

# REMOTE DIAGNOSIS OF LEAKAGE IN RESIDENTIAL HOUSEHOLDS

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## Abstract

Wide Bay Water Corporation is in the process of implementing automated meter reading technology in their water network. This technology allows the remote measurement and evaluation of water consumption at a residential and commercial level using a FIREFLY® data logger and Commstar software. By using the FIREFLY®, water usage patterns can be recorded each hour and stored for collection via a drive-by system.

This paper presents the findings from a pilot study in Hervey Bay Queensland that Wide Bay Water Corporation has undertaken in conjunction with Griffith University. The objective was to identify household water leakage in residential properties located within a selected district metered area (DMA). Research outcomes include a water use profile of the metered residential properties, the types of leaks encountered and the cost of leak repairs.

At the commencement of the program it was found that 2% of the meters accounted for 24% of the night time consumption. This study provides evidence that automated meter reading technology can quantify water leakage beyond the meter.

## Introduction

Water conservation consists of making better and more efficient use of water resources which implies a reduction in water use or in water losses. Much has been written and discussed about reservoir losses, seepage and leakage from mains and services pipes; however, end use studies on water losses at the household level, after the meter, have been limited.

Obradovic and Lonsdale (1998) pointed out that the lowest level in the hierarchy of data collection is the demand of individual customers. They suggested that it might be a worthwhile exercise to invert the hierarchy since the customer is the most important element in the system. They stated that an important



Figure 1. FIREFLY® and Water Meter installation at residential property.

reason why customer billing records should be regarded as the top is that other levels of data are often derived from the customer demand data.

Small and medium sized leaks in household plumbing are disguised amongst legitimate customer demand. The leaks may be undetected below ground, through dripping taps and toilet cisterns. When considered individually leaks may seem insignificant; however, taken collectively over a long period they result in a major loss of water (Buchberger & Palli, 2004). The rate of water loss can vary depending on the type and severity of the leak. Generally, dripping taps can lose between 3-30 litres per day, leakage from toilet cisterns can range from 10 litres per day for invisible leaks to 340 litres per day or more for leaks large enough to be seen and/or have an audible refilling sound.

Troy & Randolph's (2005) paper, which discussed water conservation from a social and behavioural perspective, indicated that 84% of survey respondents said they knew of no leaks in their water pipes or fittings. Among the minority who did report leaks, 7% said dripping taps were the culprit. Similar

**2% of meters accounted for 24% of night-time consumption.**

findings were also found by other studies. The AWWA report (Mayer *et al.*, 1999) - *Residential End Uses of Water* (REUWS) revealed that residential leakage problems typically occur in a small number of homes: nearly 67% of homes in their study leaked on average 10 gallons per day or less, but 5.5% leaked more than 100 gallons a day. Yarra Valley's Residential End Use Measurement Study (Roberts, 2004) found that leakage accounted for 7.5% of total indoor use or 39 litres per day. The study noted the findings should be handled with care given the small sample size and that the leakage was

concentrated in a relatively small proportion of the homes. In the Tampa retrofit study (Mayer *et al.*, 2004) it was found that 38% of the leaking homes were responsible for more than 88% of the total per capita leakage. In some of the houses the source of the leak could not be stated; running toilet, open tap, leaky sprinkler valve or slow leaking water pipe could cause 272 gallons lost per day. Moreover, some studies (Mayer *et al.*, 1999:2004) recommended that a leak detection and repair program could significantly reduce consumption; however they did not examine the water savings potential.

## Smart Metering

The conventional metering system in Australia has a major limitation, i.e. meters only record the total volume of water passing through and are not able to determine usage patterns. A smart meter is a normal water meter linked to a device that allows for the continuous reading of water consumption. The information is available as an electronic signal, it can be captured, logged and processed like any other signal (Hauber-Davidson & Idris, 2006), hence manual reading of the meter is no longer required.

An automated meter reading system (AMR) with this capability provides benefits for both customers and water

authorities. Customers will be able to receive more detailed information about their water usage, allowing them to understand their consumption patterns. Information may also identify internal leaks, enabling customers to fix the problem, saving water and money. Data collected can provide a more accurate picture of a city's water consumption by identifying time-of-use and water use patterns for all consumers. This will allow water authorities to develop targeted education campaigns relating to conservation and water use, and an opportunity to develop different tariff systems to influence consumer behaviour.

### Wide Bay Water Corporation

The City of Hervey Bay is situated on the Queensland coast approximately 300 kilometres north of Brisbane. It is one of the fastest growing areas in Australia with a current population of 54,000. The municipality covers an area of approximately 2,350 square kilometres stretching from Burrum Heads in the north to River Heads in the south, and encompasses the northern half of Heritage listed Fraser Island.

Wide Bay Water Corporation is Queensland's only local government corporatised water business. Wide Bay Water Corporation provides water and sewage services to the municipality and also undertakes the planning, development and operation of water distribution infrastructure in the collection, distribution and disposal of water.

The application of smart metering in Hervey Bay was aimed at providing customer consumption data for the first time at city-wide level. The smart meters and the policies that this technology enables will provide benefits to Wide Bay Water Corporation and its customers including: decreasing water use, minimising water pumping and greenhouse gas emissions and increasing infrastructure life.

During 2007 Wide Bay Water Corporation committed to the implementation of a remote meter

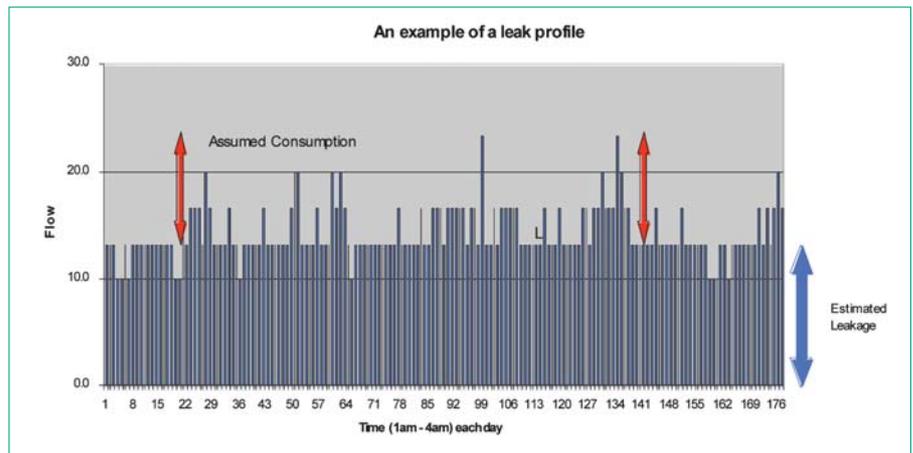


Figure 2. An example of a leak profile.

reading system. This system will combine drive-by water meter reading and data logging for all 22,000 domestic water meters.

All domestic meters in Hervey Bay have been replaced with new Elster V100 meters that have a FIREFLY® data logger attached (Figure 1). The FIREFLY® records a magnetic pulse from the meter at a rate of one pulse per five litres. These units are capable of recording hourly flow data, and transmit to a receiver on a hand-held computer or in a drive-by unit. The logger can store six reads at four hour intervals each day for a minimum of 120 days. The battery life for the logger and transmitter is expected to last for a minimum of five years.

### The Pilot Study

The objective of the pilot study was to identify household water leakage in a selected district metered area (DMA), the Point Vernon district (see Figure 2) using the automated metering system and subsequently implement a repair program to minimise water loss and assess the capability of the smart metering technology to identify in house leakage. By using the system, household leakage can be identified in two ways, i.e.:

1. Via an alarm which is picked up during the meter reading process. A trickle alert flags that no '0' has been recorded in the previous 48 hours;
2. Via a review of the profile read when data is exported in to the software.

### Research Approach

The research process of the pilot study covered four phases, i.e. leak identification, household alert, plumbing audit and household survey. The details are outlined below.

#### Leak identification

On 23rd October 2007, 2,359 residential meters were read in Point Vernon; 47 meters flagged a trickle alert; Figure 2 illustrates the location of each leak. Profiles of the 47 meters were downloaded providing information on water use for the previous 177 days. The raw data was examined; this provided hourly, daily and monthly data for each meter. In order to assess flow rates and total leakage post-meter, the leakage component had to be separated from consumption. Each meter was analysed individually each day between 1am - 4am to obtain an average minimum night flow. The information was converted to a graph, illustrating a leak pattern as illustrated in Figure 1. The most consistent level of the flow was assumed to be the leak rate, and spikes were considered to be elements of consumption. The average flow rate for those 3 hours minus estimated consumption was assumed to be the average leak rate per hour - this leak rate was subtracted from the consumption volume in each hour of the day. This allowed us to monitor the consumption versus leakage and estimate hourly losses.

The leak pattern provides a visual display of the leakage occurring over a time frame. Table 1 shows the total consumption of all meters in Point Vernon and the 47 meters as a percentage of the total. The hourly consumption between 1am and 4 am highlights that 2% of meters account for nearly 24% of recorded consumption during that time.

Table 1. Meter reading (litres recorded) on 23 October 2007.

Time	Total Consumption 2359 meters	Consumption of 47 meters	47 Meters as % of total consumption
1 - 2am	6220	1350	21.70
2 - 3am	5400	1260	23.33
3 - 4am	5520	1420	25.72

**Leak alert**

The 47 households whose meters flagged a trickle alert were contacted by letter stating that they may have a potential leak. The letter offered a free household audit and \$100 towards repair. Households who did not respond to the initial communication were contacted by telephone one week later. A second letter was then sent to the remaining households which provided more detailed information on their actual leak rate including volume loss and dollar value and again encouraged participation. For those households who yielded no response, a house visit was made in anticipation that a conversation may lead to participation. Figure 3 illustrates the response to communication

**Household plumbing audit**

A contract plumber was employed throughout the duration of the study in order to maintain the quality of work and to keep records of leaks and costs of repair. The repair program commenced on 5 November 2007 and ended on 5 December 2007. The plumber was employed for a total of 38 hours over this time.

Of the 38 households who responded, 32 were audited at a cost of \$60 each. 17 were repaired by WBW at an average cost of \$89 and 17 undertook their own repair, with only three applying for rebate within 8 weeks of the program.

The meters were read again on 20 January and the combined night time leakage/consumption of those 47 households had reduced from ca. 1300 to 356 litres per hour. In 11 (23%) of the households the leakage STILL accounted for over 70% of their daily metered consumption. Since 20 January, three more households have been repaired which brought the minimum night flow down to an average 173 litres per hour. Six households that did not respond to communication no longer had leaks; it is assumed they undertook their own repair.

**Project Cost and Savings**

Therefore the general savings as a result of the program is 1095 litres per hour. Fig 4 illustrates the change in minimum night flow as a result of the repair program. The total cost of the program including project management and staff time was \$5,168.27 (excluding rebates); materials accounted for \$448.22. If the properties had been allowed to continue leaking at the rate of 1095 litres per hour then the water lost would amount to 26,280 litres per day and 9,565,920 litres per year.

The costs for intervention to undertake the identification and repair program equated to \$0.54 to save a kilolitre of water. The pilot study does not include the cost of installing and



**Figure 3. Location of Leaking Households in Point Vernon DMA.**

maintaining the meters. Once the program has been extended into other DMA's with more diverse customer bases, installation, maintenance and metering costs and the real cost of this water loss strategy using Least Cost Planning principles can be undertaken (White & Howe, 1998).

**Household Survey**

The period monitored was from May 2007 to January 2008. 38 out of 47 households responded to the letter and house visit. Among them 32 participated in the survey, with a total of 82 people residing in these households. The survey requested information on basic demographics, age of house and type of plumbing materials. 62% of respondents said they there was no leak, 12% checked for leaks after receiving the letter and 21% thought that they had a leak.

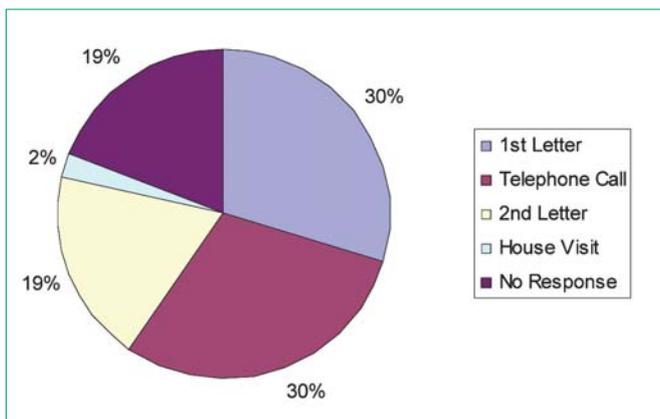
The run time of identified leaks ranged from 6 days to 277 days and the average leak duration was 156 days. The range of household loss was 864 litres to 310,262 litres and the leak flow rate varied from 5.56 litres per hour to 343 litres per hour. The lowest flow rate that the meters can reliably detect is 3.33 litres per hour. The total water lost during that period for 47 meters was 4.2 ML. It is possible to determine the start date of the leak, run time and peak flow rate: the meters commenced data logging in May 2007.

**Types of leaks identified**

This study identified seven major types of leaks, Fig 5 illustrates the number of leaks by leak type, among them toilet leaks represent 46%. The following sections discuss each leak type in detail.

**Supply pipes post meter - plastic pipes**

There were 3 leaks on the plastic pipe post meter; 2 were longitudinal splits in the polyethylene pipes and one was on a T-Junction. The splits were at what appeared to be a weak point in the polyethylene as the thickness of the pipe was not uniform. The pipes were monitored over several weeks, looking



**Figure 4. Households Response to Communication.**

**Table 2. Age of leaking households**

Age of house	
Before 1969	18.75%
1970-1979	34.37%
1980-1989	12.50%
1990-1999	28.12%
2000-2005	6.25%

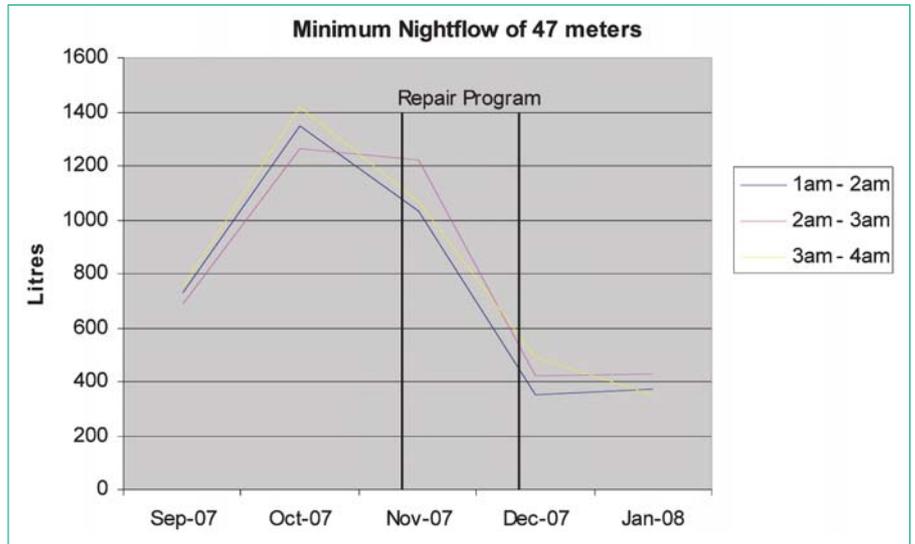
for evidence of damp patches. The property owners took meter readings last thing at night and first thing in the morning, both reported a progressive increase in the flow rate. The leaks finally appeared after 4 weeks, a successful dig located the leaks and the split sections were replaced. The T-Junction leak was found using leak detection equipment after several unsuccessful digs. The sounding stick located the leak and digging recommenced, the pipe was lying upon gravel bed and the water was seeping below ground.

**Copper pipes**

Copper pipe leaks were found at 2 homes; one home was built in 1960 - 1969 and the other between 1970 and 1979. The older property had two toilet leaks and a suspected supply pipe leak; which could not be located. The house was monitored after repair of the toilets and there was a steady increase in the flow rate from 15.57 litres per hour peaking 6 weeks later at 93 litres per hour. When the toilets were fixed, the pressure would have increased because the effective "relief valve" offered by the leak had stopped, thus decreasing flow and increasing pressure. If the leak was a corrosion hole in the copper pipe, then particles of weak material would have been lost making the hole slightly larger and the flow greater; due to the pressure and size of hole. A plumber confirmed that copper pipe work was leaking beneath the house and new pipe lagging was applied to the existing pipe. The 1970's residence had major pipe work replaced beneath the house. The flow rate was a steady 36 litres per hour. A check of historic billing records showed that the customer had received annual water bills of \$300 for 3 years; suggesting a long running leak. The leaks accounted for over 73% of actual consumption and repair costs were \$550 and \$1200 respectively.

**Galvanised pipe**

There were galvanised pipe leaks at 3 homes; the pipe work was part of an external standing



**Figure 5. Change in minimum night flow as a result of the repair program.**

tap. The area around the taps was greener in comparison to the rest of the garden and the ground damp to touch.

**Taps**

There were 5 kitchen taps and 2 external taps leaking. Washers were replaced on all taps except one; the set of taps were replaced with a flick mixer. When studying the leak graph of two further homes an erratic pattern was presented which involved no recorded consumption on some days. The plumbing audit could not find evidence of a leak and after further discussion, it was established that one occupant had difficulty in turning off the taps due to an arthritic condition and the other admitted to not always turning the taps off completely.

**Toilets**

There were 21 leaking toilets; five properties were experiencing leaks in both toilets. An audible hiss could be heard upon entering many homes. There were 8 dual flush toilets with cistern size 6/3 litres, leaking in the range of 13.3 litres per hour to 343 litres per hour. The size of the latter leak was a result of a stuck full-flush toilet button in an empty rental property. The owner was notified and turned the water off until the arranged repair date; this leak ran for 18 days. There were 5 leaks in dual flush

toilets with cistern size 9/4.5 litres: the range of flow rates was 13.3 litres per hour to 35.6 litres per hour. There were 8 leaks in single flush toilets, the flow rates ranged from 12.2 litres per hour to 38.9 litres per hour, the cistern size ranged from 11 - 15 litres capacity. The majority of toilet leaks were caused by failure of the 'top valve' in the cylindrical control units in the cisterns. Further study will investigate why are so many toilets are failing.

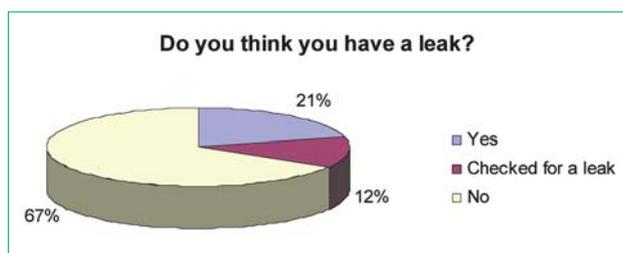
**Other leaks**

There were three meter problems; two service nuts were loose and one meter had been damaged by building works. There were two hot water system leaks and a faulty timer on an irrigation system. There were 11 leak types not confirmed, however an assumption of the leak is made according to the graph pattern.

**Summary**

The pilot study demonstrates that this technology can more accurately account for water losses at the end user level, some key findings regarding leak characteristics include:

- 2% of the meters accounted for 24% of consumption between 1am - 4am.
- Toilets accounted for 46% of the types of leak.
- Leaks occurred in both the old single flush and the newer efficient models.
- 21% of households who said that they knew of a leak; stated toilet and tap problems.
- 19% of homes did not respond to any form of communication.



**Figure 6. Household awareness of leaks.**

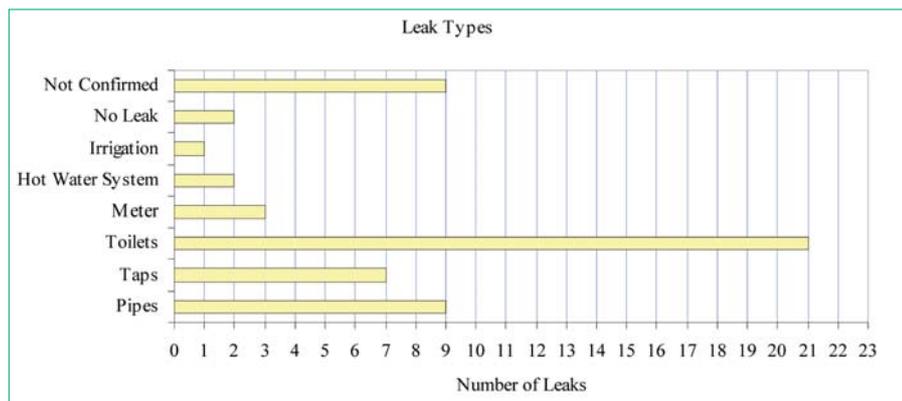


Figure 7. Type of Leaks Identified.

- The homes that experienced leaking pipes were not aware of the problem even when the leaks were large.
- Leaking taps can be fixed at the lowest cost.
- Lagging to copper pipes was the most expensive repair.

From a water business perspective the direct cost of intervention for this pilot program has been assessed as \$0.54/kL and this gives strong incentive to extend the program into more DMA's allowing the real cost of this water loss management strategy to be determined using Least Cost Planning principles. The comprehensive coverage of all residential and commercial meters throughout the city provided a unique opportunity to remotely monitor the usage and leakage components of all forms of water consumption. This information has implications for post meter leak detection, water loss prediction models and the development of effective policies to reduce such losses.

### The Greater Study

The pilot study was the first stage of a larger research project involving Griffith University and Wide Bay Water with funding provided by the Australian Research Council. The pilot study raised some important research questions; should we tolerate losses in households even though water has been metered and paid for? How do you enforce repair, who pays and what are the social and political ramifications? Would this type of enforcement be pursued only in times of water scarcity? Is leak identification and

rectification a least cost water conservation approach?

The greater study is currently expanding to other district metered areas of Hervey Bay and research objectives include quantifying the level of residential water loss; understanding the physical and behaviour reasons for the losses; quantifying the water savings potential and applying Least Cost Planning to investigate the cost and benefits of implementing active leakage control at the residential level and place in context alongside other demand management options.

The next phase of study will also consider what impact real time consumption data has on water planning and management of water resources. What is the night time consumption of residential households in Hervey Bay? Does the night time consumption compare to estimates of consumption in other national or international regions? What is the end use consumption attributed to household leakage in Hervey Bay? Does the amount of household leakage compare with earlier end use studies in Australian regions?

The research will explore policy approaches for residential water loss management and the implications for relevant stakeholders; government through to customers. Finally, the greater study seeks to provide robust evidence that leakage identification and repair rectification is a viable strategy for ensuring the sustainable conservation of water resources.

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Table 3. Average leak flow rates according to toilet type.

Toilet Type	Min Flow/Hour	Max Flow/Hour	Average Flow/Hour
6/3	13.3	343	16.7 (excl 343 outlier)
9/4.5	13.3	35.6	20
Single	12.2	38.9	19.4