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Evaluating the Impact of Pressure and Leakage Management Strategies on Urban Water Systems: A Trial Study

Mark Girard
Executive Officer, Queensland Water Directorate, Brisbane, Queensland, Australia

Rodney A. Stewart
Lecturer, School of Engineering, Griffith University, Gold Coast, Queensland, Australia

Abstract
Many water authorities, both nationally and internationally, have been forced to rethink their strategies for achieving water balance as a result of growing water demands, droughts, reduced storage yields and environmental sustainability considerations. In particular, regulatory bodies in Australia are demanding that water managers exhaust network management efficiencies before considering new water source options (e.g. dams, desalination, pipelines etc.). Demand management incentive schemes in conjunction with water recycling and pressure and leakage management (PLM) initiatives are a few examples of the strategies being adopted by water authorities to achieve water balance without expanding their existing water infrastructure asset requirements. However, justification for PLM options remains difficult due to the limited amount of quantified evidence of the achievable benefits over an urban water systems life cycle. As the first stage in the development of a holistic PLM decision support system, this paper quantifies the benefits derived from a PLM strategy in a trial area located on the Gold Coast, in South-East Queensland, Australia.

Keywords
Pressure and Leakage Management, Urban Water Systems

1. Introduction

While fresh water may be characterized as a renewable resource, it must always be remembered that once its’ capacity has been absorbed, renewal in its simplest form as rainfall is neither predictable nor consistent. This fact is catalysed by the recent drought period that has touched most of the Australian continent during the period 2001-2004. Recent trends are suggesting amplification in the rate of climate changes. It is becoming evident that average annual rainfall in the eastern parts of the state of Queensland has fallen dramatically, particularly around the central parts. Predictive models of future average annual rainfall in Queensland suggest a 15% reduction in rainfall by the year 2030 and 40% by 2070 (Stone 2004; Crimp, 2004). As the second driest continent on the planet, Australia can least afford the proposed localized impacts of climate change. After almost four years of continued lower than average rainfall and with many water supply reservoirs at the lowest recorded levels, many Australian cities and towns continue to face severe droughts. The management of water resources is increasingly becoming a major concern for residential consumers, industry and all levels of government. Many of the water issues we face today result from the legacy of poor water resource management of the past, a rapidly changing climate due to global warming and changing attitudes to water use and security of supply. Australia is facing a water crisis in both the short and medium terms. In the short term, every Australian water service provider will need to adapt to the changing climatic conditions that are already impacting on the available yields of water storages across the country. This will include adopting new approaches to water management to meet the short term water supply deficiencies. Over the medium to longer term, the Australian population will continue to grow from its current 20 million people in 2004 (ABS, 2004) to reach its' predicted population peak of approximately 30 million people in the year 2050. All levels of Government in Australia must accept that the greatest challenge we may face is how we meet the water needs of future generations of Australians by investing in adequate planning now, to ensure a sustainable water future.

In an attempt to better utilise existing urban water resources, this paper examines the benefits of PLM strategies, which appear to be one of the least cost alternatives to meeting water supply needs. PLM was applied on a trial basis on the Gold Coast to measure its impact on the performance and consumption sustainability, asset management and total urban water life cycle. The main objectives of the investigation included: (1) investigating whether PLM is a valid demand management alternative for the Gold Coast; (2) evaluating the impact of PLM initiatives on water consumption and infrastructure failures on the Gold Coast; and (3) exploring the effect of PLM on the Total Water Cycle. The outcomes of this investigation included: justification for the city-wide implementation of PLM on the Gold Coast; expansion of the water industry's knowledge of the impacts and benefits of PLM strategies; and the quantification of asset management benefits achievable from PLM implementation.

2. Pressure and Leakage Management (PLM): Gold Coast Context

In 2002/2003, approximately 10% of the potable water supplied to the Gold Coast from the Molendinar and Mudgeeraba Water Purification Plants (WPP), and from the Logan City connection, was unaccounted for. This is based on a comparison of the metered supply measured at the WPP's and the Logan boundary, and the supply to properties as measured by individual property water meters. This is comparable with the national average of 9.6%, as documented by the Water Services Association of Australia (WSAA) (WSAA Facts, 2003). Background leakage and water meter inaccuracies can explain up to 85% of system water losses. Having a program in place for the renewal of meters will address the potential inaccuracies associated with apparent losses. PLM, as addressed in this paper, aims to reduce the background leakage component of system water losses by proactively identifying and repairing leaks, and by minimising the quantity of water lost through leaks by reducing water pressure.

To effectively manage leakage and pressure on the Gold Coast involves reconfiguring the water reticulation network into a number of District Metered Areas (DMA). A DMA is a small section of the network (typically servicing 500-1500 connections) that is arranged, with appropriate valving, such that it is fed by preferably only one water main. A flow meter would be installed on that water main, as would a flow-controlled pressure-reducing valve (PRV). In a report by Wide Bay Water (2003), it was recommended that the City's existing water reticulation system could be divided into 155 permanent DMA's, however, further analysis by Gold Coast Water personnel has indicated that 108 of those would be operationally and financially viable. It is proposed that the coastal strip, which incorporates a large number of high-rise developments, will not be divided into DMA's due to the operational difficulties that pressure control would cause. The DMA flow meter allows Gold Coast Water to monitor the quantity of water entering the DMA. During low flow periods, such as the early hours of the morning (night flows), the majority of flow being measured by the flow meter would be leakage. The location of leaks can be determined using specialized equipment, such as leak noise correlators and acoustic loggers, and then repaired. Having the water network divided into DMA's would allow Gold Coast Water to identify new leaks when they occur (by monitoring the night flows constantly and observing increases), and make it easier to find where they are occurring.

Installation of a PRV on the water main supplying a DMA allows Gold Coast Water to control the water pressure experienced at properties within the DMA. By using a flow-controlled PRV, the pressure in the DMA varies according to the flow (or demand) experienced in the area. Therefore, during high demand times such as the morning and evening peak periods, the PRV allows increased water pressure, while during low flow periods, such as overnight, the pressure is reduced quite considerably. It is important to note that the PRV's would be set to ensure that the pressure never drops below the Gold Coast Water minimum level of service (220 kPa). Furthermore, in the event of high demand, such as during a fire, the PRV automatically adjusts to increase water pressure, regardless of the time of day.

3. PLM Field Trial – Burliegh Waters, Gold Coast, Australia

As part of the first phase of this research investigation, a pilot study area was established to verify the actual benefits of district metering, pressure management and leakage control at a DMA level. The DMA is situated in Burleigh Waters which is part of Gold Coast Water's supply area 07. The area supplies 3,310 connections through 46.67 km of water mains and is supplied via a 200mm *Aquamaster* "S" *Magflow* meter and pressure reduced through a 200mm *Dorot* pressure reducing valve. Additionally, the DMA is locked-in by two boundary valves. Water demand management at the DMA level comprised of four fundamental activities, including: establishment; flow and pressure monitoring; leakage detection; and pressure management (control).

3.1 Establishment

This is the physical set up of the DMA on the ground and involves closure of identified boundary valves and pressure monitoring. At this stage it was vital that a pressure zero test was conducted. This element involves shutting off the water which feeds into the DMA at the supply point, and monitoring the pressure at a point in the zone (usually the high point) to confirm the integrity of the zone. The test indicates if that DMA is "breached" (i.e. a boundary valve is open, or partly open) by observing the pressure drop at the monitoring point. If pressure does not continue to fall this indicates that the zone is being supplied by another route. All boundary valves are then checked by sounding and eventually the passing valve can be identified and fully closed (Carpenter *et al.* 2002; Lambert, 2000).

3.2 Flow and Pressure Monitoring

Flow logging allows the flow rate into a supply system to be monitored. From this data we can determine the demand of an area or if a burst has occurred. This type of incident will show up as an increase in the minimum night flow, and action can then be taken to locate the burst and have it repaired. Pressure logging determines the current pressures within the DMA and can help identify potential problems associated within a reticulation network. It is also a tool for determining whether there is scope for pressure reduction in the DMA.

3.3 Leakage Detection

Active Leakage Control (ALC) includes a number of methods, which can be used individually or collectively (Hunaidi, 2000): sounding; correlation survey; acoustic loggers; minimum night flow survey; and step testing. All of these methods were applied in the trial area.

3.4 Pressure Management

Pressure management is an effective way to reduce the amount of water physically lost in a system. Pressure management can be implemented without affecting service levels when activated during low demand periods, such as overnight. At night time pressure is often at its highest, and leakage is the main component of water use (Lambert, 2000). A small reduction in pressure can result in a significant reduction in real water losses as a result of less leakage (Thornton, 2004). It is vital to evaluate an area first such as a DMA to gain an understanding of its background losses, before the introduction of pressure control. The effect of pressure control on real losses can then be quantified. It is also beneficial to establish pressure control whilst conducting leak detection find-and-fix surveys (Carpenter *et al*. 2002; Thornton, 2004).

3.5 Results

The flow modulation controller was commissioned on the 01st December 2003 with observations of immediate water savings over the first night. The controller was set to maintain 34m of pressure at the designated critical point from the 01/12/03 through to the 07/01/04. Table 1 details the total average water volume savings after leakage control and flow modulation. Moreover, Figure 1 illustrates the total reduction in average minimum night flows during the trial period.

Table 1: Total Water Savings in Burleigh Waters from Leakage Detection & Pressure Control

Average Minimum Night Flow Pre – LD* & PR** (adjusted)	6.20 l/sec	Difference in MNF
Average Minimum Night Flow Post – LD* & PR**	4.13 l/sec	2.33 l/sec
Average Minimum Night Flow Post – LD* & PR** and Flow Modulation	3.25 l/sec	0.88 l/sec
Average Total Saving		2.95 l/sec or 0.24 ML/day or 89.15 ML/year

*LD – Leakage Detection
**PR – Pressure Reduction

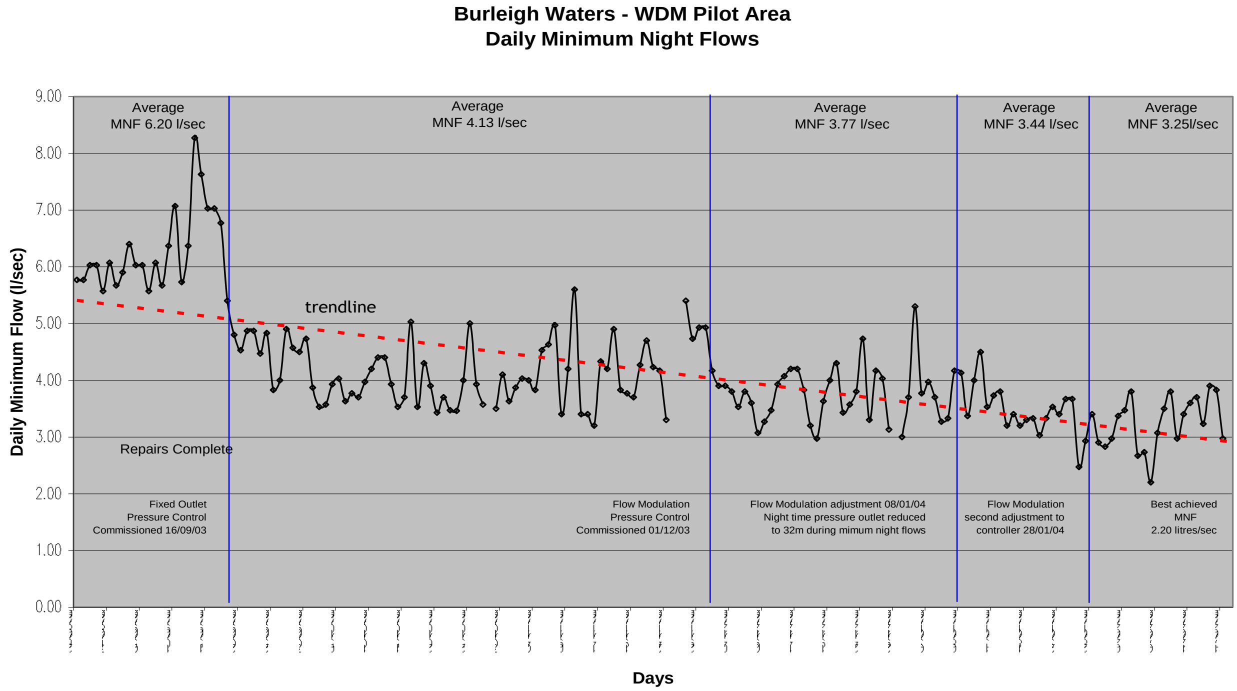

Figure 1: Changes in Average Daily Night Flow during the Burleigh Waters Trial

3.6 Outcomes, Benefits and Impacts

A number of monetary and non-monetary benefits resulted from the PLM strategies adopted in the Burleigh trial area. These benefits include:

- Short-term financial benefits associated with the costs of buying water from a bulk supplier, water treatment cost savings including the marginal costs of chemicals, power and sludge disposal and water reticulation costs.
- Longer-term benefits relate to whole-of-life asset costs and include a reduction in pipe failures, extended asset life and savings in the costs of repairing burst mains.
- Indirect financial benefits also result from more efficient use of existing water supplies. In particular, reduced water losses helps to ensure that existing water supplies can meet future increases in demand. This can defer construction of new water infrastructure such as dams, treatment plants, reservoirs and water mains.
- A degree of drought security is also possible as a lower water demand means that the security of water supply can be maintained for longer periods.
- An increased knowledge of the distribution system. This enables staff to become more familiar with the system, including the location of mains and valves. This knowledge assists staff to respond more quickly to emergencies such as mains breaks and provides an early indication of any increases in water losses from leaks.
- Improved public relations can be expected as Council can inform customers of their efforts to conserve water, save money and improve service delivery by having fewer unplanned water supply failures. Field teams undertaking water audits, leak detection and maintenance work also provide visual evidence that the water system is being well maintained.
- From a total of 3,310 connections (3,877 properties) in the pilot area, only two customer complaints were received as a result of the pressure reductions in the area. These complaints related to the

following: very low water pressure in a second storey bathroom due to corroded internal plumbing at a residence; and reduced operating capacity of an irrigation system at one gated community.

PLM also offers management offers a range of potential non-monetary benefits. Primarily, these relate to the environmental and social benefits of deferring or reducing the need for additional capacity in the water supply system. The construction of major dams can have substantial impacts on the environment through land clearing, changes to terrestrial and aquatic ecosystems, changes to flow regimes and water quality and disruption to existing communities. A further benefit is that loss reduction replaces system capacity at a very low cost to the Gold Coast, with very low operating costs and negligible power consumption. Consequently, it has substantial greenhouse gas benefits compared with providing additional system capacity.

Additionally, the trial study demonstrated the substantial asset management benefits resulting from PLM initiatives. There was a rapid decrease in water main and water service breaks following the implementation of pressure control in the trial area. Over the 8 months following the PRV commissioning, water main breaks reduced by approximately 80% and water service breaks by approximately 90%. The infrastructure (water mains and water services) within the trial area was constructed between the early 1970's through to mid 1980. According to the manufacturers' specifications, at current network pressures, the water mains and services of this vintage are approximately half way through their designed asset life. The average network pressure in the Burleigh Waters trial area is at the lower end of the range at 38m. The remaining 16 water supply zones range between 34m and 50m. Gold Coast Water manages assets that are much older than those in the trial area. On this basis they could anticipate equivalent, if not greater savings from future trial areas.

4. Future Work: Evaluating the City Wide Implementation of PLM

PLM presents a good opportunity to achieve significant water savings across Gold Coast City. By dividing the water network into zones, referred to as District Metered Areas, and installing flow meters and flow-controlled pressure-reducing valves on the supply main to those zones, it is possible to more easily detect and repair leaks that would have previously gone unnoticed. Furthermore, excessive water pressures can be reduced in such a way as to reduce the incidence of water main and property service breaks, the rate at which leakage occurs and the consumption occurring in the zone. The pilot trial in Burleigh Waters achieved excellent results, with a significant reduction in leakage and consumption of 2.95 L/s across the area, and reduced property service and water main breaks (80% and 90% respectively). On that basis, and given the pressures throughout the remainder of the city are higher and assets significantly older, Gold Coast Water have an opportunity to capitalise on obvious operational improvements to the water reticulation network. Following the least cost planning rule, pressure control should constitute one of the first infrastructure projects implemented by Gold Coast Water to improve its network efficiency and passively reduce demand for the water supply.

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