Do You Know How Misleading the Use of Wrong Performance Indicators can be?

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ABSTRACT

With the exception of the UK water industry, water losses (as well as Unaccounted-for Water (UfW), Non-Revenue Water (NRW) and leakage) are still quoted as % of System Input (or water production), although % water losses are a very misleading indicator.

The ILI, the Infrastructure Leakage Index, in the first few years known to only to a few insiders, is now widely accepted and used by practitioners around the world, as it best describes the efficiency of the real loss management of water utilities. However, regulators, funding agencies, media and, last but not least, utility managers in most countries continue to use percentage figures and are too often unaware of how misleading these are.

In the beginning of international data collection for developing the ILI methodology, it was a common understanding that an ILI of 5 would be already very 'poor' performance. Meanwhile the ILI methodology was tested around the world, and ILIs of more than 30 do not come as a surprise anymore. Taking this into consideration, a utility with an ILI of 5 would be shown to have quite good performance in a truly international competition.

The paper discusses the problematic usage of % UfW Reduction as indicator for internationally funded Management Contracts and suggests a more appropriate method.

A possible 'way forward' is described, introducing a new term, the Economic Network Efficiency (ENE), the ratio between the Economic Level of Leakage and the Current Annual volume of Real Losses, expressed in percentages - a methodology which will certainly need further research but could be very useful in discussing leakage performance publicly.

KEYWORDS
ILI; Leakage; non-revenue water; performance indicators; real losses, Economic Level of Leakage

INTRODUCTION

The level of water losses, both real and apparent, is one of the most important efficiency issues for water utilities across the world. One would assume that accurate performance indicators are used for benchmarking, international performance comparison, or target setting for internationally funded projects. But unfortunately this is widely not the case - utility managers, consultants and the International Lending Institutions continue to use a very inappropriate indicator when talking about water losses.

With the exception of the UK water industry, water losses (as well as Unaccounted-for Water (UfW), Non-Revenue Water (NRW) and leakage) are still quoted as % of System Input (or water production), although % water losses are a very misleading indicator.

As early as 1980 the UK National Water Council had started to warn that the use of percentages is wrong and misleading (Report 26). The German DVGW followed in 1986 and the subject was discussed in great detail in the UK Managing Leakage Manuals (1994). Meanwhile the IWA, the AWWA as well as national organisations in a number of countries are also discouraging the use of Percentages - and this paper intends to reinforce the message.

BACKGROUND INFORMATION AND DEFINITIONS

Non-Revenue Water (NRW) and the IWA Water Balance

Although the term Non-Revenue Water is self-explanatory, its definition shall be given, along with IWA standard definitions that are relevant when talking about water loss reduction. Additionally, the new, standardised IWA water balance (Alegre H. et al., 2000, Hirner W. et al, 2000) demonstrates how NRW fits into this concept.

Definitions of principal components of the IWA water balance are as follows:

- *System Input Volume* is the annual volume input to that part of the water supply system to which the water balance calculation relates.
- *Authorised Consumption* is the annual volume of metered and/or non-metered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorised to do so, for residential, commercial and industrial purposes. It includes water exported.
- *Water Losses* is the difference between System Input Volume and Authorised Consumption. It consists of Apparent Losses and Real Losses
- *Apparent Losses* consists of Unauthorised Consumption and all types of inaccuracies associated with metering.
- *Real Losses* on mains, service reservoirs and service connections, up to the point of customer metering. The annual volume lost through all types of leaks, bursts and overflows depends on their individual frequencies, flow rates and duration.
- *Non-Revenue Water (NRW)* is the difference between the System Input Volume and Billed Authorised Consumption. NRW consists of:
  - Unbilled Authorised Consumption (usually a minor component of the Water Balance)
  - Apparent Losses
  - Real Losses
- **Note:** *Unaccounted-for Water (UfW)* should not be used anymore, since all losses can be accounted for. However, if the term UfW is used, its definition should be the same as NRW.

<table>
<tr><td rowspan="9">System Input Volume</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-Revenue Water</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Metering Inaccuracies and Data Handling Errors</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and/or Distribution Mains</td></tr>
<tr><td>Leakae and Overflows at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to Point of Customer Metering</td></tr>
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Figure 1: IWA 'Best Practice' Water Balance and Terminology

Real and Apparent Losses

The establishment of an Annual Water Balance is an important first step when talking about Water Losses of a particular system, as the two components of Water Losses, Real and Apparent Losses, have to be quantified. Only if the magnitude of all components is known, is it possible to:

- forecast potential savings (real losses) and potential revenue increases (apparent losses)
- develop real and apparent loss reduction strategies
- set realistic targets.

Apparent Loss reduction activities include components like:

- management of unauthorized consumption
- management of customer metering errors

and can only be planned based on reliable volumetric figures from the Annual Water Balance.

The management of Real Losses consists of some combination of four primary components:

- pipeline and assets management
- pressure management
- speed and quality of repairs
- active leakage control

Traditional Performance Indicators for Real Losses

The following 4 traditional performance indicators are used

1. Water Losses and Real Losses as a % of system input volume
2. per property per day
3. per km of mains per day
4. per service connection per day

Water Losses, as a percentage of system input, is easily calculated and frequently quoted and is certainly the most common indicator. Various definitions for water losses are used, in developing countries the concept of Non-Revenue Water is most generally used. Thus the indicator is not meaningful for various reasons, mainly because of the sometimes enormous levels of unauthorised consumption (‘illegal connections'). The IWA best practice manual suggests its use only as a financial performance indicator and states clearly it is 'unsuitable for assessing the efficiency of management of distribution systems’.

Real Losses, as a % of system input, also suffer from deficiencies, mainly the level of (and changes in) consumption and variations in supply time (intermittent supply). Note: a system with 12 hours supply per day may easily have only 20% real losses. But what would this figure look like in an uninterrupted supply situation (all bursts would leak for 24 hours instead of twelve and thus twice as much water would be lost)!?

Real losses per property have to be rejected as the property (=very often the customer) has very little to do with leakage. Frequently an apartment block with 50 apartments is counted as 50 properties even though it has only one service connection which may leak.

This leaves the question of which of the remaining two indicators is more appropriate. Leakage component analyses in water distribution systems across the world have shown that the greatest proportion of annual real losses occur on services connections, including the connecting point to the main. This applies to all systems with a connection density of more than around 20 connections per km main. Only very rural supply systems normally have a lower connection density.

Therefore, in such systems:

volume/service connection/day ***when the system is pressurised***

is the best of these traditional indicators - but should always be calculated as 'wsp' - when the system is pressurised, to allow comparisons between systems with different levels of supply. However, this indicator still does not take operating pressure into account, which is a major disadvantage.

Unavoidable Annual Real Losses (UARL)

Leakage management practitioners are well aware that Real Losses will always exist - even in the very best, well managed systems. It is just a question of how high these *unavoidable* losses will be.

Without going into details (Lambert et al. 1999, 2002) the most 'user friendly' versions of the UARL equation require data on four key-system specific parameters:

- Length of mains
- Number of service connections
- Location of customer meter on service connection (relative to property boundary)
- Average operating pressure (when system is pressurised)

The UARL for a system is calculated as:

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

where Lm = length of mains [km], Nc = Number of Service Connections, Lp = length of private service pipes from property boundary to the meter [km] and P = average Pressure [m].

Lp sounds like a troublesome figure to obtain, but it will be zero in all the systems where the meter is directly at the boundary line. In other systems good average figures can be estimated and multiplied by the relevant number of connections.

The Infrastructure Leakage Index (ILI)

In 1997, the Asian Development Bank's 'Second Water Utility Data Book, Asian and Pacific Region' (McIntosh et al. 1997) was published and is an excellent source of information on most major water utilities in the region. However, it had one substantial disadvantage: UfW and NRW in % of System Input Volume were used as performance indicators for water losses. This is extremely problematic as intermittent supply is quite a common occurence in Southeast Asia. Table 1 provides some examples:

City	Supply (hours/day)	UfW [%]	Per capita consumption (l/c/d)
Calcutta (India)	10	50	202
Chennai (India)	4	20	
Bandung (Indonesia)	6	43	120
Jakarta (Indonesia)	18	53	135
Seoul (Republic of Korea)	24	34	209
Karachi (Pakistan)	1-4	30	157

Table 1: % UfW from the ADB Water Utilities Data Book

Already these few examples demonstrate the problem:

- Chennai was by no means better than the other utilities (presumably except Karachi)
- Seoul was certainly not worse than Karachi and Chennai
- Jakarta would have more than 53% with 24h supply but would still be better than for example Bandung

At about that time (1997) Allan Lambert (Lambert A., 2000) realised the need for a real loss performance indicator which would allow international comparisons between systems which very different characteristics, e.g. intermittent supply situations, low and high pressure systems, differences in consumption levels and so on. Therefore, in these early days, the ILI (nowadays Infrastructure Leakage Index), was the abbreviation of *International* Leakage Index.

The ILI, in the first few years known to only to a few insiders, is now widely accepted and used by practitioners around the world, as it best describes the efficiency of the real loss management of water utilities. However, regulators, funding agencies, media and, last but not least, utility managers in most countries continue to use percentage figures and are too often unaware of how misleading these are.

The ILI is a measure of how well a distribution network is managed (maintained, repaired, rehabilitated) for the control of real losses, at the current operating pressure. It is the ratio of **C**urrent **A**nnual volume of **R**eal **L**osses **(CARL)** to **U**navoidable **A**nnual **R**eal **L**osses **(UARL)**.

ILI = CARL / UARL

Being a ratio, the ILI has no units and thus it facilitates comparisons between countries that use different measurement units (metric, U.S., or imperial).

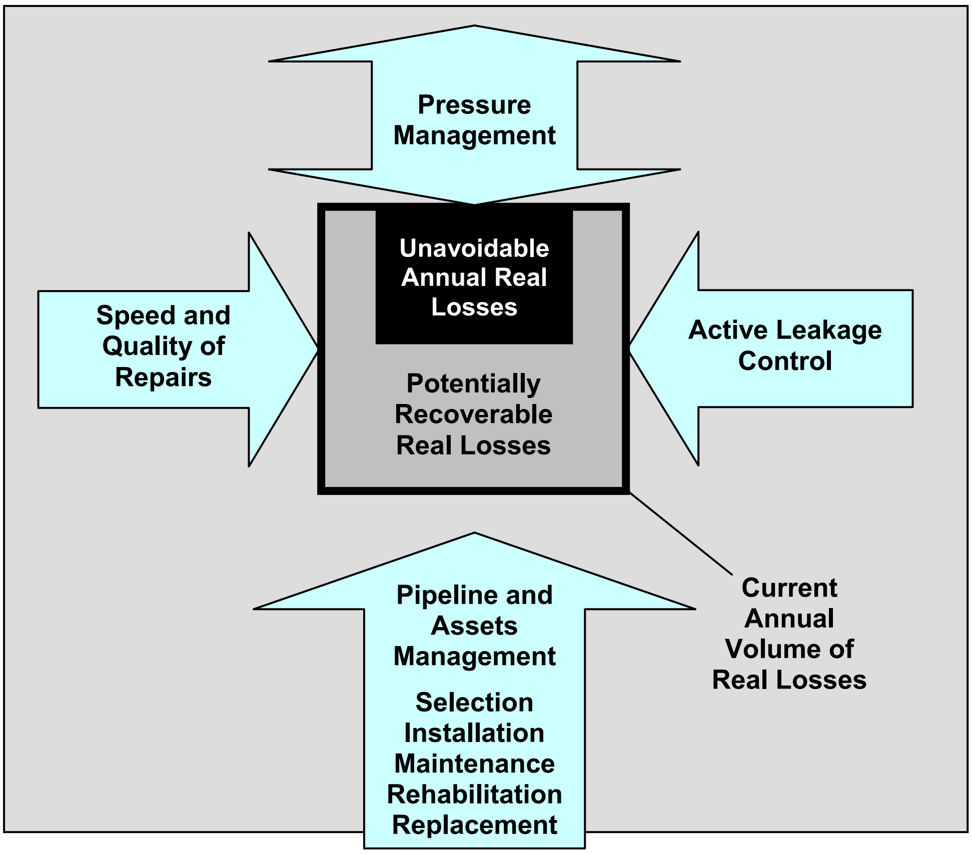

Figure 2: The four components of a successful leakage management policy

The ILI can perhaps be better envisaged from Figure 2 above, which shows the four components of leakage management. The large square represents the current annual volume of real losses (CARL), which is always tending to increase, as the distribution networks grow older. This increase, however can be constrained by an appropriate combination of the four components of a successful leakage management policy. The black box represents the unavoidable annual real losses - the lowest technically achievable volume or real loses *at the current operating pressure*. The location of the black box (not in the middle but on the top) clearly indicates that reductions in operating pressure are the only possibility to reduce the level of UARL.

The ratio of the CARL (the large square) to the UARL (the black box), is a measure of how well the three infrastructure management functions - repairs, pipelines and asset management, active leakage control - are being undertaken. And this ratio is the ILI. Although a well managed system can have an ILI of 1.0, this does not necessarily have to be the target. The ILI is a purely technical performance indicator and does not take economic considerations into account. Figure 3 shows how important it is to first establish the Economic Level of Leakage (ELL) for a system and based on that calculate the most economic ILI.

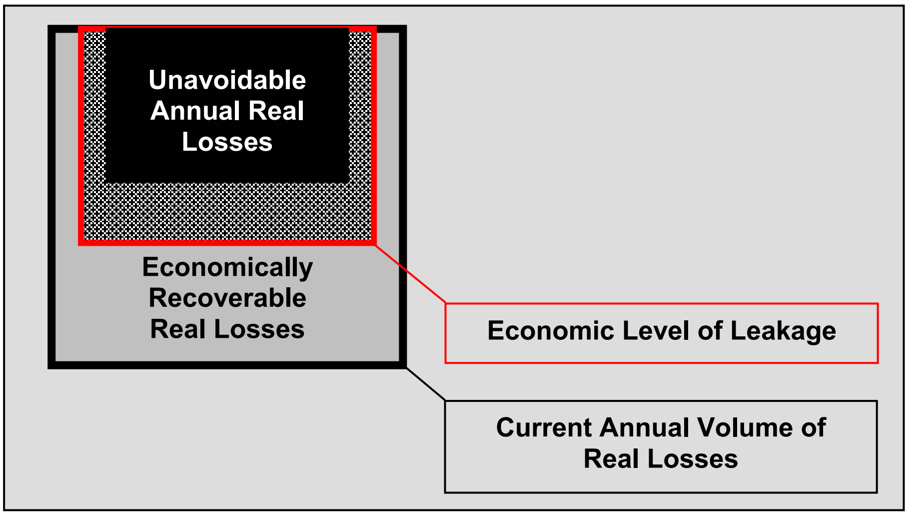

Figure 3: ILI and the Economic Level of Leakage

In the beginning of international data collection for developing the ILI methodology, many utilities with reasonably good leakage management performance provided their data and the first international data set published in AQUA (Lambert et al., 1999) showed ILI's from slightly below 1 to around 11. Since the methodology was new, it was a common understanding that an ILI of 5 would be already very 'poor' performance. Thus managers of a number of utilities with limited leakage management efforts were not interested in using the new indicator, because their present practice of using percentages was putting their performance in a much better light. Meanwhile the ILI methodology was tested around the world, and ILIs of more than 30 do not come as a surprise anymore. Taking this into consideration, a utility with an ILI of 5 would be shown to have quite good performance in a truly international competition. Figure 4 below tries to visualise ILIs from 1 to 100 - maybe a possible way to demonstrate long-term improvement or targets to media and politicians.

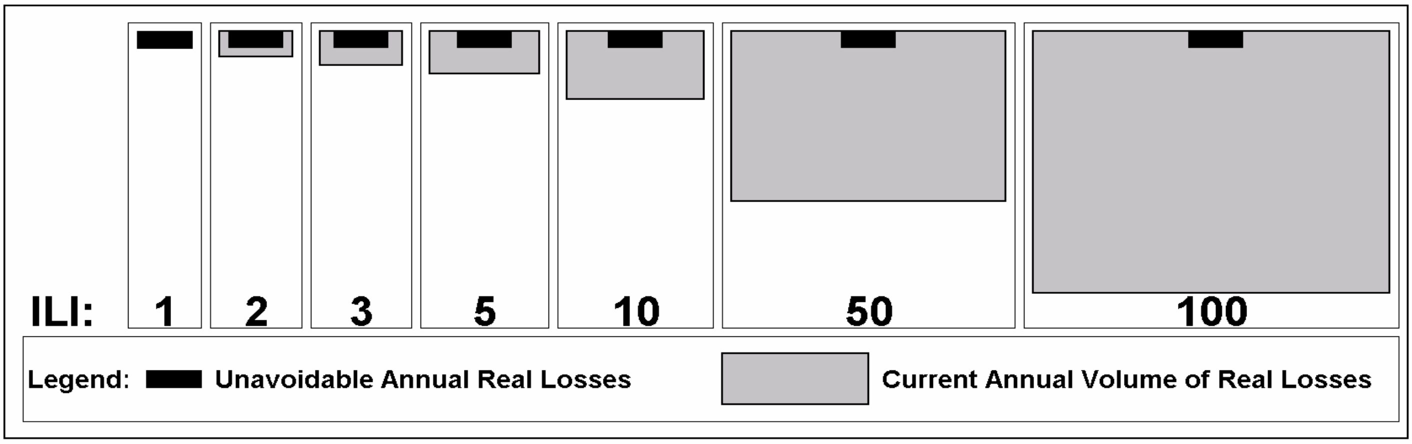

Figure 4: Graphical visualisation of ILI from 1 to 100

COMPARING ILI VALUES TO PERCENTAGES

A new data set, with data collected from countries as diverse as the United States and Tajikistan, has been generated and forms the basis for the following analysis (the complete set of data can be found in Appendix 1). Table 2 below shows the utilities ranked according to their water loss control performance expressed in percentage of system input volume.

Utility	Country	Length of Mains [km]	No. of Service Connections	CARL [% of System Input]
SA Utility 20	South Africa	456	17,264	6.0
SA Utility 6	South Africa	1,331	105,000	7.6
Vienna	Austria	3,261	100,378	8.5
Ecowater	New Zealand	1,266	58,896	9.1
SA Utility 13	South Africa	834	46,700	9.7
SA Utility 26	South Africa	103	5,872	10.1
Wide Bay Water	Australia	603	16,359	11.5
Water Board of Lemesos	Cyprus	718	70,000	12.5
SA Utility 1	South Africa	6,544	315,911	13.2
Boston	USA	1,765	87,160	16.0
Dushanbe	Tajikistan	686	38,330	16.2
Bristol Water Plc	England	5,618	395,553	16.8
SA Utility 19	South Africa	380	18,000	18.5
SA Utility 2	South Africa	2,900	278,000	18.9
Halifax	Canada	1,326	84,207	19.7
Malta WSC (Gozo Island)	Malta	200	19,000	19.7
SA Utility 30	South Africa	45	1,844	19.8
SA Utility 8	South Africa	1,073	70,000	23.9
Charlotte County Utilities (Gulf Cove Area)	USA	493	8,850	24.2
Bukhara	Uzbekistan	522	20,586	24.6
Philadelphia	USA	5,257	487,000	25.8
SA Utility 7	South Africa	3,600	80,000	26.0
Holy City of Makkah	Saudi Arabia	2,400	65,515	31.6
Samarkand	Uzbekistan	629	40,003	35.9
SA Utility 22	South Africa	300	10,400	40.3
Karaganda	Karaganda	1,027	26,991	41.1
Orhei	Moldova	115	3,970	42.6
Criuleni	Moldova	53	1,401	48.0
Cahul	Moldova	92	4,644	48.8
Soroca	Moldova	100	4,684	49.0

Table 2: Current Annual Real Losses of 30 utilities[1] expressed in Percentages

So which utilities seem to have a good leakage management performance?

The German view: Although the DVGW (worksheet W 392) states real loss targets in m3 per km main, the German National Report (IWA Berlin 2001) gave the following indicative percentage values:

low losses: < 8%
medium loses: 8% - 15%
high losses: > 15%

The US view: Although the AWWA Leak Detection and Water Accountability Committee recommended not to use percentages, unfortunately it still mentioned 10% as benchmark[2]. Regulatory bodies in nearly all US states have set their standards as % UfW, ranging from 7.5% to 25%, with 15% being most common (Beecher J., 2002).

[1] Data sources see appendix
[2] The new committee report, which at present undergoes the AWWA approval process, does not mention a percentage target anymore and recommends to use the ILI

Hong Kong has a target to reduce real losses down to 16% within the next 20 years, in *Italy* NRW figures of 15% are acceptable and *Norway* states that NRW of *less* than 20% would not be economic (all three examples from Lambert A., 2001 b).

In general, real losses of up to 15% are obviously considered acceptable and indicate a reasonable leakage management performance. Table 3 below shows the ILI values of utilities with less than 15% real losses - are *all of them* are really performing so well?.

Utility	Country	CARL [% of System Input]	ILI
SA Utility 20	South Africa	6.0	1.9
SA Utility 6	South Africa	7.6	2.6
Vienna	Austria	8.5	6.0
Ecowater	New Zealand	9.1	0.9
SA Utility 13	South Africa	9.7	1.8
SA Utility 26	South Africa	10.1	3.8
Wide Bay Water	Australia	11.5	1.2
Water Board of Lemesos	Cyprus	12.5	1.0
SA Utility 1	South Africa	13.2	6.2

Table 3: Utilities with real losses < 15% and their ILI

Taking as examples Vienna Water Works (Austria) and Ecowater (New Zealand), whose real losses are between 8 and 9%, it comes as a surprise that Ecowater's leakage management performance is 6 times better than Vienna's[3].

Conversely, utilities with CARL of more than 15% are supposed to have poor leakage management - and this is not always the case. Table 4 below shows the 10 best-performing utilities of this data set with ILIs below 4 - but their current annual real losses represent anything between 6.0 and 24.2 (!) of their total system input.

Utility	Country	ILI	CARL [% of System Input]
Ecowater	New Zealand	**0.9**	9.1
Water Board of Lemesos	Cyprus	**1.0**	12.5
Wide Bay Water	Australia	**1.2**	11.5
Malta WSC (Gozo Island)	Malta	**1.6**	19.7
SA Utility 13	South Africa	**1.8**	9.7
Bristol Water Plc	England	**1.9**	16.8
SA Utility 20	South Africa	**1.9**	6.0
SA Utility 6	South Africa	**2.6**	7.6
Charlotte County Utilities (Gulf Cove Area)	USA	**3.1**	24.2
SA Utility 26	South Africa	**3.8**	10.1

Table 4: 10 utilities with low ILI and their performance expressed in percentages

At the other end of the spectrum is the water supply system of Dushanbe, the Capital City of Tajikistan. Its ILI was calculated to be 278. However, water consumption and wastage in this city are extremely high, so that the real losses represent only 16.2 percent of total system input!

The ILI of 278 sounds unrealistically high but in individual areas in Selangor, Malaysia, ILI values of up to 485 were observed (Preston et al. 2002).

[3] Please note that the high ILI in Vienna might be perfectly justified from an economic point of view, since Vienna's water resources are plentiful and cheap.

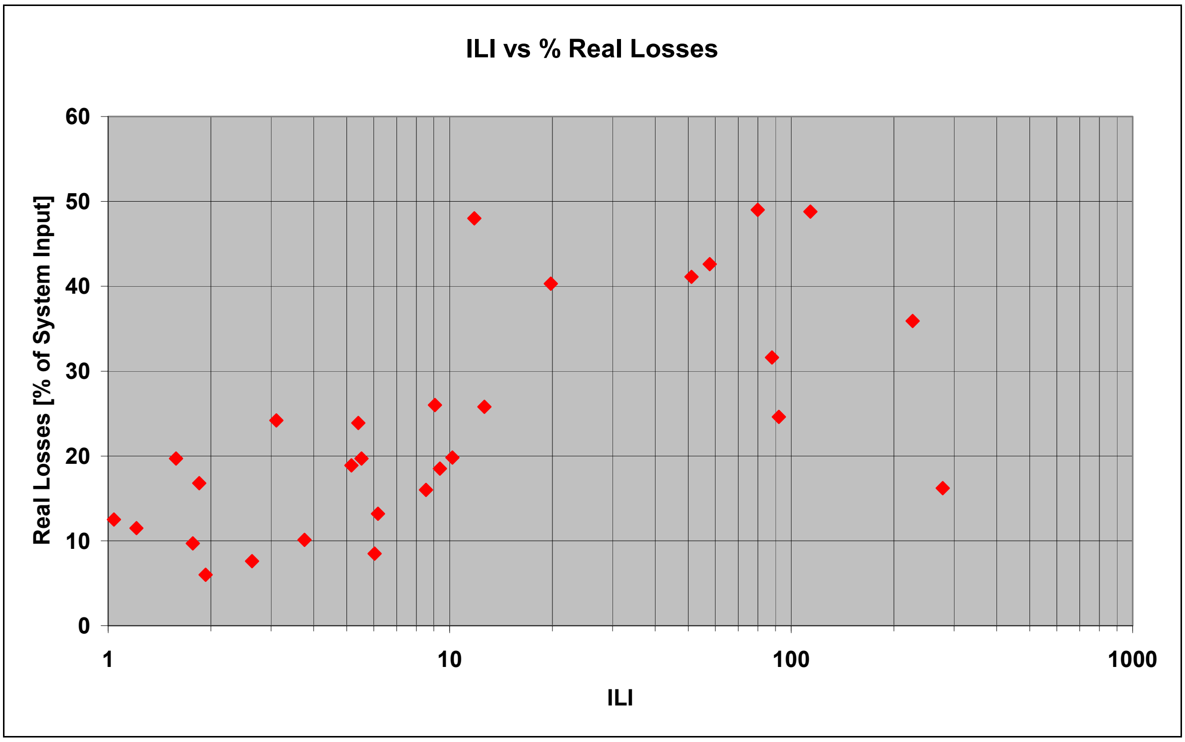

Figure 5: ILI vs real losses (data set of 30 utilities) on logarithmic scale

Figure 5 shows the leakage management performance of 30 utilities using the ILI and the respective losses expressed as percentage of total system input. It is obvious that there is no correlation, for example 50% real losses mean in one case an ILI of around 12 and in another case 114! Figure 6 below shows the same data for utilities with ILI below 10 in more detail. This chart also confirms that no correlation exists and that a real loss level of say 10% is not necessarily an indication for good real loss management.

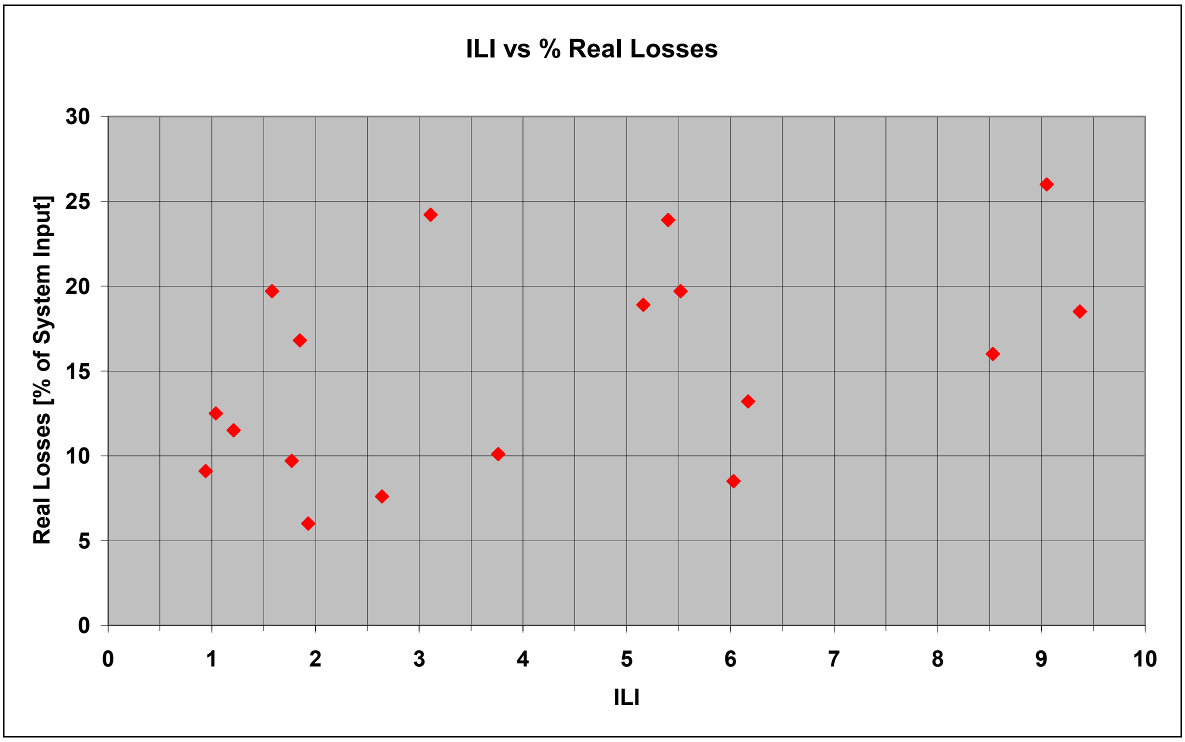

Figure 6: Utilities with ILI below 10 and their real losses expressed as percentage of total system input

TARGET SETTING FOR PERFORMANCE BASED (MANAGEMENT) CONTRACTS

Management Contracts are a first, cautious step towards private sector participation. The World Bank and other Institutions use this model mainly in countries where lease or concession contracts would not be attractive, due to high political and commercial risks and insufficient revenues, for international operators.

Usually, the payments to the international operator consist of a fixed fee and a performance based component. The performance is normally measured with a few selected indicators covering the most important aspects, for example:

- water loss reduction
- level of service improvement
- improvement of billing and collection

The selection of appropriate performance indicators and the establishment of realistic, challenging but yet achievable targets is important for (i) the Client to get maximum benefits from the project and (ii) for the Operator to allow proper risk analysis and assessment of realistic performance achievement. Accurate risk assessment and performance forecast will lead to a reduced fix-fee and thus be beneficial for the Client too.

In most of these contracts, the targets for water loss reduction were referred to as a reduction of UfW (Unaccounted-for Water) or NRW (Non-Revenue Water), not differentiating between real and apparent losses. The annual performance targets were for UfW (NRW) reduction were established as percentage of total system input volume, e.g. reduce NRW from 45% to 40% in year 1, to 35% year 2, ...

Target Setting: A Theoretical Example

The following example will demonstrate the disadvantage of using percentages of total system input for contractual targets and performance indicators.

Base data and assumption used for these examples are related to the situation found in many places in the Former Soviet Union, but could be similar in countries with poor infrastructure, mainly unmetered consumption and thus high per-capita wastage.

General: The following assumptions were made:

3 Cities, population between 350,000 and 500,000, network in poor condition, continuous supply not universal and NRW between 32 and 40%. Management Contracts for International Operators are the Clients' preferred option. The main objectives of the projects would supposedly be:

- to introduce customer metering and billing according to metered consumption
- to improve level of service (increase pressure in various areas, re-establish 24h supply)
- reduce NRW to 20%

Scenario 1: Baseline data at the time of contract preparation

Table 5 below shows the key data of the baseline scenario. Per capita consumption varies between 250 and 300 litres per day (high wastage because consumption is unmetered), billings are high, as bills are issued according to a state norm (250 l/c/d).

Only City A experiences continuous supply (City B:18h/day and City C: 22h/day). Average pressures range between 18 and 35 m). NRW ranges from 32 to 40% and the ILIs from 27 to 61.

		City A	City B	City C
Population		350,000	400,000	500,000
Per capita consumption	l/c/d	280	250	300
Total consumption	m3/d	98,000	100,000	150,000
billed 250 l/c/d acc. to 'norms'	m3/d	87,500	100,000	125,000
Distribution network	km	850	1,000	1,200
Connections		35,000	50,000	48,000
Pressure	[m]	35	18	27
Real losses (leakage)	l/conn./d	1,150.0	1,270.0	1,350.0
Supply time	h	24	18	22
Total leakage	**m3/d**	**40,250**	**47,625**	**59,400**
Total production	m3/d	138,250	147,625	209,400
NRW	m3/d	50,750	47,625	84,400
NRW	**%**	**37%**	**32%**	**40%**
Leakage	%	29%	32%	28%
UARL - per connection (l/day)		43	21	34
CARL - per connection (l/day)		1,150	1,270	1,350
Infrastructure Leakage Index		**27**	**61**	**40**

Table 5: 3 Cities - Baseline Data

The following scenarios would in practice not happen consecutively, but in parallel. They are shown consecutively to demonstrate the impact of the various actions.

Scenario 2: Introduction of Consumption Metering

Table 6 below shows the key data after the introduction of consumption metering. The per capita consumption will decrease substantially (say 140 l/c/d) and bills are issued according to the metered consumption, assuming a meter error of 5%.

NRW has now increased, as a percentage, to 49% but the ILIs are of course still at the initial level - since the condition of the network has not changed.

		City A	City B	City C
Population		350,000	400,000	500,000
Per capita consumption	l/c/d	140	140	140
Total consumption	m3/d	49,000	56,000	70,000
billed (5% meter error)	m3/d	46,550	53,200	66,500
Distribution network	km	850	1,000	1,200
Connections		35,000	50,000	48,000
Pressure	[m]	35	18	27
Real losses (leakage)	l/conn./d	1,150.0	1,270.0	1,350.0
Supply time	h	24	18	22
Total leakage	**m3/d**	**40,250**	**47,625**	**59,400**
Total production	**m3/d**	**89,250**	**103,625**	**129,400**
NRW	m3/d	42,700	50,425	62,900
NRW	**%**	**48%**	**49%**	**49%**
Leakage	%	45%	46%	46%
UARL - per connection (l/day)		43	21	34
CARL - per connection (l/day)		1,150	1,270	1,350
Infrastructure Leakage Index		**27**	**61**	**40**

Table 6: 3 Cities - Impact of Consumption Metering

Scenario 3a: Reduction in Consumption Allows Continuous Supply

The reduced water demand will allow the re-establishment of a continuous supply. Data in Table 7 below show that Leakage would increase substantially, especially in City B where NRW would now be at a level of 55%, compared to the initial 32%. And this without a single leak more than in the beginning. Consequently the ILIs are still at the initial level - since the condition of the network has not changed yet.

		City A	City B	City C
Population		350,000	400,000	500,000
Per capita consumption	l/c/d	140	140	140
Total consumption	m3/d	49,000	56,000	70,000
billed (5% meter error)	m3/d	46,550	53,200	66,500
Distribution network	km	850	1,000	1,200
Connections		35,000	50,000	48,000
Pressure	[m]	35	18	27
Real losses (leakage)	l/conn./d	1,150.0	1,270.0	1,350.0
Supply time	**h**	**24**	**24**	**24**
Total leakage	**m3/d**	**40,250**	**63,500**	**64,800**
Total production	m3/d	89,250	119,500	134,800
NRW	m3/d	42,700	66,300	68,300
NRW	**%**	**48%**	**55%**	**51%**
Leakage	%	45%	53%	48%
UARL - per connection (l/day)		43	21	34
CARL - per connection (l/day)		1,150	1,270	1,350
Infrastructure Leakage Index		**27**	**61**	**40**

Table 7: 3 Cities - Re-establishment of Continuous Supply

Scenario 3b: Reduction in Consumption Leads to Pressure Increase

At the same time, the demand reduction and re-establishment of continuous supply will also lead to pressure increases. Automatically leakage will increase (Lambert A., 2001a), and therefore NRW - to between 50% and 58% (see Table 8).

The ILIs are of course still at the initial level - since, again, the condition of the network has not changed.

		City A	City B	City C
Population		350,000	400,000	500,000
Per capita consumption	l/c/d	140	140	140
Total consumption	m3/d	49,000	56,000	70,000
billed (5% meter error)	m3/d	46,550	53,200	66,500
Distribution network	km	850	1,000	1,200
Connections		35,000	50,000	48,000
Pressure	**[m]**	**39**	**20**	**30**
Real losses (leakage)	l/conn./d	1,265.0	1,397.0	1,485.0
Supply time	h	24	24	24
Total leakage	**m3/d**	**44,275**	**69,850**	**71,280**
Total production	m3/d	93,275	125,850	141,280
NRW	m3/d	46,725	72,650	74,780
NRW	**%**	**50%**	**58%**	**53%**
Leakage	%	47%	56%	50%
UARL - per connection (l/day)		48	23	37
CARL - per connection (l/day)		1,265	1,397	1,485
Infrastructure Leakage Index		**27**	**61**	**40**

Table 8: 3 Cities - Pressure Increase

Scenario 4: Leakage Reduction

But of course enormous efforts are also made to reduce leakage - it is assumed that the network efficiency (using the ILI as indicator) is improved by 50%. Table 9 below shows that leakage is also reduced in volumetric terms (e.g. City C: from initially 59,400 m3/d to 35,640 m3/d) and the ILIs logically are 13, 30 and 20, 50% of what they were at the beginning.

However, the level of NRW expressed as a percentage of total system input would still be high: 35% instead of the initial 37% in City A, 41% and thus substantially higher than the initial 32% in City B and 37% compared to the initial 40% in City C.

		City A	City B	City C
Population		350,000	400,000	500,000
Per capita consumption	l/c/d	140	140	140
Total consumption	m3/d	49,000	56,000	70,000
billed (5% meter error)	m3/d	46,550	53,200	66,500
Distribution network	km	850	1,000	1,200
Connections		35,000	50,000	48,000
Pressure	[m]	39	20	30
Real losses (leakage)	l/conn./d	632.5	698.5	742.5
Supply time	h	24	24	24
Total leakage	**m3/d**	**22,138**	**34,925**	**35,640**
Total production	m3/d	71,138	90,925	105,640
NRW	m3/d	24,588	37,725	39,140
NRW	**%**	**35%**	**41%**	**37%**
Leakage	%	31%	38%	34%
UARL - per connection (l/day)		48	23	37
CARL - per connection (l/day)		633	699	743
Infrastructure Leakage Index		**13**	**30**	**20**

Table 9: 3 Cities - Leakage Reduction

Conclusions: Taking % NRW as the key performance criteria, the contractor has failed to improve the situation. The initial target of reducing NRW down to 20% was not achieved at all. Is this fair? No, because all the main objectives were achieved:

- demand reduction because of the introduction of consumption metering
- improved level of supply (higher pressure and continuous supply)
- substantial leakage reduction.

Although this is a theoretical example, its figures are similar to those observed during several studies in Central Asia and Eastern Europe. Therefore it has to be concluded that the Non-Revenue Water level, expressed as a percentage of System Input Volume (or Total Water Production) must be avoided as a Key Performance Indicator for internationally funded projects or as a contractual target for performance contracts of such kind.

Target Setting: Methodology used in recent World Bank funded Management Contracts

The methodology and respective indicator used for the Management Contracts in Uzbekistan (Samarkand & Bukhara) and Tajikistan (Dushanbe) were similar to the performance based NRW reduction contract in Selangor, Malaysia (Liemberger R. et al., 2002). As in Selangor, the contracts require the establishment of discreet network zones, each with a single feed and equipped with a water meter. Inflow and consumption (for each zone) have to be measured before and after all real loss reduction activities.

The contract sets annual targets for:

- % of the distribution network to be 'zoned'
- total volume of real loss reduction in the established zones (m3/d)

Target setting was done on the basis of thorough component based leakage studies (formerly BABE studies). The total level of 'excess losses' (or 'hidden losses'), caused mainly by the backlog of leaks, was forecast for the entire distribution network. It was further assumed, that in areas where zoning and real loss reduction will be undertaken, these losses can be reduced by 60%. For example: zoning in 70% of the network would lead to a 70% x 60% = 42% reduction in total real losses. The resulting volume (m3/d) was used as a performance standard in the contracts.

It certainly would have been an alternative to use the ILI as a contractual indicator. Reasons why this was not done were:

- as the studies and preparations for these contracts began (1999 -2000) the ILI was still a relatively new and not a well known indicator (concept)
- the duration of the Management Contracts is short (especially in Dushanbe - three years only), and thus it is obvious that the entire network cannot be substantially improved during the contract period. Therefore it is likely that savings made in the established zones will be (partially) lost in other parts of the system. Having an indicator which measures the performance in areas where the actual works take place seemed to be fairer and more transparent
- savings in volumetric terms (m3/d) were easy to explain to local politicians and the Project Implementation Unit
- Too little is know about what level of ILI could realistically be achieved in such deteriorating Former-Soviet-Union-Style (all unprotected steel pipes, only breakdown maintenance) distribution systems.

CONCLUSIONS

It is obvious that real losses, non-revenue water, unaccounted-for water or water losses in general must not be expressed as a percentage of total system input. Although this is well understood by professionals, regulators and water associations around the world, most people are not aware of the magnitude of the problem and therefore percentages are still widely used.

The danger exists that the status quo will remain until a simple efficiency indicator, if possible a % indicator, is promoted. Another important issue is the need to take economics into account. It makes no sense to target an ILI between 1 and 2 if water is plentiful and cheap.

Taking these two problem areas into account, this paper aims to initiate a discussion on the way forward:

the **ENE** - the Economic Network Efficiency.

Step 1: Determination of the Current Annual Real Losses

Step 2: Establishment of the Economic Level of Leakage; it is well understood that this is a very complex issue and further research is needed to develop a simple 'cookbook' procedure and software

Step 3: Calculation of the ELI, the Economic Leakage Index, similar to the ILI but replacing UARL by the Economic Annual Real Losses (EARL)

$$\mathbf{ELI = CARL / EARL}$$

This indicator should be good enough for the industry, but for media and politicians the next step is recommended:

Step 4: Calculation of the Economic Network Efficiency (ENE):

$$\mathbf{ENE\ [\%] = 1 / ELI}$$

Figure 7 shows how ILI, ELI and the ENE are related:

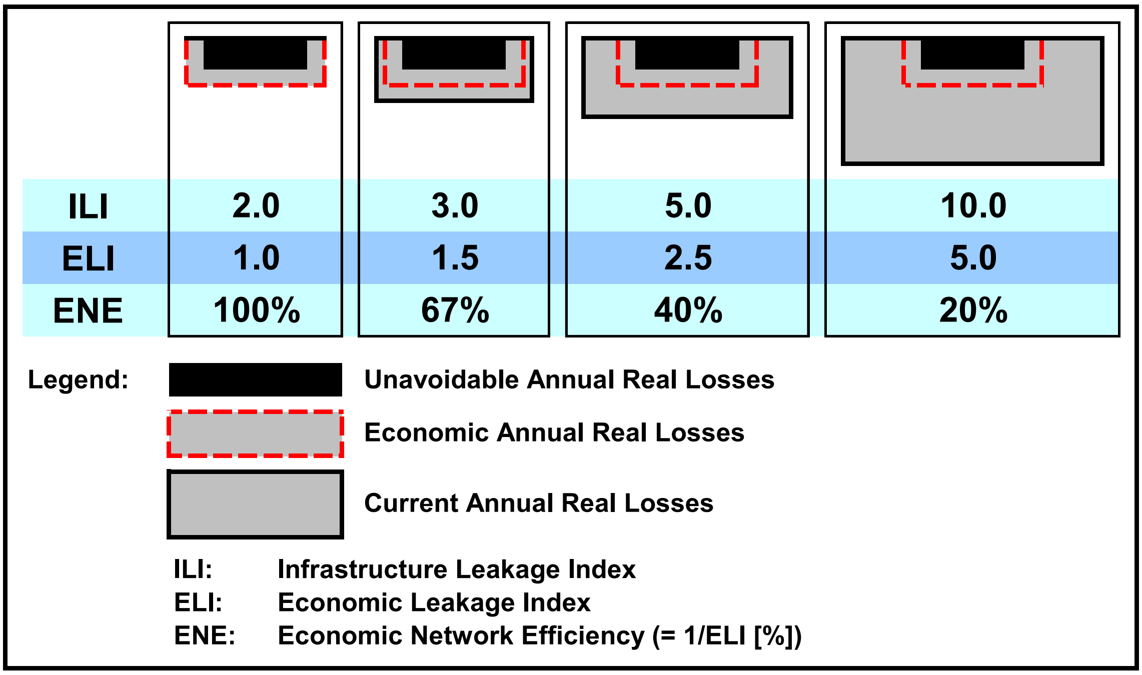

Figure 7: The way forward? The Economic Network Efficiency

Is this the way forward? This remains to be seen. New indicators always have their enemies - for various reasons. But hopefully the need for a 'media friendly' indicator will be understood by the various task forces and committees in the IWA, the AWWA and other relevant organisations.

Acknowledgements

This paper is dedicated to Allan Lambert, the 'father' of BABE and the ILI who's analytical skills and openness to new approaches have helped to turn the art (or 'guesstimation') of leakage analysis and management into precise science.

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APPENDIX

#	Utility	Country	Length of Mains [km]	No. of Service Conn.	Length from property boundary to meter [m]	Av. Pres-sure [m]	System Input volume [Mm3/yr]	Authorised Cons. [Mm3/yr]	Total Losses [Mm3/yr]	Apparent Losses [Mm3/yr]	wsp [days/yr]	CARL [Mm3/yr]
1	Boston	USA	1,765	87,160	11	47	114.54	93.38	21.16	2.80	365	18.36
2	Bristol Water Plc	England	5,618	395,553	15	46	105.59		20.33	2.59	365	17.73
3	Bukhara	Uzbekistan	522	20,586	-	20.0	70.84	42.93			365	17.40
4	Cahul	Moldova	92	4,644	*10*	29	2.81	1.36	1.44	0.073	152	1.37
5	CCU (Gulf Cove Area)	USA	493	8,850	3	44	3.45	2.59	0.86	0.03	365	0.83
6	Criuleni	Moldova	53	1,401	*10*	21	0.35	0.16	0.19	0.021	319	0.17
7	Dushanbe	Tajikistan	686	38,330	-	16.0	269.70	110.74			228	43.60
8	Ecowater	New Zealand	1,266	58,896	-	54	14.32	12.79	1.53	0.23	365	1.30
9	Halifax	Canada	1,326	84,207	7.5	51	55.70	44.04	11.66	0.67	365	10.99
10	Makkah	Saudi Arabia	2,400	65,515	*2*	40	57.18				52	18.08
11	Karaganda	Karaganda	1,027	26,991	-	23	41.77	21.09			365	17.18
12	Malta WSC (Gozo)	Malta	200	19,000	*1*	45	2.53	1.56	0.97	0.47	365	0.50
13	Orhei	Moldova	115	3,970	*10*	28	1.50	0.81	0.69	0.048	152	0.64
14	Philadelphia	USA	5,257	487,000	3.7	39	369.46	254.24	115.21	20.01	365	95.21
15	SA Utility 1	South Africa	6,544	315,911		45	285.28	238.36	46.92	9.38	365	37.53
16	SA Utility 13	South Africa	834	46,700		56	19.57	17.20	2.37	0.47	365	1.90
17	SA Utility 19	South Africa	380	18,000		45	17.69	13.60	4.09	0.82	365	3.27
18	SA Utility 2	South Africa	2,900	278,000		45	123.22	94.11	29.11	5.82	365	23.29
19	SA Utility 20	South Africa	456	17,264		38	9.80	9.06	0.74	0.15	365	0.59
20	SA Utility 22	South Africa	300	10,400		55	13.51	6.70	6.81	1.36	365	5.45
21	SA Utility 26	South Africa	103	5,872		50	4.46	3.90	0.56	0.11	365	0.45
22	SA Utility 30	South Africa	45	1,844		40	1.72	1.30	0.42	0.08	365	0.34
23	SA Utility 6	South Africa	1,331	105,000		40	54.84	49.64	5.19	1.04	365	4.16
24	SA Utility 7	South Africa	3,600	80,000		75	122.85	82.95	39.90	7.98	365	31.92
25	SA Utility 8	South Africa	1,073	70,000		45	27.95	19.60	8.35	1.67	365	6.68
26	Samarkand	Uzbekistan	629	40,003	-	10.0	100.00	52.01			365	35.90
27	Soroca	Moldova	100	4,684	*10*	22	1.53	0.73	0.79	0.046	152	0.75
28	Vienna	Austria	3,261	100,378		*40*	143.94				365	12.24
29	WB of Lemesos	Cyprus	718	70,000	*6*	47	11.39	9.27	2.12	0.70	365	1.42
30	Wide Bay Water	Australia	603	16,359		65	6.02	5.26	0.76	0.07	365	0.69

#	Utility	CARL [l/day]	CARL [l/conn/d]	CARL [l/conn/d/m]	CARL [% of System Input]	UARL [l/day]	ILI
1	Boston	50,293,151	577	12.3	16.0	5,896,553	8.5
2	Bristol Water Plc	48,578,000	123	2.6	16.8	26,257,954	1.9
3	Bukhara	47,671,233	2,316	115.8	24.6	517,296	92.2
4	Cahul	8,995,068	1,937	66.8	48.8	79,017.75	113.8
5	CCU (Gulf Cove Area)	2,283,238	258	5.8	24.2	734,807	3.1
6	Criuleni	526,027	375	17.9	48.0	44,560.29	11.8
7	Dushanbe	191,228,070	4,989	311.8	16.2	688,192	277.9
8	Ecowater	3,561,644	60	1.1	9.1	3,774,859	0.9
9	Halifax	30,109,589	358	7.0	19.7	5,458,143	5.5
10	Makkah	347,712,978	5,307	132.7	31.6	3,955,510	87.9
11	Karaganda	47,068,493	1,744	75.8	41.1	921,812	51.1
12	Malta WSC (Gozo)	1,369,863	72	1.6	19.7	867,375	1.6
13	Orhei	4,201,644	1,058	37.8	42.6	72,803.50	57.7
14	Philadelphia	260,842,472	536	13.7	25.8	20,641,388	12.6
15	SA Utility 1	102,830,137	326	7.2	13.2	16,673,436	6.2
16	SA Utility 13	5,205,479	111	2.0	9.7	2,932,832	1.8
17	SA Utility 19	8,958,904	498	11.1	18.5	955,800	9.4
18	SA Utility 2	63,808,219	230	5.1	18.9	12,357,000	5.2
19	SA Utility 20	1,616,438	94	2.5	6.0	836,730	1.9
20	SA Utility 22	14,928,767	1,435	26.1	40.3	754,600	19.8
21	SA Utility 26	1,232,877	210	4.2	10.1	327,580	3.8
22	SA Utility 30	931,507	505	12.6	19.8	91,408	10.2
23	SA Utility 6	11,383,562	108	2.7	7.6	4,318,320	2.6
24	SA Utility 7	87,452,055	1,093	14.6	26.0	9,660,000	9.1
25	SA Utility 8	18,306,849	262	5.8	23.9	3,389,130	5.4
26	Samarkand	98,356,164	2,459	245.9	35.9	433,244	227.0
27	Soroca	4,918,356	1,050	47.7	49.0	61,583.50	79.9
28	Vienna	33,521,280	334	8.3	8.5	5,560,016	6.0
29	WB of Lemesos	3,890,411	56	1.2	12.5	3,732,928	1.0
30	Wide Bay Water	1,890,411	116	1.8	11.5	1,556,178	1.2

Data Sources:

Boston:	BWS
Bristol Water:	Bristol Water plc.
Bukhara:	BWS
Cahul:	BWS
CCU:	BWS
Criuleni:	BWS
Dushanbe:	BWS
Ecowater:	A.O. Lambert
Halifax:	A.O. Lambert
Makkah:	A.S. Al-Ghamdi
Karaganda:	BWS
Malta:	Malta WSC
Orhei:	BWS
Philadelphia:	BWS
SA Utilities:	Dr. R. McKenzie
Samarkand:	BWS
Soroca:	BWS
Vienna:	Web Page Vienna Water Works
Lemesos:	WB of Lemesos
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