EU Reference document Good Practices on Leakage Management WFD CIS WG PoM

Main Report

Disclaimer:

This technical document has been developed through a collaborative programme involving the European Commission, all the Member States, the Accession Countries, Norway and other stakeholders and Non-Governmental Organisations. The document should be regarded as presenting an informal consensus position on best practice agreed by all partners. However, the document does not necessarily represent the official, formal position of any of the partners. Hence, the views expressed in the document do not necessarily represent the views of the European Commission.

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Main Report

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The following case study accounts used in the development of this main report are available in a separate Case Study document:

1. Austrian Case Study: Small Utilities.
2. Austrian Case Study: Salzburg.
3. Belgian Case Study: De Watergroep.
4. Bulgarian Case Study: Dryanovo and Razgrad.
5. Croatian Case Study: Pula.
6. Cypriot Case Study: Lemesos.
7. Danish Case Study: VCS Denmark Odense.
8. English Case Study: Anglian Water.
9. French Case Study: Beaune.
10. French Case Study: Bordeaux.
11. German Case Study: Munich.
12. Italian Case Study: Iren Emilia.
13. Maltese Case Study: Malta WSC.
14. Portuguese Case Study: Lisbon.
15. Scottish Case Study: Scottish Water.
16. Serbian & Croatian Case Study: Mentoring.

Summaries of these case study accounts are available in Section 5 of this report.

Acknowledgements

Thanks go to the authors of the case study accounts. These case study accounts are presented in a separate document and can be read in parallel to this main report. The authors are recognized in their individual case study accounts. Additionally the Drafting Group would like to thank the multitude of Water Utility professionals who permitted their data to be published in the case studies and this main report.

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List of terms and abbreviations

Term or abbreviation	Explanation
AL[1]	Apparent Losses
ALC	Active Leakage Control
AR	Asset Renewal
AZP	Average Zonal Pressure
AZNP	Average Zonal Night Pressure
BL	Background Leakage
BFm	Annual Burst Frequency (mains, per 100 km/year)
BRs	Annual Burst Frequency (service connections, per 1000 SCs/year)
CARL	Current Annual Real Losses
CROW	Independent Dutch Knowledge Organisation on infrastructure, public space, and traffic and transport
DI	Distribution Input volume (similar to SIV)
DMAs	District Metering Areas
DZ	Distribution Zone
EC	European Commission
EIF	Economic Intervention Frequency (for Active Leakage Control)
ELL	Economic Level of Leakage
GPKL	Dutch Platform Cable and Pipe from the Dutch municipalities
GSDI	Good System Design and Installation
ILI	Infrastructure Leakage Index
IM	Infrastructure Management
Klic-online	Digital system about the location of cables and pipes
KLO	Cable and Pipe Consultation
KPI	Key Performance Indicator
LoL	Level of Leakage
MARP	Minimum Annual Reference Pressure
MCoALC	Marginal Cost of Active Leakage Control
MCoW$_{WSP}$	Marginal Cost of Water for the WSP
MNF	Minimum Night Flow
NEN	Dutch Normalisation Institute
Network[2]	Mains only
NRW	Non-Revenue Water
O&M	Operation & Maintenance
PESTLE	Acronym for Political, Economic, Social, Technological, Legal and Environmental
PM	Pressure Management
PMAs or PMZs	Pressure Managed Areas or Pressure Managed Zones
PMI	Pressure Management Index
PoM	Programme of Measures
RBMP	River Basin Management Plan
REE	Resource and Economic Efficiency of Water Distribution Networks in the EU
RRul	Rate of Rise of Unreported Leakage
RL	Real Losses
SELL	Sustainable Economic Level of Leakage

[1] The simplified IWA Water Balance used in this report and for the case studies can be found in Figure 8 of Section 6.1 and in Appendix B.1. The terms and abbreviations used in this Water Balance are listed. All terms relating to the Water Balance and components are for potable water only.

[2] In different European countries, the words 'network' and 'system' can have different meanings, which can lead to errors of interpretation. In most European countries 'network' relates only to main length, and does not include service connections. 'System' includes both mains and services.

Term or abbreviation	Explanation
SIV	System Input Volume
SQR	Speed and Quality of Repairs
System[2]	Mains and service connections
TCMD	Thousand metre cubed per day
UAC	Unbilled Authorised Consumption
UARL	Unavoidable Annual Real Losses
WAFU	Water Available For Use (raw water resources available to the WSP)
WE	Water Exported
WFD	Water Framework Directive
WI	Water Imported
WION	Law Information exchange Underground Networks
WL	Water Losses (= Apparent Losses and Real Losses)
WLTF	Water Loss Task Force
WS	Water Supplied (excluding Water Exported)
WLSG	Water Loss Specialist Group
WSP	Water Service Provider
WRZ	Water Resource Zone
WTW	Water Treatment Works

1   Introduction

1.1   Background and structure of this EU Reference document

Water management authorities and water utilities in Europe face the challenge – as well as having the responsibility - to find a balance between efficiency of water distribution networks in using our natural water resources, and efficiency in the use of our human, financial and other natural resources. This balance is of key importance in contributing to achieving the environmental objectives of the Water Framework Directive (WFD).

Water, as a valuable natural resource, needs to be managed in a sustainable manner, and waste of this resource should always be minimised. Excessive leakage and excessive consumption, especially in areas of water scarcity and drought, have a direct negative impact – not only on the environmental objectives of the WFD, and on the proper application of the cost recovery principle - but also on EU citizens and economic sectors such as agriculture, tourism, industry, energy and transport. This may in turn affect competitiveness and the internal market.

The sustainable level of leakage is dependent both upon the efficiency of the Water Utility and upon the efficiency of the national or basin administrative body responsible for the administration, management, protection and sustainable development of the raw water resources at a basin and water body level. Optimal water resource efficiency occurs when both the Water Utility and the administrative body responsible for the management of water resources prior to abstraction are both achieving their quantity and quality service objectives most cost effectively (i.e. both achieve their respective objectives at least cost).

The wastage of water from leaking and inefficient water distribution networks results in the increased use of our natural raw water resources. For those locations throughout Europe where the total demand for water to meet our socio-economic needs exceeds short and long term sustainability of the resource, this results in damage to our natural environment and its related ecosystems. In these circumstances the damage caused to the environment by the unsustainable consumption of water resources is also usually associated with the additional wastage of energy and materials necessary to transfer and treat the water that leaks from a distribution system.

However, there are some circumstances where the socio-economic demand for water does not stress or damage the environment, and in those circumstances if we were to invest human, financial and other natural material resources to try to achieve a reduction in leakage that was costly, with no real benefit to society or the environment, this would also be wasteful of our resources.

This EU Reference document is intended to help guide policies that improve efficient water use by utilities throughout the EU. To enable this, this report addresses:
- General (policy) recommendations to the key stakeholder groups – policy makers/water authorities; economic and/or environmental regulators; and water utilities (section 2).
- The reasons why water utilities should reduce leakage and identify how to resolve water loss problems using today's technology in a balanced way taking account of political, economic, social, technical, legislative and environmental (PESTLE) considerations (section 3 and Appendix A).

- Documented practices, recommended by renowned experts, for performance indicators, pressure management, speed and quality of repairs, active leakage control, infrastructure management and design (section 4 and Appendix B).
- Good practices for leakage management from Case Study accounts (section 5 and in a separate Case Study document) and key sequences of activities in different contexts, providing a ready-to-use toolbox to address leakage management (section 6 and Appendix B). The toolbox recognises that it is easier and quicker to identify economic options for reducing leakage in smaller systems (less than around 30.000 service connections) than in larger systems.

The importance of the development of this reference document within the framework of the WFD Common Implementation Strategy is to raise attention and increase knowledge of the issue of leakage management and to contribute to mitigating the potential negative impacts of leakage on reaching WFD objectives among all European Member States and stakeholders. The policy recommendations and toolbox will allow Member States and stakeholders to identify whether action needs to be taken, and if so, guide them in effectively doing so.

This reference document only focuses on leakage reduction in drinking water distribution systems and does not cover irrigation systems or water distribution systems for recreational activities such as sports facilities (golf courses, football fields etc.) or urban landscaping.

This good practices document on leakage management is developed through a drafting group under the Water Framework Directive (WFD) Common Implementation Strategy (CIS) Working Group Programme of Measures. This document builds on the report *Resource and Economic Efficiency of Water Distribution Networks in the EU* (Final REE Report), published by the European Commission (EC) in October 2013. The sixteen different case studies provide recommendations on addressing real water loss, leakage, and water resources efficiency. These recommendations are advices of experts and backed by the case studies. The recommendations are not binding.

This good practices document on leakage management describes the consolidated findings and analysis of sixteen case studies on leakage and resource efficiency of water utilities across the EU, and presents conclusions and recommendations (including examples) on how these findings could be used to inform the development of a policy to improve efficiency in the use of water resources by water utilities.

The production of this EU Reference document *Good Practices on Leakage Management* is a joint effort by Member States, stakeholders and the drafting group with policy makers, economists, environmental experts, renowned non-revenue water (NRW) experts including members of the IWA Water Loss Specialist Group[3]. The (voluntary) members of the drafting group have contributed to the reference document by means of sixteen quality controlled case studies on strategies, methodologies, tools and (practical) performance indicators for leakage management by water utilities throughout the EU.

"Whilst water loss management is often pictured as the implementation of technological solutions to a hidden problem, this is really only part of the real solution, which is all about managing utility people to perform. It is about empowering them with the responsibility, training, practical tools and proven techniques, motivating them to perform, and inspiring them to believe that they can make a difference." (Conclusion of the Italian Case Study Iren Emilia).

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[3] See: http://www.iwahq.org/r8/communities/specialist-groups/list-of-groups/water-loss.html

1.2   A European perspective

Water availability is already under pressure across Europe, with one fifth of Europe's population living in countries where the total water abstraction puts pressure on water resources (see Figure 1). Leakage reduction should be considered by Member States as an important element of basic and/or supplementary measures to achieve the objectives of the WFD.
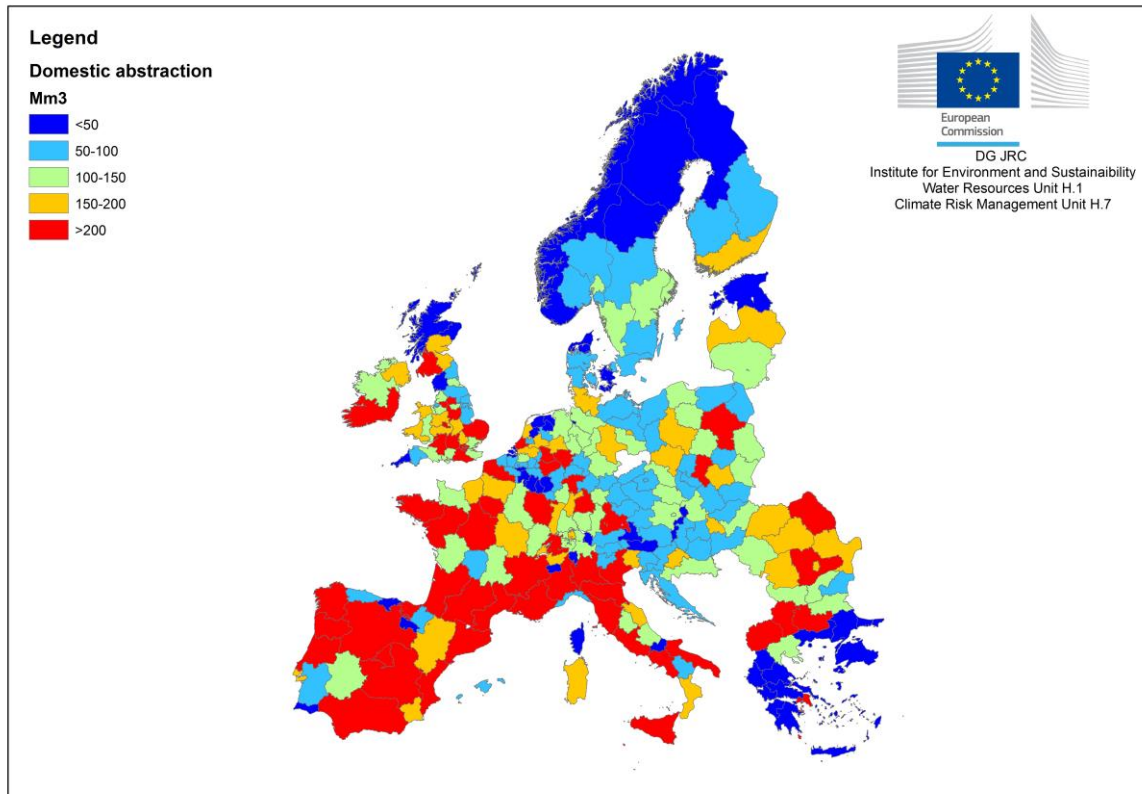
Figure 1 – Map of domestic water abstractions by NUTS2 regions in Mm^3 per annum (Source: Ad de Roo *et al*, 2012).

Across Europe, the structure of the water industry varies significantly from one country to another. Some countries have several thousand water supply organisations (e.g. Austria has 5.500, Spain has 2.800) whilst others have relatively few (e.g. UK has 25, The Netherlands has 10). There is a mix of public and private ownership, and water utilities vary in size from those supplying a few hundred customers, to those serving several million. Some utilities provide water and sewerage services; some water only. Some are responsible for abstraction, treatment and distribution, whereas others manage the distribution network only. The limits of responsibility for underground pipework ownership are different, depending upon the location and extent of customer metering.

In some cases, e.g. Scotland and Malta, there is a one-to-one relationship between Water Utility and primary regulator, though it is more common for the regulator to deal with many organisations. The regulatory functions may be split between different organisations responsible for quality, environment, price, and service; or they may be combined into a single body.

Other legislation and policies will vary from one country to another and will affect the performance that can be achieved, and the way in which appropriate targets are set and monitored. For example:
- Whether the Utility has powers to quickly repair (or quickly ensure repair of) leaks on privately owned mains, and privately owned sections of service connections.
- Whether the legislation allows free access to the Utility apparatus or whether delays are common due to dealing with the relevant highway authority or land owner.
- Whether there are standards of service for the pressure of water supplied to customers or to be maintained for the purpose of firefighting.

The case studies included in this report suggest that European countries could fall roughly into three categories:
- Those which have employed a mature approach to leakage management for 20 years or more.
- Those with some Utilities which are now actively identifying significant leakage reduction opportunities and achieving large sustained reductions in leakage.
- Those which need to reduce excessive leakage, and which have yet to embark on a significant leakage reduction programme.

As a result of this diversity, water regulation varies in certain aspects from country to country, and there is no standard method of estimating and reporting leakage, and no commonality on comparing performance or setting targets for leakage. The approaches in this document are evidence based good practices to reduce leakage, without any legally binding obligation for Member States.

1.3   Dissemination

The impact of this reference document on effectively addressing leakage will be determined by widespread dissemination and uptake of its recommendations and suggestions.

A separate dissemination plan, aiming to ensure that all relevant organisations will be targeted, has been developed. This dissemination plan will engage Member States and all relevant organisations in Europe with an interest in leakage from water distribution networks including water directors, government departments and agencies (policy makers), regulators, water utilities, trade organisations in member states, professional bodies and institutions, consultants, academia, media, etc.

The dissemination plan will be discussed as part of the new mandate of the CIS Working Group Programme of Measures, and will be updated regularly in order to:
- Decide on the role and involvement of the WG PoM in the dissemination.
- To keep the issue on the agenda and drive action where and when needed.

2 Policy recommendations

2.1 Introduction

Leakage is a highly complex issue and requires continuous actions to be effectively addressed. The majority of leakage is hidden, and is not visible. Sustainable management of low leakage levels involving a thorough understanding of the complex interplay between many key technical factors influencing leakage (see Section 4.2 and Figure 4), the influence of past and present management decisions as well as all of the other key drivers for success (i.e. all PESTLE considerations; see Section 3). Any approach to reduce leakage needs to be adapted to its own situation – there is no 'one size fits all' solution.

There are, however, some general recommendations to be made to the key stakeholder groups – policy makers/water authorities; economic and/or environmental regulators; and water utilities. These recommendations provide understanding of the key underlying dynamics of leakage and form the basis for successfully addressing leakage management, while effective implementation of actions will require specific, local and expert actions.

2.2 Recommendations for all stakeholders

The first four recommendations (on leakage targets, performance indicators, calculating leakage and water conservation) apply to all key stakeholder groups.

Leakage targets

Leakage targets should be set taking into account Political, Economic, Social, Technological, Legal and Environmental (PESTLE) considerations. Good practice procedures for setting economic leakage targets for smaller systems (less than around 30.000 service connections) can usually be simplified to some extent, by identifying activities or combinations of activities which have the highest Payback Period, Net Present Value or Benefit Cost ratio, and continuing with such schemes (whilst allowing for the other PESTLE considerations) until no further economic proposals can be identified.

> ► **Recommendation A:**
> Financial costs are one part of leakage management, but environmental and resource costs of leakage have to be explicitly considered as well (as a function of water scarcity including ecosystems needs), even though there is no conclusive methodology available at this moment. Including environmental externalities will require an increased level of leakage reduction than basing this level only on financial considerations.

> ► **Recommendation B:**
> Set targets in a volumetric parameter (see section 6.2.3 and section 6.6). The most appropriate volume measure for this purpose is an annual volume expressed as a total for the year e.g. in million metres cubed (Mm^3/year) or as an average in thousand m^3 per day (TCMD) or Mega litres per day (Ml/d).

> ► **Recommendation C:**
> For smaller systems (less than around 30.000 service connections) use the 'squeezing the box' approach until no further economic actions can be identified – see section 4.2 (Figure 4) and section 6.4.1. The target may be set using appropriate technical measures.

► **Recommendation D:**
Leakage targets for larger systems should be set for an individual water supply or unconnected water resource zone in an holistic approach, taking account of the operating environment, the network condition, the supply demand balance, resource and abstraction limitations, funding issues for investments, and willingness to pay by customers. Strategic annual zonal targets can be aggregated to the utility as a whole, and can be disaggregated to the component smaller systems (or DMAs) for operational management.

Performance indicators

Performance indicators are of importance to enable the public, NGOs and regulators to have a clear picture about water utility performance with regards to leakage reduction, including impacts on environment, resource efficiency and cost-efficiency. Inappropriate traditional performance indicators are still widely used for setting leakage targets, tracking progress, and comparing performance within and between Utilities and countries.

► **Recommendation E:**
Leakage expressed as a % of System Input Volume (SIV) is simple and easy to calculate. However, it has several limitations in interpretation which have led some Member States to stop or to reduce the use of % of SIV as a leakage performance indicator. For example, it can result in substantial under- or over-estimates of true achievements in reduction of leakage volume (see e.g. the Belgian and Bulgarian case study accounts). This is because % of SIV is a 'Zero-sum' calculation, which is unable to identify actual decreases in both consumption and leakage volume in the same period. Therefore, use a volumetric parameter for tracking progress.

► **Recommendation F:**
Use m^3/km mains/day, or litres/service connection/day or (for UK) litres/billed property/day for tracking progress in individual systems and sub-systems, but not for comparing performance between systems and sub-systems.

► **Recommendation G:**
For making technical comparisons of leakage levels between systems and sub-systems under their current pressure management regimes, calculate 'how low could you go' in Mm^3/year by entering system infrastructure characteristics and pressure in the equation for Unavoidable Annual Real Losses (UARL). Then calculate Infrastructure Leakage Index (ILI) as the multiple obtained when the system's Current Annual Real Losses (CARL) in Mm^3/year is divided by the system's UARL in Mm^3/year. As the current pressure regime may not be optimal, ILI should always be interpreted with some measure of pressure, and only used for tracking progress if all justifiable pressure management has already been completed.

Calculating leakage of potable water

Real losses (leakage) is the volume which remains after all of the components of consumption (metered and unmetered) have been deducted from the volume of potable water entering the system. Leakage, also referred to as 'Real Losses' or 'Physical Losses', is one of three components of Non-Revenue Water (NRW) in potable water transportation and distribution systems. The other two components of NRW - Unbilled Authorised Consumption and Apparent Losses (theft of water and customer meter under-registration) - represent water which is taken but not directly paid for by customers.

▶ **Recommendation H:**
The annual water balance used to calculate the average level of leakage in each system or sub-system should include volumes of potable water imported and exported, to encourage consistent calculations of embedded energy, accounting for volumes transferred between sub-systems, and confidence limits calculations for level of leakage.

▶ **Recommendation I:**
The 'snapshot' level of leakage assessed from night flow measurements, which is principally used for targeting leakage detection activities, can also be used (after adjustments for 24-hour variations in average pressure) to check the average level of leakage. This is particularly useful in systems where annual water balance calculations have wider confidence limits due to partial or ineffective metering and/or high apparent losses.

Water conservation

Leakage reduction contributes to achieving WFD objectives, especially in water scarce areas. As such, measures to reduce leakage levels should be an integral part of Member States' programmes of measures. Even though managing leakage to appropriate levels alone will not solve the problems faced by water stressed areas of Europe, it can be considered to have positive effects on customers and industries in their demand management.

▶ **Recommendation J:**
Leakage reduction should always be considered in parallel with reduction of excess or inappropriate consumption, based on demand side options such as water efficiency, metering, tariff management and water pricing.

2.3 Recommendations for policy makers and regulators

The regulatory overview may be split between different organisations or they may be combined into a single body, and the same applies for policy makers. The recommendations below are addressed to stakeholders in the policy and regulatory field. These actors, however, should also be aware of, and take into account, the recommendations for Water Utilities (Section 2.4).

Policy makers and regulators should take account of the following points:

- Leakage reduction, especially in water stressed areas, has direct benefits for the environmental and chemical objectives under the WFD art. 4. Significant pressures such as hydromorphological pressures or high concentrations of (diffuse) pollution can be addressed by addressing leakage. Furthermore, leakage reduction will have wider environmental benefits in reduced consumption of chemicals in water treatment processes and reduced energy needs.
- Cost recovery is a key principle of the WFD (art. 9). Water lost through leakage cannot be attributed to users and its costs can therefore not be recovered.
- Across Europe, fifteen percent (15%) of water abstracted from rivers and ground water is for households and industry connected to public water supply. Leakage from water distribution networks is therefore a relatively small, but nevertheless important, proportion of total abstractions.
- Except near coasts and tidal waters, leakage (unlike irrigation) is for most of Europe not generally a consumptive use of water. Most leakage (like most residential consumption) returns to surface or ground water, but at a different location from its original source.

Leakage as part of the supply – demand balance

Optimum leakage management could make a significant impact at the margins of current abstraction rates, particularly in water stressed river basins. Climate change, population increases and a growing demand for water will mean that, in the future, there will be substantial further pressure on water policy objectives, supplies and significant risks of less water being available.

► **Recommendation K:**
Regulation should promote water conservation, including leakage management, in preference to water resource development.

► **Recommendation L:**
Leakage management should be considered in the context of the current and forecast supply and demand balance for each water supply or water resource zone in a river basin, alongside water policy objectives and other water efficiency measures to control consumption and measures to increase available supplies.

Drought management

The significance of leakage increases in times of drought when available water supplies may be restricted. It is difficult though to reduce leakage quickly in response to short term situations, except in very small systems. Leakage management should be part of a long term plan of action which together with other initiatives contributes to a reduced risk of needing to impose restrictions on abstraction or compromising the environmental water objectives.

► **Recommendation M:**
Intermittent (rotational) water supply is not considered to be an appropriate response to drought; it causes more infrastructure damage than the alternative of running the system continuously at a lower pressure. The Cypriot case study account is an example of a situation where continuous supply to customers has been replaced by an intermittent supply in order to reduce consumption in times of drought. This policy has resulted in damage to the distribution system resulting in high levels of leakage. A preferable approach in severe droughts is to permit standards of service for minimum pressure to be lower during times of water shortage and lower consumption.

Country, Region and Utility specific regulation

Regulation must take account of the specific operating environment of individual utilities within each country and/or region.

► **Recommendation N:**
The process of regulation, and the method used to determine an appropriate leakage target, should be appropriate to the size of the Utility, the number of utilities being regulated, and the objectives of the regulator.

► **Recommendation O:**
Performance measures and targets should be appropriate for purpose and equitable (see Section 2.2).

► **Recommendation P:**
Leakage should be regulated at the river basin or unconnected water resource zone level, rather than for a single Utility, in a way which is consistent with the WFD. Implementation of leakage management, however, should be taking place and should be enforced at the level of the utility.

Stakeholder involvement

Customers wish to see that the Water Utility is operating efficiently and effectively in order that the impact of leakage on charges is minimised[4], and that they have value for money for the service provided. Their willingness to pay for leakage reduction is a test of their desire for lower levels of leakage, and their understanding of the benefits.

Economic regulators should expect operating and investment costs to be justified in business plans. Environmental regulators should seek to avoid undue abstractions of raw water, which deplete streams, lakes and rivers, and to mitigate the need for further water resource developments by managing demand.

Directors and shareholders should expect the Water Utility to be managed efficiently and to produce a return on investment, or in the case of publicly owned organisations, to operate within agreed budgets. They also wish to protect the reputation of their organisation.

> ► **Recommendation Q:**
>   Leakage should be managed taking account of all stakeholder views.

2.4   Recommendations for Water Utilities

Water utilities provide essential services to communities, which are vital to the general welfare and public health, the wellbeing and security of populations as well as to financial activities and environmental preservation; whilst having to deal with the challenges of short and long term variations in population, resource availability and climate in an efficient and effective manner in order to achieve a level of performance and sustainability for leakage which will enable the Water Utility to provide the required level of service to the public.

Over the past 20 years a number of effective and practical approaches to the diverse aspects of leakage management have been developed, and applied successfully, in a wide range of countries, taking into account various drivers for success and the need to adapt approaches to local circumstances.

However, many European Utilities and their stakeholders are not yet aware that these approaches exist, or are reluctant to break with traditional approaches which have a poor record in producing progressive sustained reductions in leakage over the last 20 years. A water utility will need to develop policies for pressure management and system sectorisation into pressure managed zones and district metered areas; economic frequency of Active Leakage Control (ALC) and linking ALC activity to actual or potential shortage of water resources; managing total run time of detectable leaks; efficient organisation and procedures from the initial leak alert through to the repair itself; appropriate standards for materials and workmanship; and asset performance and management. The four basic leakage control strategies are considered in more detail in Section 4 (see Figure 4).

There are numerous drivers for success in leakage management and reduction. This section lists a number of key, evidence-based, recommendations for utilities to successfully achieve reduction of leakage.

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[4] The majority of leakage is hidden, and is not visible. On the other hand, often the only visible sign of the water supply are the bursts and leaks, and an organisation's response to these – speed and quality of repair – can have a major impact on the image of the utility.

Pressure management

Pressure strongly influences burst frequency and leak flow rates on mains and service connections, and therefore also influences expenditure on active leakage control, repairs and asset replacement. The basic foundations of effective leakage management are the management of excess pressure and pressure transients, and limiting the run time of all detectable leaks whether reported or unreported.

▶ **Recommendation R:**
Pressures must be measured and monitored; excess pressures and pressure transients must be managed and reduced wherever feasible, and maximum and minimum standards of service for pressure should be flexible to promote better leakage management, where feasible.

▶ **Recommendation S:**
The sequences in which pressure management, active leakage control, leak repairs and pipe replacements are carried out is very important, if wasted expenditure is to be avoided.

▶ **Recommendation T:**
The value ($€/m^3$) of leakage (from both a utility and water resources point of view) and the energy used in each sub-system are two of the additional fundamental parameters in developing a sustainable leakage control strategy.

Leak run time and leakage on service connections

Analysis of components of annual leakage volume sometimes produces counter-intuitive results. For example, long-running small leaks on service connections frequently lose greater volumes of water than mains bursts with high flow rates that are quickly repaired, but service connection leaks traditionally receive less attention than they should.

▶ **Recommendation U:**
Management of leakage from service connections should receive equal or, in some cases, greater attention than management of leakage from mains.

Asset renewal

In areas with high burst frequencies and/or rates of rise of leakage, an economic decision can be taken to continue repairing the assets or whether to replace them. The renewal policy must be guided by the survey database and the Total Cost of Ownership (TCO) of the network. Network management and active leakage control (ALC) provide information on pipe condition. Analysis of leakage rates on mains and service pipes, using techniques such as step testing and sub-DMA metering (see Section 4.3.3), should allow improved targeting of asset replacement.

As an option for reducing leakage, asset replacement is an expensive option compared to ALC and pressure management (PM). However, in some systems, the condition of the underground assets is so poor that ALC and PM are not sustainable solutions.

▶ **Recommendation V:**
A well-managed water loss programme should always include an allowance for selectively replacing mains and/or service pipes specifically to reduce leakage and the cost of ALC, when further pressure management to remedy the situation is not a feasible option.

System design

The efficiency of leakage management measures depends on the configuration of the distribution system. Many of the Case Studies in this report relate to retrospective modifications to existing systems where reduction of leakage was not a consideration in the original system design.

► **Recommendation W:**
Dividing the system into sectors greatly assists in rapid identification of new leaks, prioritising active leakage control and identifying areas for further pressure management (see Section 4.3.5). The extent of sectorisation will depend on the current configuration of the network, making appropriate use of traditional metering and new technology. New distribution systems and extensions to distribution systems should be based on sectorised designs to operate at relatively low pressures ('every metre counts') with future leakage management and rapid leak location and repair in mind.

A long term view

Leakage reduction is sometimes viewed as a project with a start and end, and funded accordingly. However, efficient and effective leakage management is an integral part of the management of the utility generally and needs continuous attention and action.

► **Recommendation X:**
Leakage management is an essential long-term activity of the utility which carries on in perpetuity through a continuous cycle of planning, action, and review.

► **Recommendation Y:**
The tools and methodologies like the Netherlands' WION (to reduce excavation damage), uniform registration of pipe failures, benchmarking of water utilities and Performance-Based Contracting should be considered. Information on these tools and methodologies can be found in Appendix B.

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3 Holistic approach to leakage management

3.1 Introduction

Climate issues, growing populations and deteriorating water supply infrastructure are exerting unprecedented pressure on water resources throughout the world. As a result, government and regulatory bodies and water utilities are experiencing a growing awareness of the importance of accurately assessing and efficiently controlling water losses as a means to preserve water resources while facilitating growing communities. Leakage from water distribution systems impacts adversely on many diverse functions of the utility. Excess leakage adds to the overall cost of sourcing, abstracting, treating and distributing water. It adds to the water industry's energy needs, and it increases the capacity required for raw and treated water storage, water treatment works, pumping plant, transmission and distribution mains.

Leakage adds to the volume of water abstracted from the environment and must be considered as part of an holistic long term plan for river basin management to meet the objectives set out in the Water Framework Directive. Water supply in general, and water loss in particular, comes under scrutiny from the public, the media and politicians. Excess leakage is regarded as waste, and a wasteful organisation is seen as inefficient. In areas where water is in short supply, and in times of drought, there is an increased focus on leakage from a social perspective. For these reasons, leakage is a Key Performance Indicator (KPI) of interest to governments and industry regulators.

It is well known among leakage practitioners that real losses cannot be eliminated completely. There will always be a level of leakage which has to be tolerated in any system, and which has to be managed within acceptable limits. The challenge is to manage leakage in order to satisfy a number of often competing drivers from internal and external stakeholders and decision makers. Leakage reduction is an activity that requires continuous attention and action by all relevant stakeholders.

The intention of this section is to explain the reasons why water utilities should reduce leakage and identify how to resolve water loss problems using today's technology in a balanced way taking account of political, economic, social, technical, legislative and environmental (PESTLE) considerations. The PESTLE analysis is considered in detail in Appendix A.1 to A.4.

3.2 Leakage management from an environmental perspective

Water availability is already under pressure across Europe, with one fifth of Europe's population living in countries where the total water abstraction puts pressure on water resources. Around fifteen per cent of water abstracted from rivers and groundwater in Europe is for households and industry connected to public water supply. Water lost from water supply infrastructure through leakage constitutes the loss of a valuable resource and has a direct negative impact on the objectives of the Water Framework Directive. Even though water lost through leakage flows back in the environment at the place of the leakage, it is abstracted from a water body in another place. The abstraction can be decreased if the leakage further in the system does not occur, leaving the water in its original water body, where it supports ecosystems and biodiversity. In addition, leakage reduction can address significant pressure, as unnecessary abstraction may have negative hydromorphological consequences and may cause higher concentrations of pollution in the originating water body from which the water is abstracted.

In areas of water scarcity, this becomes even more important, as all water resources should remain in place as far as possible to balance the negative consequences for the environment and other uses of abstraction. Furthermore, there is a relation with the cost recovery principle of WFD art. 9. The cost of water that is abstracted should be recovered through the users of that water. Abstracted water lost through leakage cannot be attributed to users and therefore cannot be recovered, unless the costs of the leakage are recovered in the tariff charged for potable water.

A concrete example in water scarce areas is the interaction between surface water and groundwater bodies, where groundwater dependent terrestrial ecosystems are affected by water scarcity. Unnecessary abstractions as a result of leakage exacerbate this situation.

From an ecological perspective, each river basin within individual member states has unique characteristics of topography, geology, soils and land cover, and will experience variations in flow which are essential to its health. While all aspects of the flow regime are important to the health of river ecosystems, low flows represent a particular risk to migratory fish that require sufficient flow to trigger upstream movement towards spawning grounds. Furthermore, leakage represents a waste of electricity, and chemicals used in treatment processes can produce by-products such as ozone, contributing to greenhouse gas emissions.

Attempts have been made to incorporate assessment of environmental costs and benefits when building the case for economic reductions in leakage. Society also places a value of having water in the environment for aesthetic purposes, to sustain and improve the aquatic ecosystem and for recreational activities including walking, angling and boating. However, there remains concern that assessments fall short of the holistic view necessary to truly understand the environmental economics of leakage.

3.3   Leakage management from a political and social perspective

Water has a very strong political dimension. The major decisions regarding the water utilities, namely the establishment of their physical boundaries, the range of water services delivered, the ownership and management models and, often, the setting of tariffs and the appointment of the managers are political.

Leakage is probably the most important single indicator of the efficiency of water utilities. The current levels of leakage are perceived by the regulators, the public and the media as too high in most water utilities, and this exerts a strong pressure on the political decision makers to have leakage reduced. This reduction should also be beneficial to the water utilities and their stakeholders, except in the few cases in which the economic levels of leakage have already been reached. It is interesting to notice that the political concern about leakage management is not always materialized in decisions that may result in similar economic losses to the paying customers, for example authorizing street washing or the irrigation of public spaces with unbilled potable water.

In summary, it is possible and cost effective to take measures to manage and reduce leakage in most water utilities. These measures, that can only deserve political support, may have a significant environmental, social and economic impact namely through the abstraction of less raw water, lower tariffs and reduced investment and operation costs, especially if leakage reduction avoided the expansion of the system.

3.4 Leakage management from an economic perspective

Reducing leakage creates greater headroom between current demand and the amount of water available for use, making more water available for other purposes. Leakage control is therefore an integral part of managing the supply demand balance for individual water suppliers, for integrated river basin planning, and for national water policy. Excess leakage can contribute to restricted water supplies, which can be a limiting factor in economic capacity development. So, there is a macro-economic aspect to leakage management which is of concern to governments and industry regulators, as well as the micro-economic aspect which is the focus of this section.

Operating at lower levels of leakage results in lower operating costs for a Water Utility in terms of water production and distribution. Typical savings applying in all countries include lower chemical usage for water treatment, lower energy costs for treatment and pumping, and lower costs for disposal of waterworks sludge. In some cases, volumetric charges apply to water abstraction, and to taxes or local rates paid by the Utility and if these are reduced by reducing leakage then they should be included in the estimate of unit cost of water. Where the Water Utility is not responsible for abstraction and treatment, but instead purchases water from a bulk supply authority then the unit cost will be that which applies to the Utility's charges. Ideally, the Utility should understand the true marginal cost of the water, i.e. the unit cost at different levels of leakage, as the cost can vary. However, it is quite common for an average cost of water to be used in economic calculations especially in large systems.

Of course, reducing leakage costs money. As well as investment needed to install Pressure Management, create zonal metering and DMAs, and replace underground assets which have deteriorated beyond the point of economic repair, there is an ongoing operating cost for finding and fixing leaks, and maintaining control systems.

There is an economic balance to be made between the cost of water due to leakage, and the cost of the measures employed to reduce leakage. By considering the total annual operating costs (leakage plus leakage reduction) at different levels of leakage, it is possible to estimate the point at which total operating costs are minimised. That point is referred to as the economic level of leakage (ELL). This economic balance between costs and benefits, and the idea of an economic optimum level of operation, are commonplace in other industries. What is different with leakage is the higher level of uncertainty over the actual level of leakage, and its component parts, and the unit costs for making leakage reductions. Some element of uncertainty must therefore be factored into the economic appraisal particularly in larger utilities.

When operating costs alone are included in the calculation, then the optimum level of leakage is known as the short run economic level of leakage (SR-ELL). Short run operating costs should be balanced against the short run measures which can be taken to control them, such as some Pressure Management schemes and ALC – see Figure 2.

However, there are other costs and benefits which should be taken into account when considering the long run economic level of leakage (LR-ELL). Longer-term benefits include the deferment of capital expenditure aimed at bridging a forecast supply–demand gap such as the need for new resources and treatment works. Longer term control measures will include asset renewal, additional Pressure Management, and measures to improve the efficiency of ALC such as district metering.
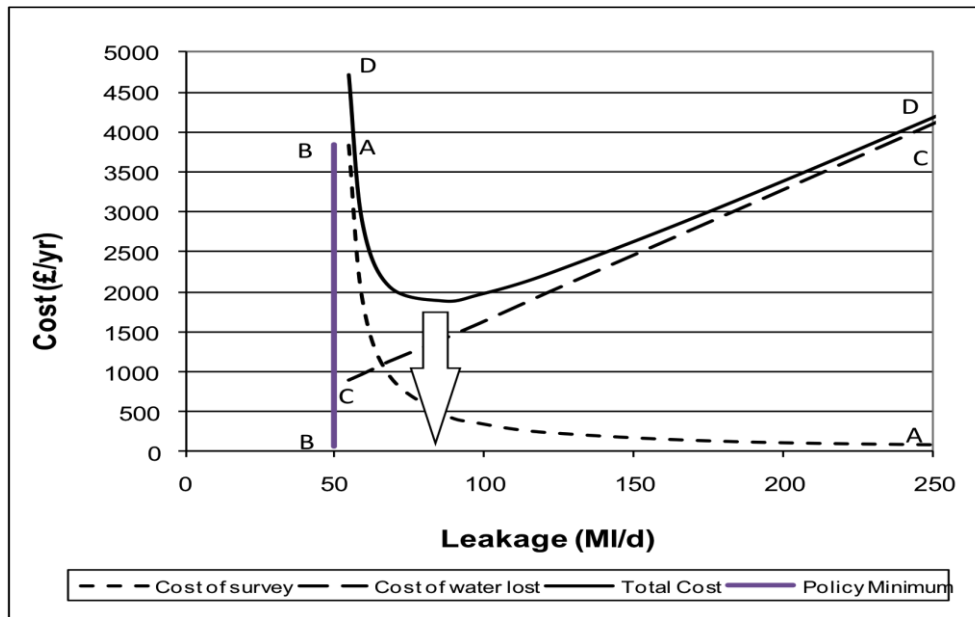
Figure 2 – Calculation of the short run economic level of leakage at current pressure.

Appendix A.2.1 is a schedule of the costs which should be taken into account when evaluating the savings to be achieved from leakage reduction.

Adding external costs and benefits to the Utility's internal costs develops what in the UK is termed the sustainable economic level of leakage (SELL). Externalities include those associated with social and environmental issues, and carbon reduction. Appendix A.2.2 sets out the factors involved in establishing a sustainable economic level of leakage (SELL).

3.5   Leakage management from a technological perspective

As distributions systems age, new leaks and bursts which occur must be detected and repaired. It's like trying to walk down a rising escalator – if you don't continue to find and repair leaks at least as quickly as they occur, you will end up with higher leakage than you started; so leakage management is not a 'one-off' exercise, it must go on forever.

Some progressive European systems have achieved leakage performance equivalent to best international technical standards (Infrastructure Leakage Index close to 1,0), others with moderately higher leakage are seeking to link their technical performance to the value €/m^3 assigned to leakage. However, the high leakage in many European distribution systems demonstrates all too clearly the consequences of past failure to invest sufficiently in leakage management. The positive aspect is that the case study accounts prepared for this report demonstrate how sustained leakage reductions can be achieved through a better understanding of the principles involved, the appropriate actions to take in the correct sequence for each situation, and the use of different meaningful leakage performance indicators for different purposes.

Several underlying concepts and factors have contributed over the past 20 years to the success stories outlined in the Case Study accounts:
▪ District Metered Areas to identify and target leaks where and when they occur.
▪ Influence of pressure on leak flow rates of different types of leaks (FAVAD concept).
▪ Component analysis of background leakage, reported leaks and unreported leaks.

- Standard IWA Water Balance, terminology and best practice performance indicators.
- Improved technology for leak detection.
- Understanding how pressure influences burst frequencies of mains and services.
- Economic ALC intervention, with or without Pressure Management.
- Enormous improvements in ease and speed of on-site data collection and transfer.
- Innovative pressure control technologies to modulate and stabilise pressures.
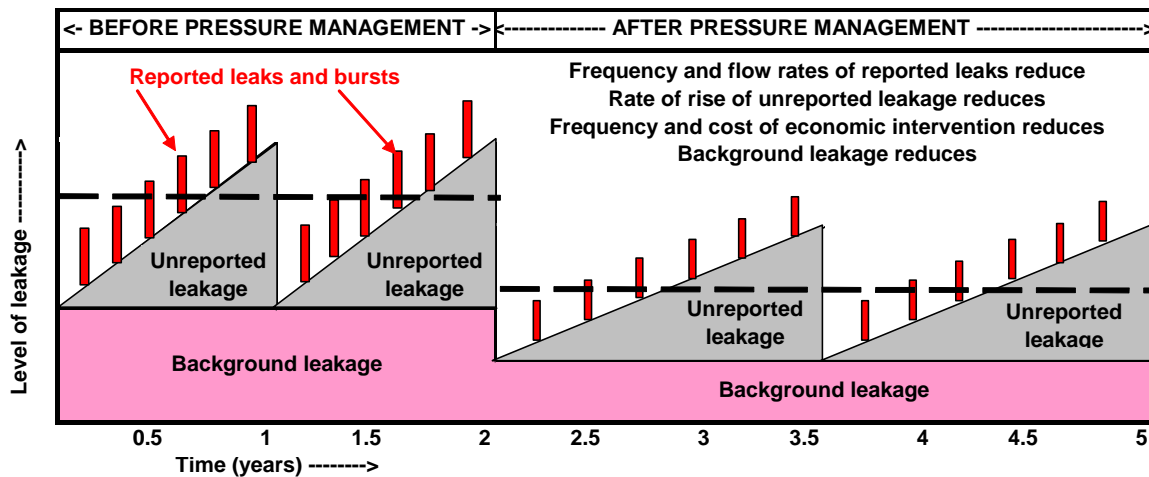
Figure 3 – Benefits of Pressure Management (source: A. Lambert and M. Fantozzi).

Leakage management is now becoming a maturing technical subject which requires a professional approach – the days of 'guesswork' or 'let's try this and see what happens' are numbered, although not everyone realises that yet. However, whatever the type of leak – background, reported or unreported – the basic foundations of effective leakage management are the management of excess pressure and pressure transients, and limiting the run time of all detectable leaks, whether reported or unreported.

3.6   Leakage management from a legal and regulatory perspective

For regulation of leakage levels to be effective, expectations from various stakeholders have to be taken into account:

- Customers wish to see that the Water Utility is operating efficiently and effectively in order that the impact of leakage on charges in optimized, and that they have value for money for the service provided. Their willingness to pay for leakage reduction is a test of their desire for lower levels of leakage, and their understanding of the benefits.
- Economic regulators expect operating and investment costs to be justified in business plans.
- Directors and shareholders expect the Water Utility to be managed efficiently and to produce a return on investment, or in the case of publicly owned organisations, to operate within agreed budgets. They also wish to protect the reputation of their organisation.
- Environmental regulators seek to avoid undue abstractions of raw water, which deplete streams, lakes and rivers, and to mitigate the need for further reservoirs by managing demand.
- National government departments aim to safeguard future water supplies to provide sufficiency for public health and for economic development, at all times now and in the future.

These expectations and limitations are sometimes competing and contradictory and a balance has to be struck taking all views and factors into account. Unlike water quality regulation there is unlikely to be a 'one size fits all' approach that is acceptable across Europe. A degree of flexibility is required within a general framework of principles. Regulation must also take account of the specific operating environment of individual utilities within each country.

The general public, the media and politicians often take a short-term reactive view when leakage is highlighted as an issue in times of drought. Where there is an effective system of regulation, which is communicated well, and which is applied fairly taking all relevant issues into account, there is less likely to be any reaction to short term issues; leakage can be managed as part of an efficient long-term strategy.

For example, in England and Wales, mandatory leakage targets have been set since 1997 in terms of Ml/d annual average. The economic regulator, Ofwat, expects each company to calculate its sustainable long term ELL (set over a 25 year planning horizon) every 5 years as part of the price setting mechanism. This is subject to third party assurance, and performance against target is monitored annually at a Company level. The Environment Agency reviews these targets and performance for each individual water resource zone.

4   Understanding leakage and leakage management

4.1   Leakage management from Water Utility point of view

Leakage is a fundamental factor for effective utility performance. High leakage levels in water distribution networks are generally perceived as inefficiency on the part of the Utility and specific actions based on a long term strategy need to be applied in such a manner as to ultimately achieve a level of leakage which is economically viable and could be sustained in the long run by the Utility.

The strategy to achieve this must be tailored to each individual utility based on the specific network conditions; a passive approach to any of the key drivers to control leakage will result in a continuous rise of leakage with detrimental effects. Gradually this deterioration may result in intermittent supply and ultimately to a complete failure by the Water Utility to continue to provide the required service to the customers/consumers. To turn around this situation and to stop the vicious circle of continuous deterioration of leakage levels it is imperative that a structured approach is established and that the required interventions, as well as progress tracking through appropriate indicators such as litres/connection/day, are put in place in order to achieve the desired results.

Operational efficiency is achieved through lowest cost inputs of labour, materials and energy. Water loss in a water distribution system can be a major operational issue, as Non-Revenue Water components can significantly affect the financial stability of a utility. Addressing the issues associated with the non-revenue components will certainly entail a significant cost for the Utility. The economic trade-offs between value of lost water and the investment to reduce this loss requires careful planning and economic judgment. The utility needs to clearly understand the type of loss as well as its magnitude. Water resource, financial and operational consequences must be weighed when considering these issues and the decision taken is unique to every system.

A water audit is a thorough accounting of all water volumes into and out of a system as well as an in-depth record and field examination of the distribution system that carries the water, with the intention to determine the operational efficiency of the system and to identify sources of water loss and revenue loss. A water audit is a critical first step in the establishment of an effective water loss management program. With the successful completion of a system water audit, the Utility gains a quantified understanding of the integrity of the distribution system and begins to formulate an economically sound plan to address losses.

The IWA Water Balance provides a standardised approach to water audits using a common international terminology based on best practice from many countries, and so is a useful tool to analyse the various components of water production, storage and distribution. Through this analysis the magnitude of the water loss problem is identified and priorities can be set for rectifying the situation based on the component analysis of the Revenue and Non-Revenue Water elements. Also, a provision for entering confidence limits for all data entry items can be used to indicate the reliability of calculated NRW and leakage volumes, and to show where to prioritise efforts to improve data reliability.

The Water Utility point of view on leakage management is considered in more detail in the separate Case Study document.

4.2   Technical background on leakage and leakage management

Leakage, also referred to as 'Real Losses' or 'Physical Losses', is one of three components of Non-Revenue Water in potable water transmission and distribution systems. The other two components of NRW - Unbilled Authorised Consumption and Apparent Losses (theft of water and customer meter under-registration) - represent water which is used but not directly paid for by customers.

Different parts of the infrastructure (mains, utility and private service connections up to the customer meter) each form distinct component groups of reported, unreported and background leakage with their own characteristic frequency, average flow rate and run time; the methods of controlling leakage impact on one or more of these variables. Current Annual Real Losses volume is the sum of leak numbers x average flow rate x average run time for each of these numerous component groups.

Leak-free distribution systems are not a realisable technical or economic objective, and a low level of leakage cannot be avoided, even in the best operated systems where water suppliers pay a lot of attention to leakage management. Sustainable management of low leakage levels requires a thorough understanding of the complex interplay between many different parameters, and the influence of past and present management decisions. Since 1999 the IWA WLSG and its predecessors use four basic control strategies, summarised in the diagram below.
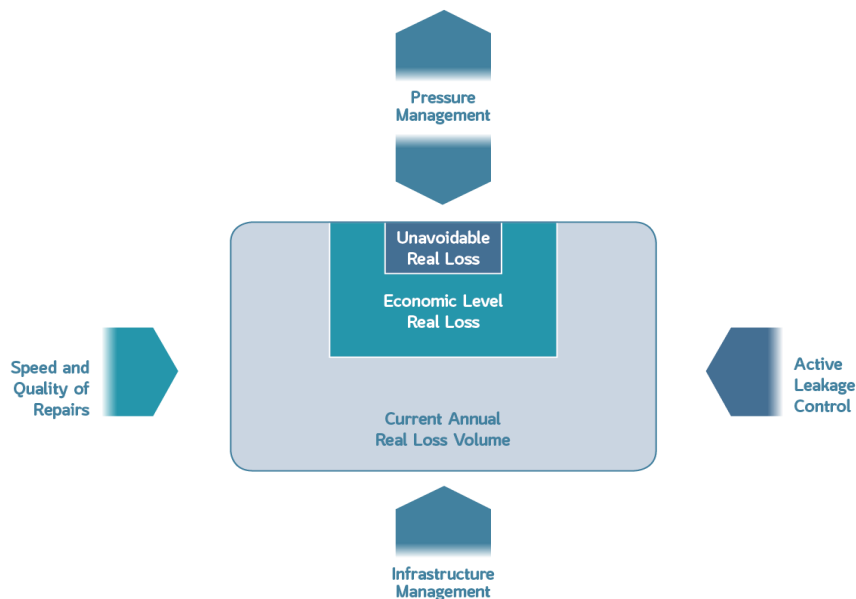
Figure 4 – The Four Basic Leakage Control Strategies (original source D. Pearson).

The large square represents Current Annual Volume of Real Losses, assessed from a Water Balance, or Night Flow measurements and daily pressure variations. As systems age, the tendency for leakage due to new leaks and bursts increases. This can be constrained, controlled, managed and reduced (or allowed to expand) by appropriate combinations of the four control strategies, balanced in cost effective combinations to different extents in individual systems, to achieve economically, environmentally and socially acceptable leakage levels. This technique is known as 'Squeezing the Box'.

The four control strategies interact with each other. Experiences over the last 13 years clearly show that reduction of excess pressure and pressure transients has a major beneficial influence on the other three control strategies. In a 2001 IWA International Report on Leakage Management, only 10 of 19 countries mentioned Pressure Management.

Nowadays it is widely accepted internationally that Pressure Management reduces leak flow rates, and reduces frequency of leaks in older mains and services, which in turn can extend infrastructure life. Other benefits, including energy management, are shown in the Table 1 below.

Pressure management: reduction of excess average and maximum pressures								
Conservation benefits			Water Utility benefits				Customer benefits	
Reduced flow rates			Reduced frequency of leaks and bursts					
Reduced excess or unwanted consumption	Reduced flow rates of leaks and bursts	Reduced and more efficient use of energy	Reduced repair and reinstatement costs mains and services	Reduced liability costs and reduced bad publicity	Deferred renewals and extended asset life	Reduced costs of active leakage control	Fewer customer complaints	Fewer problems on customer plumbing and appliances

Table 1 – Multiple Benefits of Pressure Management (WSAA, 2011).

The IWA WLSG has developed practical methods to predict many of these benefits, for better economic justification of Pressure Management proposals. For example, on average, for each 1% reduction in pressure, leak flow rates reduce by 1% and high burst frequencies reduce by up to 3%; so 'Every Metre Counts' (see Appendix B.3).

The 'Bursts and Background Estimates' concept of Component Analysis of Real Losses, identifies three categories of leakage with different characteristics – undetectable background leakage, and detectable reported and unreported leaks. This concept permits a rational analysis of components of real losses and the parameters which influence them, using information which already exists (or can be collected) by a Water Utility. The assessment of UARL in Figure 4 combines this concept with pressure:leak flow relationship to predict 'How Low Could You Go?' if water is scarce, expensive, or both, for well managed systems with different mains lengths, service connection numbers and lengths (main to meters), and average pressures.

Component Analysis splits average duration of leaks into 3 time components – Awareness, Location and Repair – which can be related to Water Utility policies. This type of analysis provides important conclusions, some of which are counter-intuitive to non-specialists; for example, a lesser volume of water is lost from a reported mains bursts with short run time than from a smaller leak on a service connections which take longer to identify and repair (Figure 5). This emphasises the importance of rapid repair and short run times for all utility leaks– not only the large ones.
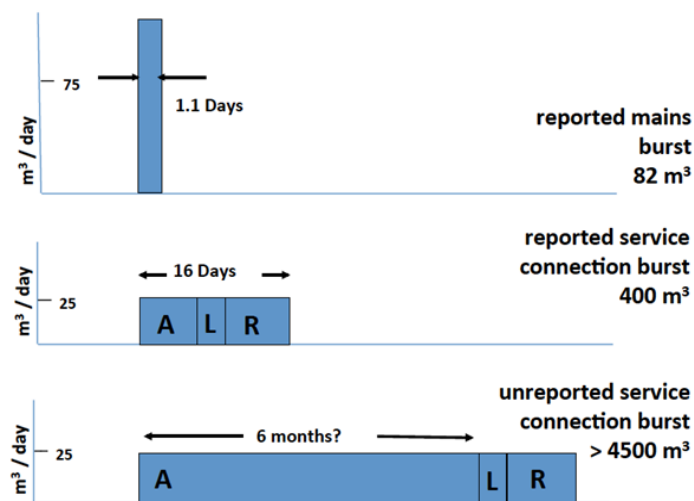
Figure 5 – Time components Awareness, Location and Repair of leaks.

4.3 How do Water Utilities manage leakage?

4.3.1 Pressure management

Reduction of excess pressure and pressure transients assists all other aspects of leakage management – it is better to prevent avoidable bursts than to have to find and repair them. When considering pressure management take account of:

- PMAs, PMZs or DMAs? These terms are unfortunately used interchangeably, perhaps because Pressure Management has often been added at relatively low cost to existing DMAs originally created only for night flow measurements and Active Leakage Control. However there are important differences, which can be identified if Utilities try to use the following terminology:
  - o PMAs have active Pressure Management, with or without metered inflow.
  - o DMAs meter inflows for ALC purposes, without active on-site Pressure Management.
- Reductions in pressure transients and small reductions in maximum pressure over large areas are likely to be more beneficial in reducing bursts (and rate-of-rise of unreported leakage) than large pressure reductions over small areas. Active Leakage Control without Pressure Management is often ineffective, so creating large PMAs with lowered rate-of-rise of unreported leakage and less frequent economic ALC intervention is a logical design concept.
- Large PMAs can then be sub-divided into more rationally sized smaller DMAs (and the occasional small PMA if necessary). This is likely to be more cost-effective in principle than equipping every small DMA with its own Pressure Management equipment. Also, in practice, failure to continuously guarantee closed boundary valves in a small PMA has more serious financial consequences than in a small DMA. An effective combination can be large PMAs (e.g. from a service reservoir) which include smaller DMAs which only meter flows; except in hilly areas, where small PMAs may be essential.
- Appendix B.3 provides further information on Basic, Intermediate and Advanced Pressure Management, pressure:leak flow rate and pressure:bursts relationships. The appendix also provides examples of advanced pressure management by pump control and by PRV pressure optimisation. Pump control – adding variable speeds controls to match pump output to demand – is preferable.

4.3.2 Speed and quality of repairs

Repairing known leaks promptly and effectively is one of the simplest and most cost effective ways of reducing leakage, and a rapidly achievable change a utility can make. Known leaks are leaks which have been found by active leakage control (see section 4.3.3) and all reported leaks. These known leaks will have to be repaired at some point in time; allowing them to run adds to the overall volume of water loss without any financial benefit. Each utility will have constraints on entry to highways which restrict its ability to effect repairs immediately, and the variation in the number of repairs must be matched with the resource available for repairs, so there will always be a minimum economic intervention time. However, the aim should be to avoid excessive repair time.

If there are contracts for leakage repairs, there should be a service level agreement (SLA) which provides an incentive to the contractor to effect repairs within a set time period, and/or a penalty for failing to do so.

The quality of repairs should be monitored by utility staff to ensure the risk of a repeat leak is minimised. The valve operations to isolate a section of main for repair should be carried out in a manner that reduces the risk of introducing pressure transients which could cause additional leaks to occur.

The policy of undertaking repairs on private pipes, and pipes on private land should be reviewed to ensure a balanced approach between the cost of repair and the impact on overall leakage levels. Where supplies are unmetered or customer meters are located at some distance after the point of delivery (where the Utility section of the service connection joins the customer's section of pipe) experience has shown that long running leaks past the point of delivery need to be effectively controlled by the Utility (see Figure 5). This may require powers to effect rapid repairs of the customer's pipe, which may or may not be subsidized by the utility, or powers to assist in pipe replacement when needed, or powers to shut off the supply until the repair is completed by the customer.

4.3.3 Active leakage control

Active leakage Control is the process of pro-actively looking for un-reported leaks and bursts (in order to reduce their run time) and pinpointing those leaks that come to the surface and are reported to the Utility. ALC consists of two distinct stages:

- Leak monitoring and localisation.
- Leak location and pinpointing.

Leak monitoring and localisation

The purpose of this stage is to identify the area of the network in which leakage is occurring in order to prioritise field surveys. A popular approach is to divide the network into District Meter Areas (DMAs) by shutting valves permanently and installing meters equipped with telemetry data loggers in order to allow the Utility to continuously monitor zone consumption from which an estimate of leakage can be made. Another method, known as mobile waste metering, involves valves being shut temporarily and mobile meters, installed in vans and connected via flexible hoses to permanent connections in the network, being used to measure flows. A hybrid system involves permanently installed meters with the boundary valves being closed temporarily to measure a night flow.
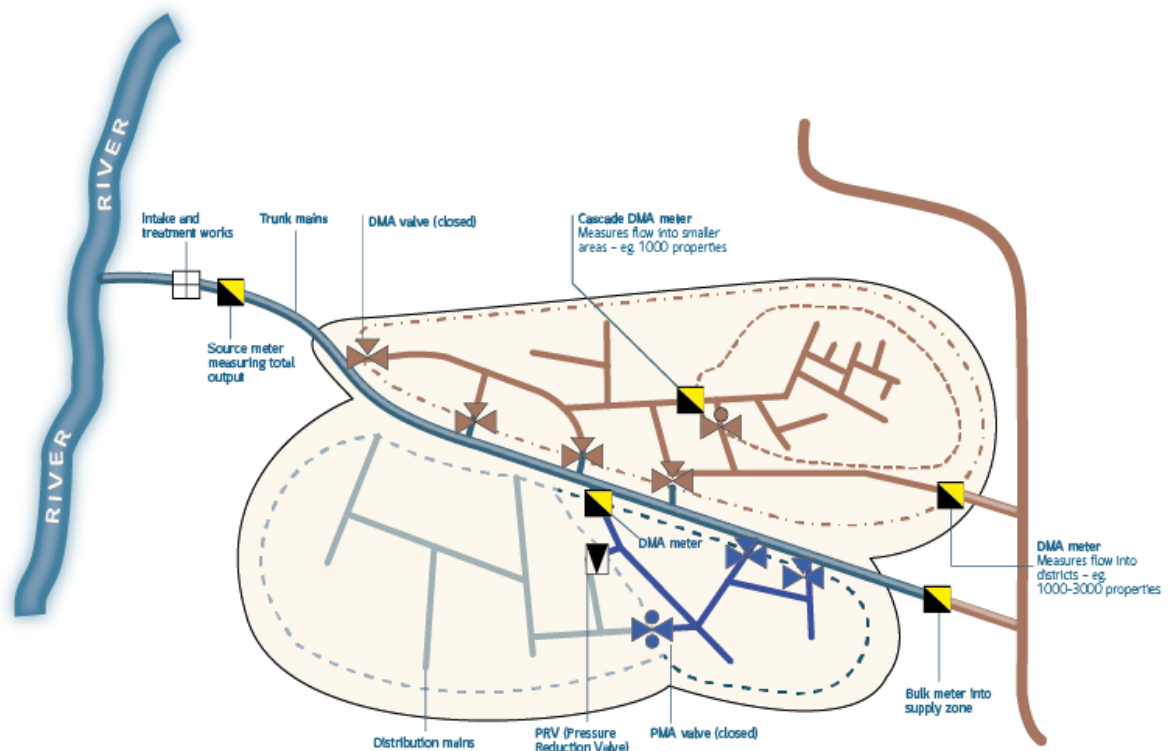
Figure 6 – Division of the network into DMAs (UK example).

Recent developments in software linked to hydraulic network models or artificial intelligence routines, use flow and pressure data to identify new leaks and suggest hot spots where field surveys should be carried out.

In areas where it is not practical or economic to install DMAs or waste meter areas, such as in city centres, or within larger DMAs, leaks may be localised using acoustic data loggers which can be installed permanently or temporarily. There are various systems on the market, some of which will automatically alarm if a new leak occurs, whilst some have the ability to correlate between installation locations and indicate the leak location. Another alternative to DMAs is the use of so-called virtual DMAs (or virtual zone monitoring) which monitor flow only or combinations of flow and/or pressure and/or noise at strategic points with software identifying any changes from the normal pattern which could indicate a new leak. When more than one parameter is measured, the methodology is known as "multi-parameter measurement".

Within a DMA, the leak can be further localised by shutting valves inside the DMA to isolate sections of main, or by operating valves to move the boundary of the DMA temporarily, in a process known as step testing. When the section of network containing the leak is isolated the drop in flow rate into the DMA will be greater than that which would be expected due to isolating customer consumption alone.

Leak location and pinpointing

Once a leak has been localised it can be located and pinpointed using a variety of techniques, details of which are beyond the scope of this reference document. The techniques can be used to indicate the general leak location, or to pinpoint it prior to excavation in order to effect repair, depending on the circumstances. As well as being used for un-reported leaks, they are also used for reported leaks, around where water is present on the surface.

In summary, location and pinpointing techniques include acoustic and non-acoustic techniques as outlined in the table (Table 2) below:

Leak detection methods		Suitability for		
		Service pipes	Distribution mains	Trunk mains
Acoustic techniques	Basic Listening stick	Yes	Yes	
	Electronic listening stick	Yes	Yes	
	Leak noise correlator		Yes	Yes
	Noise loggers		Yes	
	Multi acoustic sensor strip	Yes	Yes	
	In pipe sounding			Yes
Non-acoustic techniques	Gas injection	Yes	Yes	
	Ground penetrating radar	Yes	Yes	Yes
	Infrared photography			Yes
	In pipe hydraulic plug	Yes		

Table 2 – Leak detection methods and their suitability for types of mains.

Further details of leak detection techniques are given in an IWA Publishing document (July 2013) *Leak Detection – Technology and Implementation* edited by Stuart Hamilton and Bambos Charalambous[5].

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[5] This book is sold through the IWA Publishing Book Shop (http://www.iwapublishing.com/template.cfm?name=isbn9781780404707&type=new) and there is an alternative web link for IWA WLSG members only to obtain a free download.

4.3.4 Infrastructure management

Infrastructure management includes asset renewal to reduce the rate of occurrence of new leaks, and investment in facilities such as DMAs and telemetry to improve the efficiency of ALC operations. Good infrastructure management ('asset renewal policy and strategy') underpins the leakage management programme and the associated operational activities.

The long-term investment includes the following aspects:
- Asset renewal; water mains, service pipes, meters and valves.
- Failure mechanisms should be assessed and replacement and renewal programmes should be matched to the requirements (see the German Case Study: Munich).
- Ensure quality of installation to prevent new leakage being introduced.
- Ensure careful storage of materials, e.g. don't leave uPVC out in the sun.
- Repair and maintenance; of all distribution system assets.
- Zonal metering from treatment works through trunk mains.
- District metering and boundary valve management within the distribution system.
- Customer meter replacement to manage under-registration affecting the accuracy of the water balance.
- The provision of link mains to enable district metering and pressure management.
- Pump optimisation and replacement.
- Telemetry facilities for monitoring and control.

In areas with high burst frequencies and/or rates of rise of leakage, an economic decision can be taken to continue repairing the assets or whether to replace them. Note that replacement of mains has been shown to not always reduce leakage. A study in the UK suggested that leaks elsewhere increase, and that over 80% of mains in an DMA has to be replaced to make a difference (source: UKWIR, *Managing Leakage 2011*). However, more detailed analysis of leakage rates on mains and services, using techniques such as step testing and sub-DMA metering, should allow improved targeting of asset replacement. Adequate quality control during the replacement works, considering the replacement of vulnerable service connections, and management of pressures on completion are all essential to ensuring that the objectives of the investment are delivered.

As an option for reducing leakage, asset replacement is an expensive option compared to active leakage control (ALC) and pressure management (PM). However, in some systems, the condition of the underground assets is so poor that ALC and PM are not sustainable solutions. A well-managed water loss programme should always include an allowance for selectively replacing mains and/or service pipes specifically to reduce leakage and the cost of ALC, when further pressure management to remedy the situation is not a feasible option. It is also the practice in a number of countries to replace sections of mains which experience more than 'X' bursts in 'Y' years, not because of the water lost but to reduce inconvenience and disruption to the public.

4.3.5 Infrastructure design

The efficiency of leakage management measures depends on the configuration and design of the distribution system, and on steps taken to ensure that the propensity of the system to generate new leaks is reduced.

Some degree of system sectorisation is essential to good leakage management. Creating DMA's in a tree and branch configuration such as that shown in Figure 6, or within a grid of ring mains (e.g. in Odense, see the Danish Case Study Odense) will improve the efficiency of leakage targeting.

New extensions to the distribution system should be designed with future leakage management in mind taking account of sectorisation, pressure management, and leak location, and the opportunity should be taken to install metering and pressure management on new development sites.

The optimum size of a DMA will depend on a number of factors including:
▪ The operating environment, whether it is urban, sub-urban or rural.
▪ The configuration of the distribution network taking account of natural breaks created by rivers, major roads and open spaces.
▪ The balance between a preference for single feed DMAs, and the need to include multiple feeds for added security of supply.
▪ The rate of rise of unreported leakage, and the required economic frequency of ALC intervention.
▪ The method of data collection and analysis.

In the case studies, DMA size varies from around 5.000 (Austria, Salzburg) to less than 100 (Bulgaria) service connections, depending upon the specific objectives and local circumstances. The Austrian Case Study Small Utilities shows that as DMA size progressively reduces below around 3.000 service connections, it becomes easier to identify (from continuous night flow measurements) the occurrence of a single new mains burst, then a single new service leak (at around 1.000 service connections), then background leakage at around 400 service connections or less (Odense, Denmark). The optimum size of a DMA will be a compromise between the cost of creation and maintenance of a relatively large number of small DMAs and the additional benefit obtained from more efficient ALC. If district metering is to be employed in conjunction with pressure management, creating a PMA, the criteria for sizing will be different. The range of pressures across the zone due to the topography and operating regime become additional key factors, as discussed in Section 4.3.1.

Pressure management tends to be more cost effective when applied to large areas, so investment in the infrastructure upstream of DMA's in order to optimise pressures at a zonal level, may prove to be more economic in the long term than installing and maintaining numerous pressure reducing valves in small areas. This may require trunk main extensions, provision of large diameter control valves capable of remote operation, and optimised pump control using variable speed motors.

Service reservoirs are an excellent way of controlling pressures in the network as well as providing storage, but they can be a source of water loss from overflows and leakage, so they should be subject to continual monitoring. Other issues to consider are:
▪ Design of service connections including the location of the customer meter to minimise customer side losses.
▪ Provision of line valves for step testing and for isolating sections of main for repair.
▪ Provision of pressure logging points.
▪ Design of district meter and PRV installations to facilitate monitoring and maintenance.

Quality assurance of the installation of new mains and services is essential to ensure that new potential leakage points are not built into the system. Choice of suitable materials and fittings such as pipes, meters and valves is a key issue; buying the cheapest is not always the most cost effective in the long term.

4.4   Performance indicators for leakage

The adoption of a sound performance indicator system is essential for improving a water utility's performance through sustainable increase in efficiency and effectiveness of its operations, and improved quality of service. Governments and regulators increasingly require annual reporting of high-level performance indicators, and many also set leakage (or NRW) targets in these terms. High-level leakage performance indicators have different characteristics which make them suitable for some purposes, but not for others.

To the general public, media and politicians, high leakage levels are perceived as waste and inefficiency by Water Utilities, and damaging to the environment; but what appears to be a 'high' or 'low' level of leakage depends largely on the characteristics of the Utility and the choice of one of several different KPIs which are commonly used in different parts of Europe. Unsurprisingly, many individual utilities prefer to promote and quote the KPI which appears to show their performance in the best possible light; their critics prefer a KPI which conveys the opposite impression; reviewers have to use what data they can find (whether it is appropriate to the utilities being compared, or not), and regulators hopefully seek to identify a balanced 'level playing field' approach.

In addition to creating the standard international water balance, the 1st IWA Water Loss Task Force (1995-99) reviewed and researched Performance Indicators for Real Losses from Water Supply Systems in detail, using data from 27 water supply systems in 20 countries. It was concluded that none of the simple traditional performance indicators (% of System Input Volume or % of Water Supplied, volume per km mains, volume per service connection, volume per km of system, volume per property) were suitable for valid technical comparisons of leakage management performance between systems and sub-systems.

As an alternative zero-based approach, component analysis was used with auditable assumptions to create the UARL equation to predict 'how low could you go' for individual utility systems, allowing for length of mains, number and length of service connections and average pressure. The ILI, which is the current annual real losses expressed as a multiple of each system's specific UARL, creates a more 'level playing field' for comparisons of technical leakage management performance at current average pressure. ILI fulfils the useful purpose of expressing current leakage as a simple multiple (e.g. three times) of the lowest technically achievable leakage for each system or sub-system. However it should always be interpreted taking into account the value of leakage ($€/m^3$) and the current operating pressure (which may not be optimal for efficient leakage management).

Leakage expressed in traditional terms of m^3/km of mains or m^3/ service connection (per year or day) is not suitable for direct comparisons between systems and sub-systems. This is because each system has a different UARL base level, which varies widely depending upon density of connections, length of connections (main to meters) and average pressure. Figure 7, for customer meters 4 metres from the mains, shows that the UARL with:
- 30 connections/km, 30 metres pressure would be 500 m^3/km/year, 15 m^3/conn/year.
- 80 connections/km, 50 metres pressure would be 1.500 m^3/km/year, 18 m^3/conn/year.

If customer meters are located further than 4 metres from the mains, the variations in UARL per km or per connection become even greater.
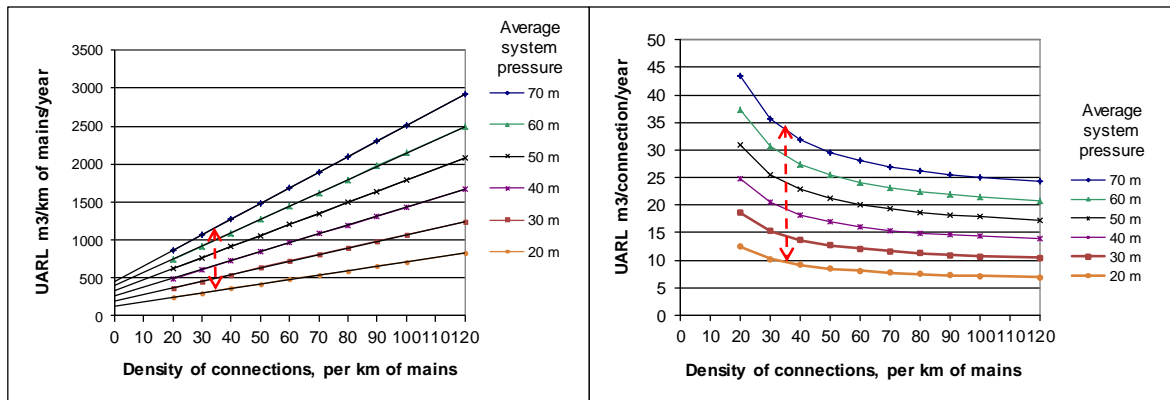
Figure 7 – UARL in m³/km/year and m³/conn/year, for systems with customer meters 4m from mains.

However, for any individual system or zone, density of connections and average length of service connection are effectively fixed, even if the system size increases over several years. So 'per km' or 'per connection' are ideal indicators for tracking leakage performance in individual systems and sub-systems - including the approximate influence of changes in pressure on UARL for any system, as shown by the vertical arrows on the graphs. 'Per connection' is technically preferable for systems with more than 20 connections / km of mains (where usually less than half of UARL occurs on mains) but individual country traditions and familiarity with one or the other of these units also influence the choice; 'per property' is traditional in the UK, from the time when there was usually one property to each connection.

In Section 5.3, the performance indicators from the majority of the Case Study accounts are summarised in two groups:
▪ KPIs for targets and tracking progress in individual systems:
  o Volume/year, m³/km of mains/day, litres/connection/day, and litres/property/day.
▪ KPIs for internal/external leakage comparisons between different systems:
  o UARL, ILI, average pressure, value of leakage Euro/m³, and repair frequencies.

The 'high-level' leakage indicators should reflect how well a Water Utility carries out a wide range of interlinked and clearly defined leakage management policies. Additional context indicators (see Section 6.4) should assist in identifying weaker points. In selecting these indicators the following principles have been applied:
▪ Fit for the intended purpose.
▪ Clearly defined and auditable.
▪ Quantifiable, avoiding personal or subjective appraisal.
▪ Reasonably achievable.
▪ Simple and easy to interpret meaningfully.

Over the last 20 years, the practice of expressing leakage as a percentage of SIV has failed to meet most of these criteria. It has been categorised as not suitable by many international standards organisations, regulators and the IWA Performance Indicators Group; Appendix B.2 explains why, with Case Study examples. It is hoped that this reference document will encourage and promote a more mature approach throughout Europe to the selection and use of leakage performance indicators that are appropriate for specific purposes, rather than perpetuating the existing rather chaotic approach where rational judgements and comparisons are not currently being achieved.

5 Good practices on leakage management by utilities

5.1 Introduction

Every Water Utility has unique characteristics and losses and a variety of tools, techniques and methodologies must be available in the leakage practitioner's tool kit. Case study accounts of individual Water Utility experiences are an important way to communicate that a particular method or approach is feasible and has succeeded in a given setting. Referencing a case study account of a successful water loss control programme is an effective way for a Water Utility manager to enhance his/her case when making a proposal for a new project or a change in rationale. It is very effective in gaining support for a proposal to provide evidence that a similar programme has been carried out in an efficient and economic manner.

The case studies prepared for this report are presented in a separate document. Section 5.2 provides for each case study a description of the utility and the main learning points. The results of the inventory and analysis for all sixteen case study accounts are summarised in five tables which are included in section 5.3 of this report.

5.2 What can be learned from each case study account?

5.2.1 Austrian Case Study: Small Utilities

Out of the 2.354 Austrian municipalities 2.128 have less than 5.000 inhabitants. Because of this structure Austria has about 5.500 water utilities (OVGW 2014):
- About 1.900 municipal utilities.
- About 165 water associations.
- About 3.400 water cooperatives.

    More than 5.000 of these utilities have less than 3.000 service connections and can be considered as 'very small utilities'; around 4.500 of these utilities have less than 1.000 service connections. A significant number of utilities serve less than 100 service connections. These small structures are common in most parts of Austria, especially in the Alpine regions and also in other rural regions, which belong mainly to the Danube River Basin.

You should read this Case Study account to learn more about:
- The conclusion in the Final REE Report, which states that high leakage of over 50% in small Alpine systems would not be exceptional. From the analysis of very small systems in Austria we learn the opposite is true, as it seems to be easier to achieve very low leakage (ILI < 1) in such systems, which are similar to individual DMAs. Reasons for low leakage in small systems are described in the Case Study.
- The guidelines developed by WLTF members between 2005 and 2009, which show that, for a lower limit of 3.000 service connections, the UARL standard formula is supported by the Austrian data and a number of practical considerations which are listed in the Case Study. The additional influence of low pressure and pipe materials on UARL are being investigated using data from larger systems with lower pressures than are available in Austria.
- Burst frequency on mains, and on services, which are also important indicators of system infrastructure condition, and are widely used in Austria. Combining water loss and failure rates gives an indication about the effectiveness of water loss management and supports decision making regarding required actions such as improvements in Active Leakage Control, Pressure Management and rehabilitation.

5.2.2   Austrian Case Study: Salzburg

This case study deals with the successful long-term management of the historical grown water supply network of the city of Salzburg in Austria. Parts of the network are more than 100 years old, but water losses and failure rates are low compared to international values. The good condition of the pipe network and the high service quality provided to the clients are a result of a consequent asset management strategy using innovative network monitoring and asset management tools.

You should read this Case Study account to learn more about:
- Maintaining water supply assets in good condition, a requirement of Austrian Water Law. Salzburg AG has implemented a sustainable asset management strategy and uses innovative rehabilitation software to ensure efficient asset renewal.
- Salzburg AG's water loss management strategy, which is similar to many other utilities in Austria. It follows OVGW guideline W 63 (2009) which includes principles of the IWA water loss management strategy. Beside network zoning of the core zones, which can be temporarily sub-divided, sections with permanent DMAs, permanent noise logging and basic Pressure Management are key measures alongside innovative infrastructure management practices. Salzburg achieves very low leakage levels with an ILI of 1,1 in 2013.
- The focus on annual maintenance activities of distribution system fittings, which are carried out for about 20% of the network per year, and combined with additional Active Leakage Control checks for small detectable leaks.

5.2.3   Belgian Case Study: De Watergroep

De Watergroep is a major Belgian Water Company, active in Flanders. Founded in 1913 as 'NMDW', it was renamed in 1987 as 'VMW' and then as 'De Watergroep' in 2013. The source water is 53% groundwater, 22% surface water and 25% bulk imports of potable water, and there are also exports of potable water to adjacent Utilities. De Watergroep has very low consumption of only 300 litres per service connection per day.

You should read this Case Study account to learn more about:
- How a consistent companywide approach is essential for efficient network and NRW management in a large Utility with multiple individual systems.
- The importance of data management within a complex and widespread distribution system.
- How low (or high) consumption adversely influences perception of leakage management performance when % of System Input Volume is used to compare performance or set targets. More meaningful performance indicators are now available; ILI was developed for comparisons between systems; litres/connection/day or m^3/km mains/day are appropriate for tracking progress in individual systems (but not for comparing different systems).

5.2.4   Bulgarian Case Study: Dryanovo and Razgrad

Most of Bulgaria experiences very high NRW, Apparent Losses and Real Losses. A tendency of reduced water consumption exists in the region due to customers' savings, closure of industrial production, etc. as well as reductions in the served population, payment of water taxes and repayment of long-term credit. So there is a lack of funds for rehabilitation.

However, some Utilities are starting to tackle the problems systematically. This Case Study contains two examples showing how the powerful combination of pressure management and Active Leakage Control in DMAs, applied in sequence, can achieve sustainable reductions in volumes of leakage in Bulgaria.

The Dryanovo example covers 12 DMAs recently established in a small town (1.470 service connections, 38,2 km mains). Razgrad is a pilot project to demonstrate benefits in 4 DMAs (716 service connections, 13 km mains) out of 24 existing DMAs in a city with 5.251 service connections and 116 km mains.

You should read this Case Study account to learn more about:
- How utilities with high leakage and few resources in Bulgaria can, with small capital investments based on knowledge and professional application of IWA practical concepts, deliver significant positive results in water loss reduction, providing a strong foundation for further gains.
- How the measurement of pressures, and application of Pressure Management in conjunction with Active Leakage Control in DMAs, is fundamental to the success of this approach.
- How the setting of targets and monitoring of leakage reduction using % of System Input Volume seriously under-estimates actual achievements (by a factor of 3 in the Dryanovo Case), and provides a disincentive for Utilities to implement effective leakage control and reduce excessive consumption and apparent losses.

5.2.5 Croatian Case Study: Pula

Waterworks Pula supplies the cities of Pula and Vodnjan, and municipalities Medulin, Ližnjan, Marčana, Barban, Svetvinčenat and Fažanu, in the south cape of the Istria peninsula in Croatia with a population of 75.000 and during the summer months an additional 100.000 tourists. The company has 32 reservoirs (32.313 m^3 capacity), 70 pumping units, 12 pump stations, 11 braking chambers, 17 water treatment plants, 25.657 service connections with 46.882 metered customers, 2.402 hydrants, and 928 km of mains of different sizes and materials.

You should read this Case Study account to learn more about:
- The importance of early recognition of water loss management as a result of a dedicated strategy initiated over 10 years ago.
- How a successful reduction and control of leakage requires goals, vision and commitment for continuous implementation.
- How an open minded management board emphasized the importance of company management, own personnel knowledge improvement and new technologies implementation.

5.2.6 Cypriot Case Study: Lemesos

The Water Board of Lemesos, established in 1951, is a semi-government Utility (Legal Person governed by Public Law) run by a Board of Directors appointed by the Council of Ministers and local Municipality appointees. The Board aims exclusively to ensure the supply of sufficient quantity water of good quality and to meet both the households' needs and its consumers' commercial and industrial requirements. The main concern and cornerstone of operations is the best possible service offered to its consumers. Lemesos, on the south coast of the island, is the second largest town of Cyprus. Ground levels in the 100 km^2 supply area fall from 450 meters at the foothills, to sea level.

You should read this Case Study account to learn more about:
- The problems of managing leakage under severe water shortage and intermittent supply conditions.
- Using Pressure Management and Active Leakage Control, from year 2002 to year 2007, to reduce leakage to ILI < 2,0.
- Being aware of how intermittent supply damages infrastructure and increases leakage in subsequent years.

5.2.7 Danish Case Study: VCS Denmark Odense

VCS Denmark is a Danish water and wastewater company with more than 150 years of operational experience in water supply and wastewater management - and a strong tradition for innovation. VCS Denmark is the third largest water and wastewater company in Denmark, operating 7 waterworks, 8 wastewater treatment plants and 3.400 km of water and wastewater pipeline networks. VCS Denmark is known as a frontrunner in the Danish water and wastewater sector, and has supplied the city of Odense with clean drinking water since 1853. Today VCS Denmark is a modern water and wastewater company with approximately 200 employees.

You should read this Case Study account to learn more about:
- How VDS Denmark has reached such low water losses with an ILI of 0,7.
- The effect of taxes on network water losses and potable water.
- The influences of system design, Pressure Management and Active Leakage Control.

5.2.8 English Case Study: Anglian Water

Anglian Water is one of 19 privately owned water companies in England and Wales, regulated by a number of organisations, which supplies water to approximately 2 million households. Rainfall in most of the Company's area is significantly less than the national average; it is classed as an area of severe water stress with many wetland and conservation sites of national and international importance. Anglian Water operates 450 Distribution Zones (DZs) with 1.800 DMAs covering 37.232 km water mains, of which 24% are actively pressure managed. About 75% of households and almost all non-households are metered.

You should read this Case Study account to learn more about:
- The way the economic regulator, Ofwat, requires an annual total leakage KPI in Ml/d based on a standard water balance and agrees targets based on a sustainable economic level of leakage (SELL in Ml/d) every 5 years. Environment Agency requires zonal leakage values to be incorporated into Water Resource management Plans, again every 5 years.
- The way the Company's supply-demand balance is at risk from growth, climate change and the reductions in deployable output that are planned to restore abstraction to sustainable levels. The Company has to manage risks from drought, deteriorating raw water quality and the impact of cold, dry weather on its distribution system and customer supply pipes. In response, a flexible and adaptive plan has been developed that commits to reducing leakage and consumption.
- The plan to increase coverage of Pressure Management from 24% to circa 50% within 5 years in order to reduce average zone pressure (AZP) from 44m to 38m (13% reduction).

5.2.9 French Case Study: Beaune

Beaune is a small town in central eastern France of 22.500 inhabitants and of an area of 31 km^2. The drinking water supply network of Beaune supplies 6.350 customers via 150 km of pipes. Beaune has the particularity to be located between the hills and the plain of the Saône so that its unique resource is the resurgence of a small stream. In addition to being restricted, this resource requires a complete water treatment (removal of pesticides and limestone, disinfection), hence leakage reduction is a strong issue to Beaune.

This issue led Veolia Water, through the renewal of the public service contract with the Conurbation authority of Beaune Côte et Sud in 2009, to commit to progressively and significantly improve the efficiency of the network up to reach a target of 80% in 2016 (network efficiency was equal to 70% in 2009). Network efficiency is a French performance indicator.

You should read this Case Study account to learn more about the first results of the Veolia Water action plan (implemented in 2009-2010) comprising:

- Deployment of an Advanced Metering Infrastructure.
- Establishment of permanent DMAs and supervision.
- Installation of permanent acoustic noise loggers.

5.2.10 French Case Study: Bordeaux

The studied system is the water supply system of CUB (Communauté Urbaine de Bordeaux). The CUB and its delegate Lyonnaise des Eaux provide the consumers of 22 cities with high quality underground water resources. The system includes 103 water intake points, 3.132 km water mains (aqueducts included), 130 treatment plants and 49 reservoirs. The whole water production system is monitored and controlled remotely 24 hours a day by the operation centre.

You should read this Case Study account to learn more about:

- How leakage in Communaute Urbaine de Bordeaux was reduced from 10,8 to 7,5 Mm^3 (ILI 3,2 to 2,5) between 2008 and 2013.
- How advanced Pressure Management and sectorisation created improved network conditions for achieving sustainable lower levels of leakage.
- How the current strategy focuses on efficient Active Leakage Control and prioritising the renewal of service connections, which are the most deteriorated part of the system and the source of 90% of all leaks.

5.2.11 German Case Study: Munich

Leakage control has a long history in German water supply, starting with first rules of the German Technical and Scientific Association for Gas and Water (DVGW) in 1986. These rules have been revised several times, the last update is still under revision right now.

The city of Munich is the capital of the state of Bavaria. It is situated at the river Isar, a tributary of the Danube river. With a resident population of 1,5 Million it is the third largest city in Germany. Population growth is proposed to about 1% per annum. Stadtwerke München GmbH (SWM) is the utility of the City of Munich for energy and water supply, urban transport und telecommunication.

You should read this Case Study account to learn more about:

- The German DVGW technical rules on Water Loss in Guideline W392.
- Groundwater quality protection through compensation payments to organic farmers and constructors, as an alternative to abstraction charges, to keep water quality so good that no water treatment is necessary.
- Leak detection in an area of sands and gravels with very high permeability, where only large leaks show at the surface, even with relatively high pressures.
- The importance of careful construction and design of infrastructure to minimise occurrence of new leaks.

5.2.12 Italian Case Study: Iren Emilia

Iren group is a major Italian multi-utility active in water, gas, energy and waste disposal, operating in the provinces of Turin, Genoa, Parma, Piacenza and Reggio Emilia in the northern part of Italy. The company was founded in 2010 by the merger of several companies in the area and serves a total of more than 2,5 million inhabitants. Water systems in Reggio Emilia province are managed by Iren Emilia. The 28 water systems in Iren Emilia supply 45 municipalities with 475.000 inhabitants through 4.940 km of mains.

You should read this Case Study account to learn more about:
- How Iren Emilia has learnt and applied the IWA concepts, since 2005, to reduce leakage (by 50%, to an average ILI of 2,5), burst repairs (by 33%) and use of electricity (by 20%) in 14 discrete systems in Reggio Emilia.
- Why implementing Pressure Management before (or during) the creation of DMAs, rather than afterwards, would have been a more efficient strategy.
- Why the implementation of technological solutions is only part of the real solution, which is all about managing Utility people to perform, by empowering them with the responsibility, training, practical tools and proven techniques, motivating them to perform, and inspiring them to believe that they can make a difference.

5.2.13 Maltese Case Study: Malta WSC

The Water Services Corporation is the national water operator for all three Maltese islands. Wholly government owned, it is responsible for both water and waste water operations. The problem of leakage has been holistically tackled since the intermittent supply problems of the mid-nineties. Almost all customers use indirect plumbing systems with large roof storage tanks, which create major meter under-registration quantified by detailed studies as being around 20% or more.

You should read this Case Study account to learn more about:
- How major reductions of leakage on the Maltese Islands since 2001 using IWA methods has resulted in 2-out-of-5 desalination plants being scrapped.
- How leakage was reduced from an ILI close to 20 in the mid-nineties to an ILI of 2,1 by 2013 (>600 to 70 litres/connection/day). This was achieved by a combination of Pressure Management and Active Leakage Control in small DMAs.
- Using snapshot ILIs from night flows to target ALC interventions and regulatory targets – and how smart metering installation is in progress to address high apparent losses.

5.2.14 Portuguese Case Study: Lisbon

The largest and oldest water utility in Portugal, Empresa Portuguesa das Águas Livres (EPAL), SA is a limited liability company, with 100% public capital, owned by the Águas de Portugal group. EPAL undertakes the extraction, treatment and distribution of potable water, encompassing both bulk supplies to around three million people in 34 municipalities and direct supply to more than half a million people in the city of Lisbon. This case study relates to the Lisbon distribution network, which receives treated water via EPAL's bulk supply network from the principal water source at Castelo de Bode, some 120 kilometres north of the city. The distribution network encompasses around 1.450 kilometres of mains, divided into five pressure zones and supplying in excess of 340.000 clients.

You should read this Case Study account to learn more about:
- How EPAL reduced leakage by 200 m^3/hour (500 to 178 litres/connection/day) between 2005 and 2013.

- Active leakage control 'find and fix' in DMAs with 'WONE' data analysis.
- Identifying pressure management opportunities that may exist in the EPAL Lisbon distribution network.

5.2.15 Scottish Case Study: Scottish Water

Scottish Water (SW) is the statutory water and wastewater services provider for the whole of Scotland, covering an area over 79.000 square kilometres (a third of the area of Great Britain), supplying 4,9 million population with drinking water through 48.000 kilometres of water pipes from 241 water treatment works. Households are not metred; all non-households are and there is market competition.

You should read this Case Study account to learn more about:
- The way in which a publically owned organisation with a one-to-one relationship with its regulator, and relatively plentiful low cost water, has outperformed the annual leakage targets agreed with the regulator with reported annual leakage reducing by 48% from 1.104 Ml/d in 2006 to 575 Ml/d in 2013.
- The process involved in estimating a sustainable economic level of leakage (SELL) for each of the 230 water resource zones and how the SELL varies considerably when reported in term of standard performance measures.
- The extensive pressure management programme combined with 96% coverage of district metering which has contributed to the reduced leakage, and which aims to further reduce average operating pressure to 40 metres. Current coverage of pressure management is 56% of the network with a weighted average pressure of 44,8 metres.

5.2.16 Serbian & Croatian Case Study: Mentoring

The Western Balkan region (Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Serbia, Macedonia and Kosovo) has around 500 water distribution systems serving some 20 million people. All utilities are public and under the control of national regulators. Individual distribution systems of separate municipalities and towns are relatively small, other than the capital cities. For example, Croatia has some 150 utilities supplying water to 4,3 million people, 20% of whom live in the capital city of Zagreb, and similar situations occur in the other countries.

The economic downturn in the 1990s due to numerous reasons had a negative impact on water infrastructure condition and leakage due to war damages, lack of preventive maintenance, limited or zero investments in rehabilitation, low revenue due to low water tariff, slow economic recovery, etc. Water resources availability and capacity are generally adequate, so leakage is not usually considered an issue of high importance by managements and workforce with little experience of modern leakage management.

You should read this Case Study account to learn more about:
- How a mentoring approach is beneficial, particularly for small utilities, for bridging the gap due to lack of national/regional educational good practices in leakage management.
- The main topics of interest in the mentoring approach for utilities regarding water loss management. These were: skills in use of leak detection equipment, free software for PIs calculation in local language, better understanding of pressure management benefits, DMAs, accurate and frequent flow and pressure measurements, operation of networks and apparent losses.

▪ How, in the light of rising capacities of employees (competencies, skills, responsibilities), mentoring of water utilities has proved a positive option in the West Balkan region, leading toward water loss reduction and increased system efficiency.

5.3   Summary Tables on the Case Study accounts

This section presents on the following five pages a summary table for:
▪ The context for each Case Study account.
▪ The Water Utility or system(s) context on infrastructure and leakage control.
▪ The assessment of annual leakage volume.
▪ The energy, economic and regulatory context.
▪ The assessment of annual leakage performance.

Note that it is important in any review of bursts that the level of ALC is taken into account. This to avoid the misconception that the asset condition is deteriorating when in fact there are more staff on the ground finding leaks. That is why some bursts rates look high; for those utilities the bursts rate has been reducing due to clearing the backlog.

Note on quality control: whilst the Drafting Group members have carried out numerous checks on the data contained in Section 5, the reliability of the information and data contained in the Case Studies remains the responsibility of the Case Study authors.

Summary table Case Studies: Context for Case Study account

Country	River Basin / Sub-basin	Utility	Case Study title	Case Study nr.	Abundant water resources		Potable Water, Own Sources				Potable water, Bulk Supplies	
					At the Basin level?	For Utility all year every year?	Surface water	Ground water	Springs	Desalination	Bulk Imports	Bulk Exports
Austria	Various	54 with <10k services	Small Systems	1	Yes	Mostly	No	Yes	Yes	No	Some	Some
Austria	Danube	Salzburg AG Wasser	Salzburg	2	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Belgium	Flanders	De Watergroep	De Watergroep	3	No	No	Yes	Yes			Yes	Yes
Bulgaria	Danube/Yantra	ViK Gabrovo - Dryanovo Region	Dryanovo City	4	No	No	Minor sources	Minor sources	Minor sources	No	Yes	No
Bulgaria	Danube/ Russenski Lom	Vodosnabdyavane Dunav EOOD - Razgrad	Razgrad Pilots		No	No	Minor sources	Minor sources	Minor sources	No	Yes	No
Croatia	Istrian	Vodovod Pula	Pula	5	No	No	Yes	Yes	Yes	No	Yes	Yes
Cyprus	Cyprus	Lemesos Water Board	Lemesos	6	No	No	Yes			Yes	Yes	No
Denmark		VCS Denmark	Odense	7	Yes	Yes	No	Yes	No	No	No	No
England	Anglian	Anglian Water	Anglian Water	8	No	No	Yes	Yes	Yes	No	Yes	Yes
France	Adour/Garonne	Communaute Urbaine de Bordeaux	Bordeaux	10	Yes	Yes		Yes			No	Yes
Germany	Danube/Isar	SWM GmbH	Munich	11	Yes	Yes	No	Yes	No	No	No	No
Italy	Reggio Emilia	Iren Emilia	Reggio Emilia	12	Yes	Yes				No	No	
Malta	Malta	Malta WSC	Malta WSC	13	No	Yes	No	Yes	No	Yes	No	No
Portugal	Targus	EPAL S.A.	Lisbon	14	Yes	Yes	Yes	Yes	Yes	No	No	Yes
Scotland	Scotland	Scottish Water	Scottish Water	15	Yes	Yes	Yes	Yes	Yes	No	No	No

Summary table Case Studies: Utility or system(s) context

Country	Case Study title	System size and density of connections			Underground service length, main to meter	Average Pressure	Annual Frequency of Repairs		Average Speed of repairs		Pressure management?	DMAs and Active Leakage Control?
		Service Conns	Mains length	Service conns			Mains	Services	Mains	Services	Basic, Intermediate or Advanced	
		nr.	km	per km	metres/conn	metres	/100 km	/k conns	days	days		
Austria	Small Systems (median)	1 396	50	27	12	50	7,5	3,8			Mostly basic	Mostly ALC
Austria	Salzburg	20 130	539	37	16	46	16,5	3,7	1,5	2,5	Basic	Yes
Belgium	De Watergroep	1 108 042	30 834	36	9	38	15,0	2,0	0,5	1,0	Basic, Int.	Yes
Bulgaria	Dryanovo City	1 470	38,2	39	5	41,5	60	21	1	7	Basic, Int.	Yes
Bulgaria	Razgrad Pilots	716	13,0	55	9	45			1	7	Basic, Int.	Yes
Croatia	Pula	25 657	928	28	10	40	26	5	1	2	Basic, Int, Adv	Yes
Cyprus	Lemesos	53 040	1020	52	8	40	21	22	1	1	Int, Advanced	Yes
Denmark	Odense	33 230	994	33	15	30	1,8	1,2	4 hrs	4 hrs	Int, Advanced	Yes
England	Anglian Water	1 842 088	38 076	48	approx. 7 *	44	12,9		2,3	5,7	Advanced	Yes
France	Bordeaux	201 001	3 093	65	5	37	12	14	3	1,7	All types	Yes
Germany	Munich	130 000	3 380	39	15	60	7,0	2,5	1 to 30	1 to 30	Basic	Yes
Italy	Reggio Emilia	94 410	4 941	19	25	43,7	16	20	2	2	Int, Advanced	Yes
Malta	Malta WSC	140 00	2 300	61	7	35	24	53	0,5	2,5	Int, Advanced	Yes
Portugal	Lisbon	87 815	1 448	61	approx. 8 *	51,2	38,2	8,4	1,0	1,0	Basic	Yes
Scotland	Scottish Water	2 305 449	52 354	44	approx. 7 *	44,8	24,5	3,2	1,8	3,7	Advanced	Yes

Note: * UK and Portuguese service lengths are estimated

Summary table Case Studies: Assessment of annual leakage volume

Case Study		Requires bulk Metering of			District Metering	Customer metering		UAC, Apparent Loss Estimates (% of metered consumption)			Leakage derived from	
Country	Case Study title	Own sources	Bulk Imports	Bulk Exports		Non-Residential	Residential	UAC	Theft	Meter	Water Balance	Night Flows
Austria	Small Systems	Yes	Some	Some	Yes	100%	100%	0% to 20%	0% to 1%	0.5% to 2%	Yes	For ALC
Austria	Salzburg	Yes	Yes	Yes	Yes	100%	100%	0,43%	0,00%	0,50%	Yes	For ALC
Belgium	De Watergroep	Yes	Yes	Yes	Yes	100%	100%	1,25%	0,25%	3,00%	Yes	For ALC
Bulgaria	Dryanovo City	Yes	Yes	No	Yes	100%	100%	10% of System Input Volume			Yes	Yes
Bulgaria	Razgrad Pilots	Yes	Yes	No	Yes	100%	100%	10% of System Input Volume			Yes	Yes
Croatia	Pula	Yes	Yes	Yes	Yes	100%	100%	0,25%	1%	2%	Yes	For ALC
Cyprus	Lemesos	No	Yes	No	Yes	100%	100%	1,00%	0,20%	4,50%	Yes	For ALC
Denmark	Odense	Yes	No	No	Yes	100%	100%	0,50%	0,20%	0,00%	Yes	For ALC
England	Anglian Water	Yes	Yes	Yes	Yes	100%	75%	5,10%	incl. in UAC	3,50%	Yes	Yes, and ALC
France	Bordeaux	Yes		Yes	Yes	100%	100%	0,5%	0,2%	2,0%	Yes	For ALC
Germany	Munich	Yes	No	No	Yes	100%	100%	0,5%	0,2%	2,0%	Yes	For ALC
Italy	Reggio Emilia	Yes	No	No	Yes	100%	100%	0,47%	0,68%	6,95%	Yes	Yes, and ALC
Malta	Malta WSC	Yes	Yes	Yes	Yes	100%	100%	0,2%	1,0%	51.5%*	No	Yes, and ALC
Portugal	Lisbon	Yes	Yes	Yes	Yes	100%	100%	0,50%	0,20%	4,05%	Yes	Yes, and ALC
Scotland	Scottish Water	Yes	N/A **	N/A **	Yes	100%	0%	13,40%	0,00%	4,50%	Yes	Yes, and ALC

Notes:
* Malta — Estimate of meter under-registration also contains billing errors, billing system being replaced by smart meters
** Scotland — Scottish Water has no imports or exports

Summary table Case Studies: Energy, economic and regulatory context

Country	Case Study title	Annual Energy used for — Production, Treatment (Million kWh)	Annual Energy used for — Distribution, Pumping (Million kWh)	Unit value of leakage — Average (Euro/m³)	Unit value of leakage — Highest (Euro/m³)	Assessed Unit Valuations of leakage takes account of — Water resource unit cost	Bulk Import unit cost	Production, treatment unit cost	Distribution, pumping unit cost	Taxes	Specific Regulator (Utility subject to regulation?)	Public Affordability Net Monthly Median Wage k€
Austria	Small Systems			< 0,1 to 0,35								1,82
Austria	Salzburg		3,34			Yes	Yes	Yes	Yes	No	Water Laws	1,82
Belgium	De Watergroep		80,0			Yes	Yes	Yes	Yes		Yes	1,81
Bulgaria	Dryanovo City			0,47		0,01	Yes		Yes		Yes	0,24
Bulgaria	Razgrad Pilots										Yes	0,24
Croatia	Pula		6,67	0,90*	1,05*	0,4	0,3	0,5		0,4*	Yes	0,73
Cyprus	Lemesos		2,5	0,65	0,69	Yes	Yes		Yes			1,41
Denmark	Odense		2,90	0,27	1,09**	Yes	No	Yes	Yes	Yes	Yes	2,22
England	Anglian Water			0,81****		Yes	Yes	Yes	Yes	N/A ***	Yes	2,08
France	Bordeaux			0,472		0,38		0,05	0,04			1,72
Germany	Munich					No	No				Water Laws	1,77
Italy	Reggio Emilia		22	0,08	0,17	Yes	No	Yes	Yes		Yes	1,34
Malta	Malta WSC		95	1,59	2,01	Yes	N/A	Yes	Yes	Yes	Yes	0,95
Portugal	Lisbon		115,8 (total)	0,05	0,10	Yes	N/A	Yes	Yes	Yes	Yes	0,69
Scotland	Scottish Water			0,59****		Yes	N/A	Yes	Yes	N/A ***	Yes	2,08

Notes:

*	Croatia — Pula	Value of leakage estimated for 2015 with new added Tax (varies with ILI ranges, likely to be 0.4 Euro/m3 for Pula ILI)
**	Denmark — Odense	Value of leakage rises to 1,09 Euro/m3 if Water Loss exceeds 10%
***	UK	Taxes are not volume related for Scottish Water and Anglian Water
****	UK	Using 1,25 Euro per pound sterling

Summary table Case Studies: Assessment of annual leakage performance

| Case Study | | KPIs for targets and tracking progress | | | | KPIs for internal/external leakage comparisons | | | Repair frequency | | Assessed value of leakage | |
Country	Case Study	Leakage Mm³/year	litres/conn/day	m³/km mains/day	litres/ billed property/ day*****	UARL Mm³/year	ILI	Average pressure metres	Mains per 100 km/year	Services per 1000 conns/yr	Average Euro/m³	Highest Euro/m³
Austria	Small Systems median		85	2,4			1,0	50	7,5	3,8		
Austria	Salzburg	0,62	84	3,1	84	0,54	1,1	46	16,5	3,7	<0,1 to 0,35	
Belgium	De Watergroep	28,09	70	2,5	61	21,94	1,3	38	15	2	0,48	
Bulgaria	Dryanovo City	0,183	340	13,1	137	0,032	5,8	42	60	21	0,25	
Bulgaria	Razgrad Pilots	4,73	2.470	112		0,11	41	45				
Croatia	Pula	1,71	183	5	100	0,6	2,9	40	26	5	0,90**	1,05**
Cyprus	Lemesos	2,46	127	6,6	77	0,97	2,5	40	21	22	0,69	
Denmark	Odense	0,41	34	1,1	23	0,41	0,7	30	1,8	1,2	0,27	1,09***
England	Anglian Water	70,34	105	5,1	95	N/A	approx. 1,5 *	44	12,9		0,81****	
France	Bordeaux	7,55	103	6,7	83	3	2,5	35	12	14	0,47	
Germany	Munich	11,50	243	9,4	242	4,4	2,6	60	7	2,5		
Italy	Reggio Emilia	8,47	246	4,7	92	3,43	2,5	43,7	16	20	0,08	0,17
Malta	Malta WSC	3,96	78	4,7	43	1,9	2,1	35	24	53	1,59	2,01
Portugal	Lisbon	5,71	178	10,8	45	1,97		51,2	38,2	8,4	0,05	0,1
Scotland	Scottish Water	209,88	249	11,0	227	N/A	approx. 4 *	44,8	24,5	3,18	0,59*****	

Notes:

* UK		ILIs have been estimated from MLE reported leakage values and other available data
** Croatia	Pula	Value of leakage estimated for 2015 with new added Tax (varies with ILI ranges, likely to be 0.4 Euro/m3 for Pula ILI)
*** Denmark	Odense	Value of leakage rises to 1,09 Euro/m3 if Water Loss exceeds 10%
**** UK		Using 1,25 Euro per pound sterling
*****		The number of billed properties is always likely to exceed the number of services connections, so leakage in litres/connection/day will frequently be significantly lower than litres/billed property/day.

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6 Methodologies for getting started

The intention of this section is to provide a framework for a water loss management programme for Utilities as well as to provide a thorough insight and mutual understanding on priorities set by Utilities themselves, by their regulators and the River Basin Management Authorities, to rectify the water loss situation.

6.1 Zonal Water Balance and/or Night Flow analysis

The IWA 'Best Practice' Water Balance and terminology (1999) is now widely used internationally. Modifications for countries and purposes which do not change these fundamental principles are acceptable. Many Systems and Zones have imports or exports of water, in addition to potable water from the Utility's own treatment works, so it is essential to clearly show the volumes of imports and exports in each Water Balance, and track the movement of these transfers between Zones. The simplified form of IWA Annual Water Balance in Mm^3 used in the Case Studies is shown below:
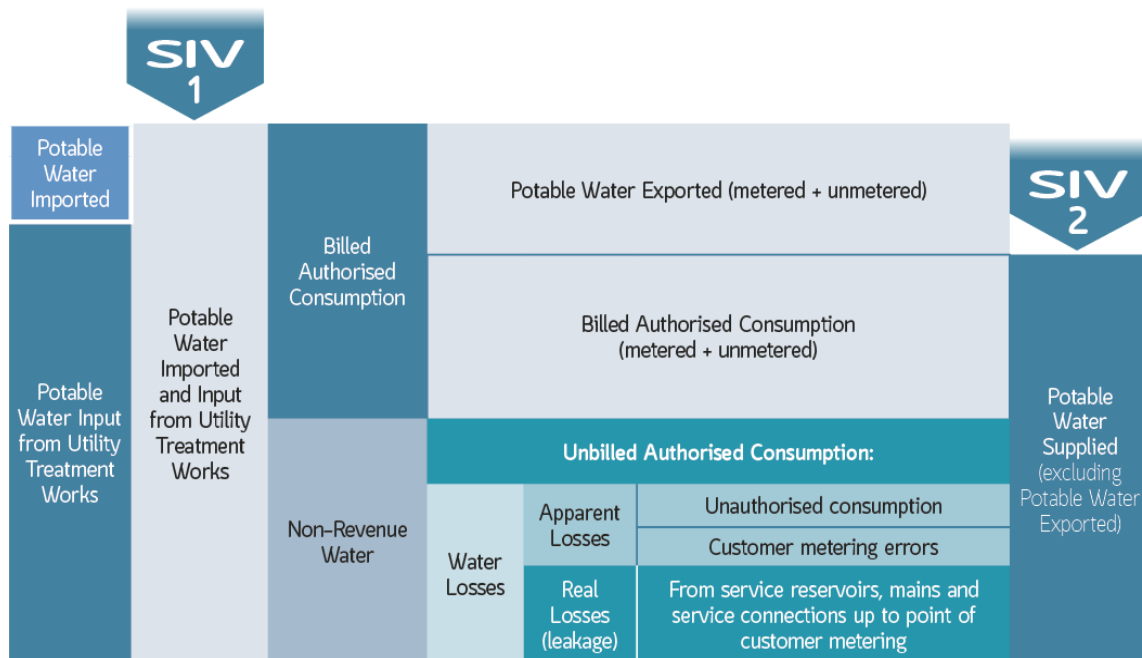

Figure 8 – Simplified form of Standard IWA Annual Water Balance in Mm^3.

In the Water Balance used in the UK, where significant numbers of residential customers are unmetered, two separate calculations of Real Losses (leakage) are made:

- 'Distribution Losses': up to the 'point of delivery' where the ownership of the service connection pipe changes from the Utility to the customer.
- 'Total Losses': up to the 'point of consumption' where the underground service connection pipe rises to enter the property.

Customer meters are located at the point of delivery or the point of consumption depending upon current and previous policies of regulator and the individual Utility.

Real losses is the volume which remains after all of the components of consumption (metered and unmetered) have been deducted from the volume entering the system. All calculations of leakage from water balances are therefore indirect assessments with limits of uncertainly, rather than direct measurements. Examples of uncertainty calculations, which can assist in prioritising actions to improve reliability of leakage assessments, are shown in some of the Case Studies.

Uncertainty of calculations can be reduced (but not eliminated) by accurate metering of bulk supplies, Zones and customers, and by ensuring that assessments of unmetered NRW components are not unrealistically high. The Water Balance used in Appendix B.1 shows guideline maximum defaults for Europe proposed in a recent paper by six European WLSG specialists. Some Case Studies have used higher values, some lower.

Guideline maximum default %s for assessed components of Non-Revenue Water are shown below:				
If higher figures are claimed they should have been validated by Utility Specific data				
	Unbilled Authorised Consumption	0.50%	of Billed Metered Consumption	excluding Water Exported
	Unauthorised Consumption	0.20%	of Billed Metered Consumption	
Customer Metering Inaccuracies	Direct pressure systems	2.00%	of Billed Metered Consumption	
	Roof storage tanks	5.00%	of Billed Metered Consumption	
	Customer Metering Inaccuracies are positive for under-recording, negative for over-recording.			

Table 3 – Guideline maximum default %s for assessed components of NRW.

If water is exported, there are two options for System Input Volume (Figure 8). SIV 1 includes Water Exported, SIV 2 (Water Supplied) excludes Water Exported and is therefore more meaningful than SIV 1 for calculations of technical KPIs for leakage in the donor system, which would otherwise be credited with unmeasured estimates of components of the water balance in the system to which water is being exported.

Minimum Night Flows (MNFs) are most frequently used to monitor leakage in PMAs and DMAs when consumption is at its lowest; new leaks can then be quickly identified and targeted to minimise leak run times. The basic IWA terminology for components of MNFs is shown in the graph below; a more detailed terminology is available if required (Fantozzi and Lambert, 2012).
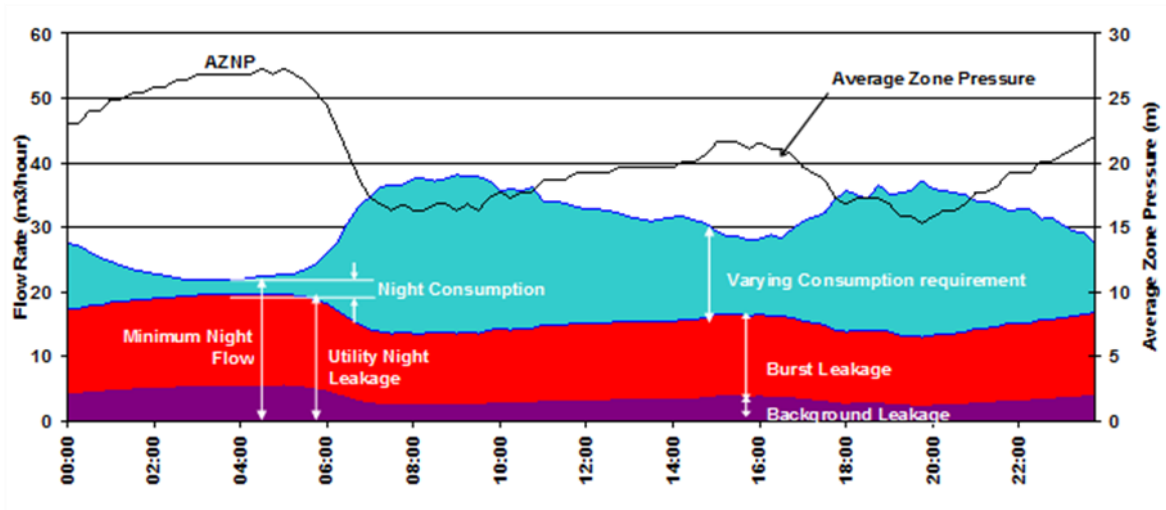
Figure 9 – Basic IWA terminology for components of MNFs (source: R. Liemberger).

MNFs can also be used to assess or check annual leakage in systems where water balance is less reliable due to significant unmetered consumption (e.g. U.K) or high apparent losses associated with customer roof tanks (e.g. Malta). It can be noted from Figure 9 that, as the Average Zone Pressure changes, so too does the rate of Utility leakage. It would be clearly incorrect to multiply the Utility Night Leakage in m^3/hour by 24 hours per day to assess the daily and annual leakage, so a parameter known as 'Night-Day Factor' (NDF) needs to be calculated to act as the multiplier.

For each Zone in which MNFs are measured, a specific location (the Average Zone Point, AZP) should be established to approximately represent the average pressure in that Zone. Where daily pressure profiles at the AZP are (occasionally, when necessary) measured, the NDF can be calculated using an appropriate relationship between pressure and leak flow rate for the Zone. NDFs can vary from 15 hours per day to 30 or more, depending upon the pressure variation in each Zone, so NDF is an important parameter that needs to be identified if annual leakage is to be assessed from minimum night flows.

6.2 Selecting zonal performance indicators (including pressure)

This section summarises good practice in the use of technical performance indicators for leakage. It does not cover environmental, social, economic and other aspects.

6.2.1 Tracking leakage management performance in an individual system or sub-system over time

The most appropriate performance indicators for this purpose are:
a) Volume per service connection per year, day or hour.
b) Volume per km of mains per year, day or hour.
c) Volume per billed property per year, day or hour.

Choice should preferably be based on technical considerations (notably density of connections per km of mains, and service connections per billed property) but individual country traditions and familiarity with one or the other of these units are also relevant.

Note: these KPIs should not be used for comparisons of leakage management performance between different systems or sub-systems with different infrastructure characteristics, notably service connection density, length of service connections and operating pressures.

6.2.2 Making comparisons of technical leakage performance of sub-systems within a larger system, or between different systems

The Infrastructure Leakage Index (ILI) was designed by an IWA Task Force in 1999 specifically for comparisons of leakage management performance between different systems with different infrastructure characteristics (connection density, length of service connections, average pressure).

- ILI = CARL/UARL.
- CARL is Current Annual Real Losses volume in m^3/year.
- UARL is Unavoidable Annual Real Losses (UARL) in m^3/year where:
  - UARL (m^3/year) = (6,57 × Lm + 0,256 × Nc + 9,13 × Lt) × Pc.
  - Lm = underground mains length (km).
  - Nc = number of underground service connections.
  - Lt = total length (km) of underground service connections (main to meter).
  - Pc = current average operating pressure (metres).

The important performance indicator of average pressure is required for the calculation of UARL and ILI, and the three (Pc, UARL and ILI) should always be considered in conjunction with each other. Where a utility is undertaking a Pressure Management programme to reduce leakage, ILI should be used in conjunction with some measure of average system pressure.

6.2.3 Setting strategic targets for medium to very large water utilities (more than 30.000 service connections)

The most appropriate measure for this purpose is an annual volume expressed as a total for the year e.g. in million cubic metres (Mm^3/year) or as an average in thousand m^3 per day (TCMD) or Mega litres per day (Ml/d).

The volume measure for the Utility as a whole should be the sum of the volume targets for individual supply zones, or water resource zones. The measure should be set as a rate for each year of a planning period to take account of the transition from the current level of leakage to the long-term target. The volume target should allow for extensions to the network for new development, asset deterioration, and asset management, and it may be at, above or below the current leakage level. If it is above the current leakage level, the relaxation of leakage control activities should be limited to measures which can quickly be re-introduced in time of drought or emergency. *Avoid rotational or intermittent supply which causes long-term damage to system infrastructure (see Cypriot Case Study: Lemesos).*

Notes:
1) *The zonal targets expressed as a technical performance measure may be very different due to the variation in connection density, length of underground service connections, system pressure, cost and value of water, water resource sufficiency, environmental and socio-political factors. Technical performance measures used to track leakage over time, or to make comparisons between systems, should not be used to set strategic targets. The practice of setting leakage targets as a percentage of system input volume is unsuitable and should not be used for tracking progress, technical leakage comparisons and target setting, for the reasons described in Appendix B.2.*
2) *The strategic annual volume targets for each supply zone, and the Utility as a whole, can be cascaded down to individual districts (DMAs or zones), in order to compare actual leakage management performance monthly or seasonally, with the performance required to meet the strategic target.*
3) *Operational targets for smaller utilities with less than around 30.000 service connections, and for sub-systems of larger utilities, may be set in, or converted into, one or more of a number of technical performance measures.*
4) *Separate guidance is given in Section 6.6 on the approach to be taken to setting targets.*

6.3 Key technical performance indicators for starting level

When a utility first starts to seriously investigate its leakage management performance, it is most unlikely that all the data needed for a detailed assessment will be available. So the initial steps are:
- Step 1: Assess your losses. Get first estimate of NRW and NRW components in volume terms using appropriate form of IWA Water Balance, and night flows.
- Step 2: Identify approximate current position using key performance indicators.
- Step 3: Analyse data you have, identify data you need and fix priorities.
- Step 4: Make a commitment, get started, and learn as you progress.

Step 1: Assess your losses
Using the Water Balance in Appendix B.1, the volumes of each major component of the Water Balance can be entered, estimated or calculated, and relevant comments added as appropriate (e.g. reasons why the actual defaults for unmetered components may be higher or lower than the guideline values). Note that all the defaults for unmetered components are assessed as simple %s of billed metered consumption (excluding water exported).

Developing leakage management strategies and identifying priorities for small systems is usually simpler than for larger systems (see Section 6.4), so system size influences the key sequence of activities. Infrastructure parameters which are not likely to change in the short term (number of service connections, service connection density, and average service connection length) can also be generally described for individual systems as 'Very Small' to 'Very Large', using the following table as a guideline for European Utilities.

Note: the terms 'rural' and 'urban' are best avoided, as some metropolitan zones can have small connection densities.

Parameter	Units of measurement	System Size Descriptions					This System	
		Very Small	Small	Medium	Large	Very Large		
Service connections:	Number	< 3k	3k to < 30k	30k to < 300	300k to < 3 million	3 mi or more	29k	Small
Service connection Density	Number per km of mains	< 20	20 to <30	30 to < 50	50 to < 70	70 or more	52	Large
Average length Main to Meter	Metres per Connection	< 4	4 to < 8	8 to < 12	12 to <16	16 or more	8	Medium

Table 4 – Guideline for system size description for European Utilities.

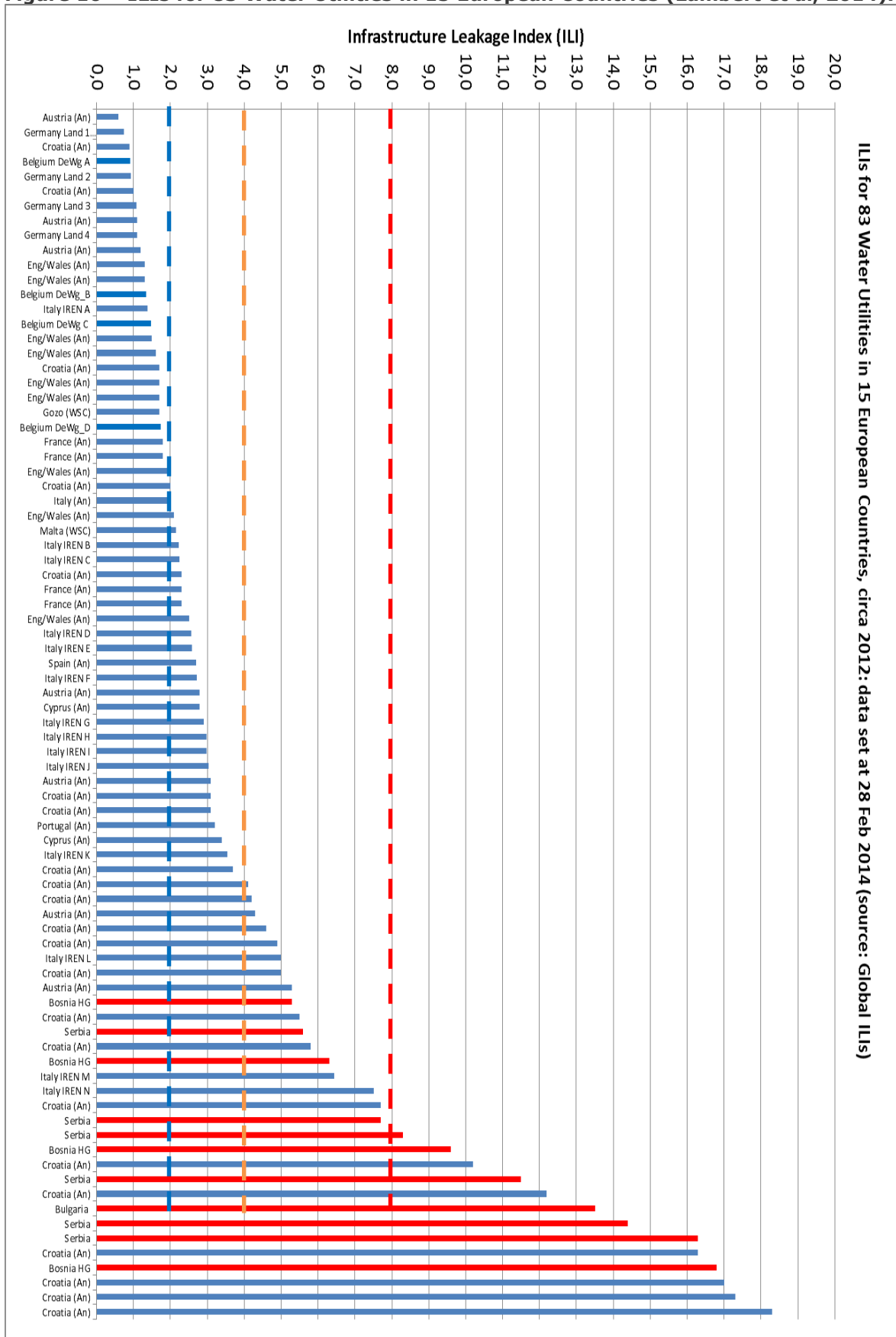### *Step 2: Identify approximate current position*
The Water Balance in Appendix B.1 also calculates the key leakage performance indicators and briefly explains which purpose they should be used for. As explained in Section 6.2, the choice for tracking leakage performance in any individual system or sub-system over time is between leakage volume per service connection, or per km of mains (per billed property is used in the UK). These PIs should be calculated, but not used for comparisons between different systems.

The Infrastructure Leakage Index (ILI) was developed to provide an overview of technical leakage management performance at the current average operating pressure, but always remember that current operating pressure may not have been optimised. ILI, calculated as the Current Annual Real Losses (CARL) divided by the Unavoidable Annual Real Losses (UARL), can be used for overview comparisons of technical leakage performance of sub-systems within a Utility, or between one Utility and others in the same State/Province, the same country, or different countries. ILI data from Europe, Australia, North America and from other countries can be downloaded free of charge – search "Global ILIs".

The bar chart in Figure 10 shows ILIs from 83 Utilities in 15 European countries. The blue columns are from Utilities in European Countries classified by IWA as 'High Income' (more than US$ 1.000 per month). Red columns are from Low Income Countries (Bosnia Herzegovina, Bulgaria, Serbia).

The simplest way to interpret an ILI of 'X' for any system or sub-system is to say that the current annual leakage is 'X' times the calculated technical minimum unavoidable leakage (at the current pressure) for that individual system's key infrastructure parameters (mains length, number of service connections, length of service connections). The range of ILIs in Figure 10 are from around 1 to 17 times UARL. Economic values for ILI at current pressure will vary with PESTLE considerations for local factors, notably the value (€/m^3) assigned to leakage.

Figure 10 – ILIs for 83 Water Utilities in 15 European Countries (Lambert et al, 2014).

Table 5 was developed by WLSG members in 2005 for initial estimates of likely priorities for action based on different ranges of ILI. Investigation of pressure management options is always a clear priority unless initial ILI is very high, when a fundamental peer review of all activities is required. Note that with this approach, ELL assessment is unlikely to be a priority if ILI exceeds 4.

Recommended actions for each ILI description	Low ILI < 2	Moderate 2 < ILI < 4	High 4 < ILI < 8	Very High ILI ≥ 8
Investigate pressure management options	Yes	Yes	Yes	
Investigate speed and quality of repairs	Yes	Yes	Yes	
Check ALC 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 burst frequencies		Yes	Yes	
5-year plan to achieve next lowest band			Yes	Yes
Fundamental peer review of all activities				Yes

Table 5 – Likely priorities for action based on ILI (after R. Liemberger, 2005).

Other recent approaches using combinations of ILI, pressure and burst frequencies are described below:

- Trow (2009) proposed a Pressure Management Index (PMI) where:
    o PMI = Average System Pressure / Minimum Annual Reference Pressure.
    o MARP = Minimum Standard of Service Pressure + 3 metres.

Plotting ILI against PMI for individual systems and zones in the format shown in Figure 11 helps to identify where the most promising initial activity might be:
- Pressure Management (vertical arrow).
- Active Leakage Control (horizontal arrow).
- Combined Pressure Management and Active Leakage Control (sloping arrow).
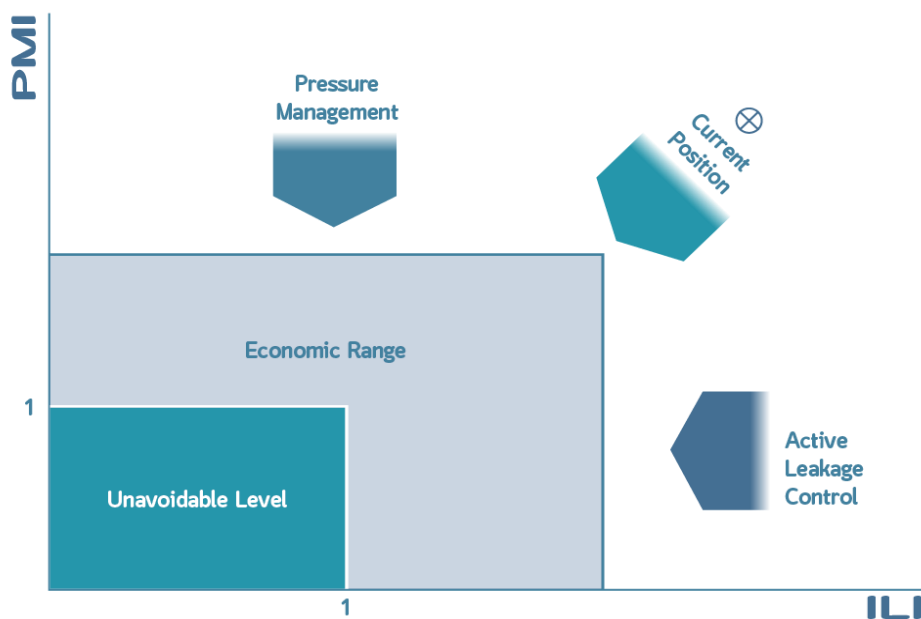
Figure 11 – Identifying the most promising initial activity from ILI & PMI (Trow, 2009).

▪ Duccini (2013) has used combinations of ILI and burst frequency to identify the broad but different combinations of leakage management policies required in Suez Environment Business Units in different countries.
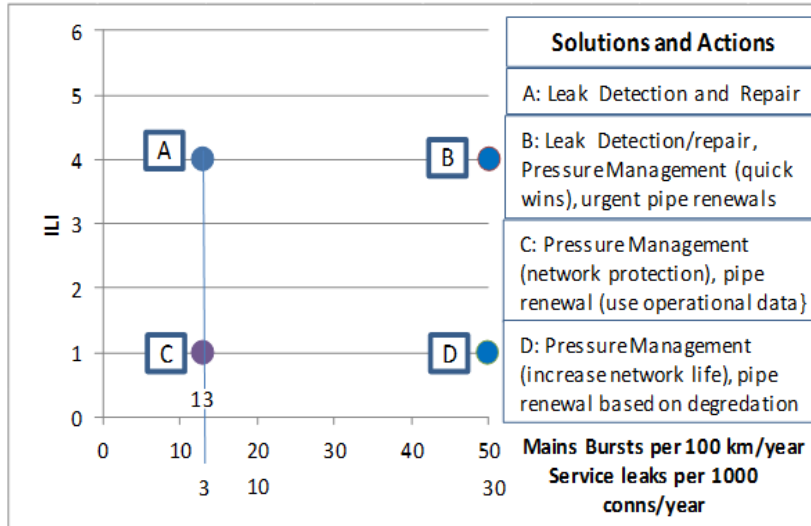
Figure 12 – Identifying leakage management policy from burst frequency & ILI.

▪ Lambert et al (2013) showed how each individual Zone has its own relationships between burst frequency and pressure (one for mains, one for services) and how burst frequency is likely to reduce when maximum pressure in the Zone can be reduced. BFnpd is the component of Burst Frequency that is not pressure-dependent (see Figure 13).
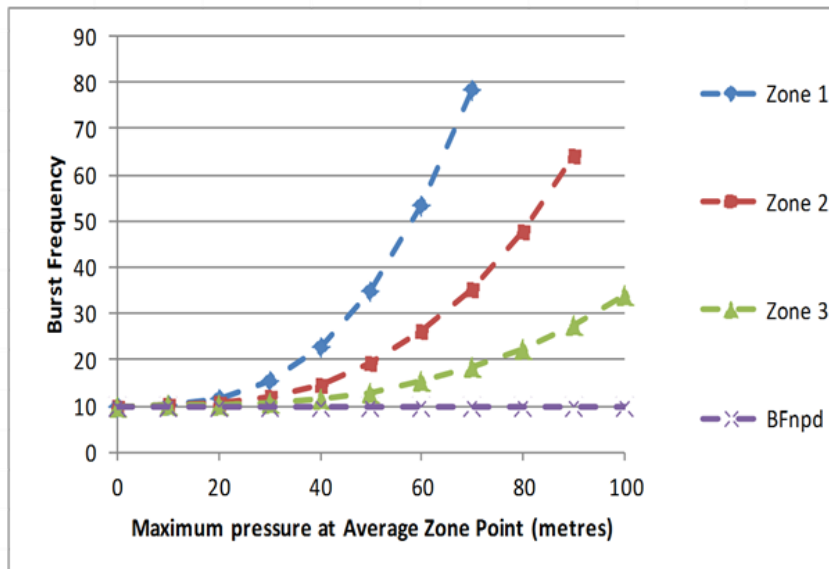
Figure 13 –Identifying pressure management opportunities (Lambert et al, 2013).

6.4   Getting started!

Section 6.3 highlights that developing leakage management strategies and identifying priorities for small systems is usually simpler than for larger systems. Also, although there is some commonality between techniques used when "getting started" in Very Small/Small systems and Medium/Large/Very Large systems (see Table 4), there are some important distinctions:

- Operators with very small or small systems are likely to want to quickly and easily identify which method of leakage reduction most appropriately applies to their system.
- Where systems with more than around 30.000 service connections (considered in this report as Medium/Large/Very Large sized systems) consist of a number of distinct, separate sub-systems, the approach for Very Small/Small systems can be applied.
- When deciding priorities and proposing action plans in integrated or linked Medium/Large/Very Large systems, the 'averaging' effect on the parameters for the whole system can hide opportunities for leakage reduction; for example, average burst frequencies for pressure management for the whole of a large utility (or even a large water resource zone) will not identify some good prospects. Establishing the weighted average pressure for the whole system is also a major task. Therefore the recommended approach is to undertake analyses for numerous small units (DMAs, PMAs, Water Resource Zones), rather than a 'top-down' averaged overview. There are good examples to support this approach in the Case Studies and elsewhere.

  However, for larger systems this analysis takes time and, before gaining approval for investment in leakage reduction, larger utilities will wish to have some high level view of the potential costs and benefits involved, and the appropriate target level of leakage overall taking account of internal and external PESTLE factors.

6.4.1 Getting started in Very Small or Small systems

This contribution is from Allan Lambert based on collaborative work with IWA WLSG members Charalambous, Fantozzi, Koelbl, Kovač, Rizzo and Galea St John since 2005.

Step 1, outlined in Section 6.1, is to assess the annual volume of real losses from a Water Balance and/or Night flows and Night-Day Factors. Step 2, outlined in Section 6.2 and Section 6.3, is an initial broad scale overview of combinations of ILI, pressure, or burst frequencies to roughly identify likely outline strategies. for further cost-effective leakage management. The next steps are shown below:

- Step 3: Analyse data you have, identify data you need and fix priorities.
- Step 4: Make a commitment, get started, and learn as you progress.

Very small and small systems are considered in this report as having less than 3.000 and 30.000 service connections respectively. For these systems, 'Squeezing the Box' (see Section 4.3) is an effective and proven strategy for cost-effective leakage management. Specific activities and projects which have short payback periods, high benefit:cost or high Net Present Value are identified and implemented in appropriate parts of the system; until no further economically viable actions can be identified.

Further analysis of additional performance indicators and context information is usually helpful with this approach. Table 6 uses additional PIs and descriptive class limits as context information which are considered to be reasonably representative of European conditions. Each small system is allocated a description for each line of the table, which includes an example at the right hand side ('This System').

Parameter	Units of measurement	System Size Descriptions					This System	
		Very Small	Small	Medium	Large	Very Large		
Service connections:	**Number**	< 3k	3k to < 30k	30k to < 300	300k to < 3 million	3 mi or more	29k	Small
Service connection Density	**Number per km of mains**	< 20	20 to <30	30 to < 50	50 to < 70	70 or more	52	Large
Average length Main to Meter	**Metres per Connection**	< 4	4 to < 8	8 to < 12	12 to <16	16 or more	8	Medium

Parameter or Context Information	Units of measurement	Performance Indicator and Context Information Descriptions					This System	
		Very Low	Low	Moderate	High	Very High		
Infrastructure Leakage Index ILI		< 1,5	1,5 to < 2,0	2,0 to < 4,0*	4,0* to < 8,0*	8* or more	2,5	Moderate
Average System Pressure	**Metres**	< 30	30 to < 40	40 to < 50	50 to < 60	60 or more	40	Moderate
Mains repairs	**per 100 km/year**	< 7	7 to < 10	10 to < 15	15 to < 20	20 or more	21	Very High
Mains - average time to repair	**Days**	< 1	1 to < 2	2 to < 4	4 to < 8	8 or more	1	Low
Service Connection repairs	**per 1000 services/year**	< 3	3 to < 4	4 to < 7	7 to < 10	10 or more	22	Very High
Services - average time to repair	**Days**	< 2	2 to < 4	4 to < 8	8 to < 16	16 or more	1	Low
Active Leakage Control	**% checked annually**	< 10%	10% to < 30%	30% to < 70%	70% to < 90%	90% or more	50%	Moderate
Rate of Rise of Unreported Leakage	**litres/service conn/day, in a year**	< 20	20 to < 40	40 to < 80	80 to < 160	160 or more	?	?
Assessed Value of leakage	**Euro/m³**	< 0,10*	0,10 to < 0,25*	0,25 to < 0,50*	0,50 to < 1,00*	1,0* or more	0,65	High
Use of Energy	**kWhr/m³**	< 0,25*	0,25 to < 0,50*	0,50 to < 1,0*	1,0 to < 2,0*	2,0* or more	4,5	Very High
* Limits for these parameters are provisional and subject to further checking and/or review								

Table 6 – Additional PIs and context indicators (Lambert et al, 2014).

Context Information Descriptions for Infrastructure Maintenance Frequencies are also under consideration for inclusion in this approach.

Although the data initially available for this type of analysis may be only approximate, the table provides a quick overview and helps to identify existing data deficiencies (in particular, missing key data) and to assess priorities for further data collection for leakage management activities likely to be cost effective. For example, 'This System' has:
- "Moderate" ILI and "Moderate" average pressure (PMAs have already been created).
- "Very High" mains and services burst frequencies (services in particular) which are being offset to some extent by "Low" repair times for both mains and services.
- "Moderate" effort on ALC, but estimates of Rate of Rise of Unreported Leakage are needed to assess if ALC intervention is at an economic frequency.
- "High" assessed value of leakage, and "Very High" Use of Energy (desalination).

A provisional conclusion could be that the ILI of 2,5 could be close to the Low/Moderate boundary but further significant improvements may be difficult to identify unless deteriorated service connections are dealt with. A component analysis model for annual components of leakage is likely to be helpful.

The range of initial activities for individual systems can vary widely, and sometimes an 'elephant in the room' is found – for example, non-repair of service leaks because the utility does not own some or all of the section of pipe from the main to the meter, or because the utility considers that only repairs of reported mains bursts are needed. However, some 'getting started' actions occur consistently in most systems:
- Create a change in approach and understanding about water leakage and losses.
- Knowledge sharing and promotion (presentations, workshops, conferences, journal articles) based on IWA methodology and in local language.
- Documentation of monthly numbers and types of repairs on mains, and on service connections.
- Commencement of systematic pressure measurements including searches for transients, establishment of Average Zone Points and Critical Points.
- Training in benefits of pressure management, and basic predictions of benefits.

- Training in use of a basic Water Balance and PI software in country language. Correct choice of appropriate performance indicators for tracking progress, and for comparing performance.
- Training in leak detection, interpretation of night flow measurements, calculation of Night-Day Factors.
- Motivating and empowering the personnel of the utility to believe that they can achieve sustainable improvements.
- The importance of good quality bulk metering and practical criteria for selecting PMAs and DMAs (including benefits of temporary DMAs or occasional night flow measurements if financial resources are very limited).
- Identifying inefficient pumping operations and improvement opportunities.
- The importance of retrieval of meaningful data from the billing system.
- Projects implementation, testing and results evaluation. Assistance to assure successful outcomes, building experience and confidence among water utility staff.

Further topics can be found in the Serbian & Croatian Case Study Mentoring as well as in Section 6.7.

6.4.2 Getting started in Medium, Large or Very Large systems

For larger systems with more than one water resource or water supply zone which can vary considerably, there should be some method of prioritising zones for investigation and action based on the performance indicators set out in Table 6, and also taking account of the water resource situation and other PESTLE considerations. The Case Study for Scottish Water (see Section 5.2.15 and separate Case Study report) shows that the PIs of their 230 zones are very different, even though they are all based on a very detailed analysis of sustainable economic level of leakage (SELL).
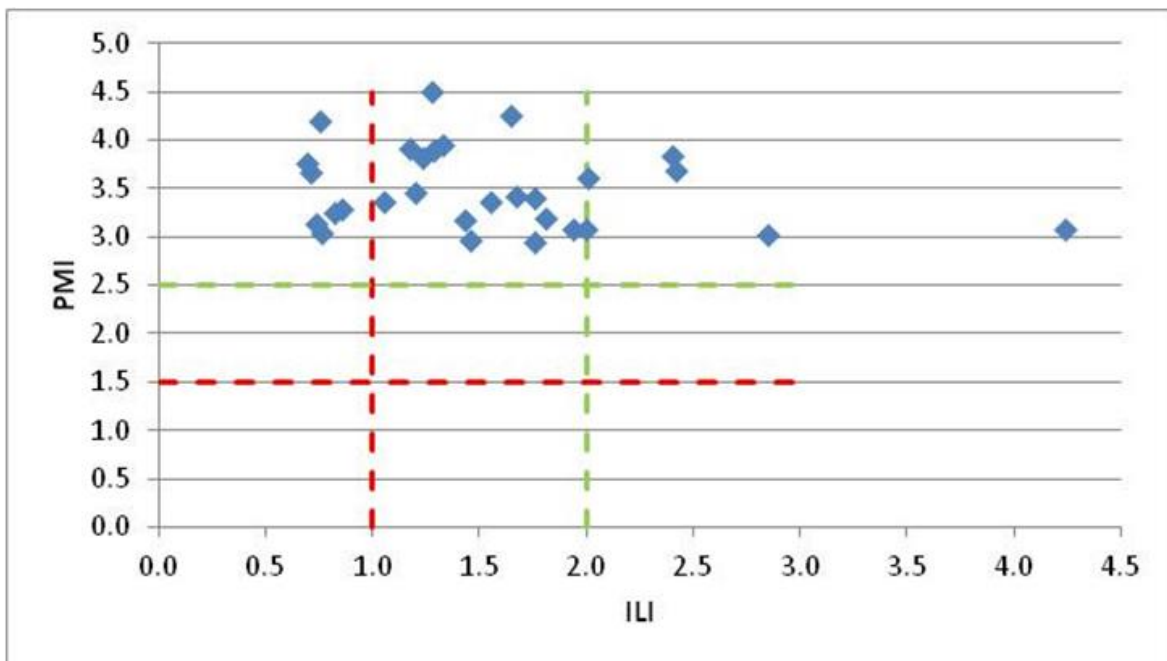

Figure 14 – ILI and PMI for zones in a large UK Water Utility.

Figure 14 shows the ILI and PMI data for one large UK water utility indicating that although some zones have ILI's which are in the moderate and high category (which may be due to factors meaning they are still economic), the pressures in most zones seem as though they could be reduced subject to economic appraisal.

An alternative approach, if the data is available, is to consider the cost of operating each zone or DMA in terms of the following:

- The cost of repairing burst mains and burst services.
- The cost of any current leakage control, reactive and pro-active.
- The cost of the water lost from the network.

The total annual cost will guide the programme to the areas of greatest benefit.

In larger systems, it is also important to estimate the contribution to total leakage from the various sources including trunk mains, service reservoirs, distribution mains, and customer service pipes and to develop a methodology for each separately. A component based modelling approach based on techniques developed over the past 25 years allows the utility to undertake "what if" analyses to determine the most cost effective course of action before significant investment is made.

In order to establish a leakage management programme (Section 6.7) and to seek management support and funding an estimate should be made of the long-term target (Section 6.6) based on currently available data, which can be reviewed in the light of lessons learned as work progresses.

6.5   Preparing the business case for leakage management

Whether the leakage management programme is being driven by internal or external factors, a utility will at some stage have to develop a business case to justify investment and possible organisational change, which depending on the scale could require sign off by the management team and/or board of directors.

The business case for smaller utilities may take the form of cost – benefit analyses of individual pressure management schemes and ALC exercises, which consider the impact of measures that can be implemented relatively quickly and which have an immediate impact. An optimum level of leakage will be reached once all beneficial schemes have been completed. Note that a payback period or an increase in NPV (if extension of remaining useful life of assets is included) might often be simpler and more practical for the business case for pressure management schemes and ALC exercises in very small or small systems.

For larger utilities, a business plan may be required before the programme can be implemented which considers all the drivers for change and strategic targets over the short and long term, the general programme of measures and systems, the means of funding the plan, and the impact on the organisation structure. Individual activities will require appraisal within this overall plan and the utility will have succeeded once all objectives and targets have been met.

6.6   Setting targets in volumetric parameters (Ml/day or Mm^3/year)

This contribution is from Stuart Trow based on the work of the IWA WLSG Target Setting Group since 2007.

The ideal target will effectively be a compromise between a number of competing factors, though it is likely that one or two factors will predominate. The ideal target should be:

- Based on economic principles to ensure efficient operations. The cost of leaking water has to be balanced against the ongoing cost of leakage control and investment in infrastructure. (see Section 3.3 and Appendix A.2).
- Practical to apply in practice; in terms of data and analytical needs.

- Sustainable in the long term and flexible in the short term. Any target should reflect the ability of the organisation to maintain water loss at a reduced level over say a 20 to 30 year time horizon. In the short term, it is likely that new information will become available as water loss reduction projects are carried out. So, it is important that there is some degree of flexibility in the target until specific experience is gained or more data collected.
- Consistent with the water resources plan, and the demand forecast to safeguard future water supplies. There will be more incentive to reduce water loss when there is insufficient 'headroom' between demand and the available supply capacity of the system.
- Understandable, transparent, simple and consistent in order to demonstrate continual improvements to customers, in order to improve public perception.
- Founded on a sound understanding of leakage and water loss mechanics, taking a component based approach.
- Sensitive to political considerations. Any target will have to recognise the influence of non-technical people from outside the industry. Leakage often becomes a political issue, linked to other newsworthy issues such as drought and water shortage.
- To meet regulatory requirements. In some countries government agencies collect data on water loss and use this to set mandatory targets.
- Able to allow for fair technical comparisons between organisations. It is inevitable that an organisation will compare its level of loss with that of other water supply organisations.

It is important that the target also allows for two significant factors, which differ from one area to another:
- Topography; which affects the economics of pressure management.
- Inherited infrastructure condition; which affects the economics of active leakage control and the need for investment in network asset management.
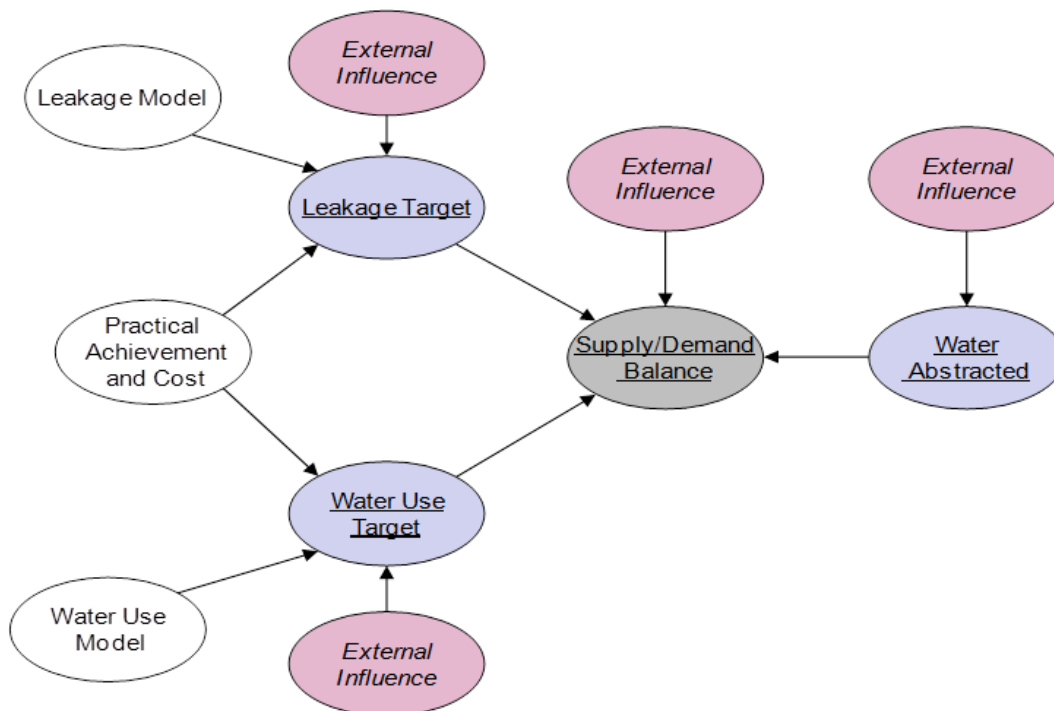

Figure 15 – Factors affecting the leakage target (original source D. Pearson).

The leakage target can be set using a mathematical model, of which several are available, initially using default values and assumptions based on experiences in similar organisations, which can be updated from the practical achievements and costs of leakage management works.

Strategic targets should be set for individual water supply or water resource zones. In some smaller utilities, there may be only one zone, and in larger utilities with an integrated transmission network, there may be relatively few. Most larger utilities will have several zones e.g. Scottish Water (Section 5.2.15) has 230 zones for which a target has been set based on Sustainable economic level of leakage (SELL). Due to the variation between zones in network density (mains length per connection), system pressure, inherited infrastructure condition, cost and value of water, water resource availability and other factors, it is not possible to set targets for leakage using a performance measure such as litres/connection/day or ILI. Although performance measures are useful for understanding the current level of leakage, and the potential for leakage reduction, none of them take all the relevant factors into account. Therefore, targets should be set in an annual volume expressed as a total for the year (see Section 6.2).

The strategic target should be set as a rate for each year of a planning period to take account of the transition from the current level of leakage to the long-term target. The zonal targets can be aggregated to give a target for the utility as a whole, and disaggregated to DMAs for tactical and operational planning of ALC and pressure management (see Figure 16).
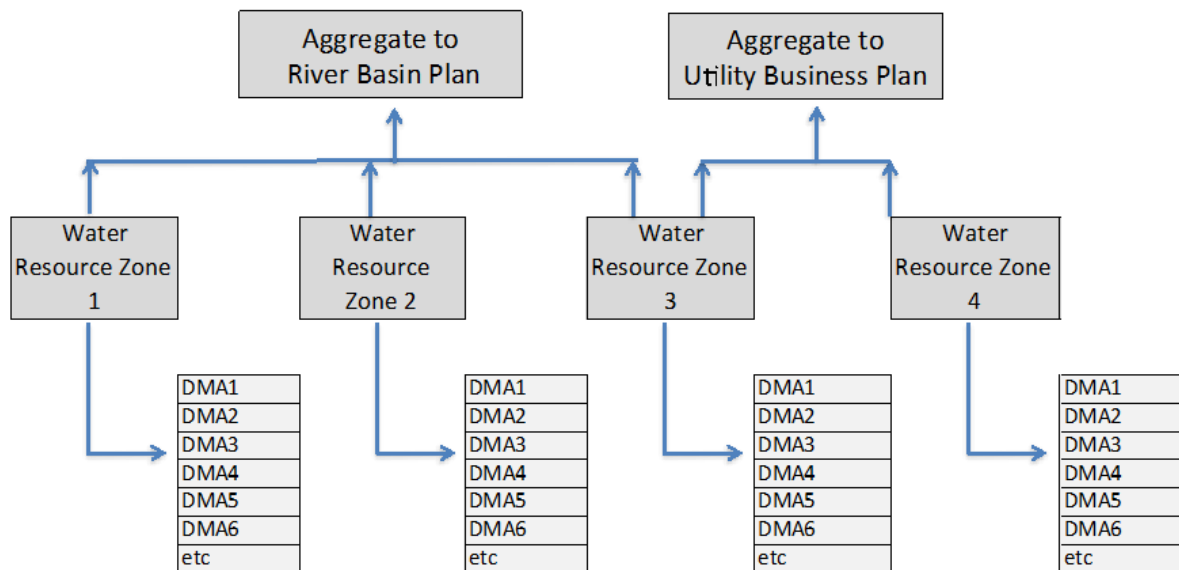
Figure 16 – Aggregating and disaggregating water resource zone targets (source: S. Trow).

6.7   Preparing a leakage management programme

The leakage management programme should be a strategic plan for the utility and/or the river basin. Its complexity will vary depending on the size of the organisation and the external factors such as the system of regulation and the means of financing the programme, but there are some key steps which are common to all situations.

Some issues, such as the need to understand the starting position, the need for good quality data, and the need to train and empower staff are common to utilities of all sizes. Good quality data is fundamental to efficient leakage management and investment in appropriate information technology (IT) systems to collect and collate data is a key requirement. The data will guide the day to day operations, assist with investment decisions, and result in an improved understanding of the long term target based on more utility specific information, and fewer default values and assumptions. Seminars, workshops, and training courses are needed to provide staff with the necessary skills to fulfil their role in the programme.

For larger utilities the leakage management programme will also include the following considerations:

The provisional long-term target: This should cover a period of 25 years and be a long-term vision of what can be achieved and sustained for the utility. It should be based on the best available information, using a model which can be adapted to make use of actual data and assumptions. The plan should be updated at least every 5 years, with interim updates being made if significant new information becomes available (see Figure 17).
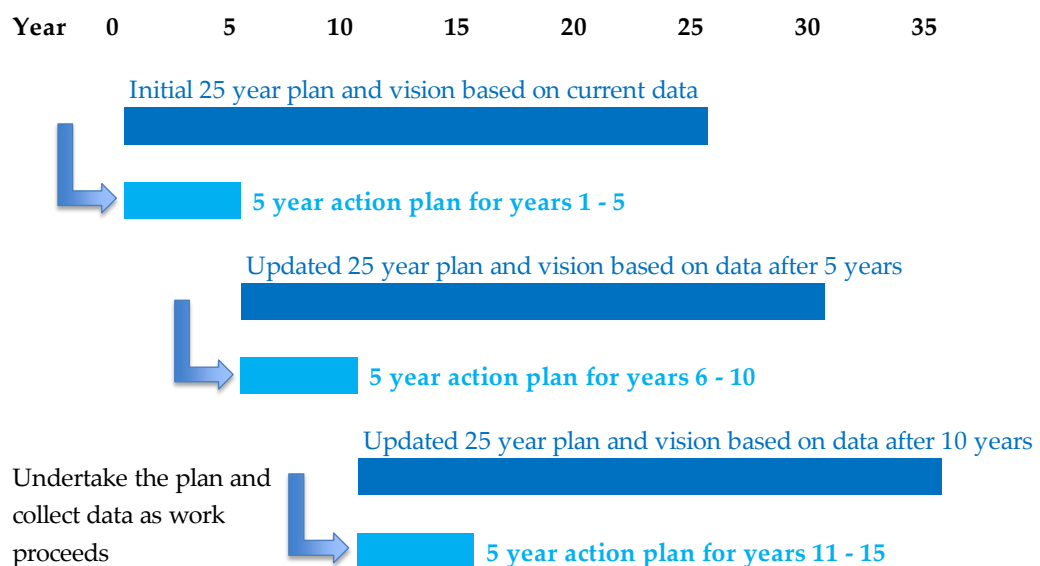
Figure 17 – The planning process (source: S. Trow).

The provisional glide path: This shows the transition from the current level of leakage to the provisional long-term target. This glide path will include annual leakage targets, and the investment required in the various leakage management options (ALC, pressure management, asset renewal, etc.). In larger utilities it is difficult to reduce leakage by more than 15% in any year although in smaller utilities more rapid reductions are possible. At the start of the programme there are likely to be pilot exercises and time required to mobilise resources. Towards the end of the programme, the law of diminishing returns will result in a slowing down of the rate of reduction. So the glide path should follow an "S" curve as shown in Figure 18 (Source: Farley, N. and S. Trow (April 2003) *Losses in Water Distribution Networks*, IWA Publishing).

Figure 18 – The glide path for leakage reduction in large organisations.

Funding needs: Finance is required to "kick start" the programme. This may come from external funding agencies, from charges to customers approved by regulators, or from internal budgets by reallocation from other sources. In all cases, the seed funding should pay back over the period of the programme.

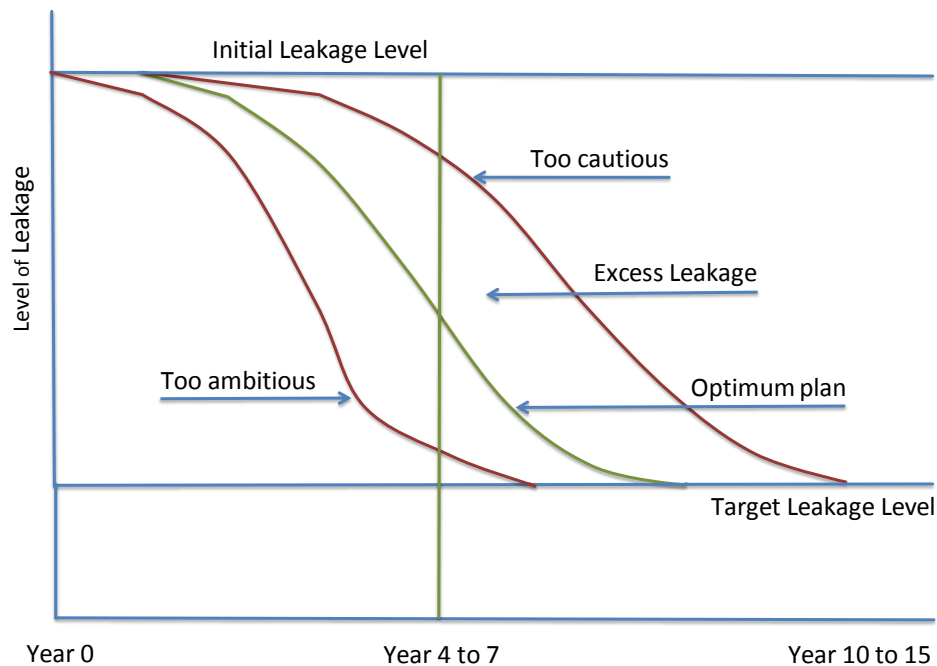*Pilot exercises*: Senior level support for the leakage management programme comes from demonstrating success. By focussing on priority areas and showing what can be achieved, leads to approval of funding for further development of the programme.

Organisational review: An effective leakage management programme relies on having the right people in place doing the right things. To change the focus of a larger organisation in order to reduce leakage, requires a change to the organisation structure itself. The transition to a lower level of leakage requires a project management approach, with the maintenance of lower leakage being embedded into the routine operations of the business.

Standard policies: There should be a consistent approach to ALC, Pressure Management, district metering, telemetry and asset renewal across the utility taking account of available and emerging technologies.

Procurement: An effective programme requires procurement of consultancy support, external field resources to make the transition to lower leakage levels, materials and equipment, etc.

Zonal planning: An integrated approach in which leakage is considered alongside pressure, levels of service to customers, and water quality, to optimise the network, has benefits over one in which leakage and other aspects of water distribution are managed in separate silos.

Annual review: A well-developed programme will include an annual review to report progress against target to regulators, directors, shareholders and other stakeholders.

6.8   Sustaining a leakage management programme

Leakage reduction is sometimes viewed as a project with a start and end, and funded accordingly. However, efficient and effective leakage management is an integral part of the management of the utility generally. Leakage management should be regarded as a long-term activity of the utility which carries on into perpetuity through a cycle of planning, action, and review.

Leakage management operations are a painstaking task requiring day-to-day activities, to support the long-term vision and strategy of the utility. All aspects of leakage management require continual effort if leakage is to be kept under control. Each zone has its own natural rate of rise of leakage which has to be overcome otherwise leakage will return to previous levels undoing the benefits of the leakage reduction programme. Leakage can be viewed as a coiled spring, which once compressed, is always trying to expand. These routine activities can be grouped under the following headings:

Operation and maintenance: Leakage is often regarded as a symptom of poor infrastructure and poor operating policies and procedures. There is an inextricable link between burst rates and leakage, and burst rates are influenced by asset condition, pressure and practices which may introduce pressure transients. So, there is a need for an integrated approach which reduces the risk of new leaks occurring.

Metering: Input meters, district meters, and customer meters all have to maintained or replaced to minimise uncertainty in leakage estimates. Boundaries of DMAs and pressure managed zones have to be monitored and maintained.

Monitoring and reporting: Systems have to be established and maintained to monitor all the components of the annual water balance, and the flows into zones and DMAs (whether real or virtual) to direct ALC staff efficiently. It is recommended that leakage values be reviewed at least quarterly to account for seasonal changes. Data has to be maintained on underground assets through the GIS, on burst records, and on pressures.

Active Leakage Control: ALC is an on-going process of detecting, locating, and repairing leaks, and responding to reports of water rising to the surface. The number of people actively engaged in the process should be linked to the estimate of the optimum target for a zone, using the component model.

Pressure management: Pressure management is more sustainable than ALC, but it does require on-going activity to monitor and maintain pressure reducing valves and pump controls, to maintain valve control systems, and to provide the data to demonstrate optimum performance.

Publicity and communication: Customers and the general public have a part to play in leakage management; whether it is reporting visible leaks, or making their own contribution to water efficiency by minimising plumbing losses. Many utilities have adopted a dedicated telephone number for reporting of leaks, and publicise this and other leakage activities on their vehicles and literature.

In some respect maintaining lower levels of leakage is more difficult than making the initial reduction. Once the focus of attention has moved to other priorities, funding becomes more difficult to obtain and the on-going activity may be viewed as a cost burden which has no return; which of course is not the case.

Appendices

Note that the case study accounts are presented in a separate document and can be read in parallel with this main report.

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Appendix A   PESTLE Consideration

The PESTLE (Political, Economic, Social, Technological, Legal and Environmental) consideration describes a framework of macro-environmental factors used in the environmental scanning component of strategic leakage management.

Appendix A.1: Political and Social Perspective

Contribution of Joaquim Poças Martins.

Water has a very strong political dimension. Public water services are essential to human life and, at least in urban areas, they are monopolistically provided by water utilities. The major decisions regarding these water utilities, namely the establishment of their physical boundaries, the range of water services delivered, the ownership and management models and, often, the setting of tariffs and the appointment of the managers are political.

Some of these decisions should be supported on technical and economic studies and take into consideration their environmental and social impacts. However, there are many intangible factors that require political judgement.

Leakage is probably the most important single indicator of the efficiency and of the quality of the management of water utilities. It depends on the coordinated action of virtually all sectors of the water utilities and it is, above all, a top management issue.

The current levels of leakage are perceived by the public and the media as too high in most water utilities. It could be argued that water systems, properly built and maintained, should not leak; on the other hand, if water would cost, say, ten times more, the systems would certainly leak much less. However, all of the existing systems in operation certainly do leak and many of them leak too much according to any standards, therefore, it is necessary to take practical decisions on leakage targets and these targets have inevitably a political component that goes beyond the well-established and site specific Economic Level of Leakage (ELL). For example, it may be difficult for a politician to explain why his or her water system leaks more than a neighbour one, even if this has more favourable technical conditions, namely regarding age and pressure.

The pipes are installed underground and the leaks that are responsible for most of the water loss are out of sight. The situation would certainly be different if the distribution pipes were visible. The perception of water loss by laymen is usually limited to the obvious visible leaks and it is interesting to notice that people tend to complain less about bursts – if they are repaired fast – than about the small leaks that are visible for a long time on dry pavements and are more likely to be associated to unkemptness and poor management.

It is interesting to notice that the political concern about leakage reduction is not always materialized in decisions that may result in similar economic losses to the paying customers, for example authorizing street washing or the irrigation of public spaces with unbilled potable water. On the other hand, the political decisions of supplying water at no cost or at nearly no cost to certain customers, have an immediate social impact on those who directly benefit from them, but their economic effect on the general tariffs and on the paying customers is also similar to leakage.

It is possible and cost effective to take measures to reduce leakage in most water utilities. These measures, that can only deserve political support, may have a significant social, environmental and economic impact namely through lower tariffs, abstraction of less raw water and reduced investment and operation costs, especially if the reduction of leakage avoids the expansion of the system.

Appendix A.2: Economic Perspective

Contribution of Stuart Trow.

Appendix A.2.1 is a schedule of the costs which should be taken into account when evaluating the savings to be achieved from leakage reduction. Appendix A.2.2 sets out the factors involved in establishing a sustainable economic level of leakage (SELL).

Appendix A.2.1: Savings from leakage reduction

The following is a schedule of the costs associated with leakage which should be taken into account when evaluating the savings to be achieved from leakage reduction to establish an economic level of leakage.

Operating Costs (Opex)

Operating costs savings at source and treatment works, and within the distribution system, include the following:

- Energy: reduction in network flows due to lower leakage levels may result in reduced power costs in treatment and for boosting and pumping the water around the network.
- Chemicals: lower chemical treatment costs to clean, disinfect and condition the water and for secondary treatment and conditioning plants within the distribution network.
- Burst frequency: mains replacement and Pressure Management to reduce leakage will have the additional benefit of a lower future burst frequency, resulting in lower cost of repairs and of dealing with the impact of these events on the network management, customer contact and the risk of discoloured water events.
- Sludge disposal: a reduction in sludge volume requiring disposal, which is not insignificant due to landfill taxes.
- Demand-related charges: in some cases business rates and government taxes are related to the output of individual treatment works, or to the total volume of water supplied.
- Abstraction charges: in some places utilities, and bulk supply authorities, pay for the water they abstract from the environment on a volumetric basis.
- Water purchase costs: where the utility buys water from a bulk supply author or a neighbouring utility these costs are demand related.

Capital costs (Capex)

Capital cost reductions can occur in the following areas:

- Source and treatment works capacity: reductions in leakage may, subject to the forecast supply-demand balance, provide capital cost benefits by deferring works required to meet increasing demand. Significant reductions in leakage may allow some older works to be taken out of service and for upgrades to be reduced.
- Network capacity: it may be possible to make savings due to reduced network flows by allowing for downsizing of mains (by slip lining or pipe bursting) and abandoning some mains completely, if leakage reduction is coordinated with water mains rehabilitation planning.
- Service reservoir storage and pumping capacity: reductions in service reservoir storage capacity and in boosting and pumping plant capacity may be possible in a system with lower leakage levels.

Appendix A.2.2: Establishing a Sustainable Economic Level of Leakage (SELL)

There are several economic levels of leakage (ELL's) which have to be estimated in order to establish a sustainable economic level of leakage (SELL):

Short run SR-ELL

This is the ELL including costs and benefits which are internal to the Utility, and which accepts that the current infrastructure is fixed. The SR-ELL is the optimum level of Active Leakage Control (ALC) with an optimum investment in Pressure Management which can be achieved in a short period of time (less than 5 years).

Long run LR-ELL

This is the ELL including internal costs and benefits only which can be achieved over a longer planning horizon (25 years is typical) allowing for investment in further Pressure Management, asset renewal, district metering and telemetry, and measures to control customer side losses. It also allows for extensions to the network and deterioration of the mains and services. The LR-ELL will also categorise zones into "constrained" (or "deficit") or "unconstrained" depending on whether there is a forecast supply-demand headroom deficit. In constrained zones, further leakage reduction options must be balanced against other water efficiency measures to reduce consumption, and supply side measures to make more water available for use.

Sustainable ELL (SELL)

This is the LR-ELL with an additional analysis to take account of the external social and environmental costs of leakage. These externalities usually lead to the value of water being higher than the internal marginal cost resulting in the SELL being lower than the LR-ELL. However, if the water has a low environmental value, and the social cost of traffic disruption etc. from additional repair and replacement work is high, then the SELL may be higher than the LR-ELL.

The table below summarises the difference between SR-ELL, LR-ELL and SELL. The interventions may involve operating costs (Opex) only such as Active Leakage Control (ALC) or they may include capital cost schemes (Capex) such as district metering.

		Sort Run ELL	Long Run ELL	Sustainable ELL
Unconstrained	Interventions	Opex	Opex & Capex	Opex & Capex
	Driver	Economics	Economics	Economics
	Marginal Value of Water	Marginal cost of water production and distribution	Marginal cost of water production and distribution	Marginal cost of water production and distribution + Externalities
Constrained	Interventions	Opex	Opex & Capex	Opex & Capex
	Driver	Headroom	Headroom	Headroom
	Marginal Value of Water	>MCW <= Marginal cost of next source	>MCW <= Marginal cost of next source	>MCW <= Marginal cost of next source + Externalities

Table 7 – Difference between SR-ELL, LR-ELL and SELL.

It is important to recognise that once long term capital investments have been made e.g. in district metering and asset renewal, the situation returns to a short run ELL analysis, with ALC and pressure management being the key measures.

Experience shows that there are six key factors which determine short run SR-ELL:

Background leakage: In any network there is a minimum achievable level of leakage. This can be assessed by estimation using formulas for Unavoidable Background Leakage (UBL) or UARL, and/or by analysing the minimum achieved levels of leakage in DMAs, zones or control areas. The level of leakage used as the asymptote for the total cost curve is often referred to as the Policy Minimum level of leakage i.e. the minimum level of leakage which can be achieved with current policies and unlimited resources on ALC. The current Policy Minimum should also include the leakage from reported bursts and other known leaks which are awaiting repair.

Unit or marginal cost of water (MCW): A higher unit cost of water will lead to a lower ELL and vice versa. Where water is cheap and plentiful the ELL will tend to be high; comparisons of leakage performance without including an economic element can therefore be misleading. However, adding to the unit cost of water (by means of taxes or other measures) may not impact on ELL as significantly as may be thought, due to the greater impact of other factors. There is, though, a psychological effect of assigning a high value to the water which encourages water efficiency generally.

Unit cost of Active Leakage control (MCoALC): The ALC cost curve will depend on the efficiency of the operations, and the method of leakage detection and location, which in turn will be influenced by the operating environment and the level of leakage in excess of the background level. Some ELL modelling methods assume a simple inverse relationship between ALC cost and the level of leakage above the policy minimum. Others determine a curve shape from historic costs.

The natural rate of rise of unreported leakage (NRR): The NRR is a measure of the condition of the infrastructure and its propensity to burst. It is the amount by which leakage would rise in a year if all ALC operations were suspended. NRR can be estimated from trends in leakage in DMAs or it can be modelled using the current unreported burst rate with an estimate of burst flow rates and run times.

Average operating pressure: Pressure will influence the level of background leakage, the flow rate from existing leaks and bursts and also the NRR. Therefore, the economic level of ALC should be established at the current operating pressure and then economic opportunities for further Pressure Management should be explored.

Current level of leakage: The gap between current level of leakage and the economic level will affect the transition costs, and therefore it has an impact on the ELL.

Whether considering the long run or short run scenario, transition costs have to be taken into account to change from the current steady state level of losses to any new steady state such as the forecast ELL. By including transition costs, the resultant ELL will tend to be higher than if they are not included. Transition costs include dealing with a backlog of repairs when moving from one steady state to another, and costs associated with organisation change.

Ideally, each of the above factors should be analysed for the Utility using data specific to that utility. However, gaps in data can be filled with assumptions based on experience in other similar utilities to provide an initial estimate of ELL which can be improved by collecting data from initial leakage reduction projects.

It is important to recognise that whilst the ELL is often established as a single point on the total cost curve, there is always an economic range to the level of leakage. Operating at the low end of the economic range may give rise to other less tangible benefits which were not included in the ELL assessment. Therefore, one option is to test the economics of various scenarios, and use an iterative approach rather than rely on a single ELL model.

Reducing leakage costs money. Unlike supply augmentation, there is less scope for economies of scale for leakage reduction. In fact the reverse tends to be true. All leakage management measures, if applied correctly, will follow a law of diminishing returns. As more money is spent on any initiative, the return in terms of units of water saved for each unit of money spent will be less. Economic appraisal should consider the optimum level of each leakage control activity, and its impact on each component element of the leakage. For the long run LR-ELL, separate assessments are required for Active Leakage Control, Pressure Management, and asset replacement, though the interaction between the activities should be taken into account.

There are a number of modelling packages available to undertake ELL studies, or the Utility may opt to develop its own model making best use of the data which it has available. It is known that different modelling methods and assumptions will produce different ELL estimates for the same system with the same source data. Therefore, the initial ELL estimate should be treated with some caution, and should only be accepted once more specific data becomes available on actual costs and benefits. Where possible, more than one method should be used to assess the ELL, and it should be subject to challenge by industry experts.

The economic level of leakage should be established for each water supply or water resource zone in the Utility as part of a strategic planning process for managing water resources. The ELLs for each supply zone can be aggregated to give an ELL for the organisation as a whole, and they can be disaggregated to give guidelines or targets for each DMA or sub-zone.

There are several ways of establishing an economic position which fall into two broad categories:
- To evaluate individual leakage reduction options aimed at making a step change in leakage, and to do the most cost effective first; then re-assess after each project has been completed. Once there are no further cost effective measures, the economic level of leakage can then be maintained. The disadvantage of this approach is that there is no target to aim for, and no vision of what may be possible in terms of leakage levels, operating costs and investment needs.
- To estimate a short and long run ELL using a component based modelling tool. This will provide a 5 to 25 year plan of action. The disadvantage of this approach is that it relies on data and assumptions which may not be available to the Utility. Using data from other utilities introduces an element of uncertainty.

In practice, a combination of these two approaches should be adopted. An initial leakage model and plan can be used to establish some high level goals based on the best available data. Pilot exercises will generate data on costs and benefits, which can be used to refine the model as work progresses.

The recommended approach to achieving an economic level of leakage is as follows:

1. Reducing the run time between from being aware of the existence of a leak and making an effective repair, to an economic level, is a relatively quick initiative which applies in all systems. Allowing known leaks to run will add to the annual volume of real losses. The repair cost will tend to be the same for most ALC policies, and so the challenge is one of processes, systems, communication and incentives. However, once the repair time is reduced below a certain threshold, the unit repair cost will tend to rise because of standby, call-out and overtime payments to staff, or supplementary payments to contractors to make additional repair teams available.

2. When leakage reduction is a primary driver for mains replacement, targeting studies should be carried out to determine which areas, and which mains within those areas, have the highest burst frequency (number per kilometre per year), and which have the highest levels of background leakage. Mains and service connection bursts should be considered separately. Reducing leakage through mains and service renewal is likely to be part of a long-term strategy, which is unlikely to have great impact in the short term.

   Asset replacement is an expensive option for reducing leakage compared to active leakage control (ALC) and pressure management (PM). However, in some systems, the condition of the underground assets is so poor that ALC and PM are not sustainable solutions. A well-managed water loss programme should always include an allowance for selectively replacing mains and/or service pipes specifically to reduce leakage and the cost of ALC, when further pressure management to remedy the situation is not a feasible option.

3. The balance between the resources employed on Active Leakage Control, and the investment in Pressure Management can then be optimised. These are the two primary short to medium term measures which can be controlled by the Utility. This balance will vary from one system to another, and can also vary over time. Component based models can be used to assess the interaction between these two measures and to undertake cost-benefit analyses.

4. The LR-ELL can be determined using a least cost plan approach in which leakage reduction options beyond the SR-ELL are incorporated into the water resource management plan alongside other demand side and supply side options to reduce any forecast headroom deficit.

5. The SELL can be assessed by considering the impact of less tangible externalities on the value of water and therefore the LR-ELL estimate. These externalities include social, environmental, and carbon costs and benefits.

Further guidance on sustainable economic level of leakage is available from the following recent UK regulation reports:

- Environment Agency, Ofwat, Defra: *Review of the calculation of sustainable economic level of leakage and its integration with water resource management planning*. Report by Strategic Management Consultants, October 2012: http://www.ofwat.gov.uk/sustainability/waterresources/leakage/rpt_com121012smcsell.pdf
- HM Government (Defra): *The Water White Paper: Water for Life*. December 2011, CMD8230: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/228861/8230.pdf
- Environment Agency: *Benefits Assessment Guidance User Guide*, January 2012.
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Appendix A.3: Technological Perspective

Contribution of Allan Lambert.

Sustainable management of low leakage levels requires a clear understanding of the complex interplay between many different parameters. As systems age, new leaks and bursts which occur must be detected and repaired. It's like trying to walk down a rising escalator – if you don't continue to find and repair leaks at least as quickly as they occur, you will end up with higher leakage than you started; so leakage management is not a 'one-off' exercise, it must go on forever.

The concept of 'Component Analysis' of leakage, developed in 1994, is a rational and practical approach to analyse different categories of leaks and the parameters which influence leak flow rates and volumes of leakage:

- Reported leaks usually have high flow rates, but short duration if repaired quickly.
- Unreported leaks have lower flow rates, duration depends on active leakage control.
- Background leakage consists of small undetectable hidden leaks that run continuously.

Pressure also influences the frequency and flow rates of leaks, and controlling and minimising the average run time of leaks is a fundamental aspect of reducing annual volume of leakage. The figure below shows the options for managing each type of leak.
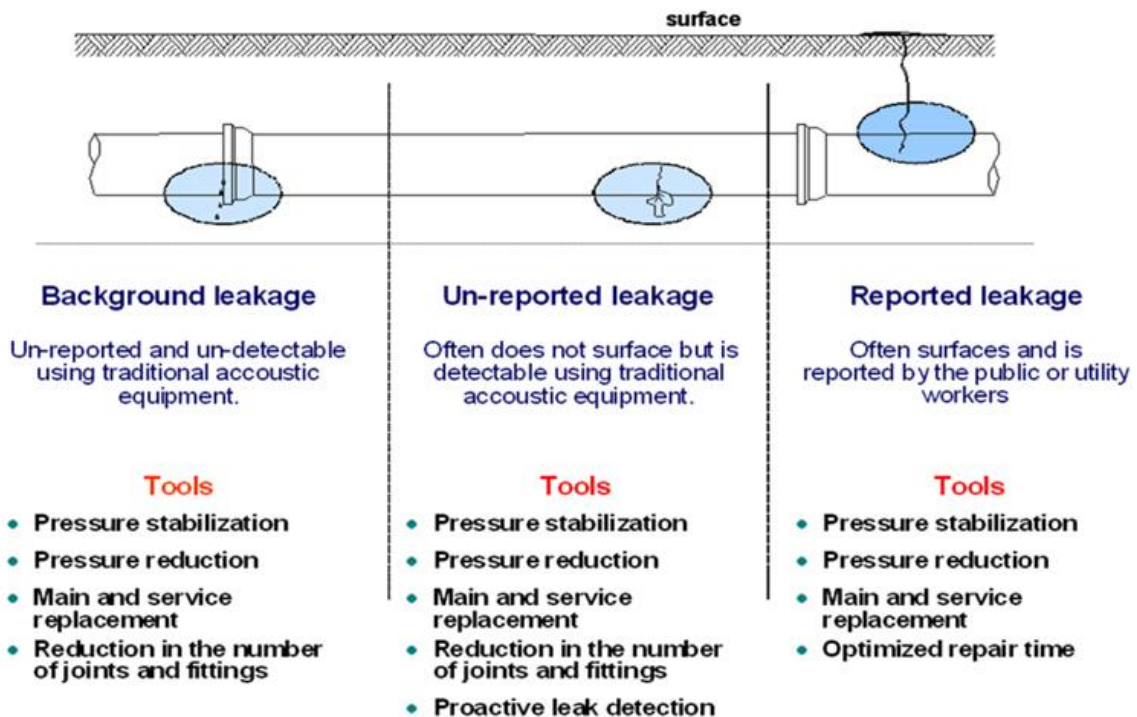
Figure 19 – Options for managing each type of leak (Source: J. Tardelli).

Different parts of the infrastructure (mains, utility and private service connections up to the customer meter) each form distinct component groups of Reported, Unreported and background leakage with their own characteristic frequency, average flow rate and run time; the methods of controlling leakage impact on one or more of these variables. Current Annual Real losses volume is the sum of leak numbers x average flow rate x average run time for each of these component groups.

Average run time (consisting of Awareness, Location and Repair times) is dictated by Utility Policies, including frequency of Active Leakage Control. Speed and quality of repair of all reported and unreported leaks, once located, is highly influential, but reducing average run time of detectable leaks is the key objective.

This type of 'Component Analysis' shows that in most well-managed systems, considerably more than half the annual real losses volume is associated with undetectable small 'background' leaks and long running small leaks on service connections , rather than from reported mains bursts with high flow rates and short run times.

Unavoidable Annual Real Losses (UARL), or 'How Low Could You Go', is an assessment by the 1st WLTF (1999), using Component Analysis, of the lowest technically achievable Real Losses annual volume for well-maintained, well-managed systems in good condition at current average pressure. System-specific values of UARL can be predicted using a single basic equation with a range of different units and timescales. The UARL equation used for calculations in m^3/year in this report is:

$$\text{UARL (m}^3\text{/year)} = (6{,}57 \times Lm + 0{,}256 \times Nc + 9{,}13 \times Lt) \times Pc$$

Where:
- Lm = mains length (km).
- Nc = number of underground service connections.
- Lt = total length (km) of underground service connections (main to meter).
- Pc = current average operating pressure (metres).

The UARL that can be achieved in small isolated systems (less than 3.000 service connections) is lower than the figure derived from the above equation, for the reasons explained in the Austrian Case Study Small Utilities. Some larger systems with particularly favourable circumstances - new infrastructure, low % of unreported leaks, lower pressures (less than 40 metres) and pipe materials with leak flow rates sensitive to average pressure - can also beat the UARL formula. However, for most distribution systems, the UARL formula will represent be a robust estimate of 'how low could you go' at the current average system pressure.

Application of this basic equation to very small isolated systems (with less than 3.000 service connections), and systems with pressures significantly below 40 metres, can result in overestimates of UARL, for reasons explained in the Austrian Case Study Small Utilities.

Values of UARL expressed 'per km of mains' or 'per service connection' vary widely for systems with different characteristics (Nc/Lm, Lt, Pc). So although these units are ideal for tracking leakage management progress in individual systems, they are not suitable for comparisons of performance between different systems.

The Infrastructure Leakage Index ILI is the ratio of Current Annual Real Losses (CARL) divided by the UARL for each particular system. This metric performance assessment indicator was developed by the 1st WLTF (1999) for 'level playing field' national and international grading of leakage management performance at current (but not necessarily optimal) pressure. Recent ILIs for 83 European Water Utilities in 15 countries vary from around 1,0 to 17 times UARL (see Figure 10), indicating many opportunities for improved leakage management. 'Snapshot' ILI can also be assessed from Night Flow measurements.

International Leakage Performance Categories for ILIs with recommended broad priority actions were developed by WLTF members in 2005 at the request of World Bank Institute, and are currently used in several European countries and internationally. Assessment of appropriate actions for each individual system can then begin using the approaches described in Sections 6.3 and 6.4.1.

Low and Middle Income Countries ILI range	High Income Countries ILI range	Leakage Performance Category LPC	Calculated ILI for this System	General description of Leakage Performance(LPC) Categories (LPC limits for Low and Middle Income Countries are double those for High Income Countries)
Less than 3	< 1.5	A1	1.3	Further loss reduction may be uneconomic unless there are shortages; careful analysis needed to identify cost-effective improvement
3 to < 4	1.5 to < 2	A2		
4 to < 6	2 to < 3	B1		Potential for marked improvements; consider pressure management, better active leakage control practices, and better network maintenance
6 to < 8	3 to < 4	B2		
8 to < 12	4 to < 6	C1		Poor leakage record; tolerable only if water is plentiful and cheap; even then, analyze level and nature of leakage and intensify leakage reduction efforts
12 to < 16	6 to < 8	C2		
16 to < 24	8 to <12	D1		Very inefficient use of resources; leakage reduction programs imperative and high priority
24 or more	12 or more	D2		

Table 8 – International Leakage Performance Categories based on ILI.

Appendix B.2 explains, with clear examples, why leakage as a % of System Input Volume is not appropriate for performance comparisons, setting targets or tracking leakage performance.

Investment in good quality infrastructure in some European countries has led to low leak frequencies and low leakage at 40 to 50 metres average pressure, and even lower leakage at 30 metres in relatively flat areas. However, most European Utilities do not possess good quality infrastructure, and many have accumulated unrepaired leaks from previous years. In such cases if existing leaks are simply repaired, or mains (but not services) are replaced, pressure rises, and more leaks break out, with no net benefit; so some pressure management (reduction of excess pressure, control of pressure transients) is usually a high priority of an effective leakage reduction program. The appropriate sequences and combinations of remedial actions are therefore an extremely important factor when introducing leakage management programs to recover a deteriorated situation.

Reduction of excess pressure reduces background leakage (which is very sensitive to pressure), the frequency and flow rates of leaks, and the rate of rise of unreported leakage and the economic frequency of active leakage control interventions. Rate of rise of unreported leakage varies widely between systems, and also between sub-systems within the same system, depending upon type of ground and underlying geology – in some cases almost all leaks surface naturally, in other cases only a small proportion do so. Economic intervention policies for active leakage control are also influenced by the value of leakage, so economic intervention policies (and consequent losses from unreported leaks) vary widely from one sub-system to another.

However, whatever the type of leak – background, reported or unreported – the foundations of effective leakage management are the management of excess pressure and pressure transients, and limiting the run time of all detectable leaks, whether reported or unreported. The WLTF and WLSG have developed practical methods using FAVAD (Fixed and Variable Area Discharges) concepts to predict many of these benefits, for economic justification of pressure management proposals. For example, a 1% reduction in average pressure reduces leak flow rates by 0,5% to 1,5% (depends on pipe material and type of leak), and burst frequencies by zero to 3%, depending upon initial burst frequency.

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Appendix A.4: Environmental Perspective

Contribution of Dean Russell.

Water is a precious and finite resource that supports the natural environment. It is one of society's most basic needs and vital for health. Without it nothing can live. All economic sectors need water; agriculture, industry and most forms of energy production are not possible without it. Navigation and a whole range of recreational activities also depend on water.

From an ecological perspective, each river basin within individual member states, due to its topography, geology, soils and land cover, is unique and will experience variations in flow which are essential to its health. These currents distribute nutrients and food down a river system, detritus for invertebrates and drifting insects for fish and birds and aid species dispersal. While all aspects of the flow regime are important to the health of river ecosystems, low flows represent a particular risk to migratory fish that require sufficient flow to trigger upstream movement towards spawning grounds.

Water availability is already under pressure across Europe, with one fifth of Europe's population living in countries where the total water abstraction puts pressure on water resources. Where this is the case there is a risk of harm to aquatic ecosystems and wetlands, as well as to the wildlife that lives in and around them. Water scarcity and drought are increasingly frequent and widespread phenomena in the European Union.

Fifteen per cent of water abstracted from rivers and groundwater in Europe is for households and industry connected to public water supply. Water is lost through leaks such as those from distribution pipes, customer supply pipes and connections. Losses of water in the network reach high multiples of the UARL in many utilities and countries. Water lost to leaking pipes, treatment works and service reservoirs is a waste of Europe's limited resources. It is water that could be left in the environment or made available for people and industry.

Climate change, population increases and a growing demand for water will mean that, in the future, there will be substantial further pressure on supplies and significant risks of less water being available. It will be more important than ever for member states to manage leakage levels and ensure the sustainable use of water resources as set out in the Water Framework Directive. In respect of longer term risks to the environment and the availability of water resources for water supplies, leakage reduction can be considered a 'no regrets' option compared to hard engineered solutions such as reservoirs.

Historically and currently, leakage reduction is typically capped at the point at which the marginal cost of additional leakage management activity to save a further unit of water equals the cost avoided by not producing that unit from other means. More recently, attempts have been made to incorporate assessment of environmental costs and benefits when building the case for economic reductions in leakage. However there remains concern that assessments fall short of the holistic view necessary to truly understand the economics of leakage. Non-monetary considerations are also pertinent, and any assessment of leakage management needs to take a long term view to ensure the best overall decision.

Reducing leakage will reduce the need for abstraction from rivers and groundwater, meaning more water available in the environment to protect flows and enhance aquatic ecosystems. Water lost to leaking pipes also represents a waste of electricity for abstraction, treatment and pumping across the distribution network, contributing to greenhouse gas emissions. The treatment process also uses chemicals and produces by-products such as ozone.

Evidence suggests that leaking water by water suppliers and distributors has a negative impact on customers' own water conservation: customers are far less likely to conserve water if their provider maintains high leakage levels. Society also places a value of having water in the environment for aesthetic purposes, to sustain and improve the aquatic ecosystem and for recreational activities including walking, angling and boating.

Where there is a quantifiable environmental benefit (including reduction of future risk) from lower levels of abstraction, the inclusion of a holistic, long term view of environmental costs and benefits is likely to result in significantly lower leakage being regarded as economic. Consideration of less tangible (less quantifiable or non-monetary) factors will only add to this case.

Appendix B   Tools, techniques and methodologies

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Appendix B.1: Simplified IWA Water Balance

DATA COLLECTION WORKSHEET FOR CASE STUDIES, BEST PRACTICE ON LEAKAGE REDUCTION					Version 2e	23-09-2014	by ILMSS Ltd
THIS WORKSHEET IS USED TO CALCULATE NON-REVENUE WATER AND ASSESS COMPONENTS NON-REVENUE WATER							
Colour coding:	**Data entry**	**Essential data entry**	**Default Values**	**Calculated Values**	**Data from another Worksheet**		
SIMPLIFIED IWA WATER BALANCE CALCULATIONS		**Anytown**		**Whole System**	# Conns =		**1.100.000**
Period of Water Balance	from **01-01-2011**	to	**31-12-2011**	**365**	days	Mm³	1000 m³/day	lit/conn/day

		Mm³	1000 m³/day	lit/conn/day
	POTABLE WATER VOLUME INPUT FROM UTILITY TREATMENT WORKS	330,000	904,1	822
Enter data for your system in yellow cells. Check the default %s in the purple cells, and change them if you have better information which will improve the reliability of the calculation. Add comments in the Comments Box below .	Potable Water Imported to this system	35,000	95,9	87
	SYSTEM INPUT VOLUME (Potable Water)	365,000	1000,0	909
	Potable Water Exported from this system	60,000	164,4	149
	Potable WATER SUPPLIED TO THIS SYSTEM	305,000	835,6	760
	Billed Metered Consumption	260,000	712,3	648
	Billed Unmetered Consumption	3,000	8,2	7
	NON-REVENUE WATER NRW	42,000	115,1	105
	Unbilled Authorised Consumption **0,50%** of Billed Metered Consumption	1,300	3,6	3
	WATER LOSSES	40,700	111,5	101
	Unauthorised Consumption **0,20%** of Billed Metered Consumption	0,520	1,4	1
	Customer Metering Inaccuracies **2,00%** of Billed Metered Consumption	5,200	14,2	13
	APPARENT LOSSES	5,720	15,7	14
	CURRENT ANNUAL REAL LOSSES CARL	34,980	95,8	87

Information entered by	**A.N.Other**	**23-09-2014**	Contact	**anyone@anywhere.com**

Comments:

Guideline maximum default %s for assessed components of Non-Revenue Water are shown below:			
If higher figures are claimed they should have been validated by Utility Specific data			
	Unbilled Authorised Consumption	**0,50%**	of Billed Metered Consumption	excluding Water Exported
	Unauthorised Consumption	**0,20%**	of Billed Metered Consumption	
Customer Metering Inaccuracies	Direct pressure systems	**2,00%**	of Billed Metered Consumption	
	Roof storage tanks	**5,00%**	of Billed Metered Consumption	
	Customer Metering Inaccuracies are positive for under-recording, negative for over-recording.			

		Potable Water Exported WE					Anytown
		60,00 Mm3					**Whole System**
Potable Water Produced from Utility Treatment Works	System Input Volume SIV (Potable Water)	Potable Water Supplied WS	Billed Authorised Consumption (excluding Water Exported)				**01-01-2011**
			Metered				**to**
			260,00 Mm3				**31-12-2011**
			Unmetered				
330,00 Mm3	**365,00** Mm3	**305,00** Mm3	**3,00** Mm3				
Potable Water Imported to this System				Unbilled Authorised Consumption UAC **1,30** Mm3			
			Non-Revenue Water NRW			Apparent Losses AL **5,72** Mm3	
			42,00 Mm3	Water Losses WL			
				40,70 Mm3		Real Losses RL	
35,00 Mm3						**34,98** Mm3	

Infrastructure Parameter				Performance Indicators for Leakage					
Distribution mains length	**27000,0**	km	**1296**	m³/km/year	**3,5**	m³/km/day	**0,15**	m³/km/hour	
Trunk and Distribution mains length	**30000,0**	km	**1166**	m³/km/year	**3,2**	m³/km/day	**0,13**	m³/km/hour	
Service Connections (to 1st meter)	1100000	Number	**31,8**	m³/conn/yr	**87**	l/conn/day	'per hour' is influenced by Night-Day Factor NDF		
Density of Connections	**36,7**	No/km	↑ Use PIs above this row to track leakage in individual systems ↑						
			↓ Use PIs below this row to compare leakage between systems ↓						
Length of underground Service	**4,0**	m/conn	Current Annual Real Losses CARL				**34,98**	Mm³/year	
Connections, Main to first meter	4400,0	km	Unavoidable Annual Real Losses UARL				**21,79**	Mm³/year	
Average Operating Pressure	**42,0**	metres	Infrastructure Leakage Index ILI =				**1,6**		
Annual Repair Frequencies	Mains (UARL)	**13,0**	/100 km	**18,0**	per 100 km	which is	**1,4**	x UARL frequency @ 50m	
	Connections (UARL)	**3,0**	/k conns	**6,0**	per 1000 conns	which is	**2,0**		

Comments:	↓ PIs based on %s are for comparison only, not recommended ↓	
	Leakage as % of System Input Volume SIV	9,6%
	Leakage as % of Water Supplied, excluding exports	11,5%

Appendix B.2: Unintended Consequences of using % SIV as a leakage PI

Contribution of Allan Lambert (Water Loss Research and Analysis Ltd and ILMSS Ltd).

Since the early 1980s, many National Technical Standards Organisations, Regulators, IWA and others striving to promote the use of meaningful leakage performance indicators, have recommended against using % of System Input Volume for setting targets, tracking progress and comparing leakage between systems. Yet % of SIV is still widely used as the traditional choice by many funding agencies, regulators, media, politicians and water 'experts'. The more often that people use %s, the more others think it is meaningful, because it is 'simple' and 'easily understood', while other better options are 'too technical' or 'too complex'.

Two thousand years ago, Sextus Julius Frontinius was the Water Commissioner for Rome. His translated memoirs show that he could never consistently quantify leakage and theft for the aqueducts, because Romans used cross-sectional areas of flow for their water balance calculations (not volume per unit time, which is the correct unit). Think for a moment or two about Julius's 13 years of wasted effort, and Mencken's aphorism "*For every complex problem there is a solution that is simple, neat and wrong*." This Appendix outlines why % of SIV is unsuitable as a leakage performance indicator.

Which % of SIV did you mean? Which % of SIV do you want?

In 2000, the IWA Task Forces on Water Loss and Performance Measures helped persuade much of the International Water Industry to move from the term 'Unaccounted for Water (UFW)' and towards the term 'Non-Revenue Water (NRW)'. This is because Non Revenue Water is easy to interpret for the non-specialist, whereas UFW fundamentally depends upon how the accounting is done (which still varies widely between countries and Utilities).

Similarly, even if a standard IWA best Practice Water Balance is used, there are wide variations in the options which countries and Utilities use for the numerator 'leakage' and the denominator 'System Input Volume' in the % calculation, for example:
- 'Leakage' could be NRW, Water Losses, or Real Losses (all of which have different meanings), and may include or exclude leakage on raw water and transmission mains.
- 'System Input Volume' could be Water Abstracted (with or without raw water imports and exports), or Potable Treatment Works output (with or without bulk imports and exports).

So a single Utility can have multiple values of 'leakage' as a '% of 'system input volume', varying from a small to large % values (e.g. 8% to 39%). How is anyone to know which % is being quoted for any particular Utility, without asking numerous supplementary questions?

What is the relationship between leakage and consumption as %s of SIV?

In continuous supply conditions, distribution systems must meet or exceed minimum standards of pressure, irrespective of changes in consumption. Leakage rate (volume/hour) as a % of SIV can reduce from 90% to 10% over the few hours each day between minimum night flow and morning demand peak, as consumption (volume/hour) increases from 10% to 90% of SIV.

The sum of leakage and consumption as %s of SIV must always equal 100%, even when SIV changes; if leakage % of SIV increases, consumption % of SIV must decrease, and vice versa. The relationship is like a see-saw in a playground; if one end goes up, the other end must come down, no matter how large the see-saw is.

In mathematical gaming theory, this is what is known as a 'Zero-sum' situation – the % gain by one party must result in an equal % loss by the other party. Both cannot show gains at the same time, the only other option is that they both show zero gains. This is a fundamental flaw in a performance indicator which is being used to measure a utility's efforts to reduce both excess leakage and excess consumption at the same time. Examples to demonstrate 'Zero-sum' situations are shown below.

Misuse of %s for setting leakage targets and tracking performance

Suppose that System Input Volume is represented by 100 delegates sitting in a conference hall. Annual volume of Consumption is represented by the 80 seats marked 'C', and annual volume of Leakage by 20 seats marked 'L'. So Leakage volume is 20% of System Input Volume, and Consumption volume is 80% of System Input Volume.

If 10% of leakage 'delegates' leave (L reduces from 20 to 18), and 10% of consumption 'delegates' also leave (C reduces from 80 to 72), SIV is reduced by 10%, from 100 to 90 units; this would surely be a good performance in demand management terms. But if % SIV is used as the performance indicator, leakage remains at 20% of SIV, and the consumption at 80% of SIV, and it appears that no progress has been made. The 'Conference Seats' explanation clearly shows why leakage expressed as a % of SIV distorts perception of performance when setting targets and tracking progress, because of changes in consumption.
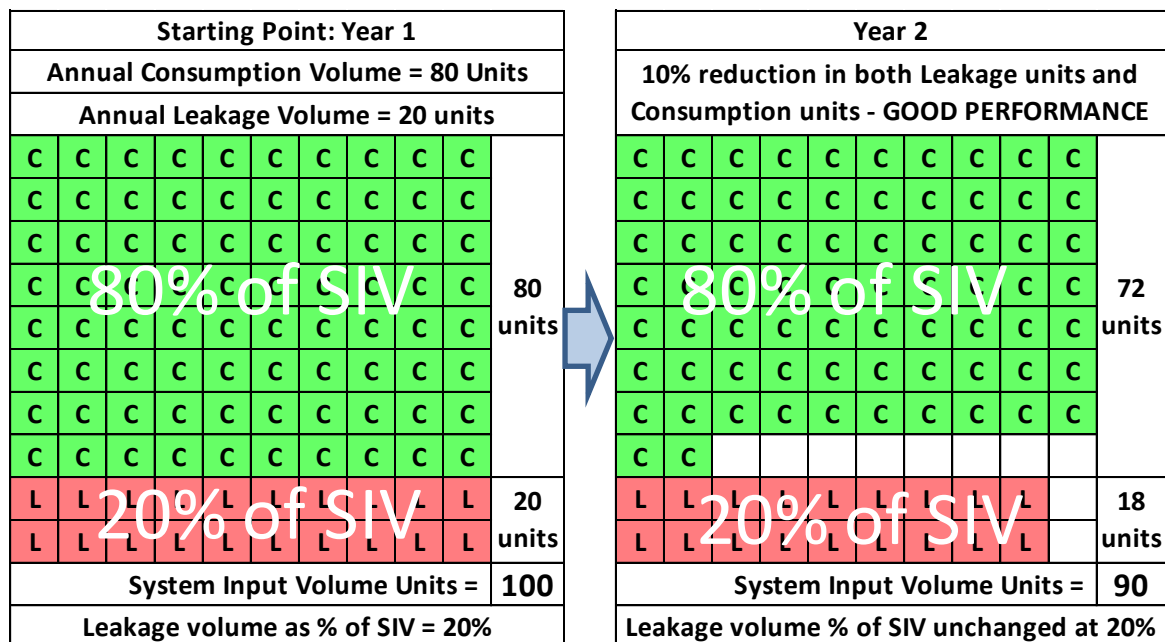

Figure 20 – Consumption and leakage both reduce by 20%, but leakage as % SIV does not.

This is not a theoretical problem, as recent Australian and European examples clearly show. In Yarra Valley Water (Melbourne) during the extended 2002/03 to 2010/11 drought:

- The number of service connections increased by 11% (from 505.000 to 553.000).
- Billed consumption was reduced by 31% (451 to 312 Ml/day) by demand management.
- Non-Revenue Water volume was reduced by 41% (from 64 to 38 Ml/day).
- Real Losses volume was reduced by 44% (from 50 to 28 Ml/day).
- ILI was reduced by 54% (from 1,3 to 0,7).
- But NRW as % of SIV was only marginally reduced (from 12,4% to 10,7%).
- And leakage as % of SIV was also only marginally reduced (from 9,7% to 8,1%).

In many European countries falling consumption over the past 20 years has caused leakage as a % of SIV to rise, where leakage in volume terms is unchanged. However, the problem of using %s to set targets and monitor progress is more serious in Eastern European countries trying to reduce high inherited leakage. The table below shows how Zagreb Utility reduced volumes of SIV, NRW and Real Losses by 5,1%, 6,2% and 6,5%, but this only showed as a marginal reduction in NRW and Real Losses as 0,6% of SIV.

Water Balance Annual Volumes expressed in Million cubic metres						Water Balance Annual Volumes expressed as % of System Input Volume					
Year	System Input Volume (SIV)	Revenue Water (RW)	Non-Revenue Water (NRW)	Apparent Losses (AL)	Real Losses (RL)	Year	System Input Volume (SIV)	Revenue Water (RW)	Non-Revenue Water (NRW)	Apparent Losses (AL)	Real Losses (RL)
	Mm3	Mm3	Mm3	Mm3	Mm3		% of SIV	% of SIV	% of SIV	% of SIV	% of SIV
2012	120.7	59.9	60.8	9.3	51.4	2012	100.0%	49.6%	50.4%	7.7%	42.6%
2013	114.5	57.5	57.0	8.9	48.1	2013	100.0%	50.2%	49.8%	7.8%	42.0%
Change	-6.2	-2.4	-3.8	-0.4	-3.3	Change	0.0%	0.6%	-0.6%	0.1%	-0.6%
% Change	-5.1%	-4.0%	-6.2%	-4.7%	-6.5%	% Change					

Source: J. Kovač.

The Bulgarian Case Study Dryanovo and Razgrad also show how substantial reductions in initial high volumes of leakage are being under-estimated when targets for NRW and leakage are set and tracked as % of SIV, to such an extent that incentives to try to reduce high consumption and high leakage are being reduced, as the true improvements are distorted by the regulatory requirement to use % of SIV as the national performance indicator.

Yet % of SIV is the performance indicator which many still prefer to use because it is supposedly 'simple' and 'easily understood'. Simple to calculate, yes; simple to interpret, no; easily understood, no.

Water Utilities and their stakeholders need performance indicators for leakage and consumption which represent 'Positive-Sum' or 'Win-Win' situations. This more rational approach is also consistent with smart systems initiatives, promoting policies such as advanced pressure management and smart metering which have multiple water conservation management and measurement benefits. Separate and more appropriate performance indicators for clearly promoting reductions in leakage, and in consumption, are required.

Misuse of %s for comparing leakage management performance in different systems

It appears simple and logical to compare leakage between systems using %s of SIV. But yet again, it's a trap for the unwary. Apart from many technical differences which influence leakage (see Section 1.3), consumption in European Utilities varies widely (see Figure 21).
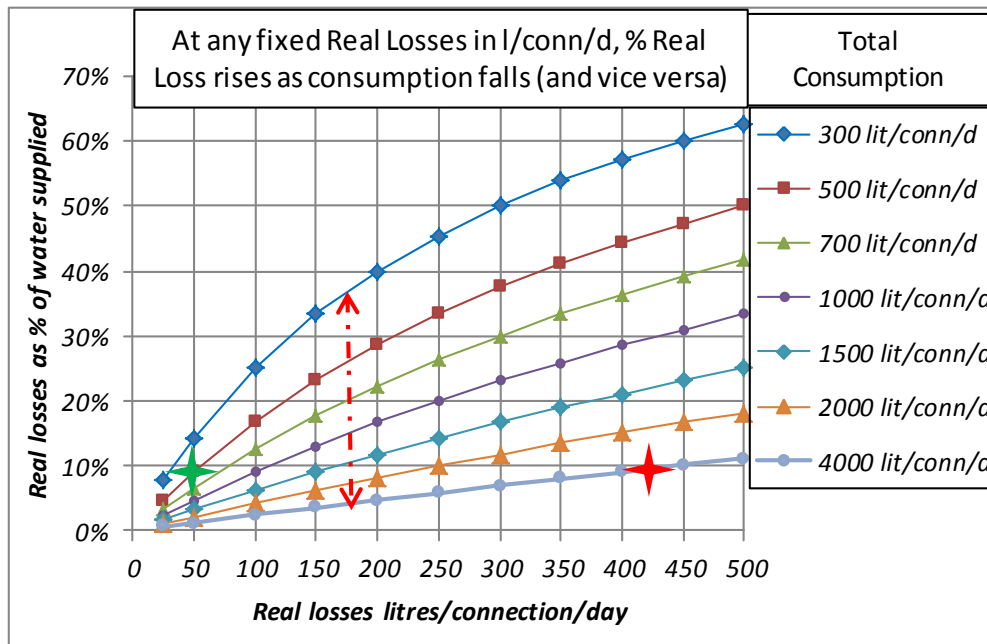
Figure 21 – Consumption in European Utilities varies widely.

So a Utility with, say, 180 litres/connection/day leakage would have 5% leakage in a metropolitan area, but 35% in a rural area. Or a metropolitan area could achieve 10% leakage with 9 times as much actual leakage as a rural area. The incorrect perceptions of performance that can arise when using % of SIV for comparisons are clearly illustrated in the Belgian Case Study De Watergroep.

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Appendix B.3: Pressure Management

Contribution of Allan Lambert with examples provided by Adam Kingdon.

Definition of Pressure Management

The IWA WLSG definition is:

"The practice of managing system pressures to the optimum levels of service ensuring sufficient and efficient supply to legitimate uses and consumers, while
   i) reducing unnecessary or excess pressures
   ii) eliminating transients and faulty level controls
   iii) reducing the impact of theft
all of which cause the distribution system to leak unnecessarily."

Basic, Intermediate and Advanced Pressure Management

There are many ways in which pressure in water transmission and distribution can be managed. The following broad classification has been proposed by the Pressure Management Team of the IWA WLSG:

- Basic:
  o Identify and reduce pressure transients and surges.
  o Achieve continuous supply (24/7 policy), even if at low pressure.
  o Strategic separation of transmission mains from distribution systems and zones.
  o Monitor pressures (inlet, critical, average), flows, bursts/leaks/repairs, complaints.
  o Avoid overflows from service reservoirs; reduce outlet pressures whenever possible.
- Intermediate:
  o Create sub-sectors (Pressure Managed Areas or Zones).
  o Reduce pressure using fixed outlet PRVs or intelligent pumping.
- Advanced:
  o Introduce time and/or flow modulation, or feedback loop from a critical node, or remote control, for valves and pumps.
  o Introduce hydraulic flow modulation for valves.

Benefits of Pressure Management

The range of benefits are shown in the Table below.

PRESSURE MANAGEMENT: REDUCTION OF EXCESS AVERAGE AND MAXIMUM PRESSURES								
CONSERVATION BENEFITS			WATER UTILITY BENEFITS				CUSTOMER BENEFITS	
REDUCED FLOW RATES			REDUCED FREQUENCY OF BURSTS AND LEAKS					
REDUCED EXCESS OR UNWANTED CONSUMPTION	REDUCED FLOW RATES OF LEAKS AND BURSTS	REDUCED AND MORE EFFICIENT USE OF ENERGY	REDUCED REPAIR AND REINSTATEMENT COSTS, MAINS & SERVICES	REDUCED LIABILITY COSTS AND REDUCED BAD PUBLICITY	DEFERRED RENEWALS AND EXTENDED ASSET LIFE	REDUCED COST OF ACTIVE LEAKAGE CONTROL	FEWER CUSTOMER COMPLAINTS	FEWER PROBLEMS ON CUSTOMER PLUMBING & APPLIANCES

Source: Water Services Association of Australia Asset Management Study PPS-3 2011, with later addition of 'reduced and more efficient use of energy'.

Pressure:leak flow rate relationships

The FAVAD concept of Fixed and Variable Area Discharges is recognised by the IWA WLSG as the best practical approach to predicting and explaining why different types of leaks and pipe materials have different relationships between pressure and leak flow rate. In its simplest form, in the FAVAD N1 approximation it is assumed that:

- Leak flow rate L volume/unit time varies with average zone pressure P^{N1}.
- Key parameters for prediction and analysis are the RATIO of average pressure before and after Pressure Management, and the N1 value.
- Leak velocity varies with $P^{0,5}$, so N1 = 0,5 for leaks with fixed area when pressure changes.
- N1 =1,5 for 'variable area' leaks in which leak area also varies with average pressure.
- Assume average N1 = 1,0 for large systems with mixed pipe materials.

Fixed Area leaks – ring cracks, corrosion holes, blow-outs in rigid pipe materials.
N1 = 0,5, Less sensitive to pressure changes

Variable area leaks: splits in flexible pipe materials, background leaks at joints.
N1 = 1,5, *More* sensitive to pressure changes

Type of leak	FAVAD N1	% reduction in average zone pressure						
		5%	10%	20%	30%	40%		
Fixed Area	N1 = 0.5	**-2.5%**	**-5%**	**-11%**	**-16%**	**-23%**	←	< % reduction in leak
Average	N1 = 1.0	**-5.0%**	**-10%**	**-20%**	**-30%**	**-40%**	←	flow rate varies with
Variable Area	N1 = 1.5	**-7.4%**	**-15%**	**-28%**	**-41%**	**-54%**	←	N1 for type of leak

Pressure:burst frequency relationships

Predictions of changes in maximum pressure on burst frequency have been published since 2006 by WLSG members. For these predictions, it is essential to analyse burst frequency for mains, and for services, separately. Articles published in 2006 showed that, for systems with high burst frequencies:

- if >25 mains repairs per 100 km/year, or >10 service repairs per 1.000 connections/year.
- average % reduction in burst frequency = 1,4 times % reduction in maximum pressure.

Further research published in 2011 showed that a wider range of pressure:bursts relationships could be predicted using relationships of the form shown in Figure 13:

$$\text{Burst Frequency BF} = BF_{npd} + BF_{pd} = BF_{npd} + A \times AZPmax^3$$

where BF_{npd} is a non-pressure dependent component, but pressure-dependent burst frequency BF_{pd} is very sensitive to the maximum pressure at the Average Zone Point.

This means that burst frequencies in many systems are very sensitive to quite small changes in maximum pressure – so in Pressure Management every metre counts. Recent examples of predictions and reductions in burst frequency in Durban CBD are shown below.
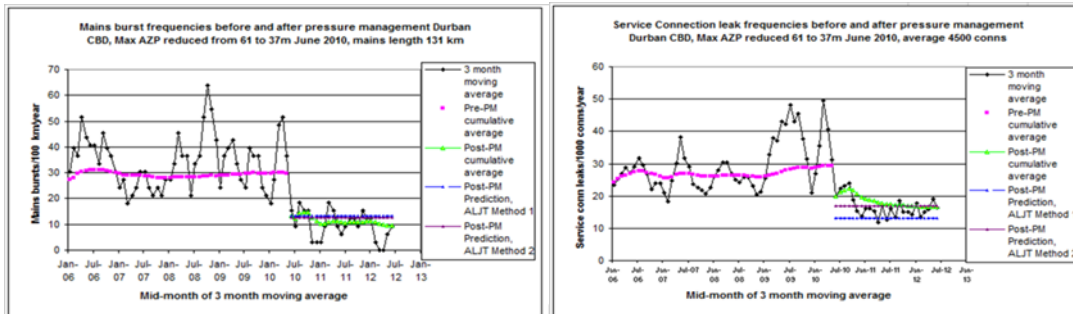
Reproduced with the permission of Ethekwini Municipality.

References
Lambert A., M. Fantozzi and J. Thornton (September 2013): *Practical approaches to modelling leakage and Pressure Management in distribution systems – progress since 2005*. CCWI 12th International Conference 'Computing and Control in the Water Industry', Perugia, Italy, 2-4 Sep 2013.

Appendix B.3.1: Advanced Pressure Management by PRV pressure optimisation

Contribution of Adam Kingdon.

Background: An average mains burst frequency of 21 burst per 100km per year and 21% leakage prompted the City of Cape Town to seek more intelligent methods for Pressure Management.

Implemented measure on leakage assessment and reduction	Yes	No
Reliable Bulk Supply Metering	√	
Reliable Customer Metering	√	
Good System Design and Installation	√	
Speed and quality of repairs	√	
Active Leakage Control at an economic frequency	√	
Sectorisation and/or District Metering Area formation	√	
Asset Renewal: service connections		√
Asset Renewal: mains		√
Indicators		Value
Leakage reduction		38%
Burst frequency reduction		58%

Table 9 – Implemented leakage reduction measure(s) in the City of Cape Town.

Approach: JOAT Group implemented i2O Water's automatic PRV pressure optimisation solution to provide automatic and continuous optimisation of pressure to specified targets at the Critical Point (CP). The trial zone selected was the Eersterivier PRV zone, which comprises 89,3km of mains and 6.218 connections to a population of approximately 19.000. Prior to the trial the zone was operating under fixed outlet pressure of 47m.

The objective of the trial was to implement automatic and progressive control of pressure, with continuous optimisation to specified CP targets.

The trial was staged in two phases. In phase one the system was programmed to achieve a single target CP pressure of 27m, which prior to the trial had averaged pressures of 34,5m during peak periods and 37m off peak. In phase two the CP target was reduced to 27m during peak periods and 23m during off peak periods.

Results: Average operating pressure, demand levels, burst frequency and leakage all reduced using this automatic PRV pressure optimisation solution:
- 27% reduction in average CP pressure during peak periods.
- 33,3% reduction in average CP pressure during off peak periods.
- Average operating pressure reduced by 26,5%.
- Minimum night flow reduced by 38,4%.
- 38% leakage reduction.
- Burst reduced from 21 per 100km to 9 per 100km – 58%.
- Average daily demand reduced by 12%.
- Cost savings on single PRV trial zone of £20.311.

Advanced Pressure Management delivers 38% reduction in leakage, 58% burst reduction and predicted 5 year asset life extension.
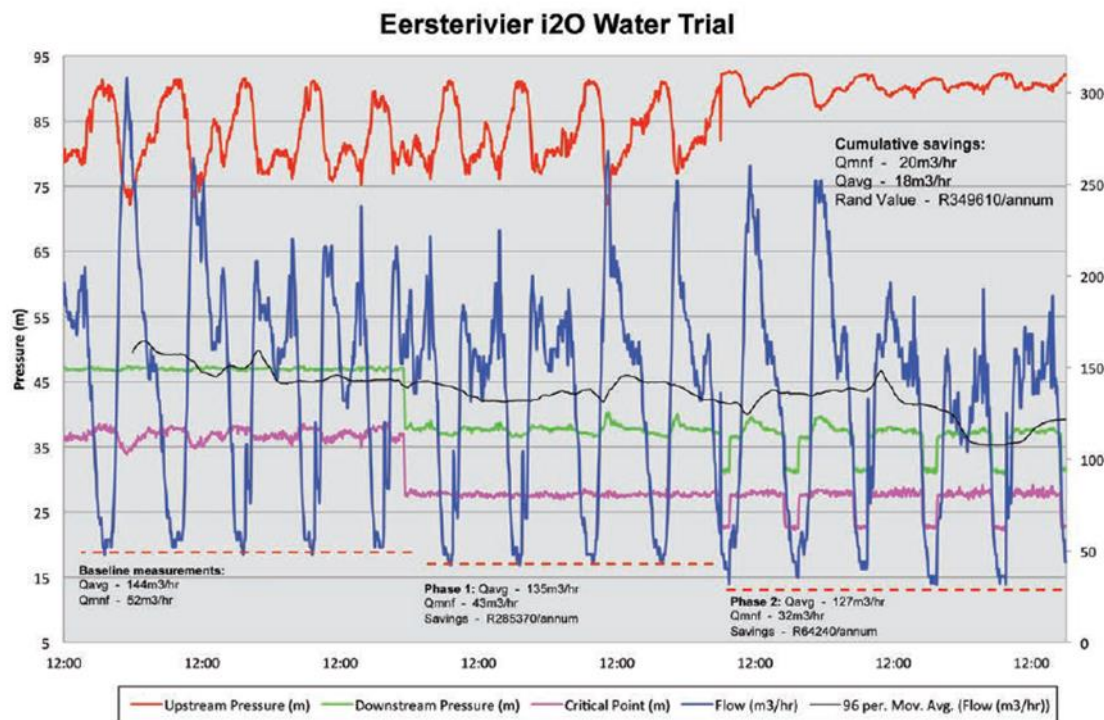

Figure 22 – Results of PRV pressure optimisation in a single trial zone.

Appendix B.3.2: Advanced Pressure Management by pump control

Contribution of Adam Kingdon.

Background: The company name is confidential. In a Romanian city with a population of 250.000, a trial of advanced Pressure Management in a pump-fed supply zone was undertaken. The purpose of the trial was to optimise pressure in the trial zone to reduce leakage and energy usage while ensuring no impact on continuous service.

Implemented measure on leakage assessment and reduction	Yes	No
Good System Design and Installation	√	
Sectorisation and/or District Metering Area formation	√	
Indicators		**Value**
Leakage reduction		10%
Energy usage reduction		20%

Table 10 – Implemented leakage reduction measure(s) in a Romanian city.

Approach: The pumping station supplies approximately 75.000 residents and is situated at an elevation of 16m above the city centre. Prior to the advanced Pressure Management trial, average leakage levels were estimated at 7 Ml/d, which could represent a level as high as 40%. Energy consumption was 1.700 kWh/d.

The trial location had three variable speed pumps with two Critical Points (CPs). CP1 was adjacent to several tall buildings where minimum pressure required was 36m. CP2 had a pressure requirement of 37m.

i2O Water's advanced pump pressure optimisation system was installed in the pumping station in March 2011 to remotely control and optimise pressure in the zone. The system controller required power and three 4-20mA connections to the variable speed pumps. Two connections provided manifold flow and pressure input, used for both logging and control purposes. The third connection was used to supply the existing pump control system with target manifold pressure through the 'remote set-point' interface.

On 17th March 2011 the system was installed and set to maintain pre-existing fixed delivery pressure. The first phase of optimisation involved identification and resolution of potential issues across the zone. During an eight-week period all identifiable issues had been resolved, including repair of burst mains, valve operations and improvements in the existing pump control system. On 18th May 2011 the pump control system transitioned into fully optimised profile, with delivery pressure varying to maintain required levels of pressure at both CPs.

Results: The results are:
- Stable and optimised pump control.
- Pressure at CPs varied by no more than 1,5m throughout the course of a day.
- Delivered improved customer service.
- Reduction in total daily flow.
- Reduction in leakage of 0,7 Ml/d = 10%.
- Reduction in energy usage of 334kWh/d = 20%.
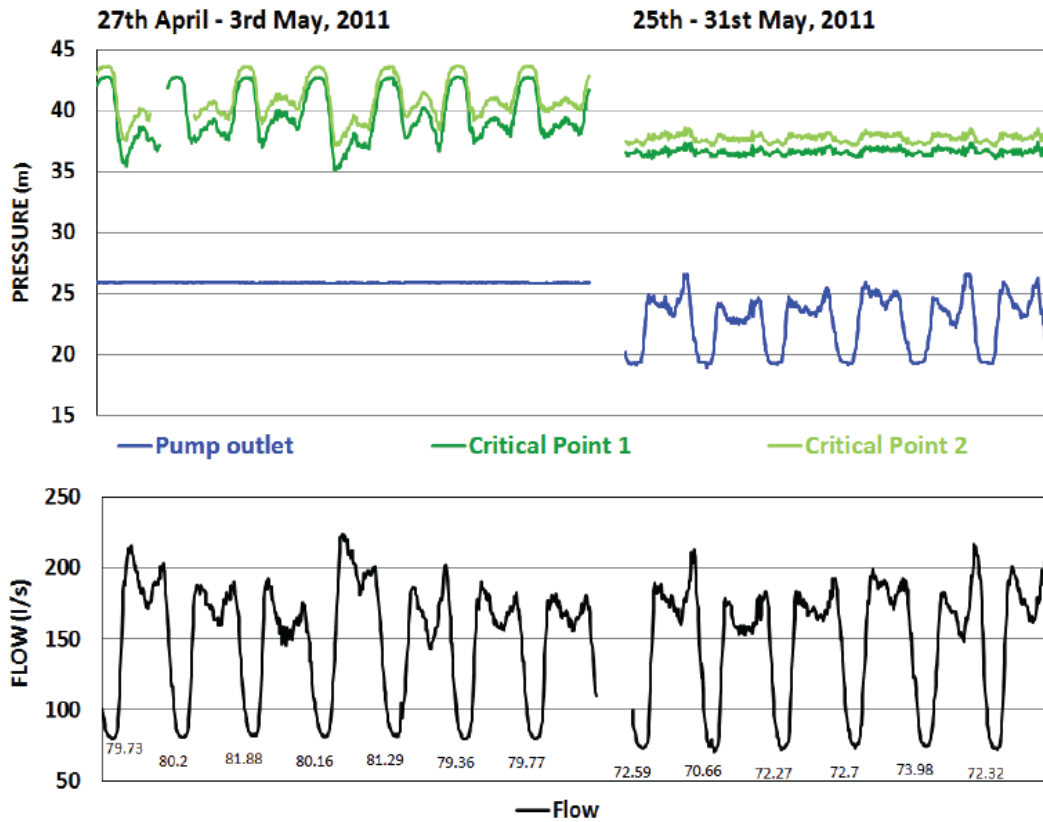- Energy cost savings of €8.500 from single trial zone.

Figure 23 – Results of stable and optimised pump control in a single trial zone.

The variation in water demand was managed and controlled automatically by the i2O pump control system. For example, increases in peak flow from 178l/s on 12th June 2011 to 243l/s on 19th June 2011 was met by an increase in pump outlet pressure, with a steady increase from 23m to 29m.

CP variation remained stable at the required level to ensure customers' supply was maintained.

Appendix B.4: Major reference documents

As the terms of the contract for this EU Reference document specified English language, only references available in English could be considered for inclusion in this Appendix.

Grundfos (2014): *Pressure management – An effective way to reduce Non-Revenue Water, improve energy efficiency and reduce operation and maintenance costs*. White paper.

Lambert, A.O., B. Charalambous, M. Fantozzi, J. Kovač, A. Rizzo and S. Galea St John (March 2014): *14 Years' Experience of using IWA Best Practice Water Balance and Water Loss Performance Indicators in Europe.*

Pedersen, J.B. and P. Klee (2013): *Meeting an increasing demand for water by reducing urban water loss – Reducing Non-Revenue Water in water distribution*. The Rethink Water network and Danish Water Forum White Papers, Copenhagen.

Hamilton, S. and B. Charalambous (July 2013): *Leak Detection – Technology and Implementation*, IWA Publishing, ISBN: 978-1-78-040470-7.

Kovac, J. and B. Charalambous (April 2012): *Coaching: an emerging need in water loss management.* Water 21, IWA Publishing.

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (March 2011): *Guidelines for water loss reduction – A focus on pressure management*. Eschborn, Deutschland. On behalf of Federal Ministry for Economic Cooperation and Development.

UKWIR (2010): *Managing Leakage 2011*. ISBN: 1-84057-63-8.

Koelbl J. (2009): *Process Benchmarking in Water Supply Sector: Management of Physical Water Losses*. PhD-thesis, Schriftenreihe zur Wasserwirtschaft, 56, Graz University of Technology, Austria. ISBN 978-3-85125-055-8.

Lambert, A.O., T.G. Brown, M. Takizawa and D. Weimer (December 1999): *A review of Performance Indicators for Real Losses from Water Supply Systems*. AQUA, ISSN 0003-7214.

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Appendix B.5: WION to prevent Real Losses in the Netherlands

Contribution of Dick Schipper.

Background and current status WION

WION is a Dutch law that came into force by July 1, 2008. WION (Law Information exchange Underground Networks) is a law to reduce damage by digging. WION is about the digital exchange of location data from underground cables and pipes between stakeholders. The law requires that anyone who requests information about the mechanical excavation work carried out in advance location of underground nets. The law also required to carry out digging work carefully. The development of the process "carefully digging" is left in hands of these stakeholders: owners of cable and pipe networks, contractors and administrators of the underground (local and national government), also named "the digging chain".

The development and implementation of the digital system for information exchange is organised by Kadaster. Agency Telecom is the regulator of the WION. Kadaster has built the system Klic-online in collaboration with the stakeholders. On request and at a cost of € 21,50 the digger can get digital information about the location of cables and pipes on the place where excavation work has to be done. Klic-online is in operation since July 1, 2010. The graph below shows the information exchange process.
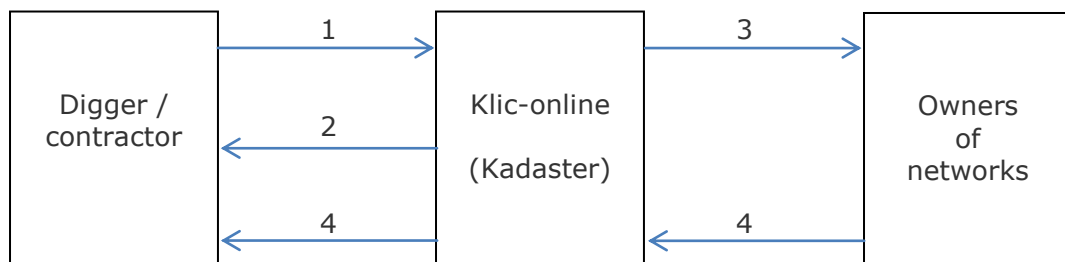
Where:
1. Expression of intension to dig.
2. Confirmation.
3. Request for information.
4. Provision of detailed location data from underground cables and pipes.

Process "carefully digging" and KLO

The Ministry of Economic Affairs has left the interpretation of the legal duty to carefully digging to the parties. Early 2006, KLO (cable and pipe consultation) was founded for this purpose. In KLO, owners of networks, contractors and governmental organisations work together in prevention of digging damage. The first focus of KLO was to measure in the sector to ease the introduction of the WION. Therefore, at the initiative of KLO, the concept of "carefully digging" was introduced. This has led to the CROW publication "guidance carefully digging process" (January 2008). In addition, KLO focus was on complimentary actions to improve the process of carefully digging, for example a standard form for incident records, uniform allocation map topography, state monopoly in the underground, etc.

For all these items, KLO has a lot of practical groups. The sectors are delivering people to bring in their specific expertise. In this way, the number of parties in KLO quickly multiplied. The distribution of seats in KLO is as following: 7 seats for network companies, 7 seats for diggers / contractors and 5 seats for public administrators.

In addition to these partners, the Ministry of Economic Affairs, Agency Telecom and Kadaster and a communication advisor are also represented. All agreements are made collectively to have a broad support base.

One of the most important products of KLO is the directive "carefully digging process": (http://www.crow.nl/publicaties/graafschade-voorkomen-aan-kabels-en-leidingen-__-r) (at present only available in Dutch) and the associated instruction card (http://www.crow.nl/publicaties/instructiekaart-zorgvuldig-graven-(1) (at present for free available in Dutch and Turkish). An important element in these documents is the description how to do a good preparation, such as the description how to make tests slots, one of the obligations before digging may commence.
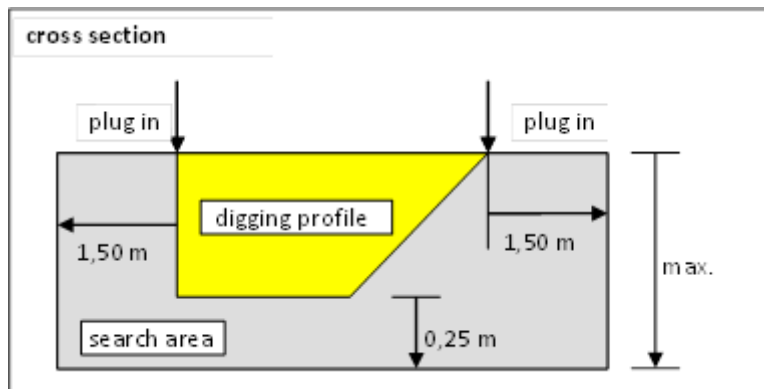
Other products are:
- Success factors in preventing digging damage (KIWA Technology).
- Incident form 2012 (KLO).
- Uniform measurement specifications (KLO).

A number of completed projects of KLO are:
- State monopoly in the underground (GPKL).
- Klic-online mobile (KLO).
- Uniformity degree plans (KLO).
- Uniformity cross profiles (NEN).

Causes of excavation damage
In May 2013, KLO commissioned a study by KIWA Technology of five companies that have relatively little involvement in digging damage. The purpose of this study was to discover which success factors played a role in preventing digging damage. In December 2013, Agency Telecom commissioned a study of five companies that are relatively much involved in digging damage. This study looked at the so-called "less-success factors'. The results of both studies are analysed. One of the key success factors is giving attention to damage prevention within the construction or infrastructure company.

Implementation guidance: KLO spear heads 2014 – 2018
KLO endorses the recommendations of KIWA Technology and has it as actions brought by the five priorities of KLO to prevent digging damage. Although studies have focused on the excavation, KLO's awareness of the fact that the prevention of digging damage is not only a matter of the digger, but the entire "digging chain". The priorities of the program KLO are, therefore, in width aimed at improving processes and the exchange of information count, which everyone should take to arrive: a careful digging process responsibility.

In the coming years, KLO will focus on five priorities:
▪ Responsibility.
▪ Count Information.
▪ Careful ordering.
▪ Benchmark.
▪ Certification.
Each priority consists of several projects, some projects are new, while others are running for some time already.

The system Klic-online (WION) itself will be changed into KLIC-WIN (WION + INSPIRE) in 2016. Further improvements are the incorporation of service connections and the use of vector data in near future.

Expected results
KLO has set a target to 25.000 digging damage in 2018 (2013: 38.317).
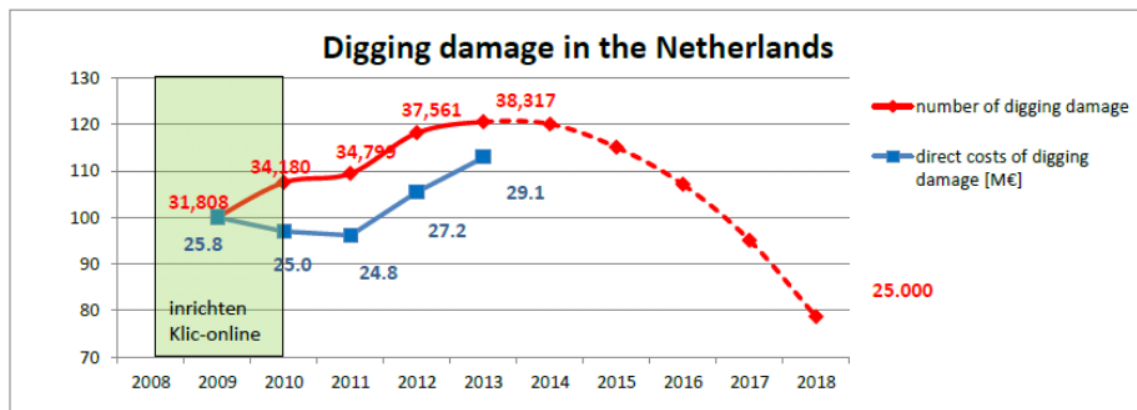

Figure 24 – Total excavation damage in Netherlands.

The depth of the water mains and pipes in the Netherlands are approximately 1m - ground to avoid freezing by frost. The deep location is a happy circumstance for the purpose of digging damage, the water mains and pipes are generally the deepest, most digging damage is to the cables in the shallower area. NEN 7171-1, a Dutch standard, gives instructions for e.g. depth location of cables, mains and pipes. Municipalities and other administrators may diverge by their specific situation. The situation for the water utilities in the Netherlands in terms of digging damage is slightly brighter than other operators: only 10% of all damages are on water mains and pipes.

Facts:
▪ 15% of all water losses in the Netherlands arise from digging damage.
▪ Water loss at Vitens is 20,3 Mm^3/year (2013) → 15% of 20,3 Mm^3/year → 3 Mm^3/year (2013).
▪ Water loss from digging damage in The Netherlands: 10 Mm^3/year (2013).

Reducing digging damage in the next four years with 40% will also affect the amount of real water losses that is lost as a result of digging damage. The reduction is estimated to be 4 Mm^3/year in the Netherlands in 2018 (40% of 10 Mm^3/year).

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Appendix B.6: USTORE and Spatial Analysis

Contribution of Adriana Hulsmann in cooperation with Peter van Thienen and Ilse Pieterse-Quirijns (KWR Watercycle Research Institute).

Summary

Failures of water mains can result in unwanted effects but also offer a great opportunity to obtain network information. As low failure frequencies prevail within the Dutch water utilities, limited knowledge can be derived from the individual failure occurrences. A system was developed to enable uniform failure registration and an exchange of information between utilities. Spatial analysis of these failure data can reveal relationships between asset failures and environmental factors such as soil characteristics. Failure databases of seven Dutch water companies were investigated to determine the condition of the distribution network and to help improve the registration system.

Importance

For planning of investment needs of water main rehabilitation, insight into the condition and deterioration of assets is required to estimate when their replacement is due. Because resources are always limited, pipes which need to be replaced with priority have to be indicated. Externalities (including consumer perception) and failure rates are generally used as indicators for the need for replacement. For financial as well as technical calculations, key figures are used for material specific lifetime estimates (usually 50 or 75 years). It is known that these are rough estimates that do not take into account factors influencing the remaining lifetime such as the surrounding soil characteristics or various loads. Maintenance and failure data can be useful sources of information to estimate failure frequencies or residual lifetime of asset populations. Most water companies keep maintenance or failure records to some degree. The quantity, quality and nature of the data determine to what extent the data can be used to provide insight in the (remaining) lifetime of asset groups (or pipe cohorts). Research has shown that by sharing the failure data of individual companies, the data became much more valuable in terms of directive outcomes for strategic asset management.

Approach

The analysis involves a combination of analysing failure data on drinking water mains and soil data using GIS. The occurrence of a failure is captured in such a way that it can be shared and analysed. A systematic process is used to transfer 'on site' failure information registration to knowledge creation by means of statistical analysis of shared failure data. This knowledge, built on information provided by pipe fitters, can help to determine when replacement is due, thereby supporting replacement decisions of asset managers, policy makers and financial planners. It is essential that all potentially distinctive features of the pipe and its surroundings are registered for each failure. The quality, quantity and detail level of the registered parameters and values determine the possibilities for statistical analysis and thereby the potential of the data as valuable input for management decisions.

Results

The USTORE initiative started in 2009 and now more than 10.000 bursts by seven water companies have been uploaded. Not only data on bursts and a number of attributes of the bursts are registered in USTORE. Also asset characteristic, information on surroundings and situational factors are considered having an influence on the occurrence of failures and are therefore registered in USTORE.
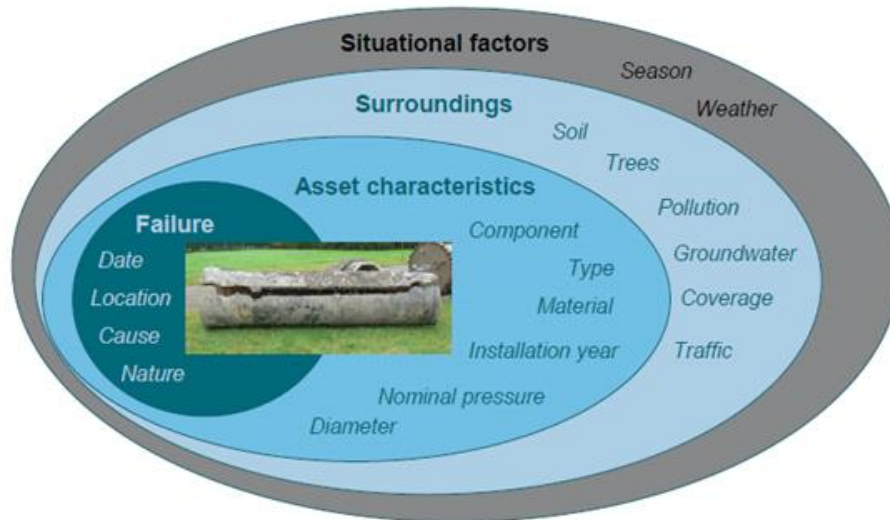
Figure 1.1 Aspects considered having an influence on the occurrence of failures. By including these aspects in the registration as parameters it will become possible to prove or disprove the assumed influence.

Implementation Guidance

The failure registration system enables uniform exchange of failure data between companies while being flexible enough to be adjusted to the various needs for implementation at each of the participating water companies. The complete system of failure registration, collection, exchange, analysis and follow-up is broken down in six steps:

1.   Failure registration.
2.   Collection.
3.   Exchange.
4.   Controlled and composition.
5.   Analysis.
6.   Follow-up.

Steps 3 to 6 are automated in USTOREweb, an internet-based application.

Combining failure data with spatial data on soil characteristics provides useful information for asset management. Spatial analysis with GIS can be a useful tool for making decisions on replacement of mains.
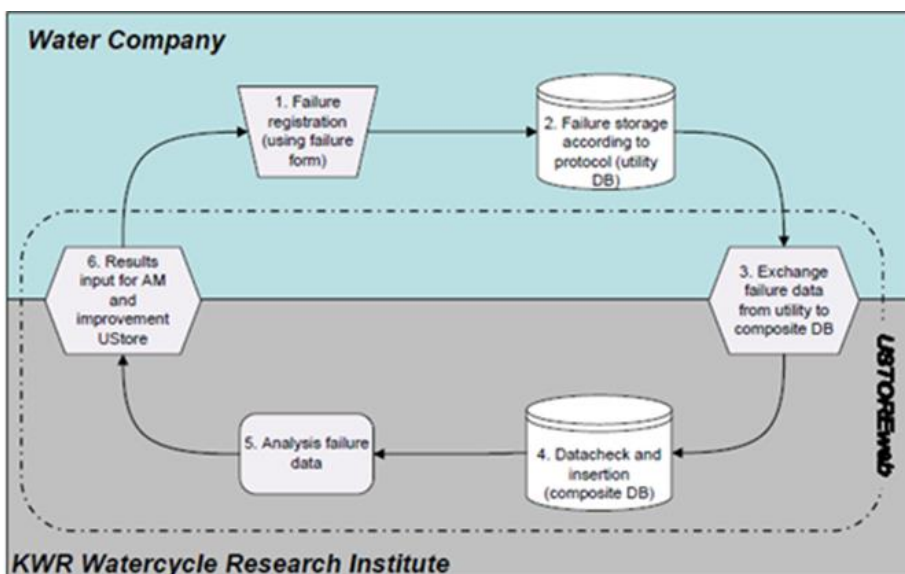
References

Vloerbergh, I. et al (2011): *Pipe fitters assist to predict investment needs for water rehabilitation*, LESAM conference paper.

Vreeburg. J.H.G. et al (2012): *Shared failure data for strategic asset management*, Proceedings IWA Conference 2010, Busan.

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Appendix B.7: Benchmarking of water utilities

Contributions of Christian Hald-Mortensen.

What is benchmarking?

Benchmarking is viewed mainly as a management tool for the utilities. In an ideal world, benchmarking is used to identify "best practices", and thereby use this for learning and optimization of processes and work routines, in order to achieve and surpass this best practice.

Benchmarking identifies where the utilities are doing things well, and where they underperform measured against comparable utilities. This implies that the utilities can focus on improving in areas, where they are not yet as effective as their peers. The participation in the benchmarking cooperation followed up by continuous management optimizing has implied that the utilities in Denmark have become more efficient. In Denmark, the task of compiling the data is done by the sector itself, and it is a voluntary endeavour.

Which parameters are relevant to benchmark?

Specifically, benchmarking permits to measure and compare the environmental impact, the costs, the pricing, the organisation, the quality and service. Recently, also CO_2 emissions have become part of the benchmarking exercise. Benchmarking also creates a necessary basis for regular adjustments of water pricing and helps to show the development of the quality of service and efficiency of the water sector. It is vital to ensure a satisfactory transparency, and therefore the benchmarking results should be published.

In an early benchmarking case study, the Water Utility association DANVA demonstrated that the costs for maintenance and operations among the participating water utilities in the project fell 21%. The water utilities became 21% more efficient in the four years that the project ran. The efficiency gains have also been backed up with consumer satisfaction polls that demonstrated increased satisfaction with the water supply and sewerage management.

Reference on the European Benchmarking Co-operation

http://www.waterbenchmark.org/content/participation.html

References on water sector benchmarking in Austria

Theuretzbacher-Fritz, H., Koelbl, J., Friedl, F. & D. Fuchs-Hanusch (2013): *How benchmarking triggers water industry improvements*. Water Utility Management International 8.2 (2013) 28, IWA Publishing, ISSN 1747-7751.

Theuretzbacher-Fritz, H., Neunteufel, R., Koelbl, J., Perfler, R. and E. Mayr (2008): *The Right Choice of Denominators and Grouping Factors in Water Supply Metric Benchmarking*. Performance Assessment of Urban Infrastructure Services. IWA Publishing, London, UK. ISBN 978-18-433-9191-3.

Theuretzbacher-Fritz, H., Schielein, J., Kiesl, H., Neunteufel, R. and J. Koelbl (2010): Introducing Country-wide Benchmarking to The Water Supply Sector in Slovenia Linked with Cross-Border Comparisons with Austria and Bavaria. - Water practice & technology 5 (2010) 1, p. 1 - 8, IWA Publishing, London, UK. ISSN: 1751-231X.

Theuretzbacher-Fritz, H., Schielein, J., Kiesl, H., Koelbl, J., Neunteufel, R. and R. Perfler (2005): *Trans-National Water Supply Benchmarking: The Cross-Border Co-operation of The Bavarian EffWB Project and The Austrian OVGW Project*. Water Science & Technology: Water Supply 6 (2005), 273-280, London, UK.

Website of OVGW benchmarking project: www.trinkwasserbenchmarking.at

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Koelbl, J (2009): *Process Benchmarking in Water Supply Sector: Management of Physical Water Losses*. PhD-thesis, Schriftenreihe zur Wasserwirtschaft, 56, Graz University of Technology, Austria. ISBN 978-3-85125-055-8.

Koelbl, J., Mayr, E., Theuretzbacher-Fritz, H., Neunteufel, R. and R. Perfler (2008): *Austrian Case Study on Process Benchmarking of Water Loss Management*. Conference Proceedings Water Loss Management, Telemetry and SCADA in Water Distribution Systems, Ohrid, Macedonia.

Koelbl, J., Theuretzbacher-Fritz, H., Neunteufel, R., Mayr, E. and R. Perfler (2008): *Benchmarking the Processes of Customer Meter Reading and Customer Meter Replacement*. Performance Assessment of Urban Infrastructure Services. IWA Publishing, London, UK. ISBN 978-18-433-9191-3.

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References on water sector and water loss benchmarking in the Netherlands

http://www.vewin.nl/english/Publications/

References on water sector and water loss benchmarking in the UK

http://www.ofwat.gov.uk/sustainability/waterresources/leakage/rpt_com121012smcsell.pdf

http://www.ofwat.gov.uk/regulating/casework/reporting/rpt_los2011-12addreliability

http://www.ofwat.gov.uk/regulating/casework/reporting/rpt_los_2009-10.pdf

http://www.ofwat.gov.uk/regulating/casework/reporting/rpt_com_leaktgtapp.pdf

Appendix B.8: Performance-Based Contracting

Contributions of Christian Hald-Mortensen.

The Water Utility can use its own staff to conduct a Non-Revenue Water reduction project, but knowledge and skills may not be sufficient to tackle what might be a systemic problem. Another option is to hire a specialist NRW reduction contractor to do the job under a Performance-Based Contract (PBC). A specialist NRW reduction contractor is hired to reduce non-revenue water compared to the IWA Water Balance, and a utility agreed baseline. Often quite detailed tendering processes are carried out with scoping studies and even more detailed feasibility studies. In the end, the winning contractor will provide the technical and managerial know-how required to deliver an NRW reduction project.

The contract should have the right incentives for efficiency:

If the PBC is well-designed, the contractor will be given incentives to find creative solutions and deliver the agreed NRW reduction performance, while sustaining the NRW reduction achieved for the life of the contract.

The contractor will often organize suppliers and other specialists so the Utility has a single point of entry. The contractor then selects the most appropriate and effective new technology for the particular operating conditions within the Utility. The contractor is also able to align staff incentives with the performance objectives of the contract and has the labour flexibility to employee staff when they are most effective (e.g. night leak detection crews).

Risk sharing

The contractor can arrange cost recovery for some or all of the project costs, with the investment made recovered from a portion of the savings achieved over the life of the contract. Risk sharing between the private contractor and the public utility is vital for the success of the relationship and the success of the project.

The contract should ensure that utility staff receive both formal training programs and in-depth on the job training, working with the contractor's staff, so that at the end of the contract, the Utility is able to take over and sustain the NRW reduction achieved. Otherwise several case studies have shown that the leakage levels go up again, after the project is completed.

Figure 25 – Mentoring utility staff on NRW reduction.

At the end of the contract, the technology installed and used during the contract will be handed over to the Utility, together with the infrastructure created during the course of the contract, such as district metering areas (DMAs), pressure zones, etc.

Benefits of a PBC

A performance based water leakage project will also provide the Utility with other benefits:

- Improved GIS data. NRW reduction projects depend on distribution network records and correcting errors in the Utility GIS data.
- Improved hydraulic network models. The contractor will most likely use hydraulic network models to design the DMAs and pressure zones and the wealth of network performance data collected from the monitored zones can be used to calibrate these models, which should be handed over to the Utility at the end of the contract.
- Improved asset management planning. The contractor will need to build up a database of leaks found and details of the repairs undertaken, with locations. This data can be used for asset management planning to identify and prioritize mains and service line replacement projects.

References on Performance-Based Contracting

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Appendix B.9: Marketplace for innovative ideas (EIP Water)

Contribution of Guido Schmidt and Robert Schroder.

The European Innovation Partnership on Water - EIP Water in short - is an initiative within the EU 2020 Innovation Union. The EIP Water facilitates the development of innovative solutions to address major European and global water challenges, such as better water management under the Water Framework Directive. At the same time, the EIP Water supports the creation of market opportunities for these innovations, both inside and outside of Europe. By 2020 the European Innovation Partnership on Water aims to identify, test, scale up, disseminate and stimulate the market uptake of innovative solutions for 10 major water related challenges.

The EIP Water aims to remove barriers by advancing and leveraging existing solutions. Its implementation has started in May 2013 with the main objective to initiate and promote collaborative processes for change and innovation in the water sector across the public and private sector, non-governmental organisations and the general public. This is mainly done via the establishment of Action and other Working Groups, and in collaboration with partners and existing initiatives, as well as by facilitating tools for innovation.

Eight priority areas have been chosen for the EIP Water. They centre on challenges and opportunities in the water sector, and on innovation-driven actions that will deliver the highest impact. Five priorities are primarily relevant to this guidance document. The thematic focus include 1) Water and wastewater treatment, including recovery of resources; and 2) Water-energy nexus. In addition, the selected cross cutting priorities include 3) Decision support systems and monitoring; and 4) Financing for innovation. 5) Smart technology has been defined as an enabling factor for all priorities.

Several of the currently 25 EIP Water Action Groups and the currently 11 FP7 INNO-DEMO research projects address priority areas linked to leakage reduction, including:
- SmartWater4Europe (INNO-DEMO) – Smart Water Management themes demonstrated at 4 well-scaled and real-life demonstration sites in France, United Kingdom, Spain and The Netherlands.
- EBCF (Action Group) – Improve water efficiency and sustainability in water and sanitation services through the roll-out of a benchmarking process that covers the entire water cycle.
- City Blueprints (Action Group) – Application of an assessment scheme for the sustainability of municipal water management systems, community of practice.
- SPADIS (Action Group) – Development of water management and risk assessment models to reduce and mitigate drought impact, and design appropriate economic instruments.
- WaterReg (Action Group) – Explore and promote innovative approaches to price-setting in the water sector and optimal operational scales in the water sector.

According to its partnership approach, different levels of involvement have been defined, and the EIP Water requires the active participation of interested parties. If you are interested to join one of the Action Groups, please contact the lead partner. The decision to add partners is made by the Action Groups themselves; and the Action Group shall come back to you on this request. Within new Calls for Action Group, you can also promote a new team to work under the EIP Water umbrella and contribute to achieving common targets.

Furthermore, everybody can access and use for free the EIP Water Online Marketplace. The heart of the marketplace is the matchmaking, where - like on a real marketplace - people meet. You may search for interesting colleagues or offer your products and services. If you search for a specific organisation, project, product or service, you have a water-specific filter system in place. So you can easily filter by region or water related topic. Information is continuously updated on the Marketplace, so no detailed description is given here on the companies/organisations, available products or showcases in the field of leakage reduction, but the European Commission is promoting this site for one-by-one exchanges on innovative solutions.

Appendix C   Author Profiles

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Allan Lambert

Allan Lambert has over 50 years experience in the UK and international water industry, split in almost equal parts between Water Resources/Hydrology, and Non-Revenue Water management, with experience in more than 40 countries. A Past President of the British Hydrological Society, and a special advisor on water resources and leakage to the House of Commons Environment Committee during the 1995-1996 UK drought, he developed Component Analysis (Background and Bursts Estimates) when he was Technical Secretary to the UK National Leakage Control Initiative in 1992-1994. He also chaired the 1st IWA Water Loss Task Force (1995-1999) which developed the Best Practice IWA Water Balance and Performance Indicators. A Fellow of the IWA, he has been researching the benefits of pressure management for almost 20 years, and is recognised as a leading international authority in leakage management.

Stuart Trow

Stuart Trow is a Chartered Engineer with 35 years practical experience of leakage management from several perspectives, initially as an engineer and manager in a large UK water company. Stuart was a member of the steering committee of the UK National Leakage Control Initiative (1990-1994). In the mid-1990's he established a company providing leakage management services to almost all of the UK water companies including target setting, pressure management and DMA design, and leak detection.

He was a director of contracting companies undertaking water mains replacement works, and MD of a company developing and selling pressure control systems. He currently undertakes regulatory reviews and provides advice for water companies to meet the needs of Ofwat and EA in England and Wales and WICS in Scotland. He is an IWA Fellow, with responsibility for representing the Water Loss Specialist Group in North West Europe.

Cor Merks

Cor Merks is a Senior Consultant Water Supply with 25 years experience in the Netherlands and international water industry, with experience in Africa, Asia, Europe and the Gulf Region. He was employed by ARCADIS Nederland BV from November 2012 up to and including December 2014, and since January 2015 by Witteveen+Bos. His experience is split in almost equal parts between water production (abstraction and treatment), water distribution, and certification of materials and chemicals for use in contact with potable water.

He has been researching innovative, state-of-the-art (proven) and cost-efficient water treatment and distribution technology throughout his career. He is recognised as a senior consultant and project manager for the implementation of ISO 9001, ISO 14001, OHSAS 18001, PAS 55/ISO 55000 Asset Management and ISO 50001 Energy Management Systems.

Bambos Charalambous – J2C Water Ltd, Strategic Advisors

Bambos Charalambous holds a BSc degree in Civil Engineering and a Masters in Business Administration. He is a Chartered Engineer (CEng) registered with the UK Engineering Council, a Corporate Member of the Institution of Civil Engineers (UK), a Fellow of the Institution of Water and Environmental Management (UK) and a Fellow of the International Water Association.

His experience in water related areas spans 35 years and has worked on many projects in Europe, Middle East, Africa and Asia. He has wide experience in the design and supervision of construction of civil engineering projects in the fields of water supply as well as considerable experience in urban water distribution networks management, including: Non-Revenue Water (NRW) and Water Loss Management with particular application to water audits and data validation; non-revenue water strategies; leakage assessment and control, asset management, benchmarking and business coaching. He has published numerous papers and taken part in many research projects, conferences, seminars workshops and debates. Bambos is Past Chair of the International Water Association's (IWA) Water Loss Task Force and is currently the Chair of the IWA Intermittent Water Supply Task Group.

Andrew Donnelly – EPAL, SA

Andrew Donnelly has been Advisor to the Board since 2005 and head of Network Monitoring Unit since 2008 at EPAL, the water company for Lisbon and Tagus valley region of Portugal, with responsibility for implementing and managing water loss control activities. Prior to this, an academic background in Environmental Sciences at Newcastle and Stirling universities was diverted into water loss control in northern Portugal at Águas de Gaia in 2000, followed by a leakage and monitoring project implementation with Atkins & Scottish Water, before a move back to Portugal. In addition, various consultancy projects have been undertaken, including Mozambique, Angola, Seychelles and several Portuguese water companies.

Stephen Galea St John – Malta WSC

Stephen Galea St John, a mechanical engineer by profession, has been in the water business for over 25 years. Over the last 20 years he has held a managerial role in the Distribution branch of the Water Services Corporation, the Maltese national water and waste water operators. During this time, he has been a key player in the evolvement of the Water Audit Section from a small peripheral unit to a central, important and highly-motivated group with the task of curbing the spiralling water losses of the national water distribution network.

Mr Galea St John has been actively involved in the strategic management of the Water Services Corporation especially with regards to leakage management. His expertise and knowledge of the distribution network have contributed to reducing the leakage levels in Malta from just under 4.000 m^3/hr in 1995 to below 500 m^3/hr at the moment. He is also heavily involved in the Corporation's ambitious project to have all its 250.000 customers on a fixed-network AMR system, which means that Malta would be the first country to have nation-wide AMR.

His current position is Chief Officer within the Network Infrastructure Directorate of the Water Services Corporation.

Marco Fantozzi – Studio Marco Fantozzi

Marco Fantozzi is a leading NRW expert with over 27 years international experience in all aspects of NRW reduction work. He is Managing Director of Studio Marco Fantozzi, a company specialized in water loss management. In 2014 Marco has been invited to join the IWA Fellows in recognition of the valuable contributions he has made to the International Water Association and has been nominated IWA water loss regional representative for South East Europe.

He is an expert evaluator for the European Commission for the Key Action "Sustainable Management and Quality of Water". Marco holds a MSc degree in Civil Engineering and a Master in Business Administration. His career included being manager responsible for water networks in ASM Brescia, one of the most advanced public utility companies in Italy.

Adriana Hulsmann – KWR Watercycle Research Institute

Adriana Hulsmann is senior advisor at KWR Watercycle Research Institute in the Netherlands. She is an Environmental Engineer (MSc) specialised in drinking water supply and EU water legislation. As such, she has extensive experience with water quality studies and water quantity studies , as well as with design and operation of water treatment plants for the production of potable water. Mrs Hulsmann is an expert on national and international standards for the quality of water intended for human consumption. She has worked at university level, at water supply companies, at water research institutes and at private consulting companies. She worked in various countries, including Indonesia, Vietnam, Romania, Bulgaria, United Kingdom and Belgium. She has obtained an engineering degree MSc from Wageningen University and a Ph.D. in Mathematics and Sciences from the University of Amsterdam. Adriana has an extensive network in all 28 Member States of the European Union through her advisory work for the European Commission DG ENV and as project coordinator of large integrated European projects.

Joerg Koelbl - Blue Networks e.U.

Joerg Koelbl holds a PhD degree in Civil Engineering-Economics and has more than 15 years of experience in the field of urban water management, with professional experience in Africa, Central and Eastern Europe and the Middle East. He was significantly involved in the development and implementation of the OVGW benchmarking in the Austrian water supply sector. The main field of activities of his consultancy company Blue Networks is the sustainable optimisation of urban water infrastructure with focus on Non-Revenue Water management, condition assessment and rehabilitation planning.

He is member of IWA Water Loss Specialist Group (WLSG) and a WLSG country representative of Austria. He was a member of the OVGW (Austrian Association for Gas and Water) Working Group "Water Losses", which revised the Austrian water losses guideline in 2009, and currently he is involved in guideline preparation activities in Germany and Eastern Europe.

Jurica Kovač – Independent consultant

Jurica Kovač has 22 years of working experience. First employment in 1992 as maintenance technician in Waterworks Osijek, Croatia, responsible for SCADA systems, pumps maintenance, performance indicators analyses. From 1997 until 2010 in private company IMGD, Croatia, building knowledge and experience in water loss management; leak detection, flow and pressure measurements, pressure management, DMAs, remote monitoring, training and education of employees in water utilities. From 2010 active as independent consultant specialized in water loss management with special focus on training, education and coaching for water utilities.

From 2006 active member of IWA and IWA Water Loss Specialist Group. Member of Croatian association for water protection, supporter of UN Habitat program GWOPA in South-east Europe, promoter of IWA methodology for water loss control in Western Balkan region.

Jurica worked for more than 100 water utilities in the Western Balkan region (Slovenia, Croatia, Bosnia and Herzegovina, Monte Negro, Serbia), Romania, Italy, Russia. Regular speaker on local and international conferences, published 32 papers since 1999 (numerous as co-author with leading world experts in water loss management).

Initiated as main editor and publisher special magazine dedicated for water utilities in Western Balkan region with aim to expand knowledge and improve communication. Special focus of interest: management skills (project, time, document), education skills (learning, memory, brainstorming, improvisation) and human behaviour (motivation, habits, change resistance, positive thinking, neuro-linguistic programming).

Dick Schipper – Vitens

Dick Schipper works at Vitens - the largest water company of the Netherlands - as a manager portfolio infrastructure since January 2012. His experience is in water production and distribution. Dick has over 35 years' experience in water projects in the Netherlands and also in Mozambique and Ghana (NRW). In the first 20 years as a people manager, in the last 15 years as project manager and policy advisor. Dick is a member of KLO, a Dutch group where owners of networks, contractors and governmental organisations work together in prevention of digging damage. His contribution to this report is because of his knowledge at KLO and NRW.

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