the blue pages

the IWA information source on drinking water issues

Losses from Water Supply Systems: Standard Terminology and Recommended Performance Measures

SUMMARY

The quantity of water lost is an important indicator of the positive or negative evolution of water distribution efficiency, both in individual years and as a trend over a period of years. High and increasing annual volumes of water losses, which are an indicator of ineffective planning and construction, and low operational maintenance activities, should be the trigger for initiating an active leakage control programme.

However, a leak-free network is not a realisable technical or economic objective, and a low level of water losses cannot be avoided, even in the best operated and maintained systems, where water suppliers pay a lot of attention to water loss control.

With the increasing international trend towards sustainability, economic efficiency and protection of the environment, the problem of losses from water supply systems is of major interest world-wide. Both the technical and the financial aspects are receiving increasing attention, especially during water shortage or periods of rapid development.

Particular problems and unnecessary misunderstandings arise because of differences in the definitions used by individual countries for describing and calculating losses. Also, traditional performance indicators often give conflicting impressions of true performance in controlling water losses [1].

In 1996 the Operation and Maintenance Committee of the IWA's Distribution Division set up a Task Force to review existing methodologies for international comparisons of Water Losses from water supply systems. The main objectives were:

- to prepare a recommended basic standard terminology for calculation of real and apparent losses
- to review and recommend preferred performance indicators for international comparisons of losses.

This publication summarises the conclusions of the Water Losses Task Force, with particular reference to the preferred Performance Indicators for assessing operational performance in control of real losses (leakage and overflows) in transmission and distributions systems. The recommended terminology and the full range of preferred performance indicators for Water Supply Services are available in the IWA Manual of Best Practice *'Performance Indicators for Water Supply Services'* [2]. The development of the equation for calculating technical minimum (unavoidable) annual real losses, based on international research is described in detail in a recent AQUA paper [3].The conclusions of the Water Losses Task Force are summarised in Section 8 of these Blue Pages.

CONTENTS

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1. INTRODUCTION

The problems of water and revenue losses are:

- **Technical:** not all the water supplied by a water utility reaches the customer.
- **Financial and Economic:** not all the water supplied is paid for.
- **Terminology:** lack of standardised definitions of water and revenue losses.

The objectives of this paper are to:

- introduce a standard terminology for international use
- recommend how the annual volume of real and apparent losses should be calculated from a Water Balance
- recommend the most appropriate Performance Indicators for international use.

The actual quantity of water lost from a water distribution system will vary from utility to utility depending upon local factors such as topography, length of mains, number of connections and standards of service, and upon how well the system is being operated and maintained. In a well-operated system, water losses should be continuously monitored and controlled, and noted each year in an annual report.

The annual volume of losses consists of two separate types of losses – Real (physical) and Apparent (non-physical), which are described in Section 3 below.

2. THE IMPORTANCE OF RELIABLE METERING

Reliable metering of all water volumes should and must be an integral component of water supply, water demand management and loss determination. (*Figure 1*). The most important part of determining how much water is being lost in a system is to accurately quantify the volume of water which is entering that system. Metering of source meters for abstraction, treatment works production, imported and exported water, input volumes and inflows to sectorised distribution systems is essential for water balance calculations.

Measurements of night flows into sectors of the distribution system[4] are extremely useful for rapidly identifying the presence of new unreported leaks, which can then be located and quickly repaired. This technique can be used irrespective of whether customers are metered or unmetered.

The primary purpose of customer meters is generating economic revenue based on metered consumption, but the accuracy of these meters is also a key issue in water balance calculations. Customer meters require careful management if representative and significant results are to be obtained.

An efficient organisation will recognise and will deal with potential problems such as improper meter type or meter sizing, incorrect meter installation, meter encrustation, deterioration with age, flow rates less than the meter can reliably register, insufficient maintenance/replacement, frequency of calibration, inability to obtain readings, and influence of meter reading cycles.

Whenever actual metering is not possible, for example in activities such as fire fighting, flushing etc, every effort should be made to estimate each component of water use accurately to determine realistic quantities for the water balance.

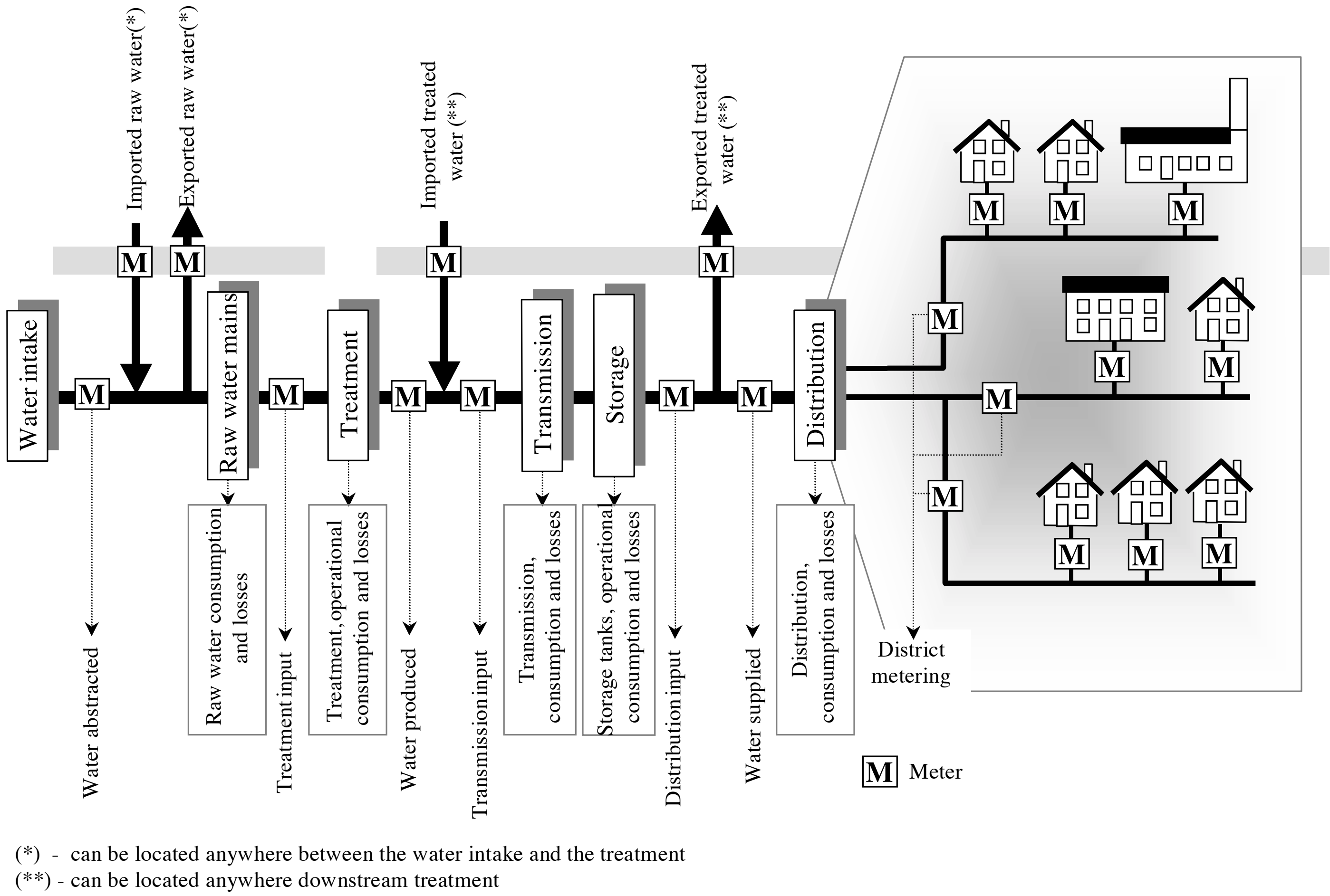

FIGURE 1: Definition of Water Supply System Inputs and Outputs

3. STANDARD DEFINITIONS FOR INTERNATIONAL USE

Any discussion relating to losses must be preceded by a clear definition of the water balance components and supplementary data used in water supply. However, there are significant differences in the definitions used in different countries. The IWA 'Best Practice' terminology in *Figure 2* has been selected from countries which already have their own well-documented (but different) standard national procedure and terminology for Water Balance (France, Germany, Japan, UK, USA).

So, each national terminology differs from the IWA standard to some extent, not least because of different languages. Accordingly, when undertaking an international comparison or benchmarking study, it is necessary to first re-allocate the components of the national water balance into the same components as shown in *Figure 2*. Where countries do not yet have a standard for such calculations, the IWA standard terminology as shown in *Figures 1 and 2* is proposed as a model version for consideration. This terminology includes the following definitions:

"Water Abstracted" is the volume of water obtained for input to raw water mains leading to water treatment plants

"Water Produced" is the volume of water treated for input to water transmission mains or directly to the distribution system

"Water Imported and Exported" relates to the volumes of bulk transfers across operational boundaries

"System Input Volume" is the volume of water input to a transmission system or a distribution system

<table>
<tr><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th></tr>
<tr><td rowspan="9">System Input Volume

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

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

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

M^3/year</td></tr>
<tr><td>Billed Unmetered * Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorised Consumption

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

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

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

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

M^3/year</td><td>Leakage on Transmission and/or Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer metering</td></tr>
</table>

- Difficulty may be experienced in completing the water balance with reasonable accuracy where a significant number of customers are not metered. In such cases, authorised unmetered consumption should be derived from sample metering of sufficient numbers of statistically representative individual connections of various categories, and/or by measurement of inflows into discrete areas of uniform customer profile (with data adjusted for leakage and diurnal pressure variations as appropriate).

** The IWA Task Force on Performance Indicators recommends that, if the term 'Unaccounted-for-Water' (UFW) is used, it should be defined and calculated in the same way as 'Non-Revenue Water' (NRW) in the above Table.

Steps for Calculating Non-Revenue Water and Water Losses

Step 1: Define *System Input Volume* and enter in Col. A

Step 2: Define *Billed Metered Consumption* and *Billed Unmetered Consumption* in Col. D; enter total in *Billed Authorised Consumption* (Col. C) and *Revenue Water* (Col. E)

Step 3: Calculate the volume of *Non-Revenue Water* (Col. E) as *System Input Volume* (Col. A) minus *Revenue Water* (Col. E)

Step 4: Define *Unbilled Metered Consumption* and *Unbilled Unmetered Consumption* in Col. D*;* transfer total to *Unbilled Authorised Consumption* in Col. C

Step 5: Add volumes of *Billed Authorised Consumption* and *Unbilled Authorised Consumption* in Col. C; enter sum as *Authorised Consumption* (top of Col.B)

Step 6: Calculate *Water Losses* (Col. B) as the difference between *System Input Volume* (Col.A) and *Authorised Consumption* (Col. B)

Step 7: Assess components of *Unauthorised Consumption* and *Metering Inaccuracies* (Col. D) by best means available, add these and enter sum in *Apparent Losses* (Col. C)

Step 8: Calculate *Real Losses* (Col. C) as *Water Losses* (Col. B) minus *Apparent Losses* (Col. C)

Step 9: Assess components of real losses (Col. D) by best means available (night flow analysis, burst frequency/flow rate/duration calculations, modelling etc), add these and cross-check with volume of *Real Losses* in Col. C which was derived from Step 8

Figure 2: Components of Water Balance for a Transmission System or a Distribution System

"Authorised Consumption" is the volume of metered and/or unmetered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorised to do so by the water supplier, for domestic, commercial and industrial purposes. It includes water exported.

Note that authorised consumption (*Figure 2*) 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. These may be billed or unbilled, metered or unmetered according to local practice.

"Water Losses" of a system are calculated as:

Water Losses = System Input Volume — Authorised Consumption

Water Losses can be considered as a total volume for the whole system, or for partial systems such as raw water mains, transmission or distribution. In each case the components of the calculation would be adjusted accordingly. Water Losses consist of Real and Apparent losses, and are effectively identical to the previous IWSA definition[1] of Unaccounted-for Water.

"Real Losses" are physical water losses from the pressurised system, up to the point of customer metering. The volume lost through all types of leaks, bursts and overflows depends on frequencies, flow rates, and average durations of individual leaks.

"Apparent Losses" consist of unauthorised consumption (theft or illegal use), and all types of inaccuracies associated with production metering and customer metering. Under-registration of production meters, and over-registration of customer meters, leads to under-estimation of real losses. Over-registration of production meters, and under-registration of customer meters, leads to over-estimation of Real Losses.

"Non-Revenue Water" is the difference between the System Input Volume and Billed Authorised Consumption (*Figure 2*).

4. COMPONENTS OF WATER BALANCE AND CALCULATIONS

The best practice in management of water losses consists of a combination of continuous water balance calculations together with night flow measurements on a continuous or 'as required' basis. The water balance, usually taken over a 12-month period, should include:

- a thorough accounting of all water into and out of a utility system, including inspection of system records
- an ongoing meter testing and calibration program
- due allowance for the time lags between production meter reading and customer meter reading.

The water balance calculation quantifies volumes of total water into the system, authorised consumption (billed and unbilled, metered and unmetered) and water losses (apparent and real), see *Figure 2*. Where continuous leak detection is not being practised, the process may also include a benefit cost analysis for recovering excess leakage, leading to a leak detection programme[5].

All water balance calculations are approximate to some degree because of the difficulty of assessing all the components with complete accuracy[1,3]. The reliability is likely to be greatest when input volumes are purchased (with duplicate metering), and all water is measured through regularly maintained accurate customer meters supplying properties which do not have storage tanks. Storage tanks can result in low flow rates through service connections, and these low flows may not register accurately on the customer meter.

Best practice, as recommended by the IWA Performance Indicators Group[2] is to assign confidence grades to each component of the water balance, incorporating both reliability and accuracy gradings. In some countries these gradings are checked independently as part of the process.

Each component of the annual water balance (*Figure 2*) should always be initially presented in terms of volume per year. The annual volumes of Non-Revenue Water, Water Losses, Apparent Losses and Real Losses are calculated using the steps shown under *Figure 2*.

Step 9 of the calculation process recommends that volumes of Real Losses calculated by difference between Water Losses and Apparent Losses should be checked if possible by assessing the individual components of Real Losses from first principles. A much improved understanding of Real Losses can be obtained by classifying components(6) as follows:

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

Methods of assessing Real Losses, other than from Water Balances, include:

- analysing night flows based on district meter data
- recording numbers and types of leaks and bursts and their average flow rates and durations
- modelling calculations which allow for background leakage and pressure.

Although physical losses after the point of customer metering are excluded from assessment of Real Losses under this definition, they can sometimes be highly significant and worthy of attention for demand management purposes.

5. FINANCIAL PERFORMANCE INDICATORS

5.1 In Volume Terms: this uses the breakdown of the volume of system input into 'revenue water' and 'non-revenue water' components, as shown in column E of *Figure 2*. The non-revenue water component, which includes unbilled authorised consumption, is expressed as a % of system input volume (this is the Financial PI known as Fi36 in *Reference 2*). However, a true financial performance indicator needs to reflect costs as well as volumes.

5.2 In Cost Terms: An improved Financial Performance Indicator can be calculated by placing appropriate monetary values, in local currency per m^3, on the annual volumes of Unbilled Authorised Consumption, Apparent Losses and Real Losses derived using *Figure 2* (this is the Financial PI known as Fi37 in *Reference 2*). An example calculation is shown as Step 2 of *Figure 3*.

An appropriate value for Apparent Losses and Unbilled Authorised Consumption would usually be the average sale price of water to customers. An appropriate value for Real Losses would be the unit cost of producing and pumping water, or a bulk supply charge, whichever is the higher(7).

Each of these valuations, and their sum, can then be simply expressed as a % of the annual running cost of the water supply. This overview allows an individual water supplier to estimate what percentage of annual expenditure is attributed to:

- Unbilled Authorised Consumption
- Apparent Losses – resulting from metering inaccuracy and unauthorised consumption.
- Real Losses

STEP 1: Annual Input Volume to Water Balance		38,000,000	m^3/year
Re-group all components of Water Balance into one of the following:			
Billed Authorised Consumption (BAC)	Unbilled Authorised Consumption (UAC)	Water Losses Volume m^3/year	
		Apparent	Real
35,050,000	200,000	500,000	2,250,000

STEP 2: Calculate Simple Financial Performance Indicators based on Valuations of Unbilled Water and Annual Cost of Running Supply System						
Local Currency	DM	Cost of running supply system * =			45 mill.	Per yr
Unbilled Volumes **From Step 1** **m^3/year**		Unit value		Valuation of Annual Losses		% of Annual Running Cost
		DM	/m^3	DM	/ year	
UAC	200,000	2.7		540,000		**1.2**
Apparent Losses	500,000	2.7		1,350,000		**3.0**
Real Losses	2,250,000	0.15		337,500		**0.8**
Total Unbilled	2,950,000			2,227,500		**5.0**

*Annual Running Costs

STEP 3: Calculate Average Daily Real Losses when system pressurised, and Technical Indicator for Real Losses (TIRL)		
Annual Volume of Real Losses	2,250,000	m^3/year (from Step 1)
% of time system is pressurised	100	% of time per year
Average Daily Real Losses when system pressurised	6,164	m^3/day when system pressurised (w.s.p)
Number of Service Connections	57,510	
Technical Indicator Real Losses (TIRL)	107.2	litres/Conn/day w.s.p

STEP 4: Calculate Unavoidable Average Real Losses (UARL) and Infrastructure Leakage Index (ILI)				
Average Pressure w.s.p			**35**	**Metres**
Density of Connections			39.4	Per km of mains
Underground pipes if meters after edge of street			633	Km (at 11 m per conn)
Components of Unavoidable Average Real Losses (UARL)				
1458	Km mains @	18	26,244	l/day/m pressure w.s.p
57,510	Connections @	0.80	46,008	l/day/m pressure w.s.p
633	Underground pipes @	25	15,825	l/day/m pressure w.s.p
Unavoidable Average Real Losses (UARL) =			**88,077**	l/day/m pressure w.s.p
UARL at average pressure of	35	m. =	**3,082,695**	litres/day w.s.p
UARL in same units as TIRL =			**53.6**	litres/Conn/day w.s.p
Technical Indicator Real Losses TIRL			**107.2**	litres/Conn/day w.s.p
Infrastructure Leakage Index =			**2.0**	= TIRL/UARL

Calculated by:	A.N.Other.	e-mail:	To be specified
Date:	23rd Oct 1999	Fax	To be specified

Figure 3: Calculation of Water Loss Performance Measures. Water Supply System: A German City; Year: 1997

6 INFLUENCES ON REAL WATER LOSSES

For each system, there are several key local influences, shown below, which constrain the possibilities for managing real water losses, and which need to be recognised when selecting Operational Performance Indicators to assess the effectiveness of managing Real Losses:

- The number of service connections
- The location of the customer meter on the service connection
- The length of mains
- The average operating pressure, when the system is pressurised
- The percentage of time per year for which the system is pressurised
- Infrastructure condition, materials, frequencies of leaks and bursts(8)
- The type of soil and ground conditions, insofar as they influence the proportion of leaks and bursts which show quickly at the ground surface.

These influences are discussed in detail in *Reference 3*, but two points need to be highlighted here – the influence of operating pressures, and the percentage of time the system is pressurised.

Published research from the UK and Japan clearly demonstrates that, as pressures on distribution systems vary, the overall leakage rates vary to a much greater extent than would be predicted by the theoretical 'square root' relationship between pressure and velocity. This is because the effective area of some leakage paths varies with pressure. For large systems, the assumption of a linear relationship between pressure and leakage rate is an acceptable simplification.

Because a continuous supply of pressurised water is the primary goal of a water supply system, the IWA Best Practice Manual: *Performance Indicators in Water Supply Systems*(2) has 'Continuity of Supply' as a 'Quality of Service' Performance Indicator (Qs10). However, because continuity of supply is not achieved in many countries, any Performance Indicators which are to be used internationally to compare average rates of Real Losses from systems must allow for the percentage of time the system is pressurised.

7 TECHNICAL PERFORMANCE INDICATORS FOR REAL WATER LOSSES

7.1 Traditional PIs: the simple traditional Technical Performance Indicators for Real Losses which are most widely used in different parts of the world to make comparisons of the Annual Volume of Real Losses are:

- As a % of Input Volume
- As a figure per length of mains per day or hour
- As a figure per service connection per day or hour
- As a figure per property per day or hour
- As a figure per length of system per day or hour
- (where length of system = length of mains + length of service connections up to point of customer metering).

It should be particularly noted that "number of connections" should be used, rather than "number of properties". This is because the real losses occur on the service connection, and it is not unusual for the service connection to split into several separate pipes serving individual properties at or after the first metering point.

% of Volume Input: Percentage of system input volume is an appropriate measure to define the financial and ecological views of water losses, as defined in 5.1 and in the IWA Manual of Best Practice: *Performance Indicators in Water Supply Systems*(2) which supports the use of % for the Financial Non-Revenue Water by Volume, and Water Resources Indicators.

But regarding the technical view of Water Losses in distribution systems, Real Losses expressed as a % of System Input Volume is unsuitable for assessing the efficiency of management of distribution systems. This is principally because:

- this Performance Indicator fails to take account of any of the key influences on Real Losses described in Section 6 above
- Differences in consumption influence the value of Real Losses expressed in % terms.

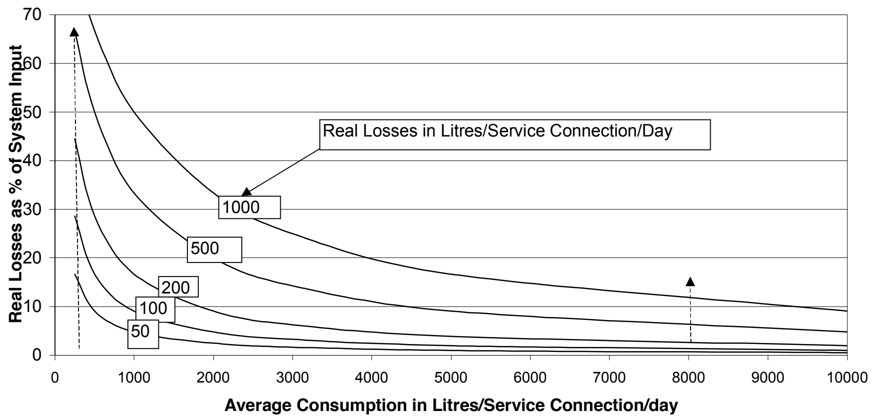

Figure 4: Real Losses as a % of System Input Volume versus Consumption in litres/service connection/day, for different values of Real Losses in litres/service connection/day (curved lines)

Figure 4 shows how the Real Losses (Y-Axis), expressed as a % of system input volume, vary with the average consumption per service connection (X-axis) and the Real Losses in litres/service connection/day (curved lines). For example, at Real Losses of 100 litres per service connection per day – which is a good technical performance – the % losses would vary from 1.2% to 29%, depending on whether the consumption is 8000 l/conn/day (e.g. metropolitan areas), or only 250 l/conn/d (e.g rural areas, villages). Real losses expressed as %s of annual input volume are also quite unsuitable for performance comparisons between intermittent and continuous supply situations.

The IWA Water Losses Task Force therefore endorses the conclusions of the IWA Best Practice Manual: *Performance Indicators in Water Supply Systems*(2) and of several National Technical Committees and their Regulators (e.g. *Reference 9*) that %s are unsuitable for assessing the efficiency of management of real losses in distribution systems.

7.3 If not %'s, Which PI?: effectively, the choice for a basic operational PI for Real Losses lies between per km of mains, or per connection. The international experience shows that the greatest proportion of losses occurs on service connections rather than on mains, except at low density of connections. This experience is confirmed by the technical and statistical analyses reported in *Reference 3*. Therefore, if a single basic PI is to be used for national and international comparisons, 'per service connection' is likely to be the more suitable for the widest range of situations.

7.4 Technical Indicator for Real Losses : the Water Losses Task Force recommended that the basic Technical Indicator for Real Losses should be the Annual volume of Real Losses divided by the number of service connections (Nc), allowing for the % of the year for which the system is pressurised, i.e.

TIRL = Current Annual Volume of Real Losses/Nc
(litres/service connection/day when the system is pressurised)

A more detailed interpretation of TIRL values (Op24 in *Reference 2*) can then be obtained by comparing the TIRL value with a 'best estimate' of Unavoidable Average Real Losses (UARL) which allows for local conditions of connection density, location of customer meters and average operating pressure, if all aspects of leakage control were being managed to the highest technical standards.

7.5 Unavoidable Average Real Losses (UARL): It is recommended that the calculation of the UARL in litres/service connection/day is based on the following form of equation. This recognises separate influences of Real Losses from length of mains (Lm in km), number of service connections (Nc), total length of service connections from the edge of the street to customer meters (Lp in km), and average pressure (P in metres) when the system is pressurised.

UARL = (A x Lm/Nc + B + C x Lp/Nc) x P
(litres/service connection/day when the system is pressurised)

The definition of UARL and derivation of appropriate values for A (18), B (0.80) and C (25) are explained in *Reference 3*. The equation and its parameters A,B,C are based on statistical analysis of international data, including 27 different water supply systems in 20 countries.

An example calculation based on this equation is shown in Step 4 of *Figure 3*. This basic equation can be presented and used in a wide variety of ways. For example, Table 1 can be used to 'look-up' predicted values for UARL in the same units as TIRL (litres/service connection/day w.s.p), for different combinations of connection density, average pressure and average distance of customer meters after the edge of the street (in metres per connection). Thus, the predicted UARL for a system with connection density of 40 per km mains at 40 m. average pressure would be:

- 50 litres/service connection/day for customer meters located at the edge of the street
- 60 (=50 +0.025 x 10 x 40) litres/service connection/day for customer metering located on average 10 metres from the edge of the street

Table 1 demonstrates clearly why it is not possible to quote a reliable single value for Unavoidable Average Real Losses, even when the units used are those for the recommended Technical Indicator for Real Losses, because of the wide range of connection densities, meter locations and operating pressures experienced internationally.

Note that it is not usually economic to achieve the 'ideal' values in Table 1 – that depends upon the local costs and availability of water.

7.6 Comparisons of TIRL and UARL: The difference between the TIRL and the UARL represents the maximum potential for further savings in Real Losses, when the system is pressurised. Also, the ratio of TIRL to UARL is a useful non-dimensional Index of the overall condition and management of infrastructure, under the current operating regime of average pressure and continuity of supply, and is recommended as an additional step in interpreting the calculated value of the TIRL for a wide range of international situations. The question as to whether the current pressure regime is unnecessarily high, or too low, should of course also be evaluated on a regular basis.

Infrastructure Leakage Index (ILI) = TIRL/UARL

For example, if the TIRL is 107 litres/connection/day, and the UARL is 53.6 litres/connection/day (as in Step 4 of the *Figure 3* calculation), the Infrastructure Leakage Index is 107/53.6 =2.0. Values of ILI calculated for 27 actual situations in 20 countries, which were used to test the validity of the methodology (Ref 3), ranged from close to 1.0, up to just above 10.0. Well-managed systems in very good condition would be expected to have ILI values close to 1.0, with higher values for older systems with infrastructure deficiencies.

Table 1: Unavoidable Annual Real Losses (UARL) in litres/service connection/day for customer meters located at edge of street

Density of of Connections Nc/Lm (per km mains)	Average Operating Pressure (P) in Metres				
	20	40	60	80	100
20	34	68	112	146	170
40	25	50	75	100	125
60	22	44	66	88	110
80	21	41	62	82	103
100	20	39	59	78	98

Note: where customer meters or unmetered properties are located on underground pipes with an average length of 'M' metres per service connection after the edge of the street, add the term [0.025 x M x P] litres/service connection/ day to Table 1 values, where P is the average operating pressure in metres.

8 CONCLUSIONS

The main messages of this paper are:

- Reliable metering of water volumes is essential for reliable assessment of water losses
- Water balance assessment should be carried out annually and preferably on a continuous basis, supplemented by night flow measurements in sectors
- All terminology associated with water balance calculations must be clearly defined, and IWA 'best practice' definitions have been provided for use when making international comparisons.
- National organisations which do not already have standard definitions may wish to use these IWA 'best practice' definitions as a model
- National organisations which already have standard definitions may wish to consider incorporating more of the IWA standard definitions if the opportunity arises (e.g. Ref.10)
- All components of the water balance should always be expressed initially in units of volume/year. System Input Volume should be split into Authorised Consumption and Water Losses
- Water Losses should be subdivided into Apparent Losses and Real Losses, using the best available means, preferably supplemented by night flow measurements and/or leakage modelling studies
- Financial Performance Indicators have been recommended both in volume terms and cost terms. The volume term 'Non-Revenue Water' is expressed as a percentage of the annual volume of unbilled water (water losses and unbilled authorised consumption) to annual system input volume. The cost term is expressed as a percentage of annual unbilled water costs to annual running costs.
- The common practice of expressing Real Losses as a % of annual Volume Supplied is unsuitable for assessing the operational efficiency of management of distribution systems because of differences and changes in consumption
- In most well-managed networks, the greatest proportion of real losses is associated with service connections. The recommended basic Operational Technical Indicator of Real Losses (TIRL) is therefore the annual volume of Real Losses in litres per connection per day, when the system is pressurised.
- A component-based methodology to assess Unavoidable Annual Real Losses (UARL), taking into account the key influences, is proposed.
- For further interpretation of the TIRL values, the difference between TIRL and UARL, and the ratio TIRL/UARL, should be calculated.
- The ratio TIRL/UARL can be used as an Infrastructure Leakage Index, to provide additional insights into technical comparisons, as it takes into account many of the key influences on real losses, and separates aspects of infrastructure management from aspects of pressure management.

With the publication of this Blue Pages, the work of the Task Force formally ends. However, research continues into refining the predictive equations for Unavoidable Annual Real Losses, and application of the Infrastructure Leakage Index to larger data sets.

It is hoped that this initiative by IWA and its members, for an improved understanding of the important issue of water losses performance indicators in water supply systems, will stimulate parallel approaches by other users of water, in the interest of better integrated management of water resources.

ACKNOWLEDGEMENTS

To the other members of the Task Force: Timothy G Brown (AWWA North American Representative), Masanori Takizawa (Japan) and Dieter Weimer (Germany). To all water suppliers that contributed data to the study, and to the many practitioners world-wide who assisted with their comments and constructive criticisms.

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