water e-journal
Online Journal of the Australian Water Association
ISSN 2206-1991
Volume 3 No 4 2018
https://doi.org/10.21139/wej.2018.038

Reducing leakage to save bulk water costs

Calculating the economic level of leakage for Unitywater's water supply network

K Goraya, M Lukin

ABSTRACT

Real losses in the Unitywater network are relatively low compared to both national and international standards. However, the cost of bulk water to Unitywater is relatively high, and is based entirely on volumetric consumption. Hence, in comparison to other large utilities, reducing leakage in Unitywater's network results in a relatively large financial benefit. The question arises as to how low should Unitywater go in reducing what is already a relatively low level of leakage? This question was answered by estimating the Economic Level of Leakage (ELL). The ELL was estimated by considering the costs and benefits from the accelerated implementation of Active Leakage Detection (ALD), Pressure Management and Network Renewals. Each assessment was conducted independently without considering the simultaneous impact of the other activity. Pressure Management appears to be a slightly cheaper pathway to reduced real losses as compared with ALD. However, both strategies are cost effective and will probably deliver similar outcomes at similar costs. Network Renewals, purely for leakage reduction purposes, were found to be not economical for Unitywater.

Key words: Water distribution network, Economic level of leakage, Active Leakage Detection, Pressure Management, Network Renewals

INTRODUCTION

Unitywater is a water distribution and retail utility in South East Queensland, Australia. It operates and maintains approximately 6,000 km of water mains servicing a population of over 700,000 people in the rapidly growing area north of the city of Brisbane. There are approximately 300,000 retail customers in the supply area and customers are metered and billed quarterly.

In 2013-14 Unitywater prepared a System Leakage Management Plan (SLMP) covering the whole water supply Connection Area within Unitywater. The aim of the SLMP was to reduce leakage in the network, primarily via the implementation of District Metred Areas (DMAs) coupled with Active Leakage Detection (ALD). The establishment of DMAs has been enhanced with the implementation of TaKaDu's network monitoring and analytical services, which monitors DMAs and detects leakage via small changes in normal diurnal flow patterns. The network monitoring allows ALD to be better targeted to areas where it is known that new leaks have recently occurred (TaKaDu is an automated cloud-based service used by Unitywater to detect, analyse and manage network events and incidents such as leaks, and bursts).

Pressure Management, which has previously been implemented in some water supply schemes, such as Redcliffe, has not been expanded by Unitywater to date.

Over the last few years a significant amount of work has been carried out to reduce leakage, better account for unmetered water use, and improve data collection and assessment. A water meter testing program indicated that the overall error in the retail meter fleet is an underregistration of 5% (Itron 2016). This is considerably more than the 2% guideline figure recommended by the Water Services Association of Australia (WSAA) for ‘top down’ water balance calculations. With this finding, the real losses in the Unitywater network are now considered relatively low compared to both national and international standards (BoM 2017; Leakssuite, 2017).

Real losses in Unitywater’s networks are in the lowest quartile of known leakage values in Australia. However, although real losses in Unitywater’s service area are low by national standards (51 L/ conn/day), the cost of bulk water is in the upper quartile amongst large utilities (BoM, 2017). In addition, this cost is entirely volumetric. Hence, in comparison to other large utilities, reducing leakage in Unitywater’s network can result in a relatively large financial benefit.

The question arises as to how low should Unitywater go in reducing what is already a relatively low level of leakage? This question can be answered by estimating what is referred to as the Economic Level of Leakage (ELL).

Leakage in Unitywater Network

According to the “Breaks and Background Estimates” concept (BABE) developed in the UK (Lambert 1994), there are three types of leakage in water supply networks:

1. Reported Bursts: Events that are visible at the surface and are reported by the public or by employees.
2. Background Leakage (undetectable): Individual small events that will continue to flow undetected until they gradually worsen to the point that they can be detected. These individual small events cannot be detected by ALD due to technology limitations, pipe material, pipe depth, etc.
3. Detectable Leakage (not visible but otherwise detectable): Leaks which can be detected by an investigation technique, e.g. regular or planned ALD programs.

For Unitywater’s network, the estimated values for the above three types of leakage were compiled from a ‘bottom-up’ estimate of losses (Goraya and Lukin, 2018).

The Unitywater specific data used for estimating these values included; number of burst mains and service mains, average response times to react and repair, estimated volume of water lost during each burst, average pressures in the network, estimated leakage rates from ALD programs, leakage rates measured during reservoir inspection programmes, TaKaDu’s assessments of the rate of rise of leakage and “SmartBall” trials (which entail inserting a multi-sensor spherical ball into trunk mains to collect information about pipe integrity and leakage).

Data was sourced from Unitywater’s maintenance management and SCADA systems, Takadu, ALD records, fire flow records and specific inspection programmes.

The accuracy of some of this data is questionable, e.g. field estimates of burst volumes, reported ALD leakage rates, etc. In addition, the assessment includes an assumption that data is representative across the network (e.g. from limited smart ball trials and reservoir inspection programs). Nevertheless, the assessment is a “best guess” at what makes up Unitywater’s real losses.

Based on this data, the current reportable losses of 51 L/conn/day is made up as follows and illustrated in Figure 1.

Reported Bursts	8.7 L/conn/day
Background Leakage	18.2 L/conn/day
Detectable Leakage	24.1 L/conn/day

Unitywater’s current aspirational long-term target is to reduce leakage below 40 L/conn/day.

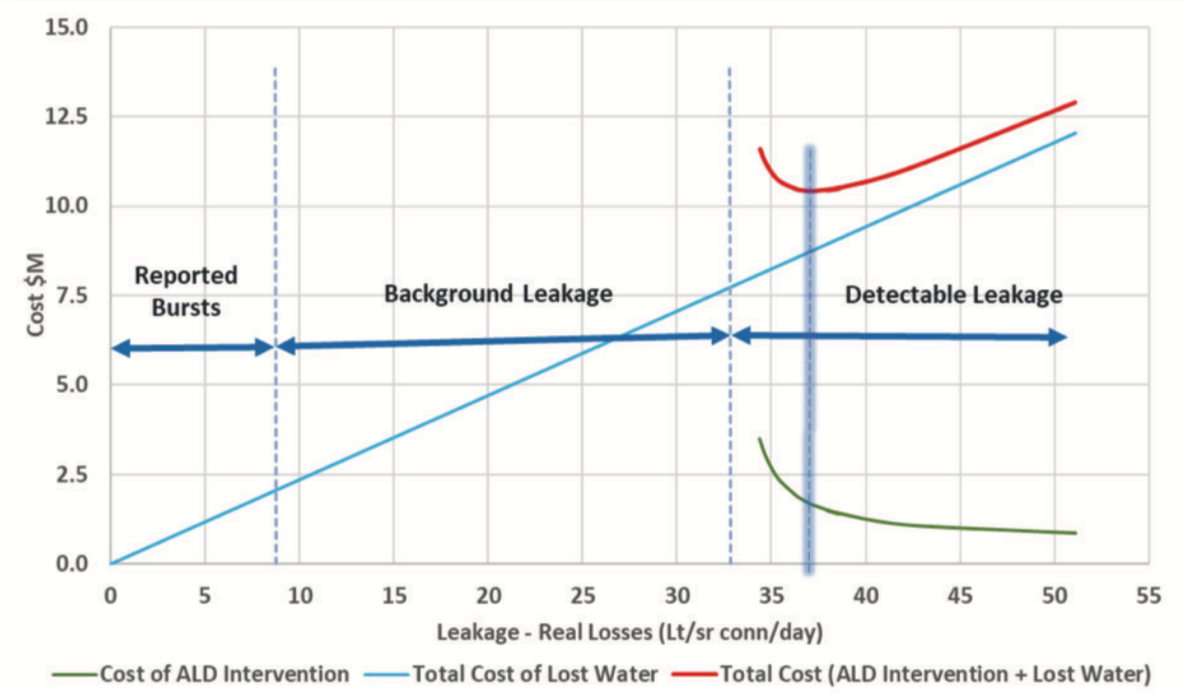

Figure 1: Economic Level of Leakage using Active Leakage Detection

ECONOMICAL LEVEL OF LEAKAGE

The Economic Level of Leakage (ELL) is defined as the level of Real Losses at which further reduction would incur costs in excess of the benefits derived from the savings (Lambert and Lalonde, 2005; Venkatesh, 2012).

There are four primary activities that can be implemented to reduce Real Losses. These activities, illustrated in Figure 2, include:

- ALD and repairs
- Pressure Management
- Network Renewals
- Quality and speed of repairs

The point to note about these activities is that they impact differently on the types of leakage illustrated in Figure 1. For example, ALD only reduces the level of detectable leakage. It does not alter background leakage, nor does it have any impact on losses from reported bursts. Conversely, pressure management reduces all three forms of leakage losses, as does improvement and replacement of infrastructure. Speed of repairs only impacts on reported bursts.

The other characteristic of these activities is that their implementation follows a law of diminishing returns. The lower the level of real losses, the higher the cost and level of resources necessary to achieve further additional benefit (Pearson and Trow, 2005; Farley and Trow 2007).

In determining the ELL, Unitywater has investigated the economic impacts of the first three activities listed above. The fourth activity, speed of repair, has effectively already been addressed both by TaKaDu, which improves the notification timeframe for larger bursts, but also via priority settings for field crews to attend reported bursts.

An assessment of the ELL for each of the first three activities is presented below.

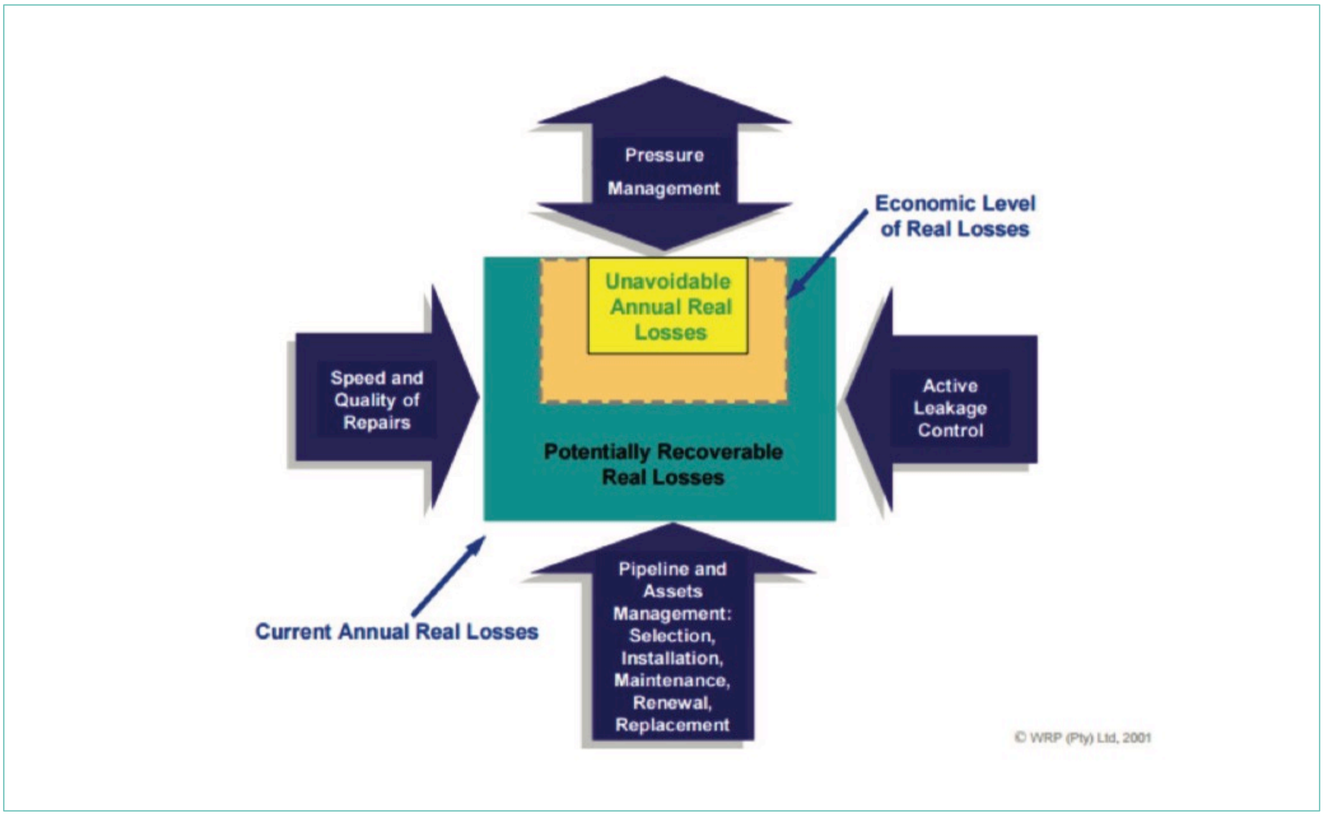

Figure 2: The four components approach to management of leakage in the network

ELL for Active Leakage Detection

Farley and Liemberger (2005) stressed that leakage monitoring is the major contributor to cost-effective and efficient leakage management. In other words, investing in an accurate leakage detection and control system is advisable from a long-term management perspective. In Unitywater, active leakage detection is used in conjunction with TaKaDu monitoring to increase detectable leakage within DMAs. These leaks can then be quickly located and repaired. The more frequently the network is “swept”, the lower the level of leakage. However, since ALD can only address Detectable Leakage (refer Figure 1), there is a limit to what ALD can achieve. To take the extreme, if the entire network were swept and all the located leaks repaired in a single day, leakage would (in theory) be reduced to 32.8 L/conn/day. This completely unachievable result represents the lower limit that could (in theory) be achieved by ALD. There is a relationship between real loss reduction and the period between ALD surveys (Farley and Trow 2007). At some point, an equilibrium is reached at which the cost of further ALD effort is equal to the cost of the additional water saved. This is the ELL for ALD.

To estimate the ELL for ALD, an approach has been developed by the UK Water Losses Task Force (Lambert and Fantozzi, 2005). The data required for this estimation includes the annual rate of rise of leakage (KL/day), the variable cost of water ($/KL) and the cost of leakage detection ($/m). The information on the last two items is readily available. Information on the rate of rise of leakage was estimated from TaKaDu’s historical records over the last three years.

Figure 1 shows the estimated cost of ALD for Unitywater’s networks to reduce Detectable Leakage. It can be observed that the cost of ALD rapidly increases as real losses are reduced below 40L/conn/d and is asymptotic to the level of the Unavoidable Real Losses. With a higher frequency of ALD ‘sweeps’ the unreported small leaks are prevented from becoming larger leaks and bursts. In Figure 1, the ALD cost curve includes the fixed annual cost of approximately $0.6M per year, which represents fixed costs attributed to business systems, equipment and staff employed by Unitywater in the reduction of non-revenue water. The economical level of ALD can then be estimated by adding the cost of water saved to the ALD cost. As shown in Figure 1, the lowest point on the total cost curve represents the economical level of leakage that can be achieved using ALD. From this total cost curve, the economical level of leakage is about 37.2 L/conn/day, and to achieve this level would require total annual expenditure of about $1.64M. The target level of leakage (40 L/conn/day) can be achieved with total annual expenditure of $1.2M.

The flatter part of the ALD intervention shows that at current levels of leakage, for every $1 spent on ALD, approximately $3 can be saved in bulk water costs. Whilst this assessment indicates considerably more expenditure on ALD could occur with a positive benefit/cost ratio, the disparity between the uncertainty of the benefits versus the certainty of costs suggests that if additional expenditure is to be contemplated, an incremental approach should be taken.

ELL for Pressure Management

Many case studies have reported leakage reduction with reducing pressure in the network (Charalambous and Kanellopoulou, 2012; Babel et al, 2009; Girard and Stewart, 2007). Pressure management impacts on all three components that make up the overall level of real losses. These three factors are illustrated in Figure 3 and are described below.

- Both background and burst flow rates will reduce because leakage flow during a reported burst is directly related to pressure (by a factor known as the N1 relationship – Lambert and Thornton, 2005).
- Burst frequency rates will also reduce due to reduced stress on the pipe network (by a factor known as the N2 relationship – Pearson et al, 2005).
- The rate of rise of detectable leakage will also reduce (Mutikanga et al, 2013)

An Excel-based model was developed to understand the impact of pressure reduction for each DMA in Unitywater. The above factors were included in the model to estimate reductions in real losses.

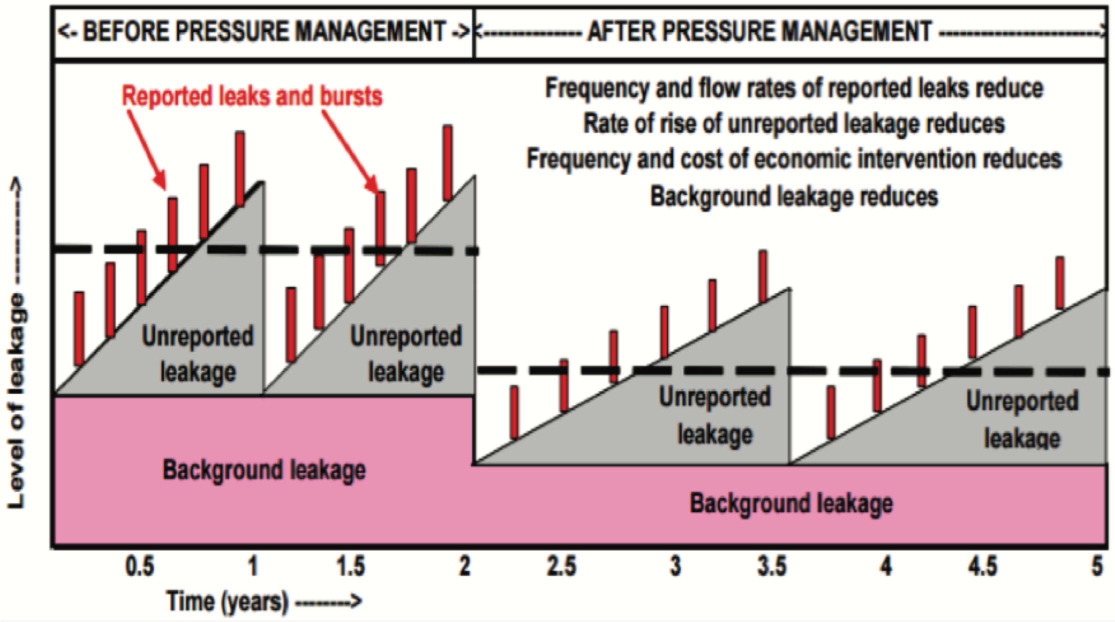

Figure 3: Illustration of impact of pressure reduction on leakage (Leakssuite, 2017A)

The static pressure across 190 DMAs within Unitywater's network ranges from 80 metres to 25 metres. This is shown in Figure 4 along with the overall network average pressure calculated as 48 metres.

To calculate the benefit of pressure reduction in the various DMAs, the assumption is first made that leakage within each DMA is a function (primarily) of residual pressure and the rate of service main failures (Goraya and Lukin, 2018). Thus, if pressure management is to be implemented, the DMAs with both higher pressure and a high number of service main failures should be prioritised. Estimated reductions in leakage in these DMAs, if pressure management were implemented, was then calculated using the outcomes of the "Golden Beach Trial" conducted by Unitywater (Unitywater, 2017). This trial suggested a linear relationship between pressure reduction and leakage losses (N1=1). The reduction in the number of breaks with pressure reduction was estimated by using the international data provided by Thornton and Lambert (2006) and (Leakssuite, 2017A). The saving in leakage was then progressively summed in the Excel model as more DMAs were selected for pressure reduction.

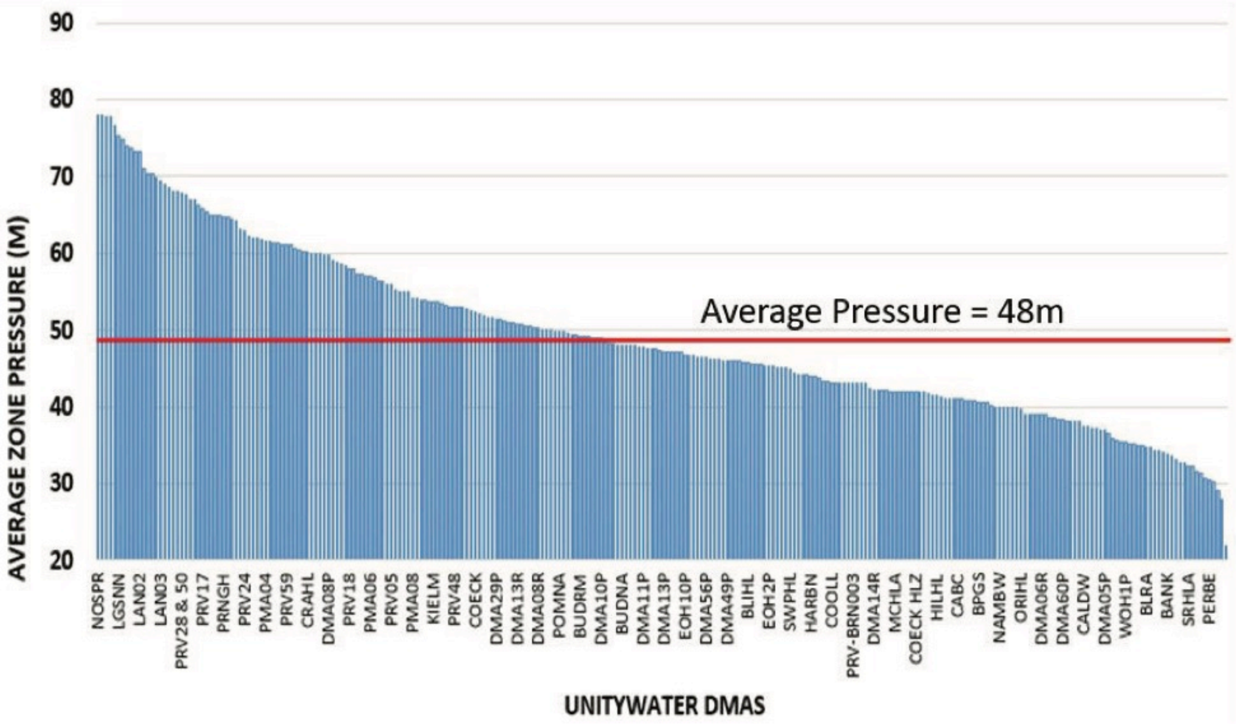

Figure 4: Existing pressure across various DMAs in Unitywater

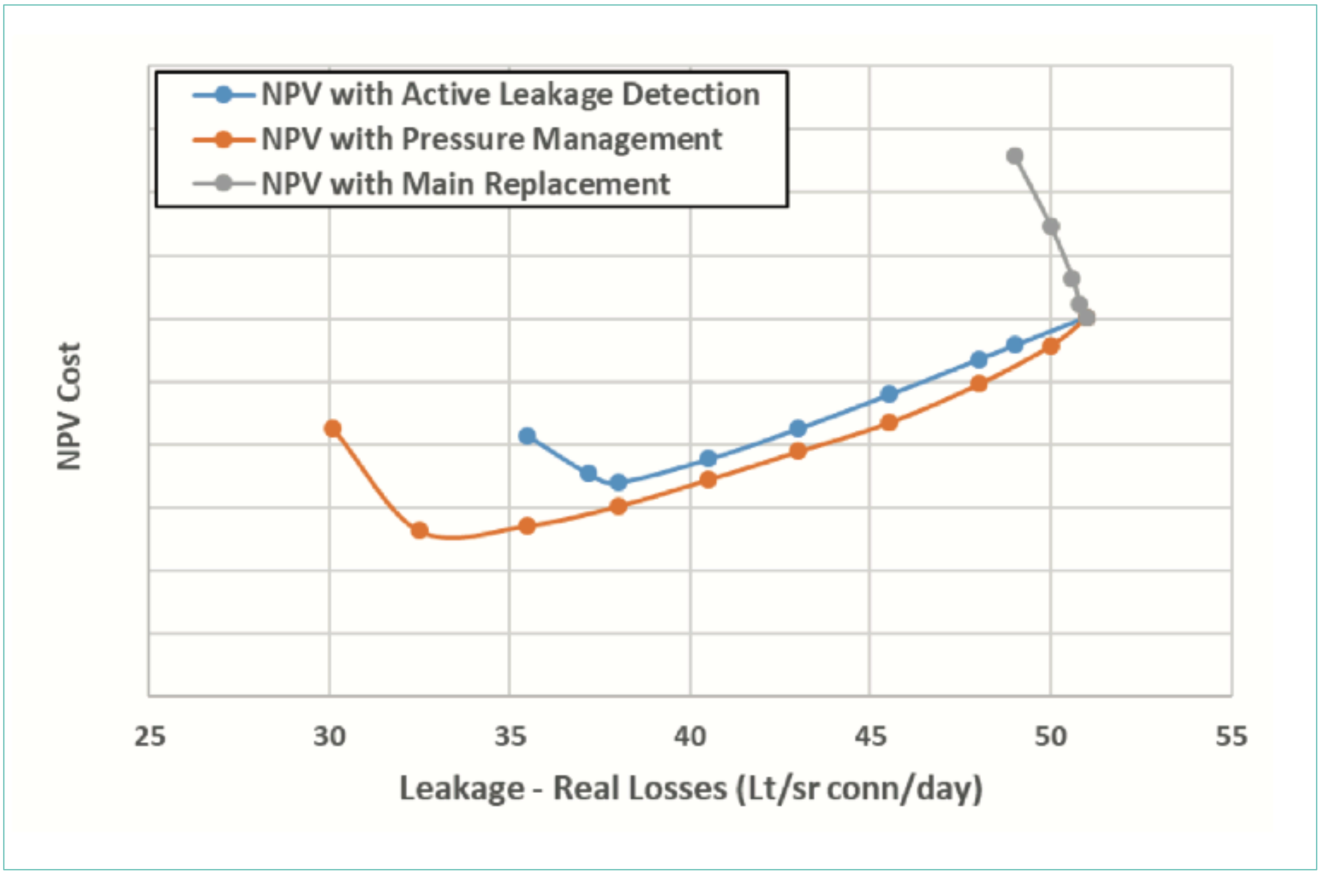

Figure 5: NPV for thirty-year cost for ALD, Pressure Management and Mains Replacement

For pressure management, the investment costs include estimates of one-off capital costs associated with the construction of a PRV chamber, zone reconfiguration and main augmentations for providing street hydrant fire flows (if required). Some communication costs will also be required to advise residents and multi-unit building body corporates, commercial business owners, etc. There are also some ongoing costs including maintenance and instrumentation renewals. Note, for ALD the cost involved is only the ongoing annual cost of the program. Hence, to make a valid comparison between the two options, a Net Present Value (NPV) assessment over a thirty-year period for both ALD and pressure management was carried out.

Some loss of income to water utilities arising from pressure management has been reported in the literature (Lambert and Thornton, 2005). However, this cost was not included in the NPV analysis as, apart from local data not being available, any such loss of income for the utility is, when viewed from a broader perspective, offset by reduced customer bills.

Figure 5 shows the comparison of NPV cost for a thirty-year period and suggests that pressure management is, overall, a marginally cheaper strategy for leakage reduction. In theory, real losses in the network can be reduced economically to about 33 L/conn/day via pressure management compared to about 37 L/conn/day with ALD only.

Table 1 below summarises the investment required to reduce leakage with pressure management in the network from the current level of 51 L/conn/day to a level of 33 L/conn/day.

Table 1: Investment required for reducing leakage by pressure management

Leakage (L/conn/ day)	Number of DMAs with Pressure Management							Total DMAs	Capital Cost
	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7		
48	6							6	$3.4M
45.5	6	7						13	$7.5M
43	5	8	10					23	$12.4M
40.5	6	10	10	12				38	$17.8M
38	5	10	10	10	10	13		58	$26.1M
35.5	10	10	10	10	14	16	17	87	$36.7M
32.5	15	15	15	15	20	20	20	120	$46.1M

In summary, to achieve a leakage reduction target of 40 L/conn/day, pressure management is required to be implemented in 38 DMAs with an investment of $17.8M (i.e. those with high residual pressures and high rates of main and service connection failures). To achieve the optimum ELL of 32.5 L/conn/d using pressure management would require a $46M investment in about 120 DMAs.

As with the approach to ALD, caution is required in relation to the Table 1 outcomes. Many of the DMAs with higher rates of leakage tend to be older low-lying coastal areas where higher density beachside development is present. Pressure reduction in these areas is problematic, given the potential to reduce available fire flows within existing multi-residential unit and commercial developments. Property owners would need to invest in upgrades of their private fire suppression systems to maintain compliance with building codes and regulations. The potential costs for private plumbing upgrades has not been considered in this assessment.

It is suggested therefore that, if pressure management is to be implemented, it should be done progressively until the true benefit and costs can be accurately established on a DMA-by-DMA basis.

ELL for Network Renewals

Network Renewals (i.e. replacement of reticulation and customer service pipes) will reduce the rate at which bursts occur in the network, as well as the amount of water lost through background leakage. This will reduce leakage as well as costs associated with the repair of mains. Figure 6 shows the distribution frequency with which main bursts occur within Unitywater's network. A small proportion of mains in the network burst at a high frequency, whilst the bulk of the network burst at a much lower frequency. For determining ELL using mains replacement, the DMAs and mains with high frequencies of failures were considered first.

To estimate the reduction in leakage that occurs with Network Renewals, the following data was used:

1. The cost of replacement of reticulation mains and service mains. The quote provided by a contractor to replace 3.5km of reticulation mains and service pipes for the Mains to Meter Trial Area (Golden Beach) was used. The quote was approximately $1000/m for main replacement including the replacement of customer service connections on both sides of the roadway.
2. The financial benefit that arises from the reduction in the number of burst main repairs.
3. The potential saving in the reduction of background leakage for the section of replaced main.
4. The marginal saving in the maintenance cost of new assets.

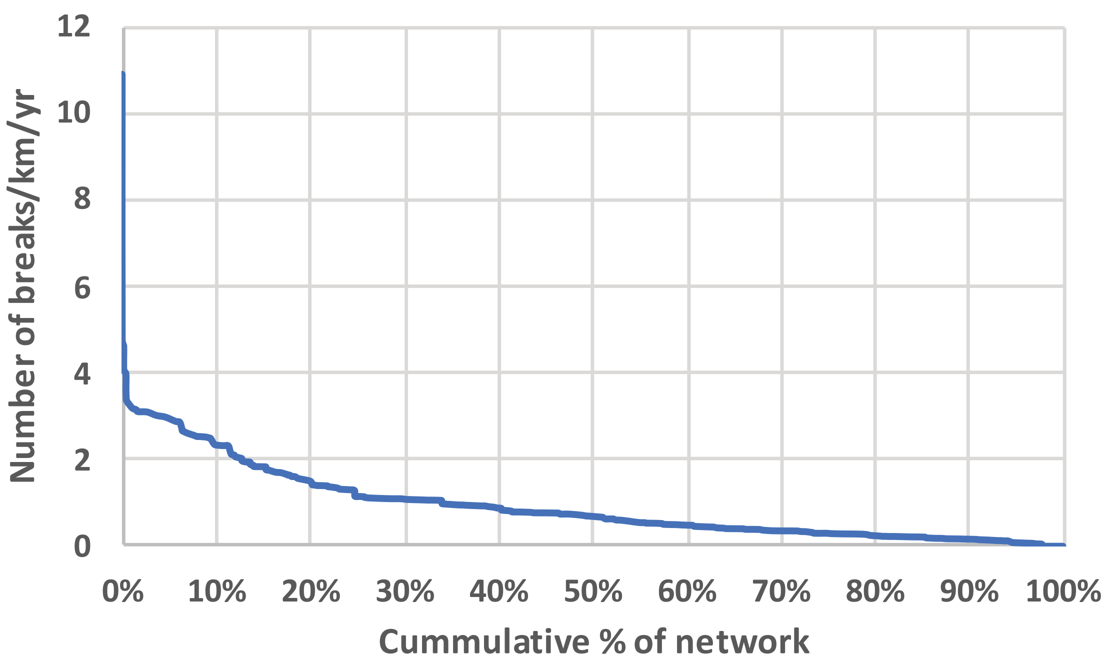

Figure 6: Frequency of mains breaks in Unitywater network

The NPV analysis for a thirty-year period of saving in leakage for main replacements is shown in Figure 5. The figure shows that replacement of mains is a very expensive option and would not result in a financially viable reduction in leakage as compared with ALD and Pressure Management. This result aligns with Trow and Farley's (2004) observation. They reported that expenditure on infrastructure improvement, even when targeted to areas most prone to high leakage, is not a particularly cost-effective method of managing leakage. Venkatesh (2012) also reported that it is difficult to justify rehabilitation economically if benefits other than just leakage reduction are not taken into consideration.

Note, this does not mean that it is not worthwhile replacing mains and service connections. Leakage reduction is only one driver in terms of asset renewal. In particular, property service pipes within Unitywater fail at rates considerably higher than international benchmarks, as opposed to reticulation mains, which have a low rate of failure (Goraya and Lukin, 2018). The rate at which property service pipes fail in some areas does impact on customer service standards, and as a result triggers replacement of these assets.

The investment required to reduce the leakage by mains replacement is shown in Table 2.

Table 2: Investment required for reducing leakage by mains replacement

Leakage (L/conn/ day)	Km of Mains Replaced (along with service connections)							Total Length (km)	Capital Cost
	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7		
46.8	5	5						10	$10.9M
46	20	10	10					40	$43.6M
44.7	20	20	20	20				80	$87.3M
41.6	25	25	25	25	25	25	30	180	$197M

Table 2 illustrates that to reduce leakage from the current 51 L/conn/day to 49 L/conn/day requires about 40km of main replacement at a cost of $43.6M. This is considerably more than the cost required to achieve the same result via ALD or Pressure Management.

CONCLUSIONS

The assessment above identifies the costs and benefits arising from the implementation of three proposed leakage reduction activities (ALD, Pressure Management and Network Renewals). Each assessment has been conducted independently, even though the implementation of one option will affect the economics of implementing the other.

The analysis shows pressure management appears to be the slightly cheaper pathway to reduced real losses. However, the incremental cost difference between ALD and Pressure Management down to the long term 40 L/conn/d target – reflected in the slope of the respective plots in Figure 5 – is probably within the limits of accuracy of this assessment. In short, both strategies are cost effective and will probably deliver similar outcomes at similar costs.

Network Renewals (i.e. the replacement of reticulation mains and property service pipes) will not be economic if done purely for leakage reasons.

At present within Unitywater, ALD is conducted largely as a reactive response to TaKaDu alerts, i.e. as TaKaDu detects new leaks within a DMA, the leak is identified in the field via ALD and repairs are triggered. However, the ELL assessment suggests that additional ALD would be financially beneficial. At current levels of leakage, for every $1 spent on ALD, approximately $3 is saved in bulk water costs. Hence it may be worthwhile conducting further periodic planned (rather than reactive) ALD sweeps in areas where service main failure rates and residual pressures are high.

Pressure Management within Unitywater is currently confined to DMAs in Redcliffe, Caboolture and Noosa. Whilst this analysis suggests Pressure Management is the (marginally) lowest cost mechanism for achieving further leakage reductions, a note of caution is required. The assessment of pressure management does not include possible cost implications for in-property fire flow requirements. In catchments with higher density and commercial developments, these costs may be significant. If further leakage reductions via Pressure Management are to be targeted, and the ELL assessment suggests they should be, then this needs to be done cautiously with modest annual expenditure increases to allow verification of the financial benefits.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the efforts of Unitywater's System Loss Team and Asset Knowledge and Planning Branch in both collating and providing the data necessary for the compilation of this paper.

REFERENCES

Babel M, Islam M and Gupta A (2009) Leakage management in a low-pressure water distribution network of Bangkok. Water Science and Technology: Water supply 9(2): 141-147.

Bureau of Meteorology (BoM) (2017) National performance report 2015-16: Urban water utilities,

Part A. Available from: http://www.bom.gov.au/water/npr/docs/2015-16/Urban-National-Performance-Report-2016-low-res.pdf

Charalambous B and Kanellopoulou D (2012) Advanced pressure management techniques to reduce and control leakage. Asian Water 28(1): 16-19.

Farley M and Trow S (2007) Losses in water distribution networks. A practitioner's guide to assessment, monitoring and control. IWA Publishing, London.

Farley M and Leimberger R (2005) Developing a non-revenue water reduction strategy: Planning and implementing the strategy. Water Science and Technology: Water supply 5(1): 41-50.

Girard M and Stewart R (2009) Implementation of pressure and leakage management strategies on the Gold Coast, Australia: Case study. Journal of Water Resources and Planning 133: 210-214.

Goraya K and Lukin M (2018) Distribution of leakage in Unitywater's water supply infrastructure. Australian Water Association, Water e-Journal 3(1). https://doi.org/10.21139/wej.2018.009

Itron (2016) Regional water meter replacement strategy: Queensland Urban Utilities and Unitywater meter replacement study report. Unitywater internal report.

Lambert A (1994) Accounting for losses: The bursts and background concept. Water and Environmental Journal 8(2): 205-214

Lambert A and Fantozzi M (2005) Recent advances in calculating economic intervention frequency for active leakage control, and implications for calculation of economic leakage levels. Water Science and Technology, 5(6).

Lambert A and Lalonde A (2005) Using practical predictions of economic intervention frequency to calculate short-run economic leakage level, with or without pressure management, Proc. Of IWA Specialised Conference Leakage 2005, Halifax.

Lambert A and Thornton J (2005) Progress in practical prediction pressure: leakage, pressure: burst frequency and pressure: consumption relationships. IWA Leakage 2005 Conference, Halifax, Canada.

Leakssuite (2017) Overview of leakage by country using reported ILI data. Available from:

http://www.leakssuite.com/ili-overviews-by-country/

Leakssuite (2017A) Pressure: Burst frequency relationships - predicting reductions in bursts on mains and services. Available from:

http://www.leakssuite.com/concepts/pressure-and-bursts/

Mutikanga H, Sharma S and Vairavamoorthy K (2013) Methods and tools for managing losses in water distribution systems. Journal of Water Resources Planning 139(2): 166-174

Pearson D, Fantozzi M, Soares D and Waldron T (2005) Searching for N2: How does pressure reduction reduce burst frequency? IWA Leakage 2005 Conference, Halifax, Canada.

Pearson D and Trow S (2005) Calculating economic levels of leakage. Proceedings of Leakage 2005 Conference, Halifax, Canada, IWA

Thorntorn J and Lambert (2006) Managing pressures to reduce new breaks. Water 21, December 2006. Available from:

https://www.waternz.org.nz/Attachment?Action=Download&Attachment_id=217

Trow S and Farley M (2004) Developing a strategy for leakage management in water distribution systems. Water Science and technology: Water Supply 4(3): 149-168.

Unitywater (2017) Annual non-revenue water report 2016-17: Projects and trial outcomes. Unitywater internal document.

Venkatesh G (2012) Cost-benefit analysis – leakage reduction by rehabilitating old water pipes: Case study of Oslo (Norway). Urban Water Journal 9(4): 277-286.

WRC (2002) Econoleak – Economic model for leakage management for water supplier in South Africa. South African Water Research Commission. Available from:

http://www.wrc.org.za/Other%20Documents/Software/econoleak/TT%20169-02.PDF

THE AUTHORS

Ken Goraya
ken.goraya@unitywater.com

Ken Goraya has more than sixteen years of experience in water distribution utilities in the fields of infrastructure planning, asset management and system leakage management.

Michael Lukin
michael.lukin@unitywater.com

Michael Lukin is the Network Planning Manager for Unitywater. He has over 30 years' experience in the planning, design and delivery of urban water and sewerage network infrastructure.