanitation Sector Board and Public Private Infrastructure Advisory Facility -PPIAF) discussing the issue of non revenue water in Developing countries, defined NRW and its components as follows:” non revenue water is the difference between the volume of water put into a water distribution system and the volume that is billed to customers”. NRW has three components:

- **Physical (or real) losses**; this comprise leakage from all parts of the system and overflows at the utility’s storage tanks. These occur as a result of poor operations maintenance, the lack of active leakage control, and poor quality of underground assets. It is “any leakage downstream of a production source and upstream of the consumer revenue meter” (UNEP/IETC 1999:221).
- **Commercial/Apparent Losses**; these are caused by customer meter under registration, data-handling errors, and theft of water in various forms;
- **Unbilled authorised consumption**; these include water used by the utility for operational purposes, water used fire fighting, and water provided for free to certain consumer groups.

The first two of these components constitute **Water Loss** (IWA 2003). Normally it is the water loss indicators that reflect the level of efficiency of management of the water supply system (Butler and Mamon (eds.), 2006:192). To be able to effect effective reduction in water loss, issues of technical, operational, institutional, planning, financial and administrative need to be coherently addressed (WHO, 2000 as cited in Butler and Mamon (eds.), 2006:192).

2.2 Strategy for Dealing with Water Losses

Perhaps the two most important components of NRW are the **real losses** and the **apparent losses**. In the view of this author these components are the ones which need much resource in terms of logistics, staffing and finance in order to control water losses. The third component, **unbilled authorised consumption** can be controlled fairly well without much resource. It is therefore important to develop the appropriate strategies for controlling water losses especially through real and apparent losses if meaningful achievements are to be made and the outcome would justify the efforts put in. The starting point to deal with water losses in any water utility, according Butler and Mamon (2006:143), is to understand the network system of the utility.

Butler and Mamon (2006:143), suggest that certain questions should be posed about the water utility with regard to the characteristics, the production process, and the operating practices, and using the available tools and mechanisms within the water utility to answer these questions form the first step in the right direction to deal with the prevailing situation. In the process of trying to answer these questions, better understanding of the network system of the water utility would now be obtained, which would then form the basis for the formulation of strategies for dealing with water losses.
Butler and Mamon (2003:143) suggest the following questions:

- How much water is being lost?
- Where is it being lost from?
- Why is it being lost?

The table 2.1 below is a summary of the tasks required to address the above questions.

Table 2.1: Tasks and tools for developing strategies for the management of NRW Source: Butler and Mamon (2003)

QUESTION/SOLUTION	TASK
How much water is being lost? - Measure components	**WATER BALANCE** - Improve estimation/measurement techniques - Meter calibration policy - Meter checks - Identify improvements to recording procedures.
Where is it being lost from? - Quantify leakage - Quantify apparent losses	**NETWORK AUDIT** - Leakage studies (reservoirs, transmission mains, distribution network) - Operational/customer investigations
Why is it being lost? - conduct network and operational audit	**REVIEW NETWORK PRACTICES** - Investigate: - historical reasons - poor practice - quality measurement - procedure - poor materials/infrastructure - local/political influences - cultural/social/financial
How to improve performance? - Upgrade the network - Design a strategy and action plans	**STRATEGY DEVELOPMENT** - Update record systems - Introduce zoning - Introduce leakage monitoring - Address causes of apparent losses - Initiate leak detection/repair policy - Design short/medium/long term action plans
How to sustain performance? - Ensure sustainability with appropriate staffing and operational structures.	**TRAINING AND O&M** - improve awareness - increase motivation - transfer skills - introduce best practice/technology - community involvement - water conservation/demand management programmes - monitor action plan recommendations - introduce O&M procedures

The first two questions, “how much” and “where from”, according Butler and Mamon (2006:145) can be answered by conducting water balance. Referring to figure 2.1, which shows the components of water losses from a network, “which is the difference between system input volume and authorised consumption” (Butler and Mamon, 2006:145), water balance can be conducted.

The third question “why is it being lost” can be answered according to Butler and Mamon (2006:146), by reviewing the management practices of the water system. The reviewing processes should identify the policies and procedures that need reviewing and those which are being done well. Having addressed the first three questions, the “how? where? and why?” of the losses in the system, it then becomes possible to address the last two questions which have to do with issues of strategies, policies and methodologies that need to be formulated and adopted to address the system’s losses and improve performance and how these strategies be maintained or sustained? According to Butler and Mamon (2006:146), the strategies, methodologies and policies referred to above do not only entail “introducing equipment for measurement and monitoring flows, leakage control equipment and leak repair policies, but also education and awareness programmes and a fully operational O&M policy”.

The two tools; water balance and network review, would enable priority areas to identified and tackled. According to Thornton (2002:172), the above tools would enable the utility to identify the priority areas and this would mean tackling apparent losses first or vice versa depending upon the outcome of the processes so far described.

2.3 Physical (real) Losses

Physical losses according to IWA (April 2004), is “the annual volumes lost from transmission and distribution systems through all types of leaks, bursts and overflows on mains, service reservoirs and service connections, up to the point of customer metering”.
The major part of real losses, according to Butler and Mamon (eds.), (2006: 193), is due to system leakages which also stems from lack of maintenance or “failure to renew and replace ageing systems” (Assets Management). It is of importance to note that the way and

manner leakages in water utility are managed has great influence on the success or otherwise on any utility systems. Successful management of leakages has both financial and social benefits to the water utility. Butler and Mamon (eds.), (2006:193), assert that the successful management of system leakages leads to systems' sustainability as well as "foster public support by providing affordable water to consumers.

Assessing physical (real) loss can be carried out by any of the following three methods; 'top-down' annual water balance; 'bottom-up' analysis of night flows; and 'component analysis' (IWA 2004). A combination of two or all three can be used at a time. Real losses can be calculated using the above methods as follows (IWA 2004):

- **Top- down annual water balance**: using the IWA "best practice" standard water balance, real loss is the difference of volume when the volumes of authorised consumption and apparent losses are taken from the system input volume. To cater for errors and uncertainties in the calculated values, 95% confidence limits are usually used in the calculations. This method has the limitation of not providing the components of the real losses, e.g. "detectable bursts (can be potentially be managed through speed and quality of repairs, and active leakage control), or real losses due to background losses (that can only be reduced by pressure management or infrastructure management strategies" (IWA 2004). It is therefore best to conduct this method with the other two methods;
- **Bottom-up real losses assessment:** in this method the real loss volume obtained from the top-down water balance is checked by bottom-up calculations of independently individual small sectors or zones of the distribution network through analysis of night flows into these zones. This approach rely on what is known as the minimum night flow (MNF) which according to IWA (2004), is usually in the early mornings between around 2.00am and 4.00am in the urban set up but would vary from zone to zone. During these periods, real losses are at their maximum percentages of the total flow. The real loss value is obtained by the difference between the legitimate night consumption by customers of the zones under consideration and the minimum night flow to these areas. There is some degree of uncertainty in these estimations since the legitimate night consumptions vary from night to night. The Bottom-up real loss, according to IWA (2004), has the benefits that, "it provides independent determination of the volume of real losses," which if

carried out across the whole distribution net work, enables areas of high real losses to be identified and mapped for active leakage control work, and as said earlier, provides a cross check on the water balance calculation. According to IWA (2004), these two values should balance but are often not “because of the cumulative errors in each method’s calculation”. The bottom-up method, through the field work “also facilitates collecting of data required for determining the pressure/leakage relationship (NI) and the infrastructure condition factor (ICF).

- **Components analysis of real loss:** annual real losses are assessed using components analysis (IWA 2004). It “uses numbers, average flow rates and average run- times of different types of leaks and bursts (background, reported and unreported) on different parts of the distribution infrastructure (mains, service reservoirs, and different sections of the service connections)”.Other data such as “basic infrastructure data (mains length, number of service connections, length of the privately owned service line from property boundary to the meter); infrastructure condition factor (ICF) for background leakage; numbers of reported and unreported bursts, and their average run-times based on utility policies; average system pressure and pressure/leakage relationships (using appropriate NI values)”. This model allows the overall volume of real losses to be broken down into its constituent components for each aspect of the system’s infrastructure and this in turn allows evaluative alternative options for the management of real losses.

According to Butler and Mamon (eds., 2006:147), real losses can be severe, it can go on for a long time (months and even years) without been detected. The severity and the volume lost would largely depend on the following characteristics of the pipe network and the leak detection and repair policy of the water utility (Butler and Mamon, Eds. 2006:47):

- The pressure in the network;
- The frequency and typical flow rates of new leaks and bursts;
- The proportions of new leaks which are ‘reported’;
- The ‘awareness’ time (how quickly the loss is noticed;
- The location time (how quickly each leak is located);
- The repair time (how quickly it is repaired or shut down);
- The level of “background leakage” (undetectable small leaks).

2.3.1 Unavoidable Annual Real Losses

According to IWA (2003), real losses can not be eliminated completely. And that the lowest technically and practically achievable annual real losses value is known as Unavoidable Annual Real Losses (UARL). This is demonstrated by the figure 2.2 below.

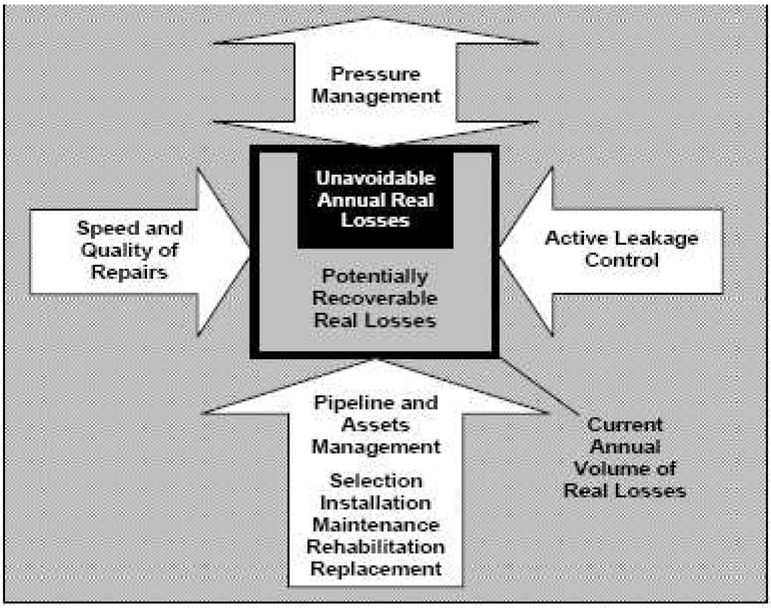


Figure 2.2: The four basic methods of managing water loss.
Source: Adopted from Liemberger and Farley (n.d)

The figure 2.2 above shows the relationship between Current Annual Real Losses (CARL), which is represented by the larger rectangle and UARL, represented by the smaller rectangle. Each of the four component methods of controlling real losses, according to Farley and Trow (2003:42), influences leakage in a specific way or manner. Long-term pipeline management influences the numbers of new leaks that develop each year while pressure management influences the frequency of new leaks and the flow rates of bursts and leaks. In the same way, the average duration of leaks is influenced by the speed and quality of repairs and active leakage control determines how long unreported leaks can run before being detected (Farley and Trow 2003:42).

2.3.2 Economics of Water Loss Management.

2.3.3 The Principles of Law of Diminishing Return

In as much as every water supply system wants to eliminates leakage and for that matter all forms of water losses, there is a limit to which this can be carried up to, after which it would no more be economical to apply resources to reduce leakage. According to Farley and Trow (2003:50), for majorities of water utilities, leakage can not be completely eliminated and that "there will always be a level of leakage which has to be tolerated and which has to be managed". The reason for this is the law of diminishing returns, where returns on investment begin to diminish in relation to the cost of production or investment.

Two major options in bridging the gap between future demand for water and the current level of supply, Farley and Trow, (2003:50) are;

- Supply augmentation- addition of reservoir, increase in pumping capacity, treatment plant expansion, and exportation of water from other area; and
- Reducing the future need for water by leakage reduction and demand management.

The economic implications of the two methods are different and should be appreciated. Whereas system augmentation has the advantages of economies of scale, leakage reduction has the disadvantages of the law of diminishing returns (Farley and Trow, 2003:50). "The more effort that is put in leakage reduction programme, the less would be the returns in terms of water saved". Each of the four "pillars" of leakage management follows the law of diminishing returns (Pearson and Trow 2005).

Referring to figure 2.2 on page 16, these pillars are:

- **Active leakage control**; the effort of starting active leakage control programme would be relatively lower. It would take less effort and probably logistics to locate and repair leaks on the mains and the distribution networks. But after the more obvious leaks and bursts have been identified and repaired, it would then take more effort to locate and repair any leaks and bursts of the same volume.
- **Pressure management**; schemes such as installation of pressure reducing valves (PRV), are more cost effective in that an action covers a large area and make 'a significant impact on average pressure'. However, if more PRVs are installed in a

particular district area, the benefits derived would be less than the cost incurred (Farley and Trow 2003:50). Again in a district meter areas (DMAs), a point would reach where the addition of further properties to the district meter area would incur more cost. This according to Farley and Trow (2003:52) may due to; the need to install additional valves, the need to provide two or more meters in the area, and the need to lay new lengths to link mains.

- **Infrastructural Management**; For instance if mains replacement is being used as a water leakage reduction strategy, then it would be more beneficial to carry out targeting studies to determine which areas of the water system are more prone to frequent bursts and leaks and even which mains within these areas have the highest frequency (number per kilometre per year) and the highest background leakage. If this exercise is carried out effectively, according to Farley and Trow (2003:53), the initial schemes would be more cost effective than the later ones and therefore, mains replacement also follow the law of diminishing returns.
- **Speed of repair**; the volume of leakage would definitely be reduced if the time taken to carry out repair works is reduced. However, after certain threshold of reduction in repair time has been reached, any further reduction in repair time would not be cost effective and the cost of further reducing the repair time beyond this threshold would be higher than the benefit that would be gained in terms of water saved. Beyond this threshold, the cost of repair begin to rise due to "standby, call out and overtime payments to staff, or supplementary payments to contractors to make additional repair teams available" (Farley and Trow 2003:53). The law of diminishing returns is again seen here.

2.3.4 Economic Level of Real Losses (ELL)

Although the use of the four methods of leakage management could control Real Losses at the current operating pressure up the UARL, it is not always economically beneficial to reduce real losses up to this level (IWA, 2004). According to Butler and Mamon (2006: 194), "leakage reduction programmes follow the law of diminishing returns- the more effort to reduce leakage, the less will be the return in terms of water saved". This calls for what is termed the economic level of leakage (ELL), in every distribution system. This is

demonstrated by the improved version of figure 2.2 as shown in figure 2.3 below (IWA, 2004). The intermediate rectangle in the figure 2.3 represents ELL.

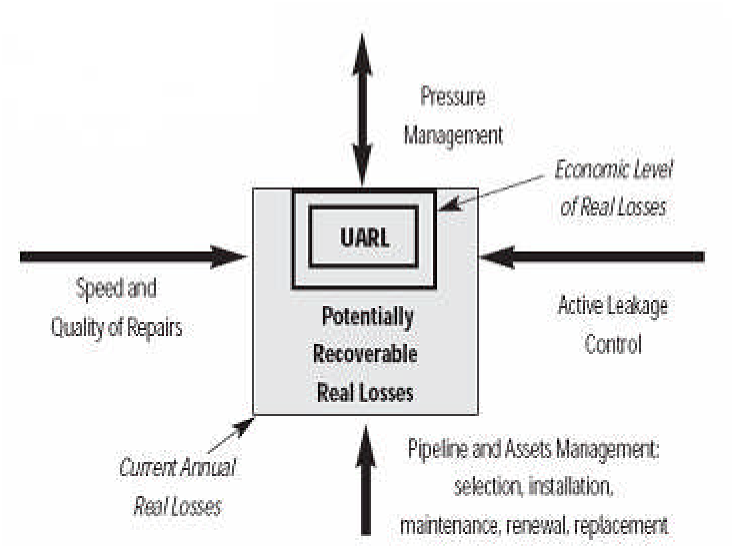


Figure 2.3A: Economic Level of Leakage (Source IWA 2003)

Economic level of real losses (ELL), WHO, (1985), as cited in Butler and Mamon, (2006:195), is "the level of leakage where the marginal cost of active leakage control equals the marginal cost of the leaking water". IWA (2004) also defines ELL as "economic level of real losses occurs when the sum of the value of the water lost through real losses and the cost of activities undertaken to minimise real losses is at the minimum". Again Farley and Trow (2003:54), expressing similar view define economic level of leakage as

the level below which “the value of water saved is less than the cost of making further reduction”. Thornton Julian (2002:158) has similar definition to the above and defines ELL as the point where the total cost, which is the sum of the cost of intervention and the cost of loss, is at a minimum. These definitions clearly explain how leakage reduction management is subject to the law of diminishing returns as has already been pointed out. Figure 2.3B below shows the graphical representation of ELL. The point of intersection of the two lines shows the economic level of intervention. It will not be financially prudent to reduce leakage beyond this level.

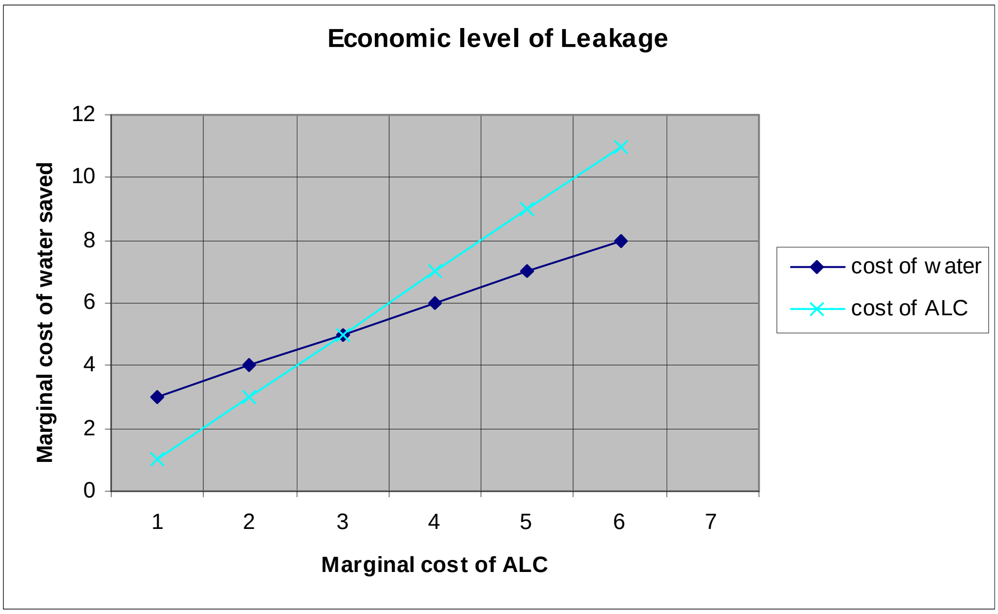


Figure2.3B: Graphical Representation of Economic Level of Leakage.
Source: Elaborated by the author.

2.3.5 Some Useful Points About ELL.

There are certain useful points about ELL which invariably influence the methods of assessing the value of ELL. Some of these points are discussed below and the bullets points below are taken directly from Farley and Trow (2003:54-55):

- There is no single ELL. The ELL will vary over time depending on factors such as seasonal changes to burst frequency, often resulting from weather conditions, mains condition improvements;
- Investments in pressure control, district metering and telemetry to reduce leakage will also change the ELL Based on the degree of active leakage control (ACL) effort;
- The value of water will change over time. It will have higher value in times of shortage, for example in drought, and a lower value in times of plenty. The value will increase as the headroom is reduced, and it will fall when new sources and treatment works come on line. The operating costs may change in future due to different water quality standards, or changes in regulations making current practices obsolete;
- New leak detection techniques will change the efficiency of detection operations resulting in a change to the ELL. The ELL will be different depending on the method used for leak detection. For example a policy of regular inspection or one based on continual night flow monitoring in district meter areas; and
- The estimation of ELL must use data, information and policy rules specific to that area and that water supply organisation. However, until significant work has been conducted to reduce leakage and so collect the necessary data on costs and effects, it is not possible to make an accurate assessment of ELL. Therefore, the calculation of ELL will follow a staged approach and could take several years to determine accurately.

In view of the above key points about ELL, according to Farley and Trow (2003:54), “leakage targets based on ELL must therefore be specific and dynamic”.

2.3.6 Infrastructure Leakage Index (ILI)

The difference between UARL (the smaller rectangle of figure two above) and the current annual real losses (CARL, represented by the larger rectangle), is the potentially recoverable real losses (Farley and Trow, 2003:43). The ratio of CARL to UARL is the infrastructure index (ILI). ILI, measures how effectively the infrastructural activities of the four component methods of leakage control (Figure 2 above), are being managed at the current pressure (Farley and Trow, 2003:43). Explaining the importance of ILI as the new performance indicator for real losses, Liemberger and Farley (undated), also define ILI as, "a measure of how well a distribution network is managed for the control of real losses, at the current operating pressure". According to Liemberger and Farley (undated), in a well manage system an ILI of 1.0 can be achieved (CARL = UARL), but this is not necessarily important "as the ILI is a purely technical performance indicator and does not take economic consideration into account" That is one can achieve ILI of 1.0 but the economic implication on the other hand would not justify such an effort.

Experts are now more interested in measuring performance using the ILI as an indicator rather than percentages of system output to input. This is because it has been realised that percentage alone does not give the true picture of the situation. According to Lambert O.A (2008, personal interview), ILI, is preferred as a performance indicator to percentages for the following reasons;

- It takes into account all the four components of water loss management- pressure, speed and quality of repairs, infrastructure management and active leakage control. This enables systems to be compared fairly since though these factors can be different from system to system but if the comparing systems are operating at the same efficiency, the ILI value of the systems would be same as ILI is a ratio of a system's CARL to its UARL at its current operating pressure; and
- Percentages of losses are influenced by the following factors; consumption rate, whether the system is operating under continues supply or under intermittent supply, and water storage systems used by the consumers. These factors according Lambert (2008) are situation specific which can not be compared and therefore comparing systems by percentages do not give the real picture. According to him,

a system's performance can not be assessed by the percentage loss without taking the above factors into consideration.

Expressing similar idea on the use of percentage of system's input volume as performance indicator for water loss management and why this does not give fair analysis of different water systems, Thornton (2002:44), indicates that this gives a misleading indicator because" water utilities are of different sizes, with different characteristics". According to her, ten percent of water losses in North America (a region with one of the highest water consumption in the World), could mean about twenty five percent water losses in any typical lower per capita consumption country.

It has also been realised that performances of different systems which use different units of measurements can not be fairly compared using the percentage of NRW. But ILI, being a ratio, [the ratio of Current Annual volume of Real Losses (CARL) to Unavoidable Annual Real Losses (UARL)it has no units and therefore allows comparisons of performance between countries that have different units of measurement to be made fairly.

ILI = CARL/UARL

2.3.7 Developing Strategy to Dealing with Real Losses

To deal effectively with water loss it is important to understand the characteristics and the significance of each of the components of water loss. Water loss varies from country to country and from place to place even within the same country (Butler and Mamon, 2006:147). The volume of water loss largely depends on the local situation, the technology for dealing with leakage and the management policies in place. It is therefore important to identify the actual causes of the leakages in the local context. It is also important that each of the components of water loss is properly assessed and measured accurately for priorities in dealing with them to be properly set (Butler and Mamon, 2006:147).

2.3.8 Understanding The Starting Position

Perhaps the best approach to start to draw up a strategy to deal with real losses in any water supply system is to understand the source of the leakages in the system. To this, Farley and Trow (2003:68) suggest that strategies that would enable a better estimate of the actual losses to be assessed include:

- Distribution input (DI) verification – reconcile leakage in District Metering areas (DMAs) with losses in the supply zone;
- Per capita consumption (PCC) studies;
- Property counts;
- Non-household water use; and
- Operational use.

Also as mentioned earlier, some of the factors that influence real losses to a lesser or greater extent (Butler and Mamon, 2006:147) are:

- The pressure in the network;
- The frequency and typical flow rates of the new leaks and bursts;
- The proportions of new leaks which are reported;
- The awareness time (how quickly the loss is noticed);
- The location time (how quickly each leak is located);
- The repair time (how quickly it is repaired or shut off);
- The level of background leakage (undetectable small leaks).

These factors in turn are also influenced by such factors as; long term pipe network management, pressure management, speed and quality of repairs and active leakage control measures in place (Farley and Trow, 2003:42). Therefore the understanding and identification of these factors is one of the major steps towards dealing effectively with real losses (Butler and Mamon, 2006:147). Again, these factors, based on local context (characteristics of pipe network, operation practices and management policies) would determine the methodology to be used to set leakage targets and strategies that would be used in achieving the set targets (Butler and Mamon, 2006:147).

This researcher, had a personal interview with Mr. Lambert O. Allan, the first chairman of the IWA Water Loss Task Force at his residence in North Wales on 26th of April, 2008, and indicated to me that without pressure management nothing else would work so far as

leakage control is concerned. Therefore the recognition and assessment of these factors is crucial in any leakage control strategies.

In the same way the intervening measures would be influenced by the level of contribution by each of the above factors to the total volume of water loss (Thornton 2002:162).Thornton (2002:171), suggest as a first step, those interventions with shortest paybacks should be put in place at the start of the programme. In this way, according to Thornton (2002:171), it is expected that the programme would be self funding after some time of programme implementation in order to sustain it. As mentioned earlier, for effective field work and to track intervention programme, it is of importance that activities are prioritized and methodology list created for the intervening programme (Thornton Julian: 171).

2.3.9 Background activities leading to the effective management of leakage.

It is necessary that certain background practical steps are taken in dealing with real losses and to ensure the sustainability of the set targets. It is of little value if real losses are minimised to the required economic levels only to reverse to the current real losses level after the implementation of the real losses programme. Figure 2.4 below outlines some of the practical steps needed to be taken for effective leakage (real losses) management.

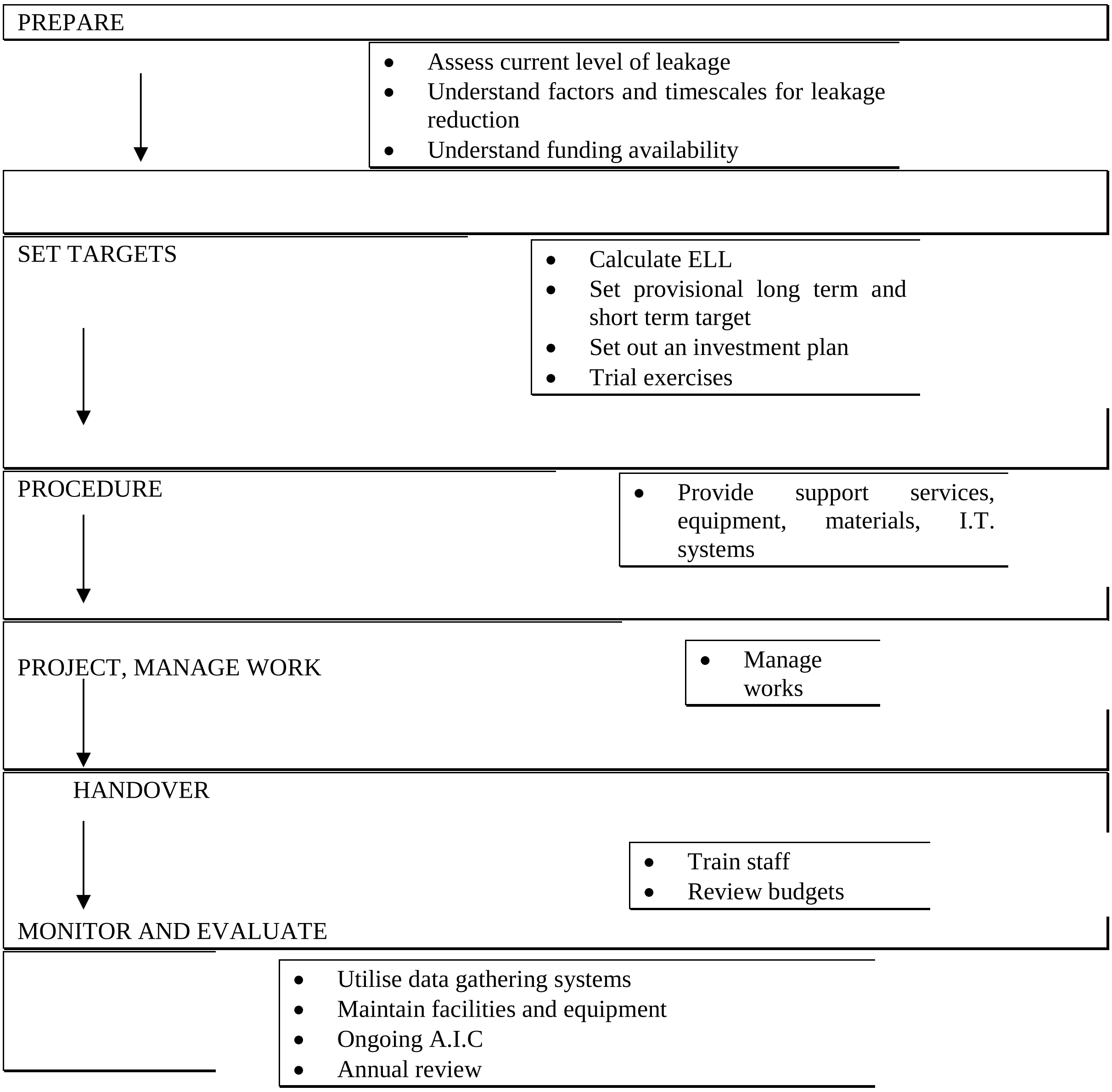


Figure 2.4. Steps in developing a leakage management strategy (Adopted from Butler and Mamon, 2006:148).

Both Butler and Mamon (2006:148) and Thornton (2002:171), agree that for effective management of real losses in the field, certain methodologies should be used in setting leakage targets and for deriving the appropriate strategies for managing leakage on the field. Below are some of the steps to follow:

Funding

For effective and sustained leakage reduction programme, there is the need to establish reduction programme, it would need to be funded up front before any payback is achieved over a long term (Butler and Mamon, 2006:148). Some the funding sources according to Farley and Trow (2003:69) are; raising charges to customers, from government sources, from international grants and loans, or by accepting lower profit during the leakage reduction work.

Funding can also come as a result of the leakage reduction programme. According to Farley and Trow (2003:69), some water suppliers receive income from the municipality for the bulk of water supplied from the treatment works through their mains whilst other get a concession to manage to manage the municipal water system and are paid according the customer demand. This means any water saved can become a source of income to the water utility.

Organisational structure;

For a major leakage reduction programme to be effective, it is necessary that a look has to be taken at the current organisational structure. This is important because, if things are done within the existing organisational structure, it could lead to failure of the programme even if economic level of leakage is attained initially. Butler and Mamon (2006:149), even suggest the appointment of a leakage control manager who would be solely responsible for leakage management whenever the workload would warrant such an appointment. The reviewing or restructuring of an organisation for the purposes of carrying out leakage reduction programme would not only ensure effective programme implementation but would also ensure the sustainability of the targets achieved by the programme.

There should be distinction between two stages of leakage management (Butler and Mamon 2006:149) in any leakage management programme, i.e. leakage reduction towards the set target and maintenance of the achieved target level. Activities involving the two should be clearly recognised. The project team takes over a zone of the water system to carry out the leakage reduction programme and when the set target is achieved, this zone is handed over to the operational staff while a zone is then taken over by the project team.

These two stages, according to Butler and Mamon (2006:149),"may run concurrently in the same organisation".

Targets setting;

This is the most important aspect of the leakage reduction programme (Butler and Mamon, 2006:149). Farley and Trow (2003:59), suggest that targets must be set specifically according to zones of the water supply system after the analysis of the ELL for the various zones. The aggregated targets from the various zones then become the overall target of the water supply system. But it should be noted that the overall target would be influenced by global policies compared to the ELL analysis of the individual zones. Other issue that are likely to influence target setting, according to Farley and Trow (2003:59) are external pressures. These external pressures (Farley and Trow, 2003:59) include:

- Comparisons with similar water suppliers. There is the natural tendency for water suppliers to compare their current leakage levels and calculated ELL to other water systems in the same region or geographical areas.
- International comparisons.
- Political influences. Some companies can come under pressures from customers and or politicians to reduce leakage level because it is perceived to be too high.

The calculated ELL can vary with time due to certain occurrences that have the potential to alter the ELL. Some of these reasons (Farley and Trow, 2003:60) are:

- **Weather**. Weather effects can cause shortages in water supply and this would raise the value of water which in turn would drive down the ELL in a particular year. Again different conditions may result in a spate of pipe bursts and leaks due to ground movement. In this case the seasonal level of leakage may exceed the ELL which will not make it economic to provide additional resources to maintain leakage at the long term ELL value.
- **The economics of demand and supply**. Where there is a shortage of experienced staff for leakage management in a country, the cost of leakage management may

be high initially. But as time goes on and more and more people begin to gain the require skills for leakage management, competition become keen and drives the value of ELL down.

- **Technology**. As new technologies are introduced which make leakage management easier and efficient, they tend to reduce ELL once these technologies are well established in the area.

Data collection

Well established procedures for the collection of all relevant data for leakage management should precede any expenditure that would be made on leakage management (Butler and Mamon, 2006:157). These data should be accurate, well organised and accountable (Thornton 2002:59). Successful leakage management depends on accurate and relevant data. And so data management software and resources for staff for data management is synonymous to successful leakage management. According to Butler and Mamon (2006:158), even though the provision of the relevant data software systems and staff resources for data management could entail initial huge capital outlay, the investment is worth it since there would be returns on that investment. According to Farley and Trow (2003:65), the data collected would fall under; operational, tactical and strategic. This is shown in by table two below.

It is the view of this researcher that well organised and accurate data would not only enable water suppliers to choose the appropriate strategies and methodology for leakage management, but it would also serve as tools for monitoring and evaluation of the leakage reduction management process and activities. In this direction, Thornton (2002:59), suggest that even where there is no previous good, accurate data, the water supply operator has to take a decision to do something by either using questionable data or estimations and to work to improve this data for future use.

Table 2.2: Data collection for Leakage Management (Adopted from Farley and Trow, 2003:66).

OPERATIONAL DATA	• Current leakage levels • Current pressure data • Outlet settings of pressure relief valves (PRVs) • Records of the number and type of leaks found • Records of hours spent on the ALC • Industrial water use
TACTICAL DATA	• Zone boundaries • Types of PRVs • Maintenance Records • PRV performance records • Asset data
STRATEGIC DATA	• Distribution input average • Water balance calculations • Results of studies and pilot exercises • Lessons learnt database • Numbers of ALC staff employed

Normally data is collected at a micro level usually by district metering areas (DMAs). This is aggregated to give the overall company data on losses (Butler and Mamon, 2006:157). But according to Farley and Trow (2003:66), it is important to reconcile data collected on leakage through triangulation. This can be done by using both top-down and bottom-up methods for the calculations of losses for the same area. Farley and Trow (2003:66), state that the aggregation of DMA losses for the estimation of the total company losses can sometimes be misleading for the following reasons:

- Leakage on trunk mains and service reservoirs outside DMAs will have to be estimated and added to the total;
- There may be issues surrounding the timing of the DMA meter readings, and the level of operationalbility (number of DMAs which are working correctly at any particular time, with reliable meter reading).
- Data should be established in a hierarchical manner in order to give the average value for a supply zone through the aggregation of the various DMAs in the zone which will also provide the average value for the company through the aggregation of the supply zone data (Farley and Trow, 2003:66). According to Farley and Trow (2003:66), with leakage statistics (which is different from other scientific statistical methods in terms of the level of accuracy), “there will always be a number of unknown values which have to be estimated or averaged”.

Another issue of equal importance in data collection, according to Thornton Julian (2002:59) is the decision of key factors that would be analysed and the assigning of the appropriate units and the decimal places to be used. Examples of parameters that would be analysed during data collection are; flow measurement, pressure measurement, analysing of volumes, levels measurement and time measurement (Thornton Julian, 2002:59). She further suggests that it is “important to use parameters and units which are both meaningful to the country or area in which we are working and also units which are easily interchangeable”.

2.3.10 Introducing The Strategy

The introduction of the leakage reduction programme is as important as the formulation and strategising the techniques for the programme. Ideally it should be introduced with an

integrated approach where all the department of the water system are brought on board. In fact for sustained lower leakage levels, there is a need to involve a number of different staffs from the various department of the system and where possible this should be extended to the regional offices and depots (Farley and Trow, 2003:79).

According to Butler and Memon (2006:159), effective leakage management requires the input of a number of different personnel who are all committed other wise it may be difficult to maintain the infrastructure which has brought about the lower leakage levels. As an integral part of the strategy for leakage management, the introduction part should be done with careful considerations of the following (Farley and Trow, 2003:79):

- A launch event such as a major seminar. This can serve as a platform to announce the introduction of the programme and to explain what is involved to the staffs who would be engaged in the programme, what is expected of them and how the whole programme is going to impact on their jobs;
- Education and training of all staff. This should not focus only on staff who would be directly involved in the programme but the entire staff of the organisation. Tools such as, awareness exhibitions, articles for in-house magazines, internal and external training courses should be used;
- A "carrot and stick" approach to staff management. Staff who are responsible for the proper management of the leakage reduction infrastructure should be rewarded and disciplinary action taken against found to wilfully not taken into account the need to keep these infrastructures in place; and
- Public relations. It is good for the organisation to maintain a image in the eyes of the public and involve the public in the leakage management programme. The public can be involved in this exercise by providing a free phone call numbers which can be written on the organisation's vehicles and in papers issued with customer accounts.

2.3.11 Savings From Leakage Management

There are enough reasons for water utilities to want to reduce leakage in their systems. To start with, leakage is a waste. It results in the wastage of precious and scarce commodity.

Leakage, as has already been noted, could lead to setting of water tariffs above that which would otherwise be reasonable (Butler and Memon, 2006:149). Apart from being wasteful, leakage has a "deleterious effects on several aspects of the operations of a well run water supply system" (Farley and Trow, 2003:50). It increases cost of production, increases the capacity requirement (treatment plant and mains size) of the water system (Butler and Memon, 2006:149), and can reduce the confidence of customers in the water utility.

On the other hand, a well managed leakage programme could lead to several savings and benefits for the organisation. These savings are varied and can be short or long term in nature, it can affect several budget areas of the water system even budgets areas which are not directly involved in the leakage management programme. For example, "a reduction in leakage will reduce the throughput of a treatment works, leading to savings in power and chemical costs" (Farley and Trow, 2003:69). Savings could also be made from leakage management programme in terms of ongoing operation costs and savings from capital works investment costs. These savings would not only be associated with distribution system of a water utility but also would be linked to the water resources from where the water utility is getting its supply (Farley and Trow, 2003:54). Lambert, O., A (2008) intimated to this researcher at a discussion in his residence in the North Wales on the 26th of April 2008, that any savings made from water loss as a result of leakage management programme is a direct income to the water utility since that amount of water could immediately be sold to a customer.

Some of the savings that could be derived from leakage management programme are as listed below (Farley and Trow, 2003:254):

- Reduction in network flows due to lower leakage levels. This in turn could lead to reduced power costs for pumping the water around the network;
- Reduction in mains burst frequency. This could lead to lower costs of repair, lower costs of dealing with impacts of bursts on the network and customer supplies and reduction in the level of emergency work and hence the number of standby staff and call-out arrangement;
- Reduced customer complaints as a results of ;

1. Reduced demand on the network leading to reduced head losses, and also due to better pressure management, causing fewer complaints of excess or inadequate pressure at customer premises;
2. Reduced number of bursts,
3. Improved water quality. Correct DMA designs which allows the water to flow in specific route to customer's premises rather than washing about the system helps improve the water quality. Correct DMA designs also helps network modelling that would allow areas with high retention times to identified and remedial actions could be taken to reduce the retention times. Reduction in leakage coupled with downsizing of the network leads to lower retention times and hence improvement in the water quality;

- Reduction in network capacity requirement. Leakage management programme could lead to reduction in system capacity requirement as a result of the following;
  1. Downsizing of the mains by slip lining or pipe bursting;
  2. Abandoning some mains completely as they are no longer required meet lower demand conditions (It should be noted that leakage in any system is considered as part of the overall water demand requirement placed in a system. Once leakage is removed or reduced, the demand requirement on the system is reduced); and
  3. Reduction in service reservoir capacity, booster and pumping plant capacity may also reduce as a direct result of the leakage reduction programme.
- Reduction in costs of source and treatment works. This would result in operational costs savings due to;
  1. Power- lower consumption of electricity, hence lower charges;
  2. Chemicals- lower chemical treatment costs;
  3. Sludge disposal-lower volume of sludge requiring disposal.
- Reduction in long term resource needs (deferment on capital works). Leakage management has the potential to delay any future capital infrastructural development to meet future demands or expenditure needs to meet enhanced water quality requirement. New water source development could also be deferred thereby protecting the scarce water resources. The monetary value of defer future capital works could be calculated using the net present value (NPV) methodology to assess the gains to the water system as a result of the leakage management programme.

2.3.12 Burst and Background Estimate (BABE) Concept

The BABE concept is a computer modelling which is used to "assess the individual components of a leakage in a supply zone and then to compare that estimate with the level of leakage derived from either the water balance or from nightline data or preferably both" (Farley Trow, 2003:70). The BABE concept which is used for the calculations of components of real losses categorises real losses into three aspects (Lambert, O. A., et al, 2000). These categories are (Thornton Julian, 2002:136):

- Background (undetectable) leakages; small flow rate run continuously ;
- Reported breaks; high flow rates, relatively short duration; and
- Unreported breaks; moderate flow rates, duration depend on intervention policy.

The BABE concept is illustrated by figure 2.5 below.

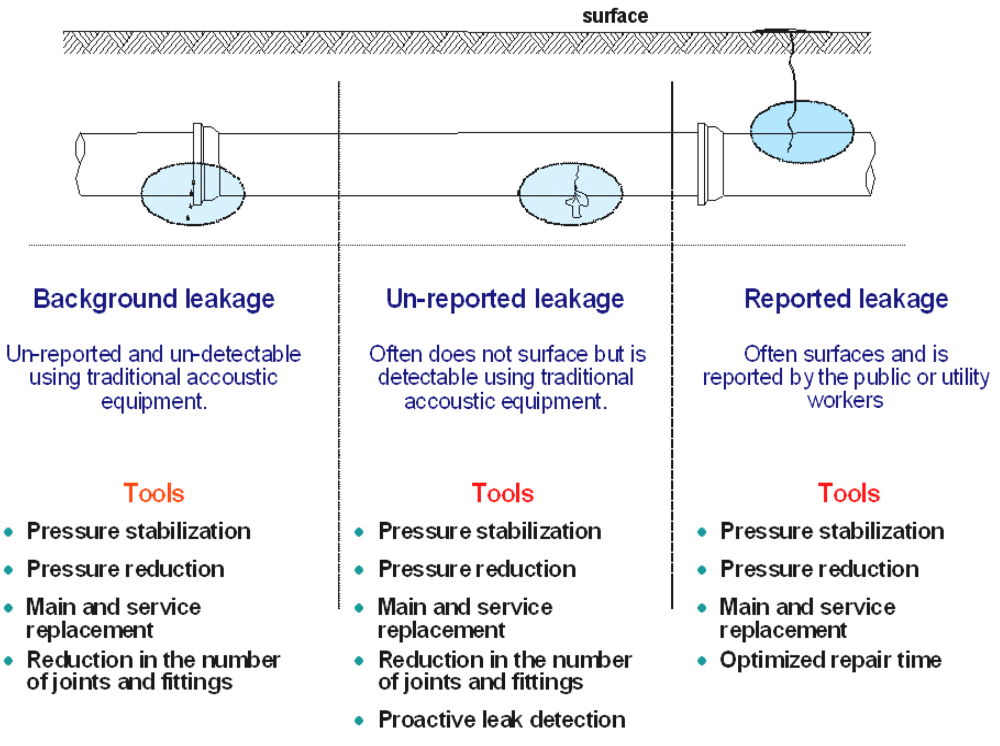


Figure 2.5: Background and bursts estimates (BABE) concept

Source: Lambert Allan (2008).

The BABE model works in a similar manner as statistical model in that it group together similar events and then perform simple calculations. The larger the number of the events

gathered, the more accuracy would be the results and for that matter BABE annual model works well with systems with more than five hundred service connections (Thornton Julian, 2002:137)

1. Background Leakage

According to Liemburger, R., and Farley, M. (n.d), background losses are individual events (small leaks and weeps) that will continue to flow, with flow rates too low to be detected by an active leakage control campaign unless either detected by chance or until they gradually worsen to the point that that they can be detected". They comprise of numerous leaks which individually are very small but collectively constitute a significant proportion of the total volume of water loss. These leakages can run for a long time without being detected (Farley and Trow, 2003:71). They normally occur in pipe joints, fittings, stop taps or on the packing glands of line valves. If the leakage reduction management strategy in a system is well under control in which leakage due to bursts is well managed, the background leakage would normally constitute the majority of the leakage in the system (Farley and Trow, 2003:71). Usually background leakage occurs on trunk mains, service pipes and distribution mains but "there are certain leakages on service reservoirs which can be considered as background leakage because, although they can be measured, it may not be worth remedying by costly repair works" (Farley and Trow, 2002:71). The table 2.3 below shows figures for unavoidable background leakage rates per metre of pressure at ICF (Infrastructure Correction Factor) of 1.

Table 2.3: Unavoidable Background Leakage Rates

Source: Liemberger, R., and Farley, M. (n.d)

Infrastructure Component	Background Leakage at ICF=1.0	Units
Mains	9.6	Litres per km of mains per day per metre of pressure
Service Connection – main to property boundary	0.6	Litres per service connection per day per metre of pressure
Service Connection – property boundary to customer meter	16.0	Litres per km of service connection per day per metre of pressure

The infrastructure condition factor is the ratio between the actual level of background leakage in a zone and the calculated unavoidable background leakage of a well maintained system" (Liemberger, R., and Farley, M). When background leakages are underestimated the recoverable leakage in a system would be overestimated and vice versa. This normally happens, according to Liemberger, R., and Farley, M. (n.d) when the wrong ICF value is used in the calculation of the unavoidable background leakage.

2. Reported Bursts

Reported bursts and leaks according to Liemberger and Farley (n.d) are those events that would usually be brought to the attention of the water utility either by the general public or the water utility's own staff. They are bursts and leaks which normally come to the attention of the water utility without the application of any form of active leakage control strategies. They normally come to the surface and so are visible to passer-bys or they are such that they impact on the level of service to customers who normally make complaints to the water supplier and therefore the supplier becomes aware of it (Farley and Trow, 2003:71). In view of the fact that action is normally taken on reported leaks and bursts quickly, they tend have relatively small volume of water loss even though they occupy a major profile when assessing water leakage.

3. Unreported Bursts.

Unreported leaks and bursts are those events that are located by leak detection team as part of their normal every day active control duties" (Liemberger, R., and Farley, M., n.d). They normally have flow rates lower than reported leaks but higher than background leakage. By their nature, they can only be detected through active leakage control strategies and therefore can run for few days or years depending upon the active control strategies being adopted by the water system. In situations where only passive or reactive leakage control is practice, it means that unreported leakage can run continuously until that

part of the infrastructure is replaced. According to Farley and Trow (2003:72), passive leakage control is accepted as the economic strategy for leakage control where water is plentiful and the cost of water production is low and moreover where there is no external pressure from government regulator to control leakage.

Background leakage may run continuously but the level of leakage in a system resulting from reported and unreported would depend on the time (duration) for which they are allowed to run. This run time has three elements (Farley and Trow, 2003:72), which have already been explained as:

- Awareness time;
- Location Time; and
- Repair Time.

Depending on how things are done in a system with regard to leakage reduction strategies, each of these time elements has effect on the volume of water loss in the system.

2.4 Leakage Management

Having considered and discussed some of the important information regarding real losses (leakage), the following sections would now look at the actual activities that are carried out by water utilities for the management of real losses. Leakage management are carried out using the four pillars of leakage control (Butler and Mamon, 2006:160) as depicted by figure 2.6 below. These pillars are:

- Active leakage control (ALC);
- Pressure management;
- Infrastructure management; and
- Speed and quality of repair.

2.4.1 Active Leakage Control

Active leakage control is different from passive leakage in a number of ways. In passive leakage control, the company only responds to reported bursts or drop in pressure which is either reported by the customer or is noted by the staff of the water system and the

necessary remedial measures are then taken to bring the situation to normalcy (Butler and Mamon, 2006;160). According to Butler and mammon (2006:160), Passive leakage control is normally practiced in areas where there are plentiful of water or where the cost of supplying the water is low. It is also practiced by less developed systems where the techniques of understanding and detection of "underground leakage is less well developed". According to Farley and Trow (2003:72), passive leakage control may be the appropriate economic strategy for leakage control in areas where water is plentiful and there is no pressure from government to reduce leakage. Even though passive leakage control may not be the ideal way of managing leakage, according to Butler and Mamon (2006:160), "it is the first step of improvement (i.e. to make sure all visible leaks are repaired). In fact passive leakage control is integral part of the overall leakage management since it is the first step towards any active leakage control programme.

Active leakage control begins when the more obvious leaks and bursts have been identified and fixed. "It is when the company staff are deployed to search for leaks which have been reported by customers or other means" (Farley and Trow, 2003:100) A higher level of effort has to be put in place in order to reduce leakage to the same volume as with passive leakage control (Farley and Trow, 2003:51). For effective active leakage control programme to be achieved there is the need for correct methodology, appropriate staffing and allocation of the required equipments for the programme (Farley and Trow, 2003:248).

2.4.2 Methodology for Active Leakage Control

Butler and Mamon 2006:160) identifies two main methods of ALC as:

- Regular Survey and
- Leakage monitoring.

2.4.3 Regular Survey

It is a method for ALC which uses one of the techniques listed below to look for leaks by starting from one end of the distribution system to the other end (Farley and Trow, 2003:100). The techniques used in this method are:

- Listening for leaks on pipe work and fittings

- Reading metered flows into temporarily-zoned areas to identified high-volume night flows and
- Using clusters of noise loggers (leak localising).

2.4. 4 Leak Monitoring

According to Farley and Trow (2003:100), leak monitoring "is flow monitoring into zones or districts to measure leakage and to prioritise leak detection activities". This is normally done by the installation of flow meters at strategic points throughout the distribution networks, with each meter measuring the flow in to a specific zone which has a well defined and permanent boundary (Butler and Mamon, 2006:160). Such a metered area or zone is called District Meter Area (DMA). The use of DMAs has become one of the most cost effective and most widely used techniques for leakage management. This

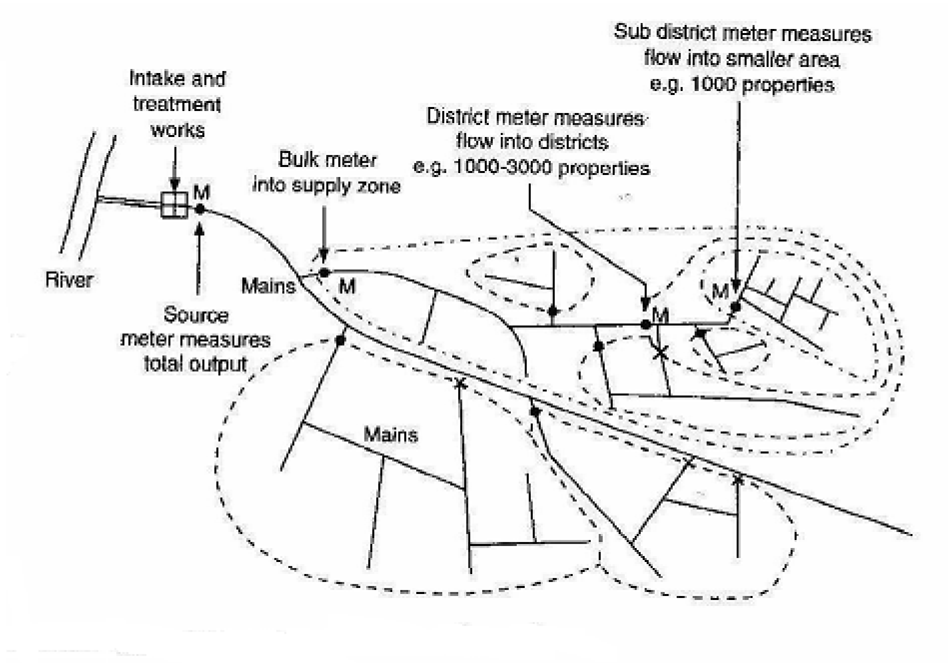


Figure2.6: Metering hierarchy and DMA design options (Source: Farley and Trow, 2003)

methodology, according to Farley and Trow (2003:103) can be used even in systems which has supply deficiencies. Zones can be created one at a time and leaks detected and repaired before moving on to create another zone. Eventually this systematic approach would improve the hydraulic characteristics of the network and also improve supply. The creation

of DMAs forms part of the act of sectorisation and zoning of the entire distribution network of water supply system. This process allows the operation team to understand as well as operate the system in smaller units which allows for better demand predictions and leakage management and control to take place (Farley and Trow, 2003:102).

The creation of DMAs in itself does not reduce leakage. Its purpose is to facilitate the identification of areas of leakage and by so doing enable the location of leakages easier and efficient (Farley and Trow, 2003:125). The regular analysis of the data from meters in DMAs allows areas with excess leakage to be identified and then prioritised for inspection according to factors such (Farley and Trow, 2003:125):

- The level of the excess. This can be assessed by the use of the number of estimated pipe bursts (ESPBs) per thousand properties in the DMA. This shows the density of the leaks in the area. Alternatively excess leakage may be assessed using litres/property/day for urban areas or ESPB/km for rural areas.
- The time between inspection periods. It is useful to set maximum inspection periods for all areas so that certain areas are not left un inspected for far too long; and
- Economic considerations. This takes into account the value of water to be saved in the area by the leakage management. The value of the water can be ascertained by multiplying the volume of the excess leakage by the unit cost of water for the area.

According to Farley and Trow (2003:102), for effective monitoring and control of the distribution system, the measurement system must be in hierarchical order, beginning at system input (production level), through zones and district levels to the customer’s meter. This system is composed of:

- Measurement of supply at the source or treatment works;
- Measurement of flow into supply zones with defined boundaries (about 10,000 to 50,000 properties);
- Flow monitoring into district meter areas (DMAs) of up to 3000 properties, with permanently closed boundary valves;
- Small leak location areas within each DMA, of around 500-1000 connections, where boundary valves remained opened except during leak location (step test) exercise; and

- Individual consumer meters, both domestic and commercial.

Pressure reducing valves (PRVs) could be incorporated in the installation of the flow meters (Farley and Liemberger.R., n.d) Even though telemetry system could be used in DMAs by linking the DMAs to a central control mechanism so flow data could continuously be monitored, according to Farley .M and Liemberger, R. (n.d) caution should be taken to ensure that the cost of the leakage management does not exceed the savings that could be made. In order to ensure the accuracy of data from DMA, it is crucial to ensure the proper maintenance of DMAs. This maintenance includes the clear maintenance of the DMA boundary, the integrity of plant and equipment (checks on the accuracy of meters and any other instruments that are in use).

Boundary maintenance includes Farley and Liemberger (n.d):

- Recording changes to the supply area and customer base;
- Making sure boundary valves are clearly marked and in the correct status;
- Educating staff as to the purpose of closed valves and ensuring that, if operated, they are returned to the correct status;

The design of leakage monitoring system apart from the creation of DMAs, for the monitoring of night flows on regular basis, also enables pressure management of the individual DMA or group of DMAs for the network to operate at the optimum pressure (Farley and Trow, 2003:104). DMA can be designed to suit one of the following design types depending on the characteristics of the network (Farley and Trow, 2003:104):

- Supplied via multiple or single feed;
- A discrete area (that is no flow into adjacent DMA); and
- An area which cascade into an adjacent DMA.

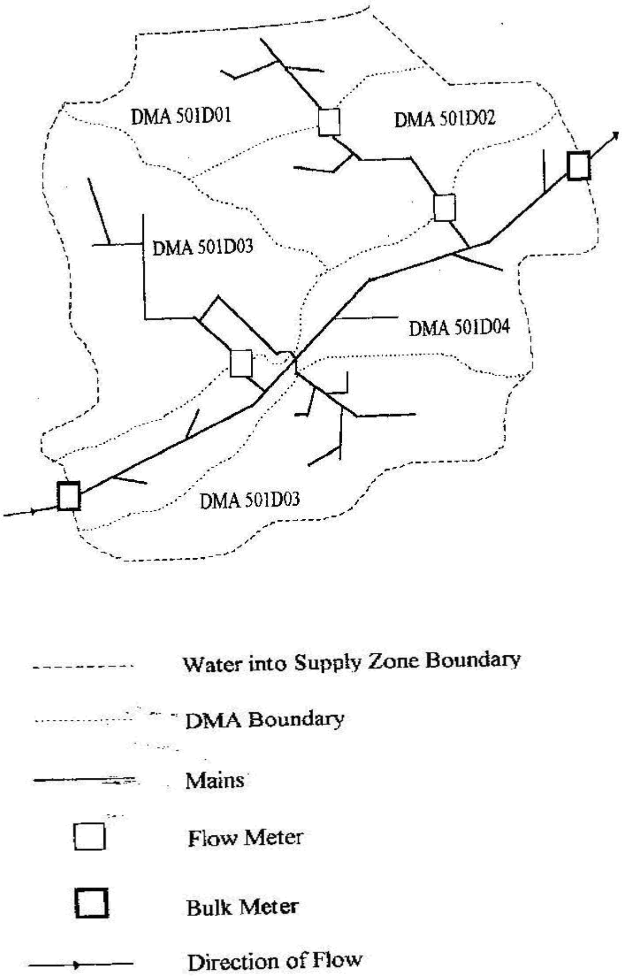


Figure 2.7: Configuration of several DMA types within water into supply (WIS) zone
Source: Farley and Trow (2003)

There are a number of problems associated with the designing and operation of DMAs. The following are direct quotation from Farley and Limberger (n.d) of some of the constraints associated with the designing and operation of DMAs and the measures to mitigate these constraints:

- Traditional engineering design criteria and reluctance to close valves;
- Too many closed valves;
- Low network pressure and critical points;
- Intermittent supply; and
- Creating dead-ends can reduce water quality.

Most of these constraints can be overcome by introducing DMAs in pilot areas, restoring supply temporarily in areas of intermittent supply, using a network model or pressure loggers to assess the effect on customer service levels, and by education and awareness training. Water quality problems can be overcome by a regular flushing programme or by re-designing the DMA boundary.

2.4.5 Selection Criteria

As to which technique or policy is suitable or appropriate would depend on a number of factors (Farley and Trow, 2003:101) such as;

- Characteristics of the networks;
- Local conditions (financial, equipment and staffing resources);
- Geology of the area- where the geology of the area allows leaks to be more surfaced, regular survey and rapid repair would be ideal for leakage management but if the area is such that most of the leaks do not surface, then leakage monitoring technique would be the ideal policy to be adopted for effective leakage monitoring; and
- The value of water.

Of these factors, according to Farley and Trow (2003:101), the value of water is the main factor that would determine the methodology to use. This is to ensure that the cost of the methodology used is economical to the savings in water that would be made. In areas where water is plentiful and the cost of producing water is low, low activities methods such as the repair of visible leaks alone would be appropriate. But in areas where water is very expensive and the cost of water production is very high, then more active leakage control would be justified. If the geology of the area according to Farley and Trow (2003:101) is such that it allows most of the leaks to surface, then regular survey to locate leaks and repairing them would be the appropriate measures to take. On the other hand, if most of the leaks occur underground, then it would be more appropriate to adopt leak monitoring and repair approach.

2.4.6 Managing DMAs

In any given water loss situation through leaks, the total volume of water loss is*; rate of flow x the length of time over which the break/burst has occurred (Butler and Memon, 2006:161).* It therefore means that if the flow data of a DMA can quickly be analysed, then it would be quicker to identify any area within the DMA that contains the leakage. If this is then followed by speedy repair, the amount of water loss would greatly be reduced. The situation calls for proper and careful management of DMAs. The best practice of analysing DMA flows, according to Butler and Memon (2006:161), is the estimation of leakage when the flow in the DMA is at the minimum. This usually occurs in the night when customer consumption is at the minimum. At these times, the leakage component would be at its greatest percentage.

Using appropriate techniques such as bursts and Background Estimates (BABE), to analyse the minimum night flows, the level of leakage and the relative volumes of background and bursts can be assessed. This process of analysing the leakage based on minimum night flow assessment can be carried on continuously night after night for a period of time with the assistance of data loggers and the appropriate software. *This process enables the leakage manager to monitor particular DMA or group of DMAs for the occurrence of new bursts and to activate repair (Butler and Memon, 2006:161).*

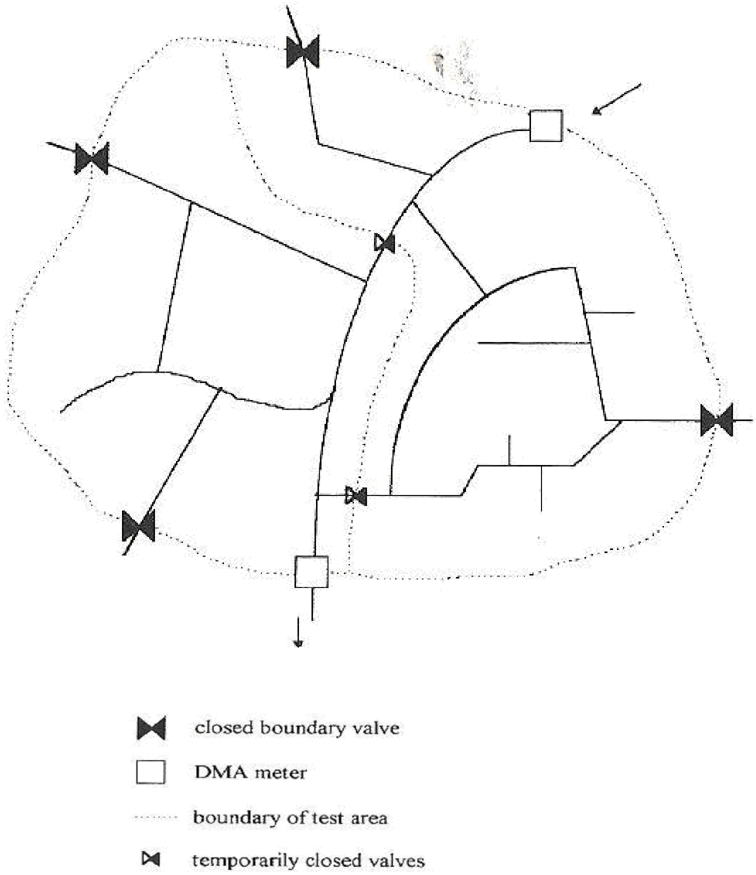


Figure 2.8: Dividing up DMA. (Source: Butler and Memon, 2006)

As has already been stated, the volume of water lost from leakage is a combination of the following factors (Butler and Memon, 2006:163):

- Awareness time- the average time from the start of the leak until the company becomes aware of it;
- Location time- the average time taken to locate the position of the leak; and
- Repair time- the average time for the company to shut off and repair the leak.

According to Butler and Memon (2006:163), the actual effect of ALC is to reduce the average duration time of a leak. The choice of either passive or active leakage control has

no effect on the repair time. The effectiveness of a company’s ability to become aware of the leak depends upon the data capturing method being used by the company. Some of these methods as outlined by Butler and Memon (2006:163) are:

- Telemetered flows- less than one day;
- Monthly night flow measurements- fourteen days; and
- Regular inspection- half the interval between inspections.

Two fundamental issues that need to be addressed, according to Butler and Memon (2006:164), in managing DMAs are:

- How often should areas be revisited?; and
- How much effort should be expended in each area before moving on to the next area?

The time period between inspections of a particular district, according to Butler and Memon (2006:164) is the average intervention interval. It “is a key element of the overall strategy” of leakage management. This intervention interval should be set with economic consideration of the cost and benefit. As has already been made mention of, most activities of leakage management follows the law of diminishing returns and as such care should be taken to ensure that the cost of carrying out the intervention activities do not override the benefits to be gained “in terms of number and quality of bursts that are found”. The frequency of the survey could be determined on economic considerations which should include the number of staffs required to maintain this frequency. The frequency of regular survey normally varies from “few weeks to about two years”.

2.4.7 Leak Detection and Location in DMAs

Leak detection "is the narrowing down of a leak or leaks to a section of the pipe network" whereas leak location "is the identification of the position of a leak prior to excavation and repair" (Farley and Trow, 2003:109).

2.4.8 Leak Detection Techniques

There are a number of techniques which are used to detect where leakage is taking place in the network. Some of these techniques are listed below (Farley and Trow, 2003:110):

- Sub-dividing DMAs into smaller areas by temporarily closing valves or by installing meters (figure below);
- Variation of the traditional step-test;
- The use of leak localisers (noise loggers); and
- Sounding surveys.

The choice of leak detection method is normally depended on (Farley and Trow: 112):

- The configuration and characteristics of each DMA;
- Operator preferences; and
- Water company policy.

For example, step test method may require the following (Farley and Trow, 2003:110):

- Involving night work;
- Require two or more operators;
- Require customer warning;
- Cause water quality problem;
- Cause bursts in weak pipes; and
- Cause inconvenience to night users

These factors may not warrant the use of the step test method in a particular organisation or in a particular DMA. In such situation leak localisers may be the prefer method. In certain situations the two methods, according Farley and Trow (2003:112), can be used in tandem.

2.4.9 Step Testing

Step testing is an activity for leak detection whereby a DMA is sub-divided into smaller areas by systematic closing of valves usually during the minimum night flow. The flow data is analysed and areas suspected to have leakage is identified to be followed up by leak location (IWA 2003). Step tests have the following advantages (Farley and Trow, 2003:111):

- Results are immediate; and
- Leak location can be done immediately.

2.4.10 Leak Localising (Noise Logging).

Leak localising is the identification and prioritising of the areas of leakage to make leak location (leak pinpointing) easier (IWA 2003).

Leak localising using acoustic loggers are increasingly replacing step testing method for leak detection. This method has the advantage that they can be used in dangerous and busy areas because they are set out during the day time (Farley and Trow, 2003:113). Again it does not require night work and also does not require the shutting down of any part of the distribution system (IWA 2003).The loggers are fitted on pipe fittings (hydrants and valves) by means of strong magnet. They are then programmed to listen for leak characteristics (IWA 2003). The loggers listen for and record noise levels automatically due to leakage in the pipe net work. Analysis of the readings of loggers fitted on adjacent fittings is done by comparison of the sound and noise readings recorded by the loggers. This would usually indicate whether there is an anomaly at one or more of the fitting and a closer inspection can then be done. Readings from loggers should always be compared and not to be read in isolation (Farley and Trow, 2003:114).

Figure 2.9 LEAK LOCALISING LOGGER FOR DETECTING AREAS OF THE NETWORK WITH LEAKS.

Source: IWA (2003).

2.4.11 Leak Location Techniques

Leak location is the pinpointing of the actual leakage position in the network once the leakage has been identified from the leak detection (localisation) technique (Farley and Trow, 2003:117). Several equipment and tools are in used for leak location exercise. These, according to Farley and Trow (2003:117), vary from "simple sounding sticks, or stethoscope to the highly sophisticated leak noise correlator". The correlator works on the principles that sensors are deployed at two locations (usually on two valves) on the pipeline at either side of the suspected leak position. Analysis of the difference in noise arrival time at each of the sensor, the pipe material, diameter and length would enable the leak position to be pinpointed precisely (IWA 2003).

Many more advance techniques and technologies are being developed and tried in the water industry usually to find the more difficult leaks especially in transmission mains. These advanced techniques include ground-penetrating radar (GRR), thermal imaging and in-pipe acoustic technology (Farley and Trow, 2003:120).

Leak detection in transmission (trunk) mains can pose some difficulties. According to Farley and Trow (2003:121), even though bursts on transmission mains can easily be identified and repaired, leak from joints on transmission mains can go undetected for years. The difficulty in detecting and locating leaks in transmission mains (especially rural transmission mains) according to Farley and Trow (2003:121) is usually due to one or more of the following factors:

- Low-pressure;
- Low noise frequency;
- Large diameter;
- Non-metallic materials; and
- Infrequent contact points for acoustic location.

Apart from these general factors that make leak detection and location difficult in transmission mains, rural transmission mains tend to have the following additional disadvantages that make leak detection and location even more difficult in rural transmission mains (Farley and Trow, 2003:121):

- They are often remote;
- They are laid over long distances;
- They can lie in difficult terrains; and
- Their exact position is sometimes uncertain.

It appears no one prescription of technique can be ideal for all situations for leak detection and location. It is normally at the discretion of the operative to choose the technique and equipment that best suits the area where the operation is taking place (Thornton Julian, 2002:186, Farley Trow, 2003:124). According to Farley and Trow (2003:124), the approach to leak detection in DMAs would generally depend on the level of the leakage above the target level. Where a large number of bursts and leaks are suspected, then the appropriate method would be to survey the whole DMA area. It is usually useful to convert excess leakage into equivalent number of service pipe bursts (ESPBs), or equivalent mains bursts (EMBs) by dividing the excess leakage (current leakage minus the target leakage) by the volume of water loss as a result of the mains burst or service pipe burst. The number ESPB or EMB would give an indication of the number of bursts to be repaired to achieve the target level.

2.4.12 Pressure Management

Pressure management is one of the most cost-effective and system optimisation measures which can in many circumstances provide the fastest pay back on large investment (Thornton 2002:261). According to Butler and Memon (2006:166), "the rate of leakage in a water distribution system, is a function of the pressure applied by pump or gravity head" and that it has been proven by laboratory and underground system tests that there is direct relationship between pressure and leakage flow rate. It is also true that bursts rate are a function of pressure, even though "the strength of the relationship and the quantification of it, is not as well understood as the relationship between flow rate and pressure (Butler and Memon, 2006:166).

According to Thornton (2002; 261), system optimisation is in most cases more cost-effective and environmentally positive than system expansion. And pressure management offers one of the best tools for system optimisation which in most cases serves as one of the best strategies for water loss reduction and efficient management of water distribution systems. Pressure management according to IWA (December, 2006) is "the practice of managing system pressures to an optimum level of service ensuring sufficient and efficient supply to legitimate uses and consumers, while eliminating or reducing pressure transients and variations, faulty level controls and reducing unnecessary or excess pressures, all of which cause the distribution system to leak and break unnecessarily". Some of the tools used for implementation of pressure management are; pump controls, altitude controls and pressure reducing, pressure controlling and pressure sustaining valves (IWA 2006). According to Butler and Memon (2006:166) pressure management strategy should be an integral part of the leakage management strategy because "it impacts on several other aspects" of the leakage management strategy. In the words Lambert who is a renowned water loss management consultant of IWA, "without pressure management nothing would seem to work" (personal interview on 26th of April, 2008).

The following are direct quotation from Butler and Memon (2006:166-167) of some of the impacts pressure management has on other aspects of leakage management strategy:

- *If pressure is reduced, the rate of increase in leakage will reduce. Therefore there is an impact on the level of leak detection resources required;*
- *The flow Rate from all leak paths (bursts and underground) will reduce;*
- *The data used to calculate leakage targets and economic level of leakage should be revised when pressure management is introduced;*
- *Reducing pressure may make existing leaks more difficult to find, because they make less noise, or do not come up to the surface; and*
- *Reducing pressure can reduce some types of consumption. Any consumption from devices connected direct to mains pressure will give a reduced flow rate at reduced pressure*.

2.4.13 Importance of Pressure Management

Whilst some countries like UK and Japan have recognised the importance of pressure management to leakage reduction strategies for over twenty years now, the concept is not currently widely been practiced in most water utilities world wide (IWA 2003). According to IWA (2003), "proactive pressure management was taking place in only five out of twenty countries; in eight out of twenty countries, it was not widely practiced to manage leakage". In spite of this low level of acknowledgement of pressure management and its importance in water loss reduction strategies, Farley and Trow (2003;151) indicate that, "pressure tends to be second most important factor in determining leakage levels, after infrastructure conditions, but pressure management is more cost effective than infrastructure management". However, there are a number of benefits (or potential benefits) that should encourage utilities to undertake proactive pressure management. The following sections outline some of the benefits that could be derived for undertaking active pressure management.

2.4.14 Positive Reasons

Lambert (2008) outlines the following as some of the importance of pressure management:

- Influences flow rate of existing leaks;
- Influences some components of consumption;
- Can significantly influence frequency of new leaks and bursts, and repair costs;
- Can influence economic frequency of active leakage control; and
- Can extend infrastructure life.

The sections below outline the potential benefits of pressure management in a more elaborate manner. The outlined benefits are taken directly from Thornton (2002:262) and Butler and Memon (2006:167) unless otherwise stated.

2.4.15 Leakage Reduction

It has been proven that both leakage volume and frequency of new bursts can greatly be reduced by reduction and stabilisation of pressure (optimisation of pressure). For example, by reducing pressure from 80m to about 40m, it is possible to reduce bursts from about seven bursts per hundred properties per year to about only one.

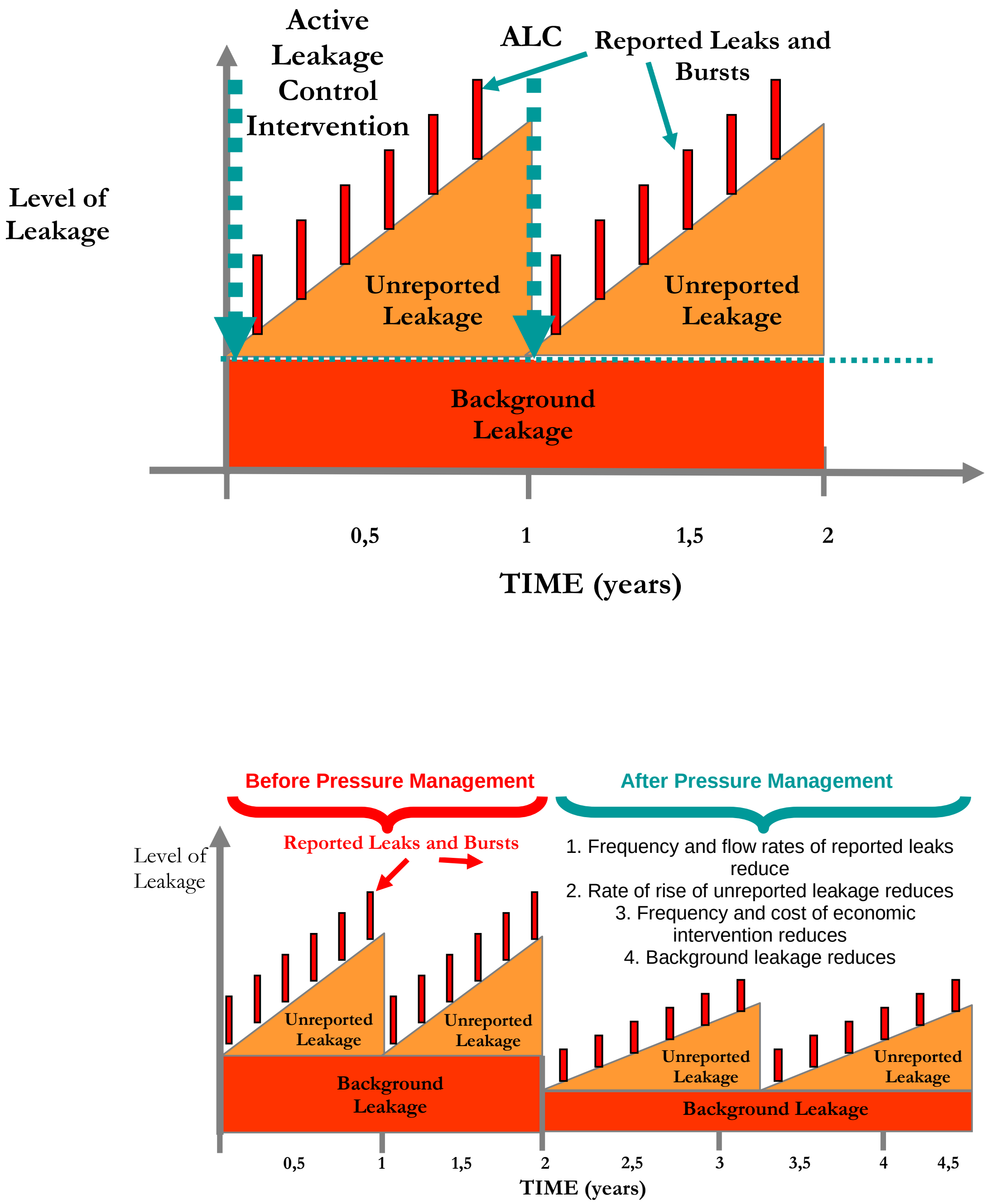


Figure 2.10: Components of Real Losses before pressure management (source: Lambert Allan, 2008).

The figure 2.11 above shows that without pressure management, even though other aspects of leakage management may be carried on, the overall volume of water loss would not change significantly. As visible bursts and leaks are identified and repaired without pressure management, more pressure is introduced on unreported bursts and leaks and background leakages thereby increasing the rate (and some times the size of the bursts) of flow of these leakages (Lambert Allan, 2008). Hence, the water loss would almost remain the same.

2.4.16 Water Conservation

In a situation in which the consumers are served under direct pressures from the water supplier, water can be conserved by pressure management. If a tap for example is left opened for a period of time, the volume of water that would be consumed under higher pressure would be greater than lower pressure for the same period. Thus pressure management can be used to prevent unwanted demand (demand management). Demand management has proven to be more cost-effective and environmentally sustainable than system expansion in order to meet increased demand;

2.4.17 Non-Payment;

In situations where due to political pressures, utilities are not allowed to cut off supply to customers due to non-payment of bills, pressure management helps to reduce the losses to the utility.

2.4.18 Emergency Situations

In drought and other emergency situations, pressure reduction (pressure management) can be used to reduce demand and as mentioned earlier, reduce leakage, all in an attempt to manage the emergency situation until the situation normalised.

2.4.19 Efficient Distribution of Water

At certain situations, it becomes difficult for the water utility to supply all customers at the same time. This may be due to, "ageing infrastructure, poor design, geographic constraints, or demographic layout". Under such situations, pressure management using pressure reducing techniques, pressure sustaining techniques, boosters, or flow control can ensure the even distribution of the resource to majority if not all of the customers at the same time. Under the above situation, most water utilities would resort to intermittent water supply, supplying water to different sections of the supply area at different times. But according to Lambert Allan who is a renown water loss management consultant (personal interview with him at his residence on 26th April, 2008), it is better to supply all consumers with water under low pressure than intermittent water supply even at higher pressures even if the amount of water the consumers are getting is low. Pressure management also ensures better services to the customers. This is because, in a well organised pressure management system, any abnormality in pressures (too low or too high pressures) to customers' premises can be traced and the necessary corrective measures taken to ensure that the customers get water at the correct pressures;

2.4.20 Guaranteed Storage

Pressure management ensures the proper storage of water at service reservoirs. The use of pressure reduction, pressure-sustaining and flow control valves ensure that there is always adequate water in service reservoirs whilst at the same help to prevent water loss through reservoir over flows; and

2.4.21 Reduction in Hydraulic Impacts

Hydraulic impacts such as surge and transient waves can cause damage (bursts) to weak sections of the pipe network. These surges and transient waves are caused by sudden closing and opening of valves, large consumer sudden drop in water use or quickly

opening of fire hydrant in an emergency. The use of pressure management techniques such as surge arrestor valves and pressure relief valves ensure that the pressures in the system are kept at the safe levels at all times. Pressure fluctuations due to conditions described above are the causes of much damage to pipe networks and other fittings in the supply network due to fatigue effect. The higher and more frequent of these fatigue effects, the damage is caused to the supply system. Pressure management techniques as stated above help smooth out pressure variations in the system and thereby help to ensure the longer life span of the assets of the water system; and

2.4.22 Reduced Customer Complaints

Pressure management as explained earlier has the potential to ensure that customers get water constantly both at the correct pressure and volume. It therefore means that customer satisfaction can be obtained under well organised pressure management systems. This situation fosters good relation between water utilities and consumers which can lead to prompt payment of bills by consumers and therefore ensures the financial sustainability of the system.

2.4.23 Background Leakage

In spite of leakage reduction measures that would be carried out by utilities there would always be some leakage that would not be detected (Thornton 2003:272). According to Thornton (2002: 272) these leakages are often referred to as background leakage. “They are made up of many small pinhole leaks, joint leaks and drips”. The only efficient way to reducing the impact of background leakages (apart from complete infrastructure replacement), according to Thornton (2002:272), is by effective pressure management.

2.4.24 Potential Concerns

It is important to note that even though there are a lot of positive reasons why utilities are encouraged to carry out pressure management, however, there are some potential problems that could be associated with poorly implemented pressure management programmes

(Thornton 2002:265). Some of the concerns that could be associated with the introduction of pressure management scheme (Thornton 2002:265) are:

- Fire flow concerns;
- Loss of revenue; and
- Reservoirs not filling at nights.

1. **Fire Flow Concerns**

Adequacy of water at fire hydrants during fire fighting could be source of concern for pressure management especially where there are laws stipulating the pressures that should be maintained at fire hydrants for fire fighting. According to Butler and Memon (2006:168) many water utilities avoid pressure management in order to avoid the situation of inadequate water pressure for fire fighting. But with the level of modern technology, it is possible to manage pressure in order to reduce leakage, whilst at the same time maintaining adequate pressure for fire fighting.

Some of the measures that could be adopted by utilities to ensure adequate pressures for fire fighting (Thornton 2002:266) are the use of multiple feeds which controlled by pressure reduction valves with flow-modulated capabilities. These valves automatically regulate pressure in line with demand and at the same time ensuring the safe pressure limit at the residual times. Another option could be the use of large sleeper valves which opens automatically when there is pressure drop as a result of additional headloss created by fire flow.

2. Loss of Revenue

Any loss of revenue as a result of pressure management programme to any utility is incorporated in the costs-benefits calculations and analysis before the programme is carried out. That is, the expected benefits in water loss reductions as compared with the expected loss of revenue as a result of pressure management programme should analysed before the programme is embarked upon. But in situations where the utility has very low level of losses and a high cost of water production, loss in revenue due to pressure management is a key factor to be considered before the programme is carried out (Thornton Julian, 2002:266). According to Thornton Julian (2002:266), in situations where loss of revenue

can not be tolerated, pressure management can be limited to night hours when authorised consumptions are at its barest minimum and pressures are very high.

However, it should also be noted that many utilities are concerned about water conservation as part of demand management. Pressure management is one of the techniques for demand management programme. The long term benefits to water utility and the environment as a result of demand management programme normally would out-weigh the short term revenue that would be accrued to utility as a result of not implementing pressure management programme for fear of loss of revenue. One of the factors to look for when considering water conservation programme as part of demand management programme is the per capita consumption of the area (Thornton Julian, 2002:266). If the per capita consumption is high, pressure management, according to Thornton Julian (2002:266), becomes a natural part of the water conservation measures.

3. Reservoir Filling

To avoid the situation where reservoirs are not filled during the lean periods of consumption (especially in the nights), some systems carry out pressure management programmes on smaller pipes and service connections whilst allowing normal pressures in the transmission mains (Thornton Julian, 2002:268). This arrangement would usually not pose any major problems to leakage reduction programmes since “most utilities find that non-visible leakage tends to occur in smaller pipes” (Thornton Julian, 2002:268), and therefore the effectiveness of pressure management would not be significantly affected by the exclusion of the larger transmission mains.

2.4.25 The Relationship Between Pressure and Some components of leakage

The relationship between pressure and some factors of leakage have been identified and some concepts have developed to calculate and predict the level of leakage that could be expected at a given pressure with a particular pipe material.

1. Pressure: Leak Flow Rate Relationships

According to IWA (October 2003), give the hydraulic equation for flow rate (L) through a hole of area A subject to pressure P is;

$L = Cd \times A \times (2gP)^{0.5}$

Cd is a discharge coefficient and g is acceleration due to gravity. The effective area (Cd x A) can be pressure-dependent for some types of individual leakage path. This relationship uses the FAVAD (Fixed and Variable Area Discharge) concept and N1 exponent. According to IWA (October 2003), for practical predictions the best practice equations are:

L varies with P^{N1} and

$L_1/L_0 = (P_1/P_0)^{N1}$

The most important factor that influences this prediction is the ratio (P_1/P_0) and not the difference in pressure. For fixed areas the value of N1 may vary from 0.5 to 1.5. For variable areas this can be more. As stated earlier, in variable areas, the effective area (Cd x A) varies with the pressure. In general, N1 exponents for large leaks in metal pipes are about 0.5 whereas "small background leaks at joints and fittings, and large leaks from flexible non-metal pipes have N1 exponents of 1.5 or even more" (IWA 2003). According to Lambert (2008), this concept when tested in the field in UK, Japan, Brazil, Malaysia, New Zealand, Cyprus and others, explained diverse results.

The N1 exponents for small systems are calculated from night test. The inlet pressure is reduced and the reductions in inflow rates and average zone pressures are measured (IWA, 2003).

The reduction in leakage rate for small changes in average pressure can be quickly predicted by multiplying the N1 by the percentage reduction in average pressure. For example, ten percent reduction in pressure for a system with an N1 number of 1.5 would give a fifteen percent reduction in current leakage rate (IWA 2003).

2. Pressure: Consumption Relationship

Some components of consumption are influenced by pressure (Lambert Allan, 2008)

Lambert (2008) describes the relationship between pressure and consumption in the following concepts:

- The FAVAD equation can be used to represent the consumption and pressure relationship, but the exponent is termed N3, not N1.
- Consumption rate C varies with average Pressure P^{N3}
- For prediction purposes in distribution systems:

$$C_1/C_0 = (P_1/P_0)^{N3}$$

So it is the **RATIO** of pressures, and the N3 exponent, that are the key parameters. These concepts "can be used to predict the effect of pressure management on different element of consumption" (IWA 2003).

3. Pressure: Burst Relationship

It has been shown by many case studies that there is remarkable reduction in new bursts frequency after pressure management (Lambert 2008). Maximum pressures and particularly surges have much influence on the frequency of new bursts. According IWA (2003), higher new leaks frequencies occurs in areas supplied directly from pumps as compared with gravity-fed areas.

2.4.26 Pressure Management Strategies

1. Opportunities For Pressure Management

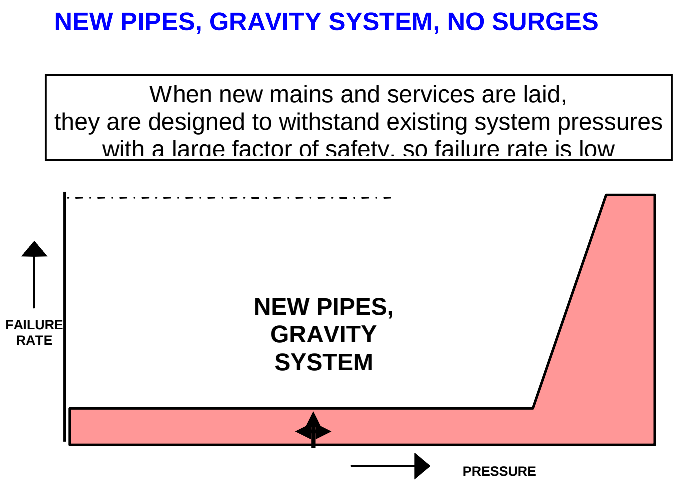
It is important to assess the system to identify the opportunities that exist for pressure management in the system. Some times it would even appear less cost effective to carry out pressure management in a system instead of other water loss strategies. For example, it will be less cost effective to carry out pressure management in flat areas as compared with grounds of that have significant undulations (Farley and Trow, 2003:150). According to Farley and Trow (2003:150), one of the most important factors that would necessity the implementation of pressure management is the condition of the infrastructure, and its susceptibility to bursts and leaks. This factor would generally be governed by (Farley and Trow, 2003:150):

- The age of the system;
- The type of pipe material;
- The method of jointing the pipes;
- The ground conditions; and
- The surface loading.

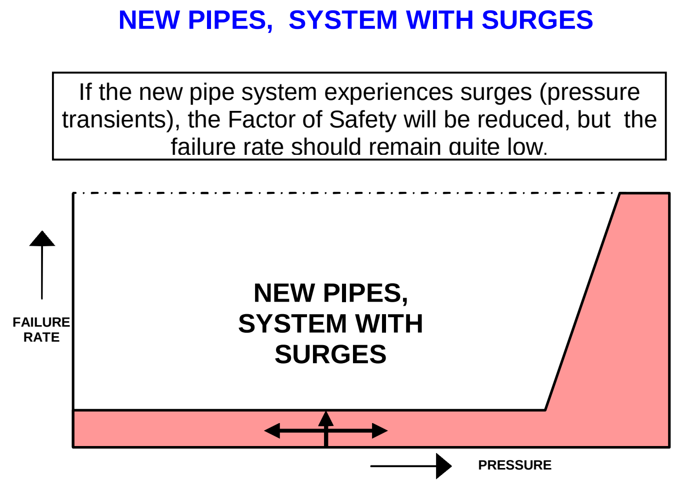
Some of the data that would be collected from such assessment exercise can be used at later stage of the pressure management programme for monitoring and evaluation. Some of the tasks that should be undertaken prior to pressure management are as outlined below (IWA 2003);

- Desk study to identify potential zones, installation points and issues;
- Demand analysis to identify consumer types control;
- Field measurement of flow and pressure (the latter usually at inlet, average zone point and critical node points);
- Modelling of potential benefits using specialized models;
- Modelling of correct control regimes to provide desired results;
- Cost to benefit analysis; and
- Analysis for requirements for maintenance and post installation monitoring to ensure sustainability of results.

The following diagrams illustrate some of the stages that normally lead to the necessity for pressure management (Lambert 2008)



Source: Lambert (2008)



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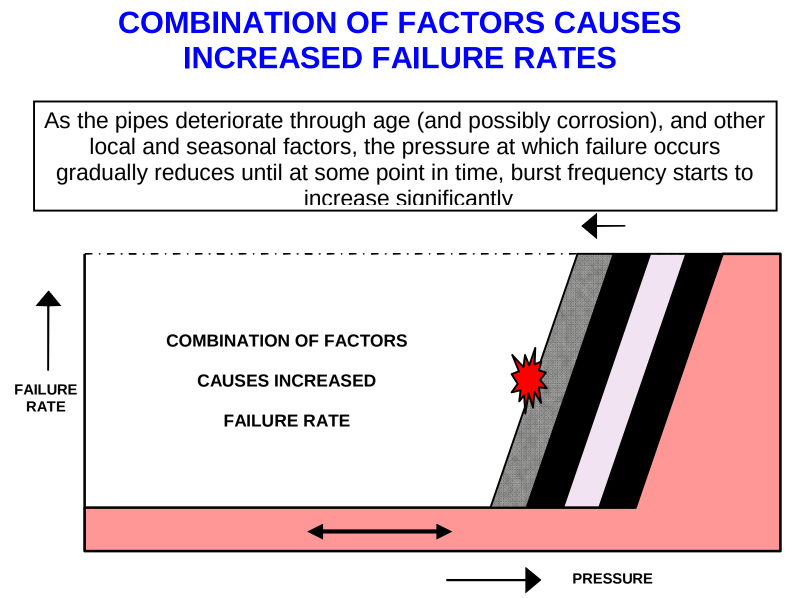

Source: Lambert (2008)

Combination of factors such as low temperatures, ground movement, traffic loading and age + corrosion would cause the speed up of failures in pipelines.

2. Tools For Pressure Management

According to IWA (October 2003), pressure management for leakage reduction falls under the following main categories:

- Pressure reducing/sustaining;
- Surge anticipation/relief; and
- Level/altitude control.

Even though the above three methods usually form part of water loss management, the most common method for pressure control is pressure reduction. Again pressure reduction can be undertaken by one or combination of the following (IWA 2003) depending on the economic level of leakage and the ability of the utility to maintain the equipment that goes with the particular method:

- Zonal boundaries;
- Pump and level control;
- Fixed outlet control valves;
- Time modulated control valves;
- Flow modulated control valves; and
- Remote node control.

3. Sectorization

Sectorisation is one of the most basic forms of pressure management in which sectors are divided either naturally or by the use of valves (Thornton 2002:268). One of the difficulties associated with solely controlling pressure by sectorisation is the enforcement of boundary valves controls. This can be reduced with telemetry devices that send information about the condition of valves to a central control any time the valves are operated which enables managers to ensure the integrity of the valves at all times (Thornton 2002:269). Sectorisation in its simple form may not require the automatic control valves which often expensive, however, it has been shown that the incorporation of automatic control valves make sectorisation more efficient and even more cost effective (Thornton 2002:269).

4. Pump Control

Pump control is the situation where pumps are used to control pressures in a system by activating or deactivating the pumps depending the on the demand levels. According to Thornton (2002; 269), pump control is effective if the reduced levels of pumping, which usually occur in the nights can still ensure the require reservoir levels. It appears the use of pumps for pressure control has energy use implications and this has to be considered carefully before the implementation of this method since inefficient pumps, according to Thornton (2002:269) can cause huge energy use. It is also possible for pumps to operate

outside their designated profiles if they subjected to upstream valve throttling and high demands. Variable speeds pumps have similar effect as pressure relief valve which allows pumps to start slowly and as demand reduces, the speed of the pumps can slow down to prevent excessive pressure build up. According to Farley and Trow (2006:164), it would be worthwhile to fit valves on the outlets of pumps which only open after the pump has started, again to prevent pressure surge.

5. Automatic Control Valves-fixed Outlets

The fixed outlet method is effective where headlosses are fairly low, i.e. areas with fairly constant demand throughout all seasons (Thornton Julian, 2002:269). However, the fixed outlets system would not be efficient in areas with very high pressure demand during peak periods. The outlet pressure has to be set to meet the minimum demand pressure at peak periods. This minimum pressure is often far in excess of the static pressure which is needed for nights flows and fire fighting which can lead to bursts and leaks (Thornton Julian, 2002:269). According to Farley and Trow (2003:171), the above situation with fixed outlet can be overcome with **flow modulation.**

Flow modulation allows adjustments in settings at the outlet flows through pressure fluctuations at the inlet valves to compensate for head loss (Farley and Trow, 2003:171). In this arrangement, according to Farley and Trow (2003:171) "it is not possible to keep pressure fixed at all points in the network and therefore a compromise has to be made between the inlet pressure and the critical point pressure in order to optimise leakage levels".

Automatic control valves are employed in system networks not only for leakage reduction but also for effective controls of flows which allows for effective management of the distribution system. The following points are quoted from Farley and Trow (2003:165) which outlines the purposes of control valves in water system:

- Regulate the flows into service reservoirs and tanks. These valves can be controlled with simple hydraulic devices such as floats to shut off the inflow when the tank is full, or they can be controlled electronically to profile the inflow according to demand on the system and other parameters which are monitored continuously;

- Control the operation of pumps;
- Sustain pressure upstream of the valve in order to maintain a minimum level of service to customers or to prevent negative pressure, e.g. where the mains run over the top of a hill; and
- Control flow rate e.g. on the supply to an industrial customer who takes water through a tank. The peak flow which occurs when the ball valve on the tank opens can cause pressure surges in the distribution system. This sudden increase in flow can be controlled by a valve which is set to prevent the flow exceeding asset limit.

2.4.27 Infrastructure Management

Infrastructure management is one of the four components of leakage reduction management strategies. The general condition of mains, service pipes, service reservoirs and other fittings of a water system is the most significant factor that affects the level of leakage in any water network. According to Butler and Memon (2006:168), the condition of the infrastructure of the water system is also usually the "singular most significant factor affecting the economic level of leakage for that network".

Normally the condition of the infrastructure is a legacy which is usually inherited from previous regimes which can not be improved upon significantly without much capital investment (Farley and Trow, 2003:76). For this reason when it comes to expenditure on infrastructural improvement for even the highest leakage prone areas in a system, it has been found not to the cost effective approach for leakage management (Butler and Memon, 2006:168). As mentioned earlier, it is always cost effective to approach leakage management strategy by implementing those strategies that would result in early pay backs so that the programme can be financially sustainable and infrastructural improvement is usually a long term strategy that could be embark upon in gradual process whilst those measures which would result in immediate pay back results and less expensive are tackled on large scale. It has also been indicated earlier that leakage reductions strategy which

when implemented once that could have a large scale effect on the whole water system are normally the most cost effective strategy.

The following points on infrastructural management are taken from Butler and Memon (2006:169) unless other stated. If infrastructural development is being carried out for other purposes rather than for leakage reduction, such as system expansion for improve service delivery, water quality requirement and for setting minimum pressure standard, then it would be of greater benefit to incorporate issues of leakage reduction in the exercise. It is, however, becoming difficult to justify the cost if leakage reduction is the primary purpose for carrying out the infrastructural development.

There are two ways of assessing the condition of infrastructure:

- Its propensity to burst. This would be governed by factors such as pressure and ground conditions and weather as well as the conditions of the mains and service pipe fabric; and
- Its propensity for background leakage. Again this is governed by pressure.

Even though at first sight it would seem that the two conditions are the same and that mains would respond to the two conditions at the same time, the presence of background leaks do not necessarily imply that there are bursts and vice versa. It is therefore important to judge the two parameters with different methods and approach.

"The main justification for carrying out infrastructural renewal and rehabilitation can be one of the following:

- The internal condition of the main is affecting the water quality delivered through it. This can be the result of corrosion of cast or ductile irons which have no internal protections;
- The internal bore of the main has reduced due to corrosion or has become build of deposits, so that it no longer able to carry out sufficient flow;
- The pipe wall has weakened and is no longer able to withstand the internal pressures of the water, or it has insufficient beam strength withstand traffic loading; and
- Some external factor has resulted in the main being unable to fulfil its current duty".

It at times becomes necessary to replace main sorely on the grounds of leakage reduction. In that case, “customer levels of service and operating cost should be the main drivers”. As stated earlier, whatever the reason for mains renewal and rehabilitation, leakage reduction issues should be considered. The renewal of mains for leakage reduction without renewal of service connections may have an adverse effect on leakage due to increased pressure as a result of increased carrying capacity of the main which would cause leaks on service connections to flow at higher rates. It has already been stated that there may be little or no correlation between high burst frequencies and background leakage. High burst frequencies tend to occur on smaller diameter mains which have low beam strength whereas background leakage tend to occur more on larger diameter mains and service connections. This can therefore mean that areas with high background leakage may have low bursts frequencies and vice versa. “Therefore each section of the main has to be assessed, and any policy based on generalisation is unlikely to be cost effective, and could produce little or no leakage reduction”.

If it becomes necessary for mains renewal and rehabilitation to be part of the leakage reduction strategy, then care should taken in order to target the areas that are greatly contributing to the overall leakage levels in the system. In this case it would be necessary to carry out assessment exercise to identify those areas that need to be renewed or rehabilitated. There is also cost implication in this assessment exercise and therefore balance has to be made between the assessment exercise and the actual cost of the rehabilitation exercise. “If insufficient effort is made on the preparatory stage, then mains will be replaced with little benefit, whereas too much investigation will add to the overall cost unnecessarily”.

In order to ensure that a cost-effective main rehabilitation is carried out, the following steps should be followed.

1. Identification of those mains that clearly needs replacement.

The first step is to identify those mains that have record of regular bursts and repairs. This could be done with consultation with the local operation and maintenance team and the examination of mains repair records. Such consultation and examination of records would

indicate a break even point with regard to the cost of repair, the value of water loss, the volume of the water loss through each burst and the cost of continuing with repair.

2. Identification of areas of high leakage record.

The next step is to identify the areas with high leakage records. The areas should be prioritised based on the prevailing conditions in each areas in terms of infrastructure condition factor, or background leakage in litres/property/day or m^3/km/day and each area is then thoroughly examined to ascertain the causes of the leakage using the appropriate leak detection strategy.

3. Cost-benefit analysis.

Each sub-area of a DMA should analysis to determine whether it would be cost effective to replace the mains in order to eliminate the leakage. The investigation of the sub-area could lead to a burst which has not been previously identified. The repair of such burst could remove the leakage leading to the avoidance of the complete removal of the mains.

4. Consideration of other benefits.

It is important to consider other benefits when considering the cost benefit analysis of the mains rehabilitation. Benefits such not having to incur repair cost, improved customer service and water quality improvement could be considered to justify the rehabilitation exercise.

5. Designing of the scheme.

"A package should be produced including a plan and all other relevant data".

6. Project Management.

There is the need for good project management in order to realise the intended benefits of the scheme.

2.4.28 Replace or Repair

It is important at some stage of infrastructure management to decide whether it is more cost effective to replace mains or to continue with repairs. According to Farley and Trow

(2003:140), the under listed factors should be considered as to whether mains have come to the end of their serviceable life and should therefore be replaced or to continue with the repair works:

- The relative costs of continuing to make repairs as compare with the cost of replacement;
- The impact on customer service of continuing to accept the interruptions to supply whilst repair works are being carried out;
- The requirement to meet set targets for leakage, which will be assisted by the installation of a new mains; and
- The availability of finance and other resources.

2.4.29 Speed and Quality of Leak Repair

This is the fourth component of leakage reduction strategy. It is in no way the less important of the previous three already discussed.

All leaks are pressure-dependent, i.e. the more the pressure the more the loss. However, it is important to note that annual water loss through leaks does not depend on pressure alone, but also factors such as awareness time, location time and time taken to carry out the repair and the quality of the repair (Thornton 2002:241). The speed and quality of repair become even more crucial in annual water loss figures since "there is no point in having a costly programme in place to become aware of and pinpoint a new unreported leakage in hours or days if it then takes weeks or months to fix the leaks" (Thornton 2002:241). According to Farley and Trow (2003:102), reduction in the time that would be taken to repair a leak once the leak is located should be one of the major initiatives in leakage reduction management strategies. As leak location practices have developed and advanced so rapidly with the results that leak awareness and detection times have been greatly reduced, it is appropriate that the corresponding speed and good quality of repair are carried out in order to maximise the savings and also to reduce customer inconveniences (IWA 2003).

As has already been mentioned earlier in this research work, all the activities undertaken for leakage management strategy follow the law of diminishing returns. It is always important to establish the economic level of intervention activities in order to make these interventions economical. This economic level of intervention applies to leak repair times. According to Farley and Trow (2003:72), a balance must be made between a policy that would ensure that time taken for repairs are not too long to cause water loss unnecessarily and a policy which is too tight to make the additional cost incurred in leakage repairs uneconomical.

Whereas repair time of four to ten day for unreported mains repair and supply pipes in the public high way would be an ideal time, supply pipes and mains on private land normally takes weeks and some times months before the repair is carried out due to factors such as the issuance of notice to gain lawful access to effect the repair works and at certain times customers have to be persuaded to carry out repair on their private pipe Farley and Trow, 2003:73).

2.5 Apparent Losses

2.5.1 Definition

Apparent losses in a water supply system constitute one of the three components of non-revenue water (NRW) to a water utility besides real losses and authorised unbilled consumption. These are demonstrated by the IWA best practice standard water balance (see figure 2.1 at page 10).

"Apparent losses consist of unauthorised consumption (theft and illegal use), and all types of inaccuracies associated with production metering and customer metering" (Thornton Julian, 2002:161). According to Butler and Memon (eds), (2006:196), the definition of apparent losses includes, "billing anomalies and inefficient management". This means that apart from inaccuracies in meter readings, wrong computations and billings systems which are difficult for utility staff to administer can contribute apparent losses. The definition is further expanded to include data-handling errors (Kingdom, et al, 2006). Again according

to Michel Vermersch (2005) apparent losses occur in three types of connections, namely; unregistered, metered and unmetered. This he explains as follows:

- Unregistered consumers (illegal connections or illegal consumption);
- Underestimation of consumption when the water meter is out of operation;
- Undermetering when the water meter is not appropriate;
- Frauds on metered connections; and
- Underbilling of unmetered (registered) customers.

2.5.2 Components of Apparent Losses

From the definitions so far given about apparent losses, four components can be identified. This is depicted by figure 2.14 below and according to Rizzo Alex, et al (n.d) "these components can act and interact interchangeably". These four components are:

- Meter Under-Registration;
- Water Accounting Error;
- Meter Reading Errors; and
- Water Theft.

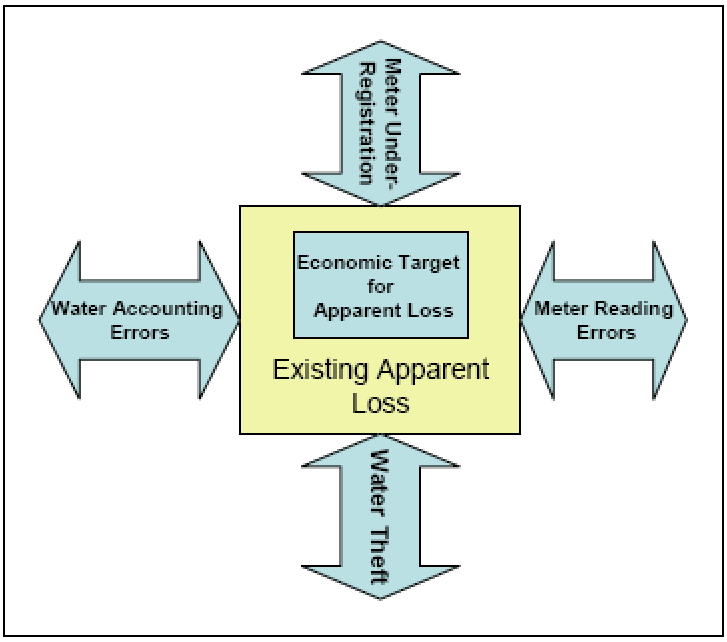

Figure 2.12: The four components of apparent losses.

Source:Rizzo Alex (n.d)

2.5.3 Meter Under-Registration

According to Rizzo Alex (n.d), the following account for meter under-registration in water utility:

- Meter wear and tear;
- Incorrect installation practice;
- Lack of maintenance or calibration; and
- Incorrect meter sizing.

Under-Registration means that, the meter will only read portion of the water that passes through it and therefore, the consumer is only billed for that portion.

2.5.4 Meter Reading Errors

This relates to inaccuracies of the manual reading of the meters of the water utility by the meter reader. Usually this happens when meter readers under read the meters but according to Rizzo (n.d), meter readers can also condone with customers to under read their meters as a way of getting 'some thing' from the customers. To Rizzo (n.d), the solution to this is automatic meter reading (AMR). But Thornton (2002:168), is of the view that AMR has hardly been justified only on the basis of improving apparent losses in a system besides other benefits that come with it, 'such as the block use analysis and pressure monitoring for real losses control'.

2.5.5 Water Theft

Water theft (illegal connection) 'is probably the easiest to conceptualise although sometimes may be very difficult to eliminate' (Rizzo n.d).According to Butler and Memon (2006:196), apart from loss of water to the water supply system, illegal connection (water theft) also play a major role in limiting the water system's ability to increase its level of service. Illegal connection or water theft is where some deliberately bypasses the water meter to get water for a period of time. Some of the causes for water theft are; water scarcity, poor management, lack of awareness, inappropriate tariff system and refusal to allow individuals the do house connection (Butler and Memon, 2006:196). Several factors

account for the difficulties for water utility staff to try to stamp out illegal connections in a water system. Some of these factors are (Butler and Memon, 2006:196),

- The assumption that water is a basic human need and therefore should not be charge for; and
- The involvement of politicians who try to win public support at the expense of sustainability.

The following measures are some of the ways adopted by some utilities of late to regularise illegal connections with aim of stamping out the practice (Butler and Memon, 2006:196);

- Providing an amnesty for those already having illegal connections for them to use the amnesty period to regularise their connections;
- Awareness creation through appeals and advertisement to enable those with illegal connections to regularise them;
- Giving 'on the spot powers' to local managers and operators to regularise illegal connections when detected; and
- Punitive measures taken against those with illegal connections to deter others from doing so. But according to Butler and Memon (2006:197) this should be the last resort and that regularisation should be preferred instead to enable consumers to still get the water they need.

2.5.6 Water Accounting Errors (Billing Errors)

These are the adjustments and procedures carried out by the water utility' billing system that results in wrong billings to consumers, usually under billing customers (Rizzo Alex, n.d). A good example of this according to Rizzo Alex (n.d) is the computerised system that estimates the consumption of 'closed' premises (inaccessible premises). This estimation often leads to under estimation of the actual value of water consumed by the customer. Gokhale (200), as cited in Butler and Memon (2006:198), also list the following as some of the causes of billing errors in a water system;

- Meter readers recording wrong figures after obtaining monetary favours from customers; and
- Inefficiencies and flaws in the billing systems especially in calculation and collection.

Staffs training and automation of billing systems are some of the measures that could be taken to minimise billing errors (Butler and Memon, 2006:198).

2.5.7 Measures to Control Apparent Losses

It is important to be able to measure the apparent losses in water system in order to be able to control it effectively. It is said that "if some thing can be measured, it can be controlled". Apparent losses, just as real losses in a water system can be measured using either top-down approach or the bottom-up approach. Again, just as real losses, it has been recognised that, "measuring apparent losses as a percentage of water supplied is a misleading and overtly simplistic" (Rizzo, et al, n.d). IWA water loss team recommend the use of a concept similar to infrastructural leakage index (ILI) of real losses for the measurement and comparison of apparent losses. This concept uses a base value of five percent of water sales as a reference, and the actual apparent loss value is calculated against this benchmark as follows (Rizzo, et al, n.d):

$$\text{Apparent Loss Index (ALI)} = \frac{\text{Apparent Loss Value}}{\text{5\% of Water Sales}}$$

Rizzo (n.d) outlines some of the approaches that can be adopted to deal with apparent losses in a water supply company. The following section discusses these strategies and the information contained in this discussing is taken from Rizzo (n.d) unless otherwise stated.

The top-down approach uses the IWA water balance in which the apparent loss component of the water supplied into region in specified period in a system is calculated as a percentage. The volume of water supplied less the metered consumption and the current annual real loss is computed as the apparent loss value. According to Rizzo (n.d), this way of calculation is not accurate enough to show the apparent losses in a system. The bottom-up approach ensures the calculation of the real losses in a system through component analysis of the water leakage using minimum night flow analysis or other accurate estimation approach. Bottom-up approach provides the real losses whilst the top-down approach provides metered volume. Subtracting these two values from the system input

gives the value of the apparent losses in a system (Rizzo n.d). The figure 2.13 below outlines the strategies necessary to control apparent losses in a system.

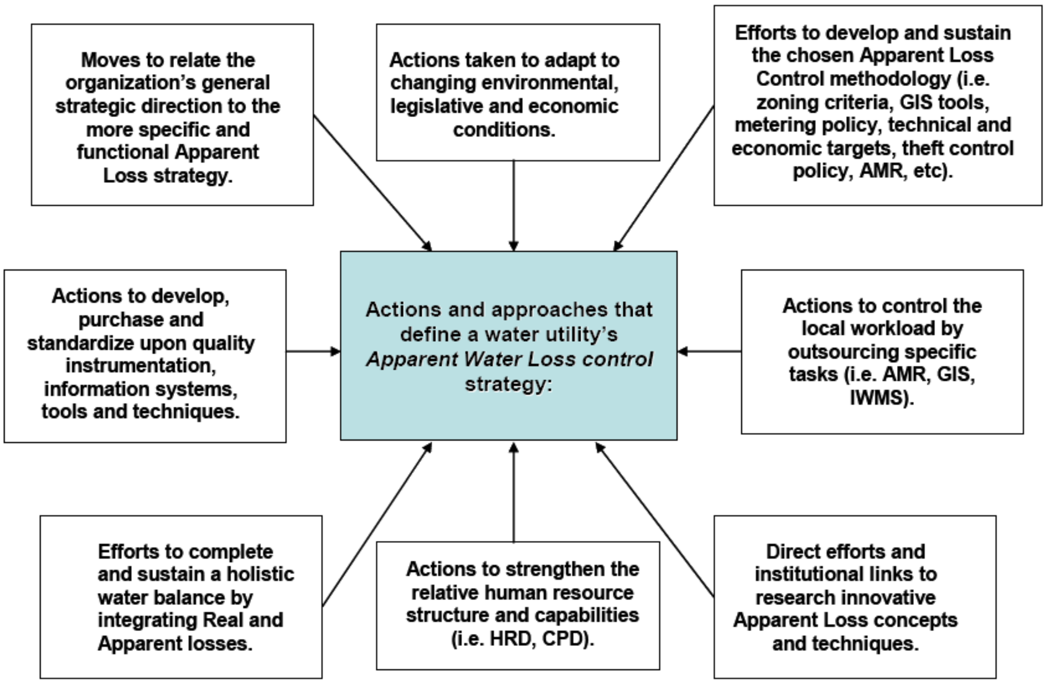

Figure 2.13: Apparent Loss control strategy.
Source: Rizzo Alex (n.d)

Companies would always like to work according to the strategic plans in place which outlines the mission, objectives and action plans for the achievement of the goals of the company. These strategic and action plans would normally informed the type of strategy that would be adopted towards dealing with apparent losses. Water utility managers are not only supposed to know their own strategic plans, but must also know the general trend of affairs prevailing in the locality in which they are operating in order to be able come up with more appropriate strategies that would earn the support of all stakeholders in order to sustain any strategy for apparent losses reduction programme. “A good management team would read the signs of the time and pre-empt the actions required to build and sustain a good apparent loss strategy. The issue is on being proactive as opposed to reactive”.

It is some times more efficient and cost effective to out source for expertise to carry out a specific activity in the water utility. This because no utility can boast of having all the

needed personnel to carry out all expected activities for effective apparent control strategies. One area that normally requires external expertise is in the area of high IT programmes. It is also important to have institutional links with the aim of sharing and supporting each other. The water system would benefit greatly if it is linked to other institutions like IWA where relevant information on water loss strategies including apparent losses are disseminated to water utilities. Not only would institutional links be of benefit to the water utility but also the establishment of its own in-house research and development unit (if this is feasible in terms of financial resources and manpower needs) that deal with issues such as correct metering systems for the water utility. It is through research that the appropriate methods of doing things that are appropriate to the individual organisation can best be obtained.

The last of the strategy to be adopted to deal with apparent losses is the need to recognise the importance of the human resource of the organisation. An organisation is comprised with three categories of resources namely; human resources which is the organisation's employees, physical resources such as information, equipment, instrumentation, plant and building , organisational resources such as internal policies and procedures. It the human resource which combine the other resources for the proper functioning of the organisation and the human resource development and capacity building is of crucial importance for the success or otherwise of any apparent loss reduction strategy. Disgruntled employees (especially the field workers) have the potential to thwarts any programme put in place by top management for apparent loss reduction control. The following factors should be seriously taken in order to ensure the success of any apparent loss reduction strategies embarked upon:

- Training of all employees involved in the various levels of the projects. This should be continuous and cyclic process;
- Ownership, employees should be made to have the feeling of being part of strategy and believe in it;
- Motivation; this should be both intrinsic (acknowledgement and praise) and extrinsic (physical rewards for exceptional achievements).Training is also a good motivator;
- Recognition and respect. These important characteristics are all too often overlooked.

It is also always worthwhile to combine top-down approach and bottom-up approach for the calculation of the water balance which integrates real losses and apparent losses for a clearer picture of the situation. The strategy for the reduction of apparent losses is essentially based upon capacity building;" that building on the HR, physical and organisational resources of an organisation". It is important to always trade-off between quality and cost. Balance should always be made between external resources and the internal staffing for the apparent loss programme to ensure cost-effective programme.

Other more technical approaches to apparent loss reduction are as outlined by Thornton (2002:162):

- Production meter testing;
- Sales meter testing;
- Correct meter sizing;
- Meter replacement;
- Improved meter reading;
- Location of illegal or unregistered connections; and
- Revenue recovery or prepaid systems in areas of low payments.

2.5.8 Apparent Loss Water Audit

Water loss auditing allows components (real and apparent) of water losses to be identified and then the right methodology applied to improve the situation. The purpose is to rigorously compare the summated consumptions of the individual consumer meters with the flows entering a particular zone. Water loss auditing serves as a first step for water balance calculation for a regional or national water system zone (Rizzo et al, n.d). The following steps show how to carry out apparent loss water auditing (Rizzo et al, n.d):

1. **Choose pilot zone**. It is also good to choose a small study zone of about twenty to fifty consumers. The zones should be chosen based on: a) the lay out of the water distribution network, allowing for the chosen segment to be isolated, and b) the ages of the consumer water meters. In this case the second point is of very

importance since the audit would look at the ageing of the meters and their performance.

2. **Metering of the pilot zone inlet flows.** This is probably the most important aspect of the auditing exercise and the water meter measuring the flow into the zone must be carefully calibrated and sized.
3. **Monitoring of the zone meter and individual meters.** The audit exercise would consist of repeatedly comparing the flows entering the zone and individual meters in the zone. This gives the value of the total water losses. The following points should noted in the exercise; the four components of the apparent losses should be assessed individually, and real losses should be completely removed from the scene by either physically removing all leakages, or by calculating the leakage component from the minimum night flow of the zone and then deducting it from the value of the equation.
4. **Studying the financial implications and extrapolating to the wider context.** This final stage is very important. It gives the justification for all future expenses by the water utility for planned apparent water loss control. Calculations must therefore be made accurately of the financial value all the apparent components and the result extrapolated to the supply area. Care should be taken that the pilot area is representative for the larger area if not a number of pilot areas must be tried. Calculations should be made on the payback period and the net present value (NPV) for the various components of the apparent loss control.

2.6 Unbilled Authorised Consumption

2.6.1 Definition

Unbilled authorised consumption is the third component of non-revenue water (NRW). It is" the annual volume of unbilled metered and/ or unmetered water taken by registered customers, the water supplier, and others who are implicitly or explicitly authorised to do so by the water supplier, for residential, commercial, and industrial purposes" (Thornton 2002:39). Farley and Trow (2003:13) list the following as some of the components of unbilled authorised consumptions:

- Water for fire fighting;
- Water for training purposes;
- Water for flushing of mains and sewers and cleaning of supplier's storage tanks; and
- Water for street cleaning, public fountains, and frost protection.

The above consumptions can be classified into two categories of volumes consumed and exonerated and the volumes consumed by the water company (Vermesch Michael 2005).According to Farley and Trow (2003:13) unbilled authorised consumption water in a water utility should normally be small component of the water balance; less than one percent of the system input and where feasible, such consumptions should be metered.

2.6.2 Control Measures

Unbilled authorised water consumption in a utility as stated earlier should under normal circumstance be very small volume on the water balance but this volume can assumed high proportions if not checked. Farley and Trow (2003:13), state that volumes of unbilled authorised consumptions can be managed down without compromising with operational efficiency. Most often due to improper documentation and estimation of these unbilled authorised consumptions, they tend to be abused by those who are legally required to use them. For example, water for fire fighting could be misused.

Vermersch (Personal correspondence, 2008) outlines the following as some of the measures that could be taken in ensuring that unbilled authorised consumptions do not

assumed high volumes. According to him the water utility should have up-to-date lists of all free supply outlets whilst an attempt should be made to answer the following questions:

- Are these supply points fitted with meters?
- How are the supplied volumes estimated?
- Is consumption under control?
- What is the legal basis for the non-charge of these supplies? Is it stipulated in the contract?

It is also necessary that the following steps are implemented:

- Classification of uses into legitimate and illegitimate;
- Optimisation of legitimate use by mitigating waste;
- Eliminate or bill illegitimate uses.

Conclusion

The discussions and presentations made so far in this chapter show that a lot are involved in the management of NRW in any water utility.

The management of NRW should begin with the assessment and measurement of all the various components of NRW as have been mentioned and discussed throughout this chapter. The non conformity of this procedure will likely not lead to the achievement of the desire results in water utility. On the other hand, the careful assessment, measurement and analysis of the various components of NRW have the sure potential to lead to the adaptation of the right procedures and programmes that will ensure the achievement of the desire results.

Chapter Three: Research Methodology

3.0 Introduction

Grinnell (1993) in Kumar (1999:6) defines research as "a careful, systematic, patient study and investigation in some field of knowledge, undertaken to establish facts or principles". Continuing, Grinnell (1993) in Kumar (1999:6) further states that "research is a structured inquiry that utilises acceptable scientific methodology to solve problems and creates new knowledge that is generally applicable". Expressing similar thought, Burns (1994) in Kumar (1999) defines research as "a systematic investigation to find answers to a problem".

When one says he/she is conducting a research to find answers to a question, according to Kumar (1999:4), he/she is implying that the process:

- Is being undertaking within a frame work of a set of philosophies;
- Uses procedures, methods and techniques that have been tested for their validity and reliability; and
- Is designed to be unbiased and objective.

3.1 Types of Methodology

Research work is usually carried out by the use of two distinct procedures; desk study (also known as literature review) and fieldwork. Each of these two approaches has its unique contribution to the success of the research. These two approaches were employed in the current research work. Then again there are several methods and tools which can be used to carry out both the desk study and the fieldwork. These include; interviewing, observation, questionnaires, document reviews and direct correspondence with experts in the subject area.

3.2.1 Literature Review (desk study)

In order to gain enough knowledge and understanding of the research topic and also to assist in the formulation of the right questions that would serve as guide for the research tools for the fieldwork, comprehensive desk study was carried out into the existing literature (see chapter two).

According to Pratt and Loizos (1992:47), it is always very important to first check the already existing information (sometimes called the secondary source) before field work is taken. Literature review (also known as knowledge review), is the systematic study to collect and analysis as much as possible the existing information on the research topic area (Skinner 2003:4.6). Literature review helps the researcher (Kumar, 1999:26, Skinner 2003:4.6,):

- To bring clarity and focus to the research problem;
- Improve the methodology to be used for the data collection;
- Broaden the knowledge base of the researcher in the research area.
- Obtain the current state of the art view of the research area;
- Identify gaps in the current knowledge; and
- Establishing links between the current research and other research on the subject.

3.2.2 Fieldwork

As mentioned earlier, the two main approaches (techniques) used for research work are literature review and fieldwork. Several meanings have been given as to what is the ‘field’ from where ‘fieldwork’ can be carried out. Issues of whether the field should be only considered as moving away from one’s geographical area to another completely new geographical area or the field can be within the same geographical area of the researcher and for that matter the field worker are frequently discussed. According to Clifford (1997) in Scheyvens and Storey (eds) (2003:8), “when one speaks of working in the field, or going into the field, one draws on mental images of a distinct place withy an inside and outside, reached by practices of physical movement”. Again, according to Geertz (1988) in Scheyvens and Storey (2003:8), “being there demands at the minimum hardly more that a travel booking and permission to land; a willingness to endure certain amount of

loneliness, invasion of privacy, physical discomfort; a relaxed way with odd growths and unexplained fevers; a capacity to stand still for artistic insults, and the sort of patience that can support an endless search for invisible needles in infinite haystacks".

Fieldwork is used for the collection of primary information just as literature review is used for the collection of secondary information (Pratt Brian and Liozos Peter, 1992:47). There are several tools and methods used for the collection of data in the field. The choice of methods depend on factors such as; purpose of the study, the resources available, the skills of the researcher, the socio-economic characteristics of the study population (educational levels, age-structure and ethnic background) and the environment (Kumar 1999:105).

3.3 Data Collection

3.3.1 Types of Data

There are two types of data; quantitative data and qualitative data. Whilst quantitative data puts numbers and size to the data collected and gives breadth but limited depth, qualitative data on the other hand expresses opinion and feeling of others and gives depth but limited breadth to the data collected. Depending on the subject matter of the research work, one of these two types of data will feature more prominently than the other. It is also possible in certain data collection techniques to for the two types of data to be featured. According to Laws Sophie with Harper Caroline & Marcus Rachel (2003:273), both qualitative and quantitative information could be collected when one uses semi-structured technique for interview. Both qualitative and quantitative data collection have their strengths and weakness and these would be discussed in the sections which follow.

3.3.2 Quantitative Data

"Quantitative data are data that represent a quantity of some sort: How much? How big? How many? "These are questions that usually elicit a numerical answer" (Skinner 2003:4.5). It is usually characterised as being 'objective, representative and most important, specified in numbers' (Scheyvens and Storey, 2003:38). Its main strength is that quantitative data "can be verified and replicated". (Scheyvens and Storey, 2003:38). Even though quantitative data has a number of values in research work, the techniques of

quantitative data collection can be wrongly used. Scheyvens and Storey (2003:50) outline some of the weaknesses of using the techniques of quantitative data collections as follow:

Representation: where conclusions are drawn based on the analysis of the data collected from a small section of a large group. There is therefore the need for the researcher to be scrupulous in the selection of the sample group. The rich can not speak for the poor; neither can men speak for women and who speak for the children? Numbers can also be deceptive. For example, the use of percentages in determining the non-revenue water as of a system, have been proven to be misleading in water loss reduction management (Thornton 2002:44).

Too much Data: one can easily be swayed by the easiness of collecting data through the use of techniques of quantitative data collection. Questionnaires can be loaded with several questions, and in the field one can be tempted to collect any bit of data that is chanced upon to the extend that given the time frame of the research work, quality work can not be produced. Data which are relevant to answering the research questions should be collected in the field.

The quality of the data collected: care should be taken to ensure that the data collected by quantitative data techniques are actually the true reflection of the situation. According to Scheyvens and Storey (2003:54), half-hearted and incomplete or incorrect observation can creep in when one is working in different cultural context. There are several techniques that are used for quantitative data collection.

3.3.3 Qualitative Data.

According to Bryman and Burgess (1999) in Scheyvens and Storey (2003:57), qualitative research seeks to fulfil three aims. “First it seeks to understand the worlds through interacting with, empathising with and interpreting the actions of its actors”. By this, qualitative methods seek to understand people’s worlds and the reason for their actions. Again qualitative methods “tend to collect data in the natural settings rather than artificial and constructed context”. And thirdly” it tends to generate theory rather than testing it”. Kumar (1999:10) also describes what a qualitative research is about by asserting, “The

description of an observed situation, the historical enumeration of events, an account of the different opinions people have about an issue, and a description of the living conditions of a community, is an example of qualitative research”. Furthermore (Skinner 2003:4.5), qualitative research seeks to answer the “why” questions. It provides in-depth analysis to opinions and attitudes.

Among the techniques used for qualitative data collection are; interviewing, focus group discussion, conversation and discourse analysis, fieldwork diaries, life histories and oral histories, photographs, films, and video and documents and participant observation (Scheyvens and Storey, 2003:58).

3.3.4 The chosen Methodology

In the current research, the following methodologies were used for the fieldwork data collection:

- Document review;
- Participant observation; and
- Interviewing.

3.3.5 Observation

Observation as a data collection technique can be used for both qualitative and quantitative data collection. Usually observation techniques result in precise measurements that are amenable in quantitative data analysis but observation might also involve measurements and analysis of human behaviour which then requires more subjective assessments of what is actually happening and being measured” (Scheyvens and Storey, 2003:39). In such situation qualitative technique of participant observation is employed. The aim of

observation in research works “is the production of public knowledge (empirical and theoretical) about specific issues which can be used by others in a variety of ways”, and where it is used as the main research method, it can be used for the collection of descriptive quantitative data (Sapsford and Jupp, eds. 1996:57).

Observation can be used for a variety of purposes in a research work; for preliminary exploration of the research or can be used at the end of the research to supplement or provide check on data collected through other techniques at the initial stages of the research (Sapsford and Jupp, eds. 1996:57).

There are two main approaches to observational research (Sapsford and Jupp, 1996:60), the more structured also known as systematic and the less structured, some times referred to as ‘ethnographic’ or ‘unstructured’ observation. The more structured observational method produces more accurate quantitative data on particular prespecified observable behaviours. On the other hand, less structured observation aims to produce qualitative description of human behaviour. It involves less prestructured plans for the data collection. This does not, however means that the researcher goes to the field with no aim and what to observe. It can be combined with other techniques such as interview and questionnaires.

The current research work used the qualitative, less-structured participant observation approach where the researcher was involved with field work with the host organisation’s (Aqua Vitens Rands) fieldworkers in carrying water loss reduction activities whilst he took note of how things were been done.

3.3.6 Strengths of Observational Research

According to Sapsford and Jupp (1996:58) observation as a research methodology has clear advantages over interview and questionnaires in the following sense:

- Information about the physical environment and about human behaviour can be recorded directly by the researcher without having to rely on the retrospective or

anticipatory accounts of others which for number of reasons such account could be inaccurate;

- The observer (in this case the researcher), may be able to 'see' what the participants can not see and provide the detailed description require. Those things which are normally taken for granted may be seen by the observer as 'strange';
- Observation can provide information on environment and behaviour of those who can not speak for themselves, such as children and animals. There are others who would not have the time or are afraid in taking part in interview or questionnaires and observation is the sure way of getting information from such ones; and
- Data from observation can be a useful check on, and supplement to, information obtained from other sources.

3.3.7 Limitations of Observational Research

In spite of the above strengths of observation as a data collection technique, there are some inherent weaknesses of using observation for data collection. Below are some the limitations of observation as a tool for data collection as outline by Sapsford and Jupp (1996:59):

- The environment, the event, or the behaviour to be observed may be inaccessible to the observer. Certain human behaviours are simply inaccessible to observers and access to certain highly elite group may be difficult;
- People may consciously or unconsciously change the way they behave once they become aware that someone is observing them. This can make the observational account of their behaviour to be inaccurate to how they would have behaved naturally;
- The third weakness is that, observations are inevitably filtered through the interpretive features of the observer and therefore the interpretation of the behaviour observed may not be the representation of the reality on the ground; and
- Fourthly, observational research is time consuming and therefore costly when compared with other research methods. In the experience of this researcher, it came necessary to travel from the UK to Ghana for the data collection as observation was one of the key research methodologies for this research work.

3.3.8 Interviewing

Interview is conducted by administering a series of questions to an informant and their responses are recorded (Laws Sophie with Harper Caroline & Marcus Rachel, 2003:286). Interviews are used as research methodology for data collection when:

- One needs to know about people's experiences or views in some depth;
- One is able to rely on information from small number of respondents;
- The issue is sensitive and people may not be able to speak in a group; and
- The respondents may not able to express themselves fully through a written questionnaire; (Laws with Harper & Marcus 2003:286).

There is a wide variety of contexts in which interviews can be conducted and there are different purposes for which interviews are conducted within and across those contexts (Daphne, 2000:6). Interviews for research defers from other interviews such as counselling interview and clinical interviews in that research interviews are "not intended to be an agent of change" and again research interviews defer from other source of data collection methods such as questionnaires in that interviews are conducted orally, which makes factors relating to interpersonal communication paramount in interviews (Daphne, 2000:20). One main advantage of interview over other forms of data collection is the ability for the interviewer to seek further clarification of the responses from the respondent by probing the initial responses. This gives richness to the data, allowing many individual differences in opinion and reasoning to be uncovered (Daphne, 2000:20). This feature of interview as a tool for data collection was an invaluable ingredient to the work of this research. Again, as mentioned earlier, its makes qualitative data collection more natural and also as a primary source of data.

In the current research work, both the structured and semi-structured forms of interview were used in a mix form as it was realised from the research questions that this was the best way to get as in-depth as possible the many dimensions (and sometimes the different approaches based on specific conditions prevailing at the particular water utility) of non-revenue water management. Again highly structured interviews do not allow good qualitative data to be elicited (Scheyvens and Storey, 2003:58).

3.3.9 Weaknesses of Interviews

The following points are some of the inherent limitations of interviews as tools for data collection (Scheyvens and Storey, 2003:58)**:**

- Recording of the responses is one of the weaknesses of interviewing. Writing while someone is speaking can put him/her off ;
- Tape recording and later transcribing is also time ; and
- Interviews can result in a one-way traffic of information from which only the researcher benefits.

3.3.10 Documents Review (Data Review)

Documents review is another source of data collection which is used for qualitative analysis of existing data. Documents, apart from being a means by which data can be collected on a subject area; they are also sources of data in their own rights. The use of documentary research analysis for data collection is known as using secondary source (Scheyvens and Storey, 2003:301-303).

3.3.11 Why the chosen Methodologies

The above three methodologies were used for the field work in Accra as they were considered more appropriate in enabling the researcher to elicit the right information that would appropriately answer the research questions. As discussed above, these methodologies have certain inherent characteristics which in the view of the researcher will help to lead to the collection of the right data for the research work. For example, during the interview section, semi-structured method with open-ended questions was used (see appendix A). This method made it possible for the respondents who were mainly professionals in their chosen positions to come out more freely of what they think about the management of NRW. Again, this methodology allowed the researcher to add additional questions to the earlier ones prepared and also to alter the wording of some of

the questions in order to press further for information as it became necessary in the course of the interview process.

Also the participant observation method afforded the researcher to gain first hand information as to what actually goes on in the field. In this method both structured and unstructured approaches were used. This was to guide the researcher to look for specific information (see appendix A) relating to NRW management whilst at the same time allowing the staff and the activities being observed to flow in a natural way to gain deeper understanding as to why certain things were done in a certain way (Sapsford and Jupp (eds.), 1996:61).

The document review was to afford the researcher the opportunity to access (using the document review guide which was prepared earlier for the fieldwork, see appendix A), the processes being adopted by the management of the water utility to manage the system with specific interest in NRW issues. This methodology made it possible for the researcher to know the management priorities and what they consider as the most important issues in the management of the water utility since in the words of Sapsford and Jupp (eds.), (1996: 302), "official documents provide valuable data for the analysis of official definitions of what is deemed as problematic, what is viewed as the explanation of the problem and what is deemed to be the preferred solution".

3.4 Preparation for the field work in Accra

3.4.1 Introduction

Whilst it is important for the researcher to prepare adequately for the fieldwork, the preparation can never be completed until one gets to the field. This is because apart from the research methodologies and other academic issues, there are also practical issues which can only be known whilst in the field (Scheyvens and Storey, 2003:77). This reality notwithstanding, it is also important that adequate preparation should be made before one embarks on any fieldwork. Certain practicalities must be worked through even before the trip is made. Adequate preparation, both in terms of methodology and practical issues would go a long way to ensure that the fieldwork is successful (Nash, 2000a and Robson et

al., 1997 in Scheyvens and Storey, 2003:77). In the light of this, the following preparations were made prior to departure for the field work in Accra, Ghana.

3.4.2 Guides for the data collection in the fieldwork

The preparation that was made in this direction was to formulate the appropriate and relevant questions that would guide the researcher to elicit the right information through the chosen methodologies which were mentioned earlier. These questions were formulated, read through several times against the research aim and objectives and reformulated with the guidance of the research supervisor before final lists of questions were chosen (see appendix A,)

3.4.3 Health and Safety Issues

Even though there was not much to be bordered about in terms of safety and health issues so far the activities of the current research work was concerned. This was because the research work does not involve activities that normally pose danger to health. Nonetheless care was taken not to expose myself and my clients to any form of danger during the course of the research work. The only area in the course of the research work, which had an element of danger in it, was the travelling arrangements that took me to the Kpong Headworks and the field trip with the lost control team. This was done with extra care

3.4.4 Contacts

About two months to the departure to Ghana, letter from the department was sent to the Ghana water company informing them of the author's coming there for data collection for the project work. Unfortunately about a month latter when contact was made to the company, I was told that they have not received any letter to that effect A series of correspondences through e-mails and telephone calls was then by the author thereafter. Fortunately, these efforts yielded the needed results with the establishment of the right contacts who coordinated the activities whilst the author was in Ghana.

3.4.5. Research Permission and Ethical Issues.

In this instance, permission was not necessary in the form of visa to the country of the research work. What was needed, however, was the permission to use official documents whilst the researcher was at the premises of the organisation for the research work. This researcher was well aware of the difficulties one can encounter in trying to gain access to official documents in Ghana. In the light of this, certain plans were made ahead of time in order to overcome any hindrances. It was decided that a persuasive and persistent approach would be adopted in the bid to gain access to the necessary documents of the organisation for the data collection. This approach proved to be successful as the researcher kept asking and “insisting” on being given the needed documents.

There was also the issue of political considerations which the researcher had to be aware of. In Ghana, like most third world countries, almost all state institutions are politically sensitive such that when one is dealing with state institutions such as the water company in Accra, one need to be cautious not step on toes of “big men” in power else that can lead to the research work being hampered. With this in mind, the researcher was careful not to go into issues that were politically sensitive. For example, it was realised that in the management contract, the grantor (the Ghana water company and for that matter the Government of Ghana) was to provide the needed infrastructural development that would facilitate the effective management of the water system. This was not been effectively done by the grantor and that has delayed the implementation of a lot of programmes by the management in order to carry out NRW reduction activities.

3.5 Fieldwork at ATMA

3.5.1 Background

The fieldwork took place in the Accra-Tema Metropolitan Area branch (ATMA) of the Ghana Water company Limited (GCWL), now known as Aqua Vitens Rand Limited (AVRL), the operator in Ghana from the 16th of June, 2008 to Friday 4th July, 2008. As the name implies, the operation area of ATMA comprises the Accra and the Tema political Metropolitan areas. ATMA (AVRL April, 2008) has an estimated population (for 2007) of

about two million nine-hundred and fifty-four thousands, ninety-one (2,954,091).The service area has customer strength of one hundred and eighty-five thousand, three hundred and eighty-seven (185,387) as at the end of April 2008 (see appendix A). The estimated production per cubic meter per day (system input) in 2007 is Three hundred and Twenty-one thousand, five hundred cubic meters (321,500m^3, see appendix D).This is against a daily demand (m^3/d) of Three hundred ninety-five thousand, eight hundred and forty-eight cubic meters (see appendix D). The entire ATMA area has been divided into three sub-administrative regions by the water utility. These regions are; Tema, Accra West and Accra East. Like the other political regions in Ghana, each of these regions have it management staffs with the Regional Chief Engineer as the head (see figure 4.2 below).

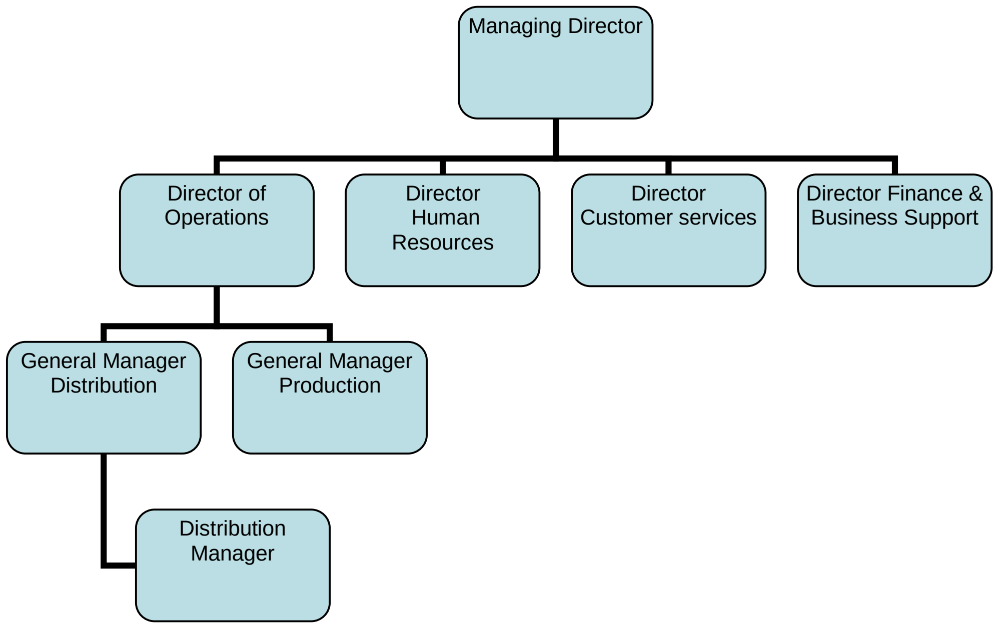

Figure 3.1: The existing management structure of GWCL (AVRL) at the Head Office

Source: Elaborated by the author.

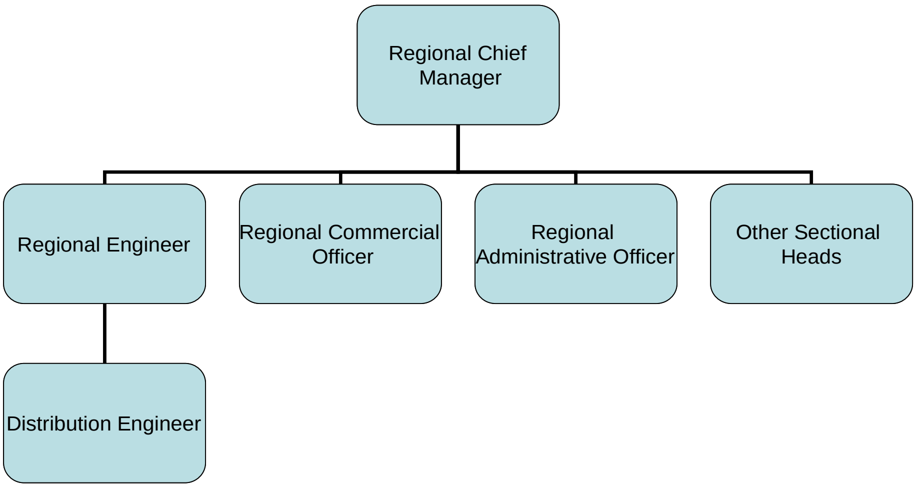

Figure 3.2: The existing Management Structure of GWCL (AVRL) at the regional levels.

Source: Elaborated by the Author.

The system is currently operating on intermittent supply using a rationing programme (see appendix E) due to the imbalance between supply and demand. This imbalance between supply and demand is basically as a result of population growth in the Accra-Tema metropolis which has not seen a corresponding increase in the water supply facility in the area.

The current water treatment works were built about forty years ago and has since not seen any expansion. The water supply to the residents is supplemented by water tanker services operated by both the private sector and the utility itself. The entire Ghana water company is currently being operated by Aqua Vitens Rand on a management contract for five year term. The contract began on the 5th of June, 2006.

3.5.2 Data Collection Methods used at ATMA

The methodologies used for the data collection for the fieldwork at ATMA, as stated earlier were:

- Documents review;
- Interviewing; and
- Participant observation.

3.5.3 Document Review

On arrival at ATMA, on the morning of 16th June, 2008, after protocols, a request was made for relevant documents for a review. The following documentations were obtained for review from the officers concern:

1. "A review of the June 2007 NRW strategy developed by Aqua Vitens Rand Limited for Ghana West Africa-Draft report by Richard Rogers, April, 2008".
2. "Non-Revenue Water; Measurement and Reduction of NRW, June 2007".
3. "Management Contract for Ghana urban water between Ghana Water Company Limited and Vitens Rand Water Services Bv and Aqua Vitra Limited, October, 2005".
4. "Report on the Establishment of GIS for ATMA, April16th, 2007, by Richard Appiah Otoo".
5. The annual reports of 2006 and 2007 of the operations of the water system.
6. "Table of ATMA water demand calculation and cover by production 2nd April 2008".
7. "A Road Map of initiatives to reduce Non Revenue water in Ghana, May 2008".

The review exercise was followed with unstructured interview with the General Manager, Operations and Maintenance (Head Office), and the General Manager, Distributions (Head Office) for further clarifications. The author also engaged in unofficial discussions with some members of staff as part of protocols.

3.5.4 Semi-Structured and Unstructured Interviews.

In all twenty staffs, both senior staffs (top management staff) and middle level staffs were interviewed from all the departments (see table 3.2 below) and the methodology used was semi-structured interview except with the Leakage Control Manager (Head Office), the General Manager, Distribution (Head office) and General Manager, Operations and Maintenance (Head Office), where in addition to the semi-structured interviews, there was a follow-up with unstructured interviews with these officers. This was done to get clearer answers on certain specific issues bordering on their schedules. The Leakage control manager had recently been appointed to this position and was drawing up programmes and activities pertaining to his area. The unstructured interview was organised with him to let

him throw more lights on his plans to controlled real losses and the specific strategies he intended to use. The General Manager, Operations and Maintenance and the General Manager, Distribution were engaged in a follow-up unstructured interviews, as indicated earlier, to throw more light generally on portions and issues stated in some of the documentations that were reviewed. For Example, why the concentration of most of the companies efforts on apparent losses as against the other components of NRW reduction strategies, the issue of measurement of NRW in the system in the absence of comprehensive metering within in the system and also the issue of contractual obligations on both the grantor (Ghana water Company Ltd.) and the operator (Aqua Vitens Rand) especially with regard to NRW management. As can be seen from tables 3.2a and 3.2b below, staff members were interviewed on areas mainly bordering on the schedules. This was done to get the "best" answers as possible for the data collection exercise.

Table 3.2a – Staff Members Interviewed and the Areas they were interviewed at ATMA (Head Office).

No.	Officer Interviewed	Area (s) Interviewed	Date
1	General Manager (operations and maintenance)	Real Losses/Apparent Losses	16/06/08
2	Leakage Control Manager	Real Losses	17/06/08
3	Communication Manager	Apparent Losses/Unbilled Authorised Consumption	17/06/08
3	Customer care Director	Real losses/Apparent Losses/Unbilled Authorised consumption	18/06/08
4	Production Manager (acting)	Real Losses/Apparent Losses	18/06/08
5	IT Manager	Apparent Losses/Unbilled Authorised Consumptions	19/06/08
6	Administrative Officer	Apparent Losses/Unbilled Authorised Consumptions	19/06/08
7	Finance and Business Services Officer	Real Losses/apparent Losses	20/06/08
8	General Manager (Distribution)	Real Losses/Apparent Losses	20/06/08
9	GIS Manager	Real Losses/Apparent Losses	24/06/08
10	Metering Shop Manager	Real Losses/Apparent Losses/Unbilled Authorised Consumption.	24/06/08
11	Customer Survey Manager	Apparent /Real Losses/Unbilled Authorised Consumptions	25/06/08

In order to make the collection of the data easier and also to facilitate the easy analysis, the collection of the data were carried out along the IWA recommended best practices for NRW reduction (IWA, 2003) as depicted by figures 2.2 and 2.14 (sections; 2.4, 2.5 and 2.6 of this report, where the internationally accepted practices for the control of NRW as

recommended by IWA have been treated) . These categories were chosen as they are the internationally accepted strategies for NRW management. This was also to enable the right recommendations to be made where appropriate for the improvement of the strategies being adopted by the management of ATMA at the end of the research work.

Table 3.2b – Staff Members Interviewed and the Areas they were interviewed at ATMA (Regional Offices)

No.	Officer Interviewed	Area of Interview	Remark	Date
1	Commercial Manager	Apparent Losses/Unbilled Authorised consumptions	Accra East Region	25/06/08
2	Chairman(Loss Control Team)	Real Losses/Apparent Losses/Unbilled Authorised consumptions	Accra East region	25/06/08
3	Regional chief Engineer	Real Losses/ Apparent Losses/Unbilled Authorised Consumptions	Accra East Region	26/06/08
4	Distribution Engineer	Real Losses/Apparent Losses/Unbilled Authorised Consumption	Accra east Region	26/06/08
5	Regional Engineer	Real Losses/Apparent Losses/Unbilled Authorised Consumptions	Accra East Region	26/06/08
6	Regional Engineer	Real losses/Apparent Losses/Unbilled Authorised Consumption	Accra West region	27/06/08
7	Regional Engineer	Real Losses/Apparent Losses/Unbilled Authorised Consumption	Tema Region	27/06/08
8	Commercial Manager	Apparent Losses/Unbilled Authorised Consumptions	Tema Region	27/06

The categories are grouped under real losses, apparent losses and unbilled authorised consumption as follows:

1. Real Losses:

- Active Leakage Control Programme;
- Infrastructural Management;
- Speed and Quality of Repair;
- Pressure Management;

2. Apparent Losses:

- Reduction of metering errors;
- Water Theft;
- Reduction of Human Errors;
- Reduction of Computing Errors;

3. Unbilled Authorised Consumption

3.5.5 Participant observation

A day's trip was made to the Kpong headworks and a day's fieldwork was also organised with the Loss Control Team at Accra East. This was to afford the researcher the opportunity to assess the input source of the water system in ATMA and also to observe how the Loss Control Team performs their work on the field.

3.5.6 Conclusion

The choosing of a research methodology for a research work is as important as the data that would be collected. The above methodologies that were used for the current research work were observed to be the ideal ones though time constraints did not allow the researcher to contact all relevant people and places for the research work. For instance, ATMA has two main headworks (Kpong and Weija) but time constraints allowed the researcher to visit the Kpong headworks only. Again it would have been ideal to have had more of field work with loss control teams and possibly the maintenance team to have more first knowledge of the activities that goes on in the field. This could have given a better view of what actually happens in the field. It is considered that just one field trip was not adequate enough to give the needed understanding of what goes on in the field and to appreciate the workload and difficulties the field staff encounter in the field.

It was however observed that choosing methodologies have proven to be effective and efficient in assisting the collection of the right data for the research work.

Chapter Four: Research Findings

4.0 Document Review

This research work was set out to investigate; the non-revenue water levels in the water system in Accra, the management strategies being adopted to address the NRW levels and to come up with some recommendations that will help to improve the water service delivery in Accra. This chapter shows the findings that were obtained at the end of the three weeks research exercise at Accra (ATMA) using the research methodologies discussed above. The documents that were reviewed were as mentioned in section 3.5.3 above. The following findings were obtained from the document review:

- The NRW within the system is estimated at 57% (figures from 2006, 2007 and first quarter of 2008 operational reports). Also see appendix A of this report.
- The calculation of the NRW within system is based more on estimation rather than actual measured figures. The following is an excerpt from the non-revenue water management strategy prepared by the management of the system to the Grantor showing the method of calculation of NRW within the water system. “The present calculation of the actual system input is based on pump characteristics and estimated running hours of pumps and some historical installed and uncalibrated magnetic and mechanical flow meters. Billed authorised consumption is estimated based on the volume delivered to the customer”;
- Average repair time is quoted as within 48 hours from the time of reported burst and leakage;
- Close to 40% of the total consumption within the system is estimated as a result of lack of complete metering within the system;
- The estimation of consumption of the unmetered customers is based on number of persons per household and where the customer was previously metered, the consumption is based on the previous records;
- Reported leakages and pipe bursts in numbers in 2007 was 9489;
- Billed customers for 2007 is 135,240 and the unbilled customers (these comprise of customers on suspension and disconnected) for the same period is 59459. The figures at the end of the first quarter (ending of April) of 2008 are 127,257 and 58,130 respectively;

- The metering ratio of the system at the end of the first quarter of 2008 is 74.0. The number of working meters at the same period is 83,525;
- There is a stated average 1% annual reduction in NRW levels for 2006 and 2007 operation years. This was against the mandated figure of annual reduction in NRW levels of 5% as stated in the management contract;
- There is the formation of Loss Control Teams (seven membership) whose mandates are mainly to check all manner of water thefts (illegal connections, by-passes and alteration of meter readings) within the system in the regions; and
- Comprehensive programmes and activities have been drawn up by management for the control of NRW in the system, as contained in the documents "Non-Revenue Water; Measurement and Reduction of NRW, June 2007" and "A Road Map of initiatives to reduce Non Revenue water in Ghana, May 2008".

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4.1 Interviews

At the end of the interview section, the following themes emerged as a result of the administering of the interview guides that were prepared at the on set of the project work (Appendix A). As stated earlier, in all twenty people were interviewed. The respondents in table 4.1 follow the same order as in tables 3.2a and 3.2b above and therefore the coding R1…..R20 correspond to the officers mentioned. The themes that emerged were:

- Technical (TC)
- Policy frame work (PFW)
- Organisational structure (OS)
- Capacity Building (CB)
- Logistics (LG)
- Socio-Cultural (SC)

Table 4.1: Themes that emerged from the Interviews

Respondents	TC	PFW	OS	CB	LG	SC
R1	√	√			√	√
R2	√					√
R3	√	√		√		√
R4	√	√				
R5		√		√		√
R6				√	√	
R7		√		√		
R8	√	√		√		
R9	√	√		√		√
R10				√		
R11	√			√	√	√
R12	√	√	√		√	√
R13		√		√		
R14	√		√	√	√	√
R15	√	√	√			√
R16	√		√			√
R17	√	√	√			√
R18	√	√				√
R19	√	√	√		√	√
R20		√	√	√		√

The following boxes further elaborate the key issues that were mentioned by the interviewees under the above themes.

Box 4.1 Technical issues

The following technical issues emerged:

1. NRW was seen as a problematic issue within the system.

2. Active Leakage control not being carried out because there are generally low pressures within the system.

3. No infrastructural programmes in place.

4. No pressure management programme in place.

5. Awareness of the deteriorating condition of the infrastructure of the system. E.g. some of bulk meters at the head works are not functioning which has made it difficult to calculate the system input.

6. It is assumed that most of the water losses in the system are from apparent losses. This is evidence by activities such as the formation of the lost control teams in the regions whose activities are mainly to check water thefts, the programme of meter repairing and replacements of faulty ones and the installation of meters on all commercial consumptions. There were no activities on the ground relating to the management of real losses besides passive leakage control.

7. Most of the top management staff at the head office are of the view that the most crucial issue now is to tackle water losses especially apparent losses rather than system expansion. This is again evidenced by the current strategies and activities being drawn-up by the management of the system as contained in the documents that were reviewed. These strategies and activities are mostly directed towards NRW management with no real programmes towards system expansion and level of service. For instance, when the this researcher suggested that system expansion and level of service have all got great potential to reduce water thefts, the customer care director was of the view that there was no point of further injecting capital resources into the system when what have already been put in place can not fully be accounted for. Also the acting production manager at the head office, intimated to the researcher during the interview that management was previous more concerned with technical issues of water production, system expansion and real losses but now the attention is on apparent losses.

Box 4.2 Logistical Issues

The main logistical problems that were mentioned as facing the organisation were transportation for field staff including meter readers, and meters for effective metering of the system.

Box 4.3 Policy frame Work

The terms and conditions of the management contract especially with regard to infrastructural management have greatly affected the NRW management programme. Top management officials at the head office expressed the view that the lack of response from the grantor for the provision of the needed infrastructure has greatly affected their programmes for the management of NRW.

Box 4.4 Organisational Structure issues

1. Some staff members in the regions were of the view that they were not involve of most of the activities and programmes being planned and implemented from head quarters. 2. Meter readers are generally seen as operating in their own "world", determine what to do and what not to do. 3. It is perceived that some staff members are condoning and conniving with the public to engage in water theft activities such as illegal connections, by-passes and tempering with water meters.

Box 4.5 Capacity Building

Lack of capacity building (training) for most staff members including the meter readers, and billing department, even though some form of training relating to general administrative and work ethics were mentioned in the annual reports as been given to staff members, no where was it mentioned during the interviews and the document review that special trainings have been organised for the members of staff specifically for the management of NRW.

Box 4.6 Socio-Cultural Issues

1. Some members of the public are seen as engaging in illegal activities to the detriment of the water system. These illegal activities include; illegal connections, by-passes, tempering with meter readings and direct stealing of the water meters.

4.2 Participant observation

A days trip was organised with the loss control team in Accra East to enable the author observe how the team carries out their activities in the field. The exercise took about eight hours. The team went to a predetermined area of the supply area and enter each house to assess whether there was water supply to the premises. If water was being supplied to the house, they would then find out whether the premise was a registered customer. They would then find out whether the supply was properly passing through the installed meter (if there is any). It was detected during the exercise in one of the houses visited that the pipeline leading to the yard standpipe was not passing through the meter. Further investigation led to the fact that that mistake was committed by the staffs of the system who were asked to change the position of the meter due to the stealing of the previous meter at the house. In the course of doing this, they mistakenly left the line leading to the yard standpipe outside the meter.

4.3 Summary of Research findings

Looking at the responses obtained from the interviews and the findings obtained from the other research methodologies, the situation at ATMA as compared with internationally accepted procedures for NRW management can be summarised as shown in tables 4.2a 4.2b below. The coding technique (Box 4.7) was used to summarise the results. The levels of implementation were determined taking into consideration the activities and procedures that are internationally accepted as best practices for the implementation of each of the components of NRW management. For each of the NRW management components, there should be a systematic and well planned procedures and activities for the implementation of that component. These procedures and activities should be monitored, measured and reviewed against the results that will be unfolding with time. For instance, for effective infrastructural management, there should be an up to date records of all the infrastructural components of the system with their dates of installation; effective periods of operations; dates for recalibration, replacements and renewal; and the possible costs and effects associated with these activities and also the benefits they will have on the water system.

Box 4.7: Coding showing the level of implementation of the strategies for NRW management at ATMA.

- Very highly been implemented – coded as 5
- Highly been implemented – coded as 4
- Averagely been implemented – coded as 3
- Lowly been implemented – coded as 2
- Not been implemented at all – coded as 1

Table 4.2a – Coded Summary of Research findings at ATMA (Real Losses)

Strategy	1	2	3	4	5	Notes
Active Leakage Control	√					
Infrastructural Management			√			
Speed and quality of Repairs			√			
Pressure Management	√					

Table 4.2b – Coded summary of Research Findings at ATMA (Apparent Losses and Unbilled Authorised Consumptions)

Strategy	1	2	3	4	5	Notes
Water Theft			√			The formation of Loss Control teams in the regions within ATMA, whose core mandate is to check water theft, is seen as step in the right direction which may lead to curbing the incidence of water theft.
Reduction of Human Errors		√				
Reduction of Computing Errors		√				
Unbilled Authorised Consumptions					√	ATMA has very few customers who fall under this consumption bracket and up to date records of these customers were available. All other customers including government departments are all billed.

Figure 4.1: The Volta River from where water is pumped for treatment at the Kpong headwork.

Figure 4.2: Office of the Kpong headwork.

Figure 4.3: Water treatment plant at Kpong head Works.

Figure 4.4: A PVC pipe which was inadvertently used to by-pass a meter to a yard stand pipe in Accra.

Figure 4.5: Senior Staff members (head office) at a review meeting on NRW at ATMA.

Chapter Five: Analysis

5.0 Analysis of the Research Findings

The actual levels of the NRW is a guess work as a result of lack of effective and adequate metering of the system both at the input side (bulk metering) and customer service side (customer meters). In the same way the basis of the 5% reduction rate as quoted in the management contract document as one of the contractual obligation for the management of the system can not be assessed. It is therefore also difficult to accept the quoted 1% NRW reductions for the two years of operation of the system by the current management as true reflection of the situation of NRW within the system. NRW management begins with measurements and determination of actual figures of water losses within a system. This can be done using the top-down annual water balance or bottom-up component analysis (IWA 2004). See section 2.3 for detail discussion of these methods. The results of such measurements can then form the basis for monitoring, evaluation and assessment of the success or otherwise of any strategies that would be adopted.

Whilst top management at the head office appear to have the view that the lack of prompt response from the grantor was having a negative impact on the programmes and activities drawn up for the management of NRW, the staff in the regions appeared to have the view that what is lacking is real commitment to tackle the issue. It would therefore be beneficial if concerted efforts are adopted to address the NRW situation in the system than the blame game currently going on. Effective NRW management calls the involvement of all the staff of the system (Farley and Trow 2003:79).

5.1. Real Losses

1. **Active Leakage Control**: there is no form of active leakage control currently in place within the system. Management attributed this to the fact that there are generally low pressures within the system and therefore it was expected that there would be minimal

leakages. But within any water utility, there are certain leakages which can go for several days and even years without being detected except through active leakage control measures.

The current strategy to deal with real losses is solely through passive leakage control. (The system only responds to leakages and bursts, as they are reported or identified by the staff of the system).

2. **Pressure Management**: there is currently no form of pressure management being carried out within the system. Again this was attributed to the fact that the system is already operating generally under low pressures.
3. **Infrastructural Management**: There was lack of complete infrastructural management procedures in place. The system currently carries out some meter repair works and recalibration of meters. There was also programme in place to fix meters on all commercial consumers' connections. These activities fall short of any meaningful infrastructural management in any water system. As discussed earlier, any infrastructural management begins with detail records of the individual components of the system, stating their dates of installation, effective periods and renewal times including the expected costs and effects these activities would normally have on the system.
    - **Speed and quality of Repairs**: Even though it was noted during the document review that reported leakages and bursts are repaired within 48 hours. It was however observed during the interview section that reported leakages can be left unattended to for days and weeks.

5.2 Apparent Losses

The current activities in the field which are specifically aimed at reducing apparent losses in the system are;

- The formation of LCTs with specific mandate of checking illegal connections, by-passes and other fraudulent activities in the field; and

- The repair and recalibration of the existing meters (there is also replacement of some of the meters and the fixing of meters on commercial service lines) to ensure more confidence in the figures of the components of NRW.

There were no programmes currently on the ground for the other strategies for the management of apparent losses (reference section 2.5.2)

The current measures which are being implemented to manage apparent losses are far below the volume and complexity of the work at hand to effectively manage apparent losses in the system. The size and the resources of the LCTs when compare with the number and the area of operations of the meter readers would make it difficult to achieve any significant results in apparent loss reductions within a reasonable time period in order to ensure meaningful pay back on the resources being committed to the exercise. Whilst the repair and recalibration of the existing meters and the fixing of meters at customer connections are means of ensuring proper accountability of water consumptions, the rate and pace at which the programme is being implemented are not adequate enough to ensure any major changes in the current levels of NRW in the immediate future. This is mostly aggravated by the lack of response from the grantor for the provision of the require meters for installation for over a year now

It was observed during the field trip exercise with the loss control team, that whilst the procedure was very effective to unravel any malfeasant in the field, the process was very slow. The whole period of about eight hours spent on the field, the team could only assessed effectively five houses. Considering the size and number of the customers of the system, such pace of work will not lead to the achievement of the expected results within a reasonable time frame.

5.3 Summary of the chapter.

The following summaries can be drawn based on both the current situation in the field with regard to strategies and activities which are been used for the management of NRW and also the current condition of infrastructural development in the system:

- The <u>actual</u> levels of the components of NRW are still not known;

- In view of the above fact, there can be no sustainable strategic measures to be adopted to effectively deal with NRW;
- Any effort that would be put in place to manage NRW without first dealing with the above fact would only be "try-and-error" approach;
- In the same vein, any gains or otherwise that would be made by any strategy that is put in place now to manage NRW would be difficult to monitor and evaluate and hence would be difficult to quantify in economic terms.

- It is still not clear as to where the real problems are within NRW components. This is partly due to non-availability of complete metering system and also the lack of holistic approach currently in place to manage NRW;
- The direct consequence of the above situation is that the quoted figures of the levels of the NRW in the system are more of a guess work rather than actual measured figures;
- There is no form of active leakage control (ALC) programme currently in place with the exception of visual inspection of the trunk mains especially from Kpong headwork to Tema to look for physical leakages, even though there is high probability of background leakages in the system looking at the age of the infrastructure in the system.
- The income levels (water sales) of the water utility is set by the meter readers and also to a larger extend the levels of the NRW in the system;
- The current measures to check and monitor the work of the meter readers are not adequate and effective enough to check the activities of the meter readers who determine the income levels of the system;

- There are also cases of what is known as unchecked meter readings by the meter readers. These happen when meter readers do not actually go to the field to read the meters but just assume that a customer's consumption may be the same as previous readings. This is an unhealthy practice since customers' consumption patterns can change at any time due to changing social factors;
- The criteria mainly used for the estimation of bills for the unmetered registered customers are the number of persons per households, previous consumptions (those who were previously having meters) and the social status (number and nature of

water usage equipment) of the consumers. These factors are not updated regularly to reflect the changing status of the customer;

- There is no clear leadership either as position or department for the management of NRW.
- As a result of the above situation, there is various interpretations as to the actual level of NRW in the system depending upon who one talks to, the levels ranges from 55% to 60% of system input;
- The current activities and measures in place aimed at managing NRW are;

    I. The formation of Loss Control Teams (LCTs), whose main function is to check for water thefts (illegal connections, by-passes, unbilled consumptions, unregistered customers, malfunction meters and wrong customer categories). They also check for any fraudulent dealings of the meter readers in the field. They report directly to the Chief Managers in the regions;

    II. Testing, repairing and recalibrating of the existing meters for metering and better assessment of customers' consumptions leading to the better assessment of NRW components (see appendix E for the current metering ratio);

- No form of educational programme is in place to sensitise the general public and consumers of the measures being adopted to manage NRW in the system;
- There is a good record of the number of unbilled authorised customers. This is perhaps as a result of the few number (apart from Tema, which has two such customers, SOS house and a Charity house, the next customers under this category are the staff members of the utility who reside in the company's bungalows) of this category of customers;
- Even though the management contract makes it contractual obligation for the operator (Aqua Vitens Rand Ltd.) to achieve an annual NRW reduction target of 5%. The annual reports of the operations of the system for the 2006 and 2007 showed annual reductions of 1%.

Although the situation in the field currently at ATMA suggests that there is little that is being done by way of effectively dealing with NRW, as is seen from the lack of

implementation of most of the strategies that are needed for effective NRW management in any water utility. However, there is hope, as the current management is developing a comprehensive programme and activities to effectively address the NRW levels at ATMA. These programmes and activities are contained in the documents that were reviewed by the researcher as discussed above.

Chapter Six: conclusions and Recommendations

6.1 Conclusion

The research work conducted in Accra on the non-revenue water (NRW) levels in the water utility came out with some findings which have been discussed earlier. This chapter seeks to draw attention to some of the key findings and later come up with some recommendations both to the water utility in Accra and also for future research work.

6.1.1 Assessment of the Research Questions in the Light of the Research Findings.

The current research was set out in order to answer the research questions below and the methodologies that were used to facilitate in finding answers to the research questions were; document reviewing, interviewing and participant observation.

Research question one: *What is the existing situation and the management strategies to deal with non-revenue water in Accra?*

The research work led to the findings that the current situation in Accra water supply system can not be said to be well and good. Whilst there is evidence to accept the fact that there is high levels of NRW in the system, the figures being quoted are more of guess work than actual in the absence of comprehensive metering arrangement. It was again found out that the current strategies being adopted by management to address NRW levels in the system are one- sided in that all efforts are currently geared towards addressing apparent losses, in particular water theft. Such loped-sided approach towards NRW management can not achieve much (see section 6.2 of this chapter for a recommended approach to address NRW).

Research question two: *To what extent has non revenue water affected the overall performance of the water utility in Accra?*

Apart from the loss of revenue that would have normally come to the system through direct sales of water, it was observed during the research at ATMA that almost all the attention of

the management of the system have been shifted to the development of strategies and activities for the management of NRW to the near neglect of other equally important activities that need to be carried out in any water utility for the optimum functioning of the system. Activities such as system expansion and quality and level of service are all important for satisfactory service delivery. But all these activities have been relegated to the background with all attention now focused on NRW management. This was evidenced by activities such as the establishment of the GIS office with the appointed and recruitment of staff for the office, the establishment of the customer survey office, the recent appointment of real loss control officer and the fact that the only major system improvement activity that has been categorically mentioned and made a mandatory obligation on the management of the system in the contract document is NRW reduction.

For instance when the issue of system expansion and service delivery levels were mentioned by this researcher during the interview with the customer care director, he was of the view that there was no need to continue to inject capital expenditure into the system when the services been delivered now can not be fully accounted for. But it should be noted that it is equally important for water utilities to aim at improving system levels and quality of service at all times. For instance if all or majority of the people of the service area of ATMA are receiving high levels of service at reasonably convenient times and price, it would have been likely that most of the socio-cultural and organisational problems identified in the research work would not have happened. It should be noted that water is life, and people will ordinary do every thing to get water for their survival whether it provided to the or not. The numerous water theft cases that have necessitated the formation of the loss control teams may not have arisen in the first place if the level service delivery were as expected. In this direction it can be said with reasonable level of confidence that the NRW situation at ATMA has greatly affected the operations of the system.

It was also observed during the research period, that series of meetings were held by the management of the system at the head office most of which were centred on NRW management. This researcher had the opportunity to sit in one of these meetings (see figure 4.5) where various officers were made to present the progress of their activities and programmes for the management of NRW. At that meeting were the GIS programme coordinator, Meter Repair Manager, Real Loss Control Manager (recently appointed), the General Manager, Operations and maintenance and the General Manager, Production.

These are precious man hours being spent and at a huge cost to the system. It can therefore be said that NRW has really taken the better part of the activities of the water system in Accra.

Research question three: How *can the current strategies be improved?*
A recommended approach to the improvement of the current strategies to address NRW situation in Accra has been discussed extensively in section 6.2 of this chapter.

6.1.2 Aims and objective

The aim of the current research work was; *to investigate the non-revenue water levels in the water service delivery in Accra and to assess the management practices being adopted to manage non-revenue water in Accra and then to come out with some recommendations that would help improve the current strategies.* Even though there were a number of constraints on the part of the researcher such as time frame for the research work that could have allowed for more thorough assessment of the NRW situation in Accra, it can be concluded safely that the aims and objective of the research work have been amply achieved. Perhaps the reason for this was that there was not much which was being done by way of programmes and activities (this refers to the situation on the ground) to address the NRW situation in the water system as most of the internationally accepted recommended strategies for the management of NRW are not been carried out. For instance, there was no Infrastructural, Active leakage control and Pressure management programmes in place.

6.1.3 Infrastructural Management

It was noted from the document review that the grantor (Ghana Water Company and for that matter the Government of Ghana) was to provide the infrastructural development of the water system. This means the management are only to manage the assets of the water system. This aspect of the contract has greatly affected the effectiveness of the management strategy to reduce NRW levels in the system. At the head office when a question was asked of the General Manager (operations and maintenance) as to why for two years into the contract no significant improvement has been made to the NRW levels in the system, it was revealed that the infrastructural development of the system that will make it more effective and perhaps even possible to manage NRW in the system was not forth coming from the grantor and that this has greatly affected the operations of the system with particular emphasis on NRW management. For instance, it was observed through the document review that the management of the system has completed assessment of the metering requirement that will make the system fully metered both at source and on service connections more than a year ago and has submitted this requirement to the grantor. Up to the time of the research work according to the management, not a single meter has been supplied.

6.1.4 Final Conclusion

The findings of the current research work suggest that all are not well in Accra water with regard to the management of NRW. This can be attributed to a number of factors. Apart from infrastructural and logistical problems, the approach current adopted by the management of “assuming” that most of the water losses in the system is emanating from apparent losses which has resulted in most of the current attention on the apparent losses is not the best approach that would eventually resulted in the achievement of the needed result.

Certain aspects of the management contract do not offer incentive for effective NRW management most especially the aspect with regard to infrastructural management. Infrastructural management is an integral component of any NRW management. For this component to be managed by two distinct bodies and yet with the aim of trying to achieving the same result makes the situation very difficult. The effectiveness of a utility's ability to manage its infrastructure for the management NRW is now the recommended bases for assessing the NRW levels of Infrastructural and

There appear to be lack of supervision and demand for the fulfilment of the terms and conditions in the management contract from both parties in the contract. Management appears not to do any thing about the non fulfilment of the duties of the grantor in terms of infrastructural development, at the same time the grantor seems to be quiet over management failures to achieve the targets set in the contract. These attitudes from both parties are not incentives for the needed efforts that must be applied to ensure the achievement of the stated targets.

6.2 Recommendations

This section sets out some recommendations that are deemed fit for the improvement of the current strategies and any future strategies that would be developed by the Management of the water supply system in Accra for improvement in the current NRW levels and also for future research work.

6.2.1 To the Management of ATMA

The strategies that are needed for effective management of NRW in a water supply system are summarised in the following system-assessment questions (Butler and Mamon, 2003:143):

- How much water is being lost?
- Where is it being lost from?
- Why is it being lost?
- What strategies can be introduced to reduce losses and improved performance?
- How can we maintain the strategy and sustain the achievements gained?

Table 2.1 at page 12 sets out the approach and tools needed for developing strategies for the above system-assessment questions. The following steps are recommended:

I. A holistic Approach

It is recommended that a holistic approach to the management of NRW in the water system be adopted. This approach begins with the assessment and the measurement of all the components of NRW (see figure 2.1 at page 10) using both top-down and bottom-up approaches for optimum results. It is better to start with this approach and nothing should be taken for granted. All assumptions should be based on careful scientific analysis of the situation. The current situation where it is only assumed that the greater part of NRW is coming from apparent losses can be misleading. It is as a result of such assessment and measurement that the actual sources of water losses within the water system can be identified with their magnitudes. These assessment and measurements can be carried out using temporary installed meters, pressures valves and gate valves.

II. **Prioritisation of activities to be carried out**.

The identification of the actual values of the components of the NRW within the water system will set the right premises for strategic planning and prioritisation of activities to address the NRW levels according to the magnitude and significant of the component of the NRW within the water system . According to Thornton (2002:171) it is better to begin with those components that will yield the quickest and highest dividend in order to sustain the programme. It is also important that actual figures and the actual sources of water losses are identified within a system before an attempt is made to address the situation. Apart from using these figures for monitoring and assessing the progress of the programmes, they are also helpful to set the economic level for any interventions. The current methodology being used at ATMA makes it difficult to quantify the cost of the interventions and assess the level of the gains that are made and therefore the sustainability of the programme can not be guaranteed.

III. The strategies and programmes currently being developed by management

This researcher became aware through the document review at Accra of the strategies which are currently being developed by the current management of the water system for the management of NRW. It was identified during the document review at Accra that the

contract is in the third year running. It is difficult to assess how possible it will be for the management of the system to actually achieve the targets set in the contract document before the end of the contract. Whilst it was identified that the programmes and activities that being developed to address the NRW situation were comprehensive enough, was also observed that the rate at which these programmes and strategies are being developed is slow. It is therefore recommended that management speed up actions on these programmes. In line with the strategies and programmes being developed by the management of the water system and the current programmes which are being implemented in Accra, the following recommendations are made:

- It is recommended that NRW Manager be appointed. A system with NRW as the single biggest problem, it would be more beneficial and cost effective to establish a unit or appoint a manager sorely in charge of NRW management who will coordinates the activities of the other department and sections of the system for the management of NRW;
- The numerical strength (for initial stages) and resources (especially transportation) of the LCTs should be increased;
- There should be more proactive measures to monitor the work of the meter readers (this can be done by effectively re-sourcing the LCTs). Rewards for efficient work done as well as punitive measures for wrong doings should be established for all staff members and this should be made explicitly clear to staff members particularly the meter readers and other field staffs;
- There should be a proactive programme of constantly reviewing the bases for estimation of bills for customers who are currently not metered to improve the accuracy of these estimates while efforts should be made to complete the metering of all customers; and
- Management should embark on educational programmes to sensitise the general public about the NRW situation in the water system and the measures being adopted to address the situation. This should be done with the view to solicit the support and cooperation of the general public by educating them of the consequences of high NRW levels to the supply of water to the inhabitants rather than only spelling out punitive measures that would be meted out to those who engage in activities that lead to NRW creation in the system.

6.2.3 Future Research work

During the current research work, it was realised that NRW management involves a wider spectrum of stakeholders than just the management and the staff of the water utility itself. Some of the key stakeholders that can be thought of when considering the management of NRW are:

- The sector Ministry of Governments;
- The customers of the water utility;
- Management (top officers) of the water utility;
- The other staff members of the utility (technicians, plumbers , meter readers and administrative support staff); and
- The general public.

The following are therefore recommended for any future research work on NRW:

- Most if not all of the above stakeholders should be contacted or considered when dealing with issues bordering on NRW;
- An integrated approach where all issues that has the potential to make or unmake any water utility to achieve acceptable levels of NRW should be considered. These issues may include socio-cultural, financial, institutional and infrastructural;
- As much as possible the views of sections of all categories of staff should be sought; and
- More field work should be planned for the research work. This is because it is in the field that the actual activities and programmes are carried out for the management of NRW.

7.0 References

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APPENDICES

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Appendix B: Table 1 – 2007 Annual figures of ATMA

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List of Abbreviations Used

ALC – Active Leakage Control

AMR – Automatic Meter Reading

ATMA – Accra-Tema Metropolitan Area

CARL – Current Annual Real Losses

ELL – Economic Level of Leakage

ICF – Infrastructural Condition Factor

IWA – International Water Association

MDAs – Ministries, Departments and Agencies

PRVs – Pressure Relief Valves

UARL – Unavoidable Annual Real Losses