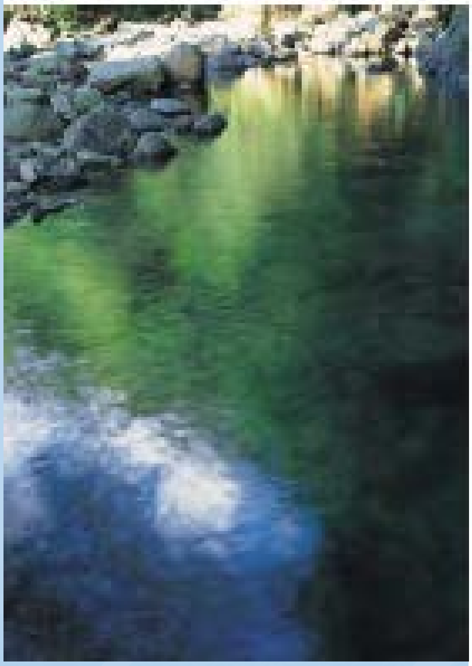
WATER NEW ZEALAND

BENCHMARKING OF WATER LOSSES IN NEW ZEALAND MANUAL

(Incorporating the User Manual for the 2008 update of the BenchlossNZ Software: Version 2a)



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Water Loss Task Force (1996 onwards)

Task Force on Performance Indicators (1996 onwards)

South African Water Research Committee

For allowing the South African version of the BENCHLEAK MODEL to be used as the starting point upon which the original April 2002 version of the New Zealand BENCHLOSSNZ model was developed

BENCHMARKING OF WATER LOSSES IN NEW ZEALAND

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IMPORTANT

PREFACE

This document is the User Manual for the 2008 upgrade of the Water Loss Benchmarking Software (BenchlossNZ) which was originally developed for the New Zealand Water and Wastes Association in April 2002. The objectives of the Software and the Manual are:

- to introduce a standard terminology for components of the annual water balance calculation
- to encourage Water Suppliers in New Zealand to calculate components of Non-Revenue Water, Apparent Losses and Real Losses using the standard annual water balance
- to promote Performance Indicators suitable for national and international benchmarking of performance in managing water losses from public water supply transmission and distribution systems.

The methodologies used in BenchlossNZ draw strongly on relevant aspects of ongoing research and recommendations of the Water Loss Task Force of the International Water Association (IWA), and experiences in implementing these recommendations in New Zealand and internationally. The more significant modifications included in this upgrade to BenchlossNZ may be briefly summarised as follows:

- inclusion of 'Water Supplied' in the Water Balance terminology and calculations
- inclusion of recommended guideline default values (as percentages of Water Supplied) for initial estimates of Unbilled Authorised Consumption and Unauthorised Consumption
- inclusion of recommended guideline default values (as percentages of metered consumption) for initial estimates of Customer Meter Under-registration
- updating references for some performance indicators following publication of the 2nd Edition (2006) of the IWA Performance Indicators Manual
- introducing '% of metered consumption' as an operational performance indicator for Apparent Losses.
- replacing the original 2002 'typical ranges' for Real Loss Performance Indicators (Excellent, Good/Fair, Below Average) with the World Bank Institute Banding System (A,B,C,D)
- introduction of lower limits (in terms of number of service connections and length of mains) for validity of Unavoidable Annual Real Losses (UARL) and Infrastructure Leakage Index (ILI) calculations

To assist in assessment of Real Losses in small systems, particularly those where residential customers are unmetered, this User Manual also now includes an Appendix J on using night flow measurements.

The BenchlossNZ software is available directly from the New Zealand Water and Wastes Association. To avoid the necessity to make the BenchlossNZ software more detailed than its existing format, an additional free software (CheckCalcsNZ) is also available to New Zealand water suppliers on request from Wide Bay Water Corporation for simplified complementary calculations to BenchlossNZ, as follows:

- providing a quick route into the calculations for water suppliers with smaller systems and for water suppliers' sub-systems
- identifying appropriate action priorities for different World Bank Institute Performance Bands A to D
- overview of pressure management opportunities and probable range of reduction of leak flow rates, new burst frequencies and income from metered customers.

The term '95% Confidence Limits' has been used in this project for expressing the highest likely margin of error for each Performance Indicator. It is important to note that the '95% Confidence Limits' calculated will not relate to the pure statistical definition of '95% Confidence Limits' since data entry will involve 'best estimates' for some water balance components.

DISCLAIMER

Although every effort has been taken to ensure that the BenchlossNZ software and this User Manual are accurate and reliable, neither the New Zealand Water and Wastes Association nor the Companies involved in the software development and updating (Global Water Resources Ltd, Wide Bay Water Corporation and ILMSS Ltd) accept any liability of any kind resulting from the use of the software. Any person making use of the BenchlossNZ software does so entirely at his/her own risk.

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software, and neither the BenchlossNZ software nor this User Manual may be copied or distributed without their permission.

TECHNICAL SUPPORT

The New Zealand Water and Wastes Association does not provide technical support for the BenchlossNZ software. However any questions or problems with the software should in the first instance be directed to the New Zealand Water and Wastes *Association (email address water@nzwwa.org.nz).*

BENCHMARKING OF WATER LOSSES IN NEW ZEALAND

Executive Summary

The BenchlossNZ software and this User Manual are part of the ongoing process of refining and improving the methodologies for calculating and presenting performance data associated with management of public water supply systems in New Zealand. Recent recommendations of International Water Association Task Forces have demonstrated that it is now appropriate to further improve on the terminology, calculation process and performance indicators traditionally used for calculating Water Losses in New Zealand public water supply systems.

By commissioning this update to the BenchlossNZ software and this User Manual, the Water Services Managers Group of the New Zealand Water and Wastes Association, as the successor to the Water Supply and Drainage Managers' Groups, has made a further commitment to promoting these improved methods. It commends these methods to its members and to other organisations involved in management of water in New Zealand.

A transition from traditional familiar terminology and methods is never easy to accomplish, and a commitment is needed from all Water Suppliers in New Zealand if improved assessment and comparisons of water losses are to be implemented. For example, the terms 'Non-Revenue Water' and 'Water Losses' should replace the familiar (but vague) term 'Unaccounted-for-Water' – because, with modern techniques, it is possible to account for all water entering a water distribution system. Also, the use of percentages as Performance Indicators for Non-Revenue Water and its components is increasingly recognised internationally as being potentially misleading, particularly when used as a measure of the operational efficiency of managing real losses (leakage and overflows) from distribution systems with different levels of consumption. Comparisons in New Zealand are further complicated by a wide range of operating pressures, density of connections per km of mains, and large numbers of unmetered residential properties in many systems. The BenchlossNZ approach deals with these issues effectively and allows leakage in different systems to be compared in a pragmatic and unbiased manner.

The process of change can be eased through the use of the BenchlossNZ software, and the associated simpler CheckCalcsNZ software. In these two softwares, all the components of the standard Water Balance are defined, and the calculation of components of water losses and performance indicators is automated, to a large extent. Also, by entering estimates of 95% confidence limits for each item of data entry, the 95% confidence limits for each component of water balance, and each Performance Indicator, are automatically calculated. In 2002, BenchlossNZ was the first nationally available software in any country to include this facility for IWA Water Balance and Performance Indicators calculations.

Several years experience in the use of confidence limits has shown that the most significant systematic and random errors in Water Balance calculations usually arise from errors in source meters and bulk supply meters, and incorrect estimates of unmeasured consumption from residential properties. The large amount of time and effort taken in estimating some of the smaller unmeasured components of the Water Balance – Unbilled Authorised Consumption, Unauthorised Consumption and Customer Meter Under-Registration – is not necessarily justified, at least for initial Water Balance and PI calculations. The practice of using low guideline default values for initial estimates of these parameters is increasing internationally, and has now been introduced into this updated version of Benchloss NZ..

BenchlossNZ and CheckCalcsNZ also calculate the Unavoidable Annual Real Losses (UARL) for any system or sub-system (provided it exceeds a specified minimum size, see next paragraph). In New Zealand, customer meters (or point of consumption for unmetered properties) are located close to the street/property boundary, so the UARL calculation requires only 3 key system-specific parameters – Length of Mains, Number of Service Connections and Average Operating Pressure. Once calculated, the Unavoidable Annual Real Losses are used in the calculation of Infrastructure Leakage Index (ILI) – which is the ratio of the Current Annual Real Losses to the UARL.

In the April 2002 version of BenchlossNZ, the lower limit of system size for calculation of Unavoidable Annual Real Losses (UARL) was 5000 service connections. This has now been substantially reduced, based on analysis of additional data; if Lm is mains length (km) and Ns is number of service connections, the UARL calculation can be made if (Lm x 20 + Ns) exceeds 3000. Accordingly the ILI calculation can now be made with confidence for a much wider range of systems and sub-systems.

For countries such as New Zealand, with a diverse range of operating situations, the ILI is the most meaningful Performance Indicator for comparing current performance in operational management of Real Losses at current pressures (metric benchmarking). The World Bank Institute Banding System – which categorises the ILI as being Bands A, B, C or D – is now used in BenchlossNZ and replaces the original provisional 'Excellent'/'Good/Fair'/'Below

Average' categories in the 2002 version. Further information on the WBI Banding system, including descriptions of what is implied by Bands A, B, C and D respectively, and guidance on the recommended priorities for action, are provided.

However, it should be noted that, for monitoring ongoing progress by a water supplier in reduction of Real Losses (process benchmarking), if the Real Loss reduction program involves pressure management, it is considered preferable to use litres/service connection/day (or m^3/km of mains/day for systems with fewer than 20 service connections per km of mains) rather than the Infrastructure Leakage Index (ILI). Section 2.3.7 of the User Manual provides further explanation of this point.

The April 2002 first issue of BenchlossNZ did not include a Performance Indicator for Apparent Losses, and this omission has now been rectified. At the time of preparing this update, the Apparent Losses Group of the IWA Water Loss Task Force has not yet finalised recommendations for an Apparent Losses Operational PI, but there are three principal options for simple PIs (% of Water Supplied, litres/service connection/day, and % of metered consumption), and the possibility of a more detailed PI, the Apparent Losses Index (ALI) with similarities to the Infrastructure Leakage Index (ILI) for Real Losses. Given that the principal component of Apparent Losses in New`Zealand is likely to be customer meter under-registration, '% of metered consumption' has been selected as the most logical choice for a simple Apparent Losses PI for the purposes of this update of BenchlossNZ. This is the only one of the three simple Apparent Loss PIs that does not discriminate against water suppliers which meter residential properties.

Performance Indicators for Real Losses and Non-Revenue are calculated automatically by BenchlossNZ and CheckCalcsNZ and compared with international or New Zealand/Australian data sets; provision is also made in BenchlossNZ to accommodate a New Zealand data set, when sufficient reliable data is available. This User Manual explains the background to the development of the IWA recommended methodologies, and takes the reader through the BenchlossNZ calculations on a step-by-step, Worksheet by Worksheet basis. The BenchlossNZ software has an example calculation alongside the actual calculation, to assist first-time users.

It is recommended that all organisations involved in Water Supply in New Zealand use the BenchlossNZ software and/or the CheckCalcsNZ software for calculating and comparing their performance in managing Water Losses in this standard format. All Water Supply organisations should at least undertake an annual calculation on a 'whole system' basis. In this manner, such information voluntarily submitted to NZWWA could be used for meaningful comparisons.

On behalf of the NZWWA and the Water Services Managers' Group, I want to particularly thank Richard Taylor for his diligence and enthusiasm in bringing this project to a speedy and successful conclusion.

Simon Carlaw
Chief Executive
NZWWA

1. LAYOUT OF THIS USER MANUAL

The user manual contains 6 sections and 11 Appendices, as described below.

Section 2: Introduction

Problems associated with the traditional use of percentages for comparing water losses are explained. The objectives of the leakage benchmarking project, and design considerations for the software, are described. A 5-step rational approach to benchmarking of water losses is outlined, and the standard terminology used in the Water Balance is explained. Five Performance Indicators are now considered as being the most appropriate for New Zealand. Four of these are Operational PIs for Real Losses and Apparent Losses), and one is a Financial PI for Non-Revenue Water. Notes are provided on important aspects of these five key Performance Indicators and limitations on their use are stated.

Section 3: Some Detailed Considerations for New Zealand

All data which are entered into a Water Balance are 'best estimates' to a greater or lesser extent, so calculated components of Non-Revenue Water have a range of error. Guidance is given in **Section 3.1** and **Appendix A** on systematic and random errors, and the use of 95% confidence limits for data entry and calculated NRW components and Performance Indicators.

Section 3.2 and **Appendix B** cross-relate the terminology used for reticulation systems and 'point of consumption' in BenchlossNZ with two examples of local terminology from New Zealand. The 'point of consumption' is the street:property boundary, so 'Consumption' includes leakage on private pipes after this point. **Section 3.3** and **Appendix C** show how leakage on private underground supply pipes can be estimated for different metered and unmetered situations.

Although there is an increasing tendency in New Zealand – particularly North Island - for metering of individual service connections at the street:property boundary, there are numerous systems in New Zealand where residential properties (and some non-residential properties) are not metered. Per property consumption, which is the volume of water passing the street:property boundary, must be estimated in such cases. In **Section 3.4** and **Appendix D**, methods of estimating unmetered residential consumption are outlined. Some basic aspects of consumption monitoring are discussed, whereby selected properties are metered but not charged by volume, to provide estimates of unmeasured consumption.

Sections 3.5 to 3.7 are intended to provide guidance to the User of BenchlossNZ on how to allocate and estimate the less obvious components of the Water Balance. **Section 3.5** and **Appendix E** outline where to allocate particular components in the standard Water Balance used in BenchlossNZ. **Sections 3.6 and 3.7** consider the detailed estimation of Unbilled Authorised Consumption and Apparent Losses; more details on Apparent Losses are given in **Appendix F**.

Section 4: Outline of the BenchlossNZ Software

The Hardware and Software requirements of BenchlossNZ are provided together with details of how the software should be installed and executed. An overview of the purpose of each of the Worksheets is provided. Input data requirements are specified.

Section 5: Using the BenchlossNZ Software

This section is essentially the “User Guide”. Each Worksheet used in the software is explained and examples are provided to assist the new user to understand the benchmarking process.

Section 6 : References

References are provided relating to leakage management, the work of the IWA Task Forces, the BABE and FAVAD concepts, as well as the benchmarking of water losses.

Appendices A to F

The general content of **Appendices A to F** has been briefly described under **Section 3** above.

Appendix G: Introduction to Leakage Modelling Concepts (BABE and FAVAD)

This Appendix outlines the basic BABE (Bursts and Background Estimates) concepts of components of real losses, and the FAVAD (Fixed and Variable Area Discharges) concept of pressure:leakage relationships. It is then explained how these concepts were used in the development of the equation for calculating Unavoidable Annual Real Losses.

Appendix H: Methods of Calculating Average Pressure

Describes methods of calculating average pressure for a distribution system, for entering in the calculation for Unavoidable Annual Real Losses.

Appendix I: Printout of the BenchlossNZ Worksheets

Appendix J: Using Night Flow Data to assess Real Losses

Explains how night flow measurements can be used to provide an alternative assessment of Real Losses, particularly in small districts where not all properties are metered.

Appendix K: Overview of the CheckCalcsNZ software

Describes the free CheckCalcsNZ software, which provides a quicker simplified version of the BenchlossNZ calculations, together with some additional features such as 'Pressure Management Options' that do not fall within the scope of BenchlossNZ.

2. INTRODUCTION TO BENCHMARKING OF LEAKAGE

2.1. PROBLEMS WITH USING PERCENTAGES AS PERFORMANCE INDICATORS

As international awareness grows that water resources are finite and require careful management, the issue of water losses from potable water distribution systems is coming under increasing scrutiny in many countries. Figures for 'Unaccounted–for Water' are often quoted by 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.

Since the early 1980's, however, it has been recognised that percentages are unsuitable for assessing the operational efficiency of management of real losses (leakage and overflows) in distribution systems (**Refs. 1,2,3,4,5,6,7**). This is because the calculated percentages are strongly influenced by the consumption of water in each individual system, and variations in that consumption.

A simple example can be used to highlight this problem. In this example a distribution system with 100,000 service connections experiences real losses of 15 000 m^3/day (150 litres/service connection/day). The % Real Losses can easily be calculated for a range of different unit consumptions as shown in **Table 2.1**.

Table 2.1: Problems with using % Real Losses as a Performance Indicator

Consumption per service connection (litres/conn/day)	Real losses (litres/conn/day)	System Input (litres/conn/day)	Real losses as % of system input volume
250 (e.g. Malta)	**150**	**400**	**38**
500 (e.g. UK)	**150**	**650**	**23**
1000 (e.g. New Zealand)	**150**	**1150**	**13**
2000 (e.g. Japan)	**150**	**2150**	**7**
3000 (e.g. California)	**150**	**3150**	**5**
8000 (e.g. Singapore)	**150**	**8150**	**2**

From **Table 2.1** it can be seen that although the real losses in litres/connection/day are identical in all cases, the percentage losses vary between 2% and 38%. It is clearly not meaningful to compare the percentage losses of a water distribution system in New Zealand with the percentage losses for systems in other countries with different levels of average consumption. This is not only true for comparisons between one country and another but it is also true for comparisons between different systems in New Zealand, where ‘per property’ consumption ranges from around 500 to over 3000 litres/service connection/day, probably averaging around 1000 litres/service connection/day.

Further complications in using %s by volume occur in distribution systems or sub-systems where water is ‘exported’ to another system or sub-system. The % loss by volume can either be calculated using the ‘System Input Volume’ (which includes Water Exported) or the ‘Water Supplied’ volume (which excludes Water Exported) as the volume. **Ref 8** clearly shows how this can influence the resulting PI; if ‘System Input Volume’ is used, systems with Water Exported will appear to have better performance than systems with no Water Exported. In this update of the BenchlossNZ software and manual, calculations of %s based on System Input Volume have been totally excluded. NRW expressed as a % of Water Supplied is not a recommended Performance Indicator, but it has been calculated and shown, for general information only, on the ‘Summary’ Worksheet.

Another example from **Ref. 8** clearly demonstrates that, if customer-side demand management activities or drought restrictions or seasonal factors significantly decrease consumption, the percentage Real Losses by volume will increase despite the fact that the volume of Real Losses remains unchanged or is even reduced. In parts of New Zealand where active demand management is practised, these considerations are particularly relevant and it is for this reason that a worksheet entitled ‘Why not %s’ has been included in the BenchlossNZ software. This spreadsheet automatically undertakes a calculation similar to the one presented in **Table 2.1** for each particular system (after the water balance calculations have been completed) and shows it in graphical form to demonstrate these effects. An example appears in **Section 5.11**.

It cannot now be regarded as best practice to use a parameter such as % by System Input Volume (or Water Supplied) as a Key Performance Indicator (KPI) which has so many flaws, so ‘% of System Input’ (by volume) has been omitted from the recommended PIs in this 2008 version of the BenchlossNZ software and

Manual, which provides the user with more meaningful and appropriate Performance Indicators.

2.2. MAKING PROGRESS

The problem to be overcome is how to calculate Non-Revenue Water and its components using a standard Water Balance and terminology, and then express them in terms that can be meaningfully compared in diverse systems. Following a successful workshop in January 2001, the Water Supply Manager's Group decided in March 2001 to commission a benchmarking system based on the recommendations of International Water Association (IWA) Task Forces in 1999 and 2000 (**Refs. 6,7**). The intention was to enable water losses in the many varied public water supply systems throughout New Zealand to be defined, calculated and compared in a standard and more meaningful manner. The objectives of the project were therefore:

- to promote the systematic identification and accounting of all components of the Water Balance
- to promote a standard terminology and methodology for calculating components of Non-Revenue Water in New Zealand
- to identify the most appropriate Performance Indicators, for comparison and Benchmarking purposes, with the emphasis on Real Losses and Non-Revenue Water
- to draw on similar initiatives being undertaken elsewhere in the world to ensure that an internationally recognised methodology is adopted
- to promote the use of the approach through close liaison with the various water suppliers
- to produce nationally applicable user-friendly software with a high quality User Manual
- to introduce 95% confidence limits into the calculation of the Water Balance components and the Performance Indicators

The success or failure of the proposed methodology ultimately depends upon whether individual water suppliers are sufficiently motivated to collate the required information and enter it into the BenchlossNZ software. If the information requested is unnecessarily detailed, the water supplier may be unwilling to assemble it on the grounds that it is too time consuming and there are insufficient resources to devote valuable time and effort. On the other hand, users of the methodology require sufficient detail to be able to gain familiarity with the process and confidence in the calculations. A key objective of the BenchlossNZ software was therefore to ensure that the information requested is relatively simple and straightforward to provide. At the same time, the results and details provided from the software should be of interest and use to the water suppliers by detailing their water balances in appropriate detail.

The potential problems of 'too much detail', or 'not enough detail' were tackled by developing BenchlossNZ as a colour-coded piece of software which, with this User Manual, provides guidance on the principles used, and the data requirements. Most of the items in the software are calculated fields with the result that the user need only provide some basic data that should be readily available from existing information systems, or can be determined with a small amount of effort (e.g. average pressure).

This 2008 update to the BenchlossNZ software and User Manual incorporates relevant aspects of ongoing international experiences of the IWA Water Loss Task Force (**Ref. 8),** and experience of using BenchlossNZ in New Zealand since 2002. The significant modifications included in this upgrade are:

- inclusion of 'Water Supplied' in the Water Balance terminology and calculations
- inclusion of recommended guideline default values for initial estimates of Unbilled Authorised Consumption as 0.5%* of Water Supplied; this default does not include any allowance for process water at Water Treatment Works, which should be separately metered.
- Inclusion of recommended guideline default estimates of Unauthorised Consumption as 0.1%* of Water Supplied
- Inclusion of recommended guideline default values for initial estimates of Customer Meter Under-registration as 2.0%* of metered consumption (excluding Water Exported) for residential properties and 2.0%* of metered consumption for non-residential properties; if a water supplier wishes to use values greater than these defaults, sufficient data should be provided to satisfy an auditor as to the accuracy of the values used

* *Note: these %s defaults are used in Australia, by the Australian Water Commission* ***(Ref 9),*** *the Water Services Association of Australia, and some State regulators.*

- updating references for some performance indicators, and removing ‘Levels’ of PIs (Levels 1, 2 or 3) following publication of the 2nd Edition (2006) of the IWA Performance Indicators Manual **(Ref. 10)**
- recommending against the use of %s of System Input Volume as Performance Indicators for Non-Revenue Water and its components
- introducing '% of metered consumption' as an operational performance indicator for Apparent Losses.
- replacing the original 2002 'typical ranges' for Real Loss Performance Indicators (Excellent, Good/Fair, Below Average) with the World Bank Institute Banding System (A,B,C,D)
- introduction of lower limits (in terms of number of service connections and length of mains) for validity of Unavoidable Annual Real Losses (UARL) and Infrastructure Leakage Index (ILI) calculations

To assist in assessment of Real Losses in small systems, particularly those where residential customers are unmetered, this User Manual also now includes an Appendix J ‘Using Night Flow data to assess Real Losses’.

Also, to avoid the necessity to make the BenchlossNZ software more detailed than its existing format, an additional free software (CheckCalcsNZ, see Appendix K) is also available on request from Wide Bay Water Corporation for simplified complementary calculations to BenchlossNZ, as follows:

- providing a quick streamlined version of the Water Balance and PI calculations for water suppliers with smaller systems and for water suppliers’ sub-systems
- allowing the Annual Operating cost – required for the NRW Financial PI Fi47, NRW% by $ value - to be calculated according to the latest IWA principles.
- quickly identifying appropriate action priorities for different World Bank Institute Performance Bands A to D
- giving an overview of pressure management opportunities and probable range of reduction of leak flow rates, new burst frequencies & customer metered income

The original project for development of the BenchlossNZ software was undertaken by Dr Ronnie McKenzie of Global Water Resources Ltd (GWR), and Mr Allan Lambert. GWR Ltd and Mr Lambert had previously completed leakage benchmarking models for the South African Water Research Commission (BENCHLEAK, **Ref 11**) and the Water Services Association of Australia (Benchloss,). The NZWWA version of Benchloss used a similar framework to these two earlier models, but was specifically customised for New Zealand conditions, and included the 95% confidence limits facility. In this manner, the BenchlossNZ software and User Manual were developed in a general format consistent with other Southern Hemisphere countries, at a lower cost than would have been possible had the software been developed from “scratch”.

The 2008 update of the BenchlossNZ software and User Manual for NZWWA was carried out as a joint project by Wide Bay Water Corporation/ILMSS Ltd and GWR.

Mr Allan Lambert of ILMSS Ltd played a key role in both projects. Mr Lambert was instrumental in the development of the Burst and Background Estimate (BABE) Component Analysis methodology, and in collating international research into pressure:leakage relationships. He also chaired the first IWA Water Loss Task Force, which developed the procedure for assessing the system-specific unavoidable (technical minimum) level of real losses that can be achieved in any given water supply system (**Ref. 6**). The updated BenchlossNZ software is based on the most recent application of these principles by Mr Lambert in New Zealand and other countries.

For the 2002 project, the Water Supply Managers Group set up a Project Steering Group, led by Richard Taylor of Waitakere City Council, with membership shown in the “Acknowledgements” section of the 2002 Benchloss User Manual. The 2002 Project Agreement was signed with GWR Ltd in May 2001, and the first draft of the software was presented to the Steering Group in early November. Following further enhancements and customisation, the final version of the software was agreed in late December, and the User Manual was completed in February 2002.

The 2008 Project Agreement was signed with Wide Bay Water Corporation in July 2007, with Richard Taylor of Waitakere City Council as the Project Co-ordinator. The BenchlossNZ 2008 software was finalised in December 2007, and the updated User Manual was completed in January 2008. The updated BenchlossNZ software and User Manual were then publicised at an NZWWA Water Loss Conference in February 2008 in Auckland **(Ref. 12)**.

2.3. BENCHMARKING OF WATER LOSSES – A RATIONAL APPROACH

2.3.1. Five steps to meaningful benchmarking

There are 5 steps in a rational approach to benchmarking:

- Use standard terminology and method of calculation for analysing data;
- Specify a structure for Performance Indicators by Water Supply function, with the option of different levels of detail;
- Identify the most appropriate and meaningful Performance Indicators;
- Calculate the values of the Performance Indicators using data from a wide-ranging set of systems, and set Benchmark values based on specified auditable criteria;
- Define any practical limitations on the range of application of the Performance Indicators.

2.3.2. Standard Terminology and Water Balance Calculation

The first step for calculating water losses from public water supply systems consists of:

- Assembling the various elements of the water balance calculation into components based on a clearly defined standard terminology;
- calculating the annual volumes of these components.

Unfortunately, it is not unusual for each country (and often for each water supplier within a country) to use a different terminology and a different method of calculation. Accordingly, the first objective of the BenchlossNZ software has been to introduce a terminology and definitions for components of a standard New Zealand Water Balance.

The outputs of the IWA Task Forces on Water Losses (**Ref. 6, 8**) and Performance Indicators (**Ref. 7, 10**) – have been adapted, with minor variations, to New Zealand conditions. The process of calculating annual volumes of Non-Revenue Water and Real Losses from an annual Water Balance can perhaps be most easily appreciated from the simplified version of the IWA Water Balance in **Figure 2.1.** In the Water Balance, all figures are initially calculated in thousand cubic metres per year.

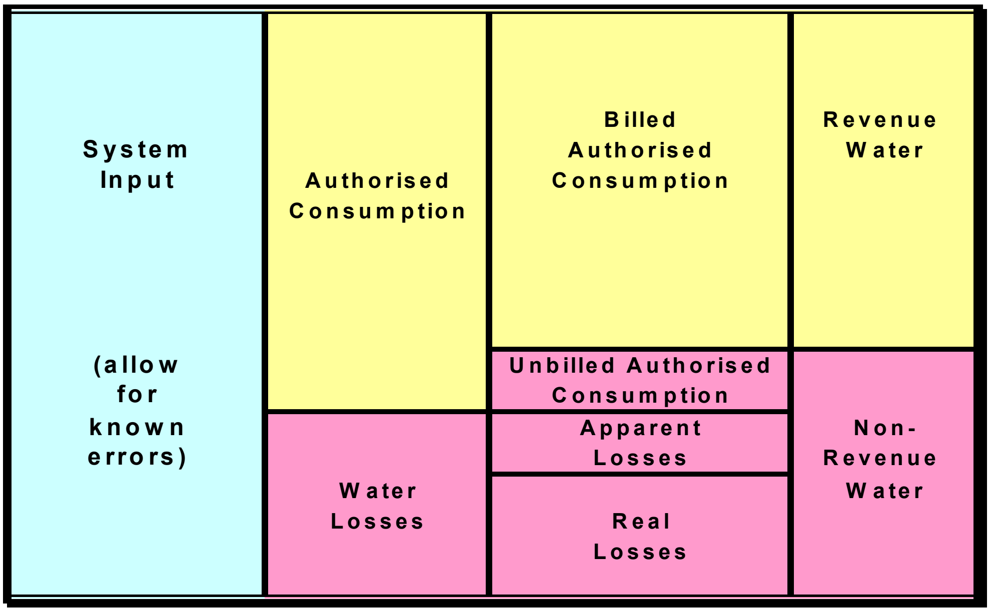

Figure 2.1: A simplified IWA Standard Water Balance

It can be imagined that the volume of water entering the figure from the left-hand side splits into various components as it passes through the system, as follows:

System Input

The volume input to that part of the water supply system to which the water balance calculation relates, allowing for known metering errors. It splits into:

- 'Authorised Consumption' + 'Water Losses'

Authorised Consumption

The volume of metered and/or unmetered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorised to do so by the water supplier, for residential, commercial and industrial purposes. It splits into Billed Authorised Consumption and Unbilled Authorised Consumption, and includes any Water Exported.

- For service connections, Authorised Consumption is the volume of water passing the street:property boundary, where a customer's water meter would normally be situated; Authorised Consumption therefore includes leakage on customers' underground supply pipes.
- Authorised consumption also includes items such as fire fighting and training, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, frost protection, building water, etc. These may be billed or unbilled, metered or unmetered, according to local practice.

Billed Authorised Consumption

The volume of authorised consumption which is billed and paid for; note that it includes Water Exported

Unbilled Authorised Consumption

The volume of authorised consumption which is not billed or paid for.

Water Losses

Calculated as the difference between System Input and Authorised Consumption

- Water Losses = Apparent Losses + Real Losses

Apparent Losses

Unauthorised consumption (theft or illegal use) plus customer meter under-registration.

- Apparent Losses are unlikely to be a major component of water balances in New Zealand, as most properties are subject to direct mains pressure without storage tanks

Real Losses

Physical water losses from the pressurised system, and overflows from service reservoirs, up to the point of measurement (or estimation) of customer consumption. The annual volume lost through all types of leaks, bursts and overflows depends on frequencies, flow rates, and average duration of individual leaks and overflows.

- Although physical losses after the point of consumption are excluded from the assessment of Real Losses, this does not imply that they are insignificant or not worthy of attention for demand management purposes. Leakage on unmetered sections of private pipework can be substantial (see **Appendix C**)
- Real Losses are calculated as the difference between Water Losses and Apparent Losses

Revenue Water

Those components of System Input which are billed and produce revenue. Equal to Billed Authorised Consumption

Non-Revenue Water

Those components of System Input which are not billed and do not produce revenue. Equal to Unbilled Authorised Consumption, Apparent Losses and Real Losses

The version of the IWA water balance diagram used in the April 2002 BenchlossNZ was more detailed than Figure 2.1, but omitted to show 'Water Supplied'. This has now been included and is shown in **Figure 2.2**, which appears on the 'Terminology' Worksheet of the 2008 version of BenchlossNZ. Definitions of the individual terms also appear on the 'Terminology' Worksheet, and in **Section 4.1** of this User Manual.

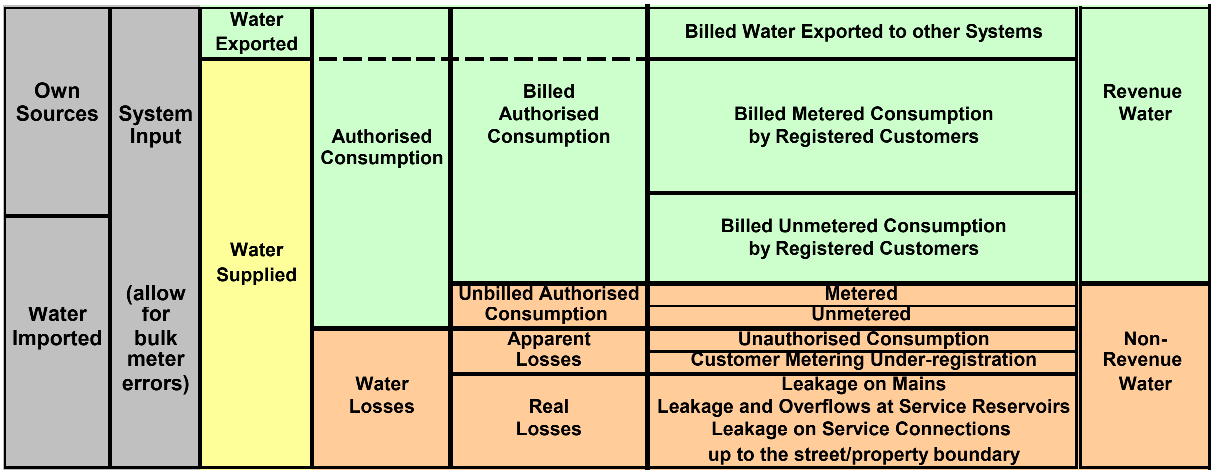

Figure 2.2: Annual Water Balance used in 2008 update of BenchlossNZ

Figure 2.2 shows that 'System Input' may consist of two components, 'Own Sources' and 'Water Imported'. 'Own Sources' is the volume of water input to a system from the Water Supplier's own treatment works; or, where no substantial treatment is provided, the volume of water input from the Water Supplier's own sources.

Figure 2.2 also clearly shows that, if there is Water Exported to other systems, there can be a significant difference between 'System Input' and 'Water Supplied'. For the purposes of BenchlossNZ calculations, it is also necessary to split 'Billed Authorised Consumption' into 'Billed Water Exported to other Systems' and 'Billed Consumption by Registered Customers (Metered and Unmetered)'.

Figure 2.2 also shows the various sub-components of Non-Revenue Water, which are Unbilled Authorised Consumption, Apparent Losses and Real Losses; and how these are further sub-divided for calculation purposes.

All components of the Annual Water Balance are initially calculated as a volume per year. Performance Indicators are obtained by introducing other parameters to facilitate comparisons between systems of different size and different characteristics. The most meaningful and appropriate Performance Indicators for Non-Revenue Water and Real Losses are described in the following sections.

2.3.3. Appropriate Structure for Performance Indicators

An appropriate basic structure for Water Supply System Performance Indicators created by the IWA Task Force on Performance Indicators in 2000 (**Ref. 7**) was updated in 2006 (**Ref. 10**). Performance Indicators are grouped by function - Water Resources, Personnel, Physical, Operational, Quality of Service and Financial. In the 2000 version, PIs for each function were assigned to one of three Levels of detail (Levels 1/2/3, or Basic/Intermediate/Detailed), but these were dispensed with in the 2006 version as they were considered to be too prescriptive.

2.3.4. Meaningful Performance Indicators

In the 2002 version of BenchlossNZ, four of the Performance Indicators recommended in the 2000 version of the IWA Manual **(Ref 7)** were considered by the NZWWA to be the most meaningful, and were included; they are shown in **Table 2.2** . References Op24, Op25, Fi36 and Fi37 in **Table 2.2** are those attributed to individual Performance Indicators in the 2000 version of the IWA Manual (**Ref. 7**)

Table 2.2: Water Loss Performance Indicators in 2002 BenchlossNZ

Function	Level	Performance Indicator	Comments
Operational: Real Losses	**Basic**	**Op24: litres/service connection/ day, when system is pressurised ***	**Allows for intermittent supply in international comparisons**
Operational: Real Losses	**Detailed**	**Op 25: Infrastructure Leakage Index**	**Ratio of Current Annual Real losses to Unavoidable Annual Real Losses**
Financial: Non-Revenue Water by Volume	**Basic**	**Fi36: Volume of Non-Revenue Water as % of System Input Volume**	**Can be calculated from simple water balance. Strongly influenced by consumption**
Financial: Non-Revenue Water by cost	**Detailed**	**Fi37: Value of Non-Revenue Water as % of annual cost of running system**	**Allows separate unit values in cents/Kilolitre for each component of Non-Revenue Water**

* Where the density of service connections is less than 20 per km of mains, use '/km mains/' instead of 'per service connection/' for these performance indicators

Table 2.3 shows the 5 Performance Indicators considered by the NZWWA to be most meaningful in the 2008 version of BenchlossNZ. However, in the 2006 edition of the IWA Manual **(Ref 9),** the 'Levels' were deleted, and there are changes in the Reference numbers.

- the original Op 24 for Real Losses has been split into two (Op27 and Op28) to show more clearly the influence of density of connections.
- the original Op 25 (Infrastructure Leakage Index) becomes Op29, with new lower size limits of application.
- An Operational PI for Apparent Losses has now been included
- The original Fi36 for NRW has been deleted, as % of System Input Volume is no longer considered meaningful
- The original Fi37 for NRW becomes Fi47

Table 2.3: Water Loss Performance Indicators in 2008 BenchlossNZ

Function	Performance Indicator	Notes on appropriate use of this PI	Comments
Operational: Real Losses	**Op27: litres/service conn./ day, when system pressurised**	**Connection density 20/km mains or more**	**Allows for intermittent supply in international comparisons**
Operational: Real Losses	**Op28: m^3/km of mains/ day, when system pressurised**	**Connection density less than 20/km mains**	**Allows for intermittent supply in international comparisons**
Operational: Real Losses	**Op 29: Infrastructure Leakage Index ILI**	**(Lm x 150 + Nc)* should exceed 3000**	**Ratio of Current Annual Real Losses to Unavoidable Annual Real Losses**
Operational: Apparent Losses	**% by volume of metered consumption (excluding Water Exported)**	**Most appropriate PI for Apparent Losses in New Zealand**	**Alternative PIs (% of System Input Volume, litres/conn/day) would favour water suppliers with less than 100% customer metering**
Financial: Non-Revenue Water by cost	**Fi47: Value of Non-Revenue Water as % of annual cost of running system**		**Allows separate unit values in cents/Kilolitre for each component of Non-Revenue Water**

* Lm = mains length (km), Nc = number of service connections

For users who may wish to compare % NRW by volume with Fi47, the 'Summary' Worksheet of BenchlossNZ shows NRW volume as a % of Water Supplied, although it is emphasised that this is NOT considered to be a meaningful Performance Indicator for Real Losses.

2.3.5. Calculating Performance Indicators and Setting Benchmark Values

The first IWA Water Loss Task Force (**Ref. 6, 1999)** obtained data from 27 diverse water supply systems in 20 countries – Australia, Brazil, Denmark, Finland, France, Germany, Gibraltar, Greece, Iceland, Japan, Maltese Islands, Netherlands, New Zealand, Singapore, Spain, Switzerland, Sweden, UK, USA and West Bank (Palestine). The diversity of the systems is indicated by the following statistics:

- Density of service connections: 24 to 114/km mains (median 47/km);
- Location of customer meters: 50% at street/property boundary; remainder up to 30m from property boundary;
- Average operating pressure: 30m to over 100 metres (median 45 metres).

The Performance Indicators appearing on the SUMMARY Worksheet of the 2002 version of BenchlossNZ were categorised using lower quartile and median values of this 1999 data set, using the following basis:

- Lowest quartile was used to define an 'Excellent' range;
- 25%ile to 50%ile was used to define a 'Good/Fair' range;
- 50%ile upwards used to define a 'Below Average' range.

Since 1999 many hundreds – even thousands – of IWA performance indicators have been calculated, and in 2005, the World Bank Institute, with assistance from members of the IWA Water Loss Task Force, developed an internationally applicable Banding System for categorising Real Losses **(Ref. 13).** The Infrastructure Leakage Index (ILI) can be used to categorise operational performance in real loss management into one of 4 Bands, which (for Developed Countries) are as follows:

- Band A: ILI < 2.0 ; further loss reduction may be uneconomic unless there are shortages
- Band B: 2.0 to < 4.0; possibilities for further improvement
- Band C: 4.0 to < 8.0; poor leakage management, tolerable only if resources are plentiful and cheap

- Band D: > 8.0; very inefficient use of resources, indicative of poor maintenance and system condition in general

The 2008 version of BenchlossNZ uses the World Bank Institute Banding System, instead of the provisional quartiles in the 2002 version. Each of the Bands (A,B,C,D) are described in more detail in Appendix J, which includes an authorised reproduction of part of the 'ILI Guidelines' Worksheet of the free 'CheckCalcsNZ' software. This also compares the calculated ILI with a data set of 23 ILI values from Australia and New Zealand, with recommended priorities for action for each of the Bands A to D.

A printout of the part of the 'SUMMARY' Worksheet which shows the key Performance Indicators is shown in **Figure 2.3**. The SUMMARY Worksheet of the BenchlossNZ software contains explanations of the detailed notes in the figure.

S3: RECOMMENDED PERFORMANCE INDICATORS

Viewpoint	Level of PI	Performance	World Bank Institute Band (see Note 1)				PI for this System	Units
			A	B	C	D		
Operational Management of Real Losses at Current Pressure	IWA Op27 DoC 20/km or more	Current Annual Real Losses (CARL)	Less	171	343	685	163	Litres/ service connection per day
		when system is pressurised	than	to	to	or	192	
		Litres/service connection/day	171	342	684	more	221	
	IWA Op28 DoC<20/km	Current Annual Real Losses (CARL)	Less	4.7	9.6	19.0	4.5	m^3 per km of mains per day
		when system is pressurised	than	to	to	or	5.3	
		m^3/km of mains/day (see Note 2)	4.7	9.5	18.9	more	6.1	
	IWA Op29	Unavoidable Annual Real Losses					81	Litres/ service connection per day
		(UARL) for distribution losses	-	-	-		86	
		Litres/service connection/day (See Note 3)					90	
		Infrastructure Leakage Index (ILI)	Less	2	4	8	1.89	Non-dimensional
		= CARL /UARL	than	to	to	or	2.25	
		for distribution losses (see Note 4)	2	< 4	<8	more	2.61	
Apparent Losses		Apparent Losses volume as % of metered consumption (excluding Water Exported) (See Note 5)					1.3%	% of metered consumption
							2.1%	
							2.9%	
Financial Management of NRW	IWA Fi47	Non-Revenue Water $ value as a % of annual system running cost (See Note 6)					3.0%	% of annual system running cost

Additional Calculation for comparison with Fi47	Non-Revenue Water (NRW) volume as a % of Water Supplied volume (See Note 7)	Not reliable for Metric Benchmarking or Process Benchmarking of NRW; shown here for information only	PI for this System	Units
			16.9%	% of Water Supplied volume
			19.3%	
			21.7%	

Fig. 2.3: Benchmarking Key Performance Indicators (Summary Worksheet)

The following notes outline important aspects of the calculation and choice of the Key Performance Indicators shown in **Figure 2.3**

Operational Performance Indicators Op27 and Op28 for Real Losses:

Op 27:Litres/service conn/day, if density of connections 20/km mains or more

Op 28: m^3/ km of mains/day, if density of connections < 20/km mains

This is the simplest of the Operational Performance Indicators. Component Analysis of Unavoidable (Technical Minimum) Real Losses (see **Ref. 6**) shows that, in well managed systems, the greatest proportion of Annual Real Losses occurs on Service Connections, if density of connections exceeds 20 per km of mains. This conclusion is supported by widespread international experience. It should be noted that the number of service connections (main to customer meter) on which real losses occur is not always the same as the number of metered accounts or properties. For the purposes of BenchlossNZ calculations in New Zealand, the number of service connections can be assumed as being the number of metered accounts, minus the total of any sub-meters (after master meters, e.g. to shops and flats), plus the number of unmetered service connections.

In summary, if the density of connections is 20 per km of mains or more, 'Number of Service Connections' (water main to customer meter) is preferred as the basic scaling factor for Real Losses, to 'Length of Mains'. In New Zealand, most systems have density of connections more than 20/km, but there are some with less than 20/km – in which case, m^3/km mains/day is the appropriate simple Performance Indicator. The BenchlossNZ software calculates the density of connections for each system under review, and identifies the appropriate comparison graphs on the 'SUMMARY' Worksheet.

The most appropriate units for the best practice simple operational Performance Indicator for Real Losses will therefore vary for different systems in New Zealand, depending upon the density of connections. However, this PI does not take account of three key system-specific factors that have a strong influence on the lowest volume of Real Losses achievable in any particular system:

- Average operating pressure;
- Location of customer meters on service connections (relative to street/property boundary);
- The actual density of service connections (per km of mains)

By defining the 'Point of Consumption' for service connections as the street:property boundary, for both metered and unmetered properties, one of these three factors is eliminated; but it is still necessary to allow for the actual density of service connections and average operating pressure when making performance comparisons.

Influence of Average Operating Pressure and Density of Connections

Data from pressure:leakage tests in numerous sectors of distribution systems in Japan, and the UK show that, for large systems with mixed pipe materials, a linear relationship may be assumed between pressure and overall leakage rate from existing leaks and bursts (Refs 17,18,19,20,21). Rates of Real Losses can therefore be expressed in litres/connection/day/metre of pressure, or m^3/km of mains/day/metre of pressure. Further information on Pressure:Leakage relationships and concepts are provided in **Appendix G.**

The influence of Density of Connections on Real Losses can be demonstrated **(Ref 22)** by plotting Density of Connections against Real Losses, in litres/connection/day/metre of pressure, and m^3/km of mains/day/metre of pressure, for Unavoidable Annual Real Losses (UARL). **Figure 2.4**, shows how the UARL, expressed in these two units of measurement, varies with Density of Connections.

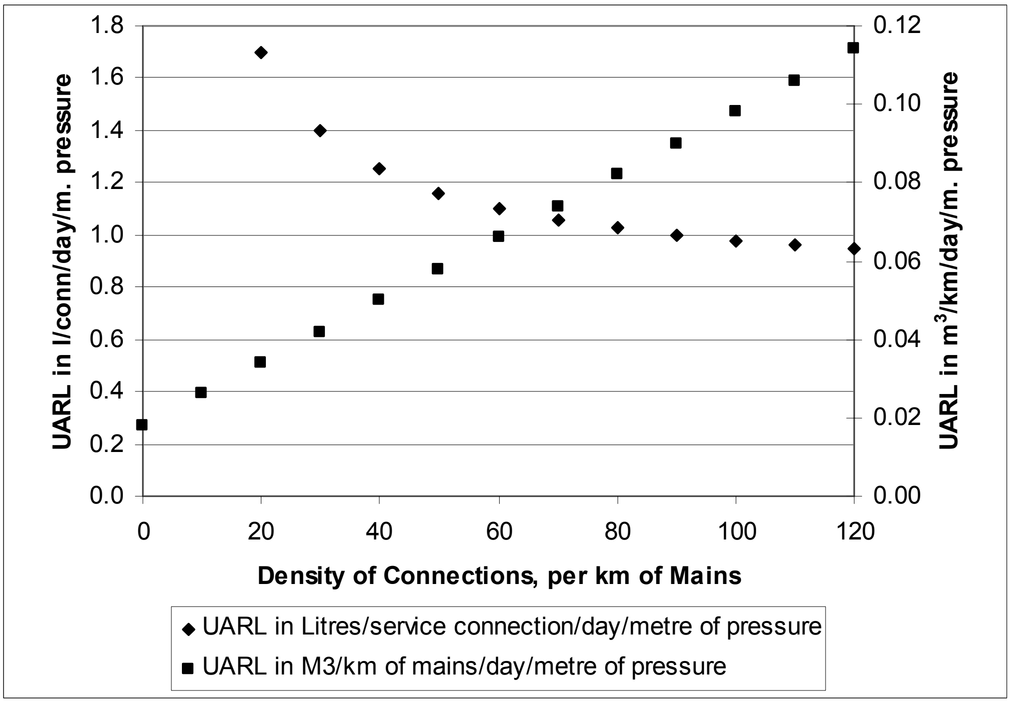

Figure 2.4: Unavoidable Annual Real Losses vs Density of Connections (customer meters at street/property boundary)

For Density of Connections in the range 60 to over 100, the UARL in litres/connection/day/metre of pressure (left hand scale and ‘diamonds’ characters) is almost uniform at 1.0 l/conn/day/metre pressure, but at lower values of Density of Connections the UARL starts to rise quite steeply. In contrast, the UARL in m^3/km of mains/day/metre of pressure (right hand scale and 'square' characters' rises rapidly over the whole range of density of connections.

Figure 2.4 shows that, for the wide range of density of connections found in New Zealand (from less than 10 to over 60 per km), the actual density of connections must be taken into account when making performance comparisons.

Operational Performance Indicator Op29 for Real Losses: the Infrastructure Leakage Index (ILI)

As shown in **Figure 2.4**, the Unavoidable Annual Real Losses for New Zealand systems (with customer meters at the street:property boundary), when expressed in will vary with both pressure and density of connections. The most appropriate Performance Indicator developed to date for operational management of Real Losses is the ratio of the Current Annual Real Losses (calculated from the standard Water Balance) to the system-specific Unavoidable Annual Real Losses (calculated from the Water Losses Task Force equations **(Ref. 6)**. This ratio is known as the Infrastructure Leakage Index (ILI). It is a measure of the effectiveness of management of Real Losses from the infrastructure, at current pressures.

This is illustrated in **Figure 2.5**. The area of the outer rectangle represents the Current Annual Real Losses volume, which is continually tending to increase as the system gets older, and new leaks and bursts occur. The four complementary leakage management activities (shown as arrows) constrain this increase, but the maximum effect they can possibly have is to reduce the Real Losses as low as the Unavoidable Annual Real Losses (UARL), indicated by the smaller box. The Infrastructure Leakage Index is the ratio of the outer area (CARL) to the inner area (UARL).

The system-specific basis for calculation of UARL is described in detail in **Appendix G.** It is based on Bursts & Background Estimates (BABE) Component Analysis concepts (also explained in more detail in **Appendix G** and **Ref. 6**), using the assumptions that:

- Infrastructure is maintained in good condition, with low background leakage;
- New burst frequencies are those appropriate to well managed infrastructure in good condition;

- Durations of unreported bursts are limited by intensive active leakage control;
- All detectable bursts are repaired rapidly, with good quality repairs;
- Unavoidable Annual Real Losses are assumed to vary linearly with pressure.

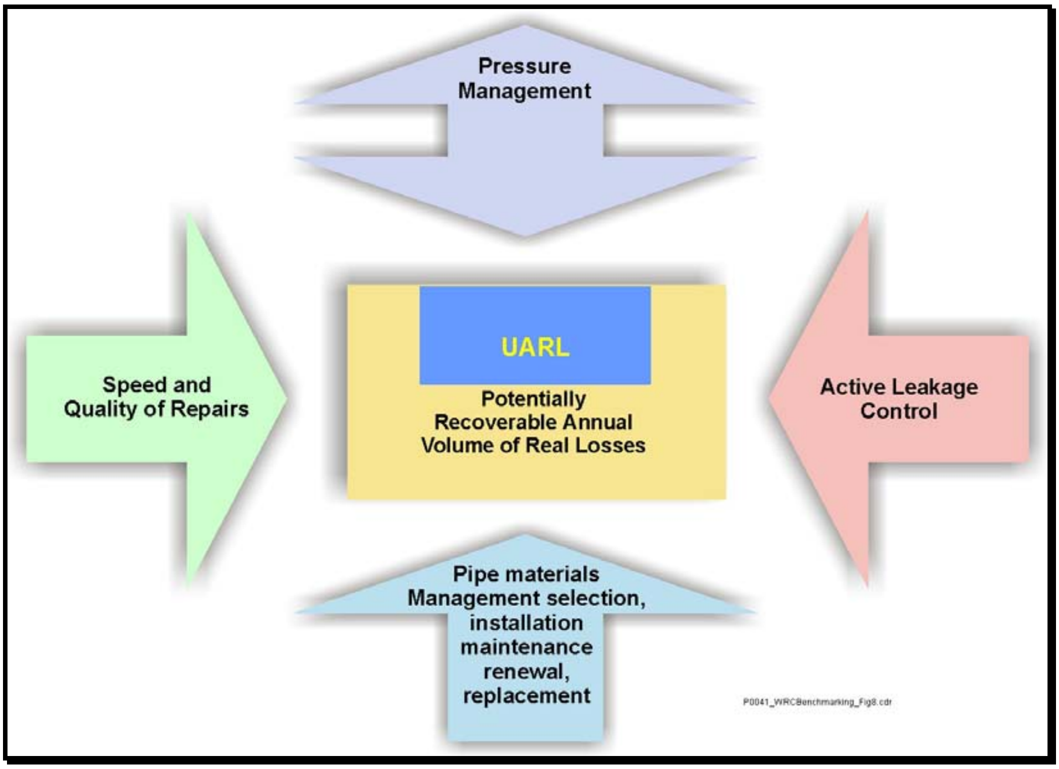

Figure 2.5: The four complimentary leakage management activities

Performance Indicator for Apparent Losses: At the time of preparing this update, the Apparent Losses Group of the IWA Water Loss Task Force had not yet finalised recommendations for an Apparent Losses Operational PI, but there are three principal options for simple PIs (% of Water Supplied, litres/service connection/day, and % of metered consumption), and the future possibility of a more detailed PI, the Apparent Losses Index (ALI) with similarities to the Infrastructure Leakage Index (ILI) for Real Losses.

Given that the principal component of Apparent Losses in New`Zealand is likely to be customer meter under-registration, '% of metered consumption (excluding Water Exported)' has been selected as the most logical choice for a simple Apparent Losses PI for this 2008 update of BenchlossNZ. It is also the only one of the three simple Apparent Loss PI options that does not discriminate against water suppliers which meter residential properties

Financial Performance Indicators for Non-Revenue Water :

Non-Revenue Water as a Percentage by Volume

The IWA Task Forces recommended **(Refs 6,7)** that the term 'Unaccounted for Water' (UFW) be replaced by 'Non-Revenue Water' for the following reasons:

- Modern concepts of water losses calculations mean that all components of the annual water balance can now be accounted for;
- The term UFW has no specific meaning internationally, as each country calculates UFW differently and on a non-comparable basis;

Non-Revenue Water expressed as a % of System Input volume is the simplest of the Financial Performance Indicators. It is, however, too crude a basis for making comparisons of Financial Performance in managing Non-Revenue Water (or any NRW Components) because the components of Non-Revenue Water in **Figure 2.1** may all have different valuations, in cents/m^3**.**

It is also, unfortunately, common to find % of System Input volume being used as an operational Performance Indicator for NRW and its components. This is not acceptable as it is strongly influenced by consumption (see **Table 2.2**), and whether "Water Exported" is included in the calculation, or not. Expressing volumes of NRW or its components as a % of 'Water Supplied' rather than as a % of 'System Input' volume provides some improvement, by eliminating the influence of 'Water Exported', but not sufficient improvement to justify retaining NRW % by volume as either a Financial or Operational Performance Indicator in this 2008 update of BenchlossNZ.

Financial Performance Indicator Fi47: Non-Revenue Water as a percentage by Value

Non-Revenue Water by Value is calculated by assigning appropriate valuations to each of the components of Non-Revenue Water in **Figure 2.1**, as follows:

- Apparent losses – usually valued at sale price of water to customers;
- Real losses – usually valued at bulk supply cost of purchase, plus marginal distribution costs; or the marginal cost (long run or short run, as appropriate) of treating and distributing water from 'own sources';
- Unbilled authorised consumption - usually valued between Apparent and Real losses valuations, depending upon sub-components.

Each of these Non-Revenue Water volume components is thus turned into a dollar value, then expressed as a percentage of the annual cost of running the water supply system.

This is a far more meaningful Financial Performance Indicator than NRW % by volume, and has been retained as a Key Performance Indicator in this 2008 update of BenchlossNZ.

2.3.6. Limitations On Using The Key Performance Indicators

In some situations, certain Key Performance Indicators should be used with caution (see Table 2.3).

When the 2002 version of BenchlossNZ was issued, the predictive equation for UARL has not yet been extensively checked on well-managed systems with low densities of connections (less than 20/km mains) or low operating pressures (less than 25 metres). Also, it was considered that some of the assumptions in the UARL equations relating to frequency and average flow rates of new bursts may not apply to small sectors with fewer than approximately 5000 service connections.

After further testing and research, it was confirmed in 2005 (**Refs 21, 23**) that:

- the lower limit for density of connections could be removed
- the lower limit for number of service connections could be reduced to around 3000
- the UARL equation could be applied at pressures as low as 10 metres for systems with predominantly rigid pipes

The first two of the above new lower limitations can be combined by limiting the size of system to which UARL can be used, by calculating (Lm x 20 + Ns), where Lm is mains length in km and Ns is number of service connections. If the resulting figure exceeds 3000, the UARL calculation should be reliable.

2.3.7. Metric Benchmarking and Process Benchmarking

In the 1st Edition of the IWA Performance Indicators Manual (**Ref. 7**), 'Levels' were assigned to different performance indicators; for example, Table 2.2 shows that real losses per service connection or per km of mains were considered as 'basic' (Level1), whilst Infrastructure Leakage Index was considered to be 'detailed' (Level 3). However, in the 2nd Edition of the IWA Performance Indicators Manual (**Ref. 7**), 'Levels' were abolished (see Table 2.3). So is there now any appropriate guidance on when it is better to express Real Losses on a simple 'per service connection' or 'per km of mains' basis, rather than to use the Infrastructure Leakage Index?

There is an interesting discussion in a 2007 AwwA Research Foundation Report **(Ref 24)** on the respective merits of using various PIs for NRW, Apparent Losses and Real Losses for Regulation, Environmental Protection, Contract Supervision, Financial Optimization and Operational Management. Also, in a presentation of the 2nd Edition PIs Manual to the AWWA Summer meeting in 2006, Cabrera **(Ref 25)** drew a distinction between:

- **Metric benchmarking** – using appropriate PIs for more demanding comparisons between water suppliers
- **Process benchmarking –** using appropriate PIs for setting targets and ongoing monitoring of progress towards those targets.

For the purposes of this 2008 update of the Benchloss NZ manual, the messages in **Ref. 24** and **Ref. 25** (in respect of selecting Operational Real Losses PIs) can be briefly summarised as being:

- Infrastructure Leakage Index (Op 29) is preferable for Metric benchmarking, as it takes account of differences in system specific key parameters (mains length, number of service connections, customer meter location, average pressure)
- Litres/service connection/day (Op 27) or m3/km of mains/day (Op 28) (depending upon service connection density) is preferable for Process benchmarking of reductions in Real Losses within a specific water supplier.

This is because pressure management will normally be an important part of any real loss reduction strategy, and the UARL denominator in the ILI calculation changes with pressure. Reduction of a water supplier's real losses in volume terms clearly shows up when Op 27 or Op28 are used for Process benchmarking, but may not be so clearly demonstrated if the ILI is used in situations where pressure management takes place.

3. SOME DETAILED CONSIDERATIONS

3.1. ASSESSING ACCURACY OF WATER BALANCE AND PI CALCULATIONS

Technical data relating to:

- infrastructure (numbers of connections, mains length, properties etc)
- average pressure
- metered volumes, estimated unmetered volumes etc

are used in the calculation of Water Balance and Performance Indicators. They are not precise exact values, but 'best estimates' to a greater or lesser extent. So, the question is often asked, "how reliable are the calculated volumes of Non-Revenue Water, Apparent Losses, Real losses, and their Performance Indicators?".

Data errors can be systematic, or random, or a mixture of both (see **Appendix A**). For example, if the check calibration of a system input meter shows that it has over-recorded by between 2% and 4%, then there is a systematic error with a best estimate of 3% over-recording of system input volume. Systematic errors in system input volume should be corrected as part of the Water Balance calculation process (see 'Waterbal' Worksheet in BenchlossNZ).

In the above example, there will also be a random error of approximately +/- 1% of the corrected system input volume (or +/- 33.3% of the best estimate of the systematic error). Similar random errors will exist for almost every item of data entry in the BenchlossNZ calculations; for example, in the figures entered for length of mains, or the calculated average pressure, or the estimates of components of unmetered consumption etc.

For most of the parameters used in BenchlossNZ, if systematic errors are identified and dealt with, the remaining random errors are equally likely to be greater than, or less than, the true value. A practical approach for assessing probable errors in calculated components of NRW, and Performance Indicators, can then be developed, using the statistical properties of a probability distribution known as the 'Normal' or 'Gaussian' distribution.

It is necessary, however, to be aware that the probability distributions of some items of data used in leakage management do not follow 'Normal' distributions. Examples

given in **Appendix A** relate to the night consumption in individual properties, and the underground supply pipe leakage on individual properties.
The characteristics of the Normal distribution function are explained in **Appendix A**.

BenchlossNZ requires the user to enter a 'best estimated' value for each input parameter. Then, to make a judgement as follows:

'I think the figure I have entered is probably within +/- X % of the true value'

The value of X is then assumed to represent the 95% confidence limits, expressed as a % of the best-estimated value.

Using the estimated 95% confidence limits for input data, BenchlossNZ uses routine statistical calculations to calculate 95% confidence limits for derived data, such as:

- the sums or differences of volumes in the water balance;
- performance indicators which use combinations of items with different measurement units.

3.2. EXAMPLES OF WATER RETICULATION LAYOUTS IN NEW ZEALAND

It seems that many of the water suppliers in New Zealand use different terms to define the components of water reticulation systems. For the purposes of BenchlossNZ, reticulation systems are divided into:

- service reservoirs – storage owned by the water supplier
- water mains – pipes providing a general supply of raw or treated water
- service connections and fittings carrying water from the main to the 'point of consumption' at the street:property boundary

Examples of terminology used by individual water suppliers are given in **Appendix B**, and cross-referenced to the terminology used in BenchlossNZ as examples to assist Users of the software.

In the BenchlossNZ terminology, the 'Point of Consumption' for service connections is at the street:property boundary, irrespective of whether the service connection is metered or unmetered. 'Consumption' on service connections can be considered to consist of 4 principal components:

- leakage from the underground supply pipe
- leakage from the above-ground plumbing

- indoor use within the buildings
- outdoor use using hosepipes, sprinklers etc

3.3. ESTIMATING UNDERGROUND SUPPLY PIPE LEAKAGE

The average leakage on underground supply pipes can be substantial, particularly in unmetered situations. In England & Wales in 2001/02 underground supply pipe leakage averaged around 17 litres/property/day (6 m^3/property/year) for externally metered properties, and 43 litres/property/day (16 m^3/property/year) for unmetered households **(Ref.5).**

In BenchlossNZ, underground supply pipe leakage is considered as part of consumption, whether the property is metered or unmetered. However, it is sometimes useful to obtain estimates of average underground supply pipe losses for purposes associated with water demand management, such as the likely benefits of introducing customer metering.

Estimates of the average annual leakage rates from large numbers of customers' underground supply pipes can be based on component analysis (Background and Bursts Estimates). Typical values depend upon parameters such as average length of such pipes (per service connection), average pressure and the numbers and types of leaks that occur, and how quickly such leaks are identified and repaired.

In **Appendix C**, and on the ‘Consumption’ Worksheet of BenchlossNZ, a simple methodology is described for estimating underground supply pipe losses in different circumstances. The basic equation used is:

$$\textbf{UGSP leakage (litres/property/day)} = F \times 0.025 \times L_p \times P_{av}$$

Where L_p is the average length of underground supply pipe, P_{av} is the average pressure, and F is a factor (between 1 and 4) for different circumstances.

	F-Factor
Externally metered properties, Class D meter, billed on 6 monthly meter readings	1.0
Externally metered properties, Class C meter, annual meter readings not used for billing	1.5
Unmetered property, strong active policies for assisted repairs	3.0
Unmetered property, no active policies for assisted repairs	4.0

For any particular system, these calculations can be made on Rows 83 to 99 of the 'Consumption' Worksheet in BenchlossNZ. This simplified approach to estimating underground supply pipe leakage will hopefully provide users with some approximate estimates of the possible ranges of underground supply pipe leakage in different circumstances. The calculation can be replaced with a more rigorous approach once sufficient factual information for such leakage in New Zealand has been collected and collated.

3.4. ESTIMATING UNMETERED RESIDENTIAL CONSUMPTION

There are many systems in New Zealand where residential consumption is not metered, and estimated values for this parameter need to be entered into the water balance calculation. At the 'Point of Consumption' at the street:property boundary, the volume of water passing across that boundary into private pipework can be considered to consist of 4 principal components:

- leakage from the underground supply pipe
- leakage from the above-ground plumbing
- indoor use within the buildings
- outdoor use using hosepipes, sprinklers etc

Even in situations where all customers are metered at the street:property boundary, leaks will occur on a small percentage of individual underground supply pipes, and on some plumbing systems.

Figure 3.1 depicts a frequency distribution of the average consumption per residential property for a sample of 4 411 residential service connections in Christchurch. It shows that this is **not** a 'Normal' distribution in which there is an equal chance of seeing values higher or lower than the mean value of 275 m^3/year.

- 93.5% of properties have consumption of less than 550 m^3/year
- 5.2% of properies have consumption between 550 and 1 000 m^3/year
- 1.3% (57 properties)have consumption of over 1 000 m^3/year (reaching up to 3 000 m^3/year)

The small percentage of properties with consumption greater than 550 m^3/year – and in particular the 1% of properties consuming over 1 000 m^3/year – have a significant influence on the mean value of consumption. The principal causes for these high individual consumptions are:

- leaks on underground service connections (which can easily lose around 20 m^3/day, or 7 000 m^3/year), without the customer being aware of the leak.
- Excessive use of water outdoors associated with gardens

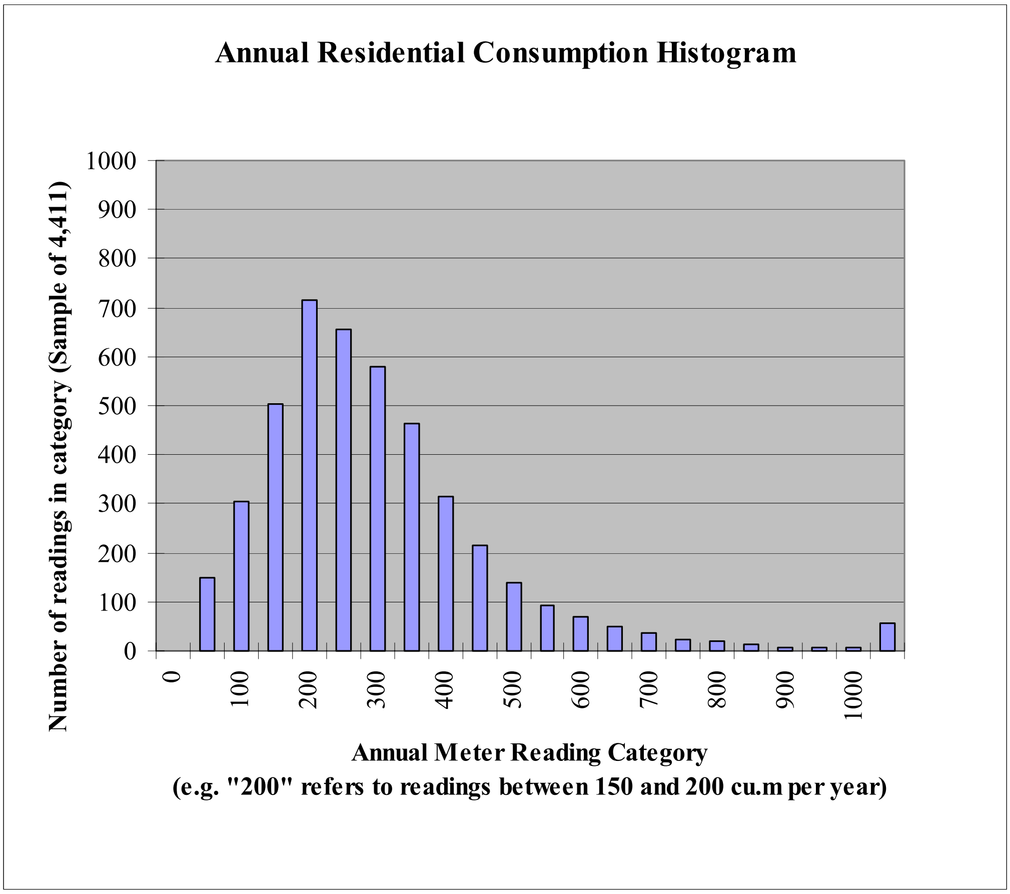

Figure 3.1: Histogram of Annual Residential Consumption, Christchurch

The simplest and crudest method of estimating annual consumption per unmetered residential property is to obtain data from several fully metered water suppliers within reasonable distance, and estimate a higher figure, to allow for higher underground supply pipe losses and greater per capita use. If possible, aspects such as toilet cistern size (single of dual flush), average residents per residential property, pressure etc., should be taken into account.

A more systematic approach is to set up consumption monitors, in which a small sample of carefully selected residential properties is metered, but the residents do not see the metered records, nor are they charged on the metered volume – the intention being that they do not change the amount of water they consumed when unmetered.

Aspects of consumption monitors which may be of interest to NZWWA members are outlined in **Appendix D**. In particular, there is one city in South Island where metered residential properties are not billed on a 'volume consumed' basis, making this a most useful potential data source for investigating appropriate procedures for setting up reliable consumption monitors in New Zealand.

3.5. ALLOCATING MINOR COMPONENTS IN THE WATER BALANCE

Figure 3.2 shows part of the standard water balance from the 'Terminology' Worksheet. In undertaking the Water Balance, it is necessary to assemble the annual volumes of water for the components in the right-hand column. In Benchloss NZ, this is achieved by entering data in the 'Consumption' Worksheet; except for Water Exported, which is entered on the 'WaterBal' Worksheet.

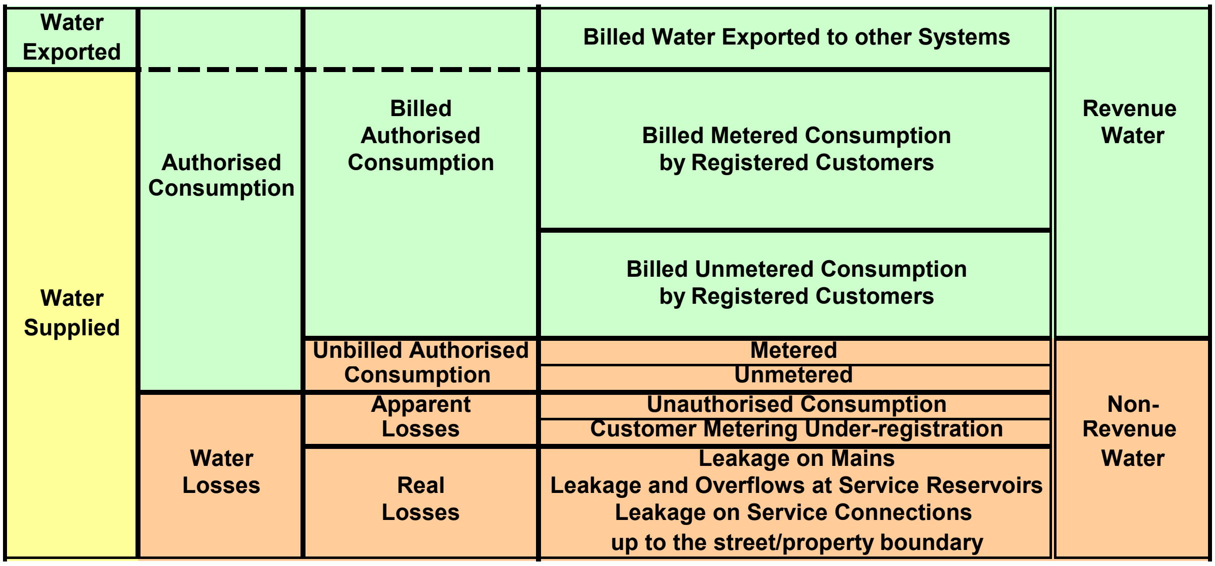

Figure 3.2: 'Consumption' Section of Standard Water Balance

The actual Item References and descriptions for data entry in the 'Consumption' Worksheet are as set out in **Appendix E**. The description of some items are fixed, but the remainder can be changed if necessary by the user.

When allocating components of consumption in the "Consumption" Worksheet , ensure that all components of consumption are "Authorised", according to the following definitions:

- The volume of metered and/or unmetered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorised to do so by the water supplier, for residential, commercial and industrial purposes. It splits into Billed Authorised Consumption and Unbilled Authorised Consumption, and includes any Water Exported.
- For service connections, Authorised Consumption is the volume of water passing the street:property boundary, where a customer's water meter would normally be situated; Authorised Consumption therefore includes leakage on customers' underground supply pipes.

Authorised consumption also includes items such as fire fighting and training, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, frost protection, building water, etc. These may be billed or unbilled, metered or unmetered, according to local practice.

3.6. ESTIMATING UNBILLED AUTHORISED CONSUMPTION

Unbilled Authorised Consumption usually consists of many small components, which may be metered or unmetered.

There are usually very few, if any, metered components of Unbilled Authorised Consumption. Such situations would only occur where the water supplier required to know the volume, but did not (or could not) charge for the water consumed. In England & Wales, an example would be water used at Fire Stations for training purposes; the volumes might be significant, but under law no charge is permitted.

In contrast, there are usually a large number of possible unmetered components of Unbilled Authorised Consumption. Typical examples indicated in the 'Consumption' spreadsheet relate to:

- System cleaning – flushing, treatment process water, discharges from hydrants, cleaning of service reservoirs, flushing of new and renewed mains etc
- Fire services – filling engines, water taken direct from mains, training using hydrants, testing of sprinkler lines
- Use of hydrants by others – sewer flushing, street cleaning,
- Backflow prevention testing

- Temporary supplies to customers during mains renewals or extended repairs

It is undoubtedly good practice to attempt to make estimates of these volumes at least once every few years, on a logical basis. However, several years experience in the use of confidence limits has shown that the most significant systematic and random errors in Water Balance calculations usually arise from errors in the source meters and bulk supply meters, and incorrect estimates of unmeasured consumption. The large amount of time and effort taken in estimating some of the smaller unmeasured components of the Water Balance – Unbilled Authorised Consumption, Unauthorised Consumption and Customer Meter Under-Registration – is not necessarily justified, at least for initial Water Balance and PI calculations.

The practice of using relatively low guideline default values for initial estimates of these parameters is increasing internationally – the defaults currently used in Australia have now been introduced into this updated version of Benchloss NZ. The principle used is that water suppliers may claim higher allowances than the guideline default values when doing their water balance, but only if such higher allowances can be justified with robust water supplier specific data.

The guideline default estimate can be calculated on the Consumption Worksheet using the instructions in Cell J32, the calculated value is then entered in Cell G32. A fixed confidence limit of +/-100% is assumed for this estimate in Cell N32.

If the user prefers to estimate individual components of Unbilled Authorised Consumption, rather than use the Guideline Default approach, then ‘zero’ must be entered in Cell G32, and Rows 33 to 51 of the “Consumption” Worksheet completed as appropriate; indications are given of some typical methods of making assessments. The cruder the estimates, the greater the 95% confidence limits which should be entered alongside the estimated values.

3.7. ESTIMATING APPARENT LOSSES

Apparent Losses consist of Unauthorised Consumption (theft and illegal use) and Metering Errors. Calculations of these volumes are preferably based on structured sampling tests, or estimated by a robust local procedure (which should be defined for audit purposes). Some quoted figures **(Ref 22)** for Apparent Losses in different countries range from 1% to 9% of System Input Volume (see **Appendix F**).

Although each water supplier should attempt to assess and manage the components of Apparent Losses for its own system(s), the guideline default approach (explained in Section 3.6) can also be used to speed up initial calculations.

Unauthorised Consumption occurs to a greater or lesser extent in most systems worldwide - the England & Wales average estimate (5) is 0.36% of Water Supplied. This component of Apparent Losses is generally associated with misuse of Fire Hydrants and Fire Service connections, and illegal connections. The guideline default used in Australia, and in this 2008 Update of BenchlossNZ, is 0.1% of Water Supplied. On the WaterBal Worksheet, a check has been introduced on Row 61 to show how the volumes entered for Unauthorised Consumption on Rows 55 to 58 compare with this guideline default value.

Customer Metering errors include:

- Systematic errors due to meters failing to accurately record low flows
- Random errors, mainly due to accounting procedure errors

When samples of customer meters are tested for accuracy, it is normal to quote the average systematic error as a % of the true metered consumption. Reference **22** shows examples of average customer meter under-registration from different countries, ranging from zero to 34% of recorded metered consumption, the higher values being associated with systems in which customers are supplied via private storage tanks.

The selection of customer meter types and classes (A to D) may be limited by water quality considerations, as well as technical and economic considerations. Economic replacement policies for residential meters based on selective testing programs in many countries generally indicate changeover periods between 5 and 10 years. Incorrectly sized commercial meters can result in significant under-registration of consumption, and checks can be made to identify if there are more appropriate meters for individual situations (by occasional monitoring of the actual frequency and range of consumption rates).

Where customers are served exclusively through storage tanks, the probability of customer meter under-registration is significantly increased, because of the tendency for a greater part of the consumption to pass through the meter at rates less than the Q_{min} specified for the meter. However, New Zealand has direct pressure systems, with no significant customer storage except in some commercial properties. The 2002 version of BenchlossNZ assumed 3% average under-registration for residential meters, and 4% average under-registration for non-residential and 'other' meters. These figures were in line with 2001/02 average data for England and Wales **(Ref 5)** of 3.3% and 4.9% respectively, but higher than the guideline default figures now used in Australia (2.0% and 2.0% respectively).

The guideline defaults for customer meter under-registration in the 2008 version of BenchlossNZ have been reduced, and are now consistent with the Australian default values. If the % under-registration entered in Cells F65 (residential) and F66 to F68 (non-residential and other meters) of the "WaterBal" Worksheet for meter under-registration exceed the guideline default values of 3% and 4% respectively (shown in Cells E65 and E66 to E68 respectively), then the figures should be justified with water supplier specific data.

4. OUTLINE OF THE BENCHLOSSNZ SOFTWARE

4.1. HARDWARE AND SOFTWARE REQUIREMENTS

To run the BenchlossNZ software, the user requires a basic PC with the Windows operating system and the EXCEL spreadsheet program. There are no special requirements as the software is a basic Excel workbook with no restrictive features or links to other programs.

4.2. INSTALLING BENCHLOSSNZ

The BenchlossNZ software will be supplied by NZWWA on a CD together with a copy of this User Manual, with a specific reference allocated to each water supplier (e.g, NZB-001) shown on the 'Licence' Worksheet. BenchlossNZ is a relatively small workbook at approximately 420Kb and can be run provided that the Excel program can be accessed. There is no sophisticated installation shield and it is suggested that the software be installed as follows:

- Set up a directory called BenchlossNZ;
- Copy the **BenchlossNZ.XLS** file into this directory; retaining the original NZWWA file in a safe place;
- Each time a new calculation is required, rename the BenchlossNZ file with a more specific name, and over-write the yellow cells and boxes with new data.

4.3. OVERVIEW OF THE SOFTWARE

The BenchlossNZ software processes basic information entered by the user in such a way that:

- Infrastructure and population data can be listed for sub-sectors and aggregated for the whole system
- Unavoidable Annual Real Losses are calculated for any individual system;
- Components of the standard Water Balance are calculated for any system and year;
- The selected Performance Indicators are calculated and compared with Benchmark values from an International Data set (**Ref. 6**), and (in future, when available) with a New Zealand data set.

4.4. THE INDIVIDUAL WORKSHEETS

The individual Worksheets, which are shown in **Appendix I**, can be briefly described as follows:

Licence: specifies the Licensee (with a unique reference number allocated by NZWWA) and the Terms and Conditions of Use. No data entry is required.

Information: this Worksheet is a shortened version of **Section 4** of this User Manual. No data entry is required.

INF&UARL: The user enters System Name and Contact Information in addition to the basic information on infrastructure and population. The Unavoidable Annual Real Losses (UARL) for the system are calculated on this Worksheet. The derivation of the equation used to calculate UARL, from **Ref. 6**, is explained in **Appendix G**. Methods for calculating average pressure appear in **Appendix H**.

Terminology: this shows the same Water Balance diagram as **Figure 2.2**, and provides detailed definitions of the main components. No data entry is required.

Consumption: this Worksheet is used to input consumption data for the year under consideration, the data are then summarised and transferred automatically to the 'Waterbal' Worksheet. The components of Authorised Consumption can be specified to whatever degree of detail is considered appropriate, with corresponding 95% confidence limits. This Worksheet also contains an explanation and calculation of the probable leakage on private underground supply pipes, in different circumstances.

Waterbal: on this Worksheet the User enters data with regard to the measured or assessed components of System Input and Exports, and Apparent Losses. Using this and other data from previous Worksheets the software calculates the various Water Balance components and their 95% confidence limits.

WBComponents: this uses the same Water Balance diagram as **Figure 2.2**, but also shows each of the components as a volume in $m^3 \times 10^3$/day, in litres/capita/day of resident population, with the 95% confidence limits. Four Pie Charts are presented. No data entry is required.

PICalcs: All the Performance Indicators are calculated in this Worksheet. The only data required are the marginal values in cents/m^3 assigned to Real Losses, Apparent Losses and Unbilled Authorised Consumption and also the annual cost of running the water supply system.

Summary: The first part of this Worksheet summarises and compares the key System Factors which influence Unavoidable Annual Real Losses, and other key factors which may influence calculations and comparisons in New Zealand (this involves entering a peak day and a peak month factor for the system). The calculated Performance Indicators for Real Losses (with 95% confidence limits) are compared with the World Bank Institute Banding System and the original IWA International Data Set. Facilities are also provided for graphical comparisons with a New Zealand data set when this is available, and has been entered in the 'Compdata' Worksheet.

Compdata: This Worksheet shows the data used to build the graphs on the 'Summary' Worksheet, and provides space for Op27, Op28 and Op29 Performance Indicators to be entered in rank order for up to 27 New Zealand data sets.

Why not %s: this Worksheet uses the calculated data to demonstrate, as a graph, why percentages are unsuitable for assessing operational performance (see also **Section 1.1**). No data entry is required.

The procedure and order for using the various worksheets is shown in **Figure 4.1**.

4.5. INPUT DATA REQUIREMENTS

Cells in the BenchlossNZ Worksheets are colour-coded as follows:

Example Data	Data entry Cells	Calculated Values	Data from another Worksheet	Default values

- Light blue cells (example data) are protected and cannot be accessed;
- Yellow cells and blocks (data entry) are to be completed by the user (some of these are optional);
- Pink cells (calculated values) are protected and cannot be accessed;
- Light green cells (data from another Worksheet) are protected and cannot be accessed.
- Purple cells (default values) are protected and cannot be accessed

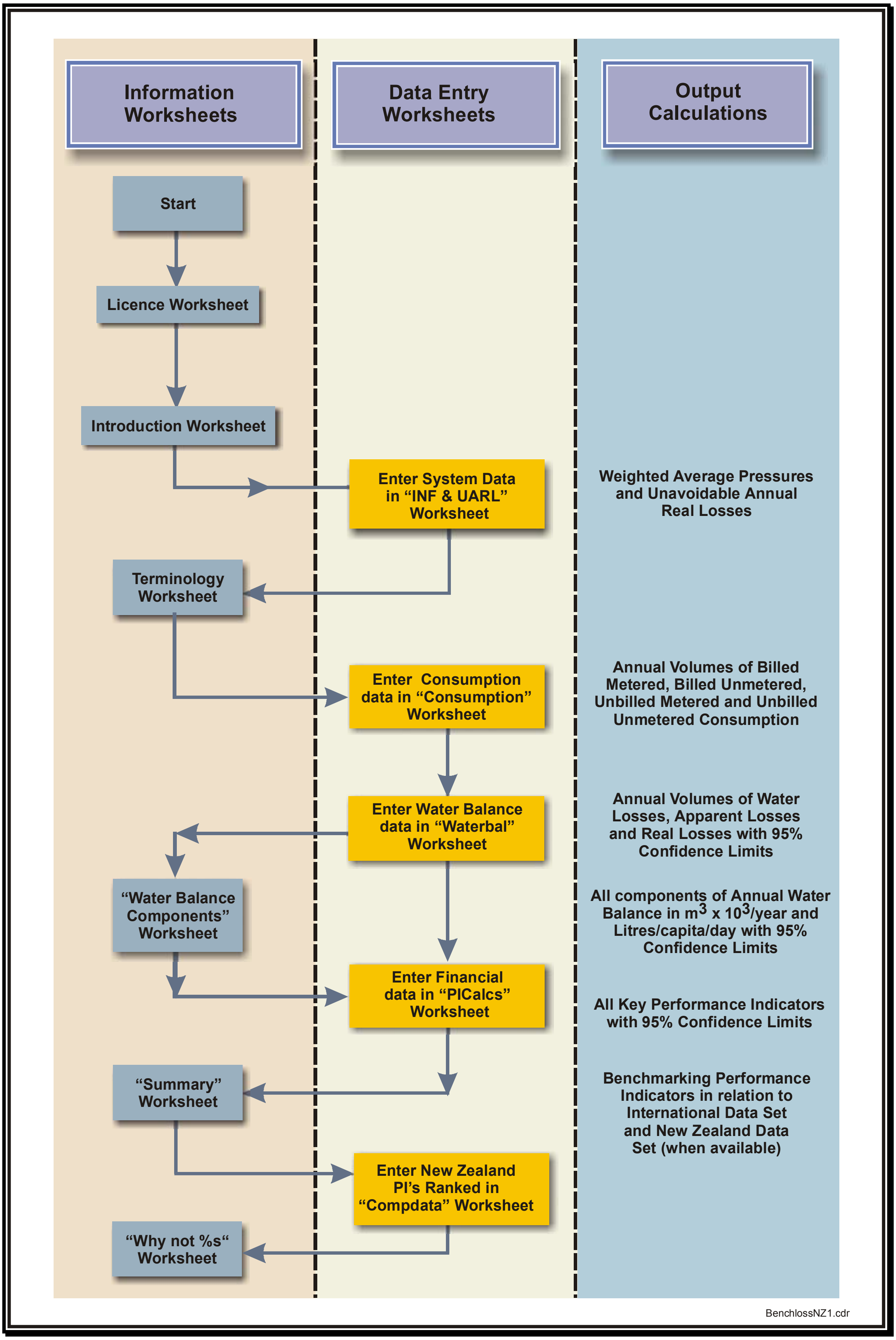

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Figure 4.1 : Procedure for using BenchlossNZ

Notes are provided throughout the Worksheets to assist the user to enter data, as required, into the yellow cells. On each Worksheet where data entry is required, there are additional yellow blocks at the bottom of the Worksheet to record the name of the person completing the Worksheet, and the date it was completed, to provide an Audit Trail.

The data entry information required is as follows;

INF&UARL Worksheet : Data Entry Sheet 1:

Section U1: General

- Name of Water Undertaking;
- Name of Water Supply System;
- Contact details (Name, Address, Telephone, Fax, e-mail).

Section U2: System Infrastructure and Resident Population

- For period ending [dd.mm.yyyy];
- Data for Calculating UARL (up to 20 individual sectors, or Whole System);
  - Zone or Sector Name or reference;
  - Length of mains (km);
  - Number of Service Connections (Ns);
  - Average operating pressure, when system pressurised (metres).

  (Note: see **Appendix H** for methods of calculating average pressure)
- Billed Properties Data (up to 20 individual sectors, or Whole System);
  - Number of metered residential properties;
  - Number of metered non-residential properties
  - Number of unmetered residential properties
  - Number of unmetered non-residential properties
- Resident Population connected to mains (up to 20 individual sectors, or Whole System);
- Description of how average pressure was assessed;

- Estimated 95% confidence limits for:
  - Length of mains (km);
  - Number of Service Connections;
  - Average operating pressure;
- Name of person who entered data, and date of entry.

Consumption Worksheet : Data Entry Sheet 2:

Note 1: Billed Water Exported is entered on the 'Water Balance' Worksheet in this updated 2008 version of BenchlossNZ

Note 2: Enter optional comments on individual items in Column J or Rows 57 to 62

Period of Data

- 12-month period of Water Balance: Start and Finish Dates [dd-mm-yyyy] and number of days in period

Billed Metered Consumption, Registered Customers (Items 1a to 1e)

- Billed Metered Residential Properties ($m^3 x 10^3$/year), with 95% conf. limits;
- Billed Metered Non-Residential Props ($m^3 x 10^3$/year), with 95% conf. limits;
- Other Billed Metered Consumption ($m^3 x 10^3$/year) with 95% conf. limits.

Billed Unmetered Consumption, Registered Customers (Items 2a to 2e)

- Residential Property average (litres/res prop/day) with 95% confidence limits
- Non-Residential Property average (litres/nrp/day) with 95% confidence limits;
- Seasonal Tourist Consumption: number per year, average duration of stay (days), average unmetered consumption in litres/capita/day, with 95% overall confidence limits;

- Other billed unmetered consumption (m^3x10^3/year), with 95% confidence limits

Unbilled Metered Consumption (Items 3a to 3c)

- Estimated components of Unbilled Metered Consumption (m^3x10^3/year) with 95% confidence limits.

Unbilled Unmetered Consumption (Items 4a to 4s)

- Default or otherwise estimated components of Unbilled Unmetered Consumption (m^3x10^3/year) with 95% confidence limits.

Private Underground Supply Pipe Leakage

- Estimated 'F-Factor' (see 'Consumption' Worksheet for explanation) and average length of private underground supply pipe (metres) for:
  - Billed metered residential properties;
  - Billed unmetered residential properties;
  - Billed metered non-residential properties;
  - Billed unmetered non-residential properties;
- Name of person who entered data, and date of entry.

Waterbal Worksheet : Data Entry Sheet 3:

Section W1b: System Input, Water Exported and Water Supplied

- Own Sources, Water Imported and Water Exported, specified in terms of:
  - Metered Volume (m^3x10^3/year), with correction to metered data (%+/-) for known systematic input meter error;
  - Any unmetered volume (m^3x10^3/year);
  - 95% confidence limits for random errors due to estimated readings etc.

Section W1e: Assessment of Apparent Losses

- Components of Unauthorised Consumption (m^3x10^3/year), with 95% confidence limits - up to 4 sub-components can be separately specified;

- Customer Metering Under-registration (%) with 95% confidence limits – for up to 4 listed components of metered consumption;
- Name of person who entered data, and date of entry.

WBComponents Worksheet : no data entry

PICalcs Worksheet : Data Entry Sheet 4:

Local Valuations of Real and Apparent Losses

- Unit Value of Real Losses (cents/m^3);
- Unit Value of Apparent Losses (cents/m^3);
- Unit Value of Unbilled Authorised Consumption (cents/m^3).

Annual Cost of Running System

- Annual Cost of Running System (Thousand dollars per year), with optional Comments.
- Name of person who entered data, and date of entry.

PICalcs Worksheet : Data Entry Sheet 5:

Section S2: Other Key Operating Factors in New Zealand

- Peak day/Average daily system input;
- Peak month/Average monthly system input.

Compdata Worksheet

- Provision for entering up to 27 ranked values of Op27, Op28 and Op29 Performance Indicator values for New Zealand Systems, when such data become available.

5. USING BENCHLOSSNZ

Printouts of each of the worksheets are shown in **Appendix I.**

5.1. THE 'LICENCE' WORKSHEET

The 'Licence' Worksheet shows:

- the name of the Water Supplier who is the Licensee of this copy of the software;
- a unique reference allocated to this Water Supplier by NZWWA ;
- The Conditions of Sale and Use.

By opening the software and proceeding from the Licence Worksheet to the other Worksheets, the User accepts the Conditions of Sale and Use .

5.2. THE 'INTRODUCTION' WORKSHEET

This outlines the procedures for using BenchlossNZ, in less detail than this User Manual, so as to provide a readily accessible source of guidance when the BenchlossNZ software is being used.

5.3. THE 'INF&UARL' WORKSHEET

Enter the General information (Water Supplier, Water Supply System, Contact details) in the yellow block on Rows 10 to 14, and the 'Period Ending' date in Cell L16.

The Infrastructure and resident population data for this Water Supply System are entered in Rows 25 to 44 (see **Figure 5.1**). If you know the overall statistics for the system under review, including the weighted average pressure, simply enter the figures in Row 25 and they will be carried forward to the 'Totals' and 'Weighted Averages' in Rows 45 and 46. BenchlossNZ calculations can be made for any size of system, sub-system, or aggregation of sub-systems. However, if the sum of 20 x Lm (mains length in km) and Number of Service Connections (Ns) is less than 3000, or the average pressure is less than 25 metres, the calculated values of Unavoidable Annual Real Losses (UARL) and Infrastructure Leakage Index (ILI) may not be reliable.

For small systems, particularly those with unmetered properties, assessments of Real Losses based on night flow measurements are an alternative option (see Appendix J)

If you want to calculate the totals and the weighted average pressure from a number of sub-systems, enter the data for each sub-system one row at a time. The 'Totals' appear on Row 45, with 'Weighted Averages' on Row 46. Weighted Average pressure is calculated based on Number of Service Connections Ns (if Density of Conns is 20/km or more), or on Length of Mains (if the Density of Connections is less than 20/km). An example of the infrastructure and resident population data for an aggregation of Sub-Systems are shown in **Figure 5.1**.

Data for Calculating UARL					Billed Properties Data (for 'Consumption' Worksheet)						**Resident Population connected to mains**
Zone or Sector Name or Reference	Length of Mains Lm km	Number of Service Connections Ns	Density of Conns per km of mains	Average Pressure Metres	Number of Metered Residential	Number of Metered Non-Residential	Number of Unmetered Residential	Number of Unmetered Non-Residential	Number of Service Connections/ Number of Properties	Check that ratio is less than 1	
Sector A	230.0	7514	32.7	65.0	6500	1000	30	20	0.995	OK	16000
Sector B	75.0	3915	52.2	61.0	3800	200	20	10	0.971	OK	9200
Sector C	55.0	2510	45.6	45.0	2400	200	15	5	0.958	OK	6000
Sector D	15.0	695	46.3	49.0	550	197	5	3	0.921	OK	1900
Sector E	50.0	267	5.3	47.0	250	17	2	1	0.989	OK	600
Sector F	135.4	601	4.4	45.0	500	100	5	3	0.988	OK	1300
Totals	**560.4**	**15502**			**14000**	**1714**	**77**	**42**		**OK**	**35000**
Weighted Averages			**27.7**	**58.9**					**0.979**		

Figure 5.1: Entry of Infrastructure and Population Data, Inf&UARL Worksheet

The software checks that the number of properties exceeds the number of service connections, and registers ‘OK’ or ‘Check’ as appropriate. Notes are provided on the Worksheet for user assistance, with optional yellow boxes for comments (e.g., relating to method of calculating average pressure).

The summarised infrastructure information appears on Rows 51 to 56 as shown in **Figure 5.2,** together with the calculated density of service connections (per km of mains). The user’s should enter best estimates of the 95% confidence limits in the yellow cells (expressed as a +/-% of the figures in the corresponding cells for ‘This System Data’. The program uses these estimates to derive estimates of 95% confidence limits for calculated values elsewhere in the software.

Input Description	Variable	Example Data	This System Data	Units	95% Conf. Limits (+/-)	Lower Estimate	Upper Estimate
Length of Mains (Transmission,Distribution,Cross-over,Rider,Sub)	Lm	1250.0	560.4	km	2.0%	549.2	571.6
Number of Service Connections	Ns	56400	15502	Number	1.0%	15347	15657
Density of Service Connections (per km of mains)	Ns/Lm	45.1	27.7	Per km	2.2%	27.0	28.3
Percentage of time system is pressurised during year	T	100.0	100.0	%			
Average operating pressure, when system pressurised	P	54.0	58.9	metres	5.0%	56.0	61.9

Figure 5.2: Summarised Infrastructure Information in INF&UARL Worksheet

It should be noted that BenchlossNZ assumes that the systems are pressurised 100% of the time. This is a fixed value that cannot be changed.

The calculation of Unavoidable Annual Real Losses then appears as shown in **Figure 5.3,** preceded by checks (Notes 7 and 8) to confirm that the system size and average pressure are adequate for UARL and ILI calculations.

U3. CALCULATION OF UNAVOIDABLE ANNUAL REAL LOSSES (UARL) for DISTRIBUTION SYSTEM							
Note 7:	Size of System for UARL & ILI Calculations: 20 x Lm + Ns =	16055	which is large enough for UARL and ILI calculations				
Note 8:	Average Pressure =	59	metres, which is large enough for UARL and ILI calculations				
Details	**Calculation**	**Example Result**	**This System's Data**	**Units**	**95% Conf. Limits (+/-)**	**Lower Estimate**	**Upper Estimate**
On mains	18 x Lm x P x 365 x T/10^8	443.48	217.04	10^3m^3/year	5.4%	205.35	228.73
On Service Connections to Street/Property boundary	0.8 x Ns x P x 365 x T/10^8	889.32	266.84	10^3m^3/year	5.1%	253.23	280.44
Total Annual Volume of Unavoidable Annual Real Losses UARL		**1332.79**	**483.88**	10^3m^3/year	5.1%	459.15	508.60
UARL in litres/service conn./day when the system is pressurised	Annual Volume of UARL x 10^6 / (Ns x 365 x T/100)	**64.7**	**85.5**	Litres/ conn./day	5.2%	81.1	90.0

Figure 5.3: Calculation of UARL in the Inf&UARL Worksheet

The name of the person completing the calculation, and the date on which the calculation was carried out should be completed at the bottom of the worksheet in the yellow blocks provided.

5.4. THE 'TERMINOLOGY' WORKSHEET

If you are unsure about any aspect of the Water Balance calculation, or the definitions of the standard terminology, open the 'Terminology' Worksheet and refer to the figure which provides the same details as those shown in **Figure 2.2** of this User Manual.

5.5. THE 'CONSUMPTION' WORKSHEET

Although this Worksheet categorises and requests data for many different elements of consumption, users should not be intimidated as the most time-consuming small unmeasured components (Unbilled Unmetered Consumption, Rows 31 to 52) can (in this updated version of BenchlossNZ) be assessed using guideline default estimates on Row 32. For systems with unmeasured properties, the largest single component of error is likely to be assumed consumption 'per property per day', and most effort should be spent on assessing that component rather than the minor components. Accordingly, Rows 64 to 88 provide a systematic methodology for estimating losses from unmeasured supply pipes, dependent upon several factors including average pressure. These estimated should then be included in the 'per property' consumption estimates in Cells M20 and M21.

Components of Authorised Consumption (excluding Water Exported)

***Note:** In this 2008 version of BenchlossNZ, **Billed Water Exported** is entered on the WaterBal Worksheet, instead of on the CONSUMPTION Worksheet as in the 2002 version of BenchlossNZ.*

The first section of the CONSUMPTION Worksheet is shown in **Figure 5.4.**

Components of Authorised Consumption (excluding Water Exported)		Consumption in $10^3 m^3$ per year					Comments and Details Relating to Data	
Item	Description	Billed Metered	Billed Unmetered	Unbilled Metered	Unbilled Unmetered	95% conf. Limits (+/-)	E = Estimated R = Based on recordings	
1	**Billed Metered Consumption, registered customers**							
1.a	Billed metered residential properties	3832.00				2.0%	R	From records of 14000 residential properties
1.b	Billed metered non-residential properties	1251.00				3.0%	R	From records of 1714 non-residential properties
1.c	Other billed metered consumption (specify)						R	
1.d	Other billed metered consumption (specify)						R	
1.e	Other billed metered consumption (specify)						R	
	Total of Billed Metered Consumption Items 1a to 1e	5083.00				1.7%		

Figure 5.4: Billed Metered Consumption Data in CONSUMPTION Worksheet

Enter the data for Billed Metered Consumption. First enter Billed Metered volumes for residential and non-residential properties; the numbers of each of these types of properties (green cells) have been brought forward from the 'INF&UARL' Worksheet. Next enter the 95% confidence limits for the recorded metered volumes; these are the random errors arising from administrative problems (estimated readings for stopped or unread meters, problems in matching meter reading dates with the start and finish dates of the Water Year, etc); systematic errors due to under-recording of customer meters will be entered under 'Apparent Losses' in the 'Waterbal' Worksheet.

Enter descriptions, volumes, 95% confidence limits and details of any other billed metered consumption. The sum of the billed metered volumes (excluding water exported) appears at the bottom of Items 1a to 1e with its 95% confidence limits.

Billed Unmetered Consumption

This section of the Worksheet is shown in **Figure 5.5.** The number of billed unmetered residential properties, and the number of billed unmetered non-residential properties, have been brought forward from the INF&UARL Worksheet. Enter your best estimates of 'per property per day' consumption for each of these components, and the calculated annual volumes appear. Comments on how you assessed these figures should be entered in Rows 58 to 63, with estimated 95% confidence limits in Cells H21 and H22. See **Section 3.4**, and **Appendix D** of this User Manual for further information on estimating the supply pipe leakage component of unmeasured ‘per property’ consumption.

Components of Authorised Consumption (excluding Water Exported)		Consumption in 10^3m^3 per year					Comments and Details Relating to Data							
Item	Description	Billed Metered	Billed Unmetered	Unbilled Metered	Unbilled Unmetered	95% conf. Limits (+/-)	E = Estimated R = Based on recordings							
2	Billed Unmetered Consumption, registered customers													
2.a	Billed unmetered residential properties		25.29			20.0%	E	77	residential props @		900	lit/res prop/day		
2.b	Billed unmetered non-residential properties		23.00			20.0%	E	42	non-res props @		1500	l/non-res prop/day		
2.c	Seasonal/Tourist additional consumption		1.68			30.0%	E	1000	for	14	days @	120	l/cap/d	
2.d	Other billed unmetered cons. (specify)						E							
2.e	Other billed unmetered cons. (specify)						E							
	Total of Billed Unmetered consumption Items 2a to 2e		49.97			13.7%								

Figure 5.5: Billed Unmetered Consumption Data in CONSUMPTION Worksheet

Next, calculate the volume of unmetered consumption by tourists. Enter the estimated annual number of tourists, the average length of stay (in days), and the average consumption per tourist per day; the software then calculates the annual volume. Enter the estimated 95% confidence limits for this value, and any additional comments. Enter descriptions, volumes, 95% confidence limits and details of any other billed unmetered consumption. The sum of the billed unmetered volumes appears at the bottom of Items 2a to 2e with its 95% confidence limits.

Unbilled Metered and Unbilled Unmetered Consumption

These sections of the Worksheet are shown in **Figures 5.6 and 5.7** respectively.

Components of Authorised Consumption (excluding Water Exported)		Consumption in 10^3m^3 per year					Comments and Details Relating to Data	
Item	Description	Billed Metered	Billed Unmetered	Unbilled Metered	Unbilled Unmetered	95% conf. Limits (+/-)	E = Estimated R = Based on recordings	
3	Unbilled metered consumption							
3.a	Water Operations Depot Consumption			3.50		2.0%	R	
3.b	Specify if applicable						R	
3.c	Specify if applicable						R	
	Total unbilled metered consumption			3.50		2.0%		

Figure 5.6: Unbilled Metered Consumption Data in CONSUMPTION Worksheet

Identify any known components of Unbilled Metered Consumption as shown in **Figure 5.6**. This category covers situations where a water supplier has metered consumption to assess volumes, but this consumption is not charged for. *[Note: in cases where customers are metered, but charges are made based on some other method than the recorded volumes, such volumes should be entered under 'Billed Metered Consumption].* Enter descriptions, volumes, 95% confidence limits and details of any components of unbilled metered consumption. The sum of the billed unmetered volumes appears with its 95% confidence limits.

The next step is to assess Unbilled Unmetered Consumption. This category usually covers a wide variety of situations where relatively small quantities of water are used by the water supplier, Fire Services, contractors etc. In this 2008 updated version of Benchloss NZ, the calculation can be simplified by using a guideline default estimate as shown on the 'Default' Row at the top of this Section, as shown in **Figure 5.7** below. To do this calculation, move to the 'WaterBal' Worksheet, complete Section W.1.b (Rows 18 to 27), identify the 'Water Supplied' volume in Cell L27. Then return to the Consumption Worksheet, and follow the instructions in the right hand box of the 'Default' Row. The default estimate is automatically assigned 95% confidence limits of +/- 100%.

Components of Authorised Consumption (excluding Water Exported)		Consumption in $10^3 m^3$ per year					Comments and Details Relating to Data	
Item	Description	Billed Metered	Billed Unmetered	Unbilled Metered	Unbilled Unmetered	95% conf. Limits (+/-)	E = Estimated R = Based on recordings	
4	Unbilled unmetered consumption							
Default	In accordance with guideline default estimate that Unbilled Authorised Consumption equal to 0.5 % of Water Supplied can be used				28.30	100.0%	E	Volume to be entered in Cell G32 is 0.5% of Water Supplied in Cell L27 of WaterBal Worksheet, minus any volume in Cell F30 of this Consumption Worksheet
4.a	System cleaning: Annual flushing program						E	Estimated from flushing records
4.b	System cleaning: Discharge from Hydrants						E	Sum of events x duration x flow rate
4.c	System cleaning: Cleaning of Reservoirs						E	Specify events and volume discharged to waste
4.d	System cleaning: Flushing of New Mains						E	[ ]km laid at [ ]m^3/km
4.e	System cleaning: Flushing of Renewed Mains						E	[ ] km renewed at [ ]m^3/km
4.f	Fire Services: filling engines						E	Estimated on basis of ....
4.g	Fire Services: water taken direct from mains						E	Estimated from actual fire events
4.h	Fire Services: training using hydrants						E	Based on No. of events in period x average m3 per event
4.I	Fire Services: Testing of Sprinkler Lines						E	Number of lines x Tests in period x Volume per test
4.j	Use of Hydrants by others: Sewer Flushing						E	Estimated on basis of ....
4.k	Use of Hydrants by others: Street Cleaning						E	Estimated on basis of ....
4.l	Backflow Prevention Testing						E	Lines with meter bypass tested x Volume per test
4.m	Temporary services during mains renewal						E	Number of jobs at [ ]m^3 per job
4.n	Other (specify)						E	
4.o	Other (specify)						E	
4.p	Other (specify)						E	
4.q	Other (specify)						E	
4.r	Other (specify)						E	
4.s	Other (specify)						E	
	Total unbilled metered consumption				28.30	100.0%		
TOTALS:		5083.00	49.97	3.50	28.30			

Figure 5.7: Unbilled Unmetered Consumption in CONSUMPTION Worksheet

If a more detailed assessment of Unbilled Unmetered Authorised Consumption is required, some typical descriptions of the likely components are listed **(see Figure 5.7)** in Items 4a to 4s for guidance, and additional components can be described in the 'Other (specify) Rows. Enter descriptions, volumes, 95% confidence limits and details of any components. The sum of the Unbilled Unmetered volume appears with its 95% confidence limits.

The totals for each type of authorised consumption appear on the bottom row of **Figure 5.7**, they next appear on the 'WATERBAL' Worksheet. Space is provided for additional comments to be made relating to any of the 'Consumption' items on Rows 57 to 62 of the 'Consumption' Worksheet.

Underground Supply Pipe Leakage

The remainder of the 'Consumption' Worksheet provides supplementary information and calculations (not directly used in the remainder of 'BenchlossNZ') relating to the estimation of underground supply pipe losses on customers' private pipework, which forms part of the volume of consumption passing the street/property boundary.

Underground supply pipe losses consist of background leakage, reported leaks and unreported leaks. The equation for externally metered properties with Class D meters read every 6 months is the same as the IWA Formula for Unavoidable Annual Real Losses (UARL) on underground supply pipes **(Ref 6),** and produces an estimate for English conditions which is the same as that quoted for independently assessed data by Office of Water Services, the Economic Regulator **(Ref. 5)**. By entering appropriate figures in the Table shown in **Figure 5.8**, the user can obtain estimates of the average annual underground supply pipe losses for each of four categories of property in the system under review.

Category of Private Underground Supply Pipe	Assumed F-Factor	Average Lp in metres per property	Average Pressure Metres	Estimated Underground Supply Pipe Leakage			
				Litres per property per day	m^3 per property per year	Number of properties	$m^3 \times 10^3$ per year
Billed metered residential properties	1.0	15	58.9	22	8	14000	113.0
Billed unmetered residential properties	4.0	15	58.9	88	32	1714	55.3
Billed metered non-residential properties	1.0	50	58.9	74	27	77	2.1
Billed unmetered non-residential properties	4.0	10	58.9	59	22	42	0.9

Figure 5.8 Estimating Underground Supply Pipe Losses, in CONSUMPTION Worksheet

The name of the person completing the Consumption Worksheet calculation, and the date on which the calculation was carried out should be completed at the bottom of the worksheet in the yellow blocks provided.

5.6. THE 'WATERBAL' WORKSHEET

This Worksheet is used for adding and subtracting components of the annual water balance until all the components of Non Revenue Water have been identified:

- The System Input (consisting of Own Sources and Water Imported) is calculated
- Water Exported is then deducted to identify Water Supplied
- Other Billed Authorised Consumption volumes from the 'Consumption' Worksheet are brought forward and subtracted from the Water Supplied to obtain the Non-Revenue Water volume.
- Unbilled Authorised Consumption volumes from the 'Consumption' Worksheet are brought forward and subtracted from the Non Revenue Water to obtain the Water Losses
- Components of Apparent Losses are then assembled and deducted from the Water Losses, to obtain the annual volume of Real Losses.

Section W1b: System Input, Water Exported and Water Supplied

Enter the recorded metered volumes for 'Own Sources' and 'Water Imported' to obtain the 'System Input' volume, then enter 'Water Exported' to obtain 'Water Supplied', as shown in **Figure 5.9.** If there are any known systematic errors in the source and bulk meters (e.g. in-situ meter calibration shows average over-registration or under-registration) enter the appropriate correction as a +/-%. Enter estimates of any input from unmetered sources. Enter best estimates of the +/- 95% confidence limits for random errors in 'Own Sources' and 'Water Imported', for example due to errors in recording of telemetry/scada data transfer.

W1b. System Input (= Own Sources + Water Imported); Water Exported; Water Supplied (= System Input - Water Exported)

Components of System Input	Example Data					This System's Data					
	Metered $10^3m^3/yr$	Correction to metered volumes		Unmetered $10^3m^3/yr$	Total $10^3m^3/yr$	Metered $10^3m^3/yr$	Correction to metered volumes		Unmetered $10^3m^3/yr$	Total $10^3m^3/yr$	95% Conf. Limits (+/-)
		+/- %	$10^3m^3/yr$				+/- %	$10^3m^3/yr$			
Own Sources:						6527.0	-1.00%	-65.3		6461.7	2.0%
Water Imported	14400.0				14400.0						
System Input	**14400.0**				**14400.0**	**6527.0**		**-65.3**		**6461.7**	**2.0%**
Water Exported						100.0	1.00%	1.0		101.0	2.0%
Water Supplied	**14400.0**				**14400.0**	**6427.0**		**-66.3**		**6360.7**	**2.0%**

Figure 5.9: System Input, Water Exported and Water Supplied in the WATERBAL Worksheet

Section W1c: Components of Billed Authorised Consumption by Registered Customers (excluding Water Exported)

All the data in this Section have been automatically summarised and carried over from the ‘Consumption’ Worksheet, so no data entry is required. **Figure 5.10** shows an example from the WaterBal Worksheet

W1c. Components of Billed Authorised Consumption by Registered Customers (excluding Water Exported)

Components of Billed Authorised Consumption by Registered Customers	Example Data in 10^3m^3/year					This System's Data in 10^3m^3/year					
	Billed Metered	Billed Unmetered	Unbilled Metered	Unbilled Unmetered	Total	Billed Metered	Billed Unmetered	Unbilled Metered	Unbilled Unmetered	Total	95% Conf. Limits (+/-)
Billed Metered Residential	9525.0				9525.0	3832.0				3832.0	2.0%
Billed Metered Non-Res.	3010.0				3010.0	1251.0				1251.0	3.0%
Other Billed metered											
Billed Unmetered Residential							25.3			25.3	20.0%
Billed Unmetered Non-Res.							23.0			23.0	20.0%
Other billed unmetered							1.7			1.7	30.0%
TOTALS:	12535.0				12535.0	5083.0	50.0			5133.0	1.7%

Figure 5.10: Billed Authorised Consumption by Registered Customers (excluding Water Exported) in the WATERBAL Worksheet

Section W1d: Components of Unbilled Authorised Consumption (excluding Water Exported)

All the data in this Section have been automatically summarised and carried over from the ‘Consumption’ Worksheet, so no data entry is required. A check is provided to compare the Unbilled Authorised Consumption (as a % of Water Supplied) against the guideline default value of 0.50%. **Figure 5.11** shows an example from the WaterBal Worksheet

W1d: Components of Unbilled Authorised Consumption (excluding Water Exported)

Components of Unbilled Authorised Consumption	Example Data in 10^3m^3/year					This System's Data in 10^3m^3/year					
	Billed Metered	Billed Unmetered	Unbilled Metered	Unbilled Unmetered	Total	Billed Metered	Billed Unmetered	Unbilled Metered	Unbilled Unmetered	Total	95% Conf. Limits (+/-)
Unbilled metered			10.0		10.0			3.5		3.5	2.0%
Unbilled unmetered									28.3	28.3	100.0%
TOTALS:			10.0		10.0			3.5	28.3	31.8	89.0%
	CHECK: Recommended default for Unbilled Authorised Consumption =				0.50%	of Water Supplied; calculations used for this system imply UAC is				0.50%	of Water Supplied

Figure 5.11: Components of Unbilled Authorised Consumption in WATERBAL Worksheet

Section W1e: Non Revenue Water and Water Losses

In Section W1e. Non Revenue Water is automatically calculated as:

Water Supplied - Billed Authorised Consumption by Registered Customers

together with 95% confidence limits.

Water Losses – consisting of Apparent Losses and Real Losses, and being the difference between ‘Non Revenue Water’ and ‘Unbilled Authorised Consumption’ are also automatically calculated and appear in the Worksheet, with confidence limits, as shown in **Figure 5.12**

W1e. Non Revenue Water NRW and Water Losses						
Details	**Example Data**	**This System's Data**	**Units**	**95% Conf. Limits (+/-)**	**Lower Estimate**	**Upper Estimate**
NRW = Water Supplied - Billed Authorised Consumption, Registered Customers	1865.0	1227.8	10^3m^3/year	12.6%	1072.7	1382.8
Water Losses = Non Revenue Water – Unbilled Authorised Consumption	1855.0	1196.0	10^3m^3/year	13.2%	1038.4	1353.6

Figure 5.12 : Calculation of Non Revenue Water and Water Losses in WATERBAL Worksheet

Section W1f: Assessment of Apparent Losses

Water Losses consist of Apparent Losses and Real Losses. The next step in the calculations is to assess the components of Apparent Losses. These consist of Unauthorised Consumption, and Customer Meter Under-Registration.

Figure 5.13 shows that up to four sub-components of Unauthorised Consumption can be specified, with separate 95% confidence limits. A check is provided to compare the Unbilled Authorised Consumption (as a % of Water Supplied) against the guideline default value of 0.1%.

W1f. Assessment of Apparent Losses									
Unauthorised Consumption				**Example Data**	**This System's Data**	**Units**	**95% Conf. Limits (+/-)**	**Lower Estimate**	**Upper Estimate**
Default estimate of 0.1% of Water Supplied				6.0	6.4	10^3m^3/year	100.0%		12.8
Alternative more detailed estimate of components (if Cell H62 = 0.0)	e.g. Unauthorised use of fire hydrants					10^3m^3/year			
	e.g. Unauthorised use of fire connections					10^3m^3/year			
	e.g. Illegal by-passing of customer meters					10^3m^3/year			
Sub-total for Unauthorised Consumption				**6.0**	**6.4**	10^3m^3/year	**100.0%**		**12.8**
	CHECK: Recommended default for Unauthorised Consumption =			**0.10%**	of Water Supplied; calculations used for this system imply UC is			**0.10%**	of Water Supplied
Customer Meter Under-registration		**Recommended default %**	**% used in this system calculation**	**Example Data**	**This System's Data**	**Units**	**95% Conf. Limits (+/-)**	**Lower Estimate**	**Upper Estimate**
Average % under-registration of	Residential meters	2.0%	2.0%	190.5	76.6	10^3m^3/year	50.0%	38.3	115.0
	Non-residential meters	2.0%	2.0%	60.2	25.0	10^3m^3/year	50.0%	12.5	37.5
	'Other' billed meters	2.0%	2.0%			10^3m^3/year	50.0%		
	'Other' unbilled meters	2.0%	2.0%	0.2	0.1	10^3m^3/year	50.0%	0.0	0.1
Sub-total for Customer Meter Under-registration				**250.9**	**101.7**	10^3m^3/year	**39.6%**	**61.4**	**142.0**
TOTAL for Apparent Losses				**256.9**	**108.1**	10^3m^3/year	**37.7%**	**67.3**	**148.9**

Figure 5.13: Assessment of Apparent Losses in WATERBAL Worksheet

For Customer Meter Under-registration, the recommended default values are shown in the purple cells. Specify the % systematic under-recording for each category of metered consumption in the yellow cells, and the software calculates the volumes. Enter estimated 95% confidence limits for each component. The Apparent losses total, with 95% confidence limits, appears at the bottom of Section W1.f.

Section W1g: Real Losses

Real Losses – being the difference between 'Water Losses' and 'Apparent Losses' are automatically calculated and appear in the Worksheet as shown in **Figure 5.14**

W1g. Current Annual Real Losses (CARL) = Water Losses minus Apparent Losses

Details	Example Data	This System's Data	Units	95% Conf. Limits (+/-)	Lower Estimate	Upper Estimate
Current Annual Real Losses = Water Losses – Apparent Losses	1598.1	1087.8	$10^3 m^3$/year	15.0%	925.0	1250.6

Figure 5.14: Calculation of Real Losses included in WATERBAL Worksheet

The name of the person completing the Waterbal Worksheet calculation, and the date on which the calculation was carried out should be completed at the bottom of the worksheet in the yellow blocks provided.

5.7. THE 'WBCOMPONENTS' WORKSHEET

This Worksheet takes the volume components calculated in the 'WaterBal' Worksheet as in **Figure 5.15** and assigns them to the boxes shown in the 'Terminology' Worksheet. The user can then produce Pie Charts of various components on the unprotected Rows of this Worksheet, examples are shown in **Figure 5.16**.

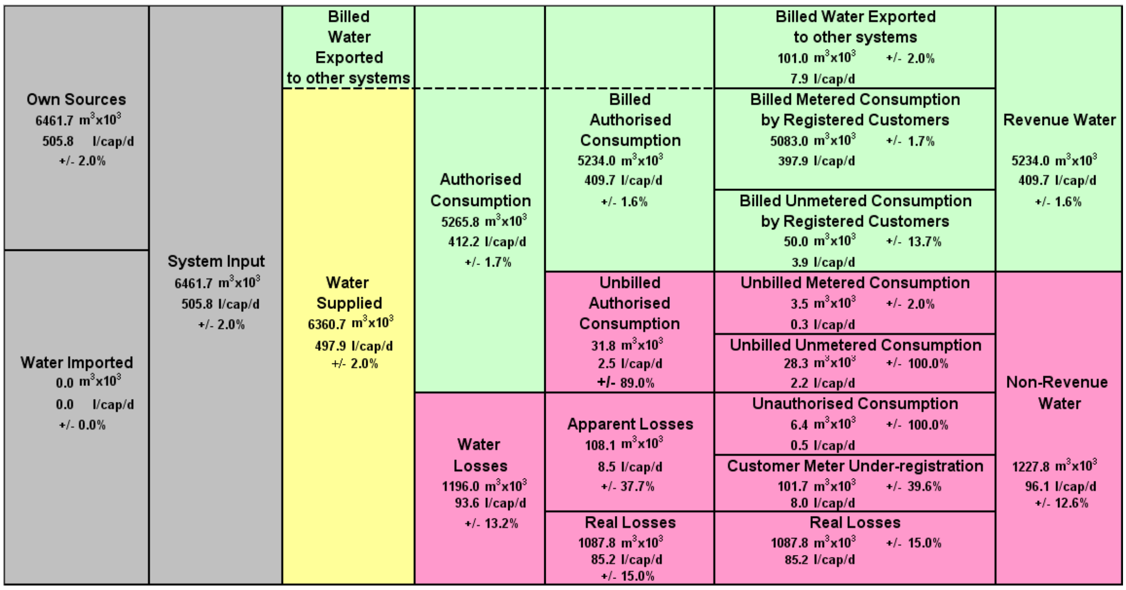

Figure 5.15: The WBComponents Worksheet

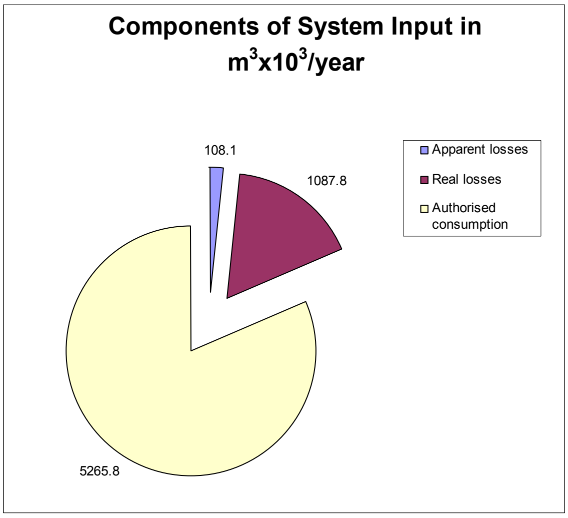

Figure 5.16: Components of System Input, WBComponents Worksheet

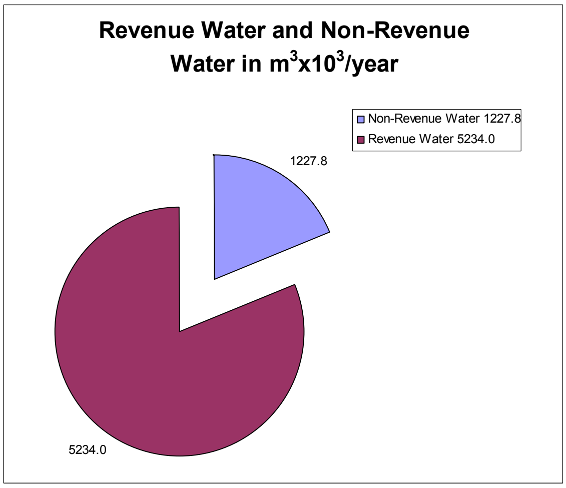

Figure 5.17: Revenue and Non-Revenue Water, WBComponents Worksheet

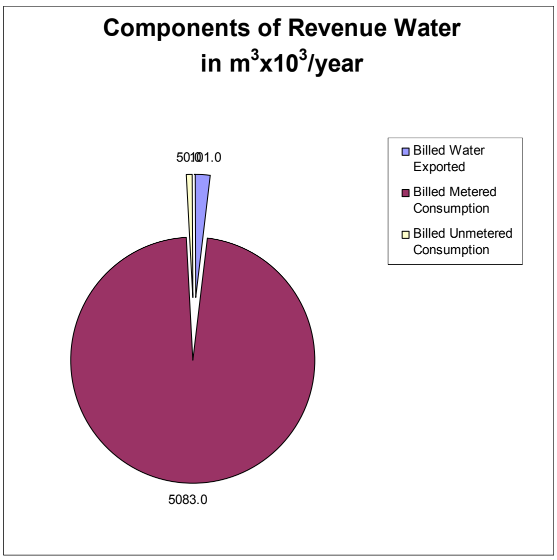

Figure 5.18: Components of Revenue Water, WBComponents Worksheet

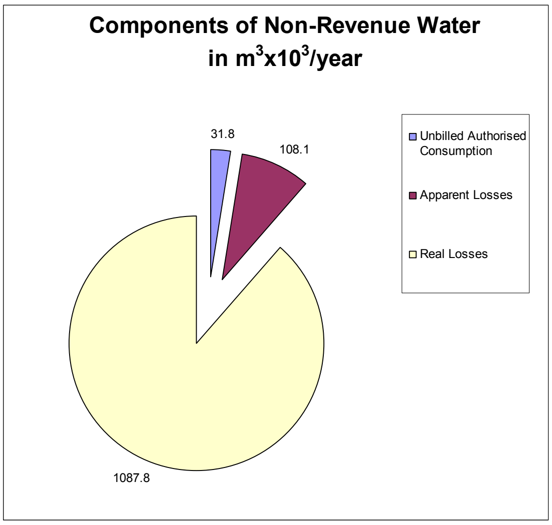

Figure 5.19: Components of Non- Revenue Water, WBComponents Worksheet

5.8. THE 'PICALCS' WORKSHEET

This Worksheet is used to calculate 3 'Operational Management' Performance Indicators for Real Losses, 1 'Operational Management' Performance Indicators for Apparent Losses and 1 'Financial' Performance Indicators for Non-Revenue Water. These are considered as likely to be the most useful and appropriate for NZWWA members.

Operational Management Performance Indicators for Real Losses
Op 27: Litres/Service Connection/Day
Op 28: m^3/km mains/day
Op 29: Infrastructure Leakage Index ILI

These Performance Indicators are calculated by the software and appear as shown in **Figure 5.20.**

Op27 and Op28 are the best of the traditional simple performance indicators for assessing effectiveness of managing distribution systems for control of Real Losses; the choice of scaling factor – service connections or length of mains – depends on the density of connections. Although these PIs do not take into account system-specific factors that are important for 'between water supplier' comparisons, - Average Operating Pressure, actual Density of Service Connections, or Location of Customer meters (relative to the street/property boundary) – they are well suited to process benchmarking, in which a particular water supplier monitors its own progress in managing Real Losses.

IWA Op27: Operational PI for Real Losses if Connection Density 20/km mains or more: Litres/Service Connection/day							
Details	**Calculation**	Example Data	This System's Data	Units	95% Conf. Limits (+/-)	Lower Estimate	Upper Estimate
Current Annual Real Losses expressed in Litres/service connection/day, when system is pressurised	CARL x 10^6 / (Ns x T/100 x 365)	**78**	**192**	Litres /conn./ day	15.0%	**163**	**221**

IWA Op28: Operational PI for Real Losses if Connection Density < 20/km mains: m^3/km mains/day							
Details	**Calculation**	Example Data	This System's Data	Units	95% Conf. Limits (+/-)	Lower Estimate	Upper Estimate
Current Annual Real Losses expressed in m^3/km of mains/day, when system is pressurised	CARL x 10^3 / (Lm x T/100 x 365)	**3.5**	**5.3**	m^3/km./ day	15.1%	**4.5**	**6.1**

IWA Op29:Operational PI for Real Losses: Infrastructure Leakage Index (ILI)							
Details	**Calculation**	Example Data	This System's Data	Units	95% Conf. Limits (+/-)	Lower Estimate	Upper Estimate
ILI is the ratio of Current Annual Real Losses (CARL) to Unavoidable Annual Real Losses (UARL)	CARL / UARL	**1.20**	**2.25**	None	15.8%	**1.89**	**2.60**

Figure 5.20: Calculation of the Operational Management Performance Indicators for Real Losses in the PICalcs Worksheet.

The Infrastructure Leakage Index (ILI) is the most detailed of the Performance Indicators for Real Losses. It takes account of the three system-specific key factors identified by the IWA Task Force on Water Losses and is the most appropriate Performance Indicator for metric benchmarking, comparing the performance of NZWWA members with each other and water suppliers in other countries. It is a non-dimensional index which assesses the overall efficiency of management of Real Losses in the system infrastructure at the current operating pressure, and is calculated by dividing the Current Annual Real Losses (CARL) by the Unavoidable Annual Real Losses (UARL, calculated on a system-specific basis). Where water is expensive, or scarce (or both), the objective should be to achieve an ILI not greatly in excess of 1.0

Operational Management Performance Indicators for Apparent Losses

Apparent Losses as % by volume of metered consumption (excluding Water Exported)

At the time of preparing this update, the Apparent Losses Group of the IWA Water Loss Task Force had not yet finalised recommendations for an Apparent Losses Operational PI, but there are three principal options for simple PIs (% of Water Supplied, litres/service connection/day, and % of metered consumption), and the future possibility of a more detailed PI, the Apparent Losses Index (ALI) with similarities to the Infrastructure Leakage Index (ILI) for Real Losses.

Given that the principal component of Apparent Losses in New`Zealand is likely to be customer meter under-registration, '% of metered consumption (excluding Water Exported)' has been selected as the most logical choice for a simple Apparent Losses PI for this 2008 update of BenchlossNZ. It is also the only one of the three simple Apparent Loss PI options that does not discriminate against water suppliers which meter residential properties

This Performance Indicator is calculated by the software and appears as shown in **Figure 5.21.**

Operational PI for Apparent Losses: % by volume of Metered Consumption (excluding Water Exported)								
Details	**Calculation**	**Example Data**	**This System's Data**	**Units**	**95% Conf. Limits (+/-)**	**Lower Estimate**	**Upper Estimate**
Apparent Losses expressed as a % by volume of Metered Consumption (excluding Water Exported)	Apparent Losses (10^3m^3/yr) x 100 / Metered Consumption (10^3m^3/yr)	2.0%	2.1%	%	37.8%	1.3%	2.9%

Figure 5.21: Calculation of the Operational Management Performance Indicator for Real Losses in PICalcs Worksheet.

Financial Performance Indicator for Non-Revenue Water:
Fi47: Value of Non-Revenue Water as % of Cost of Running System

Because of previously explained problems with using %s by volume as Performance Indicators, Fi47 is the only recommended Financial PI now included in this 2008 update of BenchlossNZ. The first step in the calculations is to place valuations (in cents/m^3) on each of the component volumes of Non-Revenue Water. This requires the User to enter valuations in the yellow cells, as shown in **Figure 5.22.** See the Notes in Cell H39 for basic guidance on assessing these valuations. Values must be entered in all three Cells F40, F41 and F42 for the calculation of Fi47 to be completed – see also Note in Cell K55.

Details	Example Data	This System's Data	Units
Unit Value of Real Losses	40.0	10.0	cents/m^3
Unit Value of Apparent Losses	150.0	70.0	cents/m^3
Unit Value of Unbilled Authorised Consumption	100.0	30.0	cents/m^3

Figure 5.22: Entering Local Valuations for Non-Revenue Water in the PICalcs Worksheet.

The final item of data needed to calculate the recommended Performance Indicator for Non-Revenue Water (Fi47) is the Total Annual Running Cost, excluding annual net interest and depreciation. This is entered as shown in the example in **Figure 5.23.** Comments can be added if appropriate.

Annual Cost of Running Water Supply System				
Details	**Example Cost**	**This System's Cost**	**Units**	Comments:
Annual Cost of running system in 1000's of Dollars per year	16000	6500	10^3 \$/year	

Figure 5.23: Entering Annual Cost of Running Water Supply System in PICalcs Worksheet.

Using the valuations placed on components of Non-Revenue Water, and the Annual Running Cost, the software calculates the percentages **by value** of the Components of Non-Revenue Water, as shown **Figure 5.24.**

IWA Fi47: Non-Revenue Water as % by Value of Cost of Running System	Example Data				This System's Data				
Components of Non-Revenue Water	Volume m^3x10^3/yr	Unit Value cents/m^3	Value 10^3 \$/year	% of Annual Running Costs	Volume m^3x10^3/yr	Unit Value cents/m^3	Value 10^3 \$/year	% of Annual Running Costs	
Unbilled Authorised Consumption	10.0	100.0	10.0	0.06	31.8	30.0	9.5	0.15	**Note**: if Unit values are not entered in **all** of the Cells F40 to F42, the calculation of IWA Fi47 will not occur and an 'n/a' will appear in Cell J58.
Apparent Losses:	256.9	150.0	385.4	2.41	108.1	70.0	75.7	1.16	
Real Losses:	1598.1	40.0	639.2	4.00	1087.8	10.0	108.8	1.67	
Total Unbilled:	**1865.0**		**1034.6**	**6.47**	**1227.8**		**194.0**	**2.98**	

Figure 5.24: Calculation of Financial Performance Indicator Fi47 for Non-Revenue Water in PICalcs Worksheet

For users who would wish to see a figure of NRW % by volume – even though it is not recommended as a PI in this 2008 version of BenchlossNZ – a calculation of NRW as a % by volume of Water Supplied is also shown on the PICalcs Worksheet., as in Figure **5.25.** This comparison highlights the importance of placing valuations – even approximate ones) on components of Non Revenue Water. The NRW% by value is usually significantly less than the NRW% by volume, unless Real Losses and Apparent Losses are assigned the same value in cents/m^3.

	Example Data			This System's Data					
Components of Non-Revenue Water	Volume m^3x10^3/yr	Water Supplied m^3x10^3/yr	% of Water Supplied	Volume m^3x10^3/yr	Water Supplied m^3x10^3/yr	% of Water Supplied	95% Confidence Limits (+/-)	Lower Estimate (%)	Upper Estimate (%)
Unbilled Authorised Consumption	10.0	14400.0	0.1%	31.8	6360.7	0.5%	89.0%	0.1%	0.9%
Apparent Losses:	256.9	14400.0	1.8%	108.1	6360.7	1.7%	37.7%	1.1%	2.3%
Real Losses:	1598.1	14400.0	11.1%	1087.8	6360.7	17.1%	15.0%	14.5%	19.7%
Total Non-Revenue Water	**1865.0**	**14400.0**	**13.0%**	**1227.8**	**6360.7**	**19.3%**	**12.8%**	**16.8%**	**21.8%**

Figure 5.25: Comparative calculation of Non-Revenue Water as % by volume of Water Supplied, in PICalcs Worksheet.

The name of the person completing the PICalcs Worksheet calculation, and the date on which the calculation was carried out should be completed at the bottom of the worksheet in the yellow blocks provided.

5.9. THE 'SUMMARY' WORKSHEET

This Worksheet:

- summarises the key factors of the System
- shows the calculated Performance Indicators
- assigns the Operational PIs for Real Losses to Band A, B, C or D in the World Bank Institute Banding System
- compares the Real Losses PIs with the original IWA international data set **(Ref 6).**
- Allows for comparisons with a New Zealand data set, when such a data set becomes available.

Section S1: Key Operating Factors Which Influence Unavoidable Annual Real Losses (UARL)

In this Section, the three Key Operating Factors which influence UARL are compared with the ranges of these factors in the International Data Set (**Ref. 6**). These comparisons are shown in **Figure 5.26.** In the New Zealand BenchlossNZ software, all consumption through service connections, whether metered or unmetered, is considered to take place at the street:property boundary.

S1. KEY OPERATING FACTORS WHICH INFLUENCE UNAVOIDABLE ANNUAL REAL LOSSES (UARL)					
Key Operating Factor	International Range			Actual Figure for this System	Units
	Low	Medium	High		
Average Operating Pressure	30	45	100	58.9	Metres
Customer meter location	Zero	10	30	Zero	Metres after edge of street
Density of connections	20	45	120	27.7	Connections per km of mains

Figure 5.26: Comparison of Key Operating Factors with International Data Set

Section S2: Other Key Operating Factors in New Zealand which may Influence Calculations and Comparisons

The higher the percentage of total consumption which is metered, the greater the reliability of the calculated volume of Real Losses. In systems with low %s of metered properties, the estimated figure for unmetered residential consumption in litres/residential property/day will have a significant influence on the calculated volume of Real Losses

Enter the Peak Day to Average Daily System Input, and the Peak Month to Average Monthly System Input. High values for these factors may categorise systems which have surplus capacity for parts of the year. Spaces for the data entries are shown in **Figure 5.27.**

S2. OTHER KEY OPERATING FACTORS IN NEW ZEALAND WHICH MAY INFLUENCE CALCULATIONS AND COMPARISONS					
Key Operating Factor	New Zealand Range			Actual Figure for this System	Units
	Low	Medium	High		
% of consumption that is metered	5	25	100	98.5%	% of total consumption
Assumed unmetered res. consumption	350	600	1000	900	litres/residential property/day
Peak Day/Ave. Daily System Input	1.2	1.5	5.0		Non-dimensional
Peak Month/Ave. Monthly System Input	1.0	1.2	3.0		Non-dimensional

Figure 5.27: Comparison of Key Operating Factors with International Data Set

Section S3: NZWWA Recommended Performance Indicators for Real Losses, Apparent Losses and Non-Revenue Water

The presentation of the five Performance Indicators on this Worksheet is shown in **Figure 5.28.** In the ‘PI for this System’ column, the central figures are the best estimates, with the +/-95% confidence limits shown in italics above and below.

The calculation of NRW as a % of Water Supplied volume is shown just below recommended PIs in Figure 5.28, followed by Notes 1 to 7.

S3: RECOMMENDED PERFORMANCE INDICATORS								
Viewpoint	Level of PI	Performance	World Bank Institute Band (see Note 1)				PI for this System	Units
			A	B	C	D		
Operational Management of Real Losses at Current Pressure	IWA Op27 DoC 20/km or more	Current Annual Real Losses (CARL)	Less	171	343	685	*163*	Litres/ service connection per day
		when system is pressurised	than	to	to	or	**192**	
		Litres/service connection/day	171	342	684	more	*221*	
	IWA Op28 DoC<20/km	Current Annual Real Losses (CARL)	Less	4.7	9.6	19.0	*4.5*	m^3 per km of mains per day
		when system is pressurised	than	to	to	or	**5.3**	
		m^3/km of mains/day (see Note 2)	4.7	9.5	18.9	more	*6.1*	
	IWA Op29	Unavoidable Annual Real Losses	-	-	-		*81*	Litres/ service connection per day
		(UARL) for distribution losses					**86**	
		Litres/service connection/day (See Note 3)					*90*	
		Infrastructure Leakage Index (ILI)	Less	2	4	8	*1.89*	Non-dimensional
		= CARL /UARL	than	to	to	or	**2.25**	
		for distribution losses (see Note 4)	2	< 4	<8	more	*2.60*	
Apparent Losses		Apparent Losses volume as % of metered					*1.3%*	% of metered consumption
		consumption (excluding Water Exported)					**2.1%**	
		(See Note 5)					*2.9%*	
Financial Management of NRW	IWA Fi47	Non-Revenue Water $ value as a % of annual system running cost (See Note 6)					**3.0%**	% of annual system running cost

Figure 5.28: Summary of NZWWA Recommended Performance Indicators in the Summary Worksheet

Performance Comparisons with International Data Set

The ‘Summary’ Worksheet continues with graphs for each of the Operations Real Losses Performance Indicators, compared to the International Data set in **Ref 6.**, as shown in **Figures 5.29.** For the 2nd and 3rd graphs (Op27 and Op 28), the most appropriate of the scaling factors (service connections or km of mains depending upon the density of connections) is highlighted.

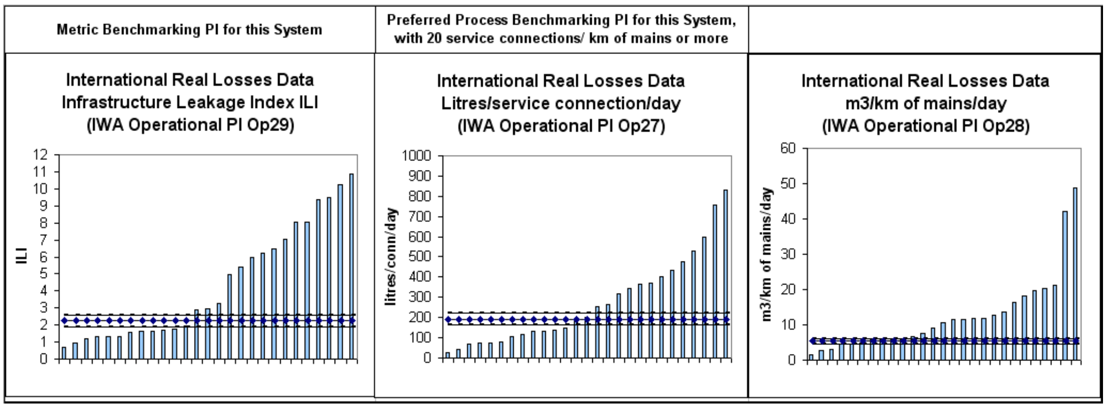

Figure 5.29: NZWWA Operations Performance Indicators for Real Losses compared with International Data

Performance Comparisons with New Zealand Data Set

The graphs on Rows 81 to 98 will enable the calculated PIs to be compared with a New Zealand data set (to be entered in the 'Compdata' Worksheet). The name of the person completing the Summary Worksheet calculation, and the date on which the calculation was carried out, should be completed at the bottom of the worksheet in the yellow blocks provided.

5.10. THE 'COMPDATA' WORKSHEET

This Worksheet lists the International Data Set values of performance indicators for Real Losses (from **Ref. 6)** in Columns B,C and D. The data in Columns E to M are taken from the 'Summary' Worksheet, and are used to build the International Comparisons graphs on that Worksheet.

As data become available for New Zealand systems, the values can be entered in Columns N to P, in rank order, in the blank yellow cells shown in **Figure 5.30**, and these values will automatically appear in the Graphs in Rows 81 to 98 of the 'Summary' Worksheet.

	International Data Set			Performance Indicators calculated for this system and shown on 'Summary' Worksheet									New Zealand Data Set		
Rank	ILI	l/conn/d	m3/km/d	ILI Best Estimate	ILI lower estimate	ILI upper estimate	l/conn/d, best est.	l/conn/d, low est	l/conn/d, high est	m3/km/d, best est	m3/km/d, low est	m3/km/d, high est	ILI	l/conn/d	m3/km/d
1	0.70	29	1.63	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
2	0.97	42	2.81	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
3	1.21	70	3.01	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
4	1.31	74	4.41	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
5	1.32	76	4.59	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
6	1.33	80	4.86	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
7	1.55	104	5.64	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
8	1.62	114	5.98	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
9	1.66	130	5.98	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
10	1.72	132	6.21	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
11	1.77	138	6.79	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
12	1.94	146	7.48	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
13	2.91	180	9.19	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
14	2.94	202	10.66	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
15	3.25	256	11.42	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
16	4.99	263	11.66	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
17	5.42	320	11.69	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
18	5.94	342	11.88	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
19	6.21	367	12.75	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
20	6.44	370	13.64	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
21	7.06	401	16.32	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
22	8.02	436	18.32	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
23	8.04	477	19.84	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
24	9.39	527	20.19	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
25	9.48	600	21.20	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
26	10.25	759	42.02	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			
27	10.86	832	48.81	1.90	1.54	2.25	162	132	192	4.48	3.66	5.31			

Fig 5.30: Compdata Entry Worksheet

The name of the person completing the Summary Worksheet calculation, and the date on which the calculation was carried out should be completed at the bottom of the worksheet in the yellow blocks provided.

5.11. THE 'WHY NOT %S' WORKSHEET

As previously mentioned, when losses are expressed as a percentage of system input volume, the resulting figure is heavily influenced by the consumption. This Worksheet is used to highlight the problem of using percentages as a Performance Indicator. The principal terms in the Water Balance have been converted to litres/service connection/day (the Operations Basic Performance Indicator for Real Losses), as can be seen in **Figure 5.31**.

ABCWater			
Water Balance Data for	**01-Jul-98**	**to**	**01-Jul-99**
System Input		**1142**	**l/conn/day**
Authorised Consumption		**931**	**l/conn/day**
Apparent Losses		**19**	**l/conn/day**
True Consumption		**950**	**l/conn/day**
Current Annual Real Losses	CARL	**192**	**l/conn/day**
Unavoidable Annual Real Losses	UARL	**86**	**l/conn/day**
CARL as % of System Input		**16.8**	%

Figure 5.31: Water Balance Data expressed in Litres/service connection/day

The difference between CARL and UARL in **Figure 5.31** represents the estimated maximum possible reduction in Real Losses which could be achieved with near-perfect infrastructure management, at the current operating pressure.

Using these figures, the BenchlossNZ software also produces a graph, shown as **Figure 5.32,** in which:

- The X-axis shows a range of international figures for True consumption per connection;
- The vertical dashed line represents the True consumption for the example data;
- The Y-axis is the Real Losses expressed as a % of System Input;
- The upper curved line represents the Current Annual Real Losses;

The lower curved line represents the Unavoidable Annual Real Losses.

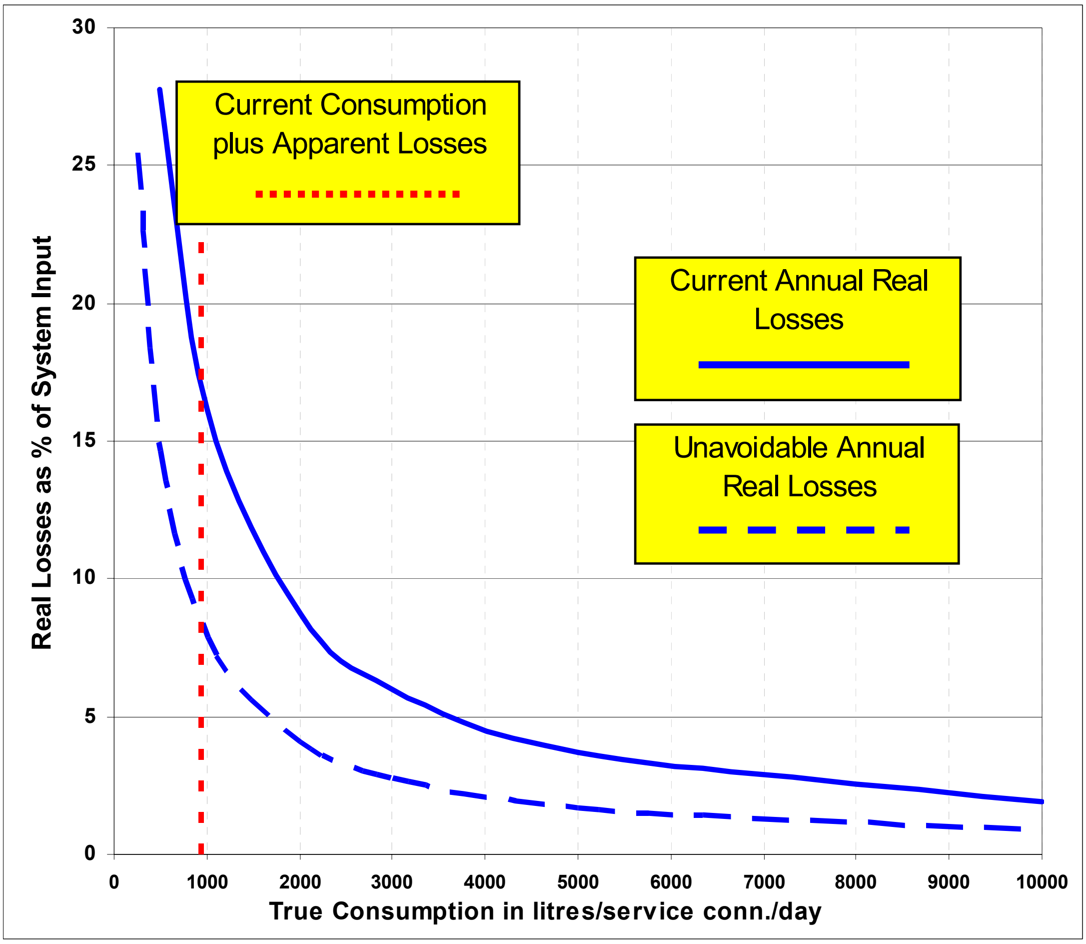

Figure 5.32: Why Percentage Real Losses are not appropriate for Real Losses Comparisons

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    Report C : **Setting Economic Leakage Targets**. ISBN: 1 898920 08 7
    Report D : **Estimating Unmeasured Water Delivered**. ISBN: 1 898920 09 5
    Report E : **Interpreting Measured Night Flows**. ISBN: 1 898920 10 9
    Report F : **Using Night Flow Data**. ISBN: 1 898920 11 7
    Report G: **Managing Water Pressure**. ISBN: 1 898920 12 5
    Report H: **Dealing with Customers' Leakage**. ISBN: 1 898920 13 3
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APPENDIX A

Assessing the Accuracy of Water Balance and Performance Indicator Calculations

APPENDIX A

A1 ASSESSING ACCURACY IN WATER BALANCE AND PI CALCULATIONS

Technical data relating to:

- infrastructure (numbers of connections, mains length, properties etc)
- average pressure
- metered volumes, estimated unmetered volumes etc

are used in the calculation of Water Balance and Performance Indicators. Yet not one of these items of data can be considered as being a precisely correct value – they are all ‘best estimates’ to a greater or lesser extent. Consequently, a question which is often asked is ‘How accurate is the calculation of Non-Revenue Water, Apparent Losses, Real losses, and their Performance Indicators?

Data errors can be systematic, or random, or both. For example, if check calibration of a system input meter shows that it has over-recorded by between 2% and 4%, then there is a systematic error with a best estimate of 3% over-recording of system input volume. Systematic errors in system input volume should be corrected as part of the Water Balance calculation process (see ‘Waterbal’ Worksheet in BenchlossNZ).

In the above example, there will also be a random error of approximately +/- 1% of the corrected system input volume. Similar random errors will exist for almost every item of data entry in the BenchlossNZ calculations; for example, in the figures entered for length of mains, or the calculated average pressure, or the estimates of components of unmetered consumption etc.

Engineers often express the probable range of such random errors by statements such as ‘I think the figure I have used is within +/- X % of the true value’. Estimated values of ‘X’ are based on local knowledge, general experience, published data, and consideration of the methodology used to obtain the data.

For most of the parameters used in BenchlossNZ, if systematic errors are identified and dealt with, the remaining random errors are equally likely to be greater than, or less than, the true value. A practical approach for assessing probable errors in calculated components of NRW, and PIs, can then be developed, using the statistical properties of a probability distribution known as the ‘Normal’ or ‘Gaussian’ distribution.

However, it is necessary to be aware that the probability distributions of some items of data used in leakage management do not follow 'Normal' distributions. For example, if the individual metered flow rates into a large number of residential properties are measured at night, then it will be found that the total night consumption is generated by a small proportion (p) of 'active' properties. The majority of properties are 'inactive', having zero metered flow at night. In such cases the use of a Normal or Gaussian distribution to represent the data is not appropriate, and the data need to be analysed using a Binomial probability distribution (see Ref. 9, Report E, Appendix A for more details on this topic).

Similarly, particular care must be taken with analysing the component of consumption relating to underground supply pipe leakage, as high flow rates from long-running leaks and bursts on a small percentage (around 2% to 5%) of service connections are responsible for a large proportion of the annual volume of underground supply pipe leakage.

A2 THE NORMAL DISTRIBUTION FUNCTION

The Normal distribution (sometimes called the Gaussian Distribution) is widely used for statistical analysis. It is characterised by:

- A mean value (the arithmetic average of all the data)
- Approximately half the items being greater than, and half less than, the mean
- The greater the difference from the mean, the smaller the probability
- A 'standard deviation' – a measure of dispersion about the mean value

A typical normal distribution curve is shown in **Figure A1**. It can be seen from the figure that the area within 1, 2 and 3 standard deviations from the mean are approximately 68.3%, 95.5% and 99.7% respectively of the whole area.

The density function for the Normal (Gaussian) distribution which can be fitted to these values is represented by the equation

$$f(\chi) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(\chi - \mu)^2 / 2\sigma^2} \quad -\infty < \chi < \infty$$

Where M is the mean value and SD is the standard deviation. The 'Standard Error' (SE) is the Standard Deviation expressed as a % of the mean.

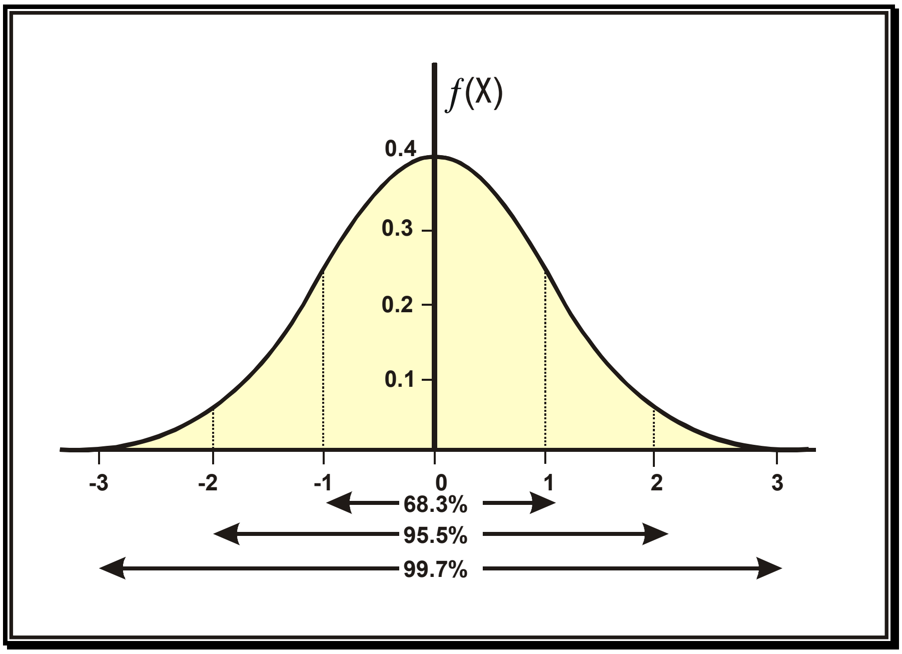


Figure A1: Typical Normal Distribution

If a frequency distribution has a mean of 50 units, and an SD of 5 units, then:

- 68.3 % of all values should lie within +/- 1 Standard Deviations of the mean, ie between 45 and 55 units
- 95.5 % of all values should lie within +/- 2 Standard Deviations of the mean, ie between 40 and 50 units
- The Standard Error will be (100 x SD/Mean)% = 100 x 5/50 = 10%

A3 APPLICATION TO WATER BALANCE AND PI CALCULATIONS

BenchlossNZ requires the user to enter a 'best estimated' value for each input parameter. Then, to make a judgement as follows:

- 'I think the figure I have entered is probably within +/- X % of the true value'

The value of X is then assumed to represent the 95% confidence limits, expressed as a % of the best estimated value.

The BenchlossNZ model divides X by 2 to obtain the Standard Error (%), then calculates the Standard Deviation as X/(2x100) x 'Best Estimated Value'. Taking the example in A2 above, if the 'Best Estimated Value' is 50 units, and the 95% confidence limits ('X') are +/- 20%, then the Standard Deviation is 20/(2x100) x 50) = 5 units.

Using the estimated 95% confidence limits for input data, BenchlossNZ uses routine statistical calculations to calculate 95% confidence limits for derived data, such as:

- the sum or difference of volumes in the water balance
- performance indicators which use combinations of items with different measurement units

APPENDIX B

Examples of Water Reticulation Layouts in New Zealand

APPENDIX B : EXAMPLES OF WATER RETICULATION LAYOUTS IN NEW ZEALAND

B1 WATER RETICULATION SYSTEMS: GENERAL

It seems that many of the water suppliers in New Zealand use different terms to define the components of water reticulation systems. For the purposes of BenchlossNZ, reticulation systems are divided into:

- service reservoirs – storage owned by the water supplier
- water mains – pipes providing a general supply of raw or treated water
- service connections and fittings carrying water from the main to the ‘point of consumption’ at the street:property boundary

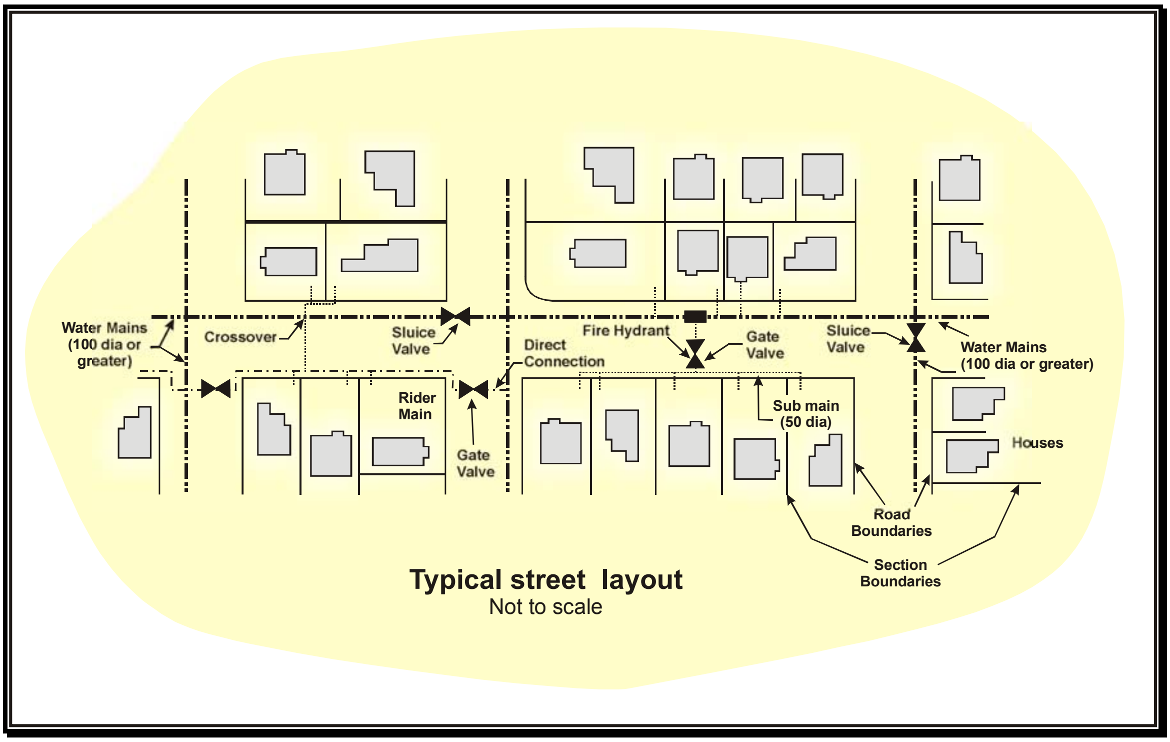
Examples of terminology used by individual water suppliers are given in the remainder of this appendix, and are cross-referenced to the terminology used in BenchlossNZ as examples to assist Users of the software.

In the BenchlossNZ terminology, the ‘Point of Consumption’ is at the street:property boundary, irrespective of whether the service connection is metered or unmetered. The volume of water passing the street:property boundary into private underground supply pipes is the ‘Consumption’. ‘Consumption’ can be considered to consist of 4 principal components:

- leakage on the underground supply pipe
- leakage in the above-ground plumbing
- indoor use within the buildings
- outdoor use using hosepipes, sprinklers etc

B2 WATER RETICULATION LAYOUT IN CHRISTCHURCH

Figures B1 and B2 show the typical Water Reticulation Layouts used for residential properties in Christchurch City. In Christchurch terminology, ‘Water Mains’ are mains of 100mm diameter or greater, and ‘Crossover mains’, ‘Rider Mains’ and ‘Sub Mains’ are less than 100 mm diameter. For the purposes of BenchlossNZ, all these categories are counted as being part of ‘Length of Mains’ entered in the ‘INF&UARL’ Worksheet.



FigureB1: Reticulation Details in Christchurch

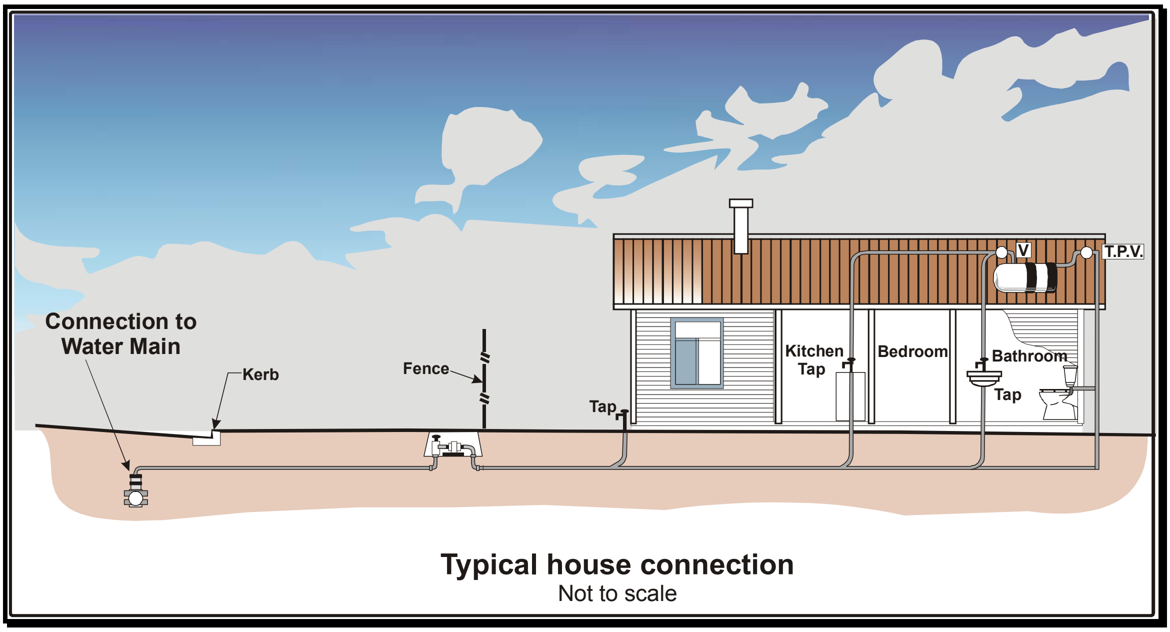


Figure B2: House Connection Details in Christchurch

All properties are metered, with customer meters being located on Service Connections close to and just outside the 'Road Boundary' (top diagram) or 'Fence' (bottom diagram). For the purposes of BenchlossNZ, this point is the ‘Street: property boundary’ and ‘Point of Consumption’.

For the purposes of BenchlossNZ, the underground supply pipe is the length of private pipe after the customer meter, and up to the individual taps or draw-off points.

B3 WATER RETICULATION LAYOUT IN WAITAKERE CITY

Figure B3 shows typical Water Reticulation Layouts used by Ecowater for residential properties in Waitakere City, Auckland. All properties are metered, with customer meters being located on Service Connections just inside the ‘Legal Boundary’ at the ‘Point of Supply’. In BenchlossNZ, this point is referred to as the ‘Street:property boundary’ or ‘Point of Consumption’.

For the purposes of BenchlossNZ, the underground supply pipe is the length of private pipe after the customer meter, and up to the individual taps or draw-off points.

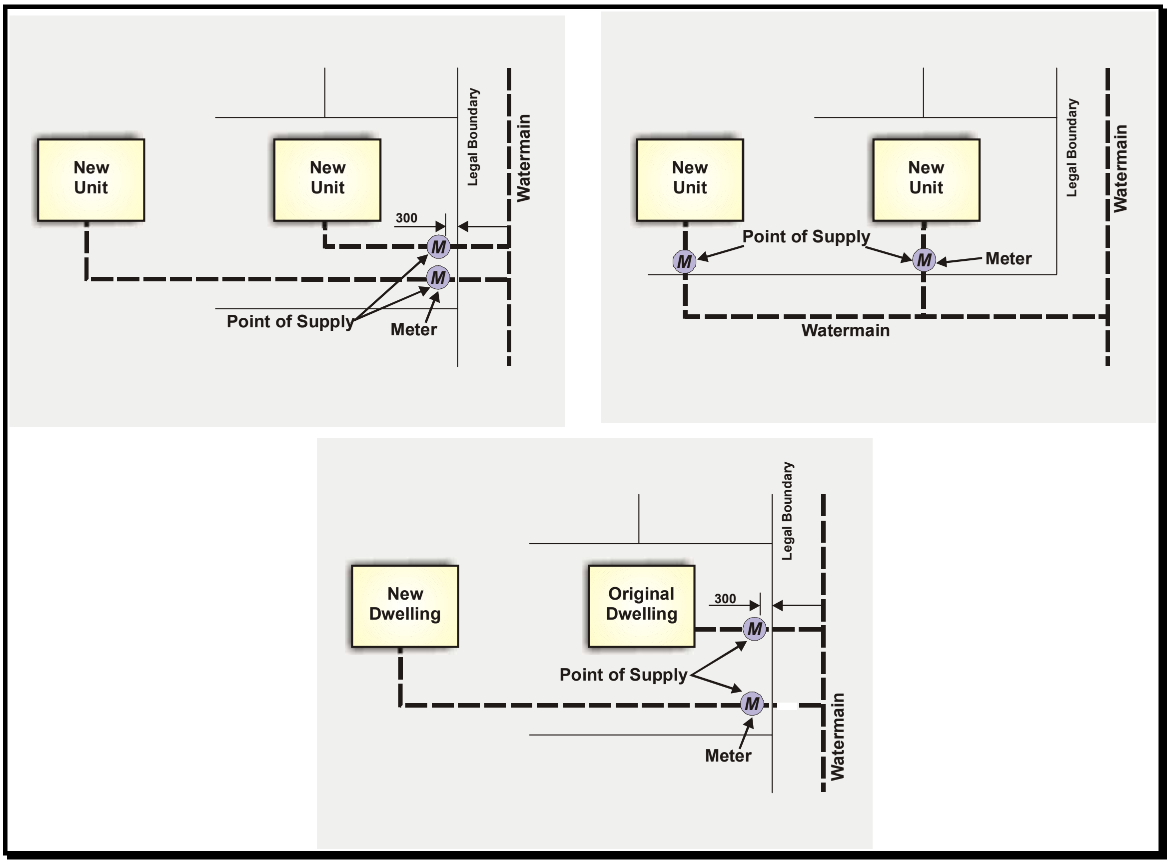


Figure B3: Example of Water Metering Layout (Waitakere City Council)

APPENDIX C

Estimating Underground Supply Pipe Leakage on Private Pipes

APPENDIX C : ESTIMATING UNDERGROUND SUPPLY PIPE LEAKAGE ON PRIVATE PIPES

C1: Estimating Underground Supply Pipe Leakage using Component Analysis

Estimates of the average annual leakage rates from large numbers of customers' underground supply pipes can be based on component analysis (Background and Bursts Estimates), which is described in Appendix G. Typical values depend upon parameters such as average length of such pipes (per service connection), average pressure and the numbers and types of leaks which occur, and how quickly such leaks are identified and repaired.

For metered properties, the average duration of such leaks depends upon the frequency with which meters are read, the low-flow accuracy of the meter, and the policy relating to speed of repair. The 'Unavoidable Annual Real Losses' formula for underground supply pipes (**Ref.6** and **Table G3** of **Appendix G**) gives an estimate of the typical average leakage for 15 metre long underground supply pipes for which unreported leaks run for approximately 3 months on average. This is equivalent to having customer meters at the street:property boundary read every 6 months, with customers billed for the whole metered volume. As average lengths of underground supply pipe vary greatly in New Zealand, the predictive equation for such situations can be changed from

25 litres/km of pipe/day/metre of pressure

and expressed as

0.025 x Lp x Pav litres/property/day

where Lp is the average length of underground supply pipe, in metres per property, and Pav is the average pressure.

C2: Comparison of IWA 'Unavoidable' Leakage with UK Metered Data

In England & Wales, underground supply pipes for households are typically around 15 metres long, and subject to an average pressure of 45 metres. For these parameter values, the above equation predicts average UGSP leakage on externally metered properties of

0.025 x 15 x 45 = 16.9 litres/property/day

This figure which compares well with the figure of 19.1 litres/property/day quoted for externally metered households in England & Wales in Table 18c of the Office of

Water Services 2005-06 Report 'Security of supply, leakage and water efficiency' (Ref. 26).

C3: Simplified Approach for New Zealand BENCHLOSS

A simple approach to estimating typical underground supply pipe leakage for New Zealand scenarios - such as unmetered properties, or metered properties with less accurate meters, or metered properties where the meters are read regularly but not used for charging purposes - is to predict the UGSP leakage as a multiple (F) times the above formula i.e.:

UGSP leakage = F x 0.025 x Lp x Pav in litres/property/day

The 'F' factor for unmetered households in England & Wales (based on interpretation of data from Ref. 26) is approximately 2.6, but this is for systems with continuous night flows to rapidly identify unreported leaks, and prompt technical assistance and subsidised repairs for significant leaks on customers' private pipes. An initial estimation of F Factors for New Zealand scenarios is shown in **Figure C1** and the values in the table should be regarded as indicative rather than definitive.

	F-Factor
Externally metered properties, Class D meter, billed on 6 monthly meter readings	1.0
Externally metered properties, Class C meter, annual meter readings not used for billing	1.5
Unmetered property, strong active policies for assisted repairs	3.0
Unmetered property, no active policies for assisted repairs	4.0

Figure C1: Examples of how F-Factors may vary with meter type, meter reading frequency, and active leakage control policies

For any particular system, these calculations can be made on Rows 85 to 88 of the 'Consumption' Worksheet in BenchlossNZ as shown in **Figure C2**. This simplified approach to estimating underground supply pipe leakage will hopefully provide users with some approximate estimates of the possible ranges of underground supply pipe leakage in different circumstances.

Category of Private Underground Supply Pipe	Assumed F-Factor	Average Lp in metres per property	Average Pressure Metres	Estimated Underground Supply Pipe Leakage			
				Litres per property per day	m^3 per property per year	Number of properties	$m^3 \times 10^3$ per year
Billed metered residential properties	1.0	15	58.9	22	8	14000	113.0
Billed unmetered residential properties	4.0	15	58.9	88	32	1714	55.3
Billed metered non-residential properties	1.0	50	58.9	74	27	77	2.1
Billed unmetered non-residential properties	4.0	10	58.9	59	22	42	0.9

Figure C2: Estimating underground supply pipe leakage in BenchlossNZ

A brief comparison with minimum night flows for Hauraki (where there are some extremely long metered underground supply pipes) suggests that the above approach could apply reasonably well even in such extreme conditions.

APPENDIX D

Consumption Monitors for Unmeasured Residential Properties

APPENDIX D: CONSUMPTION MONITORS FOR UNMEASURED RESIDENTIAL PROPERTIES

D1: COMPONENTS OF CONSUMPTION

At the 'Point of Consumption' (the street:property boundary), the volume of water passing across that boundary into private pipework is the 'Consumption'. 'Consumption' can be considered to consist of 4 principal components:

- leakage from the underground supply pipe
- leakage from the above-ground plumbing
- indoor use within the buildings
- outdoor use using hosepipes, sprinklers etc

In the case of service connections which are metered at the street:property boundary, the total registered by the customer meters includes all four of the above principal components.

Even in situations where all customers are metered at the street:property boundary, leaks will occur on a small percentage of individual underground supply pipes, and on some plumbing systems. The annual volume lost will depend upon the number of leaks, the typical flow rates, and how long they are allowed to run for without being repaired.

Figure D1 is a frequency distribution of the average consumption per residential property for a sample of 4411 Christchurch service connections. If this were a Normal distribution (see Appendix A) there would be an equal chance of seeing values higher or lower than the mean value of 275 m^3/year. However, this is clearly not a Normal distribution.

- 93.5% of properties have consumption of less than 550 m^3/year
- 5.2% of properties have consumption between 550 and 1000 m^3/year
- 1.3% (57 properties) have consumption of over 1000 m^3/year (reaching up to 3000 m^3/year)

The small percentage of properties with consumption greater than 550 m^3/year – and in particular the 1% of properties consuming over 1000 m^3/year – have a significant influence on the mean value of consumption. The principal causes for these high individual consumptions are:

- leaks on underground service connections (which can easily lose 20 m^3/year, or 700 m^3/year), without the customer being aware of a leak.
- Excessive use of water outdoors associated with gardens

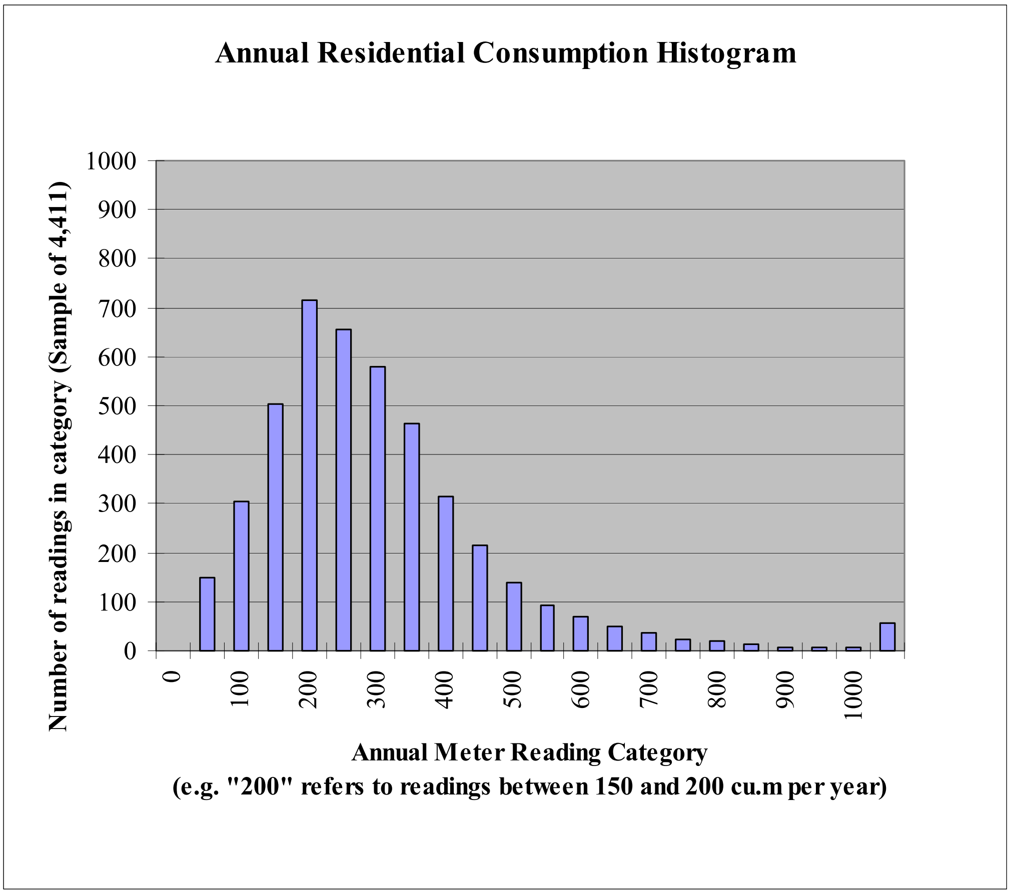


Figure D1: Histogram of Annual Residential Consumption, Christchurch

D2: ESTIMATES BASED ON CONSUMPTION MONITORS

When political elections take place, voters' intentions are assessed by obtaining data from a small sample of residents – normally around 1000 people – as to their opinions and voting intentions. The categories of people interviewed in this small sample are deliberately selected to try to be representative of a structured sample of the overall population – if this is not done, and a random sample is taken, the result may be considerably biased and the error in the predictions may be considerable.

Similar considerations apply to the selection of residential properties for inclusion in a 'consumption monitor', in which selected properties are metered, but the residents are not informed of the results, nor are they charged on a 'by volume' basis. The results are then used to predict the average consumption for unmetered residential properties. In New Zealand, it appears that there is a commendably sensible policy for all customer meters to be placed close to the street:property boundary, so this is the only meter location which will be considered in this very brief overview of consumption monitors.

Reliable consumption monitors are expensive to set up and operate. In England & Wales, large Water Companies such as Anglian, Severn-Trent and South-West Water, with 0.5 to 2.5 million unmetered residential customers, run consumption monitors of several thousand metered properties to estimate the per capita consumption in unmetered residential properties. Typical running costs are likely to exceed $NZ 5 million per year for each consumption monitor. In South-East England, several smaller Companies contribute data to a common Consumption Monitor, where the data are pooled before analysis.

There are many issues involved in setting up reliable consumption monitors, and NZWWA should seek expert advice in this field. However, there is some initial guidance which can be offered in this Manual, in the hope that it may be useful.

D3: SOME KEY QUESTIONS

Key questions which NZWWA members may wish to consider when considering whether to set up a consumption monitor are:

- What characteristics should be taken into account when attempting to select a representative sample of residential properties? Are any of these characteristics available from national Census data?
- What is the relationship between the size of sample and the reliability of the estimated average consumption?
- How can the influence of a small number of relatively large leaks on underground supply pipes, be dealt with when data is analysed?
- Are there any systems in New Zealand where residential properties are already metered, but not charged by meter? Could these be used to help to clarify some of the above uncertainties?

Dealing with the last question first, there is a potentially valuable data resource in Christchurch, where many thousands of residential properties are metered at the street:property boundary, but not charged by volume. The remainder of this Appendix outlines the results of some very preliminary analyses of this data.

D4: CHRISTCHURCH DATA: A RELATIONSHIP BETWEEN SIZE OF SAMPLE AND RELIABILITY OF ESTIMATE FOR RANDOMLY SELECTED RESIDENTIAL PROPERTIES

Figure D2 shows the general relationship between 95% confidence limits and size of sample, based on the analysis of random selections of the 4411 metered residential properties in Figure D1. None of these properties were being charged on the recorded metered volume, nor are the residents advised of the recorded metered consumption unless it is excessive.

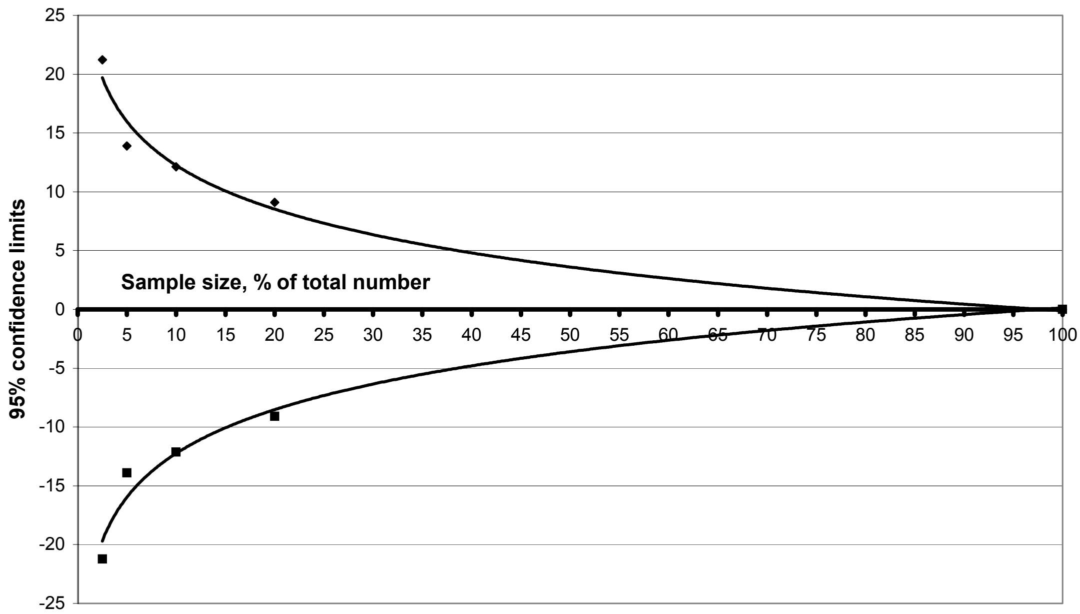


Figure D2: % Sample Size vs 95% Confidence Limits, Random samples of Unmeasured Per Capita Consumption, 4411 Christchurch Residential Properties

Figure D2 indicates, for example, that a consumption monitor based on a 10% random sample of residential properties might give an estimate of unmetered residential consumption to within 95% confidence limits of +/- 12%

D5: REDUCING THE UNCERTAINTY

In almost all consumption monitors world-wide, the number of residents per residential property is a key factor in selecting properties for a consumption monitor. Although this information is not available on a 'property-specific' basis from Census data, a brief preliminary investigation by Christchurch leakage staff found that:

- It is possible to derive a Table relating 'Number of Residents' to 'Number of Dwellings' (e.g. **Table C1**)
- It is possible, for each meshblock in the Census data, to obtain:
  - the number of dwellings
  - the population and average residents per dwelling

No. of Residents per Dwelling	Number of Dwellings in this Category	% of Dwellings in this category
0	843	0.72
1	27,453	23.47
2	39,822	34.04
3	19,809	16.93
4	17,727	15.15
5	7,767	6.64
6	2,370	2.03
7	759	0.65
8	243	0.21
9	84	0.07
10 or more	105	0.09
Total	116,982	100.0

Table D1: Data derived by Christchurch from 1996 Census

Other characteristics which can be derived on a meshblock basis are:

- the average capital value
- the average land value

It is possible that research into samples of Christchurch data based on average population per dwelling, and capital and/or land values, could establish the strength (or otherwise) of relationships between residential consumption and these parameters, leading to a more structured selection procedure for consumption monitors.

D6: ALLOWING FOR UNDERGROUND SUPPLY PIPE LEAKAGE IN CONSUMPTION MONITORS

Underground supply pipe leakage will consist of background leaks that are too small to register on the customer meter, and larger leaks which will show as an increase in metered consumption. Although these larger leaks are rare – perhaps occurring on only some 1% to 5% of properties each year – they can have high flow rates, which can significantly bias the results from a consumption monitor.

The best guidance that can be given for dealing with these is that if any such large leaks are identified in the consumption monitor, adjust the recorded data so that their influence is eliminated, before calculating average consumption. This procedure results in the influence of significant underground supply pipe leaks being suppressed in the initial calculation of unmeasured residential per capita consumption from the Consumption Monitor. It is therefore necessary to add an additional allowance ‘per residential property per day’ for the reported and unreported leaks on the underground supply pipe at the end of the calculation. Such allowance depending upon the average frequency, flow rate and duration of leaks for the whole system, see Appendix C.

APPENDIX E

Allocating Specific Components to the Water Balance

APPENDIX E : ALLOCATING SPECIFIC COMPONENTS TO THE WATER BALANCE

E1: CATEGORISING AND ALLOCATING MINOR COMPONENTS IN THE WATER BALANCE

Figure E1 shows part of the standard water balance from the 'Terminology' Worksheet. In undertaking the Water Balance, it is necessary to assemble the annual volumes of water for the components in the right-hand column. This is achieved by entering data in the 'Consumption' Worksheet in BenchlossNZ.

		Billed Water Exported to other Systems	Revenue Water
Authorised Consumption	Billed Authorised Consumption	Billed Metered Consumption by Registered Customers	
		Billed Unmetered Consumption by Registered Customers	
	Unbilled Authorised Consumption	Metered	Non-Revenue Water
		Unmetered	
Water Losses	Apparent Losses	Unauthorised Consumption	
		Customer Metering Under-registration	
	Real Losses	Leakage on Mains	
		Leakage and Overflows at Service Reservoirs	
		Leakage on Service Connections up to the street/property boundary	

Figure E1: 'Consumption' Section of Standard Water Balance

The actual Item References and descriptions for data entry in the 'Consumption' Worksheet are as set out in **Figure E2.** The description of some items (1a, 1b,1c, 2a,2b,2c) are fixed, but the remainder (being yellow cells in BenchlossNZ) can be changed if necessary by the user.

The key words to remember when allocating components of consumption are:

- All consumption entered on this Worksheet must be 'Authorised'
- Unauthorised consumption is entered on the 'WaterBal' Worksheet
- All Billed metered consumption must go into Item Group 1
- All Billed unmetered consumption must go into Item Group 2
- All Unbilled metered consumption must go into Item Group 3
- All Unbilled unmetered consumption must go into Item Group 4

Item	Description
1	**Billed Metered Consumption, registered customers**
1.a	Billed metered residential properties
1.b	Billed metered non-residential properties
1.c	Other billed metered consumption (specify)
1.d	Other billed metered consumption (specify)
1.e	Other billed metered consumption (specify)
	Total of Billed Metered Consumption Items 1a to 1e
2	**Billed Unmetered Consumption, registered customers**
2.a	Billed unmetered residential properties
2.b	Billed unmetered non-residential properties
2.c	Seasonal/Tourist additional consumption
2.d	Other billed unmetered cons. (specify)
2.e	Other billed unmetered cons. (specify)
	Total of Billed Unmetered consumption Items 2a to 2e
3	**Unbilled metered consumption**
3.a	Specify if applicable
3.b	Specify if applicable
3.c	Specify if applicable
	Total unbilled metered consumption
4	**Unbilled unmetered consumption**
Default	In accordance with guideline default estimate that Unbilled Authorised Consumption equal to 0.5 % of Water Supplied can be used
4.a	System cleaning: Annual flushing program
4.b	System cleaning: Discharge from Hydrants
4.c	System cleaning: Cleaning of Reservoirs
4.d	System cleaning: Flushing of New Mains
4.e	System cleaning: Flushing of Renewed Mains
4.f	Fire Services: filling engines
4.g	Fire Services: water taken direct from mains
4.h	Fire Services: training using hydrants
4.I	Fire Services: Testing of Sprinkler Lines
4.j	Use of Hydrants by others: Sewer Flushing
4.k	Use of Hydrants by others: Street Cleaning
4.l	Backflow Prevention Testing
4.m	Temporary services during mains renewal
4.n	Other (specify)
4.o	Other (specify)
4.p	Other (specify)
4.q	Other (specify)
4.r	Other (specify)
4.s	Other (specify)
	Total unbilled metered consumption

Figure E2: Components of Authorised Consumption from BenchlossNZ

Unbilled Authorised Consumption usually consists of many small components, which may be metered or unmetered. There are usually very few, if any, metered components of Unbilled Authorised Consumption. In contrast, Part 4 of Figure E2 shows that there are usually numerous possible unmetered components of Unbilled Authorised Consumption.

It is undoubtedly good practice to attempt to make estimates of these volumes at least once every few years, on a logical basis. However, several years experience in the use of confidence limits has shown that the most significant systematic and random errors in Water Balance calculations usually arise from errors in the source meters and bulk supply meters, and incorrect estimates of unmeasured consumption. The large amount of time and effort taken in estimating some of the smaller unmeasured components of the Water Balance – Unbilled Authorised Consumption, Unauthorised Consumption and Customer Meter Under-Registration – is not necessarily justified, at least for initial Water Balance and PI calculations.

The practice of using relatively low guideline default values for initial estimates of these parameters is increasing internationally. The guideline default currently used in Australia for Unbilled Authorised Consumption is 0.5% of Water Supplied, and this has now been introduced into this updated 2008 version of Benchloss NZ. The principle used is that water suppliers may claim higher allowances than the guideline default value when doing their water balance, but only if such higher allowances can be justified with robust water supplier specific data.

The guideline default estimate can be calculated on the Consumption Worksheet using the instructions in Cell J32, the calculated value is then entered in Cell G32. A fixed confidence limit of +/-100% is assumed for this estimate in Cell N32.

If the user prefers to estimate individual components of Unbilled Authorised Consumption, rather than use the Guideline Default approach, then ‘zero’ must be entered in Cell G32, and Parts 4a to 4s of the “Consumption” Worksheet completed as appropriate. The cruder the estimates, the greater the 95% confidence limits which should be entered alongside the estimated values.

APPENDIX F

Estimating Apparent Losses

APPENDIX F: ESTIMATING APPARENT LOSSES

F1: COMPONENTS OF APPARENT LOSSES

Apparent Losses consist of Unauthorised Consumption (theft and illegal use) and Customer Metering Errors. Actual calculations of these volumes are preferably based on structured sampling tests, or estimated by a robust local procedure (which should be defined for audit purposes). Some quoted figures **(Ref 22)** for Apparent Losses in different countries (as % of System Input Volume, SIV) are:

Malaysia	Apparent losses 9% of SIV
Korea	Apparent Losses 9.2% of SIV in 1998, target 3% of SIV in 2011
England & Wales	Apparent losses 0.8% to 3.6% of SIV (median 2.0%) in 2005/06
Australia	Apparent losses 1% to 3% of SIV

It is now recognized (Ref 10) that, if Apparent Losses are to be expressed as a % of a Water Balance input volume, it should be as a % of Water Supplied, rather than as a % of System Input Volume (which includes Water Exported).

The major difference between Malaysia/Korea, and England/Wales/Australia, is that in Malaysia and Korea, customers have private storage tanks on their properties, and customer meter under-registration is much greater due to the low flow rates. New Zealand has direct pressure systems, with no significant customer storage except in some commercial properties.

The practice of using relatively low guideline default values for initial estimates of Apparent Losses components is increasing internationally. Because Apparent Losses in New Zealand should be relatively low, as in Australia and England/Wales, this simplified approach to estimating Apparent Losses (at least for initial water balance calculations) can be justified.

The following guideline default values currently used in Australia have now been introduced into this updated 2008 version of Benchloss NZ:

- Unauthorised Consumption default is 0.1% of Water Supplied
- Customer meter under-registration default is 2.0% of recorded consumption, for both residential and non-residential customers.

The principle used is that water suppliers may claim higher allowances than the guideline default value when doing their water balance, but only if such higher allowances can be justified with robust water supplier specific data.

F2: Assessment of Unauthorised Consumption

Unauthorised Consumption occurs to a greater or lesser extent in most systems worldwide - the England & Wales estimate median value (Ref 26) is 0.33% of Water Supplied. The standard default of 0.1% of Water Supplied used is this 2008 version of BenchlossNZ therefore represents a demanding standard to achieve in practice.

F3: Assessment of Customer Meter Errors

Customer Metering errors include:

- **Systematic errors** due to meters failing to accurately record low flows
- **Random errors**, mainly due to accounting procedure errors – due to differences between dates of source meter readings and customer meter readings, misread meters, incorrect estimates for stopped meters, adjustments to original meter readings, improper calculations, computer programming errors etc.

When samples of customer meters are tested for accuracy, it is normal to quote the average systematic error as a % of the recorded metered consumption. Several of the National Reports referred to in **Ref 22** draw attention to the problem of customer meter under-registration.

- Malaysia : Customer meters economic life-span 7 to 10 years
  10-year meter change expected to limit under-registration to within 5%
- Spain: Problems with measuring low flow consumption (including housing leakage); Class B single jet meters tests in houses show average 6% under-registration
- Denmark: Customer meters must be spot tested or replaced every 8 years
- Bangkok: Customer meter under-registration 2%, malfunction 2.5%
- Germany ‘Meter errors at extremely low flows’ are now allocated a specific component in the DVGW standard Water Balance documentation
- Morocco Customer meter under-measurement 10% to 15%]

The latest OFWAT Report (Ref 26) for England & Wales shows median customer meter under-registration of 3.0% for household meters, and 4.8% for non-household meters. The standard default of 2.0% of Water Supplied used is this 2008 version of BenchlossNZ therefore represents a demanding standard to achieve in practice.

The selection of customer meter types and classes (A to D) may be limited by water quality considerations, as well as technical and economic considerations. Economic replacement policies for residential meters based on selective testing programs in many countries generally indicate changeover periods between 5 and 10 years. Incorrectly sized commercial meters can result in significant under-registration of consumption, and checks can be made to identify if there are more appropriate meters for individual situations (by occasional monitoring of the actual frequency and range of consumption rates).

APPENDIX G

Introduction To Babe And Favad Concepts, And Calculation Of Unavoidable Annual Real Losses

Introduction To Babe And Favad Concepts, And Calculation Of Unavoidable Annual Real Losses

G 1 HISTORICAL BACKGROUND

As a result of the privatisation of the England & Wales Water Service Companies in 1989, it became necessary for all water suppliers to be able to demonstrate to their regulators that they fully understood their position on leakage. This did not imply that all water suppliers had to achieve the lowest possible leakage levels, but simply that correct and appropriate technical and economic principals were being applied to leakage management.

Accordingly, in 1990 a National Leakage Control Initiative (NLCI) was established in England & Wales by the Water Services Association and the Water Companies Association, to update and review the 'Report 26' guidelines (**Ref. 2**) for leakage control that had been in use in the UK since 1980. Considerable progress had been made in equipment and metering technology over the previous ten-year period, but methods of data analysis had not kept pace with these technical improvements.

In order to co-ordinate the various research efforts, described in the 'Managing Leakage' series of Reports (**Ref. 14**), Mr Allan Lambert, then Technical Secretary of the NLCI, developed an overview concept of Component Analysis of real losses, and the parameters which influence them. This concept, based on internationally applicable principles, is known as the Burst and Background Estimates (BABE) methodology. The BABE concepts were first applied and calibrated in the UK, and three simple pieces of standard software using the BABE concepts were made available at the time of issue, in 1994, of the 'Managing Leakage' Reports (**Ref. 14**).

Prior to 1994, a single relationship between minimum night flow and pressure was normally assumed in the UK, based on the 'Leakage Index' curve in Report 26.. The 1994 'Managing Pressure' Report recognised that there was not a single relationship, but did not offer an alternative method. However a much improved understanding of the range of relationships between pressure and leakage rate was introduced separately from the 'Managing Leakage' Reports in 1994, when John May published his FAVAD (Fixed and Variable Areas Discharges) concept (**Ref.15**). Using FAVAD, it has been possible to reconcile apparently diverse relationships and data from laboratory tests and distribution sector tests in Japan, UK, Brazil, Saudi Arabia, and Malaysia.

Since 1994, the BABE and FAVAD concepts have been applied in many countries for the solution of a wide range of leakage management problems, as described in **Ref. 16**.

Figure G.1 shows the typical range of leakage management problems which can be successfully tackled with these concepts. The remainder of this Appendix explains the application of BABE and FAVAD concepts to the development of the International Performance Indicators for Real Losses.

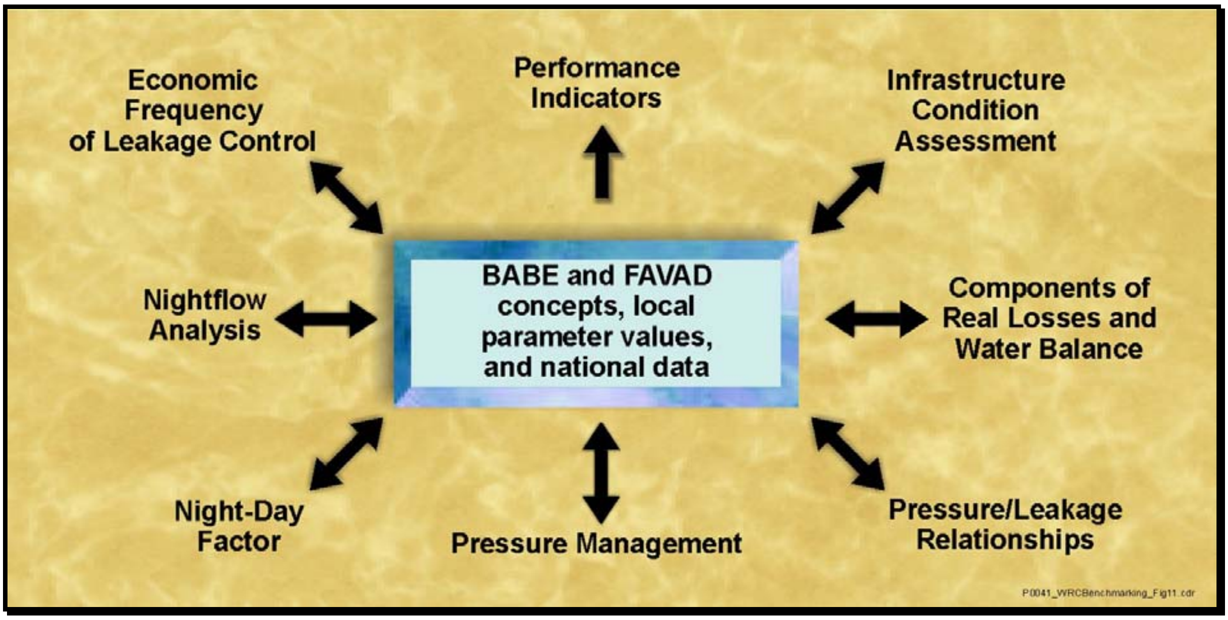


Figure G1: Problem-Solving using BABE and FAVAD concepts

G.2 USE OF FAVAD AND BABE CONCEPTS IN DEVELOPMENT OF PERFORMANCE INDICATORS

As explained in **Section 2.3** of the User Manual, the best of the traditional basic IWA Performance Indicators for Operational management of Real Losses is either Litres/service connection/day, or m3/km.mains/day, depending upon whether the density of service connections is respectively more than, or less than, 20 per km. of mains.

These basic operational Performance Indicators, however, do not take account of three system-specific key factors that have a strong influence on lowest volume of Real Losses which can be achieved in any particular system. These are:

- Average operating pressure;
- Location of customer meters on service connections (relative to the street/property boundary);
- Density of service connections (per km of mains).

The simplest form of the relationship between leakage rate and pressure (**Refs. 17, 19**), based on the FAVAD concept, is that leakage rate (L) varies with Pressure (P) to the power N1, i.e.

L varies with P^{N1}

International research has shown that different types of leakage paths and different pipe materials have different values of N1, which can range from 0.5 to 2.5. Values of N1 derived from tests on small sectors of distribution systems are usually in the range 0.5 to 1.5. When a weighted average of these N1 values is calculated, for application to larger distribution systems, the average N1 value is usually quite close to 1.0 (**Refs. 17 & 19**), i.e a linear relationship between leakage rate and pressure can be assumed for large systems.

Using this assumption of a linear relationship between leakage rate and pressure leaves the two other system-specific key factors which can influence the lowest volume of Real Losses which can be achieved in any particular system, i.e.

- Location of customer meters on service connections (relative to street/property boundary);
- Density of service connections (per km of mains).

The best Operational Performance Indicator for Real Losses - the Infrastructure Leakage Index - deals with both these factors, and average operating pressure, by calculating a system-specific value for ‘Unavoidable Annual Real Losses’ (UARL).

The ratio of the Current Annual Real Losses (CARL, calculated from the standard Water Balance) to the UARL, is the Infrastructure Leakage Index (ILI), i.e.

Infrastructure Leakage Index ILI = CARL/UARL

The equation for UARL is based on BABE (Background and Bursts Estimates) concepts, using auditable assumptions. With BABE concepts, it is possible to calculate, from first principles, the components that make up the annual volume of Real Losses. This is because the leaks occurring in any water supply system can be considered conceptually in three categories:

- Background leakage – small undetectable leaks at joints and fittings;
- Reported bursts – events with larger flows which cause problems and are reported to the water supplier;
- Unreported bursts – significant events that do not cause problems and can only be found by active leakage control.

The larger detectable events are usually referred to as bursts, while those too small to be located (if not visible) are referred to as background leaks. The threshold between bursts and background leaks can vary from country to country, depending upon factors such as minimum depth of pipes, type of ground and surface, etc. In the UK a threshold limit of 500 litres/hour was used in the 1994 Managing Leakage Reports, but advances in technology and other factors suggest that a figure of around 250 litres/hour would be more appropriate in New Zealand. In other words:

Events	**>**	**250 litres/hour**	**=**	**Bursts**

Events	**<**	**250 litres/hour**	**=**	**Background Leaks**

In all water supply systems there are likely to be both bursts and background leaks since it is not possible to develop a system completely free from leakage. However, using the BABE concept it is possible to calculate the Unavoidable Annual Real Losses on a System-Specific basis.

G3. CALCULATION OF UNAVOIDABLE ANNUAL REAL LOSSES (UARL)

The procedure to estimate the unavoidable annual real losses (UARL) was developed by Lambert during the period of the International Water Association's

Task Force on Water Losses. The methodology is described in a paper in AQUA (**Ref. 6**) and basically involves estimating the unavoidable losses for three components of infrastructure, namely:

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

In the New Zealand BENCHLOSS software, the third of these components can normally be ignored as customer meters are located close to the street:property boundary, and underground supply pipe leakage is considered to be part of ‘Consumption’, for both metered and unmetered properties.

The parameters used in the calculation of the losses are indicated in **Table G.1**. From this table it can be seen that the one variable common to all elements is pressure. This is also the one variable that is normally excluded from most commonly used leakage performance indicators such as percentage, leakage per connection per day and leakage per km of mains per day etc.

Table G.1: Parameters required for calculation of UARL

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

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

Each of the elements in **Table G.1** can be allocated a value appropriate to infrastructure in good condition, operated in accordance with best practice, based on the analysis of data from numerous systems throughout the world. The results are provided in **Table G.2**.

Table G.2: Parameter values used to calculate UARL

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

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

The parameter values indicated in **Table G.2** are based on international data for minimum background loss rates and typical burst frequencies for infrastructure in good condition, and for typical average flow rates of bursts and background leakage at 50m pressure. For reported bursts, the multiple of average flow rate by average duration may be conveniently considered as an average 'volume per burst', as large reported bursts tend to be fixed more quickly than smaller ones. The average duration for unreported bursts is based on intensive active leakage control, approximating to night flow measurements once per month on highly sectorised water distribution systems.

Methods for calculating the average pressure in the system under consideration are explained in **Appendix H**.

Assuming a simplified linear relationship between leakage rate and pressure, the components of UARL can be expressed in modular form, for ease of calculation, as shown in **Table G.3**. Sensitivity testing shows that differences in assumptions for parameters used in the 'Bursts' components have relatively little influence on the 'Total UARL' values in the 5th column of **Table G.3**.

Table G.3: Calculated Components of Unavoidable Annual Real Losses

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

NOTE: the UARL leakage from Service Connections after the street/property boundary are considered as part of Consumption in the New Zealand context, but can still be calculated if required (see Appendix C and 'Consumption' Worksheet). The real losses from the service connections (main to street:property boundary) tend to dominate the calculation of UARL in New Zealand, except at low density of connections (20 or less per km of mains).

Based on the figures provided in **Table G.3** the calculation of the UARL in the NZ BENCHLOSS software can therefore be expressed as follows:

UARL = (18 * Lm + 0.80 * Ns) * P

Where:

UARL	=	Unavoidable annual real losses (Litres/day)
Lm	=	Length of mains (km)
Ns	=	No. of service connections (main to street:property boundary)
P	=	Average operating pressure at average zone point (metres)

In the April 2002 version of BenchlossNZ, the lower limit of system size for calculation of Unavoidable Annual Real Losses (UARL) was 5000 service connections. This has now been substantially reduced, based on analysis of additional data; if Lm is mains length (km) and Ns is number of service connections, the UARL calculation can be made if (Lm x 20 + Nc) exceeds 3000. Accordingly the ILI calculation can now be made with confidence for a much wider range of systems and sub-systems.

Example: A New Zealand system has 114 km of mains, 3920 service connections, and an average operating pressure of 50 metres. Calculate the UARL to the street:property boundary

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

APPENDIX H

Methods Of Calculating Average Pressure In Distribution Systems

Methods Of Calculating Average Pressure In Distribution Systems

H1. A SYSTEMATIC APPROACH TO CALCULATING AVERAGE PRESSURE

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

- For each individual zone or sector, calculate the weighted average ground level;
- Near the centre of the zone, identify a convenient pressure measurement point which has the same weighted average ground level – this is known as the **Average Zone Point**;
- Measure the pressure at the Average Zone Point, and use this as the surrogate average pressure for the Zone.

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

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

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

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

If Network Analysis models are not available, the approach used in part H2 of this Appendix should be followed. If Network Analysis models are available, follow the approach in part H3.

H2. AVERAGE ZONE PRESSURES WHERE NO NETWORK MODELS EXIST

H2.1 Calculate Weighted Average Ground Level for Each Sector

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

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

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

Whichever infrastructure parameter is selected, the weighted average ground level can then be calculated as shown in **Table H1** below**.**

Table H1: Example calculation of weighted ground level

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

Weighted Average Ground Level = 3907 / 357 = 10.9 m

B2.2 Measure or Calculate Average Zone Pressure

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

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

Example: In the sector data in **Table H1**, the average inlet pressure at a service reservoir is 1.5 metres below the overflow level (which is 65.0 metres above mean sea level - amsl).

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

H2.3 Calculate Weighted Average Pressure for Aggregation of Zones

The weighted average pressure for sectors of a distribution system, consisting of aggregations of individual zones with different average pressures, is obtained by calculating a weighted average for all the zones. If possible, the Number of Service Connections should be used as the weighting parameter (if not available, use length of mains or number of hydrants). An example calculation is shown in **Table H2**.

Table H2: Example calculation of weighted ground level

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

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

H3. AVERAGE ZONE PRESSURES USING NETWORK MODELS

H3.1 Calculate Weighted Average Ground Level for Each Sector

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

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

APPENDIX I

PRINTOUT OF BENCHLOSS
VERSION 2a WORKSHEETS

APPENDIX J

Using Night Flow Measurements to assess Real Losses

APPENDIX J: USING NIGHT FLOW DATA TO ASSESS REAL LOSSES

J1 USING NIGHT FLOW DATA TO ASSESS REAL LOSSES

In the BenchlossNZ 2008 and CheckCalcsNZ software, Real Losses are assessed from an annual Water Balance. However, the estimate of Real Losses that results may have wide confidence limits, particularly for partially metered systems where there are large uncertainties in estimates of unmeasured residential consumption (including supply pipe losses).

Night flow measurements can also be used to provide an alternative assessment of Real Losses, particularly in small districts where not all properties are metered. This Appendix is an introduction to the general concepts of assessing Real Losses in small systems.

Measurement and analysis of night flows from small systems, or sub-systems within a larger distribution system, is also a practical and effective way to identify:

- the presence of significant amounts of detectable leakage
- changes in leakage
- priorities for leak detection activities

but these topics are not covered in this Appendix

For the purpose of this Appendix, systems where night flows are measured will be referred to as District Metered Areas (DMAs), whether the night flow is measured continuously or only occasionally.

The easiest way to identify distribution DMAs with high leakage is a visual check on the 24-hour flow and pressure profiles. DMAs where the night flow is consistently a high proportion of the average inflow (**Figure J1**) will generally have higher leakage, and be a priority for active leak detection.

In contrast, DMAs where the night flow is only a low proportion of the average inflow **(Figure J2)** will generally be those with lower leakage, and not such high priorities for active leak detection.

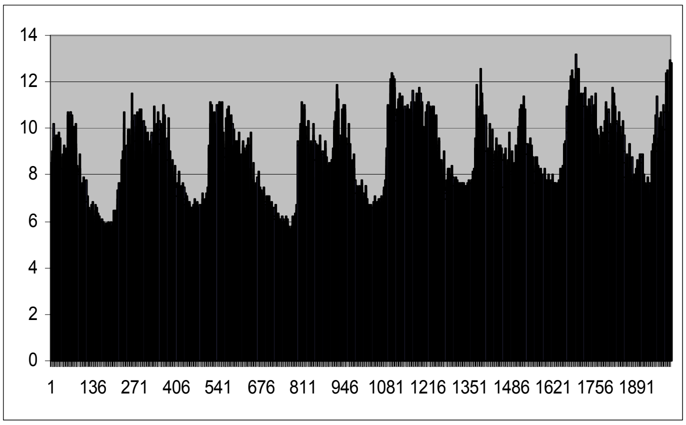


Figure J1: Sequence of Inflows for one week to a DMA with high leakage

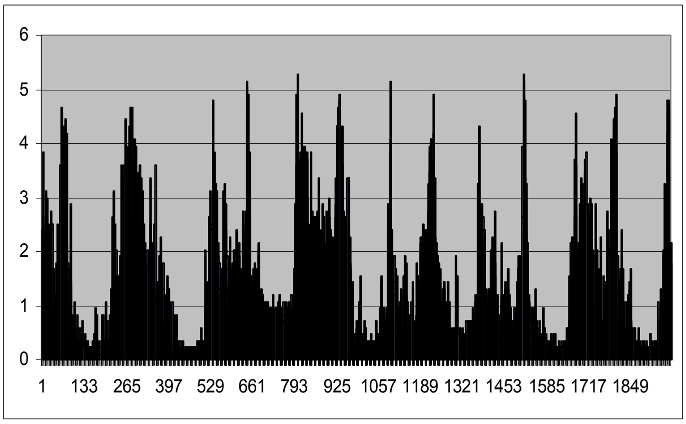


Figure J2: Sequence of Inflows for one week to a DMA with low leakage

Visual inspection of graphed flow and pressure data is always the first and most important step in any analysis of DMA data, and an important aspect of data quality control, prior to more detailed analyses.

J2 THE INFLUENCE OF PRESSURE VARIATIONS, AND NIGHT-DAY FACTORS

Figure J3 shows a 24-hour profile of inflow and average Zone Pressures for a DMA supplied by gravity. In the early hours of the morning (normally sometime between 1 am and 4 am) customer night use is at a minimum, and leakage is at a maximum because of the higher average pressures at night.

If an estimate can be made of the customer night use, at the time of minimum night flow, then what remains is leakage. However, this leakage is not only on the water supplier's distribution system, but also on the customers' private supply pipes and plumbing systems.

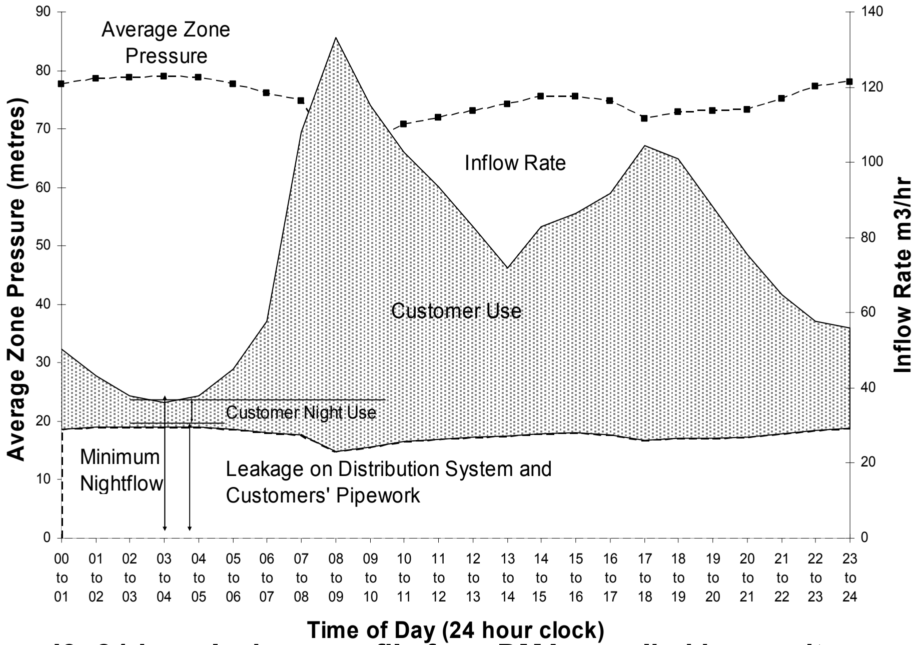


Figure J3: 24-hour leakage profile for a DMA supplied by gravity

It can also be seen from **Figure J3** that, as customer use and inflow vary over the 24 hours, the average pressure in the system changes, and (because leak flow rates change with pressure) the leak flow rates also change. So in the case of a DMA supplied by gravity, it can be seen from **Figure J3** that the average leakage over 24 hours will be less than 24 times the leakage at night (in m^3/hour).

In contrast, **Figure J4** shows a 24-hour profile of inflow and pressure for a DMA supplied with modulated pressure control (or by pumping), where average pressure at night is less than that during the day. In this situation, it can be seen that the average daily leakage will be more than 24 times the leakage at night (in m^3/hour).

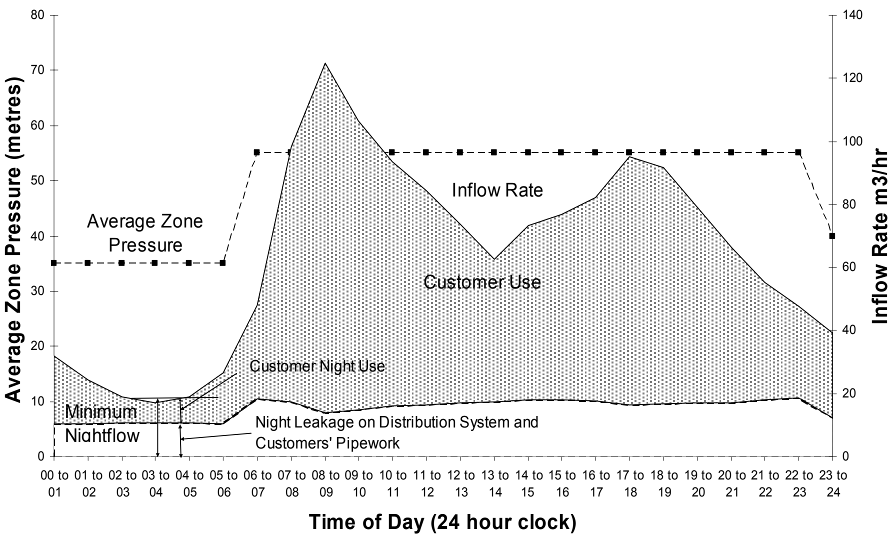


Figure J4: 24-hour leakage profile for a DMA with pressure modulated input.

To convert a night leakage rate in m^3/hour, to an average daily leakage rate in m^3/day, it is necessary to multiply by a Night-Day Factor NDF, with units of Hours/day. The term 'Hour-Day Factor' is also used in the UK.

Night-Day Factors can be assessed by taking pressure measurements at the 'Average Zone Point' in a DMA, using an appropriate FAVAD N1 value (see Appendix G). The 'PressCalcs' Standard software (www.Leakssuite.com) includes a more comprehensive explanation and Worksheets to define the AZP point, estimate N1 values, and calculate NDFs from pressure measurements at the Average Zone Point.

For DMAs supplied by gravity, Night-Day Factors typically vary from 18 to 23 hours/day. DMAs with pumped of pressure-modulated inflow typically have NDFs ranging from 24 to over 30 hours/day.

It will be evident from the above, that pressure has a major influence on the leakage component of night flows, and that reconciliation of night leakage rates with Real Losses calculated from an annual water balance needs an understanding, and proper application, of the principles involved.

J3 'SNAPSHOT' ESTIMATES OF REAL LOSSES

However, it is possible to get 'Snapshot' estimate of real losses from night flow measurements. To do this, it is first necessary to select an appropriate time of year, when the only components of night use are the aggregations of small individual customer night use (e.g. toilet flushing). **Figure J5** shows the annual pattern of daily system inflows, and night flows, in a large DMA in Australia. Clearly, any attempt to estimate Real Losses from night flows during the summer 6 month period is going to be invalidated by the large and unknown amount of exceptional night use due to garden watering, late night holiday activities, etc.

In such circumstances, it is preferable to take and interpret night flow measurements at times of the year when exceptional night use is at a minimum – typically April to October in New Zealand (times will vary between North and South Island).

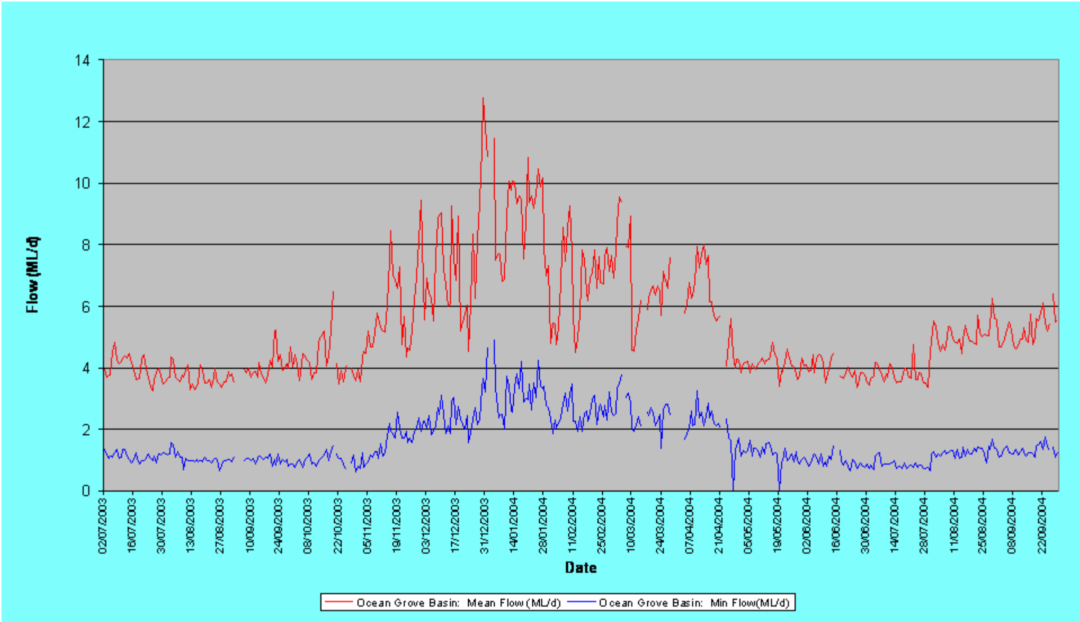


Figure J5: Annual variation of daily inflows and night flows in a Victoria DMA

Looking again at **Figures J3 and J4**, it can be seen that, when estimated customer night use is deducted from minimum night flow, the leakage remaining includes leakage on customers' supply pipes and plumbing systems after the property line. So to estimate the leakage rate on the water supplier's mains and service connection up to the property line, an estimate of leakage after the property line needs to be made.

Given the widely different conditions between different DMAs and small systems in New Zealand in terms of F-Factor (see Appendix C), length of supply pipes Lp, and night pressure, estimates of 'customer leakage at night' can be expected to vary widely; the influence of toilet cistern leaks can also be significant. If customer night use and customer leakage are aggregated, values of 'Customer night consumption' are likely to vary from less than 2 litres/service conn./hr in urban areas with single service connections to single residential properties, to more than 10 litres/conn/hr in some rural areas. Guidance on the most appropriate figure to choose for night consumption in individual Zones normally requires a more detailed approach to component analysis, which is outside the scope of this relatively brief Appendix.

However, once an estimate of the assessed Customer Night Consumption has been made, a 'Snapshot' estimate of Night Leakage Rate on the water supplier's infrastructure can be made using **Step 1** of the ILMSS software **NLRxNDFCalcs,** see **Figure J6** Confidence limits are a useful feature of this calculation.

STEP 1: CALCULATE SNAPSHOT NIGHT LEAKAGE RATE		09/07/05	to	15/07/05
Number of Service Conns = 3310 Length of Mains (km) = 47.00 when AZNP (metres) = 59.00	Litres/ sec	m^3/ hour	Litres/ conn/ hour	95% Conf. Limits
Minimum Night Flow MNF	6.50	23.40	7.07	2.0%
Assessed customer night consumption CNCa	1.84	6.62	2.00	40.0%
Exceptional customer night consumption CNCe	0.00	0.00	0.00	20.0%
Snapshot Night Leakage Rate NLR = MNF - CNCa - CNCe	4.66	16.78	5.07	16.0%

Figure J6: Estimation of Snapshot Night Leakage Rate, NLRxNDFCalcs

If the Night-Day Factor is also available, the Snapshot Daily leakage can also be estimated, as in **Step 2** of **NLRxNDFCalcs,** see **Figure J7**

STEP 2: MULTIPLY NIGHT LEAKAGE RATE (NLR) by NIGHT DAY FACTOR (NDF) to obtain SNAPSHOT DAILY LEAKAGE	m^3/ hour	Hours/ day	m^3/ day	95% Conf. Limits
Night Leakage Rate NLR	16.78			16.0%
Night-Day Factor NDF		20.00		5.0%
Snapshot Daily Leakage = NLR x NDF			336	16.8%

Figure J7: Estimation of Snapshot Daily Real Losses, NLRxNDFCalcs

The Snapshot Daily Leakage can then be used to calculate Snapshot values of the Real Losses Performance Indicators, as in **Step 3** of **NLRxNDFCalcs,** see **Fig. J7**. However, any calculation of ILI which is not based on an annual water balance can only be regarded as an indicative value.

This is because 'Snapshot' ILIs derived from different limited sets of night flows will vary around the annual ILI value, and may even be less than 1.0 soon after an active leakage control intervention, when all reported and unreported bursts have been repaired, and only background leakage remains. So a 'Snapshot' ILI should always be considered as being an approximate value, always treated with caution, and always referred to as a 'Snapshot' value to avoid confusion with the ILI calculated from the annual water balance.

STEP 3: CALCULATE SNAPSHOT VALUES OF REAL LOSSES PERFORMANCE INDICATORS			
The Snapshot Daily Leakage is	335.6	m3/day	
	101	litres/connection/hour +/-	16.8%
The Snapshot Night Leakage Rate is	16.78	m3/hour at 59 metres AZNP	
The Unavoidable Annual Real Losses are	8.59	m3/hour at 59 metres pressure	
So 'Snapshot' Infrastructure Leakage Index is	1.95	which is in WBI Band	A

Figure J8: Estimation of Snapshot Real Losses Performance Indicators, NLRxNDFCalcs

In summary, this Appendix has only sought to outline the methods by which Real Losses can be estimated from night flow measurements. The IWA Water Loss Task Force DMA Guidance Manual provide more information, and can be downloaded free of charge from the IWA Water Loss Task Force Website www.iwaom.org/wltf

APPENDIX K

Overview of the

CheckCalcsNZ software

APPENDIX K: OVERVIEW OF CHECKCALCSNZ SOFTWARE

K1 REASONS FOR PROVIDING CHECKCALCS, IN ADDITION TO BENCHLOSS

The BenchlossNZ 2008 software and User Manual are designed to provide the user with a comprehensive step-by-step introduction to the IWA Water Balance and the most appropriate Performance Indicators for public water supply systems in New Zealand. However, there were practical limitations on how much new additional relevant material could be added to the existing format and structure of the original 2002 BenchlossNZ, in the 2008 update.

To overcome this problem, ILMSS Ltd and Wide Bay Water Corporation offered to produce a customised version (CheckCalcsNZ Version 3a) of their existing CheckCalcs software which would be complementary to BenchlossNZ 2008, to:

- provide a quick streamlined version of the Water Balance and PI calculations for New Zealand water suppliers with smaller systems and for water suppliers' sub-systems
- allow the Annual Operating cost – required for the NRW Financial PI Fi47, NRW% by cost - to be calculated according to the latest IWA principles.
- quickly identify appropriate action priorities for different World Bank Institute Performance Bands A to D
- provide an overview of pressure management opportunities and probable range of reduction of leak flow rates, new burst frequencies and income from metered customers.

All New Zealand water suppliers purchasing a copy of the BenchlossNZ 2008 software and User Manual are entitled, on request to Wide Bay Water Corporation (the Distributor of ILMSS LeaksSuite in New Zealand), to a free copy of the January 2008 version of CheckCalcsNZ Version 3a. ILMSS Ltd retains the Copyright and Intellectual Property Rights of all LEAKSSuite software in New Zealand, Australia and internationally.

K2 INDIVIDUAL WORKSHEETS IN THE CHECKCALCSNZ SOFTWARE

There are 12 Worksheets in the January 2008 version of CheckCalcsNZ Version 3a. Worksheet tabs are colour-coded as follows:

Worksheets containing information only	Worksheets requiring Essential or Optional Data Entry

The individual Worksheets are briefly described below.

Licence: this Worksheet specifies the Water Supplier Licensee (with a unique reference number for each New Zealand water supplier) and the Conditions of Distribution and Use **(Fig K1)**. No data entry is required.

Welcome to CheckCalcsNZ

which is part of the **'LEAKS'** Suite of **L**EAKAGE **E**VALUATION and **A**SSESSMENT **K**NOW-HOW **S**OFTWARE

Copyright and All Rights Reserved.

Copyright in the whole and every part of this program is the property of ILMSS Ltd (the Owner).

This program is distributed in New Zealand by Wide Bay Water Corporation (the Distributor)

The purpose of this free program is to assist water suppliers in New Zealand to quickly identify opportunities for saving money and saving water

CheckCalcsNZ Version 3a	Standard 10th Jan 2008	Free Check on Leakage and Pressure Management Opportunities
New Zealand	NZL.000	This copy licensed to: ABC Water

Conditions of Distribution and Use:	
1.	The program is specifically designed for issue to, and use by, water suppliers in New Zealand. Electronic copies must not be provided to third parties or used for any systems other than those in New Zealand, except with the prior permission of both the Owner and the Distributor.. The program is protected with passwords which will not be revealed.
2.	No liability will be accepted by the Owner or the Distributor in respect of loss or damage that may occur as a result of viruses transferred or claimed to have been transferred through use of the program, which has been virus checked before dispatch. The User should also check the program for viruses.
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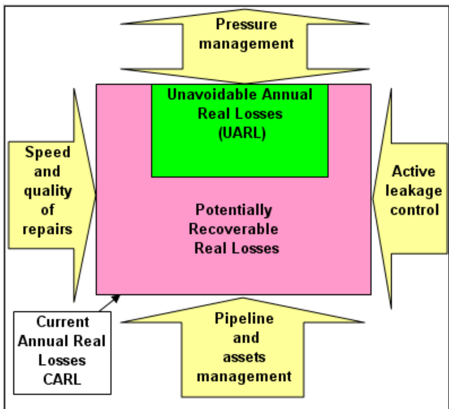
4	Any disputes relating to the program or its use shall be dealt with under Australian Law in Australian Courts.
5	By opening the software and proceeding from this Licence Worksheet to the other Worksheets, the User accepts these Conditions of Distribution and Use.
6	This program is designed to operate using Microsoft Excel 2003 Version. If any difficulties are experienced with the installation or operation of this program, please contact the Distributor (grahamc@widebaywater.qld.gov.au)

After reading this Worksheet, please move on to the **'Intro'** Worksheet >>>>

Figure K1: Licence Worksheet, CheckCalcsNZ

Intro: this worksheet provides a short introduction to CheckCalcsNZ, and explains how it is complementary to BenchlossNZ 2008. No data entry is required.

4 Comps: this worksheet outlines the 4 component activities necessary to manage Real Losses (**Fig. K2**). No data entry is required



Real Losses consist of leakage and overflows from transmission and distribution systems up to the point of customer metering or consumption. This diagram is widely used by members of the IWA Water Loss Task Force, as it summarizes the 'best practice' principles of managing real losses.

Suppose that the large red box in the diagram represents the current annual volume of real losses (CARL) for any system, calculated using a standard IWA annual water audit (or water balance). Real Losses tend to increase as systems grow older, but can be managed by an appropriate combination of all four component activities shown as arrows:
Speed and quality of repairs: *to minimise the run-time of all leaks and bursts*
Pressure management*: to reduce the numbers of new breaks and all leak flow rates*
Active leakage control: *to find and fix unreported leaks and bursts*
Pipeline and assets management: *selection, installation, maintenance, renewal, replacement*

The green box represents the lowest technically achievable Real Losses, or 'Unavoidable Annual Real Losses' (UARL). The UARL can be calculated on a system-specific basis, as a volume per day or year, based on mains length, number of service connections, location of customer meters (average distance from property line to customer meter) & average pressure.

The difference in volume between the Current Annual Real Losses (CARL: red box) and the Unavoidable Annual Real Losses (UARL: green box) represents the Potentially Recoverable Real Losses. The ratio of CARL/UARL is known as the Infrastructure Leakage Index (ILI). The Economic Level of Real Losses usually lies somewhere between the CARL and the UARL.

For more information on the standard IWA Water Balance and terminology, go to the **'Terminology'** Worksheet >>>>

To start a simplified calculation of CARL, UARL and ILI for your system, go straight to the **'System Info'** Worksheet >>>

Figure K2: 4 Comps Worksheet, CheckCalcsNZ

Terminology: Worksheet shows the Water Balance diagram for New Zealand (**Fig.K3**); definitions of the terms used are also given. No data entry is required.

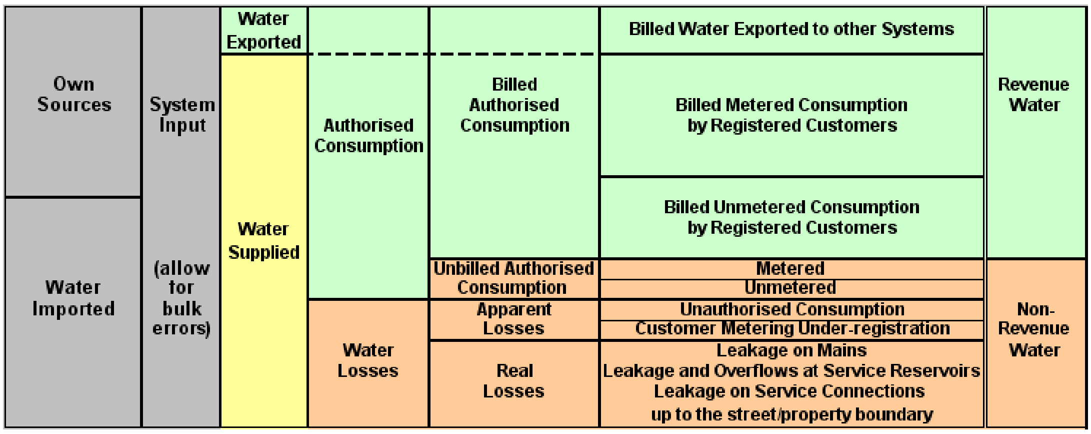


Figure K3: Water Balance diagram, Terminology Worksheet, CheckCalcsNZ

System Info: used to enter Infrastructure and pressure data for the system under review (**Fig K4**). Cells in the Worksheets are colour coded as follows:

Colour coding	Data entry	Essential Data Entry	Default Values	Calculated	From another Worksheet

STEP 1: Enter WATER SUPPLIER and SYSTEM NAME, PERIOD and basic information on SYSTEM PRESSURE						
Country	New Zealand	Water Supplier	ABC Water			
System	Anytown	Period	01/07/98	to	01/07/99 365	days
STEP 2: Enter basic information on INFRASTRUCTURE and PRESSURE for this system					95% Conf limits +/- %	
Length of Transmission and Distribution Mains (Lm)			560.4	km	2.0%	
Number of service connections, main to property boundary line			15502		1.0%	
Number of service connections per kilometre of mains (Lm/Nc)			27.7	per km	2.2%	
Estimated average pressure over the year (P)			58.9	metres	5.0%	
% of time system is pressurised (T)			100.0%	Brief comments:		
Is supply input mainly by Gravity (G) or Pumping (P)?			G			
Audit trail	Calculation by	A.N. Other	Date 10/01/08	e-mail	another@anywhere.co.nz	
When you have completed this Worksheet, move on to the '**Water Balance**' Worksheet >>>>						

Figure K4: Calculations in System Info Worksheet, CheckCalcsNZ

Enter the 8 items of Essential data entry, and preferably also complete the other yellow data entry Cells relating to 95% confidence limits, Brief comments if appropriate, and Audit trail (Name, date, contact e-mail)

Water Balance: Worksheet is used to calculate Non Revenue Water, Current Annual Real Losses and Unavoidable Annual Real Losses. The calculations are shown in **Fig. K5** below; a 6-step procedure for completing this Worksheet is provided on Rows 39 to 54 of the Worksheet, below the calculations.

Colour coding	Data entry	Essential Data Entry	Default Values	Calculated	From another Worksheet

IWA WATER BALANCE CALCULATIONS for			Anytown			95%	ABC Water			
01/07/1998	to	01/07/1999	365	days	Volume	conf.	Supplementary Checklist relating			
COMPONENTS OF IWA WATER BALANCE					$m^3 \times 10^3$	+/-%	to volumes in calculation			
INPUT FROM YOUR OWN SOURCES					0.0	0.0%	< Corrected for known			No
Water Imported to this system (WI)					6461.7	2.0%	< Corrected for known			No
SYSTEM INPUT					6461.7	2.0%				
Water Exported from this system (WE)					101.0	2.0%	< Corrected for known			No
WATER SUPPLIED to this system (WS)					6360.7	2.0%				
Billed Metered Consumption	14000	Residential Properties (BMCR)			3832.0	2.0%	< Corrected for meter lag?			No
	1714	Non-Residential Properties			1251.0	3.0%	< Corrected for meter lag?			No
Billed Unmetered Consumption	77	Res. Props @	900	lit/prop/d	25.3	20.0%	< Includes	66	lit/prop/d	supply pipe leakage
	42	Non-Res Props @	1500	lit/prop/d	23.0	20.0%	< Includes	66	lit/prop/d	
	Other	Seasonal/Tourists			1.7	30.0%	**Value of NRW components**			
Billed Authorised Consumption (Metered and Unmetered)					5133.0	1.7%	$/m3		$ x 10^3	
NON-REVENUE WATER (NRW)					1227.7	12.6%	0.16		194	
Unbilled Authorised Consumption			0.50%	of WS	31.8	100.0%	0.30		10	
WATER LOSSES (WL)					1195.9	13.2%	0.15		184	
Unauthorised Consumption			0.10%	of WS	6.4	100.0%	0.70		4	
Customer Meter Errors	Residential		2.00%		76.6	50.0%	0.70		54	
	Non-Residential		2.00%		25.0	50.0%	0.70		18	
APPARENT LOSSES (AL)					108.0	37.8%	0.70		76	
CURRENT ANNUAL REAL LOSSES (CARL)					1087.9	15.0%	0.10		109	
UNAVOIDABLE ANNUAL REAL LOSSES (UARL)					483.5	5.1%	0.10		48	
CURRENT ANNUAL REAL LOSSES (CARL) minus UARL					604.4	27.1%	0.10		60	
Comments:										
Audit trail	Calculation by		A.N. Other		Date	######	e-mail	another@anywhere.co.nz		
Move to **'Running Costs'** Worksheet if you wish to calculate the NRW Financial PI '% NRW by Value' for a water supplier's entire system >>										
For systems or sub-systems where this Financial PI is not appropriate, move on to the **'Performance'** Worksheet >>>>										

Figure K5: Calculations in Water Balance Worksheet, CheckCalcsNZ

This Worksheet has several useful practical features:

- all water balance volume calculations are on one worksheet, with confidence limits, for easy sensitivity testing
- a supplementary checklist for volumes used in the calculations, relating to:
  - bulk supply meter corrections
  - meter lag corrections
  - supply pipe leakage assumptions for unmetered properties can be shown
- standard defaults for Unbilled Authorised Consumption, Unauthorised Consumption, Customer Meter Error, are explained using red triangle 'Comments'
- each NRW component volumes can be easily converted to a $ value
- Unavoidable Annual Real Losses (UARL), and excess of Current Annual Real Losses (CARL) over UARL, are calculated and shown immediately below CARL
- Comments Box for entering additional notes.

Running Costs: if the User wishes to calculate the IWA Financial Performance Indicator Fi47 (Non Revenue Water % by value) for the water supplier's whole system, this worksheet can be used to calculate Annual Running Costs. Specific items of financial information from the Water Supplier's accounts are required. This Worksheet does **not** need to be completed if the User wishes to calculate only Apparent and Real Loss Performance Indicators, or if the calculation is for a water supplier's sub-system.

Performance: this Worksheet shows calculated values of recommended best practice performance indicators for NRW, Apparent Losses and Real Losses in New Zealand. The calculations are shown in **Figure K6** below; brief information notes on these Performance Indicators are provided on Rows 24 to 30 of the Worksheet.

Colour coding	Data entry	Essential Data Entry	Default Values	Calculated	From another Worksheet

ABC Water	Anytown	01/07/1998	to	01/07/1999	Density of Conns =	27.7	per km mains

Type of PI	Description of Performance Indicator		95% Conf Limits, +/-%	Comments
Operational management of Real Losses at Current Pressure	IWA Op27: litres/service connection/day	192	15.1%	Litres/conn/day is the better simple PI for this system, with 20 connections/km of mains or more
	IWA Op28: m3/km of mains/day	5.3	15.2%	
	IWA Op29: Infrastructure Leakage Index ILI	2.25	15.9%	The best PI for Operational Management of Real Losses
Apparent Losses	Apparent Losses volume as % of metered consumption (excluding Water Exported)	2.1%	37.8%	The most appropriate simple PI for Apparent Losses in New Zealand
Financial management of Non Revenue Water	Estimated Value of NRW in $ x 10^3	194	12.6%	From 'Water Balance' Worksheet
	Annual Cost of Running this system in $ x 10^3	6500	10.0%	From 'Running Costs' Worksheet
	IWA Fi47: NRW value as % of annual running cost	3.0%	16.1%	A better NRW PI than % by volume
Note: for comparison with Cell F16 only: NRW as % by volume of Water Supplied		19.3%	12.8%	**Not** a recommended PI

Audit trail	Calculation by	A.N. Other	Date	10/01/08	e-mail	another@anywhere.com

To compare the ILI for this system with World Bank Institute Guidelines, move on to the 'WBI Guidelines' Worksheet >>>>>>

Figure K6: Calculations in Performance Indicators Worksheet, CheckCalcsNZ

WBI Guidelines: first categorises the calculated ILI into Band A, B, C or D of the World Bank Institute Banding system, to give an overview of performance **(Fig K7)**.

THIS WORKSHEET PROVIDES AN OVERVIEW OF POSSIBLE OPPORTUNITIES AND ACTIONS FOR IMPROVING LEAKAGE MANAGEMENT PERFORMANCE

World Bank Institute (WBI) Guidelines

The World Bank Institute has recently introduced, into its NRW Training Modules, a target matrix for Real Losses management performance, based on real losses in volume/service connection/day for a range of average operating pressures, and classified into Bands A to D. The targets assume that customer meters are located at the property boundary, with an average connection density of around 40 per km mains. Bands A to D in the WBI target matrix can also be shown as an equivalent range of ILIs, which can be applied to a wider range of connection densities and customer meter locations, as shown below. Band limits in terms of ILIs, general descriptions of each Band, and appropriate recommended actions are as follows:

Developed Countries ILI range	BAND	Calculated ILI for this System	General description of Real Loss Management Performance Categories for Developed and Developing Countries
Less than 2	A		Further loss reduction may be uneconomic unless there are shortages; careful analysis needed to identify cost-effective improvement
2 to < 4	B	2.3	Potential for marked improvements; consider pressure management, better active leakage control practices, and better network maintenance
4 to < 8	C		Poor leakage record; tolerable only if water is plentiful and cheap; even then, analyze level and nature of leakage and intensify leakage reduction efforts
8 or more	D		Very inefficient use of resources; leakage reduction programs imperative and high priority

Figure K7: WBI Bands: WBI Guidelines Worksheet, CheckCalcsNZ

The WBI Guidelines worksheet then compares the ILI for the system with a recent (2004/05) set of Australian and New Zealand ILI values **(Fig. K8**), and suggests recommendations for priority actions appropriate to the WBI Band that the ILI lies within **(Fig K9**).

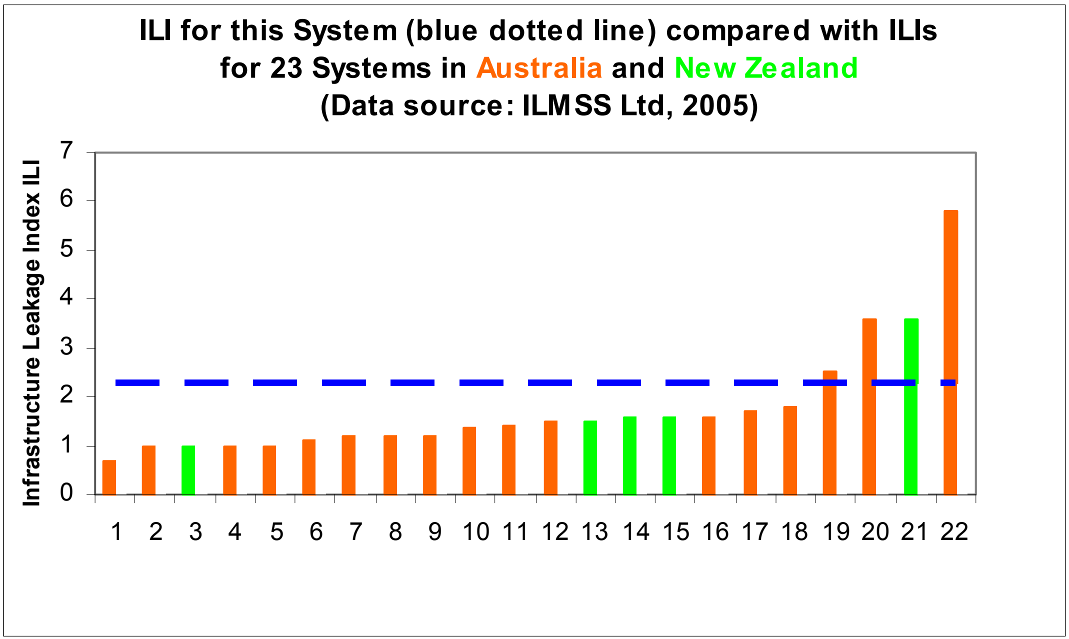


Figure K8: ILI comparisons: WBI Guidelines Worksheet, CheckCalcsNZ

Priority Recommendations for WBI BANDS	A	B	C	D
Investigate pressure management options *	Yes	Yes	Yes	
Investigate speed and quality of repairs	Yes	Yes	Yes	
Check economic intervention frequency **	Yes	Yes		
Introduce/improve active leakage control **	Yes	Yes	Yes	
Identify options for improved maintenance		Yes	Yes	
Assess Economic Leakage Level ***	Yes	Yes		
Review break frequencies		Yes	Yes	
Review asset management policy		Yes	Yes	Yes
Deal with deficiencies in manpower, training and communications			Yes	Yes
5-year plan to achieve next lowest band			Yes	Yes
Fundamental peer review of all activities				Yes

Figure K9: Priority Recommendations, WBI Guidelines Worksheet, CheckCalcsNZ

* Footnotes for the asterisked items are provided on the Worksheet

Pressure Management Opportunites: Management of surges (pressure transients) and reduction of excess pressures are very effective techniques for reducing leak flow rates, the frequencies of new leaks and bursts, and some components of consumption. The **PMOpportunities** Worksheet provides a simple screening process to obtain an overview of pressure management opportunities, as shown in **Fig. K10**. The User can then consider whether further investigation of pressure management options is likely to be justified.

THIS WORKSHEET PROVIDES AN OVERVIEW ASSESSMENT OF POSSIBLE PRESSURE MANAGEMENT OPPORTUNITIES						
If system pressures are excessive, or subject to surges, then some or all of the following benefits may be achieved by pressure management:						
◻ Reductions in flow rates from existing leaks and bursts						
◻ Reduced numbers of new bursts, reduced annual repair costs, and extended infrastructure life (if pressure reductions are permanently maintained)						
◻ Reductions in residential consumption, mainly due to consumption outside the property (irrigation etc).						
The simple screening process shown below helps to quickly identify the probability of pressure management opportunities.						
Step 1:	Check for presence of surges by recording sample pressures in system at 1-second intervals.					
Step 2:	Assess probability of Pressure Management opportunities based on type of supply (gravity or pumped) and average pressure					
ABC Water			Type of System	Average Pressure	Probability	
Anytown			Gravity supply	Less than 30 metres	LOW	
Average System Pressure Pav is	58.9	metres		30 to 40 metres	MODERATE	
System is supplied principally by gravity with	Continuous supply			40 to 60 metres	MEDIUM	
Using this information, and the assessment method shown, the probability of pressure management opportunities for this system can be provisionally categorised as	MEDIUM			More than 60 metres	HIGH	
			Direct pumping	All	HIGH	
			Intermittent Supply	All	HIGH	
Step 3: Predict possible changes in leak flow rates, frequency of new bursts and repair costs, and residential consumption, for change in pressure						
Assumed change in average system pressure	-5.00	metres	Probable range of predicted changes:	Lower	Average	Upper
Assumed % change in Pav	-8.5%		% change in current leak flow rates	-4%	-8%	-12%
% of annual residential consumption outside property	30%		% change in new burst numbers and annual repair costs	-6%	-12%	-24%
Do customers have private storage tanks? (Yes/No)	No		% change in residential consumption	-0.3%	-0.8%	-1.3%
Step 4: If you require information on the Pressure Management software in LEAKSSuite, go to the **'LEAKS Suite Software'** Worksheet >>>>						

Figure K10: Pressure Management Opportunities Worksheet, CheckCalcsNZ

LEAKSuite Software: this Worksheet provides an overview of the Free, Standard and Professional Softwares in LEAKSSuite

Twin Track: the final Worksheet shows a Twin Track Approach to managing Real Losses, using BenchlossNZ, CheckCalcsNZ and other LEAKSSuite software (**Fig.K11**)

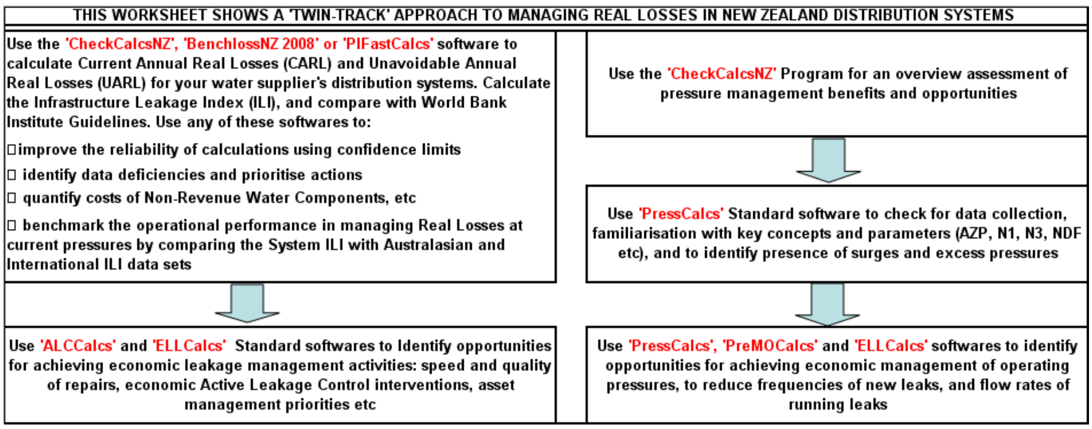


Figure K11: Twin Track Worksheet, CheckCalcsNZ

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The New Zealand Water & Wastes Association Waiora Aotearoa

A consistent approach across the 3 waters sector