Managing Water Loss: Strategies for the Assessment, Reduction and Control of Non-Revenue Water (NRW) in Trinidad and Tobago.

Carol Balkaran
Gordon Wyke

CONTENTS **PAGE**

TABLES **PAGE**

FIGURES **PAGE**

Comments and suggestions may be submitted to:

Executive Director

Regulated Industries Commission

Furness House – 3rd Floor

Corner Wrightson Road and Independence Square

Port of Spain, Trinidad

Tel: 1-868-625-5384; 627-7820/0821/0503

Fax: 1-868-624-2027; 624-9396; Email: ricoffice@ric.org.tt

Copies of this document are available from the RIC Information Centre.

LIST OF ACRONYMS

Acronym	Full Phrase
ALC	Active Leakage Control
AMP	Asset Management Plan
ATV	Annual Taxable Value
DMA	District Meter Area
ELL	Economic Level of Leakage
GIS	Geographic Information Systems
ILI	Infrastructure Leakage Index
IWA	International Water Association
MCM	Million Cubic Metres
NRW	Non-Revenue Water
Ofwat	Office of Water Services
PRV	Pressure Reducing Valve
UFW	Unaccounted for Water
WASA	Water and Sewerage Authority
WLC	Water Loss Control
WWMD	Waste Water Meter District

GLOSSARY OF TERMS

Non-Revenue Water (NRW)

The difference between system input volume and billed authorised consumption. It can be separated into:

a. Water consumed but not recorded by consumer's meters or otherwise accounted for by government or other public use. This is referred to as **apparent losses** or in the past **non-physical losses or commercial losses** and is reflected in lost revenue. It includes water consumed through illegal connections and the under registering of meters.
b. Water lost through leakage, also referred to as **real losses** or in the past **physical losses.** This is a resource loss and is reflected in the cost of production.
c. Unbilled authorised consumption that includes water used for fire fighting, flushing of mains and sewers, watering of public spaces and construction water.

System Input Volume

The volume of water delivered into the distribution network

Consumption

The volume of water that can be accounted for by legitimate use, whether metered or not.

Authorised Consumption

The volume of 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 domestic, commercial and industrial purposes. It includes water exported.

Note that authorised consumption includes items such as fire fighting and training, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, construction water. These may be unbilled or billed, metered or unmetered according to local practice.

Unaccounted for Water (UFW)

It is defined in the same manner as NRW.

Water Losses

The difference between system input volume and authorised consumption.

Waste

Water arising from wasteful use by the consumer or from defective fittings. It occurs as customer side leakage and as such is NOT part of UFW/NRW.

Demand

The volume of water that has to be put into the distribution network to satisfy the requirements of customers plus UFW/NRW that may be incurred in the process. It is the same as system input volume.

Minimum Night Flow

The minimum rate of supply of water into any area during the night.

Net Night Flow

The difference between minimum night flow and metered consumption at night.

ABSTRACT

Unaccounted for Water now better known as Non-Revenue Water remains a major concern in Trinidad and Tobago. Levels are estimated at approximately 45 to 50 percent, high by international standards. This paper seeks to present a way forward for dealing with NRW levels making use of modern concepts and definitions currently in use in the UK and presenting technologies for the implementation of a comprehensive water loss programme.

Strategies for the assessment of leakage levels and determination of an optimum or economic level of leakage (ELL) and the benchmarking of the local situation making use of the Infrastructure Leakage Index (ILI) technical performance indicator first proposed by the IWA are outlined. An examination of the local NRW situation is given culminating with the development of a four-pronged leakage strategy for the recovery of real losses. The authors strongly recommend the use of a performance based NRW reduction contract to address the problem and submit an implementation strategy that embraces proven measures for NRW reduction in Trinidad and Tobago.

This paper constitutes an occasion where an applied technical approach is being employed to the leakage question in this country in an effort to come to terms with the problem and drive the process forward from its present modest state.

MANAGING WATER LOSS: STRATEGIES FOR THE ASSESSMENT, REDUCTION AND CONTROL OF NON-REVENUE WATER (NRW) IN TRINIDAD AND TOBAGO.

INTRODUCTION

Water loss is a problem for all water utilities. Typically, unaccounted for water (UFW) now known as non-revenue water (NRW), is between 15% and 30% in the developed world but elsewhere it is more likely to be in the 30% to 60% range (Bridges, 1994). In Trinidad and Tobago it stands at 45%. However, it has been shown that proper delivery of the resource is a possibility and can be achieved (Ofwat, 2001). This is of concern locally as viability of the Water and Sewerage Authority (WASA) hinges on the fact that its product - water - can be effectively and efficiently delivered to its customers.

What therefore can be done to reduce the high levels of leakage that characterize many systems in the developing world? One measure, active leakage control (ALC) has proven to be cost effective throughout the world (Bridges, 1994). In the United Kingdom, the economic regulator for the water and sewerage industry in England and Wales, the Office of Water Services (Ofwat) had mandated water companies to set annual leakage targets in an effort to bring leakage under control. It has also increased its effort in monitoring leakage such as extra reporting, specific investigations and where necessary enforcement orders. These measures have largely succeeded but the issue is not relevant to the regulator alone

The role of other stakeholders cannot be underestimated. Often the public is irritated by visible leakage and vents its anger at the Authority even though waste may be occurring on customer premises implying that blame is not solely the utility's. Nevertheless visible leakage is not healthy and must be addressed. The influence of the State is crucial. Often it is concerned with high levels of leakage but dealing with it may not be politically expedient, as corrective measures require higher tariffs, huge investments and disruptions to the lives of citizens, matters no politician happily relishes. However, in circumstances when the decision is taken to proceed with active leakage policy, the long-term results have proven to be greatly beneficial to citizenry.

The implementation of a water loss policy in Trinidad and Tobago is no less crucial. Recent statements have revealed that our water resources exceed by about ten times our water demand (3600 MCM/yr to 317 MCM/yr) putting the country in a supposedly excellent position. However, current water demand in Trinidad and Tobago amounts to 317 million cubic meters per year (MCM/year) while water supply amounts to 272 MCM/year (Draft National Water Resources Management Policy, 2002). With the level of NRW ostensibly at 45%, the unreliability of the supply due to low surface water flows during severe dry seasons such as the one just completed and high turbidity of surface water can result in even further exacerbation of this deficit (Draft National Water Resources Management Policy, 2002).

What then for WASA? A good starting point is identifying a policy that can be pursued for successful reduction of water loss. The replacement of affected pipe is one key component of a water loss reduction programme (new pipes will leak less). There also exist other frameworks and methodologies that will address issues that pipe replacement cannot (customer leakage, invisible leakage, supply demand management and apparent losses to name a few).

To address the above, the paper considers the following:

- NRW in Trinidad and Tobago;
- Major factors contributing to high levels of NRW in the country;
- Benefits of reducing NRW;
- Review of present WASA strategies for the reduction and control of NRW;
- Development of water loss strategies;
- A Water Loss Management Program for the Authority.

Prior to this discussion however, are four factors required to shape this study:

- The definition of NRW; what is it really?
- The assessment of NRW; how much is actually leaking both in real and apparent terms;
- The need to determine the amount of effort required for its implementation so as to provide a positive economic balance, that is, the cost of implementation must be less than the value of water saved (Bridges, 1994). This introduces the concept of the **Economic Level of Leakage (ELL**);
- An indication of how well the strategy is working in comparison to other jurisdictions; this introduces the concept of the **Infrastructure Leakage Index (ILI).**

These will now be mentioned briefly here and are treated more fully in **Appendix I**.

NON REVENUE WATER: A SETTING

Defining NRW

NRW reflects the difference between the volume of water delivered to the distribution system and the water sold by the utility. It includes physical or technical losses such as pipe breaks (leaks) and overflows and commercial losses (meter under-registration, illegal use including fraudulent or unregistered connections and legal, but usually unmetered, uses like fire fighting).

NRW is usually expressed in a number of different ways such as:

- Difference between water supplied and water sold expressed as a percentage of net water supplied (this is the most common form of expression);
- Difference between water supplied and water sold expressed as a volume of water 'lost' per km of water distribution network per day; and

- Difference between water supplied and water sold expressed as a volume of water 'lost' per water connection.

Lambert and Hirner (2000) go further, and define Non-Revenue Water, as the difference between the System Input Volume and Billed Authorised Consumption. **(Figure 1)**

Measuring NRW

The components of a water balance calculation are illustrated in **Figure 1.**

Figure 1. Components of Water Balance for a Transmission or a Distribution System

System Input Volume M^3/ year	Authorised Consumption M^3/year	Billed Authorised Consumption M^3/year	Billed Metered Consumption (including water exported)	Revenue Water M^3/year
			Billed Un-metered Consumption	
		Unbilled Authorised Consumption M^3/year	Unbilled Metered Consumption	Non-Revenue Water M^3/year
			Unbilled Unmetered Consumption	
	Water Losses M^3/year	Apparent Losses M^3/year	Unauthorised Consumption	
			Metering Inaccuracies	
		Real Losses M^3/year	Leakage on transmission and/or distribution mains	
			Leakage and overflows at Utility's storage tanks	
			Leakage on service connections up to point of customer metering	

The steps for calculating NRW using water balance calculations are as follows:

- Step 1: Obtain *System Input Volume*
- Step 2: Obtain *Billed Metered Consumption* and *Billed Unmetered Consumption* and add together to calculate *Billed Authorised Consumption* and *Revenue Water*
- Step 3: Calculate the volume of *Non-Revenue Water* as *System Input Volume* minus *Revenue Water*
- Step 4: Obtain *Unbilled Metered Consumption* and *Unbilled Unmetered Consumption* and add together to calculate *Unbilled Authorised Consumption*

- Step 5: Add volumes of *Billed Authorised Consumption* and *Unbilled Authorised Consumption* to calculate *Authorised Consumption*
- Step 6: Calculate *Water Losses* as the difference between *System Input Volume* and *Authorised Consumption*
- Step 7: Assess components of *Unauthorised Consumption* and *Metering Inaccuracies* by best means available, and add these to calculate *Apparent Losses*

Determining the ELL

The ELL is the level of leakage at which the additional cost of reducing leakage is equal to the additional benefit gained from further leakage reductions, in other words it refers to that level of leakage at which it would cost more to make a further reduction in leakage than to produce the water from another source. For a company operating at the ELL it therefore means that the total cost to the customer of supplying water is minimised. In other words an ELL approach sets economic targets for the water company rather than targets for the company to set economically.

The key stages in determining the ELL are outlined in **Table 1**.

Table 1. Key Stages in ELL Process

Define area basis	**Decide zonal disaggregation (consistent water supply and leakage management areas)**
Establish the current position	Calculate current leakage (trunk mains and supply system, distribution mains and customer service pipes) Determine current policy minimum (existing policy)
	Establish leakage detection and repair costs (existing policy) Establish current and future supply/demand balance and alternative investment costs (resources and demand management)
Review future/alternative options	Consider new policy and technology options (for leakage management, pressure management, mains replacement, etc) Develop family of leakage/cost relationships
Calculate the economic target	Option 1 = leakage level output of least cost planning analysis (programme with lowest NPV) Option 2 = relationship between active leakage control cost curve and cost of water

The Infrastructure Leakage Index (ILI)

In an effort to develop more rigorous methods for measuring real losses the IWA has developed the Infrastructure Leakage Index. It is a measure of how well a distribution network is managed (through repairs, pipelines and asset management, active leakage control) for the control of real losses, at the current operating pressure. It is the ratio of Current Annual volume of Real Losses (CARL) to Unavoidable Annual Real Losses (UARL).

The term CARL is self-explanatory. However, suffice it to say that as a system ages the CARL tends to increase (natural rate of rise). UARL, which occurs even in the very best managed system, as there will always be real losses, can be calculated by the following formula:

UARL (litres/day)= (18 ? Lm + 0.8 ? Nc + 25 ? Lp) ? P

where Lm = length of mains (km);
Nc = Number of Service Connections;
Lp = length of private service pipes from property boundary to the meter (km);
P = average Pressure (m); and
the numbers relate to the volume of leakage expected from the different constituents of the equation.
While Lp sounds difficult to obtain, it will be zero in all the systems where the meter is directly at the boundary line. In other systems it can be estimated.

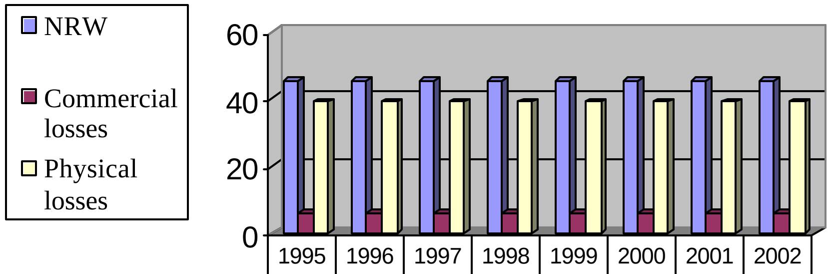
UARL is similar in concept to the lowest technically possible policy minimum level of leakage used in the ELL determination process (Tripartite Group, 2002).

NRW IN TRINIDAD &TOBAGO

A major concern about the operations of any water utility is the level of Non Revenue Water (NRW). WASA estimates that about **45%** of the water distributed annually is lost as NRW. Of this amount, **39%** is due to technical losses and **6%** to illegal usage. The best practice for this indicator is less than **23 %** for most developing countries**. Figure 2** illustrates the percentage of UFW for the 1994-2002.

The high level of NRW loss led to the establishment of a Water Loss Control (WLC) Section in 1992 in order to implement elements of the leakage control strategy proposed in the Thames Water International (TWI) Report of 1991. The Section's early work was limited to meter measurements due to the lack of equipment and staff and not much work was accomplished. This improved in 1995 and a consultant was also brought on board to assess the program and make recommendations for a proposed leakage control strategy. The Section was transferred to the Operations Division from the Capital Investment Division in 1997 in order to integrate with mains repair efforts there. Under the Severn Trent Management, the concept of District Meter Areas (DMA) was introduced and the WLC Section was at the forefront of having these areas established. This has met with limited success. With the advent of the desalination plant, more water is now available for the population at large resulting in a better continuity of supply. Unfortunately this may push the NRW efforts further into the background resulting in problems in the years ahead as water demand continues to rise and the water supply is not able to match it.

Figure 2. Non Revenue Water for the period 1995-2002 (%)



	1995	1996	1997	1998	1999	2000	2001	2002
NRW	45	45	45	45	45	45	45	45
Commercial losses	6	6	6	6	6	6	6	6
Physical losses	39	39	39	39	39	39	39	39

MAJOR FACTORS CONTRIBUTING TO HIGH LEVELS OF NRW IN TRINIDAD AND TOBAGO

There are several reasons for the high level of NRW in the country. These are mentioned and briefly discussed below.

Illegal Connections

There is a significant number of illegal users of water. WASA estimates that 40,000 households (1992 figure) do not pay water rates but receive water from its distribution system. As a consequence, they contribute significantly to apparent losses and revenue loss to the Authority. These connections are often poorly laid just a few inches below the surface (the WASA standard is 45cm [18"]) and will break easily resulting in real losses taking placed in the form of leakage. Illegal connections are therefore of major concern

Age of Pipe Network

It is estimated that fully 40% of the pipe network was laid over 70 years ago. These include cast iron, asbestos cement, galvanise wrought iron and steel pipes. All these materials suffer from degradation over time due to operational measures, environmental conditions and general wear and tear and result in increased leakage in the network. It is therefore necessary to replace older mains so that less leakage occurs.

Poor Maintenance of Network

Historically, WASA has been plagued by poor maintenance of its system although this has improved in recent years. This has been due to its difficult financial situation and also to poor workmanship especially to service connections that were often laid too close to the surface. The lack of funding to buy proper materials and poor construction resulted in increased leakage in the system.

Water Scheduling

The problem of water scheduling caused by an intermittent supply results in leakage. With a cyclic pressure situation created due to having the supply turned on and off, increased levels of leakage are experienced due to stress being inflicted on the pipes causing them to rupture. There is clearly irony in this situation as the problem of water scheduling is caused by water shortages due in no small part to leakage. Due to high levels of water loss, a continuous supply is not available resulting in water schedules. The elimination of water schedules then, is a desired goal.

Customer side Leakage

Because of the nature of the tariff system in the country and the generally low rates paid by customers, there is little incentive to conserve water. Consequently, leaking toilets, tanks and fittings remain unrepaired for long periods thereby contributing to significant waste. While this is not considered to be NRW, it is a significant component of water lost and a strain on the delivery of water.

Absence of coherent strategy for ALC

Despite its best efforts WASA had not yet implemented an ongoing holistic plan for water loss reduction and control. This has allowed NRW to grow to its present level of 45% with no diminution of this figure in sight. An overview of WASA's current strategies is detailed later in this paper.

BENEFITS OF REDUCING NRW

Improvement in Demand Management Policies

NRW reduction and control is one area of demand management where the objective is to limit the demand for water services by users. The utility is one such user, a major one at that, and continued water loss impacts negatively on the effort to limit demand. This can be translated into economic terms, as more efficient use of existing supplies becomes an increasingly cost effective alternative to supply augmentation and management (Versteeg and Tolbom, 2003).

There are several economic benefits of reducing NRW:

- It costs money to produce water - in terms of chemicals, energy, staff and maintenance of the infrastructure. Reduced NRW means increased savings in these areas;

- Capital costs for expansion works to meet the demands for uncontrolled water use can be deferred. These savings can be applied elsewhere;
- With the attendant increase in revenue water, additional income is available to the utility for its use;
- There will also be reduced costs to the treatment of wastewater due to reduced flows to the treatment works.

Improved Public Perception of Utility

Once a programme for NRW reduction and control is instituted, this should redound to the benefit of the Authority as the public sees its efforts bearing fruit. Improved service, fewer leaks and extension of the distribution system are some of the positive outcomes of reducing NRW. However, there is need for the programme to be properly communicated nationally so that the good work is not viewed as disruptive, and without any information being provided as to the long-term benefits.

REVIEW OF PRESENT WASA STRATEGIES FOR THE REDUCTION AND CONTROL OF UFW/NRW

Water Loss Control (WLC) Section

Present Activities

As stated previously, the WLC Section has been engaged in the setting up of District Meter Areas (DMAs). Progress has been slow with 31 being set up out of a total of 152 identified by the Bristol Water Report on the preparation of the Water Loss Programme. Of these, 11 are in Tobago, 12 in North and 8 in South Trinidad.

The WLC Section prepares a monthly UFW report based on the leakage found in these DMAs. They also locate leaks within these DMAs and report them to the Operations Division repair staff who should respond within one week. The next month's UFW report should then reflect any improvements with regard to leakage.

The Section also responds to ad-hoc requests from Operations to detect and/or locate leaks in various parts of the country. They are also beginning the use of data loggers to record system pressures for Full Service Equivalent (FSE) determination.

Staff

There are a total of 15 people working in the section headed by an Engineer. By their own admission, this is wholly inadequate and there is dire need for more personnel.

Equipment

The Section has a variety of equipment including sounding equipment, data loggers, leak-noise correlators, leak locators and valve finders. There is need for additional equipment in order for DMAs to be brought on line and properly monitored, and for leak detection/location to be improved.

Budget

The budget is inadequate and being further trimmed due to financial constraints.

Referencing WLC Reports and Consultancies

The Plan intended to guide WLC activity, the Bristol Water Report is not being used. This is probably due to the fact that there is insufficient funding to carry out the proposals of the Report.

In summary then, activity of the WLC Section has been ongoing over the last five years. However it falls woefully short of what is required. Immense effort as well as an injection of funding is required to increase and sustain the level of effort required to reduce UFW to an acceptable level.

Other Activities

Repair to visible leaks

Over the last five years WASA has made good progress to the repair of visible leaks. This was achieved with the introduction of STORMS, a maintenance management software package to record and plan jobs and the introduction of contractors to support existing WASA staff with the repair of leaks. In 2000 and 2001 over 55,000 leaks were repaired. This has evidenced itself in that there is no longer the image of numerous leaks running heavily on roadways for several weeks. Nevertheless, there are still isolated complaints from the public about leaks being seen in places and existing for several weeks and months. The response time for leaks still requires improvement as they may run for a week or more before being repaired.

The quantity of leak repairs continues to be high at WASA. **Table 2** details the number of mains and supply pipe breaks reported from 1997 to 2002. The number showed a sharp increase in 2001 as the Authority began to employ contractors to assist its crews with repairs to leaks and bursts. With 5800 km of mains, the number of mains breaks per year per km for 2002 was 6.08. This is well above the global best practice range for developed countries of less than 0.5 and still higher than that for developing countries of less than 1. This high figure reflects the poor state of the network, the need to replace aging infrastructure and the need for further leakage control strategies.

Table 2. Mains and Supply Pipe Breaks

Type of Complaint	1997 (6 months)	1998	1999	2000	2001	2002
Mains Breaks reported	97	620	936	784	4779	9597
WSC Breaks reported	2584	16871	18598	15575	21142	25688

Customer Demand Monitor

The use of a Customer Demand Monitor to provide an improved understanding of consumption patterns of residential users was proposed by the Severn Trent management. The monitor provides volumetric measurement from a selected sample of customers who although metered would still pay rates according to the ATV system. This will provide data on per capita usage and nighttime usage that will aid in the estimation of distribution losses and customer side leakage. Despite its usefulness in this regard, and while it was advocated for implementation it has not yet been established.

Pressure Management

No specific programme is currently being pursued with respect to the setting up of pressure zones or the installation of pressure reducing valves (PRVs) although this strategy was successfully implemented in 1995 off the North Oropouche water supply system.

Trunk Main and Reservoir Leakage

No programmes have yet been developed for measuring leakage from these elements of the distribution system.

Bulk Metering

Preparation of a bulk metering system has been proposed in the Short Term Improvement Plan (STIP) as a strategy for online monitoring of systems. This will address previous efforts proposed under earlier capital investment programs.

Pipeline Replacement

This continued apace with an estimated 230 km of pipeline targeted for replacement up to March 2003.

Reduction of Apparent Losses

The Authority has done little to maintain its meters and as a consequence most are in a non-functional condition. Consequently, there is no way to properly measure consumption, most of which is now estimated. There is no meter maintenance facility, so for the meters that do work, no planned testing and calibration is done. This no doubt has resulted in errors at functioning customer meters, many of whom are large users of water.

With respect to illegal use, little effort has been made to track down persons who steal water. A house-to-house assessment survey undertaken in 1995-96 probably assisted in identifying illegal users but it is not known whether any attempt was made to curb this use and convert those identified into legal customers.

DEVELOPMENT OF WATER LOSS STRATEGIES

In order to achieve a reduced level of NRW there are four primary components that need to be in place. These are identified in **Figure 3**, [Liemburger (2002)]. They are detailed below.

Pipeline and Asset Management

At the pipe network ages the propensity for increased leakage exists. The use of asset management therefore becomes vital. Asset management is the process of guiding the acquisition, use and disposal of assets to maximise the most of their service delivery potential and to manage the related risks and costs over their entire life (The Asset Management Series Glossary, 1995). Using this process, there will be proper and continuous selection, installation, maintenance, renewal and replacement of pipelines over a specified period of time so that leakage in the system is kept under control.

Pressure reduction and control

This method while not a direct form of leak detection is useful, as a reduction in pressure may reduce the rate of escape from each leak as well as reduce the number of leaks that occur. Pressure zoning provides a permanent means of reducing pressure to specified existing high-pressure areas so that leakage can be reduced throughout.

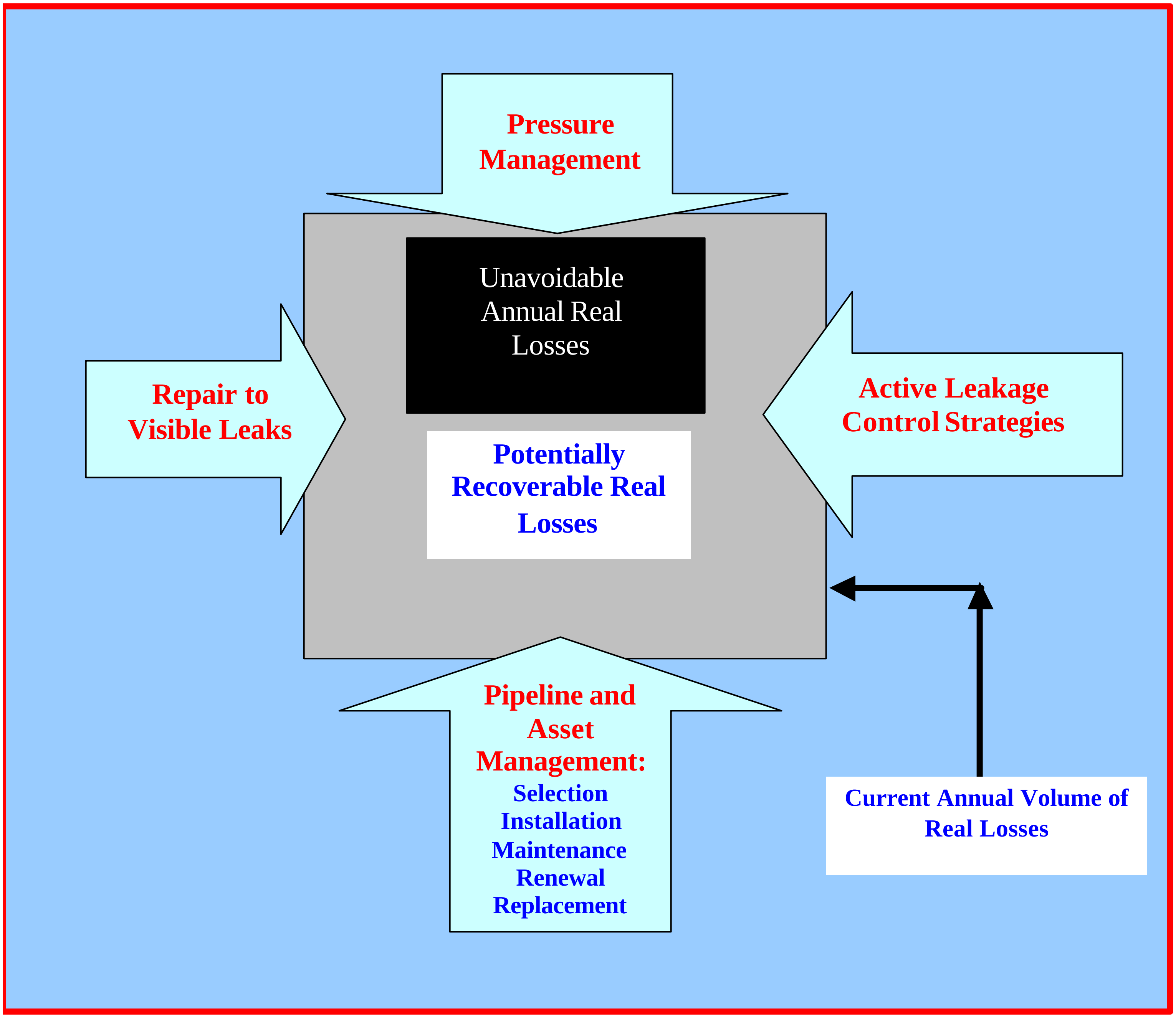
Repair to visible leaks

Visible leakage occurs when water escaping from a broken main or water connection reaches the surface. This is undesirable as it affects customer supply, is unsightly and conveys a negative image of the service provider. In addition, the response time to repair these leaks is important in order to minimise the volume of water lost.

Active Leakage Control Strategies

These would include leak location measures such as sounding, District Meter Area (DMA) setup, Waste Water Meter District (WWMD) setup, trunk main and reservoir leakage and the support structures to implement and maintain them such as training, human resources, transport and equipment, public communication and IT support.

Figure 3. The Four Components of a Successful Water Loss Management Policy



In addition to the above, there are other planned activities of the utility which are necessary in themselves but lend critical support to a leakage management strategy. These would include **universal metering, tariff adjustment, bulk metering, improvement to infrastructure records, telemetry installation and network analysis.**

With all these components impacting on leakage it can be reasonably expected that water losses can be recovered and the ILI be pushed downwards. It also requires the support of all relevant stakeholders and the creation of a project environment and framework, adequately staffed and funded at least for the first 5-10 years in order for NRW to be brought under control. It is with these considerations in mind that a successful strategy can be outlined for WASA for the years ahead. The Programme below builds on these components and revisits some of the strategies outlined by Bristol Water that are still relevant today.

WATER LOSS MANAGEMENT PROGRAMME

The RIC proposes two options for the improvement to NRW levels in Trinidad and Tobago. These are:

- An in-house leakage reduction unit to run the programme. This already exists at WASA but as shown previously is understaffed, under funded and lacks a coherent programme.
- The use of an expert contractor undertaking a NFW performance based contract with clear performance targets to be met. This is being utilised on a global scale at present and has yielded successful results in several countries notably Malaysia, Brazil, the United States of America and Morocco (Liemberger, 2003; Djerrari, 2003). This is the preferred choice for several reasons:

- It allows the utility to get expert help immediately for a challenging situation.
- Leakage control is manpower intensive and requires significant project management and organisational skills that may not always be available in-house (Liemberger, 2001). Staff is usually not available to conduct it, being utilised in other supposedly critical areas.
- The responsibility for the initial capital investment is removed from the utility and from Government.
- This approach provides an excellent opportunity for private contractors, thereby promoting competition within the utility sector.
- If full-scale privatisation is not desired or possible it allows for a possible limited alternative.
- It presents a cost-effective solution to the leakage function.
- It allows for an accelerated implementation programme.

- The RIC suggests a programme that will be conducted in three phases that will run over a period of seven (7) years in the first instance. This is outlined in **Table 3** and the following gives details of the proposed actions. These actions can be pursued internally or used as the basis of negotiating a contract with any prospective companies.

Table 3. Water Loss Management Programme

Phase 1 – 18 months		
Preparation		
Acquisition of funding for Programme		
Determination and procurement of materials and equipment for Programme		
Establishment of components of water balance, estimation of leakage level and determination of ILI and ELL		
Setting of Leakage Targets		
Implementation		
Active Leakage Control Strategies	**Support Structures**	**Other NRW Strategies**
Repair to visible leaks	Training	Universal Metering
Sounding Programme	Human Resources	Tariff Setting
Repair to customer side leakage	Transport and Equipment	Mains Replacement
	Public Education and Information	
	IT support	
Phase 2 – 42 months		
Pressure zoning		Bulk Metering
DMA setup		Infrastructure Records
WWMD setup		
Trunk main leakage		
Reservoir leakage		
Apparent Losses *		
Phase 3 – 24 months		
		Telemetry
		Asset management
		Network Analysis
Phase 4 – Ongoing		
Maintenance		
Night Flow Monitoring	Record Keeping	
Reassessment of leakage control activities		
Improvement to ELL calculation		
New policy and technology options		
Maintenance or facilities and equipment		

** Not an ALC measure but related to water loss reduction*

The programme is also presented using the logical framework methodology (**Table 4**), which provides a concise presentation of the project. The overall objectives, project purpose, results, activities and their causal relationships are presented systematically (vertical logic). In addition to the logical relationship between activities, results, project purpose and overall objectives, there are external factors (assumptions) that influence the success of the project and they are also included in the logical framework. The overall objectives, project purpose and results are described by means of indicators and the sources of verification necessary to obtain the information by which they are measured. The means and costs are detailed in the bottom row.

Table 4. Logical Framework for Water Loss Management Programme

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
Programme Goal: To improve the operation and management of the Water and Sewerage Authority in Trinidad and Tobago	**1.** WASA has achieved net profit margin **2.** Satisfactory product and service **3.** Customer Satisfaction	**1.** Annual Reports **2.** Level of Service Reports **3.** Standards met **4.** Customer Surveys **5.** RIC reports	**1.** Government support and minimal interference **2.** Investment Funding found for improvement measures
Project Purpose: **1.** To reduce and control leakage **2.** To improve system management and service delivery **3.** To achieve economic efficiency	**1.** Leakage targets set and achieved **2.** Infrastructure Leakage Index of 5 or less over a period of 7 years **3.** Service Delivery improved **4.** Appropriate savings as a result of leakage saved	**1.** WASA Finance Data **2.** WASA NRW data **3.** RIC reports	**1.** Leakage Management Programme commenced within reasonable timeframe
Outputs: **1.** Program in place to reduce and control leakage (3 phases over 7 years) **2.** Support (training, staffing and logistics) structures put in place **3.** Water Balance determined **4.** ELL, ILI established **5.** Sounding Programme implemented **6.** Customer side leakage reduced **7.** DMA, WWMD and pressure zones set up **8.** Trunk main and reservoir losses quantified	**1.** Contract awarded to private concern or WLC Unit adequately staffed and funded **2.** Performance targets met over period **3.** No. of leaks/month reported from sounding programme **4.** 152 DMAs, 425 WWMDs installed over 5 year period **5.** Bulk Meters installed **6.** Consumption, supply and loss figures calculated **7.** Public forums held & media kits disseminated	**1.** Performance reports **2.** Input Volumes **3.** Consumption figures **4.** DMA dossiers and nightlines **5.** Pressures readings **6.** Flow measurements **7.** Project Monitoring & Reporting **8.** Media Outputs **9.** Public Response	**1.** Concise contractual negotiations **2.** Extra support strategies implemented **3.** Supportive public response **4.** Media Support **5.** Extra Support strategies implemented
Inputs: **1.** RIC - project oversight **2.** WASA - project management & execution **3.** Contractors - project execution **4.** Education Program to inform public **5.** Repair to leaks **6.** Repair to customer side leakage **7.** Network upgrade **8.** Leakage monitoring and control **9.** Pressure management **10.** Apparent Losses Programme	**1.** Contractor capital outlay **2.** Contractor annual payment for leakage management **3.** Capital funding for programme **4.** Staff **5.** Equipment **6.** Transport **7.** Materials **8.** Hardware/Software	**1.** Financing inputs from contractors **2.** Revenue flow to WASA to fund program **3.** Organizational Structure	**1.** Fiscal support for contractor **2.** Contractor business and financial strength **3.** WASA revenue to support 10 year program realized **4.** Extra Support strategies approved

Phase 1 – 18 months

Establishing components of water balance, estimation of leakage level, ELL and ILI determination

As outlined earlier, one of the first steps in NRW determination is to measure and/or estimate the values for the various components of the water balance given in **Figure 1**. Leakage itself cannot be measured directly and has to be estimated. This can be done by two methods outlined in the Ofwat summary report on leakage target setting for water companies in England and Wales (Ofwat, 2002). These are:

1. The integrated flow approach (top down) where
   Leakage = distribution input – consumption
2. The minimum night flow approach (bottom up) where
   Leakage = (minimum night flow – legitimate night use) * pressure adjustment factor

Given WASA's present situation with regard to lack of metering and lack of programme output in the leakage sector, it would be difficult to accurately assess water balance components and to estimate a leakage level. The lack of DMAs precludes any use of the bottom up approach. Nevertheless preliminary water balance components can be found and leakage estimation done using the top down approach. This can be achieved by:

- Determination of system input volume by measurement where available and by estimates from unmetered sources.
- Creating a customer demand monitoring system to determine per capita consumption in the absence of universal metering and so determine overall household consumption.
- Inclusion of commercial and industrial customers metered consumption and unmetered consumption derived from estimates.
- Estimation of water used for operational use and unbilled use (flushing of mains, fire fighting, illegal customers etc.). Admittedly this is a difficult item to ascertain.
- Estimation of losses from service reservoirs and trunk mains if possible.

This determination should be done over a 12-month period in the first instance.

The difference between system input volume and the other components would yield a leakage value. It is expected that this will be an imprecise figure but it is a starting point. As WASA implements its other leakage and support strategies this value will be improved, as DMAs will yield a nightline leakage value, universal metering will give actual consumption by customers and bulk meters will accurately measure source supplies.

Determination of ELL by WASA

Without the detailed leakage data necessary for analysis WASA would be hard pressed to complete an accurate ELL determination at the present time. Yet this is a necessary first step for establishing targets and leakage strategies. The Tripartite Group (2002) recognizing this, provided potential alternatives that could be used to set leakage targets. These included:

- Policy set by marginal cost of water
- Theoretical target set on system characteristics
- Target set on policy minimum
- Trading in leverage permits/credits
- National reallocation of water resources
- Targets set on abstraction levels
- Deregulatory approach to leakage targets

Of these the target set to policy minimum approach is the most feasible in the short term. The policy minimum (or base background) level of leakage is already a key stage in the ELL process (**Figure 2).** Once this is determined the ELL can then be set for water zones at a 20-30% level **above** this base level. The process therefore ends at the black line (**Figure 2**) avoiding the initial copious amounts of data needed for a more robust calculation. It is felt that WASA can compute the ELL this way utilizing its existing DMAs and grossing up to a utility average.

It will be expected that a more accurate ELL based on the best practice principles will be computed as the Water Loss Management Programme continues. This is a priority when viewed in the wider context of the supply-demand balance. WASA has not been able to balance its own supply/demand equation. For example, in 2002 the total demand was 386 MCM and supply was 347 MCM. Consequently, as the Authority formulates plans to address this problem it must assess the costs of reducing NRW with respect to the cost of developing new water resources. In other words it must develop a least cost plan or utilize the marginal cost of water approach in planning investments. A long-term solution for the ELL must therefore be sought.

Determining the ILI

The ILI, discussed earlier can also be calculated. Apart from the components mentioned for finding the CARL and UARL, the following parameters are also required to compute the ILI (IWA, 2000):

- Total length of pipe network
- Total number of service connections
- Average length of a service connection
- Number of days per year the network is pressurised
- Number of hours per day the pipe is pressurised

- Average operating pressure when the system is pressurised

The non-dimensional performance indicator can then be calculated and compared with other jurisdictions around the world to establish system performance.

<u>Setting Leakage Targets</u>

Once the ELL has been established, the Authority can now set annual manageable targets for NRW reduction based on the premise that NRW will fall to ELL levels within a specified timeframe. A time scale of between 4 and 7 years is recommended; any less is too ambitious and any more will not be as economic (Farley and Trow, 2003). It has been found that resource and organizational constraints make it difficult to achieve anything more than a 15% reduction in leakage in any year (Farley and Trow, 2003). WASA should be aware of this when setting leakage targets.

Targets should be specific to particular supply zones and the overall target should be the aggregation of the zonal targets. Since the ELL does not remain constant but changes as active leakage policy changes constant re-evaluation of targets will be expected.

<u>Active Leakage Control Strategies</u>

<u>Repair to visible leaks</u>

Visible leaks will continue to be an issue for all water service providers and WASA is no different. During the eighties and early nineties this was a major problem for the utility as leaks were visible everywhere. Before and during the period of Severn Trent International at the helm of WASA (1996 – 1999), programmes were instituted to cope with the many leaks, and gradually, with the help of contractors, WASA has managed to bring the situation under control (see **Table 2**).

WASA should continue its programme of repair to visible leaks using current staff and contracted workers. It presently utilises a job maintenance system that has improved the job planning and the carrying out of repairs. It also has a hotline telephone number for persons to call and report leaks. It should also endeavour to meet the RIC's standard for the repair to leaks that ranges from 24 hours for heavy leaks to within 7 days for light leakage flow.

<u>Sounding</u>

Sounding is a common and trusted leakage detection method remaining in use because of its simplicity and effectiveness. Sounding occurs via the use of listening sticks and geophones placed on valves, hydrants and water service connections (WSCs) in order hear noises that emanate from leaks in the system.

Sounding should be the first plank of an established water loss management programme in Trinidad and Tobago. It is relatively easy to perform and can yield quick and beneficial results (Bristol Water, 1997).

While other methods are being developed for future implementation, sounding should be immediately instituted via a coordinated effort in selected areas in order to identify leaks on service connections and within properties. There are difficulties with sounding that need to be addressed such as the inaccessibility of stopcocks, they being covered over or inside of premises, as well as low system pressures which make leaks hard to find. The Authority must also address the need for nighttime sounding which although much more effective is also more costly.

As DMAs are developed the use of sounding will gradually shift to identification of leakage from night flow runs made. The early intensive effort can then be phased out and replaced with more targeted sounding efforts.

<u>Customer side leakage</u>

Once the supply reaches past the stopcock on the WSC, any use is the responsibility of the customer. Waste usually can occur because of leaking appurtenances in the consumer's home. This type of loss while not comprehensively measured is considered significant because leaks may not be repaired as quickly as those on the system side. In addition, there can also be excessive use of water. The nature of the tariff system in Trinidad and Tobago is such that there is little incentive for consumers to conserve water. At present, WASA does not have any programme in place to address customer side leakage.

WASA should institute the following measures to deal with customer side leakage:

- Review of legislation to ensure that measures are in place for the prevention of customer side leakage and appropriate authorisation for entry to premises to repair leaks;
- Identify customer side leakage by sounding or inspection on supply pipes. This should be done in tandem with the sounding programme;
- Report identified leakage to the section responsible for job repair;
- Send letters to identified customers informing them of situation and advising them to effect repairs within a certain time frame;
- Enforce repair to leaks if customers do not respond.

WASA should also consider free repair of customer side leakage if it considers it a significant problem that needs to be controlled in order to improve the supply/demand situation.

<u>Support Structures</u>

<u>Human Resources</u>

Aligned to the strategic measures that need to be taken to control and reduce leakage are the support structures that provide expertise and resources. The first of these is adequate personnel. Whether WASA seeks to conduct leakage control in-house or outsource as a performance contract, it should identify an appropriate work force to conduct a comprehensive programme. This should be based on the quantity of work identified, the geographical extent of the programme, the type of resources needed and linkages to other functional areas in the Authority such as records of the infrastructure and repairs and replacement of mains and supply pipes. The RIC feels that the following minimum categories of staff will be needed:

- A Leakage Manager – for overall control of the Programme
- Engineers – for regional operations and specialised functions
- Leakage Inspectors – for sounding and detection of leakage
- DMA technicians – for equipment setup and takedown and data collection
- Data analysts – to analyse data from the zones and so direct where field activities should take place
- Administrative staff – to support the Unit

Training

Leakage management is increasingly becoming a very specialised area and it is critical that all personnel be well versed in leakage technology and equipment usage. WASA's Water Loss Control (WLC) staff has been provided with training in the past but from reports it appears that it did not meet requirements, having concentrated on the use of the leak-noise correlator (Bristol Water, 1997). If WASA decides to continue with an in-house programme its staff would be required to undergo continuous updated training in the following areas:

- The theory of leakage control
- Practical demonstrations and experience in the use of a wide variety of equipment such as leak-noise correlators, data loggers, flow meters etc.
- The maintenance of all equipment
- The electronic detection of pipelines
- Sounding
- The setup and measurements of flow using various types of meters
- The setup of DMAs, WWMDs and pressure zones
- Field training in operational work including downloading of data
- The analysis of data using leakage software

Transport and Equipment

There will be additional logistical needs for an expanded programme over and above the present resources that WASA now has. Ofwat (Tripartite Group, 2002) categorises equipment needs based on the three main leak detection processes shown in **Table 5.**

Table 5. Leak Detection Technology

Awareness	Localisation	Pinpointing
Metering	Step testing	Listening Sticks
Data logging	Acoustic logging	Geo phones
Communications		Correlators

Should WASA seek to continue its in-house programme its present equipment status would have to be assessed and additional items procured if necessary to cater for work in each of the three categories. These would include:

- Pressure and flow data loggers and attendant software for use in the zones
- Flow Meters – both insertion type for spot measurements and turbine meters for zone measurements
- Geophones – for sounding activities
- Listening Sticks – for sounding activities
- Correlator – for the detection of invisible leakage
- Main Tracers
- Valve locators
- Protective gear
- Support equipment such as torches, spanners, radios etc
- Vans for transporting staff

<u>Public Education and Information Programme</u>

It will be to the benefit of the Authority to institute a public education and information programme that runs parallel to the leakage management programme. Indeed, it should form part of the overall strategy so that there is consistency and harmony with the objectives of the programme. As a leakage programme unfolds, the public will become visibly aware of changes that are taking place. These changes might be perceived as negative, such as road excavations, disturbances at night and decreased pressures at times and positive, such as a 24-hour supply and increased pressures. It is therefore important and in WASA's interest to ensure that information is constantly relayed to the public so that they are kept up to date and aware of what is happening. This will bring goodwill between the public and WASA and allow the Authority to enlist the help of the public in reporting leaks, repairing leakage on their premises and in conserving water.

Actions that should be implemented in a public education and information programme are:

- Formation of a Public Education Strategy
- Workshops to train WASA staff - administrative, maintenance and commercial to communicate the message and respond to the public.
- Assembly of media kits and dissemination of information via the media.

- Production of brochures and other visual aids.
- Public forums to educate public and hear views.
- Public tours of WASA facilities and field sites to see how the leakage management strategy is unfolding.

The public relations campaign should be for the duration of the project. As there may be similar project exercises taking place simultaneously with the leakage project it may be useful to have shared resources. However, adequate personnel and support must be available so that exclusive coverage of this project is provided.

Information Technology Support

Water Loss management is data intensive; therefore steps should be taken to ensure the collection of all relevant data. Data will fall into three general categories – operational, tactical and strategic – and these are detailed in **Table 6**.

It may be necessary to upgrade existing hardware to cater for increased usage of a full-scale programme. It would also be useful to ensure Internet availability, network connectivity and adequate peripherals for printing and reporting, faxing, scanning and copying.

Apart from the software used to transfer data from data logging equipment, analytical tools are also available to support a range of leakage management requirements such as:

- Flow and pressure monitoring
- Night flow assessments
- Water balance
- Consumption and demand analysis

WASA should investigate what tools are available for successful use in the local environment.

Other NRW Strategies

Universal Metering

There are other measures, which though not directly related to leakage, support the leakage programme and help with reduction of leakage. Universal metering is one such measure that if implemented with an appropriate tariff structure will help in reducing customer side leakage as measures are taken by consumers to reduce consumption.

Table 6. Data Collection for Water Loss Management

Operational Data	Current leakage levels Current pressure data Outlet settings of PRVs Records of the number and type of leaks found Records of hours spent on ALC
Tactical Data	Zone boundaries Types of PRV Maintenance records PRV performance records Asset data
Strategic Data	Distribution input averages Water balance calculations Results of studies and pilot exercises Lessons learnt database Numbers of ALC staff employed

Source: Farley and Trow

Metering comprises just 3% of the account base (WASA Commercial Section, 2002). Some domestic meters were installed over 10 years ago, but these have not been maintained and are generally inoperable. Volume is therefore estimated. The situation is virtually the same with commercial and industrial meters installed in a programme about 10 years ago. Clearly then, a comprehensive metering programme, embracing meter installation, reading, testing and maintenance and proper billing procedures is required to be put in place as a separate adjunct to a leakage programme.

The RIC has proposed such a programme[1] but it will not be discussed here. It calls for private sector participation in the installation of meters as an alternative to WASA having to find a large capital outlay to fund the programme. It is recommended that WASA implement this programme both to achieve the objectives required by metering and also to assist with the leakage management programme.

Tariff Setting

A proper tariff structure is required in conjunction with metering if water utilisation and wastage by customers is to decrease. The act of metering itself does not cause people to use water with more care. It is the method by which a price can be levied so that the charge varies in proportion to the volume used (Delcan/Lee Young & Partners, 1992). The price should be an optimal one to cause customers to take notice of their charges and so reduce their consumption.

[1] See *Water Metering in Trinidad and Tobago – the way forward* (RIC, 2002)

WASA currently uses the annual taxable value (ATV) of property method for billing. Simply put, a percentage of the ATV is charged as a flat rate to domestic customers subject to a minimum quarterly or monthly charge. There are metered customers, mainly commercial and industrial who are charged volumetric rates but these constitute a small part of the customer base as stated previously. There is therefore no incentive to customers with the existing method to conserve water. It has also been shown that present tariffs are set below the levels necessary for WASA to be financially viable (London Economics/Castalia, 1998). Consequently, for WASA to meet its financial objectives and to curb customer wastage it must:

- Move to universal metering as quickly as possible;
- Apply an appropriate tariff to enhance collections and to encourage conservation.

Mains Replacement

A successful leakage strategy employs several methods to reduce leakage as listed above. Less water is lost from the system infrastructure as mains repair and pressure reduction are used successfully to improve supply. However, due to ageing infrastructure there will come a time when water mains and supply pipes will have to be changed out in order to improve the supply to customers.

WASA has been able to track its repair programme since 1992 and this was improved with a job management system in 1997 under the Severn Trent management contract[2]. It has collected approximately 5 years of data that can be used to identify where its distribution network is deteriorating and facilitate the introduction of corrective measures to replace mains. WASA in its Corporate Action Plan of 2002 planned to engage in the replacement of 230 km of pipeline for the period June 2002 to March 2003. This is a laudable objective but based on a total mains infrastructure base of 5800 km, this amounts to a replacement rate of nearly 4% over a nine-month period. Can this be sustained? High replacement rates can only be entertained in relatively affluent parts of the world (Bridges, 1994) and with WASA's financial difficulties 4% may be difficult to maintain. Nevertheless efforts should be made to continue this process with continuous change out, possibly at a rate of 0.5 to 1%, of the parts of the network in need of replacement. All this will be done in tandem with the ALC strategies of the water loss programme.

Phase 2 – 42 months

Active Leakage Control Strategies

Pressure reduction and control

This method, while not a direct form of leak detection, is useful as a reduction in pressure may reduce the rate of escape from each leak as well as reduce the number of leaks that occur. Pressure reduction may be achieved by reducing pumping heads, installing break pressure tanks and by using pressure-reducing valves

[2] An Interim Operating Arrangement (IOA) between Severn Trent International/Wimpey operating as Trinidad and Tobago Water Services (TTWS) and WASA to manage the Authority was in place from 1996-1999.

(PRVs). WASA has successfully used the latter strategy for the North Oropuche water system in 1995 (Bristol Water, 1997). Pressure zoning provides a permanent means of reducing pressure to specified existing high-pressure areas so that leakage can be reduced throughout.

In order to effectively reduce and control high system pressures WASA should:

- Identify areas presently experiencing high pressures.
- Design zones in these areas so that pressures do not exceed the quality standards of a minimum of 15m head and a maximum of 70m head. Operationally, the pressure should be of the order of 40-50m head. For practical reasons only zones that have a 24-hour supply should be considered for this exercise.
- Introduce pressures reducing schemes in other areas of high pressure to improve system management and reduce leakage.

The installation of pressure reduction techniques must be carried out before the establishment of DMAs. If the DMAs are introduced first then there will be the need for considerable redesign of the boundaries if pressure zones are implemented after (Bristol Water 1997).

Set-up of DMAs

The District Meter Area (DMA) is an area of typically 1000 to 3000 properties in which there is continuous monitoring of flows, usually weekly or monthly. Minimum night flow is used as a measure and it comprises distribution losses (leaking glands, joints and minor bursts) and night flow delivered (consumer's use and losses within the consumer's supply pipe). Leakage is then estimated by subtracting this flow from legitimate night use. This is known as the bottom up approach to leakage estimation. DMA leakage estimation is becoming the principal method of leakage control worldwide, currently in common usage in the United Kingdom and expanding to several other countries including the United States of America. Although originally developed for leakage control purposes DMAs are now being used for other purposes such as demand forecasting, consumption monitoring and network modelling principally in the UK (Bristol Water, 1997).

WASA has already started the installation of DMAs across the country and this process should continue until DMAs exist for all areas in Trinidad and Tobago. Also, the Authority has to ensure the following is done in conjunction with the establishment of the DMAs:

- They should not be implemented until visible leaks and sounding programmes are underway and effective;
- They should first be implemented in Class I areas where the supply is uninterrupted and then progress to other areas as water becomes available;

- They should be used in conjunction with WWMDs (see relevant section) in order to optimise the time taken to detect and locate leaks;
- There is a need for good infrastructure records for the establishment of both DMAs and WWMDs. This will have to be put in place;
- The Authority should investigate the means of frequency of downloading data either by manual collection or via telemetry. This is vital to proper assessment and management of leakage for effective reduction and control.

Set-up of Waste Districts

The Waste District is a qualified form of district, the inflow to which is measured through a waste meter and step testing is done to trace leakage to relatively small sections of the distribution system (Thames Water, 1991). It typically consists of about 500-1000 properties and can be a subset of the DMA or exist on its own. Runs in a waste district are not done as frequently as the DMA monitoring and as such it is not a tool to rapidly identify leakage but instead to pinpoint it.

WASA should continue the development of WWMDs in conjunction with DMAs (combined district and waste metering) so that as leakage is identified within the DMA the WWMD is used to further locate where the heaviest leakage is occurring. In addition, the following is necessary:

- They should first be implemented in Class I areas where the supply is uninterrupted and then progress to other areas as water becomes available;
- They should not be implemented until visible leaks and sounding programmes are underway and effective;
- There is a need for good infrastructure records for the establishment of both DMAs and WWMDs. This will have to be put in place;
- The use of sounding will still be used for leak detection within WWMDs as the means of precisely identifying where leaks are occurring.

Trunk Main Leakage

Trunk mains are not part of the DMA setup and as such leakage has to be measured separately. They are usually upstream of service reservoirs so there is little fluctuation in flow and losses can be difficult to measure and locate.

WASA should implement its bulk-metering programme under Phase 2 of the leakage management strategy. This would then be available for detection and measurement for trunk main leakage. It is understood that development of a bulk metering system will take place over a few years and as such it will be necessary for other means of identifying leakage to be used. This would entail clearing the trunk main reserves where necessary and walking the path to identify any leaks on the mains and appurtenances.

Reservoir Leakage

Service reservoirs in T&T are mainly of concrete and steel construction. Leaks can therefore occur along construction joints and corroded seams of the steel tanks. In addition, overflow or washout pipes have been known to leak due to poor construction or defective valves.

WASA should commence a programme of conducting drop tests of all its reservoirs to ensure water tightness and to reveal leakage if present. Physical inspections should also be carried out with special attention being paid to overflow chambers and valves to ensure leakage is not occurring in this fashion.

Assessment and Management of Apparent Losses

Apparent losses include unauthorised consumption (theft and illegal use) and errors occurring in meters. It is not actual physical loss due to leaks and burst but is counted as loss on account of revenue being lost due to it not being recorded and billed. It could be a significant figure reaching as high as 9% of system input volume (Lambert, 2001).

Concerning these components, WASA has experienced problems with illegal connections and water theft. However, meter accuracies are not a significant problem since there are few installed meters and many are not in working condition.

WASA should therefore undertake the following to reduce apparent losses:

- Closed accounts should be investigated to ensure that there is no further water use. If these accounts are still active they should be disconnected.
- Illegal connections once identified should be converted to legal connections and billed.
- The publication of penalties and fines for illegal use should be promoted.
- Some form of incentives for legal customers should be introduced. They should be attractive enough to appeal to illegal users so that they can be persuaded to becoming legal users.
- The Geographic Information System (GIS) at WASA should be used to establish a link between customer accounts and actual properties and/or buildings.
- The Authority should offer free leak detection services to commercial customers. This may help identify illegal use if present and also provide information on consumption.
- Fire hydrants can be a major source of illegal use. They should be investigated by selected sample metering to determine consumption and if found to be excessive then metering can be extended and data recorded on a permanent basis.
- For meters that are working, these should be investigated for under registration and with a view to change out under a universal metering programme (*see Section on Universal Metering*).

Other NRW Strategies

Bulk Metering

Bulk metering is a vital strategy for accurate recording of the quantity of water into supply. This method in conjunction with consumption measurements provides for an accurate assessment of leakage. Measurement of the production, transmission and parts of the distribution system are made in order to provide water into supply data along the distribution network.

WASA should commence a programme to meter all water treatment plants, pumping stations and large offtakes in order to measure system volumes so that accurate and reliable data are available for analytical purposes including leakage management. Such a system would help in the identification of large bursts and areas of excessive leakage as and when they occur.

Infrastructure Records

This is a vital component of leakage management. If adequate records do not exist then the design and setup of DMAs, WWMDs and pressure zones are difficult to achieve. Other infrastructure activities such as distribution operations, network modelling and asset management plans are also severely affected. Mains and appurtenances records need to be kept up to date.

The GIS Section at WASA has the responsibility for keeping infrastructure records. The Section possesses mapping records in a digital environment. This allows for better data capture, and document delivery is available in different size format and with several content types. However, Bristol Water (1997) noted that the Section became involved in several other projects and its main objective of mapping infrastructure records got sidetracked. There is a need to ensure that the GIS captures all mains information including mains laid in the past few years under the North and South Water Projects. Old paper maps whose information has not yet been captured need to be digitized. This will then require field verification and updates/inputs from operations staff. To achieve this goal in an expeditious manner it may be necessary to employ a contractor for the collection and digitizing of mains information while the GIS Section maintains the data and provides relevant maps to leakage and operations personnel.

Phase 3 – 24 months

Other NRW Strategies

Telemetry

The use of telemetry can be employed once leakage zones are up and running. Telemetry involves automatic transmission and measurement of data from remote sources by wire, radio or by other means. Instead of infrequent manual collection of data, remote logging of data can provide a frequent, easier means of data capture and assure faster discovery of leakage problems and the concomitant decision making.

Telemetry is a costly endeavour but these costs are reducing annually and even a partial use could be of benefit.

Asset management

An asset management programme (AMP) will put in perspective the need to replace asset infrastructure based on sound economic, financial and technical reasons. It will examine the network in a holistic way based on costs, condition and performance and allow proper decision-making in the replacement of assets.

WASA should seek to reactivate its asset management programme so that it will be a powerful support mechanism to a long-term water loss management strategy.

Network Analysis

Computer based network modelling is now a well-established technique for the analysis of water distribution systems. An area where models are particularly useful is the design of leakage management schemes. Models are built with the existing infrastructure and system knowledge and calibrated to provide scenarios for the creation of leakage management zones. This can then be used to improve the zones that already exist.

WASA currently undertakes some network modelling but this is probably affected by inadequate mains data. This would have to be improved as mentioned previously. The Systems Optimization department should seek to ensure that data are accurate and properly captured so that effective modelling can be performed.

Phase 4 – Ongoing Maintenance

At the end of Phase 3 the project implementation phase of the programme will have been completed. The next stage involves a maintenance phase where monitoring of zones and maintenance of data, facilities and equipment become the main agenda. Elements of work here would include:

- Night flow monitoring;
- Proper record keeping;
- Reassessment of leakage control activities;
- Improvement to ELL calculation;
- Maintenance of facilities and equipment;
- Investigating new policy and technology options.

In addition, it is expected that periodic reassessment of the initial items of the programme in Phases 1 to 3 will be undertaken so that the cycle of water loss management is continually being accomplished so as to further drive down NRW and ultimately the operational cost to the Authority.

Costs of the Programme

It is difficult at this inchoate stage to assess the full costs of the programme. However, some comparisons can be made. Bristol Water in their Water Loss Report of 1997 estimated that a similar program would cost in excess of TT$200 million dollars over a 10 year period. In the State of Selangor, Malaysia, a similar albeit larger programme was contracted out for US$105 million dollars (TT$661 million) over a period of 9 years (Liemburger, 2001). This project was to serve a population of 5 million and a pipe network of 13,000km. A limited one-year programme in Port Moresby, Papua New Guinea is being accomplished at a cost of US$ 590,000 dollars (TT$3.7 million). This project provides works and services to a distribution system that supplies 165 megalitres (Ml) a day. Supply in Trinidad and Tobago is of the order of 910 Ml a day. Clearly then, from these examples, a significant amount of funding will be necessary to undertake a local effort.

CONCLUSION

NRW has emerged as an important and vital issue to water utilities around the world. Decreasing water resources over the years along with rising populations have resulted in the existence of water shortages in many regions. The conservation of the commodity is therefore of major concern. In addition, the efficacy of the utility has been brought to the fore. Customer acceptance of poor performance and inadequate supply partially due to leakage coupled with high tariffs is no longer to be tolerated and the utility will inevitably feel the brunt of the customer's ire.

Trinidad and Tobago has a fairly rich endowment of water resources (Draft National Water Resources Management Policy, 2002). To a cash strapped utility however, the winning, treatment and transporting of the resource is a difficult proposition and much has to be done towards the conservation of existing supplies. The operations of the utility must be such that preservation of the supply is of prime consideration. This would relate to stemming the physical loss in the implementation of measures such as repair to visible leakage and leakage control strategies and the identification and elimination of apparent losses by effecting proper consumption measurement and billing procedures among other tasks.

This paper has attempted to evaluate and update the local situation with respect to the identification of the economic level of leakage (ELL) and proposes appropriate solutions for the reduction and control of NRW. It is hoped that it will be a catalyst for increased and enhanced awareness and implementation of water loss solutions in the country.

REFERENCES

1. Alegre, H. et al (2000) *Manual of Best Practice – Performance Indicators for Water Supply Services* IWA Publishing, London, England
2. Anonymous (1999) *The pipes aren't leaking but the water's gone*. The Urban Age Magazine, Winter 1999 Issue.
3. Bridges, G. (1994) *Leakage Control – the neglected solution?* 20th WEDC Conference, Colombo, Sri Lanka.
4. Bristol Water Enterprises Ltd./Howard Humphreys (1997) *Preparation of the Water Loss Programme – Draft First Report.* Water and Sewerage Authority, Trinidad and Tobago.
5. Delcan International Corporation/Lee Young and Partners (1992) *Feasibility Study on Cost/Benefit Analysis of Universal Metering in Trinidad and Tobago - Final Report.* Water and Sewerage Authority, Trinidad and Tobago.
6. Djerrari F. (2003) *Best practice in urban water resource management: Contribution of LYDEC in Casablanca*. World Bank Water Week 2003, Unaccounted for Water reduction Session.
7. Farley, M. and S. Trow (2003) *Losses in Water Distribution Networks – A Practitioner's Guide to Assessment, Monitoring and Control.* IWA Publishing, Alliance House, London, England.
8. Hueb, J.A. (2000) *Advantages of Leakage Control and the Reduction of Unaccounted for Water.* Proceedings of the International Symposium on Efficient Water Use in Urban Areas.
9. Hirner, Dr. W and A. Lambert (2000) *Losses from Water Supply Systems: Standard terminology and recommended performance measures.* IWA– The Blue Pages, London, England.
10. Jeffcoate, P. and A. Saravanapan (1987) *The Reduction and Control of Unaccounted for Water – Working guidelines.* The World Bank, Technical Paper No. 22.
11. Kelda Group (1999) *Establishing the Economic Level of Leakage in the Yorkshire Region – 1999.* Yorkshire Water, Bradford, England.
12. Lambert, A. O. (2001) *Water Losses Management and Techniques – International Report.* IWA 2nd World Water Congress, Berlin, Germany.
13. Liemburger, R. (2001*) Performance Target based NRW Reduction Contracts – A new concept successfully implemented in Southeast Asia*. IWA 2nd World Water Congress, Berlin, Germany.
14. Liemburger, R. (2002) *Do you know how misleading the use of wrong performance indicators can be?* IWA Managing Leakage Conference, Lemesos, Cyprus.
15. Liemburger, R. (2003) *Competitive Tendering of Performance Based NRW Reduction Projects.* IWA Efficient 2003 Conference, Tenerife, Canary Islands.
16. London Economics/Castalia (1998) *WASA Tariff Study – Draft Final Report*. Water and Sewerage Authority, Trinidad and Tobago.
17. Ofwat, (1998) *Leakage and the efficient use of water – 1997-1998 report.* Office of Water Services (Ofwat), Birmingham, England.

18. Ofwat (2000) *Leakage and Water Efficiency – Report by the Comptroller and Auditor General.* Office of Water Services (Ofwat), Birmingham, England.
19. Ofwat, (2001) *Leakage and the efficient use of water – 2001-2001 report.* Office of Water Services (Ofwat), Birmingham, England.
20. Preston, S.J. and R. Sturm (2002) *Use of the Infrastructure Leakage Index (ILI) in Malaysia.* IWA Specialised Conference, Leakage Management – A Practical Approach, Cyprus.
21. Reynolds, J. and S. Preston (2001) *The International Application of the BABE concepts – from feasibility studies to performance target based NRW reduction contracts.* IWA Specialised Conference - System Approach to Leakage Control and Water Distribution Systems Management, Brno, Czech Republic.
22. Rizzo, A. (2000) *Leakage Control and Unaccounted for Water Analysis.* Proceedings of the International Symposium on Efficient Water Use in Urban Areas.
23. Stephens, I. (2003) *Regulating Economic Levels of Leakage in England and Wales.* Presentation at 'World Water Week'. World Bank Washington D. C. 2003. Office of Water Services (Ofwat), Birmingham, United Kingdom.
24. Thames Water International/AdeB Consultants (1991) *Feasibility Study to determine Methods of Leak Detection.* Water and Sewerage Authority, Trinidad and Tobago.
25. The Asset Management Series (1995) *Glossary*
26. Tripartite Group (2002) *Leakage Target setting for water companies in England and Wales – Summary Report.* Office of Water Services (Ofwat), Birmingham, United Kingdom.
27. Versteeg, N and J. Tolboom (2003) *Water Conservation: Urban Utilities* Water Resources and Environment, Technical Note F.1 (Series Eds. R. Davis and R. Hirgee) The World Bank, Washington DC, USA.
28. Water Resources Management Unit (2002) *Draft National Water Resources Management Policy* Ministry of Public Utilities and the Environment, Government of Trinidad and Tobago
29. WSO (2002) *Leakage Management Assessment and Training, Philadelphia, USA* Water Systems Optimization Inc.
30. Yepes, G. (1995) *Reduction of Unaccounted for Water*. Best Practices, Water and Sanitation Division, The World Bank, Washington DC, USA.
31. Yepes, G. and A. Dianderas (1996) *Indicators – Water and Wastewater Utilities 2nd Edition.* The World Bank, Washington DC, USA.

APPENDIX I

Defining NRW

The term UFW seems self-explanatory. However, the actual definition and individual components of UFW often vary across utilities and countries. Despite this, a good starting point is provided by Yepes and Dianderas (1996), who in a paper prepared for the World Bank, note that UFW reflects the difference between the volume of water delivered to the distribution system and the water sold. It includes physical losses (pipe breaks i.e. leaks and overflows) and commercial losses (meter under-registration, illegal use including fraudulent or unregistered connections and legal, but usually not metered uses like fire fighting). Recently, the IWA has used the term NRW and recommended that the term UFW, if used, be defined and calculated in the same way as NRW. This term is therefore adopted for the remainder of this paper.

NRW is usually expressed in a number of different ways such as:

- Difference between water supplied and water sold expressed as a percentage of net water supplied (this is the most common form of expression);
- Difference between water supplied and water sold expressed as a volume of water 'lost' per km of water distribution network per day; and
- Difference between water supplied and water sold expressed as a volume of water 'lost' per water connection.

Liemberger (2002) notes that the traditional indicators listed above can be misleading. Instead he notes that the IWA recommends their use as financial performance indicators and proposes that the Infrastructure Leakage Index (ILI) be used as an operational indicator as it best describes the efficiency of the real loss management of water utilities.

The issue of appropriate performance indicators for NRW is discussed further below.

Similarly, Lambert and Hirner (2000), in a paper prepared for the International Water Association (IWA), note that the Water Losses of a system can be calculated as:

Water Losses = System Input Volume – Authorised Consumption

where water losses consist of real and apparent losses. Real losses are physical water losses from the pressurized system, up to the point of customer metering. It is the volume lost through all types of leaks, bursts and overflows and dependent on frequencies, flow rates, and average durations of individual leaks. Apparent losses consist of unauthorized consumption (theft or illegal use), and all types of inaccuracies associated with production metering and customer metering. Water losses can be considered as a total volume for the whole system, or for partial systems such as raw water mains, transmission or distribution.

In each case the components of the calculation would be adjusted accordingly. The authors note that under-registration of production meters, and over-registration of customer meters, lead to under-estimation of real losses. The converse is also true. System Input Volume is the volume of water input to a transmission system or a distribution system. Authorised Consumption is the volume of metered and/or un-metered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorized to do so by the water supplier, for domestic, commercial or industrial purposes. It includes exported water. Note that authorized consumption includes items such as fire fighting and training, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, frost protection and other such uses.

Additionally, Lambert and Hirner (2000) go further, and define Non-Revenue Water, as the difference between the System Input Volume and Billed Authorised Consumption.

Measuring NRW

If a utility is to be able to control the problem of NRW, then planners must know the amount of water being lost as NR and the amount of water attributable to its specific components. A system must therefore be put in place to measure it. If this is done then it is possible to:

- Forecast potential savings (real losses) and potential revenue increases (apparent losses);
- Develop meaningful real and apparent loss reduction strategies; and
- Set realistic targets.

Lambert and Hirner (2000) note that the best practice in the management of water losses consists of a combination of continuous water balance calculations (top-down approach) together with night flow measurements on a continuous or 'as required' basis (bottom-up approach). The water balance, usually taken over a 12-month period, should include:

- A thorough accounting of all water into and out of a utility system, including inspection of system records;
- An ongoing meter testing and calibration programme;
- Due allowance for the time lags between production meter reading and customer meter reading.

The water balance calculations quantify volumes of total water into the system, authorised consumption (billed and unbilled, metered and unmetered) and water losses (apparent and real). All water balance calculations are approximate to some degree because of the difficulty of assessing all the components with complete accuracy. The reliability is likely to be greatest when input volumes are purchased (with duplicate metering), and all water is measured through regularly maintained accurate customer meters supplying properties that do not have storage tanks. Storage tanks can result in low flow rates through service connections, and these low flows may not register accurately on the customer meter.

Lambert and Hirner (2000) also note further that best practice, as recommended by the IWA Performance Indicators Group, is to assign confidence grades to each component of the water balance, incorporating both reliability and accuracy gradings. In some countries these gradings are checked independently as part of the process. The components of the water balance calculation are illustrated in **Figure 1.**

Figure 1. Components of Water Balance for a Transmission or a Distribution System

<table>
<tr><td rowspan="9">System Input Volume

M^3/ year</td><td rowspan="4">Authorised Consumption

M^3/year</td><td rowspan="2">Billed Authorised Consumption

M^3/year</td><td>Billed Metered Consumption (including water exported)</td><td rowspan="2">Revenue Water

M^3/year</td></tr>
<tr><td>Billed Un-metered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorised Consumption

M^3/year</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-Revenue Water

M^3/year</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses

M^3/year</td><td rowspan="2">Apparent Losses

M^3/year</td><td>Unauthorised Consumption</td></tr>
<tr><td>Metering Inaccuracies</td></tr>
<tr><td rowspan="3">Real Losses

M^3/year</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 point of customer metering</td></tr>
</table>

The steps for calculating NRW using water balance calculations are as follows:

- Step 1: Obtain *System Input Volume*
- Step 2: Obtain *Billed Metered Consumption* and *Billed Unmetered Consumption* and add together to calculate *Billed Authorised Consumption* and *Revenue Water*
- Step 3: Calculate the volume of *Non-Revenue Water* as *System Input Volume* minus *Revenue Water*
- Step 4: Obtain *Unbilled Metered Consumption* and *Unbilled Unmetered Consumption* and add together to calculate *Unbilled Authorised Consumption*
- Step 5: Add volumes of *Billed Authorised Consumption* and *Unbilled Authorised Consumption* to calculate *Authorised Consumption*
- Step 6: Calculate *Water Losses* as the difference between *System Input Volume* and *Authorised Consumption*
- Step 7: Assess components of *Unauthorised Consumption* and *Metering Inaccuracies* by best means available, and add these to calculate *Apparent Losses*

- Step 8: Calculate *Real Losses* as *Water Losses* minus *Apparent Losses*
- Step 9: Assess components of real losses by best means available (night flow analysis, burst frequency/flow rate/duration calculations, modelling etc), add these and cross check with volume of *Real Losses*.

The individual components of *Real Losses* can be classified as follows:

- Background losses from very small undetectable leaks - typically low flow rates, long duration, large volumes;
- Losses from leaks and bursts reported to the water supplier – typically high flow rates, short duration, moderate volumes;
- Losses from unreported bursts, found by Active Leakage Control (ALC) – medium flow rates, but duration and volume depends on ALC policy; and
- Overflows at, and leakage from, service reservoirs.

While water balance calculations are most accurate in jurisdictions in which there is a high level or almost 100% metering, it is still possible to utilize such calculations where the number of metered customers is insignificant. In such cases, authorised unmetered consumption could be derived from sample metering of sufficient numbers of statistically representative individual connections of various categories, and/or by measurement of inflows into discrete areas of uniform customer profile (with data adjusted for leakage and diurnal pressure variations as appropriate).

In jurisdictions where there is little or no metering, such as in England and Wales, where it is estimated that about 79% percent of the domestic customers are not metered (Stephens, 2003), the approach adopted by companies that are regulated by the Office of Water Services in the United Kingdom (Ofwat) is insightful. There the focus is on the Real Losses component of NRW, that is leakage. In its 1997/1998 Leakage Report, Ofwat recommended the use of the integrated flow/water balance method combined with the minimum night flow method (minimum nightlines {night flow data} based on District Meter Areas) to calculate leakage.

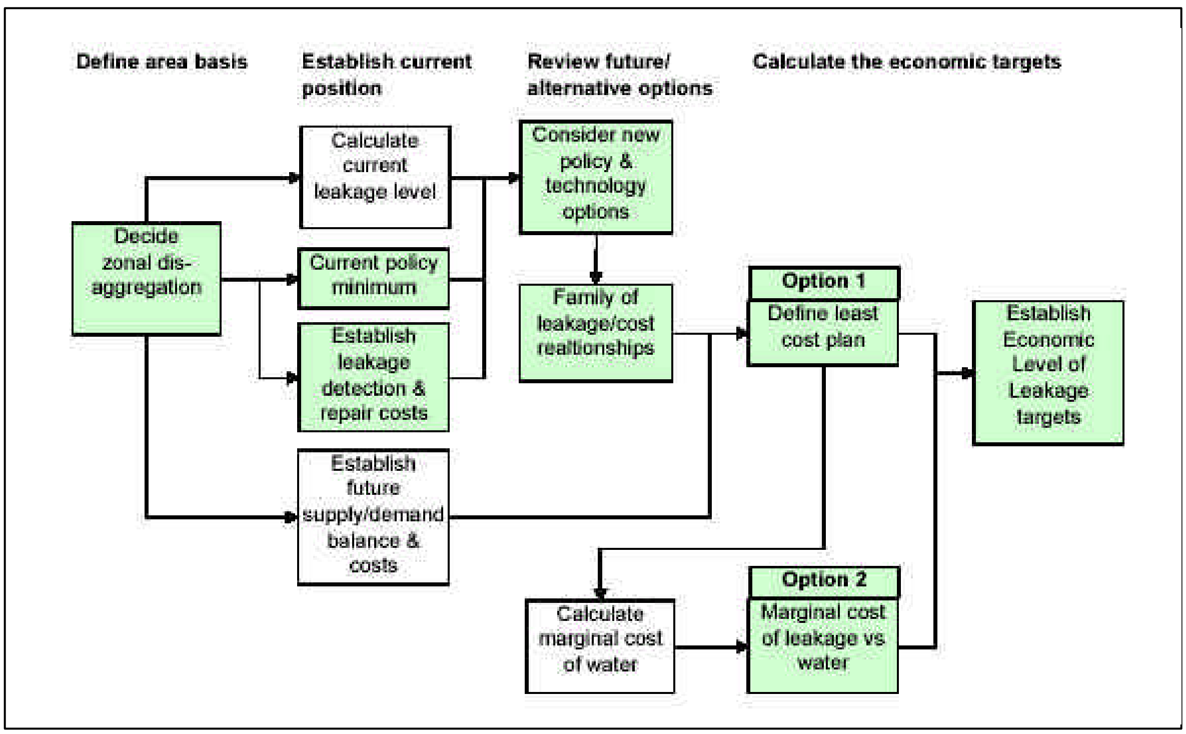
<u>Determining the Economic Level of Leakage (ELL)</u>

This section draws on the report entitled Future approaches to leakage target setting for water companies in England and Wales (WRc with Stone and Webster Consultants for the Tripartite Group of the Department for Environment, Food and Rural Affairs, the Environment Agency and Ofwat, 2002). That report presents a best practice approach to leakage setting for companies in England and Wales. The study objectives were to establish a set of key principles to be followed when calculating the Economic Level of Leakage (ELL) arising either from best practice aspects of companies' methodology or other improvements proposed by the consultant, and to develop a forward looking approach.

The approach presented builds on the extensive work that has taken place to control the level of leakage in England and Wales, where Ofwat has set leakage targets for some time. However, while the concept is extremely useful, the data required to calculate the ELL is not currently available in the local context.

The above mentioned report defines the ELL as the level of leakage at which the additional cost of reducing leakage is equal to the additional benefit gained from further leakage reductions, in other words it refers to that level of leakage at which it would cost more to make a further reduction in leakage than to produce the water from another source. Therefore a company operating at ELL means that the total cost to the customer of supplying water is minimised. In other words an ELL approach sets economic targets for the water company rather than targets for the company to set economically.
The ELL target setting process map is outlined in Figure 2.

Figure 2. The ELL target setting process map



The key stages in this process are outlined in **Table 1**.

Table 1. Key Stages in ELL Process

Define area basis	**Decide zonal disaggregation (consistent water supply and leakage management areas)**
Establish the current position	Calculate current leakage (trunk mains and supply system, distribution mains and customer service pipes) Determine current policy minimum (existing policy) Establish leakage detection and repair costs (existing policy) Establish current and future supply/demand balance and alternative investment costs (resources and demand management)
Review future/alternative options	Consider new policy and technology options (for leakage management, pressure management, mains replacement, etc) Develop family of leakage/cost relationships
Calculate the economic target	Option 1 = leakage level output of least cost planning analysis (programme with lowest NPV) Option 2 = relationship between active leakage control cost curve and cost of water

Performance Indicators

It is well accepted that the level of water losses, both real and apparent, is one of the most important efficiency issues for water utilities. However, with the exception of the UK water industry, water losses are still quoted as a percentage (%) of System Input (water production), although this can be a very misleading indicator.

The Infrastructure Leakage Index (ILI)

In an effort to develop more rigorous methods for measuring real losses the IWA has developed the Infrastructure Leakage Index. It is a measure of how well a distribution network is managed (through repairs, pipelines and asset management, active leakage control) for the control of real losses, at the current operating pressure. It is the ratio of Current Annual volume of Real Losses (CARL) to Unavoidable Annual Real Losses (UARL).

The term CARL is self-explanatory. However, suffice to say that as a system ages the CARL tends to increase (natural rate of rise). UARL, which occurs even in the very best managed system, as there will always be real losses, can be calculated by the following formula:

UARL (litres/day)= (18 ? Lm + 0.8 ? Nc + 25 ? Lp) ? P

where Lm = length of mains (km);

Nc = Number of Service Connections;

Lp = length of private service pipes from property boundary to the meter (km);

P = average Pressure (m); and

the numbers relate to the volume of leakage expected from the different constituents of the equation. While Lp sounds difficult to obtain, it will be zero in all the systems where the meter is directly at the boundary line. In other systems it can be estimated.

UARL is similar in concept to the lowest technically possible policy minimum level of leakage used in the ELL determination process (Tripartite Group, 2002).

A ratio of 1 for the ILI would be an indication of a well-managed system. Since this is virtually impossible to achieve, the economic level of leakage (ELL) is seen as the desired level of leakage to achieve. This should be as near to 1 as possible. Conversely, a high figure indicates a system where leakage is high and further management is needed. For example the city of Philadelphia has an ILI of 13.2 (WSO, 2002), which is regarded as high.)

It is important to note here that **the ILI is strictly a technical performance indicator** and does not take into account economic considerations. **Figure 3** illustrates the ILI as well as the Economic Level of Leakage (ELL). In order to determine the most economic ILI the ELL must first be established.

Figure 3. The ILI and the Economic Level of Leakage