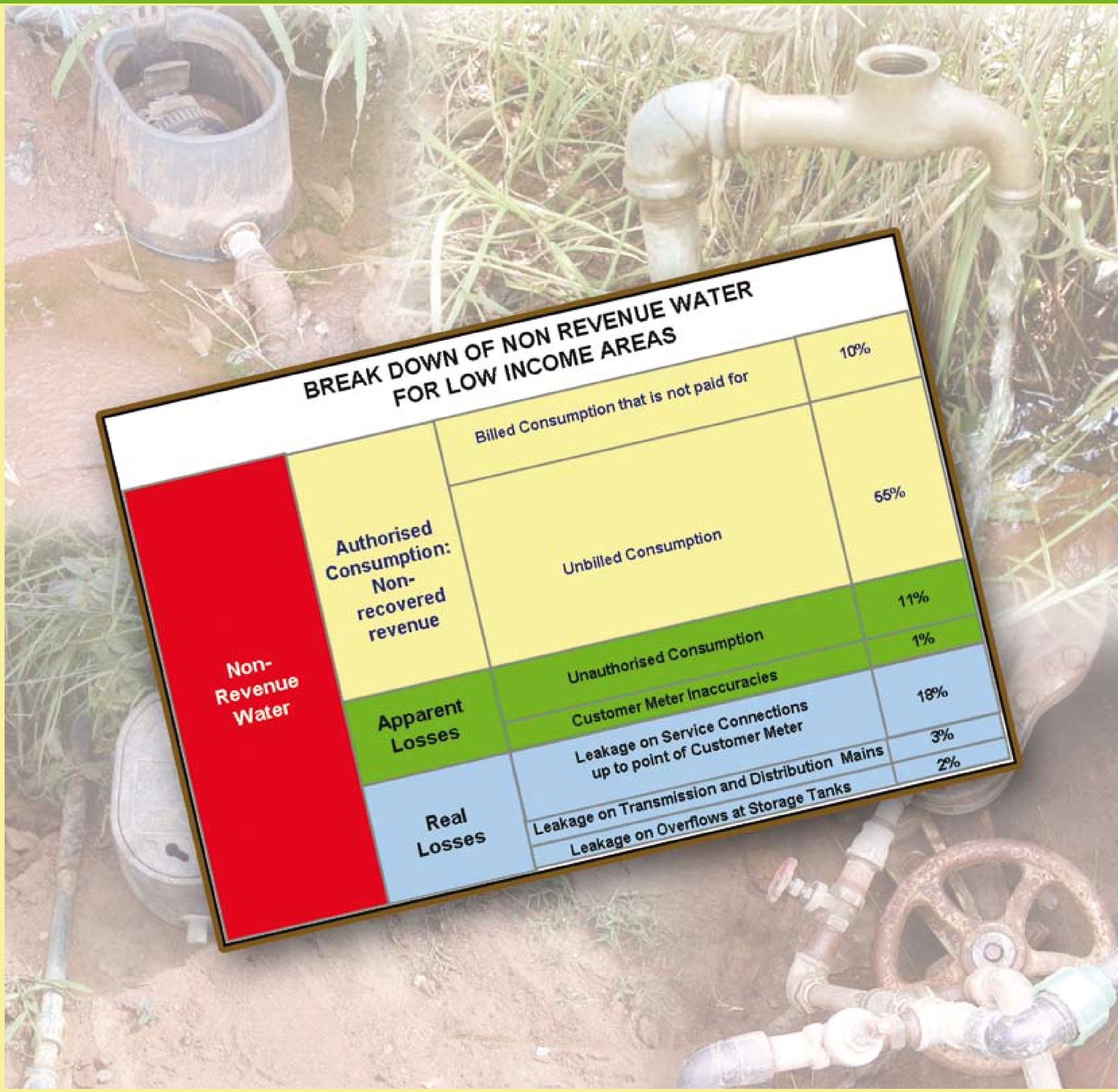
An Assessment of

Non-Revenue Water in South Africa

CJ Seago & RS McKenzie



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An Assessment of Non-Revenue Water in South Africa

CJ Seago & RS McKenzie

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IMPORTANT

PREFACE

This document provides details of the annual water balances for approximately 60 systems throughout South Africa. The results were collected as part of a WRC project aimed at estimating the total level of non-revenue water in South Africa. The report summarises the information collected during the study and addresses the following issues:

- The report provides a brief background to the principles of the standard IWA annual water balance;
- It explains how to complete the water balance to provide meaningful results;
- It provides details of the many water supply systems throughout South Africa that were included in the study;
- Finally, the results from the available systems are extrapolated in order to make a preliminary estimate of the total level of non-revenue water for all water supply systems in South Africa.

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TECHNICAL SUPPORT

The WRC does not provide technical support with regards to the use of the free water audit software (BENCHLEAK) used in this study and any questions or problems associated with the software should be directed to the model developer at ***ronniem@wrp.co.za.*** The software can be downloaded from the WRC website on **www.wrc.org.za** and the upgraded version (AQUALITE) will be available from 2007.

ACKNOWLEDGEMENTS

ACKNOWLEDGEMENTS

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Jay Bhagwan	WRC
Hannes Buckle	Rand Water
Cain Chunda	DWAF
Tony Cross	Johannesburg Water
Andre Dyer	Amatola Water
Mike Rabe	Alliance for Saving Energy
Chabedi Tsatsi	DWAF

EXECUTIVE SUMMARY

Municipal water use in South Africa has been under investigation for many years and the Department of Water Affairs and Forestry has been trying to establish the levels of wastage from all water supply systems countrywide. This has proved a very difficult task due to the absence of reliable data in many Municipalities as well as confusion regarding how such wastage should be estimated. Until the wastage can be quantified accurately, it is impossible to develop and prioritise the actions that must be taken to ensure that water is used effectively and efficiently in this water scarce country.

To address this important issue, the Water Research Commission has supported several projects over a period of 10 years to develop a suitable methodology for establishing the levels of water wastage in all municipal water supply systems. The latest project (which is discussed in the remainder of this report) is the first project in which the water balance methodology has been used to estimate the magnitude of non-revenue water from reticulation systems throughout the whole of South Africa. While many problems have yet to be resolved, the results from the current study provide the first plausible estimate of water losses and non-revenue water occurring in South Africa using the standardised water balance methodology supported by the International Water Association (IWA).

Despite many problems associated with the gathering of data from the various water utilities, the study was able to obtain information from 62 of the largest water reticulation systems throughout South Africa. From the analyses of the water balances for each of the water reticulation systems, the following conclusions were drawn:

- *The average bulk system input volume per property served for the 19 low income areas analysed as part of the study was approximately* ***37 kℓ per property per month****. This can be compared to an expected value of approximately* ***12 kℓ per property per month*** *which is considered to be a realistic value for monthly water use per property in low income areas where wastage is under control through proper metering and billing procedures.*
- *The average monthly water use per property in the medium to high income areas was estimated to be in the order of* ***46 kℓ per property per month****.*
- *It is clear that the relative magnitudes of the different components of the water balance vary significantly between the low income areas and the medium to high income areas.* ***In the low income areas, the greatest problem issue concerns***

the unbilled authorised consumption which is generally due to the underestimation of water use in areas where tariffs are based on a "deemed consumption" or assumed meter readings.*

- ***In the middle and high income areas, the greatest source of water loss is through physical leakage** rather than unauthorised use or unbilled use.*
- *It is essential that all water suppliers undertake a standard water balance annually for their supply system(s) in order to assess the levels of non-revenue water and also the total losses (i.e. real and apparent losses), if possible.*

Recommendations regarding use of Performance Indicators (PIs)

Following the IWA Water Loss Taskforce workshop held in Australia in February 2005, the following recommendations are made:

- ***The use of percentages as an indicator for real losses should be discouraged** although it is accepted that percentages will continue to be used by many Water Utility Managers who are not prepared to discard percentages completely from their list of PIs. It is, therefore, important when using percentages to highlight the potential pitfalls and to ensure that other PIs are also used. The authors therefore recommend that if percentages are used, they should not be used in isolation and must be accompanied by at least one other PI – preferably the losses in litres/connection/day and/or the ILI.*
- *It was agreed that the ILI is a very useful and powerful indicator which should be used in place of percentages if possible.*
- *In addition to the ILI, the following PI for real losses should be used:*

litres/connection/day

- *This indicator will be suitable for most systems where the density of connections is greater than 20 connections per km mains. In cases where the density of connections drops below 20 per km of mains, it is often appropriate to rather use the following indicator:*

m^3/km mains/day

- *The average operating pressure should be used as a PI since many systems are apparently achieving very low levels of leakage but are being operated at very high pressures which are often not necessary.*
- *Finally the Infrastructure Leakage Index (ILI) is a useful indicator for real losses and can often be used to benchmark the real losses from one system against another.*

Infrastructure Leakage Index ILI = CARL/UARL

Summary of Results for South African Water Reticulation Systems

Based on the results obtained from the 62 water reticulation systems, the following conclusions were reached:

- *The density of connections for the South African systems ranged from a maximum of approximately **135 connections/km mains to 18 connections/km mains**. The expected density of connections for a typical system in a developed country is in the order of 50 connections per km mains.*
- *The average operating pressure for the South African systems ranged from a **minimum of 24 m to 63 m**. It should be noted that this represents the weighted average pressure for the whole reticulation system and pockets of very high or very low pressure may still exist in various systems. These pressures are typical of most normal systems in the world.*
- ***The average ILI was found to be 7.6** (1.0 being very good and greater than 10 being very poor). Excluding one or two small outlier systems, the ILI ranged from approximately 2 (very good) to more than 20 (very poor). The average ILI value places South Africa in the middle of the world data set and indicates that the real losses in the country are high with significant scope for improvement but lower than most other developing countries.*

This information showed that these water reticulation systems have an average ILI of 7.6. It should be noted, however, that the ILI alone is not a clear indicator of how a water reticulation system is performing regarding the various components of non-revenue water.

Overall Water Balance for South Africa

One of the aims of the study was to use the results obtained from the largest Water reticulation systems in order to carry out an overall assessment of non-revenue water throughout South Africa. Unfortunately the information available from the various water reticulation systems in the country is either not available or of dubious quality in many cases with the result that ***any conclusions made regarding the level of non-revenue water for the country as a whole must be considered as a preliminary estimate that should be revised in future as more reliable data become available.***

In order to make any estimate of the non-revenue water occurring from water reticulation systems throughout South Africa, it was necessary to establish the total water used by the domestic sector. The National Water Resources Strategy of DWAF, states that South Africa's total urban and rural water requirement for 2000 is 3 471 million m^3*/annum. If this value is extrapolated using an assumed growth of 3%, it suggests a total municipal water use in 2005 of approximately 4 000 million* m^3*/annum. This is the value that will be compared to the results from the 62 water reticulation systems since these results are also based on the 2005 water audits. The total bulk system input volume figure obtained for the 62 systems analysed was 2160 million* m^3*/annum which represents approximately 54% of the total urban/rural water requirement of the country. This figure was then used to extrapolate the results obtained from this study in order to derive an estimate of the likely non-revenue water and total water losses for the whole country.*

Based on these figures the following assumptions and extrapolations were made:

- *The total water losses (real and apparent) for the 62 systems analysed was estimated to be 670 million* m^3*/annum or 31% of the total water supplied. The non-revenue water is effectively the sum of the total water losses and the estimated un-billed consumption. Estimating the un-billed consumption was difficult in many areas due to a lack of reliable information, however, it was estimated in the cases where proper data were available and subsequently extrapolated to cover the whole country. The un-billed consumption was conservatively estimated to be approximately 104 million* m^3*/annum which, in turn, provides an estimate of 774 million* m^3*/annum for the non-revenue water – approximately 36% of the water supplied.*

- *Based on the above figures, the extrapolated total losses from water reticulation systems for the whole of South Africa are likely to be in the order of 1 150 million m^3/annum (extrapolated from the 54% sample size). The total non-revenue water for the whole country is estimated to be 1 430 million m^3/annum (extrapolated from the 54% sample size). It should be noted that the free basic water allocation is not included as part of the non-revenue water and is considered to be revenue water which is billed at a zero rate.*
- *The potential savings that can be achieved from the 62 water reticulation systems analysed are estimated to be 263 million m^3/annum based on the methodology discussed in this report.*
- *If the above figure is extrapolated to the whole country (based once again on the 54% sample size), the potential savings are estimated to be almost 500 million m^3/annum, representing approximately 12.5% of the total system input.*

It should be noted that one of the main problems experienced during this project was the collection and validation of the data required to undertake the water balance, particularly with reference to the unbilled water use. The data are very basic and should be available from any well managed water utility. The fact that the majority of water utilities in South Africa are unable to provide such data is a reflection on the state of management of the utilities. To address this problem, it is essential that the various government departments take action to enforce an annual water audit for all utilities and that it must be fully supported by the appropriate politicians. It is therefore recommended that the methodology used in this project is adopted for such water balances since it has been accepted and adopted as the "standard" by the International Water Association.

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ABBREVIATIONS

DWAF	Department of Water Affairs and Forestry
ILI	Infrastructure Leakage Index
IWA	International Water Association
NRW	Non-Revenue Water
PI	Performance Indicator
RDP	Rural Development Programme
UARL	Unavoidable Annual Real Losses
UFW / UAW	Unaccounted for Water
WDM	Water Demand Management
WRC	Water Research Commission
WSA	Water Services Authority
WSDP	Water Services Development Plan
WSP	Water Services Provider

1 INTRODUCTION

1.1 Background

There is an increasing awareness in South Africa that water is a limited resource and that careful management should be applied when dealing with this scarce resource. Water lost from potable water distribution systems remains a major issue when examining the overall water wasted throughout the country. It is of utmost importance that Water Service Authorities (WSAs) in South Africa have a comprehensive understanding of their levels of leakage and other aspects of non-revenue water and begin to implement measures to reduce them.

This particular study is an extension of the work undertaken in two previous research studies carried out by the Water Research Commission (WRC). Software was developed in the first study in order to undertake a standardised annual water audit (McKenzie and Lambert, 2002). It was recommended that the software be used to assess the levels of leakage and non-revenue water in various systems throughout South Africa.

The second study involved the use of the software in order to Benchmark the leakage of 30 water reticulation systems throughout South Africa (McKenzie and Seago, 2005) In the process of the study, the whole water audit methodology gained considerable momentum and exposure. In addition, the study helped to address certain shortcomings and problem areas that had been identified during the numerous water audits undertaken as part of the study. It was recommended that the water audit process should be extended to cover the whole of South Africa and this was strongly supported by various initiatives introduced by DWAF.

This third study therefore involved a more comprehensive assessment of the levels of leakage and Non-Revenue Water in a larger sample of WSAs throughout South Africa and also used the previously developed BENCHLEAK software.

1.2 Objectives

The following five aims were set out in the study proposal:

- To use and improve the previously developed Leakage Benchmarking methodology in order to estimate and analyse elements of non-revenue water;

- To develop a database system which will facilitate the collection and collation of necessary data from the various WSAs;
- To develop a set of indicators to facilitate the benchmarking of the contributing elements of non-revenue water;
- To analyse the results in order to estimate the total level of non-revenue water and its elements, as well as the total level of real leakage for the country as a whole;
- To provide generic guidelines and recommendations on how to address the various elements of non-revenue water in a form that WSAs can easily understand and use.

The study therefore focussed on obtaining and analysing information from WSAs representing the 100 largest water reticulation systems throughout South Africa. This information was used to determine and compare various performance indicators for the different water reticulation systems. The information was also used to develop an approximate distribution of the various components of non-revenue water for two different types of Water reticulation systems namely, low income areas and medium to high income areas.

1.3 Methodology

A number of tasks were carried out through the duration of the study as summarised in **Table 1-1**.

Table 1-1. Project Tasks

Task	Description
1	Development of conceptual model/review of international best practice
2	Selection of 60 water suppliers in various categories and request info from them
3	Preparation of computerized data capture system for capturing the info from 60 water suppliers
4	Population of data capture system and verification of results
5a	Develop a basic benchmarking system for comparing the results from the various water suppliers
5b	Population of benchmarking system and produce results
6	Finalisation of project report
7	Write technical paper / summary report on results

1.4 Report Layout

This report is structured in the following manner: the first section contains a literature review in which the latest trends and international best practice are discussed, followed by details of two international conferences where non-revenue water was the key focus point. The subsequent section presents the methodology used to carry out the study highlighting the data collection process; after which the results are presented. Finally, conclusions and recommendations are presented.

2 LITERATURE REVIEW AND REVIEW OF LATEST INTERNATIONAL TRENDS

The first task of the study involved a review of best practice worldwide with respect to water auditing and the use of key performance indicators to measure and define non-revenue water. In this regard it was decided to discuss the issue with various leading specialists from around the world and to assess what was being used in various countries. Numerous papers and reports were obtained and have been reviewed together with papers presented at the International Water Association (IWA) workshops held in Australia (February 2005), the UK (May 2005) and Canada (September 2005) on the topic of non-revenue water assessment. In this manner it is possible to gather information on the very latest international thinking and best practice on the subject. The various papers on the subject that were considered are listed in the references in **Section 6.** The issue of non-revenue water and use of performance indicators to benchmark Water Services Institutions from around the world is a very topical subject. The methodologies are continually being revised and improved through the combined efforts of a key team of water loss management specialists from around the world as part of the International Water Association's "Water Loss Task Force".

2.1 Terminology

In recent years there has been a growing realisation that a standard methodology and terminology is required to assist Water Utilities in assessing the water balance of their systems. The use of terms such as leakage, Unaccounted-for Water (UFW) (or sometimes abbreviated to UAW), Non-Revenue Water (NRW), real losses and apparent losses tends to confuse not only the audience but also the user. For example in an Australian publication (White, 1998) the statement:

"Unaccounted-for water (also known as non-revenue water) includes all water which is delivered in bulk but is not registered on a meter as having been used".

The above statement is not only confusing but is technically incorrect since UFW is not the same as NRW. This statement from one of the leading Water Demand Management (WDM) specialists in Australia clearly demonstrates the need for clear and concise definitions of the various terms used regularly by Water Services Institutions and politicians alike to express levels of leakage in a system.

Before proceeding to document the current best practice worldwide with regards to water auditing and leakage assessment, it is necessary to define the terminology clearly so that there is absolutely no confusion regarding the various terms used in this manual.

Until recently the standard approach of expressing leakage/losses in a system involved taking the water supplied into a system and subtracting the authorised use in order to establish the total losses which were also often termed to be the UFW. This standard water balance is shown in **Figure 1**. As can be seen, the UFW is a collective term covering a multitude of different losses including both physical leakage as well as administrative losses (i.e. meter error and theft etc.). Such unaccounted-for losses were also generally expressed in terms of a percentage of the system input which is a poor performance indicator and one that should be avoided if possible. As a result of the development of the Burst and Background Estimate procedures, it became possible to assess various components of the losses in a system to the extent that much of the UFW could in fact be accounted for. By some careful and selective manipulation of the figures it is now possible to greatly reduce the UFW significantly without any form of improvement to the system. This is shown in **Figure 2** from which it can be seen that the level of UFW has reduced significantly from that shown in **Figure 1** and is indicated as the "balancing Error".

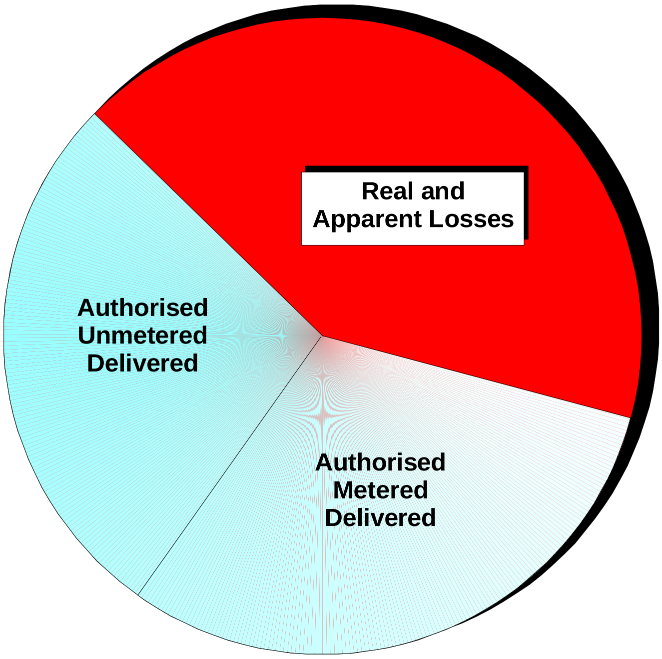

Figure 1: Traditional Water Balance

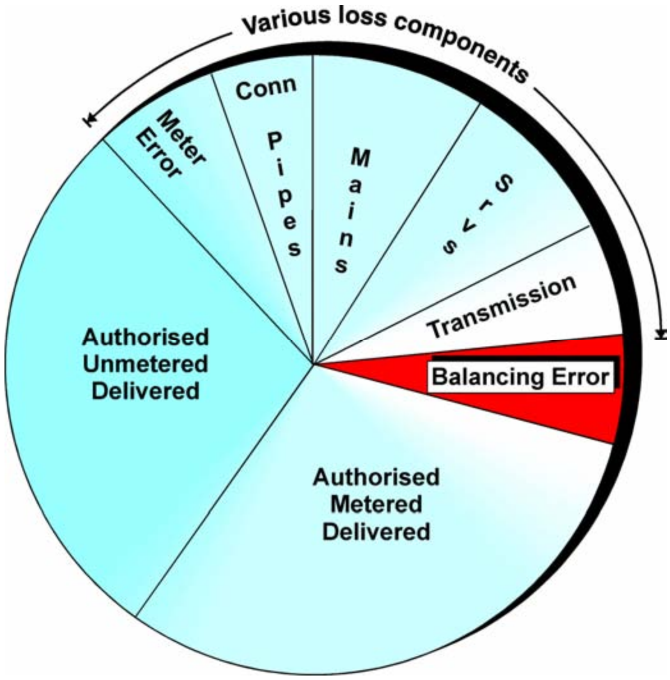

Figure 2: BABE Water Balance Approach

The key problem with the term UFW is the fact that there is no universal definition for the term and it varies from country to country and even from one Water Services Institution to another within the same country. The second key problem is that the level of UFW can be manipulated quite easily as is shown from the following simple example based on the paper presented in Australia by the Chairperson of the IWA Water loss Task Force, Ken Brothers (Brothers, 2005). In his paper of the subject Mr Brothers provides his “Cheat Sheet” which can be used by a Water Services Institution to “manage” their levels of UFW (as shown in **Figure 3**). If we assume that a Water Services Institution has a total system input after any known bulk meter errors have been taken into account of 1 000 units and an authorised consumption of 750 units, the level of UFW is 250 units or 25% of the total system input. This would be the standard approach for defining UFW as used by many Water Services Institutions throughout the world.

"Unaccounted - For" Water Use Estimates *(i.e.. The Cheat Sheet)*

Water Breaks - Accounted for…	1- 2%
Hydrant Flushing	1%
Fire Fighting	1%
Public Works	2 - 3%
Meter Error	3 - 4%
Allowable Leakage	3%
Unmetered Water / Theft	1%
Total (Off the Top) …………….	11 - 15 %

Figure 3: Typical "Cheat Sheet" for manipulating UFW (from Brothers 2005)

If the values suggested in **Figure 3** are applied to the simple example, the level of UFW decreases by at least 120 units to 130 units representing 13% compared to the previous estimate of 25%. This form of water auditing is unacceptable since it is clearly very subjective and open to abuse and manipulation.

Before developing a standard water auditing procedure, it is therefore essential to develop and use the same standard terminology. In this regard, it is now generally accepted throughout most countries in the world that the standard terminology used and promoted by the International Water Association (IWA) is the most robust and comprehensive approach. The elements of the IWA water balance are shown in **Figure 4**. This water balance represents many years of discussion and debate and has been accepted by virtually all water auditing and leakage management specialists worldwide.

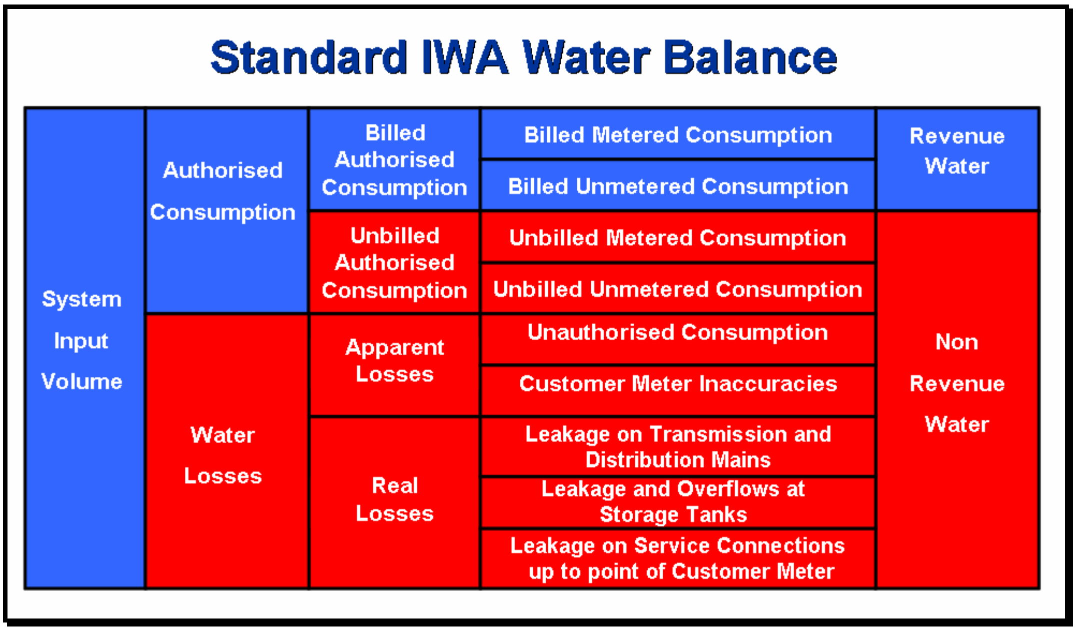

Figure 4: The Standard IWA Water Balance

The various elements of the standard water balance have been discussed in great detail in the two previous WRC project reports and are therefore presented in **Appendix A**.

Figure 5 presents a modification to the IWA water balance for South African circumstances. It was felt that this modification is necessary because water that is billed for is not necessarily automatically paid for by users in South Africa. Billed water can therefore not always be termed revenue water. This "bad-debt" phenomenon is universal, however, the modification is necessary for South Africa due to the relatively large quantities of billed water that for which no income is received. In addition to this, the policy in South Africa is to provide 6 kℓ of water per property per month free of charge. This water is authorised, and is billed (metered or unmetered), but is billed at a zero rate. The application of this policy is a complex issue and is discussed further in **Section 4.5.1**. It still falls under the revenue water component of the water balance, but is showed separately as WSAs do not derive direct income from the users of this water.

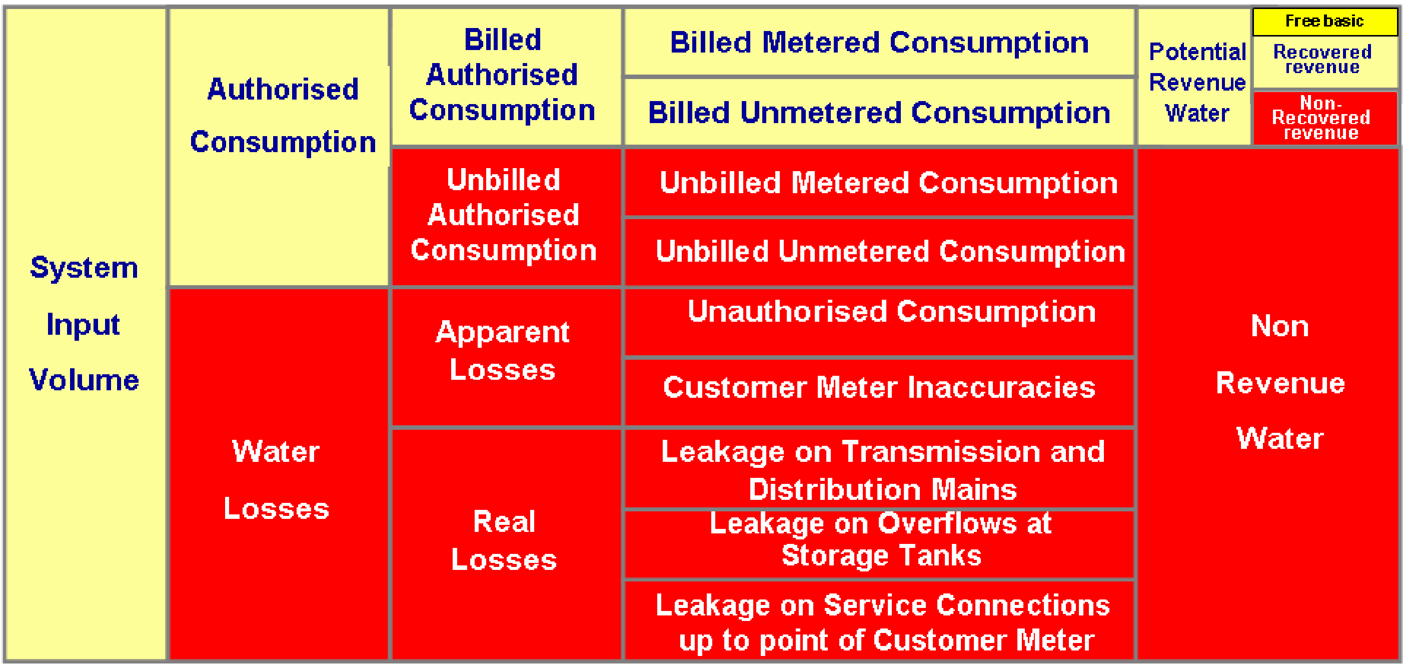

Figure 5. Modification of IWA water balance for South Africa

To overcome the controversy concerning the use and abuse of the term UFW, there is now growing consensus throughout the informed water supply community that the term Non-Revenue Water (NRW) should be used in place of UFW. This does not mean a complete substitution of the term UFW with NRW, but rather an adjustment in volumes of water that are reported on and discussed. Although there can still be some manipulation between some of the terms shown in **Figure 3**, the overall level of NRW is unaffected by such changes. It is therefore a more meaningful and reliable indicator of water supply efficiency in a water supply system.

A transition from traditional familiar terminology to a new and more technical terminology is never easy to accomplish, and a commitment is needed from all water suppliers if improved assessment and comparisons of water losses are to be implemented. For example, the terms ‘Non-Revenue Water’ and ‘Water Losses’ should now be reported on in place of the familiar (but vague) term ‘Unaccounted-for-Water’ – since, with modern techniques, it is possible to account for virtually all water entering a water distribution system.

2.2 History of Water Auditing

The methodology for water auditing has progressed significantly since it was first introduced by Mr A Lambert in December 1999 (Lambert et al.). An attempt to summarise the various developments is provided in **Appendix B** although it should be noted, that many other WDM specialists from around the world have also produced their own versions of the water-auditing software with the result that the list is far from comprehensive. It does, however, include most of the key developments where new features and/or updates to the methodology/definitions have been added.

2.3 Performance Indicators

2.3.1 Problem of using percentages to define leakage

As awareness grows throughout the world that water resources are finite and require careful management, the water lost from potable water distribution systems is becoming an important issue throughout the world. Figures for UFW are often quoted in the media or in public presentations, usually expressed as a simple percentage of system input volume. Such figures tend to be accepted blindly by both the media and public, who find them easy to grasp and assume they are a meaningful indicator of performance.

Over the last decade, however, it has been recognised that the term UFW and the use of percentages are often unsuitable and can be very misleading due to the fact that percentage figures are strongly influenced by the consumption.

A simple example can be used to highlight this problem. In this example a distribution system with 250 000 consumers and 1 000 km of mains experiences real losses of 10 m^3/km mains/day. The percentage Real Losses can easily be calculated for a range of different unit consumption as shown in **Table 2-1**.

Table 2-1: Example showing the problem of using percentages to quantify leakage.

Per capita Consumption (litres/head/day)	Daily Consumption (m^3 per day)	Distribution Losses (m^3 per day)	Daily Input (m^3 per day)	Losses (%)
25 (Standpipe)	6 250	10 000	16 250	62
50 (Jordan)	12 500	10 000	22 500	44
100 (Czech Rep)	25 000	10 000	35 000	27
150 (UK, France)	37 500	10 000	47 500	21
300 (Japan)	75 000	10 000	85 000	12
400 (USA)	100 000	10 000	110 000	9

From **Table 2-1** it can be seen that although the real losses in m^3 per day are identical in all cases, the percentage losses vary between 9% and 62% as a result of the varying per-capita consumption. It is clearly not meaningful to compare the percentage losses of a water distribution system in parts of Africa for example with a system in the USA. Similarly it may not be meaningful to use percentages to compare a system in Africa with another system in Africa even if they are adjacent to each other since the average per-capita water use may be different which in turn will influence the results. If one utility has a single large consumer, it will have the effect of lowering the percentage losses and if the consumer re-locates to another area, the percentage losses will increase despite the fact that the real losses may not have changed. Conversely if the Water Utility is able to persuade all users to use MORE water, the percentage real losses will decrease – hardly an acceptable WDM measure!

Another interesting point to be considered is the implementation of a water demand management programme to promote more efficient water use amongst the consumers. If such a programme is successful it may reduce the per-capita consumption significantly which would be an indication of a successful programme. In such a case, however, the percentage losses will increase and not decrease unless action is also taken to reduce the real losses.

The problem to be addressed is therefore how to express real losses in such terms that the leakage in one system can be meaningfully compared to the leakage in other systems. To address this problem the Infrastructure Leakage Index was introduced by Lambert et al. (1999) and is based on the ratio of the actual level of real losses compared to a theoretical unavoidable level of real losses or UARL. This performance indicator has now been widely accepted and used in many parts of the world and the remainder of this section provides details of the ILI as well as recommendations regarding its use.

2.3.2 UARL: Unavoidable Annual Real Losses

One of the most important concepts used in the BABE procedures concerns the minimum or unavoidable level of leakage for any given system. Effectively, it is a simple concept based on the fact that no system can be entirely free from leakage and that every system will have some level of leakage which cannot be reduced any further. Even a new reticulation system with no use will have some level of leakage, although it may be relatively small. The minimum level of leakage for a system is termed the unavoidable annual real losses or UARL. This is the level of leakage that can be achieved if the system:

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

The procedure to estimate the UARL was developed by Lambert during the period of the International Water Association's Task Force on Water Losses. The methodology is described in a paper in AQUA (Lambert et al., 1999) and the original metric parameters have been converted to US units as indicated in certain tables. The estimation of the UARL involves estimating the unavoidable real losses for three components of infrastructure, namely:

- Transmission and distribution mains (excluding service connections);
- Service connections, mains to street/property boundary;
- Private underground pipe between street/property boundary and customer meter.

The various elements of the distribution network included in the UARL calculation are shown in **Figure 6** and **Figure 7** which highlight the two most common configurations – one where the meter is located at the property boundary and the second where the meter is located just inside the property.

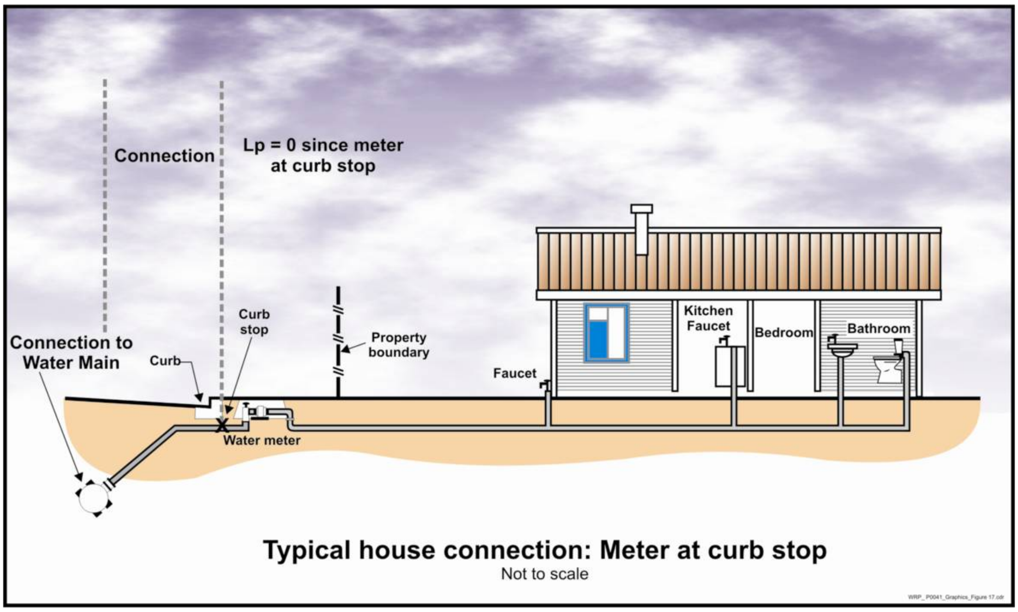

Figure 6: Configuration with meter at property boundary

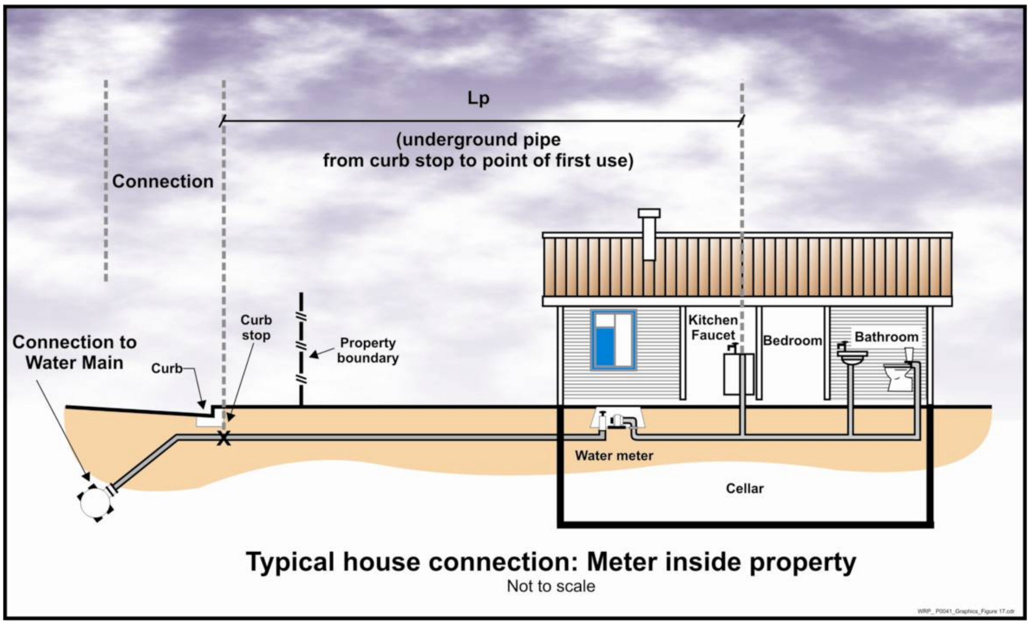

Figure 7: Configuration with meter inside property.

More details on the UARL methodology development are presented in **Appendix A** under the section definitions of terms.

2.3.3 Recommended Performance Indicators

For many years, various water loss specialists from around the world have been proposing and recommending the use of one or other performance indicator to define real losses (leakage) from a water distribution system. There have been numerous attempts at introducing new indicators some of which have been accepted and others rejected outright. Following the IWA Water Loss Taskforce workshop held in Australia in February 2005 it appears that the situation is gradually becoming clearer. From this workshop and the experiences of the authors of this report, the following recommendations are made:

- The use of percentages as an indicator for real losses should be discouraged although it is accepted that percentages will always remain since few Water Utility managers are prepared to discard percentages completely from their list of PIs. It is therefore important when using percentages to highlight the potential pitfalls and to ensure that other PIs are also provided.

- It was agreed that the ILI is a very useful and powerful indicator. It was also, highlighted, however, that few people, especially the general public can associate with the ILI and that it cannot be used on its own.

- In addition to the ILI, various previously recommended PIs for real losses should be used namely:

litres/connection/day – metric units

- This indicator will be suitable for most systems where the density of connections is greater than 20 connections per km mains. In cases where the density of connections drops below 20 per km of mains, it is often appropriate to rather use the following indicator:

m^3/km mains/day – metric units

- The average operating pressure should be used as a PI since many systems are apparently achieving very low levels of leakage but are being operated at very high pressures which are not necessary. For this reason the average system pressure is a key indicator which can be used to determine if some form of pressure management is required in a specific area.

- Finally the Infrastructure Leakage Index is a useful indicator and can often be used to benchmark one system against another.

Infrastructure Leakage Index ILI = CARL/UARL

2.3.4 Norms and standards

There are few documented norms or standards for the various items included in the annual water audit. Having analysed several hundred systems from around the world, however, the authors have developed some rough guidelines which tend to be helpful when undertaking a new water balance for an area. The figures given are not foolproof and some systems may have values outside the suggested range which are found to be valid. The figures do, however, provide an indication of what would normally be expected and if values are provided by a utility which fall outside the range, they should be checked carefully to ensure that they are correct. The following suggestions are made:

- **Density of connections**: normally more than 20 conn/km mains and less than 135 conn/km mains in normal urban systems;
- **Average operating pressure**: normally greater than 30 m and less than 90 m
- **UARL**: normally in the order of 50 litres/conn/day;
- **Bulk system usage**: normally in the order of 12 kℓ/property/month in low income areas where water is metered and bills are issued based on metered consumption;
- **Bulk system usage**: normally in the order of 35 kℓ/property/month in medium to high income areas where water is metered and bills are issued based on metered consumption. In some high income areas, the monthly water use can exceed 100 kℓ/property/month depending on the extent of garden watering and swimming pool use.

2.4 Non-Revenue Water

In many instances the term Unaccounted for Water (UAW or UFW) is used to indicate the level of wastage in a water distribution system and this has become the standard term adopted by most utilities around the world. This term, however, is open to subjective judgement with the result that it can be manipulated to some extent based on various assumptions as discussed previously in **Section 2.1**. Numerous papers and presentations on the subject have been presented at conferences around the world and all clearly recommend that the term UAW is replaced with the term Non-Revenue Water (NRW) which cannot be manipulated to the same extent. This issue is discussed in several sections of this report and further details and explanation are provided by Liemberger and McKenzie (2005), Seago and McKenzie (2005).

2.5 International discussion and debate

2.5.1 Confidence limits

The use of confidence limits in the assessment of selected leakage parameters was first introduced in the SANFLOW model (WRC, 1999) which adopted a systematic modelling approach whereby the user specifies an upper and lower bound for each variable used in the calculation. This was later modified by Lambert who preferred to use the idea of the 95% confidence limits based on the Normal Distribution. This method has since been used in most Water Audit models and was first introduced in the New Zealand version of BENCHLEAK in 2002 (Lambert and McKenzie, 2002).

The inclusion of the confidence limits is considered as an advance by some and of dubious value by others. Having discussed this issue with both the supporters as well as the critics, it appears that it is a useful enhancement to the estimation of the various PIs and provides the user with some level of understanding regarding the importance of the different parameters in the calculation. The main criticism of the use of the confidence limits concerns the use of “specified” limits where a user is led to believe that they are tied to a specific percentage limit – normally the 95% limit. While the 95% limit is used in various calculations, it is relatively meaningless when the user is asked to provide their own estimate of the upper and lower bounds for a specific variable with a 95% confidence limit. Most users will suggest the same upper and lower bounds irrespective of whether they are asked to give the limits at a 95% confidence limit or an 80% confidence limit. It is clear that the use of the confidence limits is to some extent a subjective judgment on the part of the user and it should be recognised as such. To try and place too much emphasis of the exact value of the confidence limits is open to criticism and cannot be justified. The confidence intervals must therefore be considered as rough guidelines rather than exact statistical limits. In this manner they are extremely useful in identifying which elements of the overall water balance have the greatest influence on the results and the various Performance Indicators. It should be noted that the current version of the WRC BENCHLEAK Model (from which most of the current models have been developed) does not incorporate confidence limits and has therefore fallen behind the accepted methodology currently favoured by the IWA. The BENCHLEAK Model was developed in 2000 and it should be updated in the foreseeable future to bring SA back into the forefront of Water Audit technology.

2.5.2 Performance Indicators

Following the considerable debate on the issue of PIs for a water distribution system it is clear that no single PI is able to provide the definitive indicator of leakage in a system. While the ILI is considered to be better than most other indicators because it takes, connections, mains and pressure into account, it also has certain limitations. To gain a full and detailed understanding of water losses from as system it is necessary to include the following PIs:

- Real losses as a % of system input (with cautionary note)
- Real losses as a % of system running costs;
- Real losses in terms of litres/conn/day (or m^3/km mains/day for rural systems)
- ILI
- Average system pressure.

In addition to the above PIs which are universally applicable, it is necessary to include at least one additional PI for the apparent losses in a system. While the issue of apparent losses is currently under review by the IWA, the current recommended PIs for the apparent losses are :

- Apparent losses as % of system input
- Apparent losses in litres/customer/day

No one PI can provide a comprehensive assessment of non-revenue water in a system and it has become clear that three to five indicators are required in most cases.

2.5.3 Using the ILI for Benchmarking Water Utilities

While it was recognised that several PIs are required when assessing water losses from a supply system, various new recommendations were recently (Australia, February 2005) proposed involving the use of the ILI as a key indicator for excessive leakage in a system. The first set of values was suggested by Mr Tim Waldron from Wide Bay Water in association with Mr Allan Lambert with specific reference to the Australian water industry which it should be recognised has some of the lowest leakage levels in the world. The proposed guidelines are provided in **Figure 8**.

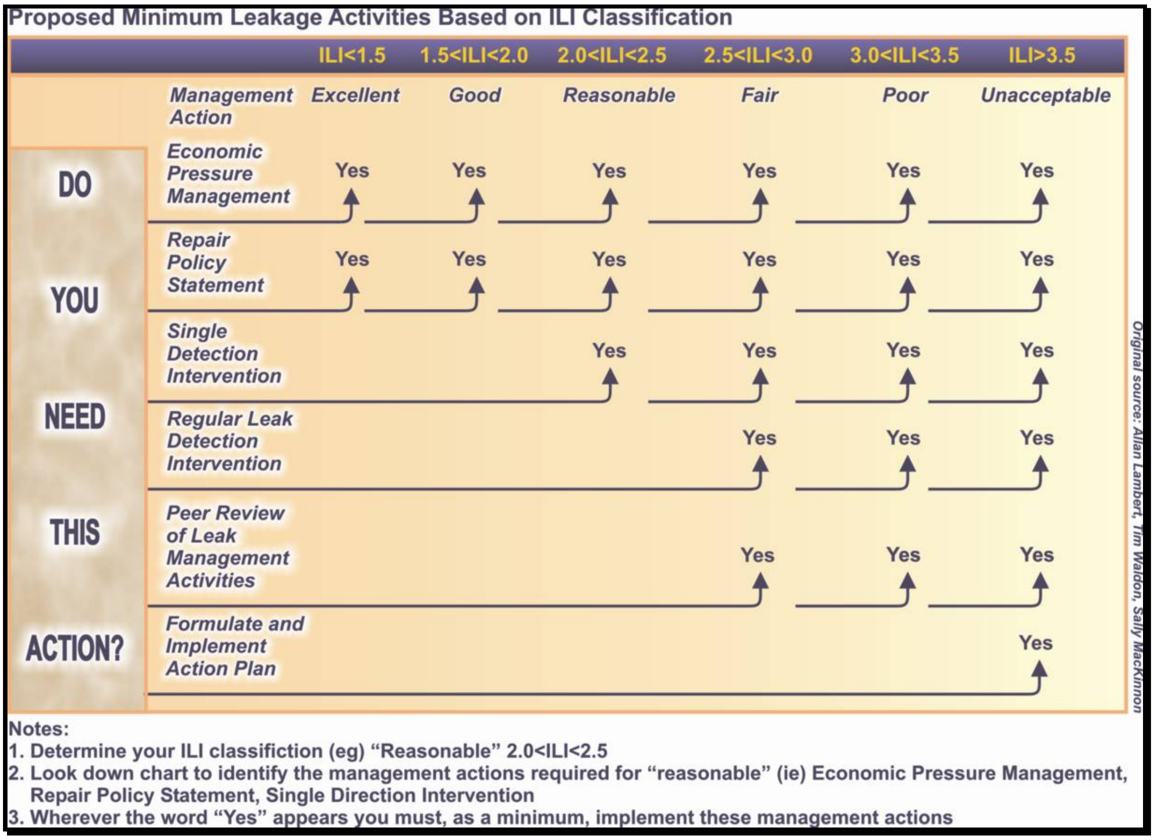

Figure 8: Proposed ILI classification for Australia **(from Waldron and Lambert)**

As can be seen from **Figure 8**, the ILI is being used as an indicator to highlight when specific remedial measures should be implemented. The higher the ILI value, the greater need for more comprehensive leakage reduction activities. An important issue that should be appreciated from **Figure 8** is the relatively low ILI values used in the assessment. Due to the relatively low levels of leakage experienced in Australian water supply systems, the

ILI bands used in the analysis are very narrow and the overall ILI values relatively low. In many other countries with greater levels of leakage, it is necessary to look into a more comprehensive and flexible process where a greater range of ILI values can be accommodated.

To address water supply systems in countries with high levels of leakage and correspondingly high ILI values, a revised proposal was suggested by Liemberger (Liemberger, 2005). The proposed approach is shown in **Figure 9** and was first presented to the IWA Water loss Task Force in February 2005. The approach was well received and it was considered appropriate for use in both developed as well as developing countries as opposed to the previous approach which was not applicable outside Australia.

Technical Performance Category		ILI	Litres/connection/day (when the system is pressurised) at an average pressure of:				
			10 m	20 m	30 m	40 m	50 m
Developed Countries	A	1 - 2		< 50	< 75	< 100	< 125
	B	2 - 4		50-100	75-150	100-200	125-250
	C	4 - 8		100-200	150-300	200-400	250-500
	D	> 8		> 200	> 300	> 400	> 500
Developing Countries	A	1 – 4	< 50	< 100	< 150	< 200	< 250
	B	4 – 8	50-100	100-200	150-300	200-400	250-500
	C	8 - 16	100-200	200-400	300-600	400-800	500-1000
	D	> 16	> 200	> 400	> 600	> 800	> 1000

Figure 9: Proposed use of ILI as PI in developed and developing countries **(Liemberger, 2005)**

As can be seen from **Figure 9**, the figure attempts to differentiate between developing and developed countries which was not captured in the earlier Australian proposal. The proposal by Liemberger also attempts to classify the leakage levels within the water utilities into 4 categories based on the ILI value as follows:

- A = excellent – no specific intervention required.
- B = Good – no urgent action required although must be monitored carefully;
- C = Poor – requiring attention.
- D = Very Bad – requires immediate water loss reduction interventions.

It should also be noted, that unlike the Australian recommendations, Liemberger does not attempt to define the water loss reduction interventions required. This is in line with general water loss management principles where it is normal practice to identify the key problem areas after which the most appropriate interventions are recommended in order to provide the greatest returns for limited budget. In many areas of high leakage for example, the leakage may be due to persistent mains bursts which often indicate that some form of selective mains replacement is required. In other areas with similarly high leakage, the leakage may be confined to the properties in which case pressure management followed by selective retrofitting may be the most appropriate option. Such issues tend to be complicated and the intervention measure is often not as simple or clear cut as suggested in **Figure 8.** The less prescriptive and more flexible approach suggested in **Figure 9** is therefore better suited to the South African environment where the ILI values tend to bridge both the developed and developing country categories.

2.5.4 Apparent Losses

The issue of apparent losses continues to be a problem area particularly in the South African context. Due to the manner in which water is measured and billed in certain parts of the country, it is often very difficult to differentiate between the apparent losses and the real losses. Under normal circumstances, apparent losses are valued in terms of the selling price of the water on the assumption that such losses can be converted to sales if the water is measured properly and billed effectively. In the South African situation, this is often not the case since much of the unbilled water is effectively household leakage or simply gross wastage occurring after the domestic meter. The problem arises in such cases where the water is either not being billed according to the metered consumption (as is the case with a flat rate tariff) or it is not being paid for. Various projects have been initiated to address this issue and in most cases, the water consumption drops significantly when the payment issue is resolved and the consumers start to pay for water based on the metered use. Various forms of pre-payment have been initiated and are currently being implemented in many parts of the country while in other areas the billing and metering systems are being improved to ensure that water is measured correctly and that customers are encouraged to pay for what they use. The issue of apparent losses has not been fully resolved but various recommendations have been made on how to estimate such losses in the annual water audit and certain default values have been proposed which can be used in the absence of any more reliable information.

Various organisations around the world have now adopted a very similar approach involving the use of default values in the absence of any more reliable values to estimate the apparent losses in a system. It should be noted that the default values tend to be the lowest values that could normally be achieved and if any higher values are used by the Water Utilities in their annual audits, they must be properly motivated and justified through proper field investigations. Such values are appropriate for well managed systems with high payment levels which will also be appropriate in many parts of South Africa where water payments are based on metered consumption and the payment levels are high. In other areas where payment levels are low, the default values will not be appropriate and a more comprehensive assessment of the apparent losses will be necessary. To date, there are at least 4 countries where default values for the Apparent Losses have been used including, Australia, New Zealand, USA and Canada. The suggested default values for each country are shown in **Table 2-2** (from Lambert, 2005 personal communication). The values proposed for use in South Africa are presented in **Table 2-3** (McKenzie and Seago, 2005).

Table 2-2: Suggested default values for apparent losses (international) ***(Lambert, 2005, personal comm.)***

	Unbilled Authorised	Unauthorised Consumption	Domestic Meter Under-registration	Non-domestic Meter Under-registration
Australian WSAA, American WWA M36, UK (OFWAT), Canada *	0.5% of Total System Input	0.1% of Total System Input	2% of metered consumption	2% of metered consumption

*** = as proposed by A Lambert – yet to be formally accepted**

Table 2-3: Suggested default values for apparent losses for South Africa

Illegal connections		Meter age and accuracy			Data transfer	
			Good Water	**Poor Water**		
Very high	10%	Poor > 10 yrs	8%	10%	Poor	8%
High	8%					
Average	6%	Average 5- 10 years	4%	8%	Average	5%
Low	4%					
Very low	2%	Good < 5 yrs	2%	4%	Good	2%

Note: Percentages represent percentage of current annual real losses

As can be seen in **Table 2-2**, the allowances are generally small and effectively represent the “best practice” values that could be expected from a very well managed system. The previous BENCHLEAK approach of selecting 20% as a lumped value is no longer acceptable and the proposed limits now force the Water Utility to accept relatively low apparent losses or undertake proper field investigations and surveys to identify the true level of apparent losses in their systems. In this manner unrealistically high estimates of apparent losses are no longer acceptable unless supported by factual information.

2.6 Summary and Conclusions

From the assessment of the latest developments regarding water loss evaluations throughout the world it is clear that South Africa is one of the more progressive countries in this field. The initial model development undertaken through the WRC (i.e. BENCHLEAK) represented a major step forward in the assessment of leakage in a Water Utility. The South African approach has since been adopted and/or improved for use in many other parts of the world and there are now several new models which incorporate useful features not included in the original BENCHLEAK Model. It is therefore recommended that the BENCHLEAK Model be improved at some point in future to bring it into line with the latest developments. It does, however, remain a useful and robust tool for undertaking an annual water audit for a Water Service Institution.

With regard to the use of the water audit methodology used in the BENCHLEAK model, several improvements have been made which help to ensure that the results are consistent between different Water Service Institutions. For example, the definition of connections used in the calculation of the ILI has been clarified to avoid confusion and a more pragmatic approach has been proposed for the estimation of the Apparent Losses which represents a significant improvement on the “lump sum” approach used in BENCHLEAK.

3 METHODOLOGY

3.1 Selection process

The initial objective of the project was to assess the non-revenue water for 60 water reticulation systems throughout South Africa. Shortly after the project's inception, it was decided to evaluate the non-revenue water in approximately 100 water reticulation systems throughout South Africa. For the purpose of this study, a Water Reticulation System is defined as a homogeneous area for which a water balance can be established. For example, the City of Johannesburg, which is a Water Services Authority, was divided up into 9 discrete areas, each of which could be considered as a separate WRS. The nine areas included under the City of Johannesburg were:

- Midrand;
- Ivory Park;
- Sandton;
- Alexandra;
- Johannesburg Central;
- Roodepoort;
- Diepsloot;
- Soweto;
- Deep South.

It was therefore agreed to obtain 100 data sets from around South Africa. The process of selecting the water reticulation systems involved detailed analysis as well as discussions with the WRC and members from the Steering Committee. Having examined the possibilities of different types of water reticulation systems and presentation of the selection process, it was decided that the project should focus on the 100 largest water reticulation systems by population in South Africa. In this manner it was anticipated that the study would provide an indication of the real losses from water distribution systems from the country as a whole. This would provide the water sector with an estimate of real losses from South African water reticulation systems for the first time based on measurements. While it would be useful to know the levels of non-revenue water for smaller water reticulation systems and those positioned in rural areas, it was felt that this project should rather concentrate on the areas where most of the urban population reside and which are more likely to be the areas of higher non-revenue water.

Table 3-1 and **Figure 10** present the 100 largest water reticulation systems that were targeted by the Study Team. The number of Water Services Authorities covering these water reticulation systems is 35, distributed throughout the 9 provinces of South Africa.

Table 3-1. Selected Water Reticulation Systems

No.	Province	Water Services Authority	Number of WRSs targeted	Name of WRS targeted
1	Eastern Cape	Nelson Mandela Metropolitan	3	Despatch
2				Port Elizabeth
3				Uitenhage
4		Buffalo City	2	East London
5				Mdantsane
6		OR Tambo District	1	Umtata
7		Chris Hani District	1	Queenstown
8	Free State	Dihlabeng	1	Bethlehem
9		Maluti a Phofung	1	Puthaditjhaba
10		Mangaung	3	Bloemfontein
11				Botshabelo
12				Thaba 'Nchu
13		Matjhabeng	4	Welkom
14				Riebeekstad
15				Thabong
16				Bronville
17		Metsimaholo	1	Sasolburg
18		Moqhaka	1	Kroonstad
19	Gauteng	City of Johannesburg	9	Midrand
20				Ivory Park
21				Sandton
22				Alexandra
23				Soweto
24				Johannesburg Central
25				Roodepoort
26				Diepsloot
27				Deep South
28		City of Tshwane	8	Akasia
29				Atteridgeville
30				Centurion
31				Mamelodi
32				Odi
33				Pretoria
34				Soshanguve
35				Temba
36		Ekurhuleni Metropolitan	18	Alberton
37				Bedfordview
38				Tokoza

No.	Province	Water Services Authority	Number of WRSs targeted	Name of WRS targeted
39				Benoni
40				Daveyton/Etwatwa
41				Brakpan
42				Tsakane
43				Boksburg
44				Vosloorus
45				Germiston
46				Katlehong
47				Springs
48				Kwa Thema
49				Nigel
50				Duduza
51				Kempton Park
52				Tembisa
53				Edenvale
54		Emfuleni	4	Vereeniging
55				Vanderbijlpark
56				Sebokeng
57				Evaton
58		Mogale City	3	Krugersdorp
59				Kagiso
60				Magaliesburg
61		Randfontein	1	Randfontein
62	KwaZulu-Natal	Ethekwini	7	Inner West MLC
63				North Central MLC
64				North MLC
65				Outer West MLC
66				South Central MLC
67				South MLC
68				Umkomaas
69		Ilembe District	1	Stanger
70		Msunduzi	1	Pietermaritzburg
71		uMhlathuze	2	Esikhaweni
72				Empangeni
73	Mpumalanga	Emalahleni	1	Witbank
74		Govan Mbeki	6	Secunda
75				Evander
76				Trichardt
77				Leandra
78				Bethal
79				Kinross
80		Lekwa	1	Standerton
81		Mbombela	1	Nelspruit
82		Steve Tshwete	1	Middelburg

No.	Province	Water Services Authority	Number of WRSs targeted	Name of WRS targeted
83	North West	City Council of Klerksdorp	1	Klerksdorp
84		Potchefstroom	2	Potchefstroom
85				Ikageng
86		Rustenburg	3	Rustenburg
87				Marikana
88				Phokeng
89	Northern Cape	Khara Hais	1	Upington
90		Sol Plaatjie	1	Kimberley
91	Northern Province	Polokwane	1	Polokwane
92	Western Cape	City of Cape Town	6	Blaauwberg
93				Cape Town
94				Helderberg
95				Oostenberg
96				Southern Peninsula
97				Tygerberg
98		Breede Valley	1	Worcester
99		Drakenstein	1	Paarl
100		George	1	George
TOTAL	9 provinces	35 Water Services Authorities	100 WRSs / data sets	

Figure 10: The 100 Water Reticulation Systems included in the study

3.2 Data gathering process

Significant effort was spent on the collection and collation of data in order to carry out a BENCHLEAK analysis on the targeted water reticulation systems. Unfortunately, the efforts exerted did not necessarily produce all the data sets originally anticipated despite the many visits, phone calls and e-mails made by the Study Team. It is unclear whether the lack of information was due to it not being known or simply due to hostility as a result of WSAs constantly having to submit information and not having the time to do so. This second reason was anticipated at the beginning of the study and, to avoid this, it was decided that each WSA would be visited and interviewed personally by the Project Team in order to gather the information. This helped to eliminate the perception that it was merely another questionnaire that WSAs were being asked to complete, and put a face and name to the person requesting the information. This approach, however, was also unsuccessful in many cases and some of the WSAs remained unwilling or unable to provide the information after numerous follow up phone calls. As a result, not all of the WSAs were visited while some that were phoned were willing to provide data. There was effectively no correlation between data received and the methodology used to request the data.

Where it was not possible to obtain the data first hand, Water Services Development Plans (WSDP) and Census information were reviewed. All information required to prepare a water balance is requested in DWAF's WSDP guidelines and the WSDP is the only legally mandated document that a WSA must complete. Unfortunately, a WSDP is generally a high level document that does not always provide the water balance information at the required level of detail to complete a water balance for each sub area of a WSA. For example, Mogale City's WSDP presents all bulk water purchases from Rand Water over the last few years. The WSDP itself does not require that the WSA break down these bulk input volumes per area, and it therefore becomes very difficult to prepare a water balance for Mogale City's areas of Kagiso, Krugersdorp and Magaliesburg separately using information from the WSDP. This issue involving the breakdown of the information into smaller areas is discussed in the following section.

Section 3.3 clearly presents the various sources of information obtained, as well as provides a confidence level of each information source.

3.2.1 Analysis of Water Service Authority vs Water Reticulation System

It is not always meaningful to review the water balance for a whole WSA since key problem areas can often be skewed by the overall water balance. The following example from Emthanjeni Local Municipality highlights this problem as can be seen in **Table 3-2** which presents the data and results for Emthanjeni Local Municipality which serves three relatively small towns. It should be noted that this information was gathered as part of a different study carried out in the area.

Table 3-2: Input data for Emthanjeni Municipality, South Africa

Variable	Description	Units	Britstown	Hanover	De Aar
Lm	Length of mains	km	20	15	114
Ns	Number of service connections	no.	979	919	5485
D	Density of service connections	conns/km	49	62	48
P	Average operating pressure	m	20	38	30
T	% time system is pressurised	%	100	100	100
	Population served by the system	no.	4024	2695	26027
UARL	Unavoidable annual real losses	m^3/yr	8345	13 942	70 518
	Unavoidable annual real losses	litres/conn/day	23.4	41.5	35.2
INP	Total system input volume	m^3/yr	220 552	171 404	1 839 785
CON	Total authorised consumption	m^3/yr	123 369	137 104	1 465 865
AWL	Annual Water Losses	m^3/yr	97 183	34 300	373 920
%AL	% apparent losses	%	20	20	20
AL	Apparent losses	m^3/yr	19 437	6 860	74 784
ARL	Annual real losses	m^3/yr	77 746	27 440	299 136
	Consumption	litres/conn/day	345	409	732
ILI*	Infrastructure Leakage Index		9.32	1.97	4.2

*See **Appendix A**.

When the WRS was analysed as one service area (i.e. the WSA), the ILI value obtained was 4.5. This would most likely have been considered acceptable in the South African context where the average levels of leakage tend to be relatively high and ILI values lower than 5.0 tend to be ignored in preference of the areas with higher leakage. In this case, however, (as shown in the table), Britstown had an ILI of 9.3 which is considered unacceptable even in South Africa. While this figure is potentially unreliable to some extent since the area has less than 2 000 connections it proved most useful in directing the project team to a key problem area. On closer inspection it was found that Britstown had a serious billing problem due to a large number of new properties that had been added into the system but were not being billed properly. The issue was eventually addressed and the ILI decreased significantly as expected.

3.3 Data Sources

Table 3-3 provides details of the data sources for each WRS. It is divided into the various categories of data as these were obtained from different sources in some cases. The following codes are used as references for the data sources in the Table.

- 0: Data could not be sourced
- 1: Data provided by representative of WSA after interview
- 2: Data provided by representative of WSA after telephonic conversation
- 3: Data sourced from WSDP
- 4: Data obtained from Census database
- 5: Data obtained from report, not a WSDP
- 6: Data obtained from Study Team via project carried out in the area
- 7: Data estimated
- 8. DWAF survey, June 2006

Table 3-3: Details of data sources

No.	Name of WRS	Length of mains	Number of properties	Number of connections	Average operating pressure	System input volume	Authorised consumption volume
1	Akasia	1	5(5)	5(5)	1	6	6
2	Alberton	6	6	6	6	6	6
3	Atteridgeville	1	5(5)	5(5)	1	6	6
4	Bedfordview	0	0	0	0	0	0
5	Benoni	6	6	6	6	6	6
6	Bethlehem	2	2	2	2	2	2
7	Boksburg	6	6	6	6	6	6
8	Brakpan	6	6	6	6	6	6
9	Bronville	6	6	6	6	6	6
10	Centurion	1	5(5)	5(5)	1	6	6
11, 12, 13, 14, 15, 16	City of Cape Town	0	3	3	0	8	8
17	Daveyton/Etwatwa	6	6	6	6	6	6
18	Deep South	1	6	1, 7	1	1	1
19	Duduza	6	6	6	6	6	6
20, 21	East London & Mdantsane	6	6	6	7	6	6
22	Edenvale	6	6	6	6	6	6

No.	Name of WRS	Length of mains	Number of properties	Number of connections	Average operating pressure	System input volume	Authorised consumption volume
23, 24, 25, 26, 27, 28, 29	Ethekwini	2	2	2	2	2	2
30	Evaton	6	6	6	6	6	6
31	George	0	3	3	0	3	3
32	Germiston	6	6	6	6	6	6
33, 34, 35, 36, 37, 38	Govan Mbeki Local Municipality	0	0	0	0	0	0
39	Ikageng	1	1	1	1	1	1
40	Johannesburg Central	1	6	1, 7	1	1	1
41	Katlehong	6	6	6	6	6	6
42	Kempton Park	6	6	6	6	6	6
43	Kimberley	0	4	4	0	8	8
44	Klerksdorp	0	3	3	0	3	3
45	Kroonstad	0	0	0	0	0	0
46	Kwa Thema	6	6	6	6	6	6
47	Mamelodi	1	5 (5)	5 (5)	1	6	6
48, 49, 50	Mangaung Local Municipality (1)	2	2	2	2	2	2
51, 52	Mhlathuze Local Municipality	0	0	0	0	0	0
53	Middleburg	0	0	0	0	0	0
54, 55	Midrand & Ivory Park	1	6	1, 7	1	1	1
56, 57, 58	Mogale City Local Municipality (2)	6	6	6	6	6	6
59	Msunduzi Local Municipality	0	3	7	0	3	3
60, 61, 62	Nelson Mandela Metro (3)	1	1	1	1	1	1
63	Nelspruit	1	1	1	1	1	1
64	Nigel	6	6	6	6	6	6
65	Odi	1	5 (5)	5 (5)	1	6	6
66	Paarl	2	2	2	7	2	2
67	Polokwane	0	4	4	0	1	1
68	Potchefstroom	1	1	1	1	1	1
69	Pretoria	1	6	1, 7	1	6	6
70	Puthaditjhaba	0	2	2	0	2	2
71	Queenstown	6	6	6	6	6	6

No.	Name of WRS	Length of mains	Number of properties	Number of connections	Average operating pressure	System input volume	Authorised consumption volume
72	Randfontein	3	3	3	7	3	3
73	Riebeekstad	6	6	6	6	6	6
74, 75	Roodepoort & Diepsloot	1	6	1, 7	1	1	1
76, 77, 78	Rustenburg Local Municipality	0	0	0	0	8	8
79, 80	Sandton & Alexandra	1	6	1, 7	1	1	1
81	Sasolburg	0	0	0	0	0	0
82	Sebokeng	6	6	6	6	6	6
83	Soshanguve	1	5(5)	5(5)	1	6	6
84	Soweto	1	6	1, 7	1	1	1
85	Springs	6	6	6	6	6	6
86	Standerton	0	0	0	0	0	0
87	Stanger	0	0	0	0	0	0
88	Temba	1	5(5)	5(5)	1	6	6
89	Tembisa	6	6	6	6	6	6
90	Thabong	6	6	6	6	6	6
91	Tokoza	6	6	6	6	6	6
92	Tsakane	6	6	6	6	6	6
93	Umtata	0	0	0	0	0	0
94	Upington	6	6	6	6	6	6
95	Vanderbijlpark	6	6	6	6	6	6
96	Vereeniging	6	6	6	6	6	6
97	Vosloorus	6	6	6	6	6	6
98	Welkom	6	6	6	6	6	6
99	Witbank	1	1	1	1	1	1
100	Worcester	0	3	3	0	3	3

Note (1): Includes the combined WRSs of Bloemfontein, Botshabelo and Thaba 'Nchu

Note (2): Includes the combined WRSs of Krugersdorp, Kagiso and Magaliesburg

Note (3): Includes the combined WRSs of Port Elizabeth, Despatch and Uitenhage

Note (4): Includes the combined WRSs of Rustenburg, Marikana and Phokeng

Note (5): Report: Strategic Plan for the Eradication of Water and Sanitation Backlog in Tshwane

The above Table summarises how the 100 water reticulation systems were reduced to 70 by combining certain water reticulation systems where data could not be provided at the originally requested level (Refer to **Table 3-1**). **Table 3-4** summarises the quantities of information obtained from each source. Six categories of data were requested from 70 water reticulation systems. This totals 420 units of data. A reliability indicator is also assigned to each source. A value of 3 is considered reliable, 2 average and 1 unreliable (no verification took place). These indicators are considered average for each data source as they vary within a specific source, and should merely be used to obtain an idea of the accuracy of the data.

Table 3-4: Summary of data sources

	Source of data	% data obtained from source	Reliability of data
0	Data could not be sourced	15	NA
1	Data provided by representative of WSA after interview	19	3
2	Data provided by representative of WSA after telephonic conversation	6	3
3	Data sourced from WSDP	6	1
4	Data obtained from Census database	1	2
5	Data obtained from report, not a WSDP	3	3
6	Data obtained from Study Team via project carried out in the area	47	2
7	Data estimated	1	2
8	DWAF survey, June 2006	2	3

Data could not be obtained from 8 of the 70 water reticulation systems, and the final number of water reticulation systems analysed was therefore 62. This was broken up into the following categories:

- Low income areas: 19 water reticulation systems;
- Medium to high income areas: 31 water reticulation systems; and
- Combination areas where no breakdown was possible: 12 water reticulation systems.

The categories are broadly defined by the typical types of houses one would find in the various areas. Low income areas generally consist of townships with RDP type housing. Medium to high income areas represent the remainder of the urban areas in South Africa and are basically similar to most first world areas with similar levels of service. It should be noted that the medium and high income areas tend to experience relatively few problems regarding payment for services. Internal household leakage in these areas also tends to be very low unlike the low income areas where such leakage is often a serious problem. Combination areas include both low income and medium to high income areas.

3.4 Benchmarking system

One of the main objectives of the study was to develop a basic benchmarking system which could be used to compare different systems throughout South Africa. As the study progressed, however, it became clear that due to the lack of available data in many municipalities it would not be possible to populate the full data base for all water utilities in South Africa. For this reason, it was decided to reassess the methodology used to gather the data and make certain assumptions in some cases to complete the overall water balances.

For example, a Water Services Authority that purchases water from a Water Services Provider (WSP) should know the volume of water they purchase on a monthly, or at very worst, annual basis. It may not have full details on how and where that water is distributed to consumers, as the meters may be broken, or non existent. In most cases, WSAs who do not know this information tend to ignore the data request form since they feel that because they cannot supply all of the information requested it is not worthwhile supplying a partly completed water balance. To overcome this problem, the water utilities were contacted directly and where necessary the project team assisted to complete the balance by making certain assumptions based on previous experience. In this manner, it was possible to develop water balances for more than 60 systems throughout South Africa.

The basic model of the new benchmarking approach is presented in **Appendix C**. It is colour coded as follows:

- Yellow blocks are questions that are directed at the WSA;
- green blocks are possible answers that could be received; and
- blue blocks then guide the interviewer as to which direction to take.

It is recommended that further work be carried out and agreement be reached regarding the norms and standards in order to complete the model. For example, if the only information that a WSA can provide is the volume of bulk water entering a system and the number of households this water supplies, what is the acceptable norm in litres per household that a WSA can expect allowing for certain losses on the distribution system and service connections.

4 RESULTS

4.1 Information obtained

Table 4-1 presents the information that was obtained for the 62 water reticulation systems as described in **Section 3.3**.

Table 4-1: Basic information obtained

Name of WRS	Length of mains (km)	Number of properties	Number of connections	Average operating pressure (m)	System input volume (mill m^3/ann)	Authorised consumption volume (mill m^3/ann)
Akasia	319	25 296	25 296	50	11.87	9.57
Alberton	649	28 402	28 402	56	21.32	18.05
Atteridgeville	273	35 260	20 115	40	8.29	5.77
Benoni	798	62 971	62 971	39	22.43	21.54
Bethlehem	470	22 249	19 783	50	13.55	12.47
Boksburg	924	55 614	55 614	43	29.01	24.8
Brakpan	168	19 942	19 942	56	11.76	5.43
Bronville	123	2 647	2 647	50	0.55	0.24
Centurion	1 178	51 106	31 309	50	37.28	31.05
City of Cape Town		675 000	562 300		269.08	224.99
Daveyton/Etwatwa	354	64 105	64 105	29	14.75	7.36
Deep South	861	111 353	19 615	50	24.63	18.12
Duduza	115	27 493	27 493	34	4.06	2.03
East London, Mdantsane	1 367	83 513	83 513	50	43.73	24.8
Edenvale	415	34 810	34 810	62	16.51	16.14
Ethekwini	11 400	407 000	407 000	50	288.4	204.51
Evaton	538	55 574	55 574	49	16.46	6.30
George		28 158	27 864		10.63	9.01
Germiston	1 010	85 455	85 455	62	53.16	46.92
Ikageng	192	18 899	12 290	30	3.33	2.89
Johannesburg Central	2 694	242 780	123 062	50	168.14	145.96
Katlehong	576	105 492	105 492	26	11.77	5.89
Kempton Park	759	54 141	54 141	56	33.68	26.14
Kimberley		42 866	37 657		26.88	16.28
Klerksdorp		93 034	86 657		24.62	15.31
Kwa Thema	173	33 020	33 020	29	8.51	5.46
Mamelodi	436	75 849	66 599	50	15.18	9.56
Mangaung Local Municipality	2 827	153 209	101 814	24	61.76	39.16
Midrand, Ivory Park	738	82 419	29 646	50	19.67	15.58
Mogale City Local Municipality	2 200	63 051	60 037	48	23.56	17.44
Msunduzi Local Municipality		84 745	60 495		41	28.08

Name of WRS	Length of mains (km)	Number of properties	Number of connections	Average operating pressure (m)	System input volume (mill m^3/ann)	Authorised consumption volume (mill m^3/ann)
Nelson Mandela Metro	3 445	232 131	178 020	45	82.34	56.25
Nelspruit	266	9 541	9 541	55	10.03	8.82
Nigel	176	10 673	10 673	46	4.64	4.08
Odi	1 676	79 329	50 220	40	23.11	14.86
Paarl	386	19 348	19 348	45	10.21	8.7
Polokwane		21 774	17 656		17.67	12.23
Potchefstroom	184	16 401	15 973	40	10.48	9.53
Pretoria	3 647	171 304	171 304	50	130.72	105.13
Puthaditjhaba		81 386	46 077		15.07	2.24
Queenstown	264	22 693	17 609	50	6.89	5.56
Randfontein	361	19 304	19 304	50	7.5	5.6
Riebeekstad	106	2 680	2 680	36	1.58	0.7
Roodepoort, Diepsloot	2 694	111 353	56 532	50	49.61	45.5
Rustenburg Local Municipality					26.57	18.4
Sandton, Alexandra	1 803	124 796	71 591	50	78.08	67.94
Sebokeng	626	54 509	54 509	50	20.51	6.80
Soshanguve	962	78 466	72 058	50	15.28	10.00
Soweto	2 107	320 146	168 103	50	130.36	86.52
Springs	580	29 793	29 793	48	17.39	12.27
Temba	842	52 031	25 156	40	13.54	6.66
Tembisa	311	73 602	73 602	38	12.36	7.53
Thabong	283	36 736	36 736	49	5.66	2.49
Tokoza	798	35 877	35 877	50	5.33	2.67
Tsakane	422	55 455	55 455	35	12.98	6.49
Upington	263	12 555	12 555	30	12.02	10.08
Vanderbijlpark	893	37 565	37 565	39	21.56	15.70
Vereeniging	720	50 184	50 184	63	20.57	14.09
Vosloorus	348	49 145	49 145	34	11.8	9.64
Welkom	387	10 962	10 962	50	8.39	3.7
Witbank	389	55 849	55 849	30	30.17	18.36
Worcester		20 091	18 443		12.29	8.63

Source: See Table 3-3

4.2 Performance Indicators

Table 4-2 presents the results obtained from the calculations performed with the data.

Table 4-2: Performance indicators (calculations based on data presented in Table 4-1)

Name of WRS	Density of connections	UARL (l/con/ day)	System input per property (kℓ/prop /month)	Total losses (mill m^3/ann)	Apparent losses (mill m^3/ann)	ILI
Akasia	79	51	39.1	2.30	0.39	4.0
Alberton	44	68	62.6	3.27	0.4	4
Atteridgeville	74	42	19.6	2.52	0.43	6.8
Benoni	79	40	29.7	0.89	0.1	0.8
Bethlehem	42	61	50.8	1.08	0.1	2.2
Boksburg	60	47	43.5	4.21	0.5	3.8
Brakpan	119	53	49.1	6.33	0.8	14.2
Bronville	22	82	17.3	0.31	0	3.5
Centurion	26	74	60.8	6.24	1.06	6.2
City of Cape Town			33.2	44.09		
Daveyton/Etwatwa	181	26	19.2	7.39	1.3	10.1
Deep South	23	80	18.4	6.51	1.5	8.8
Duduza	239	30	12.3	2.03	0.3	5.6
East London, Mdantsane	61	55	43.6	18.93	2.8	9.6
Edenvale	84	63	39.5	0.37	0	0.4
Ethekwini	36	65	59	83.89	16.8	6.9
Evaton	103	48	24.7	10.16	2.6	7.8
George			31.5	1.62		
Germiston	85	63	51.8	6.24	0.8	2.8
Ikageng	64	32	14.7	0.44	0.1	2.5
Johannesburg Central	46	60	57.7	22.18	2.4	7.4
Katlehong	183	23	9.3	5.88	1	5.4
Kempton Park	71	59	51.8	7.54	1	5.6
Kimberley			52.2	10.59		
Klerksdorp			22.1	9.31		
Kwa Thema	191	26	21.5	3.05	0.5	8.1
Mamelodi	153	46	16.7	5.61	0.95	4.2
Mangaung Local Municipality	36	31	33.6	22.6	3.4	16.6
Midrand, Ivory Park	40	62	19.9	4.09	0.4	5.4
Mogale City Local Municipality	27	70	31.1	6.12	0.9	3.4
Msunduzi Local Municipality			40.3	12.92		
Nelson Mandela Metro	52	52	29.6	26.09	3.9	6.6
Nelspruit	36	72	87.6	1.21	0.1	4.4
Nigel	61	50	36.2	0.56	0.1	2.5
Odi	30	56	24.3	8.25	1.4	6.7
Paarl	50	52	44	1.51	0.1	3.7
Polokwane			67.6	5.44		
Potchefstroom	87	40	53.2	0.95	0.1	3.7
Pretoria	47	59	63.6	25.59	4.35	5.7

Name of WRS	Density of connections	UARL (l/con/ day)	System input per property (kℓ/prop /month)	Total losses (mill m^3/ann)	Apparent losses (mill m^3/ann)	ILI
Puthaditjhaba			15.4	12.83		
Queenstown	67	53	25.3	1.33	0.2	3.3
Randfontein	53	57	32.4	1.9	0.3	4
Riebeekstad	25	54	49.1	0.88	0.1	14.7
Roodepoort, Diepsloot	21	83	37.1	4.11	0.5	2.1
Rustenburg Local Municipality				8.17		
Sandton, Alexandra	40	63	52.1	10.14	1.1	5.5
Sebokeng	87	50	31.4	13.71	3.3	10.4
Soshanguve	75	52	16.2	5.28	0.9	3.2
Soweto	80	51	33.9	43.84	10.1	10.7
Springs	51	55	48.6	5.12	0.7	7.4
Temba	30	56	21.7	6.88	1.17	11.1
Tembisa	237	33	14	4.83	0.8	4.5
Thabong	130	46	12.8	3.17	0.5	4.3
Tokoza	45	60	12.4	2.66	0.5	2.8
Tsakane	131	33	19.5	6.49	1.1	8.1
Upington	48	35	79.8	1.94	0.3	10.2
Vanderbijlpark	42	48	47.8	5.86	1.1	7.2
Vereeniging	70	67	34.2	6.48	1.2	4.3
Vosloorus	141	32	20	2.16	0.3	3.3
Welkom	28	72	63.8	4.69	0.5	14.5
Witbank	144	28	45	11.81	2.2	16.9
Worcester			51	3.66		

4.3 Analysis of results

4.3.1 Density of connections

The maximum norm for density of connections is approximately 135 connections per kilometre of pipeline which is based on a minimum street front edge of 14 m for each property on either side of the road for the entire area (McKenzie and Seago, 2005). A few of the low income areas, mainly in Ekurhuleni, have higher then that and it is likely that there is an error in either the number of connections or the associate length of pipeline. The graphs for the densities of connections for the three groups are provided in **Figures 11** to **13**.

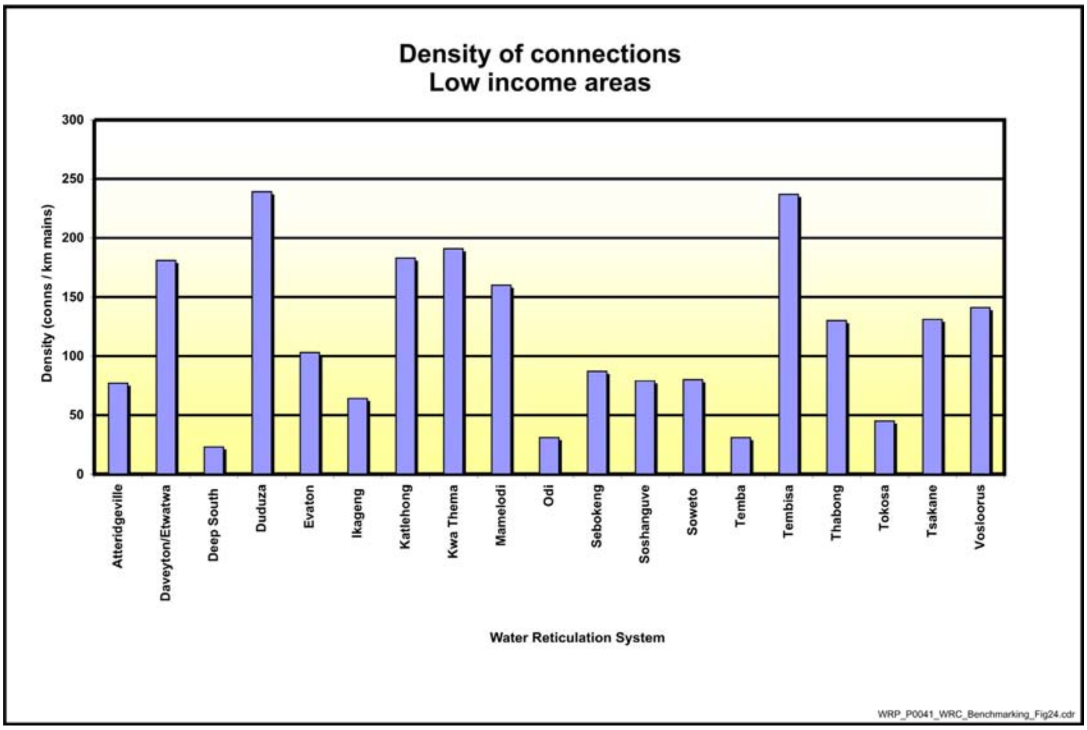

Figure 11: Density of connections: low income areas

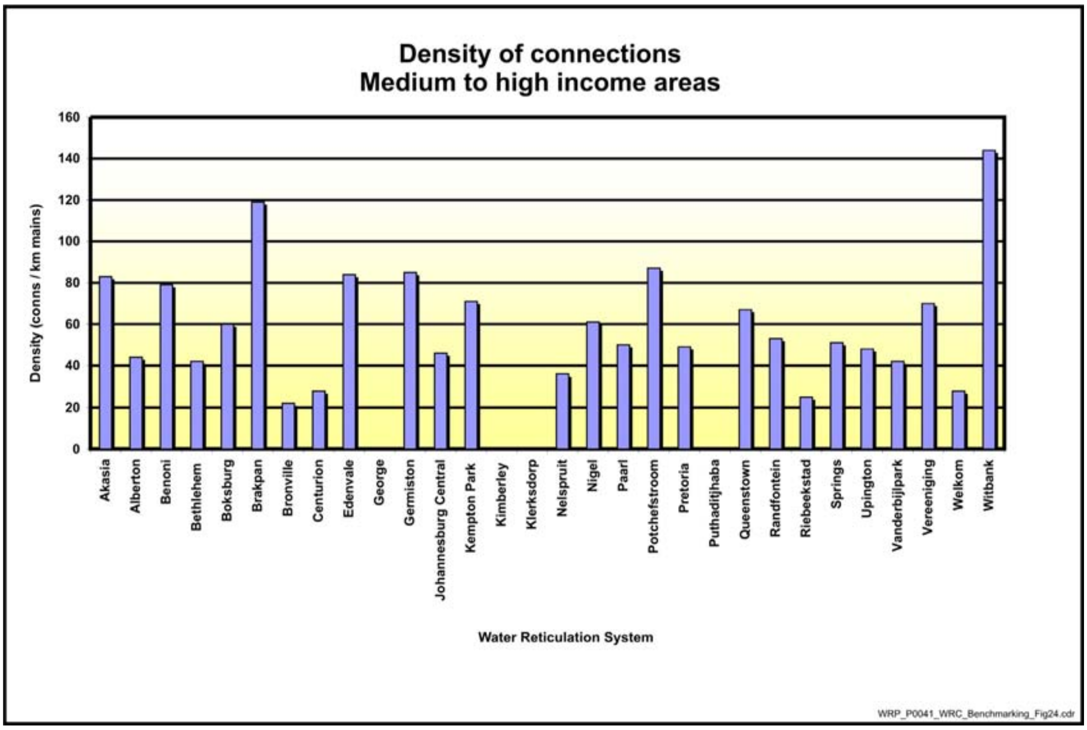

Figure 12: Density of connections: medium to high income areas

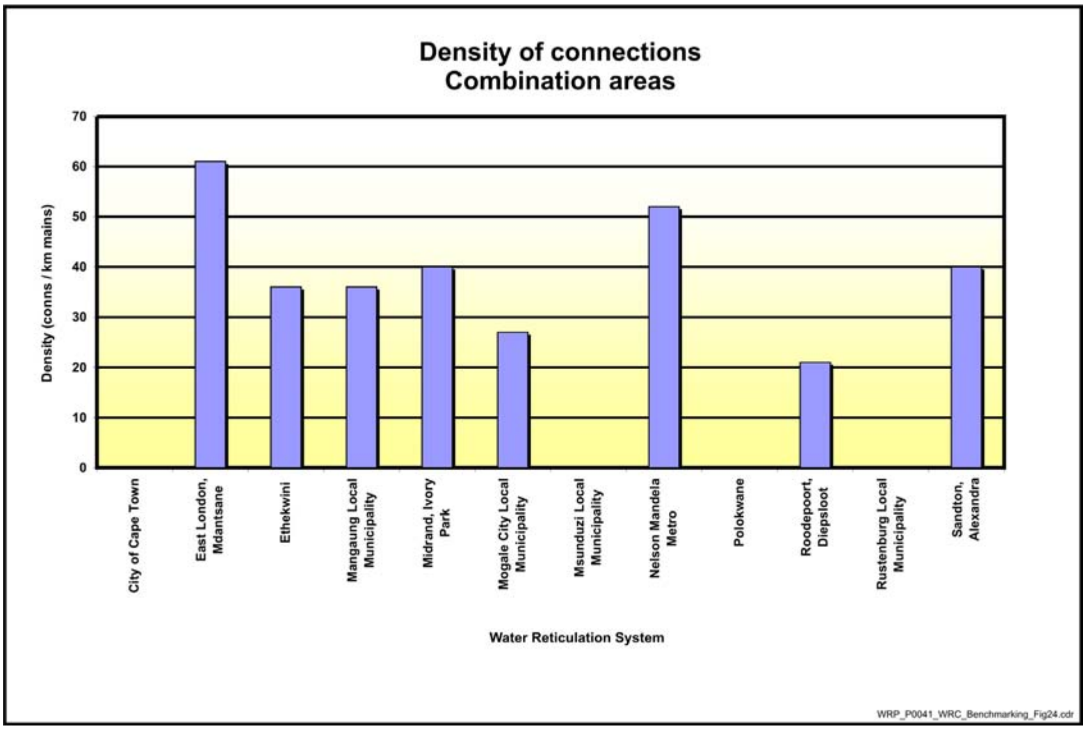

Figure 13: Combination areas

4.3.2 Unavoidable Annual Real Losses

The UARL values range from 23 litres per connection per day to 83 litres per connection per day. The norm for UARL is approximately 50 litres per connection per day at standard pressure of 50 m (McKenzie and Lambert, 2004). Most of the water reticulation systems fall within this range except for Roodepoort / Diepsloot and Bronville which are greater than 80 litres per connection per day. Areas where many houses contain water from standpipes relative to the length of mains can have skewed results as it is each standpipe connection that is counted rather than each property. In the case of Bronville it is likely that either the length of mains or number of connections is inaccurate resulting in the abnormally high UARL. The average UARL over all the water reticulation systems included in the study is 52 litres per connection per day. The UARLs for the different sized water reticulation systems are provided in **Figures 14** to **16**.

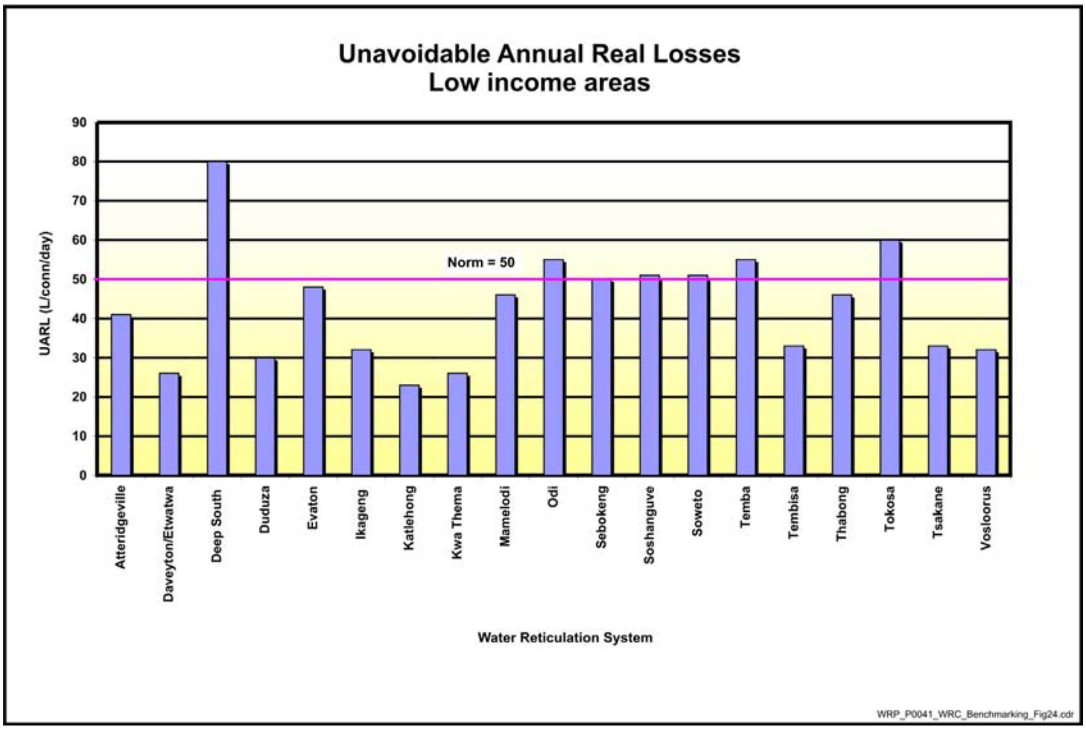

Figure 14: UARL: low income areas

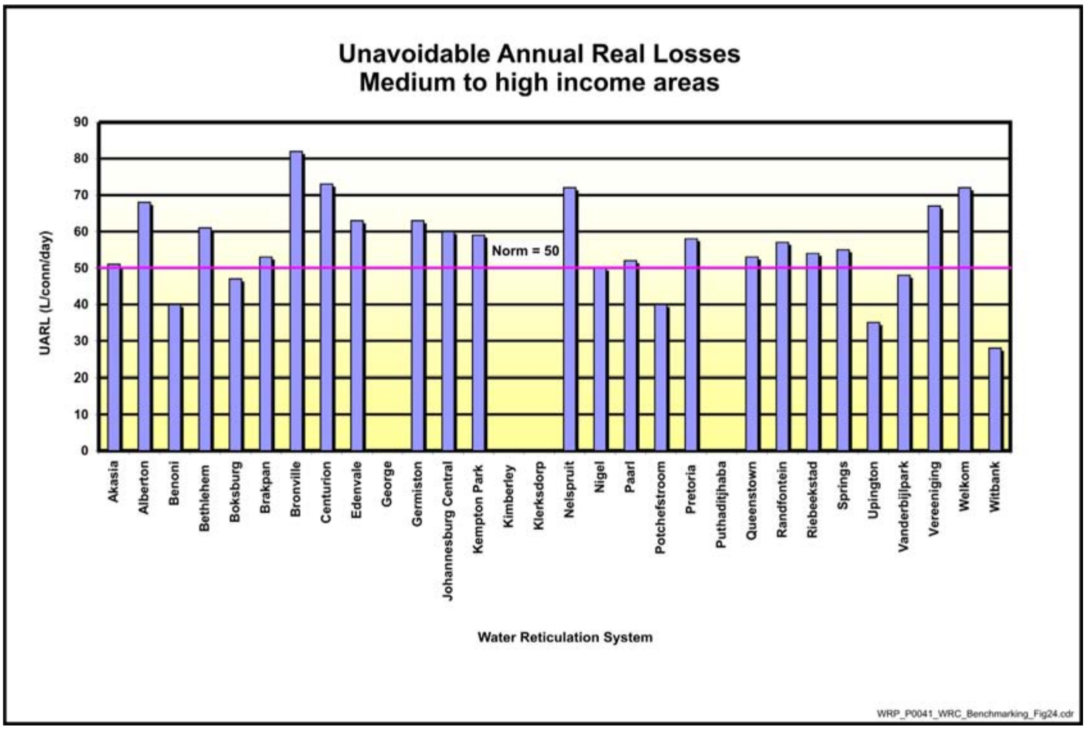

Figure 15: UARL: medium to high income areas

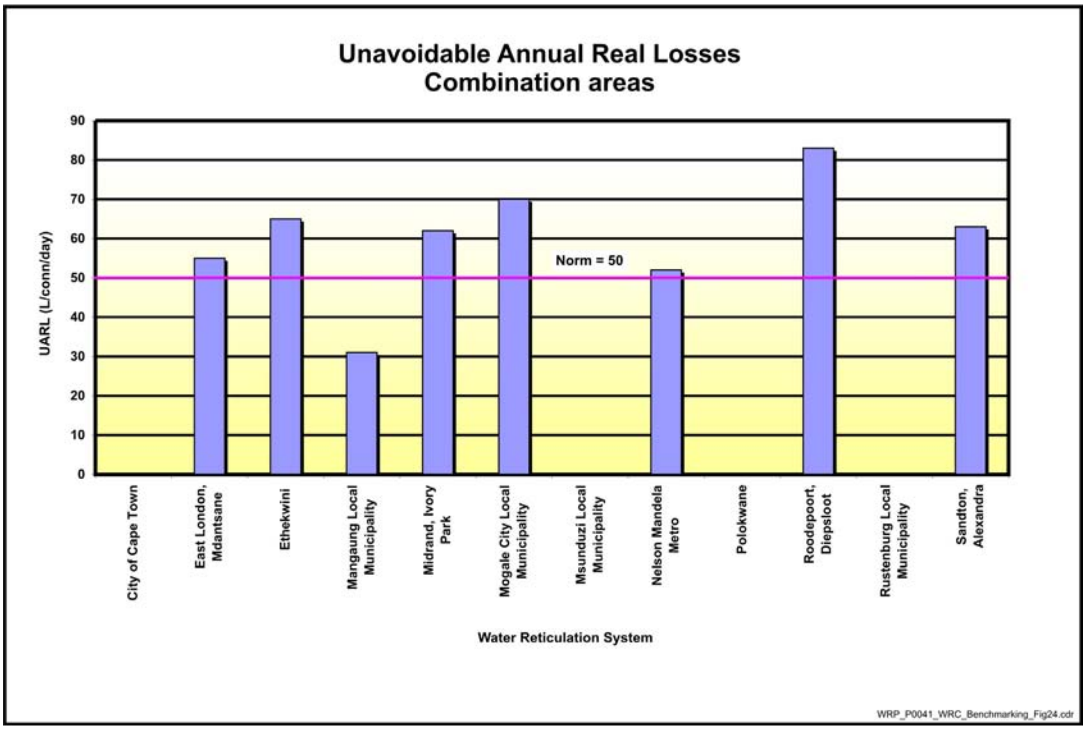

Figure 16: UARL: combination areas

4.3.3 Bulk system input volume per property

The authorised consumption per property served is a useful indicator of water use in any system since it represents the actual water use excluding the real losses. Unfortunately it is very difficult in many cases to split the total water use into the various components used in the IWA water balance. For this reason it was decided to present bulk system input volume per property served as it is still a useful indicator. The results obtained range from 9.3 kilolitres per connection per month in Katlehong to 87.6 kilolitres per connection per month in Nelspruit.

The following two guidelines are useful standards to aim towards when comparing this indicator for certain income level groups (Personal Communication, 2006):

- 12 kilolitres per connection per month in low income areas where people are not paying for water;
- 35 kilolitres per connection per month in medium to high income areas where people are paying for water.

It should be noted that the figures of 12 and 35 kilolitres per connection per month are approximate, and if the actual demands are found to be high, closer inspection of the situation is required. For example, an area containing many industrial connections is likely to have a higher volume per connection than a predominantly residential area. It is not necessary to target areas using higher than these advised volumes where payment is being received. The bulk system input volume per connection for the different sized water reticulation systems are shown in **Figures 19** to **21**.

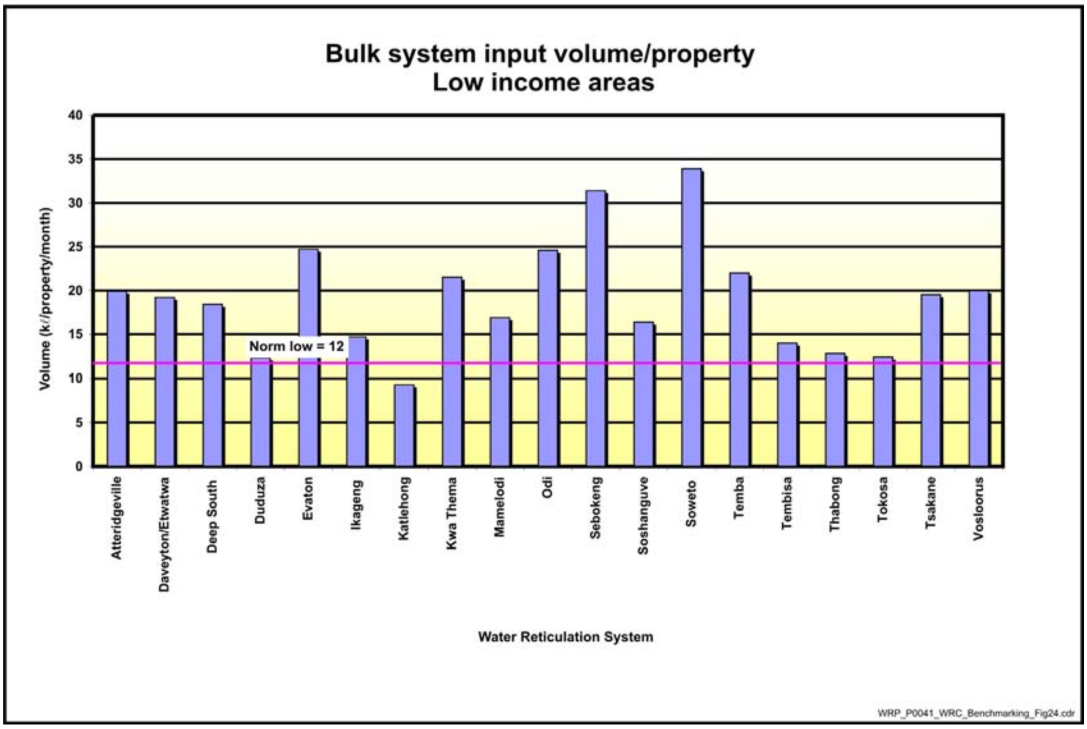

Figure 17: Bulk system input volume per property: low income areas

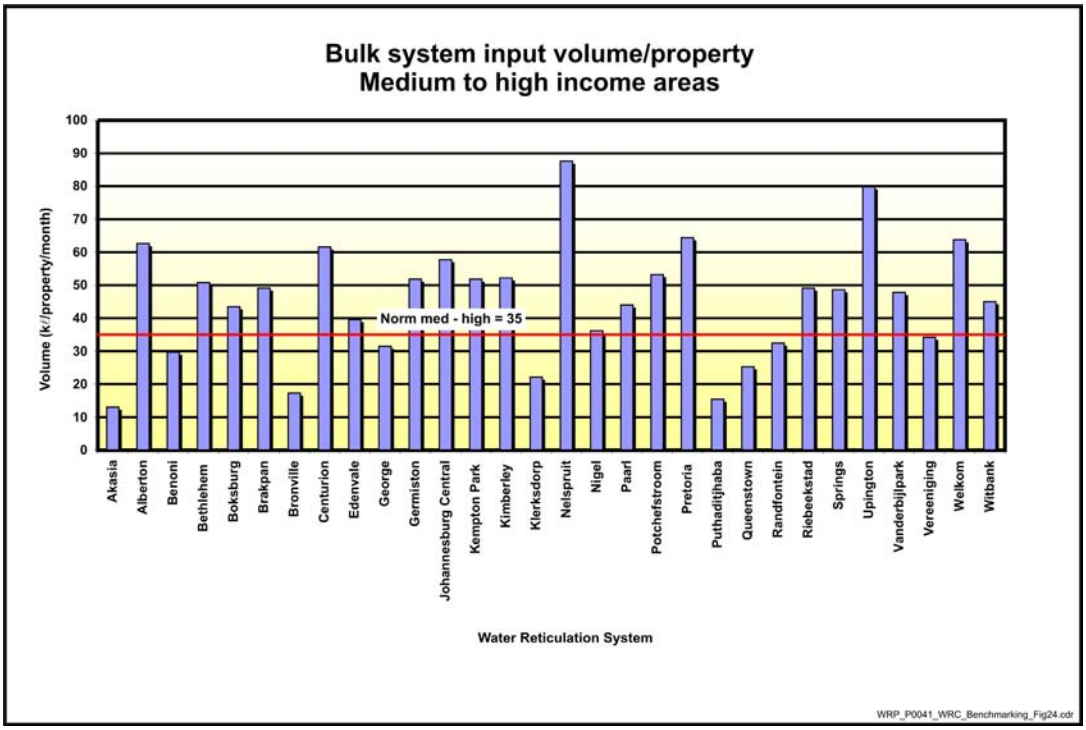

Figure 18: Bulk system input volume per property: medium to high income areas

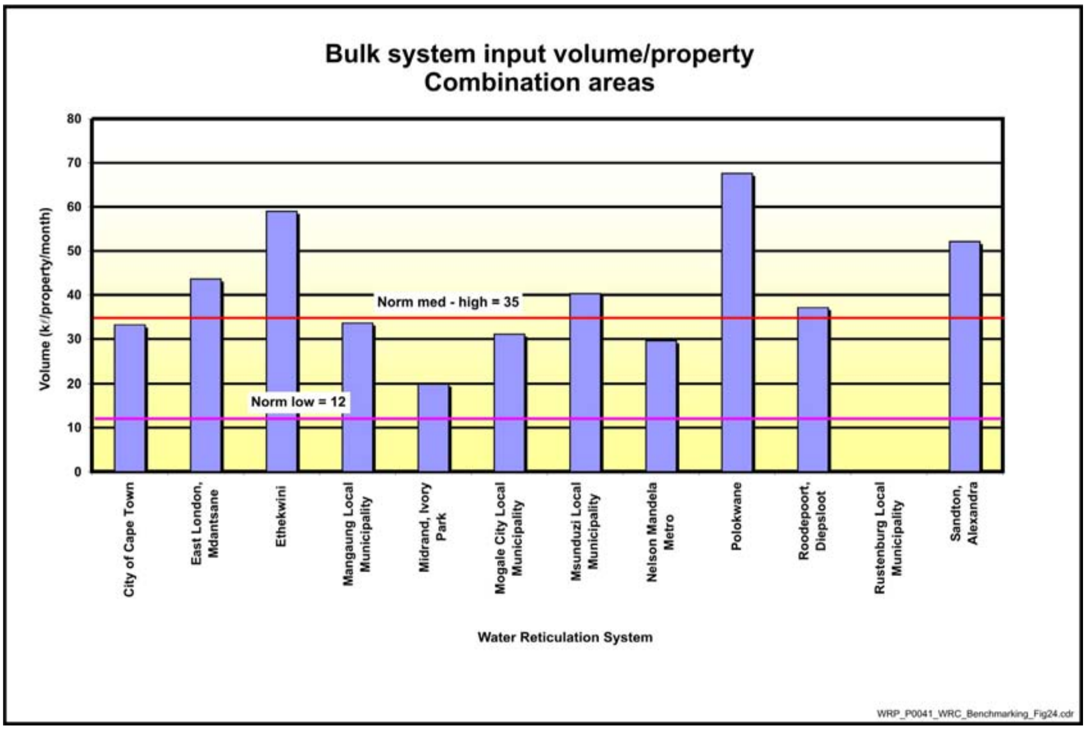

Figure 19: Bulk system input volume per property: combination areas

From the results, the following areas should be investigated in more detail.

Table 4-3: Areas to target based on system input volume per property

Name of WRS	System input (kℓ/prop /month)	Comments
Alberton	62.6	Industries and high rise buildings which use more water than normal
Atteridgeville	19.6	> 12 Level of payment needs to be considered
Bethlehem	50.8	Level of payment may be satisfactory
Boksburg	43.5	High industrial use
Brakpan	49.1	High industrial use
Centurion	60.8	Many townhouse complexes counted as one property but use much more water
Daveyton/Etwatwa	19.2	> 12 Level of payment needs to be considered
Deep South	18.4	> 12 Level of payment needs to be considered
E. London,/Mdantsane	43.6	This area should be split in order to obtain indicator for low vs high level of payment
Edenvale	39.5	High industrial use
Ethekwini	59	This area should be split in order to obtain indicator for low vs high level of payment
Evaton	24.7	> 12 Level of payment needs to be considered
Germiston	51.8	High industrial use
Ikageng	14.7	> 12 Level of payment needs to be considered
Johannesburg CBD	57.7	Industries and high rise buildings which use more water than normal
Kempton Park	51.8	High industrial use
Kimberley	52.2	Level of payment may be satisfactory
Kwa Thema	21.5	> 12 Level of payment needs to be considered
Mamelodi	16.7	> 12 Level of payment needs to be considered
Msunduzi	40.3	Level of payment may be satisfactory
Nelspruit	87.6	Needs closer inspection
Nigel	36.2	High industrial use
Odi	24.3	> 12 Level of payment needs to be considered
Paarl	44	Level of payment may be satisfactory
Polokwane	67.6	Needs closer inspection
Potchefstroom	53.2	Level of payment may be satisfactory
Pretoria	63.6	Industrial use and high
Riebeekstad	49.1	Level of payment may be satisfactory
Sandton, Alexandra	52.1	This area should be split since Alex and Sandton are not similar in water use.
Sebokeng	31.4	> 12 Level of payment needs to be considered
Soshanguve	16.2	> 12 Level of payment needs to be considered
Soweto	33.9	> 12 Level of payment needs to be considered
Springs	48.6	High industrial use
Temba	21.7	> 12 Level of payment needs to be considered
Tembisa	14	> 12 Level of payment needs to be considered
Tsakane	19.5	> 12 Level of payment needs to be considered
Upington	79.8	Needs closer inspection
Vanderbijlpark	47.8	High industrial use
Vosloorus	20	> 12 Level of payment needs to be considered
Welkom	63.8	Possibly large number of industries
Witbank	45	High industrial use

Name of WRS	System input (kℓ/prop /month)	Comments
Worcester	51	Level of payment may be satisfactory

4.3.4 Apparent losses

The percentage of real losses which is allocated to apparent losses was determined using the process given in **Table 2-3** whereby illegal connections, meter age/accuracy and data transfer errors are all taken into account. Where this information was not provided by the WSA, averages were used based on estimates made regarding the WRS. Apparent losses are currently being investigated by an IWA task force and results from this investigation should provide greater clarification on how to deal with apparent losses. These results should be available by the end of 2007 (Rizzo, 2006).

4.3.5 ILI

The ILI is an important performance indicator which refers to the physical leakage or real losses occurring from a water distribution system. It should, however, never be looked at on its own when determining problematic areas. This is because a WRS with a high volume of non-revenue water does not necessarily have a high ILI value if the major components of the non-revenue water (see **Section 4.5**) are for example unbilled authorised consumption or unauthorised consumption. The methodology for determining authorised consumption and real losses in areas where the measured volume entering the area is much larger than the sum of all the consumer volumes billed on a flat rate basis is discussed further in **Section 4.5.3**.

The ILI values obtained range from 0.4 in Edenvale (unrealistic due to data transfer errors) to 16.9 in Witbank. The average ILI for all the water reticulation systems analysed is approximately 6.9. The following graphs present the ILI values obtained for the various areas for the different sized water reticulation systems.

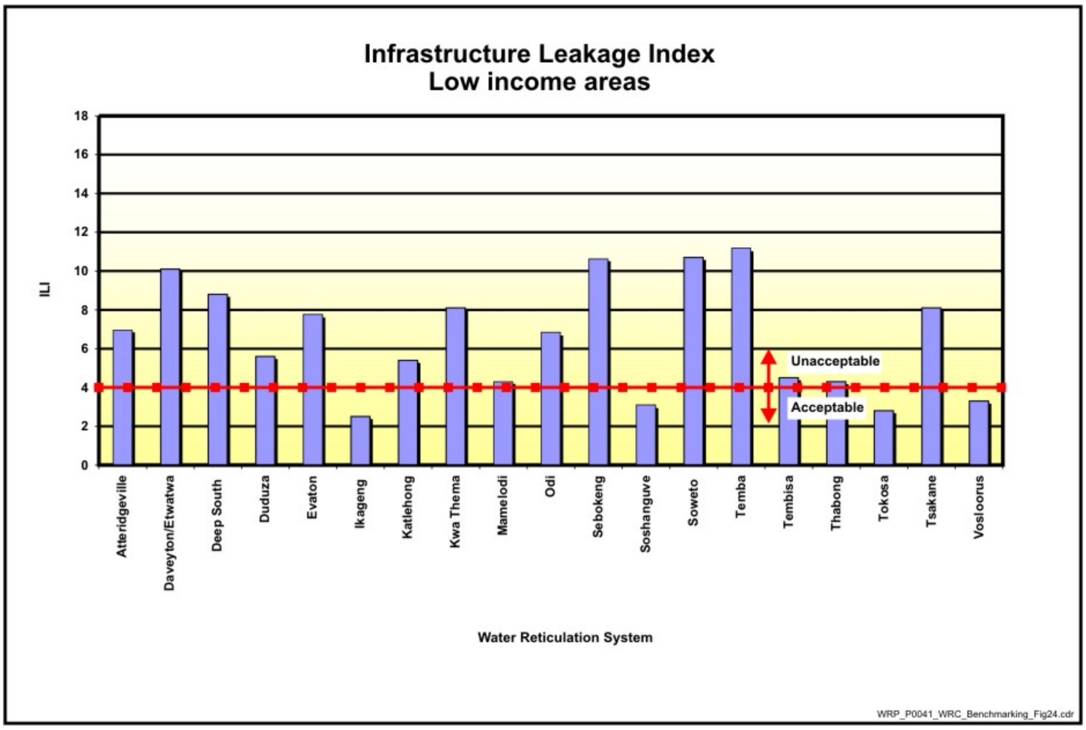

Figure 20: ILI: low income areas

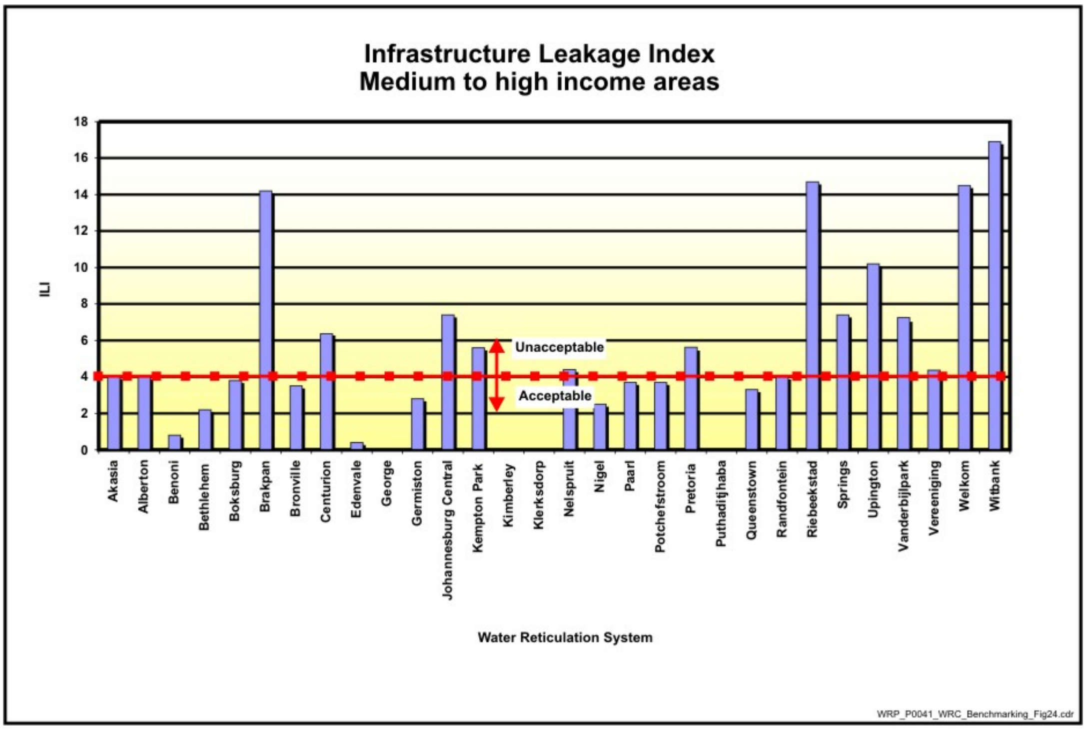

Figure 21: ILI: medium to high income areas

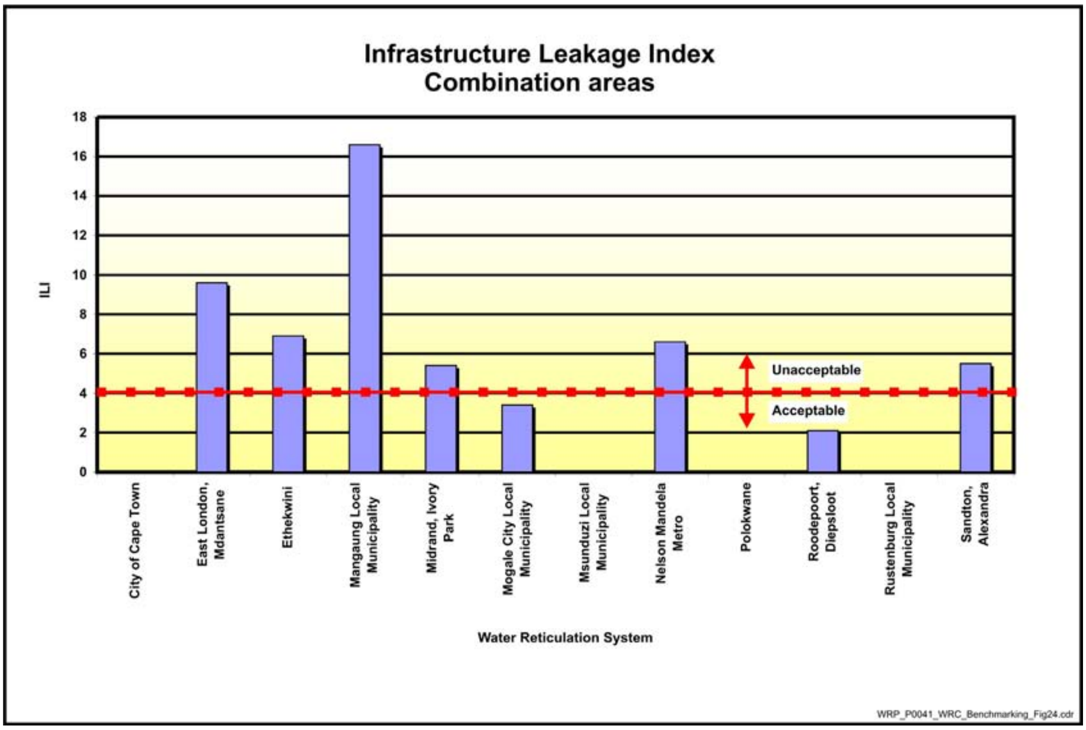

Figure 22: ILI: combination areas

A number of water reticulation systems fall into the unacceptable range of ILI greater than 4 and it is recommended that these should be targeted for intervention at the earliest possible opportunity.

4.4 Free basic water

The policy in South Africa is to provide 6 kℓ of water per property free of charge. The application of this policy of providing free basic water is a complex issue and does not fit easily into the IWA standard water balance. As discussed under **Section 2.1**, the IWA standard water balance was modified slightly in order to separate the free basic component from the billed recovered revenue component. Some WSAs incorrectly consider this free basic water to be non-revenue water due to the fact that even though it is billed (at a zero rate) the WSA does not receive any income from the users of this portion of water. However, this water is effectively subsidised by the government and therefore payment is received for it from a different source.

Another argument for keeping the free basic component in the revenue water section is as follows. The theory behind non-revenue water is that a WSA's aim should be to convert all non-revenue water to revenue water. Consider a WRS whose total authorised consumption is exactly 6 kℓ per stand. The total authorised consumption is therefore only the free basic component. If the free basic component is considered non-revenue water, it would mean that this example WRS is operating very poorly as 100% of water supplied is non-revenue water. However, a WSA can not do anything about this 6 kℓ of free water which is stipulated by the government. In actual fact, the WSA is operating very well if it is keeping its supplied water down to a level of 6 kℓ per stand. The free basic component is therefore considered as revenue water which is charged at a zero rate and is now shown as a separate block in the water balance. This portion cannot be targeted for reduction since it is effectively "revenue water" unlike the true non-revenue water components.

4.5 Components of non-revenue water

The following eight categories form the non-revenue water component of a WRS.

- Billed consumption that is not paid for (non recovered revenue, new category added to SA water balance);
- Unbilled metered consumption (authorised consumption);
- Unbilled unmetered consumption (authorised consumption);
- Unauthorised consumption (apparent losses);
- Customer meter inaccuracies (apparent losses);
- Leakage on transmission and distribution mains(real losses);
- Leakage on overflows at storage tanks (real losses); and
- Leakage on service connections up to the point of customer meter (real losses).

One of the aims of the study was to gain a better understanding of the approximate distribution of non-revenue water amongst the eight categories mentioned above in South African water reticulation systems. Again this proved difficult as even the most basic data was difficult to obtain; however, some water reticulation systems were willing and able to provide rough estimates of their water balance which are discussed in the remainder of **Chapter 5**.

4.5.1 Billed consumption that is not paid for

As discussed previously, to address the South African situation it was necessary to add a final column to the IWA water balance whereby revenue water (or more accurately termed "potential revenue water") is divided up into recovered and non-recovered revenue. This section deals with the non-recovered revenue water which is water that is billed but never paid for. These figures are often difficult to obtain from WSAs as the revenues collected generally lie within the financial section of the WSA rather than the technical section. Some WSAs indicated that this is a major problem since the technical section is often held accountable for non-revenue water; however, they do not obtain accurate figures for this portion of non-revenue water. The City of Cape Town indicated that their current outstanding debt for water services is R1 billion and growing annually (City of Cape Town WSDP, 2006/2007).

Many properties situated in low income areas are fully serviced and receive their 6kℓ of water per month for free. The problem arises, however, when these properties utilise water above the free basic limit before the end of the month. Most WSAs which provide individual connections do not have systems in place to manage the use of the basic 6kℓ (Personal communication, 2006). Where the WSAs are not metering and billing consumers on an actual volume of water used, all water above the 6 kℓ is considered to be non-revenue water that could potentially be revenue water. Some WSAs are finding that a limit of 6kℓ free is too low in urban areas and that users are using more than that. They have found that the logistics of metering and billing this use is too large for the amount of revenue that is likely to come from these users. For this reason, they have stated that the allowable free basic use could be as much as 10 kℓ per property per month. This will be elaborated on under **Section 4.7**.

The following presents a breakdown of the billed authorised component of the water balance. The three main segments are:

- water sold for which an income is obtained;
- water billed at a zero rate and therefore no income is obtained, no intervention can reduce this volume; and
- water used which should be paid for, interventions should convert some of this volume to revenue water.

It is very important to realise that in the South African situation, it is unlikely that much of the authorised (currently both billed and unbilled) water that is not paid for can in fact be converted to fully recovered revenue water. As soon as the payment process is formalised and enforced, the water consumption tends to drop significantly. For example 5000 households in a certain area do not pay for water because they do not receive a bill or because payment is not enforced. These 5000 households each use on average 50 kℓ per month of which 6 kℓ / household / month is the free basic component and 44 kℓ / household / month should effectively be paid for. The WSA that supplies these households sells water at R2 / kilolitre. The WSA should not assume that it will automatically obtain R440 000 (44 kℓ x 5000 houses x R2) if payment is enforced. This is because it is likely that much of the 44 kℓ / household / month is wasted as the users never intend to pay for it. Should payment be enforced they are likely to use water much more sparingly and could drastically drop their consumption.

4.5.2 Unbilled metered consumption

The general trend appears to be that most water reticulation systems (Johannesburg, Tshwane, Polokwane, Potchefstroom and Sasolburg) do not have significant unbilled metered consumption. This component was usually through uses such as buildings, parks and swimming pools. Most water reticulation systems that were questioned on this issue indicated that they do bill and collect income from various other Municipal departments.

Another component of unbilled metered consumption occurs in areas where meters are in place but are not read and customers are therefore not billed. This occurs either because the WSA does not have a system in place to do so, or because the users prevent their meters from being read as shown in **Figure 23.**

Figure 23: A customer meter which can not be read

4.5.3 Unbilled unmetered consumption

A new portion of the unbilled unmetered consumption component was introduced due to the specific circumstances of some South African WSAs. **Figure 24** shows the proposed breakdown of bulk system input volume where it is known that consumers are being billed on a flat rate amount that is a lot less than their actual consumption.

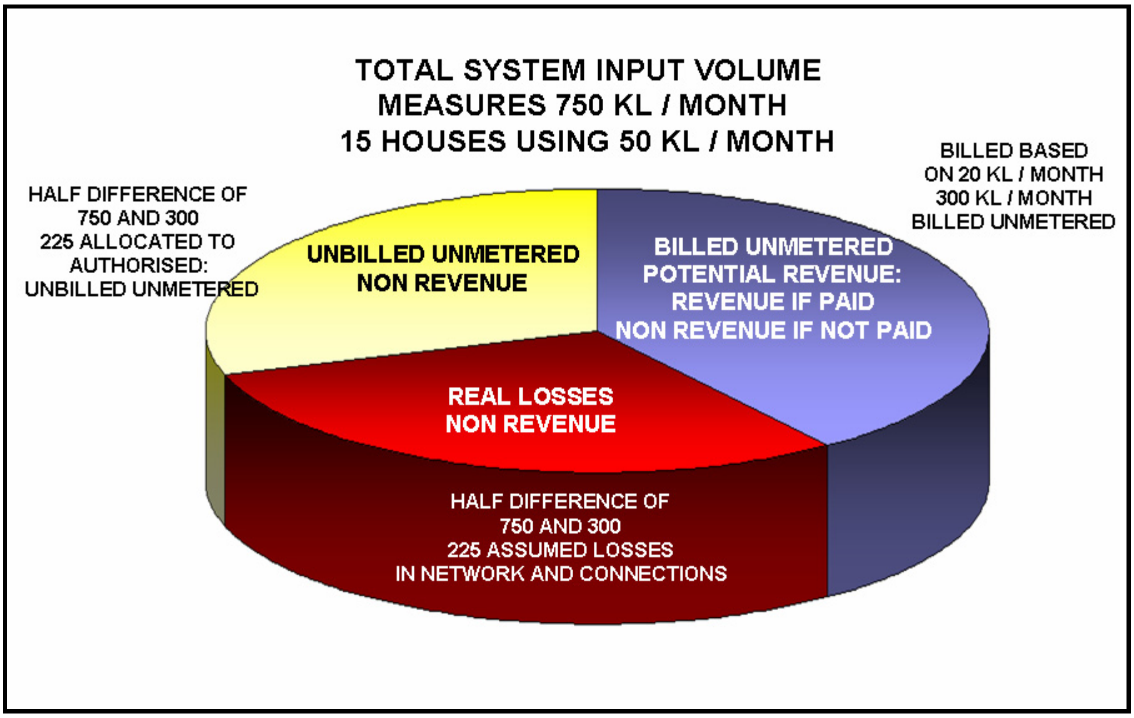

Figure 24: Illustration of water billed on a flat rate tariff basis

The City of Johannesburg's figures are used to illustrate this example. **Table 4-4** shows the water that is billed in the three systems presented. It also shows the amount of known authorised consumption in the three areas and the measured water that is actually entering the areas.

Table 4-4: Deemed areas in the City of Johannesburg

WRS	Standpipe use Unbilled unmetered(1)	Billed Volume (1)	Measured Volume (1)	Real losses (2)	Unbilled unmetered consumption (2)
Alexandra	187	2 097	14 653	6 185	6 185
Soweto	6 027	36 442	130 359	43 945	43 945
Deep South	1 762	2 359	12 520	4200	4 200

Note 1: Source: City of Johannesburg
Note 2: Estimated based on proposed 50 – 50 split (described hereafter)

It should be noted that it has been assumed that the unaccounted for water is split evenly between real losses (leakage) and unbilled unmetered consumption which tends to be wastage and/or leakage after the meter (if any).

The following schematic represents how the Sandton / Alexandra and Soweto areas were analysed according to the above mentioned methodology. The Deep South area was analysed in the same way as Sandton / Alexandra and is therefore not presented.

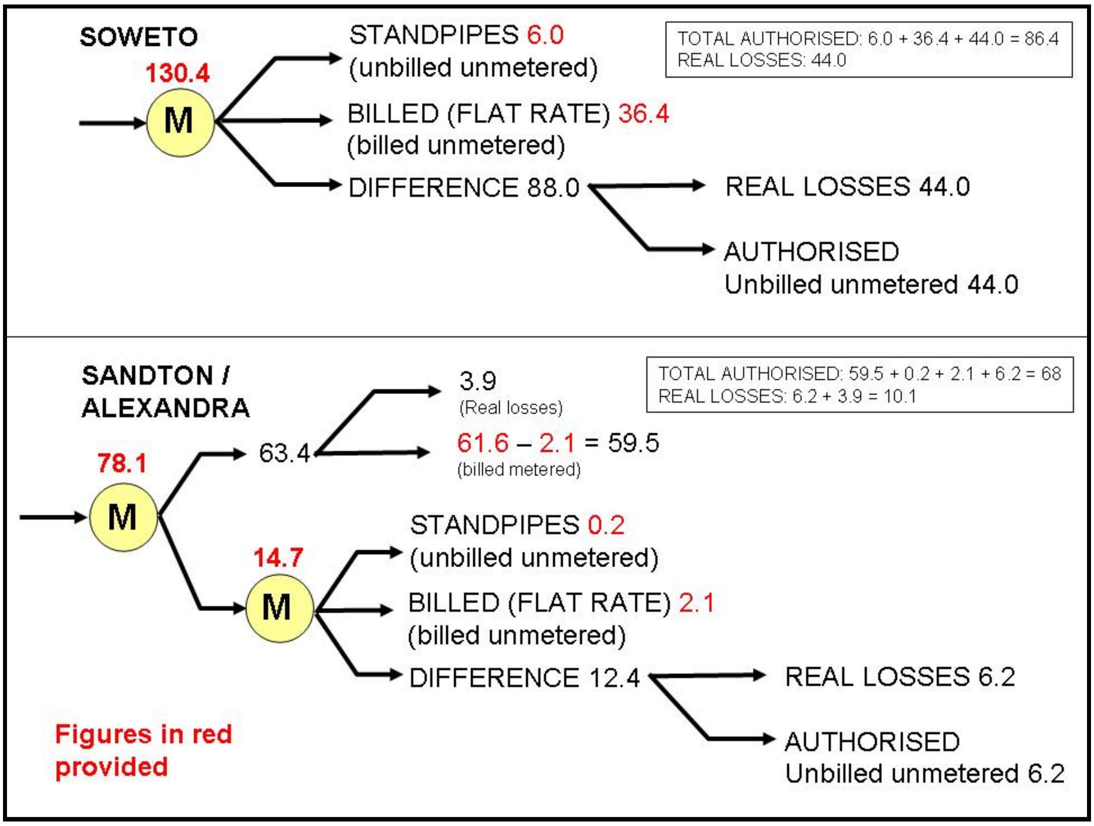

Figure 25: Schematic representing water balance in deemed areas

It should be stated that the above examples highlight a social problem rather than a technical problem. It can be seen that the measured volumes entering the three areas are significantly larger than the sum of the volumes on all the bills sent out (and often not paid for). It is unclear as to where this difference is actually "lost" and unless some detailed information is available; the missing volume is split evenly between real losses (through pipelines and service connections) and unbilled authorised consumption. The usage is considered authorised since the consumers are not technically "stealing" the additional water they use, and are charged on a flat rate basis. This issue still requires further investigation, however, the proposed split appears realistic in many cases. This situation only occurs in WSAs that bill on a flat rate based on a lower volume than that actually measured at the main bulk meters entering the area.

If only the billed volume was used in the water balance, it would suggest that the WRS is operating very poorly and has a huge volume of real losses. This is not the case in most areas and it is estimated that half the water is actually used by residents.

Another major portion of the unbilled unmetered consumption is due to the use of standpipes in many of the lower income areas which occur in most WSAs. This volume of water is often estimated and therefore forms part of the water balance as it is considered to be authorised consumption. Most standpipes, however, are not metered and the users do not pay for water obtained from standpipes. Some WSAs maintain that generally people who are walking to a standpipe to fetch water do not carry more than their allocated 6 kℓ per month free, and therefore need not pay for the service. A large volume of water can however be lost through standpipes when users do not turn them off or through leakage if they are not properly maintained. A common occurrence appears to be the practice of removing the spindle from taps which prevents taps from being turned off. This can be seen in **Figure 26** and **Figure 27** and it is clear that a significant volume of water can be lost in this way.

Figure 26: Standpipe left running after spindle was removed

Figure 27: Pressure at a standpipe which can not be turned off

The remaining portion of the unbilled unmetered component is mainly due to water used through fire hydrants and from mains flushing. Representatives from the Municipality of Polokwane for example are aware that fire connections are a major problem in their area as they are not metered. The officials feel that a significant portion of their unaccounted for water is being used illegally through fire connections. Fire hydrants are also often used to drain the reticulation system in order to drop pressures to undertake pipe maintenance, and such water is seldom measured. Another unfortunate reality is that some fire hydrants are no longer only used for fire fighting, with many being abused and used for other purposes such as washing taxis or other general water theft.

4.5.4 Unauthorised consumption

The following WSAs stated that unauthorised consumption (illegal connections) was not a problem in their areas: Bethlehem, Bloemfontein, Nelspruit, Potchefstroom, Sasolburg and Polokwane. The following WSAs stated that illegal connections were a problem in their areas: Ethekwini (26% of real losses), Johannesburg, Tshwane, Ikageng and Witbank. It is difficult to generalise the impact that illegal connections have on WSAs in South Africa.

Experience shows that illegal connections tend to be highest in low income areas where billing is taking place. Most of the WSAs were aware of the problem and were attempting to eliminate it by pulling out any illegal connections that they found as well as metering all fire fighting connections.

It may be argued that there is no longer a problem of illegal connections in South Africa since all people have the right of access to basic water use. The definition of an illegal connection used here is where a consumer connects directly onto a distribution pipeline or other water source without the WSAs knowledge, or when a person who has an existing metered service connection bypasses the meter and uses more than the basic allocated amount. Examples of this are shown in **Figure 28** and **Figure 29**.

It should be noted that one common problem where illegal connections certainly exist concerns the situation where residents convert a single standpipe connection into multiple individual household connections. This can cause problems with system capacity constraints since the original system was designed for standpipe use and not individual metered connection use.

Figure 28: An illegal connection where a consumer meter has been bypassed

Figure 29: An illegal connection on an air valve

4.5.5 Customer meter inaccuracies

Customer meter inaccuracies are mostly dependant on the age of the meter, as well as the water quality of the area. Most WSAs stated that they thought their meters were in a fair condition except for Soweto and Deep South where they indicated that the meters are in a poor condition. It is difficult to estimate the amount of water theoretically "lost" through meter under registration. Poor customer meters are generally found in lower income areas.

4.5.6 Leakage on transmission and distribution mains

Often viewed as the main contributor to real losses, leakage on water mains is made up of bursts and background leaks. As discussed previously, a certain portion of leakage is unavoidable, and all systems will leak to some extent. Leakage in excess of the accepted minimum levels is usually due to low maintenance on distribution systems. A lack of maintenance, in turn, often results from insufficient funds and/or capacity within the WSA and tends to be more of a problem in lower income areas. Another contributing cause of such leakage occurs when consumers are not aware of the necessity to save water and therefore allow bursts to continue without reporting them. Water losses in such cases can often be reduced through social interventions such as public awareness campaigns and education activities.

Figure 30: A leak which has not been reported

Keeping good records of pipe bursts within a WSA can often assist the WSA in determining problem areas within their systems. Pipe bursts are usually a result of either high pressures or older pipes. Plotting the bursts on a map as they occur will highlight these areas and assist with planning of interventions such as pressure reduction or pipe replacement. It is also useful to continue record keeping once interventions have taken place in order to show the affects of such interventions. Tshwane was the only WSA that provided information on pipe bursts on request.

4.5.7 Leakage on overflows at storage tanks

When questioned on the condition of their storage systems, most WSAs stated that they were in a fair condition and that they did not feel that a large portion of real losses were a result of leakage from storage tanks. Unfortunately the issue of reservoir overflows is often underestimated since much of the spillage occurs at night when no-one is aware of the leakage. In general, however, most reservoirs in South Africa are of reasonable quality and reservoir leakage is regarded as a minor issue in most areas. **Figure 31** shows overflow at a reservoir.

Figure 31: Overflow at a steel reservoir structure

4.5.8 Leakage on service connections up to the point of customer meter

In most systems, leakage from connections is by far the greatest source of physical leakage; often 80% or more of the total physical losses (Tim Waldron, personal communication). A portion of the service connection leakage also contributes to the unavoidable annual real losses. The total volume of water lost as a result of this leakage is therefore dependant mainly on the number of service connections within a system and the average operating pressure.

Figure 32: A leak at a service connection

4.6 Distribution of non-revenue water components

Having discussed the various components of non-revenue water, it is necessary to break them down on a percentage basis in order to gain a thorough understanding of the larger components of non-revenue water in South Africa. The breakdown is subjective to some extent based on experience as well as discussions with many WSAs. **Figure 33** and **Figure 34** show the approximate proportions of the eight components of non-revenue water for two different categories of water reticulation systems, namely, medium to high and low income areas. It is important to note that these are approximate estimates of the non-revenue water component and not the bulk system input volume. Further investigation and measurements are required to verify these figures. The figures show that the greatest contribution to non-revenue water in medium to high income areas lies with real losses, (i.e. physical leakage) while for low income areas the greatest contribution to the non-revenue water originates from authorised consumption that is not paid for. This does not imply that the actual volumes of real losses are higher in medium to high income areas since the overall level of non-revenue water in such areas is likely to be much lower.

BREAK DOWN OF NON REVENUE WATER FOR MEDIUM TO HIGH INCOME AREAS

Non-Revenue Water	Authorised Consumption: Non rec. revenue	Billed Consumption that is not paid for	3%
		Unbilled metered Consumption	2%
		Unbilled unmetered Consumption	2%
	Apparent Losses	Unauthorised Consumption	1%
		Customer Meter Inaccuracies	5%
	Real Losses	Leakage on Service Connections up to point of Customer Meter	70%
		Leakage on Transmission and Distribution Mains	16%
		Leakage on Overflows at Storage Tanks	1%

Figure 33: Non-revenue water components in a medium to high income area

BREAK DOWN OF NON REVENUE WATER FOR LOW INCOME AREAS

Non-Revenue Water	Authorised Consumption: Non-recovered revenue	Billed Consumption that is not paid for	10%
		Unbilled Consumption	55%
	Apparent Losses	Unauthorised Consumption	11%
		Customer Meter Inaccuracies	1%
	Real Losses	Leakage on Service Connections up to point of Customer Meter	18%
		Leakage on Transmission and Distribution Mains	3%
		Leakage on Overflows at Storage Tanks	2%

Figure 34: Non-revenue water components in a low income area

4.7 Potential water savings methodology for South Africa

In addition to analysing the performance indicators and determining the components of non-revenue water, a methodology was developed to determine realistic water uses for the various areas based on the number of properties being served. Using this realistic use combined with the actual bulk system input volumes; it was possible to estimate approximate savings that each WSA could expect should they attempt certain water demand management interventions. The following figure presents the approach to calculating potential water savings in South Africa as discussed below.

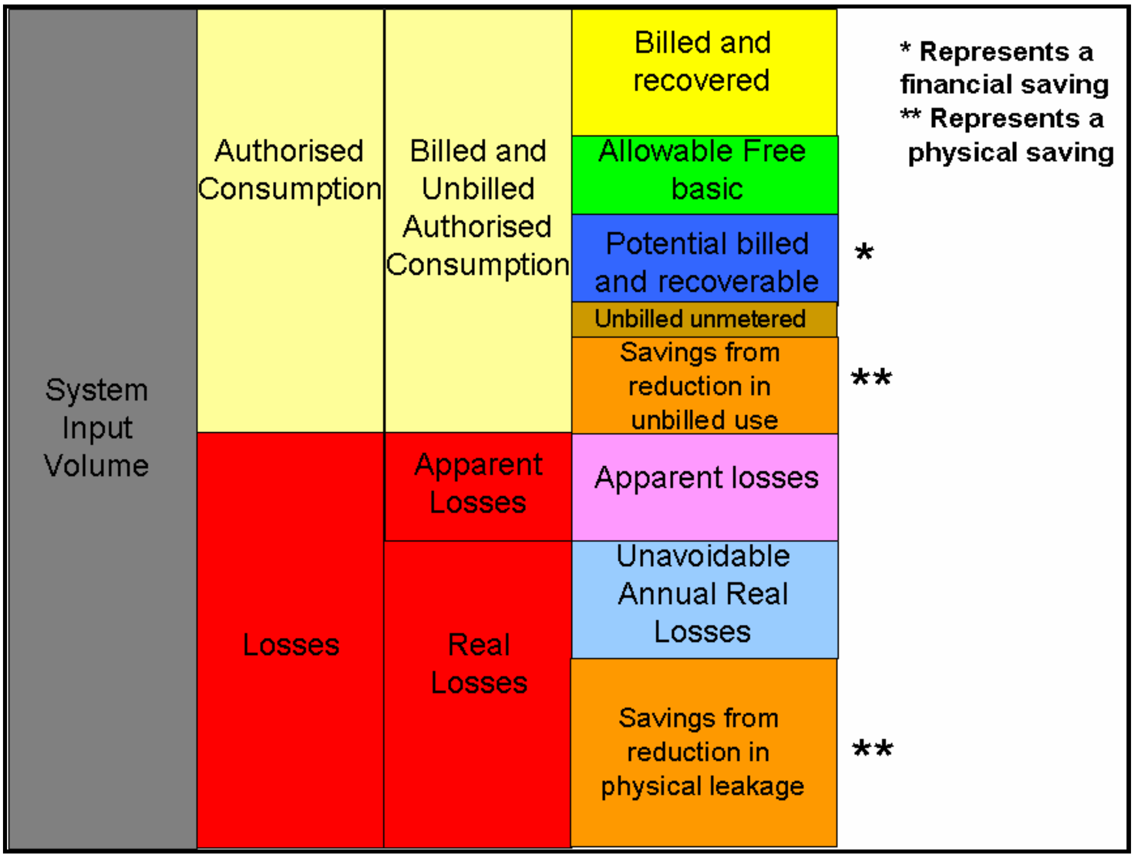

Figure 35: Breakdown of system input volume into realistic components for South Africa

The descriptions for each of the categories are as follows:

Billed and recovered: this volume of water is all water, either metered or unmetered, that payment is received for the sale thereof.

Potential billed: This is a volume of water that is currently either metered or unmetered, however, the customer is not billed and therefore does not pay. It is unlikely that the current water use will drop should the customer suddenly be billed, and therefore its volume does not form part of the savings. It would merely be a financial income to the WSA should billing start. The volume of potential billed water is usually calculated to be about 2% of system input volume.

Allowable free basic: This volume of water is where most savings would be made should WSAs reduce it to a satisfactory amount. It is made up of consumers who are currently billed but do not pay, as well as water users who are not billed at all. A realistic volume of use per household is about 12 kℓ / month in most low income areas. This includes the 6 kℓ that are provided for free. It is likely that WSAs that implement an effective payment system for use above the allowable free limit will achieve significant savings as a result of a drop in use as well as wastage from internal plumbing leaks. This is clearly shown by the Soweto project being implemented by Johannesburg Water where the water use per property has dropped from over 50 kℓ / household / month to less than 12 kℓ / household / month through the implementation of pre-payment for water.

Apparent losses: The apparent losses were based on an assessment of the levels of illegal connections in the system as well as the age of the meters and quality of the water. This approach is subjective to some extent and dependant on the in-depth knowledge of the system by the manager who completed the water audit.

UARL: This volume of water is calculated from the standard UARL equation and is a function of length of mains, number of service connections and average operating pressure.

Unbilled unmetered: This component of unbilled authorised consumption will also not reduce as a result of proper billing and/or income recovery since it is based mainly on water used for fire fighting and mains flushing. This component is normally very small in most systems.

Savings: The overall water savings as a result of interventions are made up of a combination of lower consumption by users that are limited to the allowable free basic use and savings from a reduction in physical use. The balance between these two portions of savings will differ between systems.

Figure 36 represents the savings calculated for each area using the following formula based on the above methodology.

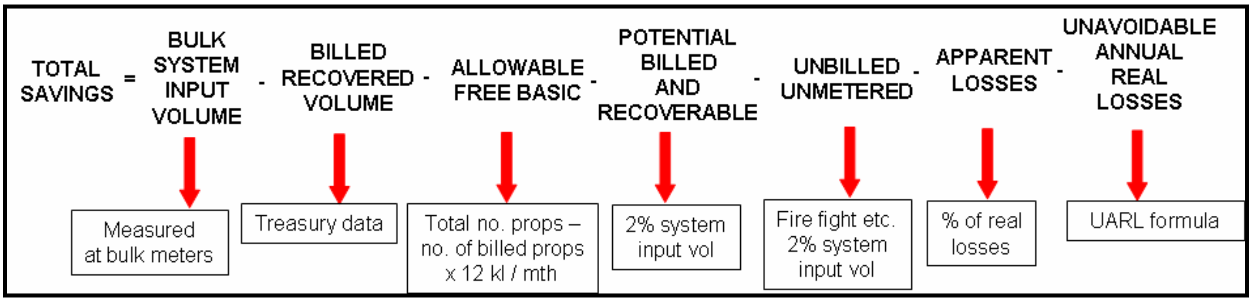

Figure 36: Formula used to calculate potential savings from Water Reticulation Systems

Figure 37 presents these savings graphically for the water reticulation systems which provided information. Some cases resulted in a negative total saving when a value of 12 kℓ per property per month was used as the allowable free basic. In these cases, the allowable free basic was decreased to 6kℓ per property per month. If the total savings were still negative after this adjustment, they were set to zero implying that no savings could be achieved in the area being considered. This usually occurred in areas with intermittent supply where the water being supplied to the system was already insufficient to meet the minimum level of service. In such cases, any savings that can be achieved through WDM measures will simply result in a more reliable supply to the consumers which will gradually increase until it reaches the 6 kℓ per property per month level.

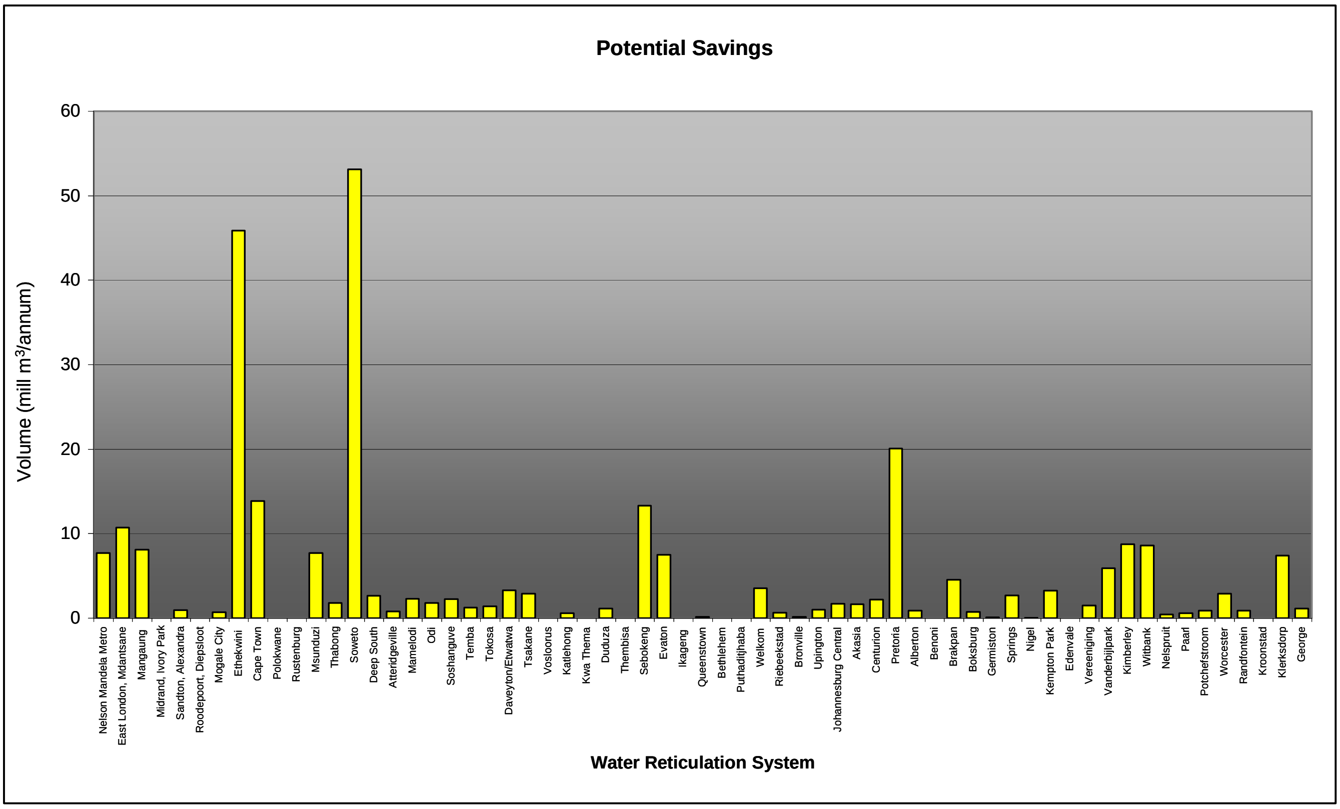

Figure 37: Potential savings

4.8 Extrapolation of results

One of the aims of the study was to use the results obtained from the largest water reticulation systems in order to carry out an overall assessment of leakage throughout South Africa. Unfortunately the information available from the various water reticulation systems in the country is either not available or of dubious quality in many cases with the result that **any conclusions made regarding the water leakage for the country as a whole must be considered as preliminary estimates that will be revised in future as more reliable data become available.**

In order to make any estimate of the total water losses occurring from water reticulation systems throughout South Africa, it was necessary to establish the total water used by the domestic sector. The National Water Resources Strategy of DWAF, states that South Africa's total urban and rural water requirement for 2000 is 3471 million m^3/annum. If this value is extrapolated using an assumed growth of 3%, it suggests a total municipal water use in 2005 of approximately 4 000 million m^3/annum. This is the value that will be compared to the results from the 62 water reticulation systems since these results are also based on the 2005 water audits. The total bulk system input volume figure obtained for the 62 systems analysed was 2149 million m^3/annum which represents approximately 54% of the total urban/rural water requirement of the country. This figure was then used to extrapolate the results obtained from this study in order to derive an estimate of the likely losses for the whole country.

Based on these figures the following assumptions and extrapolations were made:

- The losses (real and apparent) for the 62 systems analysed was estimated to be 623 million m^3/annum or 29% of the total water supplied. The split between physical leakage and administration losses will vary significantly from one system to another and it is not possible to provide an accurate split in this regard.
- Based on the above figures, the extrapolated water losses from water reticulation systems for the whole of South Africa are likely to be in the order of 1 150 million m^3/annum (based on the 54% sample size).
- The potential savings that can be achieved from the 62 water reticulation systems analysed are estimated to be 266 million m^3/annum based on the methodology discussed in this report which includes a combination of real and apparent losses. If this figure is extrapolated to the whole country (based on the 54% sample size), the potential savings are estimated to be almost 500 million m^3/annum (based on the 54% sample size) which represents approximately 12.5% of the system input.

5 CONCLUSIONS AND RECOMMENDATIONS

Based on the work undertaken as part of this project, it is clear that there is a general lack of understanding of the issues surrounding the non-revenue water among high-level politicians in many of the major municipalities and metro's throughout South Africa. While there may be technically competent personnel operating and running the water supply departments of the municipalities, there is a serious problem due to the lack of technical background at the political level. One of the key problems is the manner in which most water supply divisions are separated from the treasury side (i.e. billing and revenue) of the operation. This causes major confusion and inefficiencies which in turn lead to high levels of non-revenue water both in the form of physical leakage and administrative losses (e.g. meter error, billing errors etc.). If the water supply and billing departments can be merged into a single operating unit, many of the problems and inefficiencies will be resolved since they will fall under a single department and the various problems cannot be ignored or blamed on someone else.

Despite many problems associated with the gathering of data from the various water utilities, the study team was able to obtain information from 62 of the largest water reticulation systems throughout South Africa. From the analyses of the water balances for each of the water reticulation systems, the following conclusions were drawn:

- The average bulk system input volume per property served for the 19 low income areas analysed as part of the study was approximately **37 kℓ per property per month**. This can be compared to an expected value of approximately **12 kℓ per property per month** which is considered to be a realistic value for monthly water use per property in lower income areas where proper metering and billing procedures are in place. The value of 12 kℓ/prop/month is based on actual results obtained from several large scale projects in low income areas throughout South Africa where payment levels are close to 100% through the implementation of pre-paid metering. It also agrees closely with water use in Sao Paulo in Brazil where similar conditions and payment profiles exist.
- The average monthly water use per property in the medium to high income areas was estimated to be in the order of **46 kℓ per property per month**. In such areas the actual water use depends to a greater degree on the incidence of swimming pools and garden irrigation. Once again, these figures represent water

consumption in areas where water is being properly billed and paid for by the consumers.

- It is clear that the relative magnitudes of the different components of the water balance vary significantly between the low income areas and the medium to high income areas. **In the low income areas, the greatest problem issue concerns the unbilled authorised consumption** which is generally due to the underestimation of water use in areas where tariffs are based on a “deemed consumption” or assumed meter readings. In such areas, the actual water use is significantly higher than the “deemed consumption” since there is no incentive to use water efficiently.
- **In the middle and high income areas, the greatest source of water loss is through physical leakage** rather than any unauthorised use or unbilled use. It is important to recognise the differences in water losses between the low and high income areas to ensure that the appropriate leakage intervention measures are adopted. In the low income areas, it is important to address the payment issue and to ensure that payment is based on metered consumption. In the medium and high income areas, the key problem is physical leakage in the reticulation system and it is therefore more important to undertake active leakage control at regular intervals since the metering, billing and payment is generally under control.

It is essential that all water suppliers undertake a standard water balance annually for their supply system(s) in order to assess the levels of non-revenue water and also the real and apparent losses, if possible. Such a water balance should not only be encouraged but should be enforced since legislation already exists to support such water balances. Although some form of legislation is already in place to ensure that water utilities undertake annual water balances for their systems, it appears that this is either not being done properly or simply not being done at all. It is essential that all water utilities should at least know the basics of their water reticulation system which includes information on:

- Length of mains;
- Number of service connections;
- Average operating pressure;

- Annual water supplied to the system;
- Annual water supplied and/or billed to the consumers;

Other information to assess the split between real and apparent losses is usually not available which, in turn, leads to great confusion concerning whether the problem is a technical problem caused by physical leakage or an administrative problem caused by poor billing and revenue collection. It is recommended that the BENCHLEAK Model developed by the Water Research Commission in 1999 be used to undertake the water balance. Other similar models can also be used as long as the same basic methodology is employed and it is further recommended that the BENCHLEAK Model be updated to conform with the latest IWA developments in the water auditing field.

Recommendations regarding use of Performance Indicators (PIs)

For many years, various water loss specialists from around the world have been proposing and recommending the use of some or other PIs to define real losses (leakage) from a water distribution system. There have been numerous attempts at introducing new indicators, some of which have been accepted and others rejected outright. Following the IWA Water Loss Taskforce workshop held in Australia in February 2005, it appears that the situation is gradually becoming clearer. From this workshop and the experiences of the authors of this report, the following recommendations are made:

- **The use of percentages as an indicator for real losses should be discouraged** although it is accepted that percentages will always remain since few water utility managers are prepared to discard percentages completely from their list of PIs. It is therefore important when using percentages to highlight the potential pitfalls and to ensure that other PIs are also provided. The authors do not propose the removal of percentages as a PI for real losses but rather recommend that it should not be used in isolation and must be accompanied by at least one other PI – preferably the losses in litres/connection/day and/or the ILI.
- It was agreed that the ILI is a very useful and powerful indicator. It was also highlighted, however, that few people, especially the general public, can associate with the ILI and that it cannot be used on its own.

- In addition to the ILI, the following PI for real losses should be used:

litres/connection/day

- This indicator will be suitable for most systems where the density of connections is greater than 20 connections per km mains. In cases where the density of connections drops below 20 per km of mains, it is often appropriate to rather use the following indicator:

m^3/km mains/day

- The average operating pressure should be used as a PI since many systems are apparently achieving very low levels of leakage but are being operated at very high pressures which are often not necessary. For this reason the average system pressure is a key indicator which can be used to determine if some form of pressure management is required in a specific area.
- Finally the Infrastructure Leakage Index (ILI) is a useful indicator and can often be used to benchmark the real losses from one system against another.

Infrastructure Leakage Index (ILI) = CARL/UARL

Summary of Results for South African Water Reticulation Systems

Based on the results obtained from the 62 water reticulation systems, the following conclusions were reached:

- The density of connections for the South African systems ranged from a maximum of approximately **135 connections/km mains to 18 connections/km mains**. The expected density of connections for a typical developed system is in the order of 50 connections per km mains.
- The average operating pressure for the South African systems ranged from a **minimum of 24 m to 63 m**. It should be noted that this represents the weighted average pressure for the whole reticulation system and pockets of very high or very low pressure may still exist in various systems. These pressures are typical of those experienced in developed countries.
- **The average ILI was found to be 7.6** (1.0 being very good and greater than 10 being very poor). Excluding one or two small outlier systems, the ILI ranged from

approximately 2 (very good) to more than 20 (very poor). The average ILI value places South Africa in the middle of the world data set and indicates that the real losses in the country are high with significant scope for improvement but lower than most other developing countries.

This information showed that these water reticulation systems have an average ILI of 7.6. It should be noted, however, that the ILI alone is not a clear indicator of how a water reticulation system is performing regarding the various components of non-revenue water.

Overall Water Balance for South Africa

One of the aims of the study was to use the results obtained from the largest water reticulation systems in order to carry out an overall assessment of leakage throughout South Africa. Unfortunately the information available from the various water reticulation systems in the country is either not available or of dubious quality in many cases with the result that **any conclusions made regarding the water leakage for the country as a whole must be considered as preliminary estimates that will be revised in future as more reliable data become available.**

In order to make any estimate of the total water losses occurring from water reticulation systems throughout South Africa, it was necessary to establish the total water used by the domestic sector. The National Water Resources Strategy of DWAF states that South Africa's total urban and rural water requirement for 2000 is 3471 million m^3/annum. If this value is extrapolated using an assumed growth of 3%, it suggests a total municipal water use in 2005 of approximately 4 000 million m^3/annum. This is the value that will be compared to the results from the 62 water reticulation systems since these results are also based on the 2005 water audits. The total bulk system input volume figure obtained for the 62 systems analysed was 2149 million m^3/annum which represents approximately 54% of the total urban/rural water requirement of the country. This figure was then used to extrapolate the results obtained from this study in order to derive an estimate of the likely losses for the whole country.

Based on these figures the following assumptions and extrapolations were made:

- *The total water losses (real and apparent) for the 62 systems analysed was estimated to be 670 million m^3/annum or 31% of the total water supplied. The non-revenue water is effectively the sum of the total water losses and the estimated un-billed consumption. Estimating the un-billed consumption was difficult in many areas due to a lack of reliable information. However, it was estimated in the cases where proper data were available and subsequently extrapolated to cover the whole country.*
- *The un-billed consumption was conservatively estimated to be approximately 104 million m^3/annum which in turn provides an estimate of 774 million m^3/annum for the non-revenue water – approximately 36% of the water supplied.*
- *Based on the above figures, the extrapolated total losses from water reticulation systems for the whole of South Africa are likely to be in the order of 1 150 million m^3/annum (extrapolated from the 54% sample size). The total non-revenue water for the whole country is estimated to be 1 430 million m^3/annum (extrapolated from the 54% sample size). It should be noted that the free basic water allocation is not included as part of the non-revenue water and is considered to be revenue water which is billed at a zero rate.*
- *The potential savings that can be achieved from the 62 water reticulation systems analysed are estimated to be 263 million m^3/annum based on the methodology discussed in this report.*

It should be noted that one of the main problems experienced during this project was the collection and validation of the data required to undertake the water balance. The data are very basic and should be available from any well managed water utility. The fact that the majority of water utilities in South Africa are unable to provide such data is a reflection on the state of management of the utilities. To address this problem, it is essential that the various government departments take action to enforce an annual water audit for all utilities and that it must be fully supported by the appropriate politicians. Without such political support, the establishment of realistic water balances will remain a problem throughout South Africa. It is recommended that the methodology used in this project is adopted for such water balances since it has been accepted and adopted as the "standard" by the International Water Association.

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APPENDIX A:

DEFINITIONS OF TERMS

7 APPENDIX A: DEFINITION OF TERMS

Apparent Losses

Apparent losses are made up from the unauthorised consumption (theft or illegal use) plus all technical and administrative inaccuracies associated with customer metering. While it should be noted that the apparent losses should not be a major component of the water balance in most developed countries, it can represent the major element of the total losses in many developing countries. A systematic estimate should be made from local knowledge of the system and an analysis of technical and administrative aspects of the customer metering system.

Authorised Consumption

Authorised consumption is the volume of metered (authorised metered) and/or unmetered (authorised unmetered) water taken by registered customers, the water supplier and others who are implicitly or explicitly authorised to do so by the water supplier, for residential, commercial and industrial purposes.

It should be noted that the authorised consumption also includes ‘water exported’ and, in some cases may include items such as fire-fighting and training, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, building water, etc. These may be billed or unbilled, metered or unmetered, according to local practice.

Billed Authorised Consumption

Billed authorised consumption is the volume of authorised consumption which is billed by the WSA and paid for by the customer. It is effectively the revenue water which, in turn, comprises:

- Billed metered consumption;
- Billed unmetered consumption.

Non-Revenue Water

Non-revenue water is becoming the standard term replacing unaccounted-for water (UFW) in many water balance calculations and is the term recommended by the International Water Association in preference to UFW. It is a term that can be clearly defined, unlike the unaccounted-for water term which often represents different components to the various water suppliers. Non-revenue water incorporates the following items:

- Unbilled authorised consumption;

- Apparent losses; and
- Real losses.

Real Losses

Real losses are the physical water losses from the pressurised system, up to the point of measurement of customer use. In most cases, the real losses represent the unknown component in the overall water balance and the purpose of most water balance models is therefore to estimate the magnitude of the real losses so that the WSA can gauge whether or not it has a serious leakage problem. The real losses are generally calculated as the difference between the total losses and the estimated apparent losses.

System Input

The system input represents the volume input to the water supply system from the WSAs own sources allowing for all known errors (i.e. errors on bulk water meters) as well as any water imported from other sources – also corrected for known bulk metering errors.

Unbilled Authorised Consumption

The unbilled authorised consumption is the volume of authorised consumption that is not billed or paid for. The level of unbilled authorised consumption will vary from WRS to WRS and in some areas virtually all water is metered and billed in some manner with the result that the unbilled authorised consumption is zero.

Water Losses

Water losses are the sum of the real and apparent losses and are calculated from the difference between the total system input and the authorised consumption. In most countries the water losses were also considered to be the unaccounted-for water (UFW) although, as mentioned previously, the exact definition of the UFW can vary from country to country.

Unavoidable Annual Real Losses

The minimum level of real losses for a specific system that can be achieved under the most efficient operating conditions. It is an indication of the level of leakage that can theoretically be achieved if everything possible is done to minimise the leakage and is generally not an achievable target for most water suppliers since the UARL is normally well below the economic level of leakage.

APPENDIX B:

SOFTWARE DEVELOPMENTS

8 APPENDIX B: SOFTWARE DEVELOPMENTS

8.1.1 1999: MS Word File

The first water audit sheet produced by Mr Lambert in 1999 was a simple MS WORD file in which the users simply added their figures into a simple table. There were no arithmetic capabilities of graphical features added to the MS Word file and it was simply a form of check list whereby a Water Utility could undertake a water balance in a simple and pragmatic manner. The file did, however, include the calculation of the Infrastructure Leakage Index (ILI) which has since been recognised throughout the world as a useful performance indicator for leakage in a water distribution system.

8.1.2 2000 MS Excel Spreadsheet

Shortly after the development of the initial MS WORD file, the calculations and water auditing methodology were converted into a simple MS EXCEL spreadsheet. A spreadsheet is ideally suited for such an application and this was quickly recognised by various leakage specialists who created their own personalised versions of the water audit and the ILI calculation.

8.1.3 2000 BENCHLEAK

In 2000, the WRC recognised the need for a standard approach to water auditing in South Africa and commissioned a small project to develop a simple model for this purpose. The resulting BENCHLEAK Model was developed through the project and was the first comprehensive water balance model available on which numerous other models were eventually based. It should be noted that the BENCHLEAK user guide was only published in 2002 (McKenzie and Lambert, 2002) although the model was developed and fully operational in 2000. In place of the single page version of the earlier model described in **Section 8.1.2**, the BENCHLEAK model contains 3 pages namely:

- Summary : Overview with Performance Indicators (PIs) etc.;
- Detail 1: Main input data and unavoidable annual real losses (UARLs) calcs etc.;
- Detail 2: Water balance form with various graphs etc.

8.1.4 2000 BENCHLOSS

The BENCHLOSS model was based on the earlier BENCHLEAK model for the Australian Water Services (McKenzie, R and Lambert A, 2000) and was also completed in 2000. The model is very similar to BENCHLEAK in that it is a basic MS EXCEL spreadsheet with a few additional features that were not included in the earlier South African model. For example, the Australian model has been split into 9 pages which provide some additional flexibility over previous models. The 9 pages are as follows:

- License;
- Introduction;
- UARL Calcs;
- Terminology;
- Water Balance;
- Consumption Data;
- Water Balance Components;
- PI Calcs;
- Why not percentages.

Effectively there was very little difference between BENCHLOSS and BENCHLEAK apart from the obvious cosmetic differences resulting in the 9 forms in place of 3 forms with the earlier model. The Consumption Data form allowed the user to provide more detail with regard to the various components of the water balance and the information provided on this sheet was summarised and passed through to the main water balance form. Otherwise the calculations were identical and there were no additional features on the model.

8.1.5 2002 BENCHLOSS NZ

Following the introduction of the BENCHLOSS model to the Water Services Association of Australia, a similar model was then introduced to the New Zealand Water and Waste Association and was called BENCHLOSS_NZ. The model included an additional 2 forms bringing the total number of forms to 11 and also incorporated confidence intervals for the first time. The various forms included in the BENCHLOSS-NZ model are as follows:

- License;
- Introduction;
- INF & UARL;
- Terminology;
- Consumption;
- Water Balance;
- WB Components;

- PI Calcs;
- Summary;
- Compare Data;
- Why Not percentages

The major difference between the New Zealand Model and the previous models was the incorporation of confidence limits on certain key input data which allows the user to provide an estimate of the reliability of the data. In this manner, the resulting calculated values and PIs are accompanied with upper and lower bounds which provide the user with an estimate of the reliability of the value. In addition to the confidence intervals, the New Zealand model clearly differentiated between the preferred PI for Real Losses for systems with greater or less than 20 connections per km of mains. Both PIs for litres/conn/day and m^3/km mains per day were given in the model for cases of greater and less than 20 connections per km mains respectively.

8.1.6 2004 AQUALIBRE

Following the development of the New Zealand model, several other versions were soon developed for use around the world. In most cases the models were developed in Excel as simple spreadsheets. For ease of use and to make the process simpler, some versions were condensed onto a single form in order to move away from the more complicated models. In effect, the models simply reverted back to the original single paged versions although they now incorporated a few additional features including the confidence limits. In 2002, the development of a new range of models was initiated by Bristol Water Consultancy, the consultancy arm of the private Water Utility supplying Bristol and the surrounding areas in the UK. The initial objective of the development was to create a very comprehensive and detailed water audit model which could be used throughout the world. The new model became known as AQUALIBRE and was the first model of its type to be written in a proper object orientated programming language – in this case DELPHI. AQUALIBRE was developed as a commercial product to be sold on the world market and the development took more than 2 years to complete. The model was finally completed in 2004 after a number of setbacks caused by the need to use “professional” programmers which proved to be both expensive and problematic due to the quality control required for such software development.

AQUALIBRE now represents the most sophisticated and comprehensive model of its type currently available and was only released for sale in May 2005. The model contains all the features of previous models plus certain new features, many of which are unique to AQUILIBRE. One of the key features in AQUALIBRE is the twin track approach to the assessment of Real Losses in a water distribution system. The model not only includes the standard "Top-down" water balance but also a more detailed "Bottom-up" balance which in turn is based on the standard Burst and Background Estimate (BABE) methodology. This effectively adds a new dimension to the water balance assessment and allows the user to analyse the real losses using an assessment of known burst and background leakage in the system. While this is a key feature of the new model, it is sometimes too complicated for smaller Water Utilities which do not have any reliable data on their bursts – key input required to undertake a bottom-up assessment of the Real Losses. In such cases, the model can be used as a standard "Top-down" balance model.

8.1.7 2004 AQUAFAST

While AQUALIBRE is recognised as the most comprehensive water audit model currently available it is sometimes too complicated for some of the smaller Water Utilities which cannot provide the burst and background loss data required to complete the "bottom-up" balance. To address this issue, a simplified version of the model was developed specifically for the USA market called AQUAFAST. This model represents a "trimmed-down" version of AQUALIBRE which only incorporates the basic "Top-down" water balance and is restricted to USA units (gallons and pound per square foot of pressure etc.). This model is similar to AQUALIBRE in all other respects and was used to provide a standardised water audit approach for the American Waste Water Association Research Foundation (AWWARF).

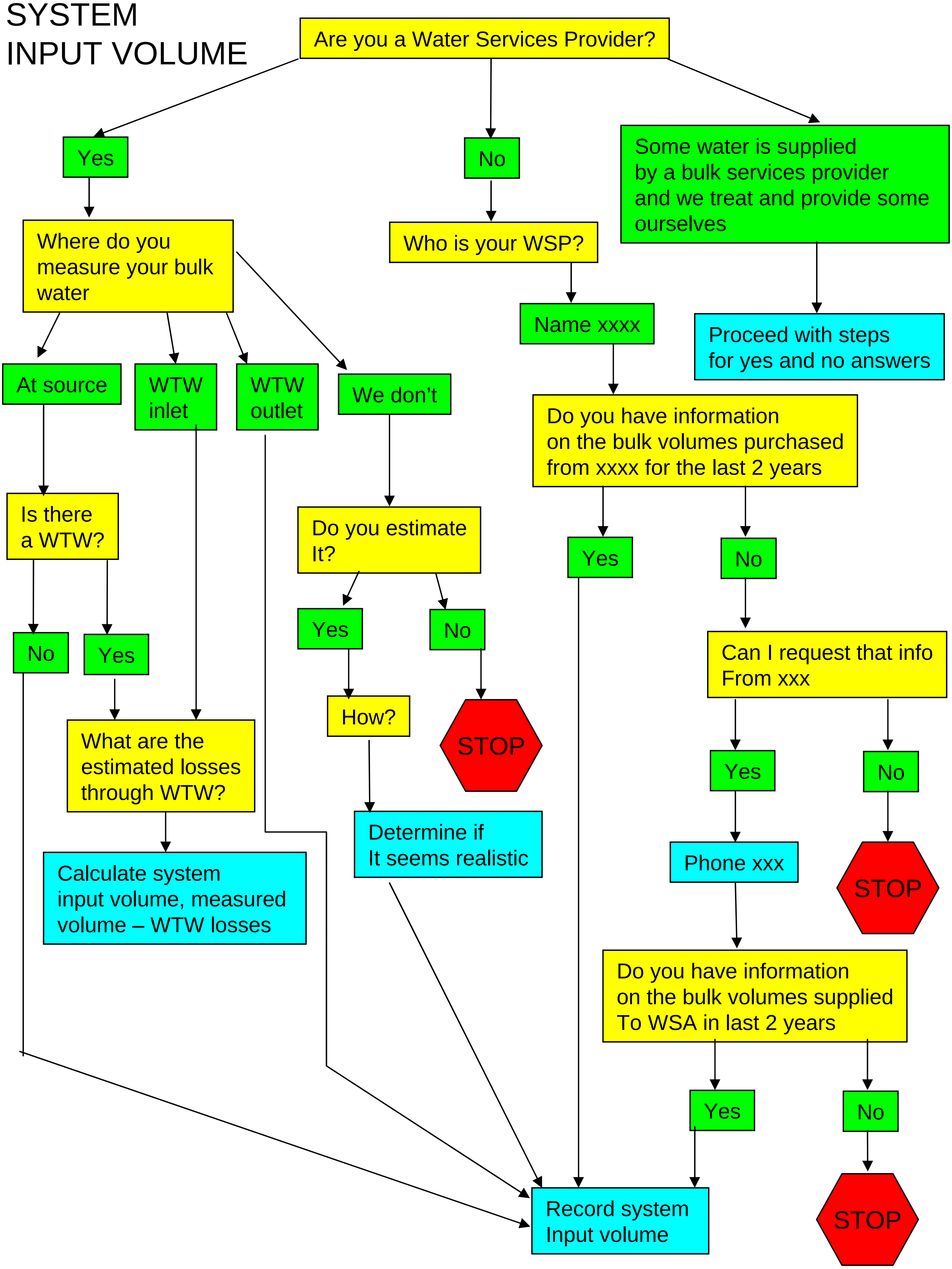
Since AQUAFAST was first provided to the AWWARF in 2004, there has been considerable interest in the model to such an extent that various versions have now been created for other countries and even for specific clients. Versions of AQUAFAST are currently being commissioned for the World Bank as well as for several large Water Utilities around the world.

Having developed the model using proper object orientated programming methods, it is now relatively quick and straightforward to modify or convert to different unit sets and even customise for different languages. AQUAFAST is likely to be the platform on which several new water balance models will be developed over the next few years and it appears set to become the standard water audit tool in many parts of the world despite the numerous other Excel based models which are currently being developed.

APPENDIX C:

BASIC BENCHMARKING APPROACH

SYSTEM INPUT VOLUME

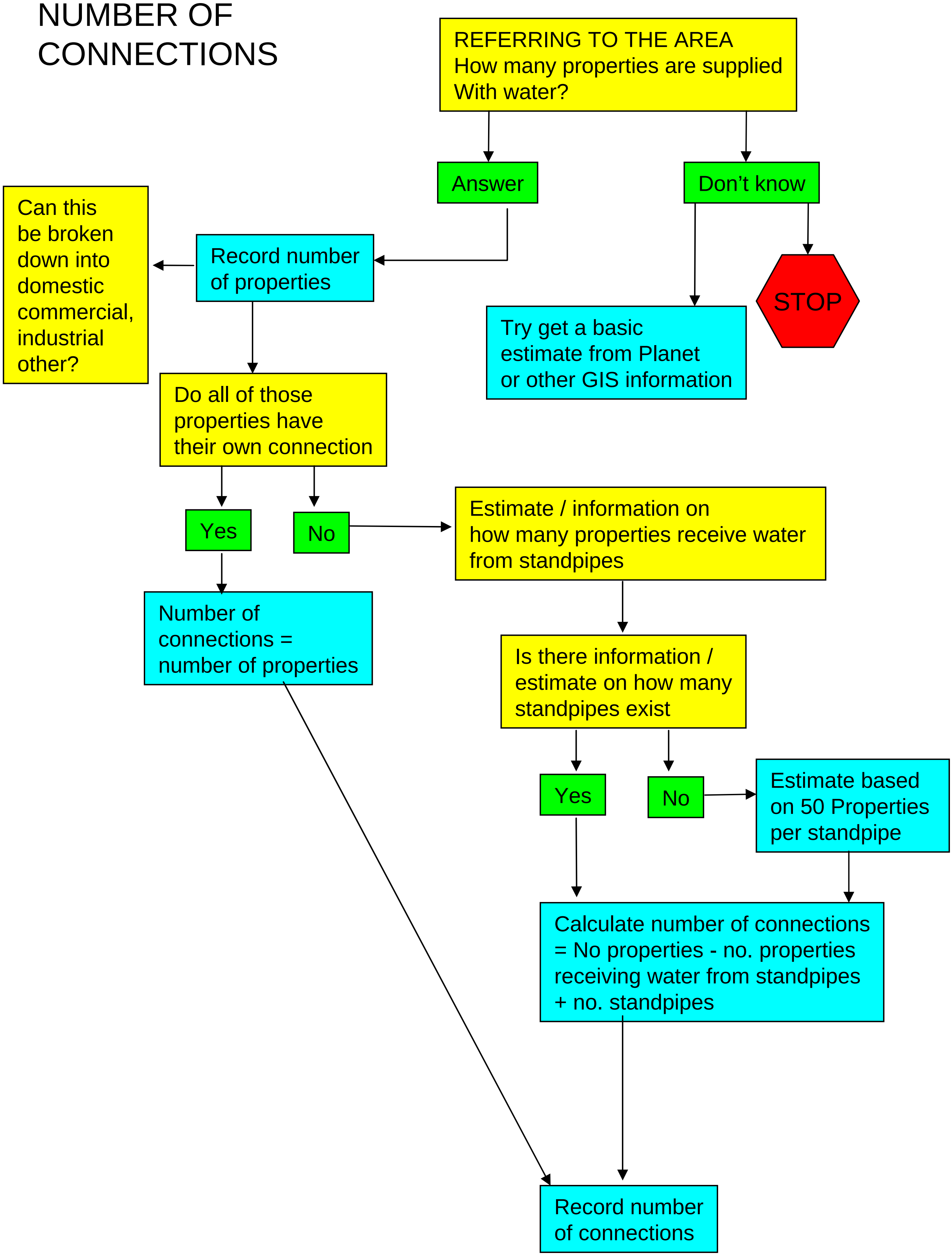


No conclusions can yet be deduced about the system Input volume.

However, one can deduce that the WSA has a serious problem if it is not known either by them or the WSP

Can use information to assess losses through WTW

NUMBER OF CONNECTIONS

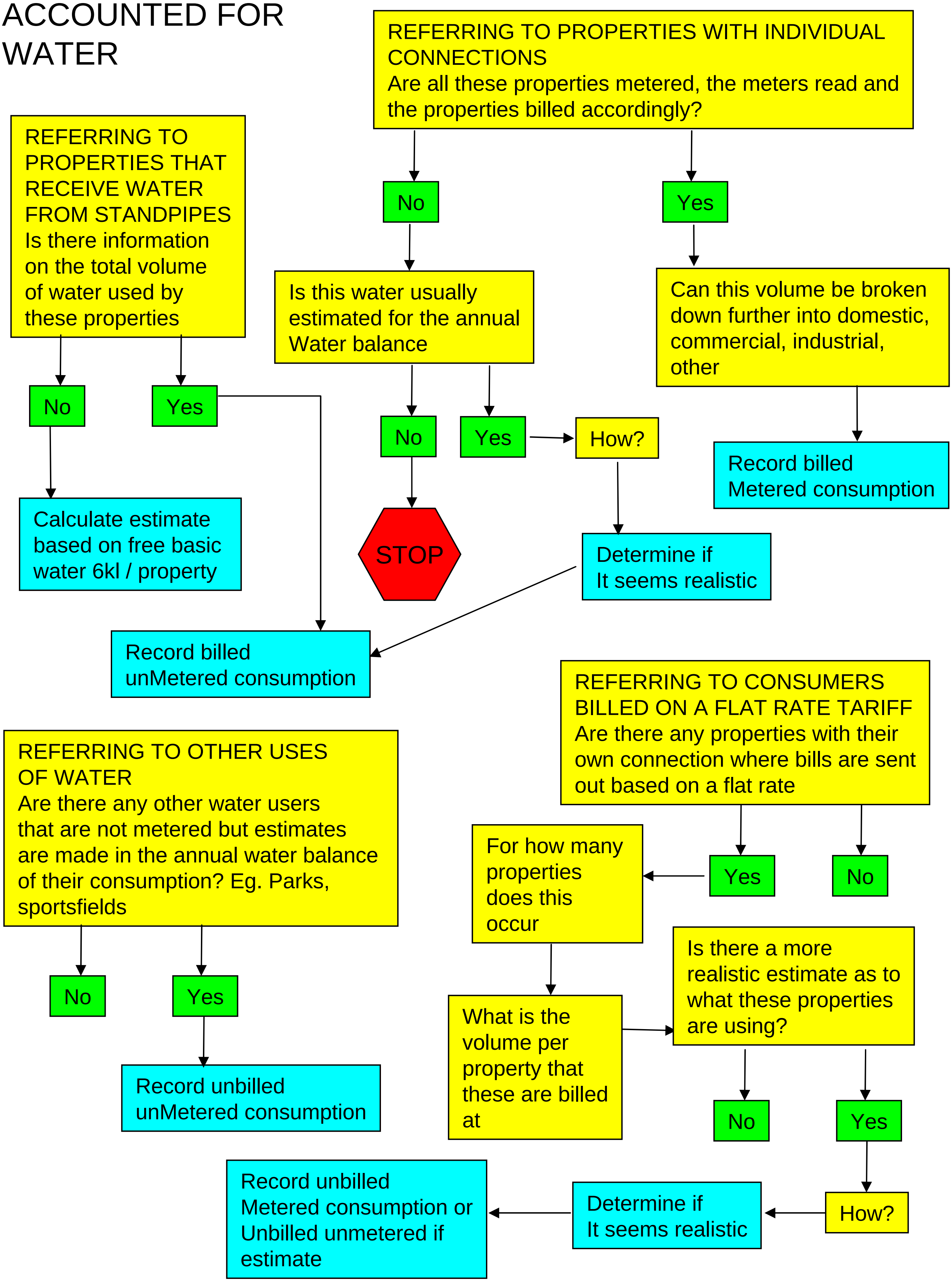


Level 1 information: Total number of properties
Total No. of properties / System input volume
Provides rough benchmark, use with care as not sure of large users
The norm should be xxx
NB. Some water lost through real losses in system so not very accurate

Level 2 information: Properties broken up by category
Domestic properties / estimate of System input volume not being used by large users
Provides rough benchmark, use with care as not sure of large users actual use
The norm should be xxx
NB. Some water lost through real losses in system so not very accurate

Level 3 information: Know proportion of standpipes to individual connections
Can assume that standpipes only use 6kl per property (able to carry) get a better idea of water use in properties with individual connections.
Individual properties / estimate of System input volume not being used by large users and through standpipes
Provides rough benchmark, use with care as not sure of large users
The norm should be xxx
NB. Some water lost through real losses in system so not very accurate

ACCOUNTED FOR WATER



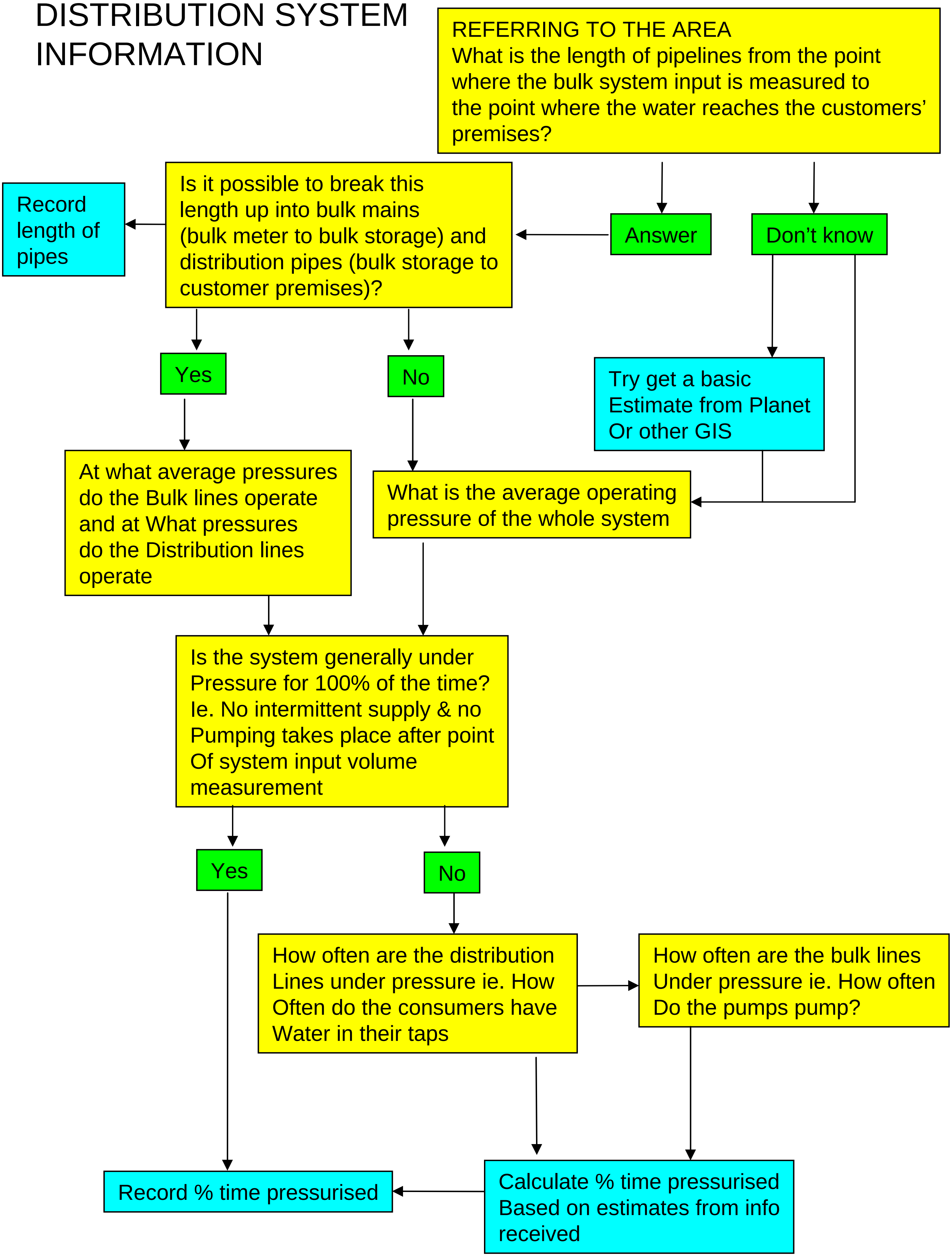
Level 1 information: total volume of accounted for water
Total No. of properties / volume of accounted for water
Provides rough benchmark, use with care as not sure
of large users
System input volume – accounted for water = real losses
Assuming all users are Domestic the norm should be xxx

Level 2 information: accounted for water broken up by category
Domestic properties / domestic water
Provides rough benchmark,
Domestic the norm should be xxx

Commercial propertes / commercial water
Industrial properties / industrial water

Level 3 information: know proportion of standpipes to
Individual connections
Can assume that standpipes only use 6kl per property (able
To carry) get a better idea of water use in properties
With individual connections.
Individual properties / estimate of System input volume not
Being used by large users and through standpipes
Provides rough benchmark, use with care as not sure
Of large users
Assuming accurate estimate to Domestic the norm should be xxx
NB. Some water lost through real losses in system so not very
accurate

DISTRIBUTION SYSTEM INFORMATION



Level 1 information: total length of pipelines, average operating pressure, % time pressurised.
Can calculate UARL on pipelines:
18 x length of pipes x pressure x % time pressurised

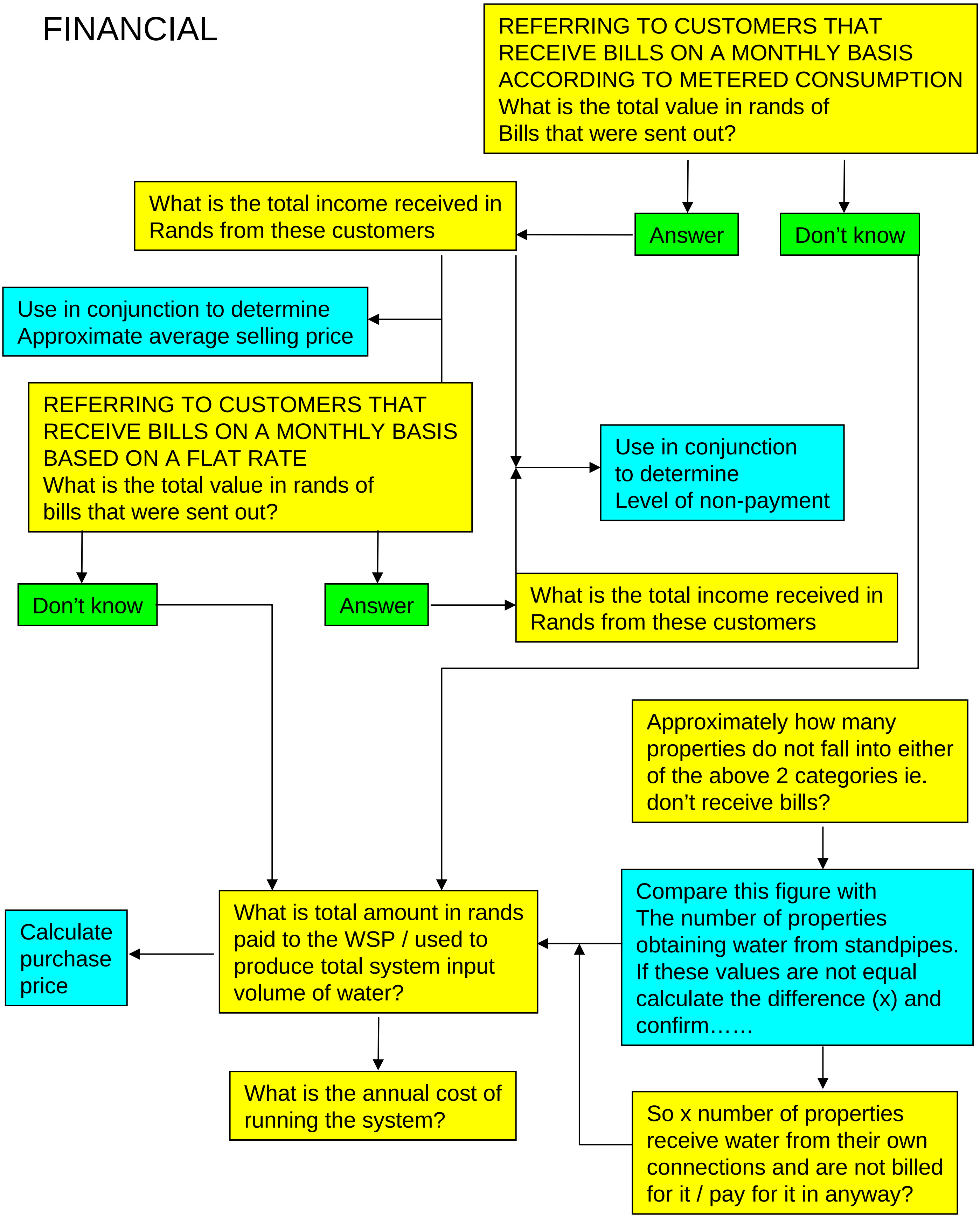
Level 2 information: length of pipelines, average operating pressure, % time pressurised all divided up into bulk and distribution pipes
Can calculate UARL on bulk pipelines and distribution pipelines seperately:
18 x length of pipes x pressure x % time pressurised

Can calculate UARL on connections using previous connection information as:
0.8 x number of connections x pressure x % time pressurised

Can calculate ILI performance indicator as:
CARL / UARL

UARL = UARL on pipelines + UARL on connections
CARL = Real losses – apparent losses

FINANCIAL


REFERRING TO CUSTOMERS THAT RECEIVE BILLS ON A MONTHLY BASIS ACCORDING TO METERED CONSUMPTION What is the total value in rands of Bills that were sent out?
Answer
Don't know
What is the total income received in Rands from these customers
Use in conjunction to determine Approximate average selling price
REFERRING TO CUSTOMERS THAT RECEIVE BILLS ON A MONTHLY BASIS BASED ON A FLAT RATE What is the total value in rands of bills that were sent out?
Use in conjunction to determine Level of non-payment
Don't know
Answer
What is the total income received in Rands from these customers
Approximately how many properties do not fall into either of the above 2 categories ie. don't receive bills?
Calculate purchase price
What is total amount in rands paid to the WSP / used to produce total system input volume of water?
Compare this figure with The number of properties obtaining water from standpipes. If these values are not equal calculate the difference (x) and confirm……
What is the annual cost of running the system?
So x number of properties receive water from their own connections and are not billed for it / pay for it in anyway?

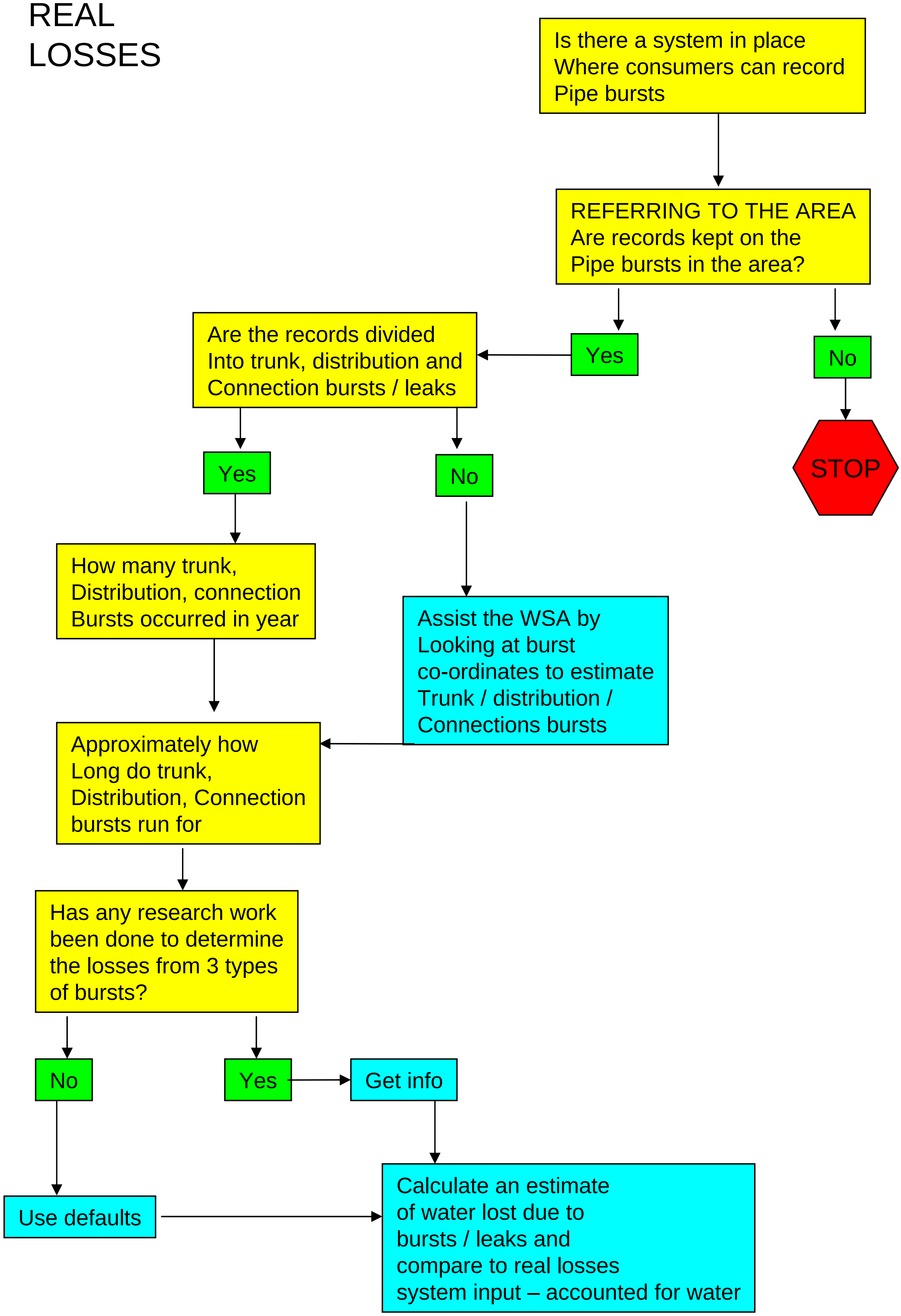
Bills sent out vs income received
Can determine the amount of non-revenue water resulting from customers not paying: ie. potential revenue water that is actually non-revenue water

Flat rate tariff income:
Can determine the amount of income lost as a result of billing customers on a flat rate tariff basis that amounts to a lower amount then what they would pay if they were billed on measured consumption.

Average purchase price determines the cost of real losses in the system ie. how much income the WSA could save if they reduce real losses

Average selling price determines the cost of apparent losses in the system ie. how much more income the WSA could receive if they reduce illegal use and losses due to meter error.

REAL LOSSES


Is there a system in place Where consumers can record Pipe bursts
REFERRING TO THE AREA Are records kept on the Pipe bursts in the area?
Yes
No
STOP
Are the records divided Into trunk, distribution and Connection bursts / leaks
Yes
No
How many trunk, Distribution, connection Bursts occurred in year
Assist the WSA by Looking at burst co-ordinates to estimate Trunk / distribution / Connections bursts
Approximately how Long do trunk, Distribution, Connection bursts run for
Has any research work been done to determine the losses from 3 types of bursts?
No
Yes
Get info
Use defaults
Calculate an estimate of water lost due to bursts / leaks and compare to real losses system input – accounted for water

APPARENT LOSSES

REFERRING TO THE REAL LOSSES
The idea here is to “find” the difference between calculated real losses and actual estimated from bursts

↓

What is the approximate age of the domestic meters?

↓

What condition are the meters in

↓

Are illegal connections a problem in the area

↓

Is the water quality good, average, poor ito could it affect meter accuracy over a long time period