

University of Southern Queensland
Faculty of Engineering and Surveying

Water Metering and Revenue Protection

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Abstract

It is common for water supply authorities to have considerable, “Unaccounted-For” water (UFW) through water loss (‘leakage’) from the water distribution system. Water loss reduces the amount of available water for end users and impacts upon the Water Supplier financially, as it strives to supply water at a fair and reasonable price, while seeking to recover the cost of supplying water to its customers.

It is difficult to clearly identify leakages, due to the delay between water usage, customer billing and receipt of payment, in a water distribution system with a large customer base. It is difficult to accurately report water usage over short periods, thus it is difficult to clearly identify where and when leakage occurs.

This project identifies strategies to improve the water-accounting system through timely data-collection and processing.

The purpose of this project is to review the current water-metering and data-collection system used, in order to benchmark this process against current best-practice methods employed by Water Supply Authorities (WSA).

The result of this investigation is a review of available metering and data-collection systems, in line with operational demands and current technological capabilities, including:

- Identification of unaccounted (non-revenue) water loss.
- Review of billed customer water-usage (revenue water).
- Metering and data-collection system options, using Automatic Meter Reading (AMR) systems.

AMR systems provide the ability to improve system monitoring and increased efficiencies related to water supply system management.

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**ENG4111 *Research Project Part 1* &
ENG4112 *Research Project Part 2***

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Glossary of terms

| | |
|------------------|--|
| Apparent Losses | All types of inaccuracies associated with customer metering as well as data-handling errors (meter reading and billing), plus unauthorised consumption (theft or illegal use). It is important to note that reducing apparent losses will not reduce physical water-losses, but will recover lost revenue. |
| AMR | Automatic Meter Reading (AMR) is the term given to a system which can obtain meter readings automatically. The AMR device can either be built into a meter or can exist as a stand-alone device connected to an existing meter. |
| AWWA | American Water Works Association |
| COAG | Council of Australian Governments. A joint committee established in 1994 to address water supply issues and reform within Australia. |
| IW | Ipswich Water |
| IWA | International Water Authority |
| Meter Assessment | A single consumption reading, measured through a calibrated and certified water meter, for the purpose of customer water-use billing. |
| NRW | Non-Revenue Water is the portion of outflow from the system, which is not billed and therefore, does not generate revenue for the water provider. This equates to unbilled authorised consumption plus Real and Apparent water-losses. |
| NWI | National Water Initiative. A water-loss management program implemented by COAG. |
| PATHWAY | “PATHWAY” Meter Billing system, used by Ipswich Water |
| Real Losses | Physical water-loss from within the distribution system (between production meters and customer meters). This volume is lost through leaks, breaks and overflows and depends on frequencies, flow rates, average leak duration, breaks and overflow. |
| RW | Revenue Water (RW) is the portion of system outflow which is consumed, billed and generates revenue (known as Billed Authorised Consumption). This equates to billed metered consumption plus billed un-metered consumption. |
| Smart Meter | A type of advanced meter that identifies consumption in more detail than a conventional meter and communicates that information via a communication network, back to the utility provider, for monitoring and billing purposes. |
| UC | Unauthorised consumption is any unauthorised use of water, which is not billed. This may include illegal water withdrawal from hydrants (eg. For construction purposes, illegal connections, bypasses to customer meters or meter tampering). |
| UFW | “Unaccounted-For” Water, also known as NRW. |
| UK | United Kingdom |
| Water Accounting | A process used to define water supplied, billed and lost within distribution systems. |
| Water Balance | (See, Water Accounting) |
| Water Meter | A device used to measure water use by volume. |
| WSAA | Water Services Association of Australia |
| WSA | Water Supply Authority |

1.0 Introduction

“If you don’t measure it, you can’t manage it”. (Lord Kelvin)

Ipswich City is located approximately 40km east of Brisbane, in South East Queensland. Ipswich has a population of 144,000 residents and was founded in 1850. Ipswich Water is a commercial business unit of Ipswich City Council and is responsible for ensuring a clean and reliable potable water supply to the city’s residents, businesses and industries.

The Ipswich residential population is forecast to double within the next 20 years. “The South East Queensland Regional Plan produced by the Queensland Government, anticipates Ipswich’s population will grow from 145,000 to 317,000 by 2026 – an increase of 177,000 over the next 20 years, equivalent to 4% per annum” (Ipswich Water Performance highlights 2006-07) based on the 4% growth rate from the previous year. This signifies an urgent need to evaluate the capacity of the existing water supply infrastructure capabilities in order to plan for future infrastructure investment and to comply with regulation requirements in relation to water supply, consumption and reporting. This demands a thorough understanding of customer consumption patterns and requirements.

1.1 Freshwater Scarcity

South-East Queensland (along with most of Australia’s more heavily populated regions) has experienced prolonged drought conditions since the start of this decade, which has resulted in reduced runoff and inflows to water storages, causing water storage levels to drop (Figure 1).

Population growth, especially through urban migration, has found the existing storage capacities to be inadequate and unable to meet the increased consumption levels associated with:

- Drought
- Increased urban density,
- Neglected infrastructure planning and development,
- Inefficient water use / Wastage (high water use per capita)
- Water loss (System leakage and Un-Authorised use)

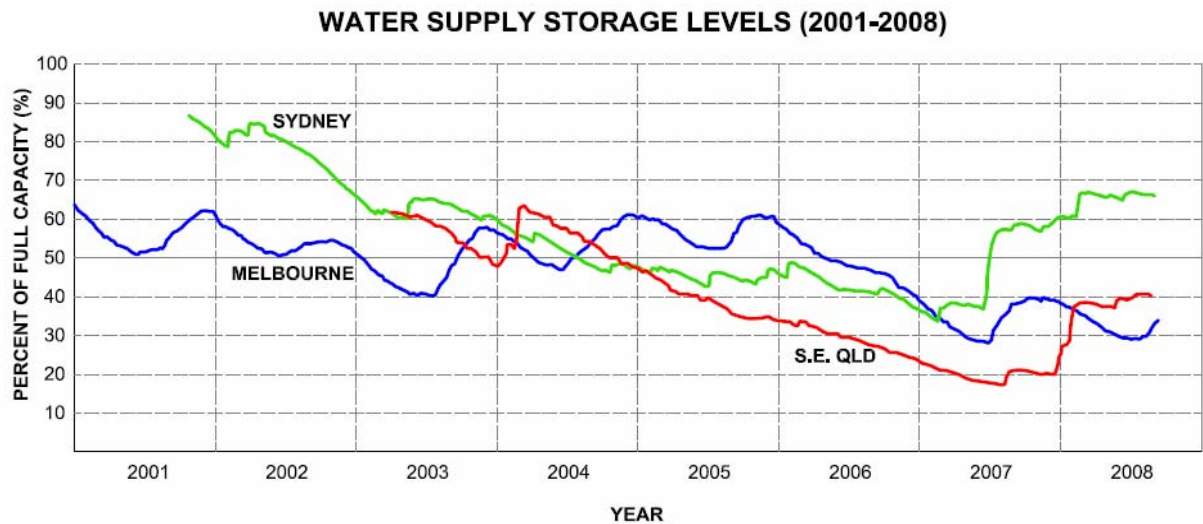


Figure 1: Dam Storage Level History for Brisbane, Sydney and Melbourne.
(Source: <http://www.iliveinsydney.com/water/damstats.php>,
http://www.melbournewater.com.au/content/water/water_storages/water_storages.asp,
<http://seqwater.com.au/content/standard.asp>)

In response to the dwindling availability of freshwater supplies in most urban areas of Australia, government and industry bodies have legislated specific requirements for Water Supply authorities to secure reliable water availability now and into the future. Australian Water Supply Authorities must fulfil their reporting requirements in accordance with the Queensland Water Act 2000 and Queensland Local Government Act 1993.

Water Supply Authorities are required to perform the following tasks:

- Monitor water use by end users
- Educate customers (usage, targets, habits)
- Prompt, reactive repair of reported (visible) leakages
- Proactive infrastructure maintenance (leak detection and asset replacement)
- Quantify and report water losses from their system

The following actions are reported in the Ipswich Water Performance Highlights (2007), as being targeted requirements for ongoing Water Loss Management and Demand Management Strategies:

- Analyse demand patterns
- Establish and monitor the extent of actual system loss
- Monitor leak detection technologies
- ‘Water Loss’ reduction of 10% (or better)

- Water pricing structure review (Discounted off-peak consumption charges)

Ipswich Water have developed Total Management Plans (TMPs) to achieve these requirements, which consist of strategy documents, including:

- Strategic Asset Management Plan (SAMP),
- Customer Service Standard (CSS),
- Annual Performance Plan (APP)
- Water Efficiency Management Plans (WEMPs),
- Demand Management Strategy (DMS),
- Pressure Management Plan (PMP), and
- Drought Management Plan (DMP).

1.2 Project Objectives

This project reviews the definition of “Unaccounted-For” Water in a water supply system and researches available metering and data acquisition technologies, which enable Water Supply Authorities (WSA) to monitor and capture accurate water-use information. This information is essential for Demand Management Planning, based on determining water-use (Diurnal) patterns and identifying water losses (Leakage) within the system, in order for leakage reduction programs and infrastructure planning to be implemented.

The concept of District Metering Areas (Zones) is reviewed as a method for monitoring system flows and locating leakage locations. A model is also implemented in order to determine water losses from the system. This provides an improved accounting and billing system for water-usage.

Determining a method for collecting data which relates to system performance, is a process urgently required by Ipswich Water and other water providers.

1.3 Project Background

Due to the problem of decreasing water storage levels, water must be recognised as an asset and must be managed as any other asset, as it has a value both financially and environmentally.

Ipswich Water supplies potable water to its population of 144,000 residents, through a network of varying pipe materials, which form a total length of 1,536km and includes 27 storage reservoirs, 30 pumping stations, 51,400 residential connections and 4,600 non-residential connections (Ipswich Water Performance Highlights 2007).

In the last year, Ipswich Water received 42,000 (significant, compared to 56,000 metered connections) customer enquires in relation to water supply. Some details are measured in relation to the nature of customer enquires. However, this detail is not sufficient to gauge the level of customer satisfaction, in relation to the water supply system performance.

Enforcement of water restrictions has resulted in customers taking a greater degree of responsibility for their water use. Scrutiny (by these customers) of their level of use and the fees they are charged for this use, results in a large number of enquiries. This may account for the increase in inquiries from the previous year (28,655, Ipswich Water Performance Highlights 2007). Real-time system monitoring is crucial for the needs of operational personnel and customer management personnel.

Analysis of a similar sized water supply authority complaints record (Consumer Council for Water, Birmingham, UK) shows that 89% of complaints originate from households and 37% of complaints are in relation to metering and billing problems. Therefore, metering solutions required for Water Supply Authority operational purposes, may also aid in decreasing customer complaints. This results in increased customer satisfaction, due to fewer disputes with the water authority, in relation to billing and metering.

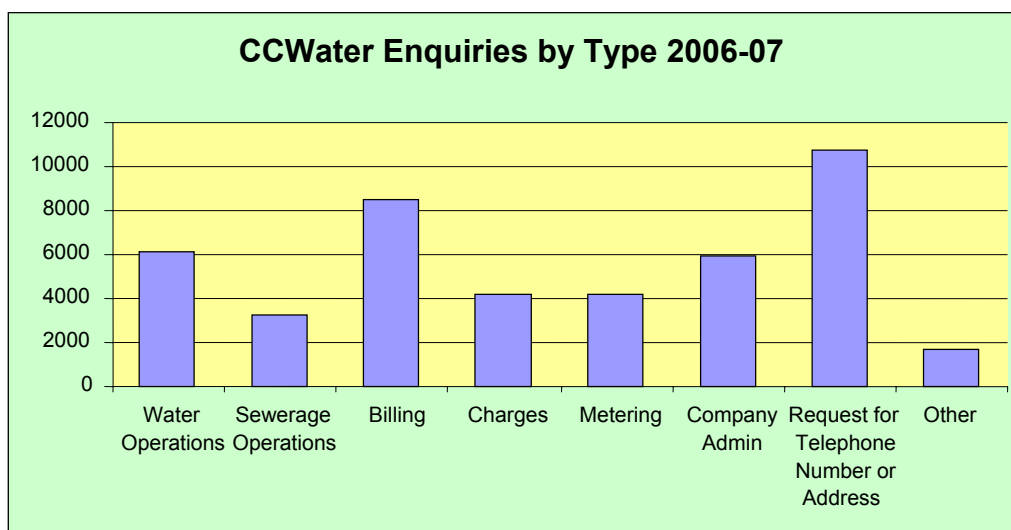


Figure 2: Customer Enquiries, UK example, for water supply issues (Source: Annual Report 2006-2007, CCW Consumer Council for Water, Birmingham, UK, www.ccwater.org.uk)

2.0 Literature Review

My literature review comprised of accessing many sources (written documentation and verbal interviewing) including, Ipswich Water personnel, technical publications, product catalogues, manufacturer publications, professional journals, databases, public libraries, organisational collections and other electronic resources, such as the internet.

2.1 Identifying “Unaccounted-for Water”

“Unaccounted-for Water” (UFW) refers to the difference between the quantity of water supplied (inflow) into the water distribution system and the quantity of water consumed from the system. UFW is the volume of water, which is “lost” between the system inlets and outlets. The term “Unaccounted-For water” (UFW) is now being phased out and is replaced with the term, “Non-Revenue Water” (NRW) which is defined in the IWA/AWWA water balance method, being adopted by countries throughout the world.

Inflows are measured by bulk flow meters, which measure the water exiting the water supply point (such as a waterway, lake, water treatment plant or storage reservoir) and entering the distribution system. Water taken from the system (outflow) is typically measured by customer meters for the purposes of billing users for their water use at the rates and tariffs designated by the water supply provider. In reality, the volume of outflow is equal to the volume of inflow, however, not all outflows can be measured directly and accurately, therefore all points of loss are generally grouped as UFW / NRW.

Walski et al (2001), identifies the most common reasons for these water losses are:

- Leakage,
- Measurement errors,
- Un-metered usage.

A water supply provider must be able to determine its NRW in order to form water-loss reduction strategies and modeling of customer demand requirements. The problem faced by water providers, is being able to reliably and rapidly, identify the location, flow-rate and duration of these water losses. Access to measurements, especially at defined points in time is essential for defining baselines, which form the basis of identifying water losses in the system, based on field data collected.

2.1.1 Leakage

Leakage refers to distribution system water losses from trunk mains, service connections and storage tanks or reservoirs. The amount of system leakage varies from system to system, but can often be a major component of NRW. Walski et al (2001), states there is a general correlation between the age of a system and the amount of NRW. Newer systems may have as little as 5% leakage, while older systems may have 40% leakage, or higher. Leak detection and repair strategies (such as the use of acoustic detection equipment) are required to prevent leaks increasing over time.

Several factors contribute to leakage:

- System pressure
- Burst frequencies
- System age
- Component materials

These make leakage difficult to estimate and measure with any degree of certainty. Improved methods of determining leakage are required for proper management of leaks.

Thornton (2008), states that developments in the last 20 years have resulted in a greater understanding of the interaction between four fundamental leakage management practices:

- Infrastructure management
- Pressure management
- Active leakage control
- Speed and quality of repair

This project investigates AMR options for the purposes of providing accurate and on-demand system monitoring, in order to perform the leakage management process noted above.

2.1.2 Meter Registration Errors

Flow measurement errors also contribute to NRW. Flow meters can over-register and under-register customer usage. This results in further measurement errors, relating to the volume of water used. Registration errors are caused by:

- Meter age
- Wear and corrosion of meter components
- Low-flow errors
- Un-authorized tampering with meters or totalisers

2.1.3 Un-metered Usage

Un-metered connections do not provide reliable usage readings. Un-metered water includes:

- Authorised un-metered water use
- Un-authorized (theft) usage
- Fire-hydrants
- Maintenance connections
- Public use

2.2 Water Loss Management

Some causes of high water losses include:

- Cultural attitudes (consumption habits)
- Geography and demographics (aging infrastructure, expanding and shifting populations)
- Water Utility Organisational Structure (eg. water suppliers controlled by local governments, whose political boundaries do not coincide with natural catchment boundaries)
- Environmental Pressures (high losses result in oversized infrastructure and excess energy usage)
- Government actions (legislation required to manage losses and replace aging infrastructure with more efficient systems, beyond the current 'reactive' system of repairing burst or broken water mains when reported by customer complaints)

The American Water Works Association (AWWA) estimates that \$325 billion needs to be spent in the next 20 years, to upgrade distribution systems in the United States. The annual value of lost water and revenue is estimated to be \$3.4 billion, in the US and \$81.5 billion worldwide. (Thornton, 2008)

Australian Water Loss Management activities have rapidly grown over the last few years, (led by IWA Water Loss Task Force deputy chair Tim Waldron, who is CEO of Wide Bay Water Corporation, Hervey Bay, Queensland), following increasing community and political focus, due to widespread, severe and long-term drought conditions (starting in 2002) causing water scarcity in many of Australia's largest cities and populated regions. This launched water-loss management into headline news and forced Government regulation relating to water-loss management and increased government funding for water loss management activities.

The Australian water industry consists of over 300 water utilities, which are responsible for managing the majority of Australian water distribution systems. On a world scale, water losses in Australia are quite low (infrastructure leakage index is typically between 1 to 1.7). The low levels of water loss are the result of relatively new infrastructure, quick response times to known bursts and high standards for asset management throughout the Australian water industry.

Despite this measure, the problem of insufficient water availability still exists and drives the need for investment by the water industry, in water-loss management programs, based on the following fundamentals:

- The Australian water industry has adopted the methodologies of the International Water Association's Water-Loss Task Force, as an organising concept for its programs. Software tools and information, which use the water balance and terminology promoted by the IWA forms a de facto Australian standard.
- Regulatory reform, led by the Queensland government, which requires all Queensland water service providers to:
 - Prepare a system loss management plan using IWA methodologies (water losses are to be valued at the retail sale price of water)
 - Implement cost effective water loss management actions (eg active leakage control, pressure management etc). Cost effective actions are defined as any activity that will achieve a payback in less than 4 years.

Most notably in South East Queensland water service providers are currently working on a system to implement DMAs and pressure management in communities currently servicing more than 2 million consumers. The savings being achieved through these programs are significant despite the relatively low levels of these losses prior to project implementation.

Water providers seek to implement their water-loss management strategies, based on the principle and actions, which have proven to be highly successful leakage management practices, used in England and Wales:

- Improved business focus
- Improved data quality
- Routine calculation of water balances and performance indicators
- Network zoning and DMA establishment
- Pressure management
- Response time to leak repairs
- Customer side leakage
- Improved leak detection efforts
- Asset management

Water Loss Management programs focus on improving all factors of the supply process from treatment to end-use. These programs are implemented in four stages, as recommended by Thornton (2008):

1. Water audit and analysis using performance indicators
2. Pilot study to demonstrate initial recommendations of the water audit analysis
3. Global intervention
4. Ongoing maintenance of the loss control mechanism.

Thornton suggests the following tasks, which target losses and forms part of the Water-Loss Management program:

1. Overhead reduction tasks (Real Losses)
 - a. Leakage reduction
 - b. Hydraulic controls (pressure management)
 - c. Pipe repair and replacement
 - d. Customer service pipe replacement
 - e. Condition assessment and rehabilitation
 - f. Energy management
 - g. Resources management
2. Revenue stream enhancement tasks (Apparent Losses)
 - a. Baseline analysis
 - b. Meter population mgt

- c. Meter testing and change-out
 - d. Correct meter sizing and change out
 - e. Periodic testing
 - f. Automatic meter reading (AMR)
3. Billing structure, analysis and improvements (Billed & Unbilled Consumption)
- a. Non-payment actions
 - i. Turn off supply
 - ii. Reduce supply to a minimum
 - iii. Legal action
 - iv. Prepayment schemes
 - v. Reduction of fraud and illegal or unregistered connection
 - vi. Continuous field inspections and testing
 - b. Rate or tariff management
 - c. Customer base management
 - d. Modelling for efficient installation
 - e. Modelling to ensure economic efficiency

Automation is often a common component in a Water-Loss Management program.

However, in order to implement the most appropriate system, Thornton (2008) suggests the following actions need to be completed:

- Understand nature and scope of water loss occurring in public water supply systems
- Assess loss conditions of any system by using a Water Audit
- Implement field interventions to control Real Losses
- Implement field interventions to control Apparent Losses
- Implement demand control
- Perform cost-to-benefit calculations
- Identify when and how to use a contractor or consultant

Ipswich Water have many strategies underway to address most of the problems, however, obtaining measurements and system data performance, is still focused primarily on billing purposes. This does not provide reliable and frequent detail in relation to identifying water losses within the water distribution system.

2.3 Water Accounting

Supplying quality, reliable water comes at a cost. Costs are incurred with supplying water through; collection, treatment, storage and distribution to customers. Government legislation demands that the full cost of providing this utility (C.O.A.G., 1994), must be recovered on a volumetric, user-pays basis via metering (hence, the two-tier tariff pricing system).

A ‘Water Accounting’ process is used to define water supplied, billed and lost within distribution systems. This model defines two basic groups of water use. Firstly, Revenue Water (RW), refers to water-use which is billed to customers. This is determined through metered consumption. Secondly, Non-Revenue Water (NRW), refers to water which is not accounted-for (Apparent losses and Real Leakage), and therefore does not generate revenue towards recovering the cost of supplying this water. This results in one of two actions:

- Financial loss by the Water Supply Authority
- Additional costs are passed on to customers (generally not a well received option)

Conducting a reliable water audit, or water balance, is the critical first step towards managing water losses in public water supply systems. The terms *Water Audit* and *Water Balance* are often interchanged. A Water Audit is the process of tracking, assessing and validating all components of flow of water from the site of withdrawal or treatment, through the water distribution system and into customer properties. The water audit is usually in the form of a worksheet or spreadsheet, which details the various forms of consumption and losses that exist within in a water distribution system. A Water Balance is the summarised results of the Water Audit in a standardised format.

The first task of a water audit process is to verify the working condition of source meters within the system.

Methods developed by the IWA Task Force on Water Loss, are recognised worldwide as representing a “best practice” model for water auditing and performance measurement. This method has been developed and tested thoroughly since the mid 1990s, when England and Wales experienced their own severe and prolonged drought. This method has been tested using data from dozens of countries, since its publication. Several countries

including South Africa, Australia, Germany, Malta and New Zealand have adopted the IWA best practice model for water auditing and performance indicators, as the basis for their national best practice water loss management regulations. The US also employs this concept, but it is defined in terms of their procedure reference, AWWA M36 manual.

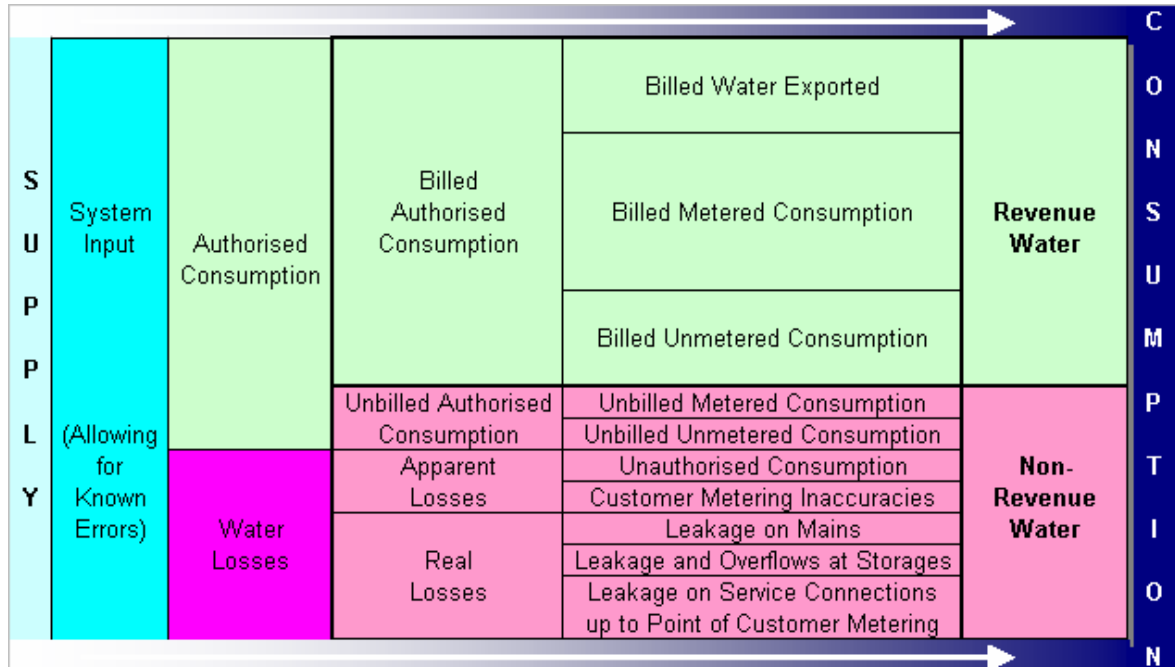


Figure 3 – IWA Water Auditing Accounting Standard

Thornton summarises the advantage of the IWA/AWWA methodology as follows:

- This method is structured to serve as a standard international best practice methodology and terminology definitions for calculations and performance indicators, based on the conclusions of IWA task forces on water loss.
- This method questions the desirability of the common north American practice of counting unavoidable water losses and discovered leaks and overflow as part of authorised consumption
- This method includes a system-specific method for calculating unavoidable real losses.
- This method counters the deficiencies in the performance indicators most commonly used in North America (eg. percentage of system input volume and losses per kilometre of mains).
- This method has dropped the term “Unaccounted-For Water” (UFW) in favour of non-revenue water (NRW) because there is no internationally accepted definition of UFW and all components of the water audit can be accounted for using the IWA/AWWA methodology.

- This method does not leave room for ambiguity. Every type of water use and loss has an appropriate component in the water balance, which assures that the results are meaningful and compatible.
- This method has been successfully applied in numerous countries and utilised around the globe.
- This method provides a meaningful comparison of water audit results and performance indicators, independent of location, size and operational characteristics of the water supply system.

Australian Water Supply Authorities are typically, unable to reliably measure their amount of water loss. Water loss is determined through a process of working backwards through the supply process (at a later date, after metered data is obtained), by comparing billing information with water supplied into the water distribution system from storage reservoirs.

Several benefits are achieved by reducing system losses:

- Customer pays only for water used (not lost)
- Reduced financial losses
- Deferred infrastructure investment
- Preservation of water sources

2.4 Revenue Water

Revenue Water (RW) is the annual volume of metered and/or un-metered water taken by authorised (paying) customers, the water supplier, and others who are authorised to do so. This generates revenue (known as billed authorised consumption) for the water provider, equal to billed metered consumption plus billed un-metered consumption.

2.5 Non-Revenue Water

Non-Revenue Water (NRW) is defined as the difference between system input volume and billed authorised consumption, consisting of Apparent Losses plus Real Losses, which is not billed and does not generate revenue, equal to unbilled authorised consumption plus real and apparent water losses.

Water-Loss (Non-Revenue Water) comes in two basic forms:

- Real Losses (also referred to as physical losses)
- Apparent Losses (also referred to as non-physical losses)

Lambert and Herner's definition for real and apparent losses is as follows:

- 'Real Losses' are physical losses from the distribution system, up to the point of customer metering. The volume lost through all types of leaks, bursts (breaks), and overflows depend on frequencies, (system pressures) flow rates and average durations of individual leaks.
- 'Apparent Losses' consist to unauthorised consumption (theft or illegal use) and all types of inaccuracies associated with production metering and customer metering. Under-registration of production meters and over registration of customer meters, leads to under-estimation of real losses. Over-registration of production meters and under-registration of customer meters, leads to over-estimation of real losses.

Each water system has different types and degrees of loss and each has a potential solution with an associated cost. Before Cost-to-Benefit ratios can be calculated, the potential solutions have to be identified and graded.

In addition to having a good return or Cost-to-Benefit ratio, it is important to consider local conditions and the sustainability of the method or solution adopted. Water losses don't go away. Water loss control is not a one-off project. It is a continuous and changing solution to an ever-changing problem. Diligence is required by the water provider to sustain Water-Loss Management programs.

2.5.1 Real Losses

Real Losses (supply-side) are physical water losses from the distribution system and the water provider's storage tanks, up to the point of customer use (the customer meter). The volume lost through leaks, breaks and overflows depends on frequencies, flow rates, average duration of each leak, breaks and overflows.

Real losses can never be completely eliminated, but they can be minimised.

Real losses are made up of three components:

- Reported breaks and leaks
- Unreported breaks and leaks
- Background leakage

Current Annual Real Losses (CARL) is the volume of water lost from all kinds of leaks (breaks and background losses) during the reporting period. This includes water lost from (still) hidden breaks as well as from breaks, which have been found and repaired during the year. It also includes possible losses from storage tanks, and is equal to the component real losses of the annual water balance.

Unavoidable Annual Real Losses (UARL) are Real Losses that cannot be totally eliminated. The estimated volume of Unavoidable Annual Real Losses (UARL) represents the lowest technically achievable annual Real Losses for a well-maintained and well-managed system. Equations for calculating UARL for individual systems were developed and tested by the IWA water loss task force, allowing for:

- Background leakage
- Reported leaks and breaks
- Unreported leaks and breaks
- Pressure/leakage rate relationships.

The UARL equation recommended requires data on four key system-specific factors:

- Length of mains
- Number of service connections
- Location of customer meter on service connection
- Average operating pressure

Infrastructure Leakage Index (ILI) is a performance indicator of how well a distribution network is managed (maintained, repaired, rehabilitated) for the control of Real Losses, at the current operating pressure. It is the ratio of Current Annual volume of Real Losses (CARL) to Unavoidable Annual Real Losses (UARL)

$$ILI = CARL / UARL$$

The most common cause of Real Losses in a water system, are:

- Pressure
- Corrosion
- Vibration from traffic loading
- Incorrect backfill
- Poor material or workmanship
- Lack of periodic maintenance
- Environmentally related (eg hot and cold weather extremes)

Thornton suggests the following potential solutions for real losses

- Leak detection to locate non-visible leakage
- Increased response to visible reported leakage to reduce annual loss volumes
- Zoning to identify volumes of loss in a continuing and efficient manner
- Pressure mgt to reduce volumes of loss and frequencies of new leaks
- Level control reduce overflows from storage
- Corrosion control to reduce frequency of new leaks
- Mains replacement
- Mains rehabilitation
- Service replacement

Chosen intervention methods, depend on factors contributing to real losses in the system.

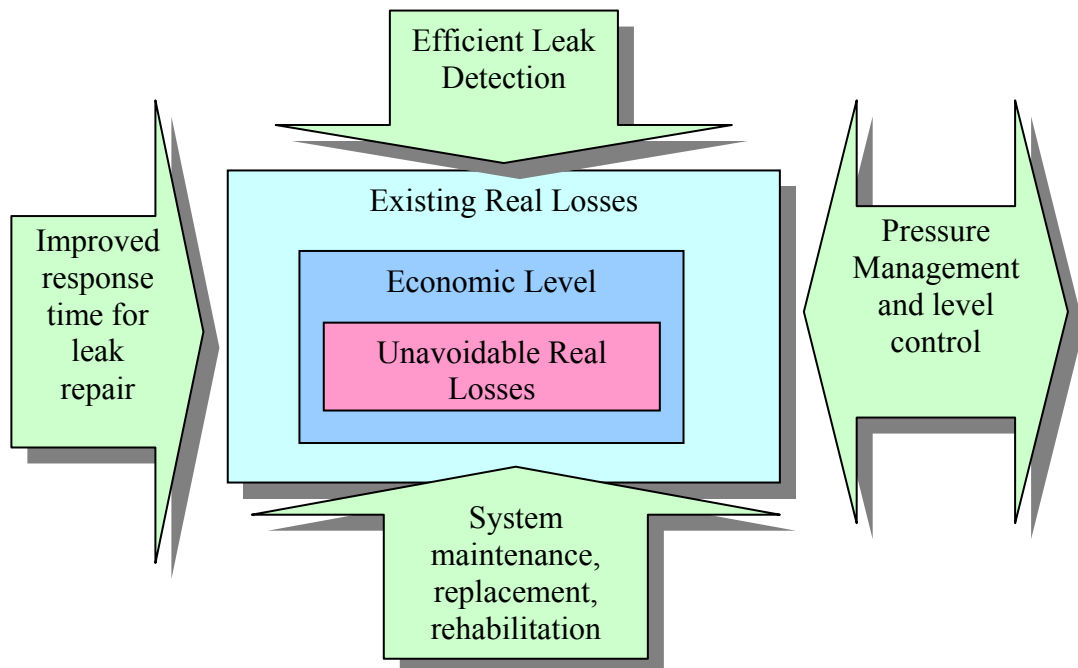


Figure 4: Components of an Active Real Loss Management program
(Source: Thornton, 2008)

2.5.2 Apparent Losses

Apparent losses are all types of inaccuracies associated with customer metering as well as data-handling errors (meter reading and billing), plus unauthorised consumption (theft or illegal use). It is important to note that reducing Apparent Losses does not reduce physical water-losses, but will recover lost revenue.

Apparent Losses occur in three primary ways:

- Customer meter inaccuracies
- Errors in water accounting and data-handling
- Unauthorised consumption

There are many reasons for Apparent Losses in water systems. These include:

- Water quality affecting water meters
- Environmental conditions, such as extreme heat or cold affecting water meters
- Lack of periodic testing and maintenance
- Incorrect specification, sizing and installation of water meters
- Out-of-date meter population database
- Uncontrolled population growth
- Incorrect repair
- Theft
- Inefficient reading and billing methods

Solutions for Apparent Losses include:

- Production meter testing
- Sales meter testing
- Correct meter sizing
- Correct meter specification (the best meter is not always chosen for the application, particularly in low flow situations)
- Meter replacement
- Improved meter reading
- Improvements in billing
- Location of illegal or unregistered connections
- Revenue recovery or prepaid systems in areas of low payment

Methods chosen to rectify Apparent Losses within the system, depend on the causes.

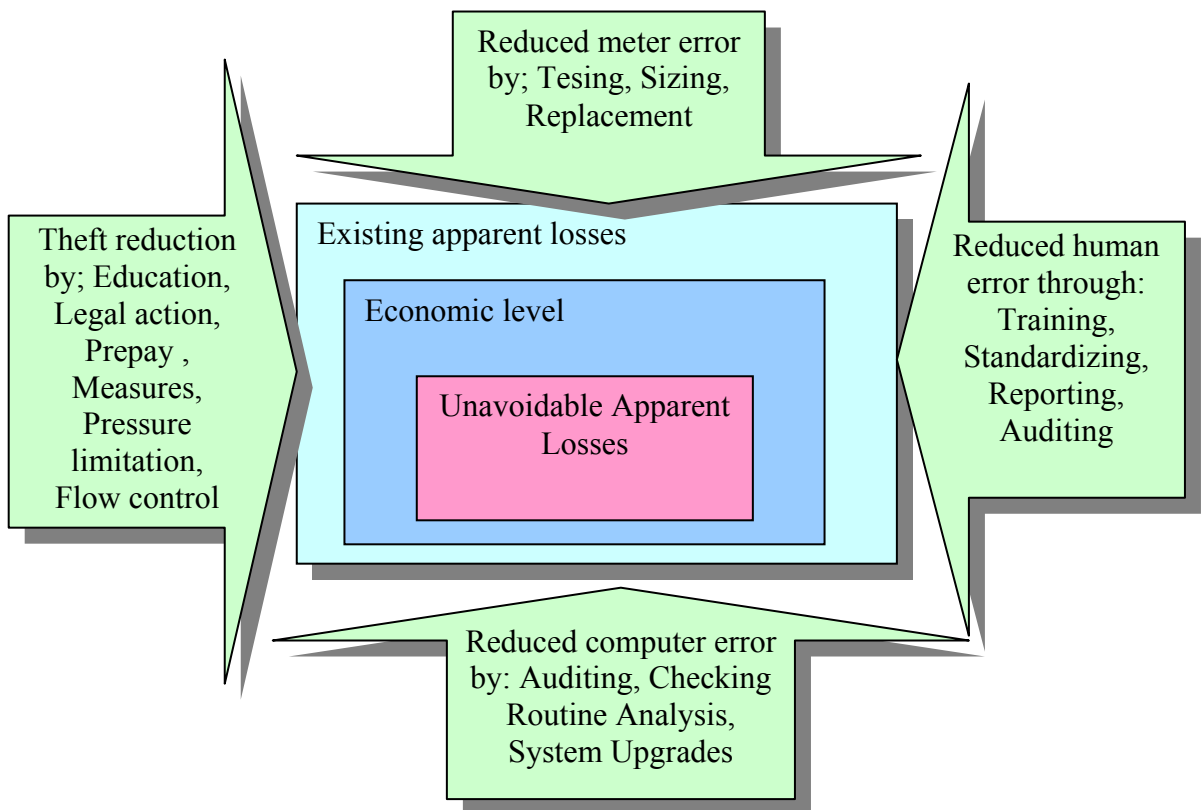


Figure 5: Components of an Active Apparent Loss Management program (Source: Thornton, 2008)

In order to maintain metering reliability and accuracy, it is recommended that customer meters monitor and record consumption patterns and rotating the meter out of use on a regular basis (for testing, re-calibration, repair, or replacement).

Many systems use estimates of customer consumption for accounts where water meters are non-existent, defective or unreadable. Estimates can be inaccurate if they are not devised in a rational manner or kept up-to-date with changing customer consumption pattens, hence another form of inaccurate water measurement in introduced.

Meter reading is a critical process for collecting accurate water consumption data. Errors in meter-reading, are essentially measurement errors. The development of Automatic Meter Reading (AMR) systems, provides the opportunity for meter reading error to occur on a less frequent basis than errors associated with traditional Manual Meter Reading (MMR) processes. Before embarking on an AMR implementation program, the water provider must assess the accuracy of meter reading processes when transferring actual measured water consumption into the information handling (billing) system.

Thornton, (2008), highlights the following ways in which errors can occur when handling customer accounts:

- Customer water consumption data is modified during billing adjustments
- Some customers who use water are inadvertently (or intentionally) omitted from the billing records and go unmonitored
- Certain users are accorded non-billed (free or subsidised) status and actual consumption is not recorded
- Human errors occur during data analysis and billing
- Weak policies which create loopholes in billing and water accounting
- Poorly structured meter reading or billing systems
- Poor tracking of changes in property ownership or other changes in customer account status
- Lack of understanding of technical and managerial relationships in assessing, reducing and preventing apparent loss

2.5.3 Unauthorised Consumption

Unauthorised consumption is any unauthorised use of water. This may include illegal water withdrawal from hydrants (eg. For construction purposes, illegal connections, bypasses to customer meters or meter tampering).

All water suppliers must acknowledge the potential for unauthorised consumption within their systems. Just as retail establishment must take safeguards against shoplifters, water systems should have appropriate controls to monitor and control unauthorised consumption.

2.6 Developing a Usage Model

Water demand varies continuously over time depending on daily, weekly, seasonal and long-term (such as population changes and future system performance) factors. These influence customer usage patterns, habits and demand requirements. Modelling attempts to predict customer use, based on certain scenarios, however, modelling requires baseline

demand data, (exposed to demand multipliers and peaking factors), which may be influenced by time-varying values and/or steady-state factors.

Models can simply produce numerical results. Model analysis and presentation can be improved by integration with commercially available GIS systems, to provide interactive manipulation and visual display of results, trends and spatial interaction and information.

Modellers need reliable and accurate data inputs, in order to create and calibrate meaningful models for the purpose of determining diurnal usage patterns. These results are necessary for determining future infrastructure planning and development.

Model data must be accurate, reliable and up-to-date, especially during periods of reduced water availability, such as prolonged periods of drought.

Allocating NRW within a model is often done by estimating or averaging, then allocating this amount of NRW to certain points within the system, or by averaging the quantity of NRW throughout the system. The modeller must be aware this method tends to flatten the diurnal demand curve and therefore may mask actual peaking factors (Walski et al 2001). Accurate identification and reduction of NRW is therefore critical to improving system planning capabilities.

Walski et al 2001, suggests the ideal process, whereby system data is automatically loaded into a model, (on demand) from another source. Coote and Johnson (1995) developed a system in which each customer account was tied to a node in their hydraulic model. The popularity of geographic information systems (GIS) among water providers, enables GIS systems to be utilised for storing and manipulating demand data.

This data is obtained using meters. Therefore, meters and their resulting measurements form the backbone of the entire water management system. Use of meter data (readings) for revenue collection is generally the main priority for water providers, however, current technological developments, environmental factors (eg. water scarcity, population growth, etc) and government regulation is the driving force behind using and obtaining meter data more frequently for a real-time analysis of water use, for the purposes of system monitoring and management, in addition to billing requirements.

2.7 Data Acquisition

Selecting an appropriate system for obtaining meter data, is the first essential step towards determining and monitoring NRW. Once NRW is identified, the next stage is implementing strategies for the purpose of minimising this NRW (“water loss”).

Obtaining metered data is the essential element for determining water use. The ability to obtain this data is constantly improving due to technology advancements, which enable data to be recorded, communicated and archived.

Customers are typically billed according to a volumetric measure of their usage during defined period, such as a monthly or quarterly cycle. Using these periodically recorded usage volumes, customer usage rates can be computed on a historical basis. Billing records therefore provide enough information to determine a customer’s baseline demand, but not enough to determine fluctuations in demand. Walski et al (2001), recognises the importance of employing meters throughout a system, as they can be the best source of data for determining customer demands.

Customer meters continuously register water flowing through them, however, meter readings are traditionally gathered on a periodic basis (30 or 90 day period, monthly or quarterly) to determine water consumption for the previous period for billing purposes. Rapidly developing technologies more enable this data to be gathered more frequently, even continuously, via data-logging or fixed network automatic meter reading (AMR) systems.

Data acquisition is the key process, which distinguishes AMR from MMR. Water Providers have a range of AMR options. The simplest option, automates the traditional MMR process, which still passes (‘Walk-by’ or ‘Drive-by’) each customer meter on a defined meter route, but significantly speeds the process and eliminates data-entry errors. Advanced AMR options consist of Advanced Metering Infrastructure (AMI), which enables multiple daily reads, at specified times, through a fixed communications network. These readings are transmitted to a central billing system, using modern communication technology. This provides real-time system monitoring functionality, reporting and system management.

Fixed network AMR systems enable customer consumption to be recorded as frequently as every few minutes. This provides the water provider with a detailed profile of the consumption variation (diurnal patterns) throughout the day. This data can be used to indicate leakage in customer premises or DMAs. Water consumption profiles can then be developed to assist modelling calibration and operational needs such as infrastructure and supply management. Therefore, the customer meter now provides many additional purposes other than the fundamental purpose of generating accurate water bills. It is critical that the meter population is maintained at a high level of functionality, reliability and accuracy.

AMR offers less susceptibility to data handling errors, compared to manual meter reading, however, both methods incur errors, depending on the size of the customer population, method of meter reading, regulations and policies.

Thornton recommends the following indicators to be considered for closer investigation when determining data handling errors:

- Accounts without actual meter readings for one year or longer
- Accounts which show zero consumption, for more than two consecutive billing cycles.
- Accounts suddenly evidencing a significant drop or increase in consumption after a stable usage history
- Accounts with confirmed AMR equipment failures
- Accounts known to have suffered from manual meter reading inaccuracy from one or more meter readers confirmed to be inattentive or dishonest
- Accounts known to have suffered data distortion in transferring data from handheld meter reading devices into the customer billing system.

Thornton provides the following Data management requirements checklist:

- Data should be accurate
- Data should be organised
- Data should be accountable
- Bad data should be clearly high-lighted
- Estimations can be made, but should be clearly marked as such
- Raw data should be kept, as well as calibrated data

- Constant measurement values should be used
- A column alongside the audit sheet with relevant comments will help future auditors understand the process followed during the previous audit

2.7.1 Data Transfer and Systematic Data-Handling Errors

The customer meter is the beginning of a series of data transfer tasks which are performed in order to collect the meter reading and generate billing processes. Water providers manage meter data for thousands of customers. Systematic data-handling inaccuracies can be easily hidden within the sheer volume of bulk data. The following steps are typically performed in the order shown, to capture meter data to a historical archive.

1. Customer meter registers water flow
2. Routine meter reading taken, (manually or automatically)
3. Meter readings are transferred to customer billing
4. Customer consumption is shown on water bill and archived
5. Aggregate consumption data is summarised on reports

The following lists are not exhaustive, but do indicate areas where data-handling during any of the above steps, can introduce errors into the data, such as :

Data transfer errors

- Manual meter-reading errors
- Automatic meter-reading equipment failure

Data analysis errors

- Use of poorly estimated volumes in lieu of meter readings
- Customer billing adjustments granted by manipulating actual metered consumption data
- Poor customer account management (accounts not activated, lost or transferred erroneously)

Policy and procedure shortcomings

- Despite policies for universal customer metering, certain customers are intentionally left unmeasured or unread. This is common for municipally owned buildings in local government water utilities

- Provisions allowing customer accounts to enter ‘non-billed’ status, a potential loophole often exploited by fraud, or unmonitored due to poor management
- Adjustment policies that do not take into account preservation of actual consumer consumption
- Bureaucratic regulations or performance lapses that cause delays in permitting, metering or billing operations
- Organisational divisions or tensions within the utility that do not recognise the importance or ‘big picture’ of water-loss control

Three primary meter problems (identified by Thornton), contribute to apparent water losses, due to customer meter inaccuracies:

- Gradual decline of the meter’s mechanical accuracy, due to wear and age.
- The meter or meter-reading device may fail or stop altogether.
- Meters may not be of the proper size or type to accurately register the full range of water flows encountered in a given customer supply.

2.7.2 Mechanical Wear Errors

Loss of meter accuracy due to the mechanical wear of meter components, is caused by:

- Aggressive water quality
- High rates of accumulated flow measured
- Chemical or residual build-up
- Abrasive materials in suspension (such as sand)
- Air running through the meter after a system outage

Trends analysis can be performed for the meter fleet, by regularly testing meter performance (for various meter age and volume measured). Factors can then be determined to calibrating meters currently in service to correct the actual meter readings to allow for performance reduction, until the meter error becomes excessive and is scheduled for replacement, as part of a meter management, repair and replacement program.

2.7.3 Zero Consumption Errors

Meters which show no registration (since the last reading) may be due to zero consumption or may be the result of the register failing and not registering the full volume of water consumed between meter reading and billing cycles. This can introduce large amounts of Apparent Losses and lost revenue (Non-Revenue Water).

2.7.4 Improper Meter Selection Errors

Many brands of meters are known to have their own inherent inaccuracies and performance characteristics, which increase with the age of the meter and the accumulated volume of water measures.

2.8 Meter Management

A water meter is a device used to measure the volume of water usage. Like all measurement tools, calibration is required on a regular basis to ensure reliable measurements are obtained.

Customer meters are often called the “cash registers” of the utility. Customer meters are responsible for ensuring accurate determination of water use. These meters are the legal tool for collecting revenue for the utility, based on measured customer usage.

Meter management systems must be implemented to ensure reliable data acquisition. Water providers within Australia are required, by government legislation, to recover the full cost of providing the service, via a volumetric, user-pay process. The method typically used to obtain customer consumption levels is via the process referred to as Manual Meter Reading (MMR). However, due to the rapid development of communication technologies during the last decade, other capabilities are being developed which enable this data to be captured electronically and transmitted to the billing centre. This process of electronically capturing consumption figures is commonly referred to as Automatic Meter Reading (AMR).

Meter management begins with correct meter selection and installation. Meter measurement errors occur due to incorrect meter selection and flow totalisers may not register correctly for several reasons, including (Arregui, 2006):

- Incorrect selection, installation, positioning and orientation.
- Low-Flow errors (under-reading)
- Increased error by to age, corrosion and wear of meter components
- Increased error due to wear from accumulated volume flow.

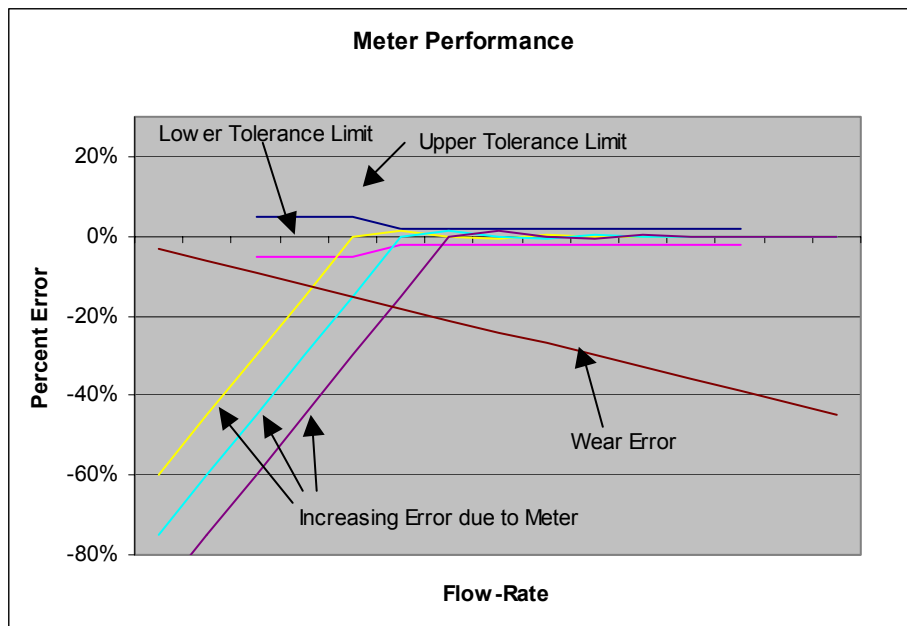


Figure 6: Typical meter measurement error profiles

2.8.1 Meter Selection and Performance

Walski et al, (2001) notes that many older water systems have little or no metering between the master (production) meters and the customer meters. System operators require information about the flows within their distribution systems, and at specific locations throughout the system, in order to better understand water use, quantify available system capacity, and compute the amounts of NRW in different parts of system.

Knowledge of NRW sources, is required as part of the process for managing leak detection, repair and planning water-main replacement programs. Once a meter is in place, it can provide additional information for fine-tuning model calibration.

Sub-system metering (Sub-Metering) is a method commonly practiced in the UK, where individual customers are not universally metered. The concept is equally useful in Australia, for system monitoring application and for use in multi-dwelling and strata-title installations such as; apartments, office blocks and shopping complexes. Sub-metering uses meters placed at selected points throughout the system, to determine water use within the service area (due to the cost and difficulty of installation). Commonly adopted locations selected for metering points are pump-stations and PRV pits (Pressure Reducing Valves, at pressure zone boundaries) and in pipelines, which carry virtually all flow into an area.

Sizing the meters is primarily a problem of understanding the range of flows that the meter will experience. The meter needs to be selected to pick up both the high and low range flows. Previously, the operator would estimate the range of flows based on either the number (and type) of customers or on readings from a temporary meter. Even temporary meters require time-consuming excavation, installation, in-situ calibration and uncertainty as to the validity of the readings, which may or may not have been installed at the right time, for capturing extreme events or the full range of usage flow patterns and characteristics, due to the temporary nature of their installation.

Generating a demand pattern and projected conditions enable the operator to see the kinds of flow the meter is likely to encounter. Meter selection can then be based on pipe size and type of meter. The required flow range operation also varies greatly depending on whether the flow operates continuously (small operating flow range) or intermittently (eg. Pump station) which has the full flow range from zero flow to maximum operational flow.

The selection of a meter depends on the nature of the flow, the site and operator preference. The pipe network model can be used to provide information on the range of flows once the meter is in place, the model can be improved with information from the flow meter.

Once the range of flows has been determined, the type of meter can be selected. Small flows such as those in 100 to 150mm pump discharge lines, can be metered by turbine meters, equipped with some type of pulse counter that produces flow rate information in analogue form, suitable for AMR equipment.

For greater flows, more commonly used meters are electromagnetic (Mag) meters, differential head meters (venturi, orifice, flow tube, and nozzle types) or ultrasonic meters. Differential head meters are usually the most reliable and least expensive, and can be run without power. Unfortunately they are limited to uni-directional flow and can produce significant head loss as the velocity increases. Advances in technology have produced several types of PRVs, which can also serve as flow meters.

Thornton highlights the following considerations required by the person responsible for the selection of meter sizes and types for use as production, DMA or customer meter applications:

- Size of main
- Flow range
- Head loss at peak flow rates
- Reverse flow requirements
- Accuracy and repeatability
- Data communication requirements
- Cost of the meter
- Cost of ownership, maintenance and replacement requirements
- Water utility preference or preferred supplier agreements

There are several water meter types available for selection in water distribution systems. These styles are listed below, along with their general advantages and disadvantages (Arregui et al, 2006), which must be taken into account during the meter selection process. These meters are ranked in general order; from smallest pipe diameter applications to larger flow-rate and larger pipe diameter applications.

Single Jet Meter

- Advantages:
 - Resistant to suspended solids. Adequate for hard waters or those with a number of suspended solids
 - Great variety and availability. Easy to find the right model for the application
 - Reliable technology, used for decades
 - Small. Can be installed in tight spaces.
 - 13, 15 and 20mm meters are probably the cheapest that can be found in the market among all technologies.
 - Class C single jet meters are a good substitute for combination meters for large users with a wide range of flows (schools, industries, swimming pools, etc)

- Relatively low sensitivity to the velocity profile
- Disadvantages:
 - The impeller, bearing and mechanical parts are likely to wear in non-ideal conditions.
 - They are generally affected by the installation orientation
 - To date, no Class D (ISO 4064:1993) model available
 - In shorter meters, clogging of the strainer or a gasket fitted too tight may lead to errors.
 - By-pass regulated meters may produce positive errors at higher flows. Conflicting with users.
 - Starting flow rates are not low enough to detect leakage at the user's side, although latest models show improvement. Depending on the construction, starting flow rates can increase dramatically with time.

Multi-Jet Meter

- Advantages:
 - Very reliable metering technology, used for decades around the world
 - Forces on the impeller are balanced, providing a long life for the meter
 - Not sensitive to the velocity profile at the entrance. The pipe preceding the meter does not need to be straight.
 - Good resistance to suspended solids. Adequate for hard water or water with suspended particles.
 - Great variety of models, construction, sizes and prices. An option for almost every use can be found.
 - Meters ranging from 20 to 40mm are very competitive in price compared to other technologies.
- Disadvantages:
 - Larger than single jet meters, especially for small diameters.
 - Affected by the installation position.
 - Error curve is often displaced to positive errors for medium and large flows. Potential conflict with users.
 - Above 50mm, their flow registering capacity is much smaller than the Woltmann.
 - There is no Class D (ISO 4064:1993) model known to date. Class C meters above 30mm are rarely found.
 - Starting flow rates are not low enough to detect most leaks on the user's side. Depending on the quality, this parameter can deteriorate quickly.

Oscillating Piston Meter

- Advantages:
 - Very reliable technology used for decades
 - Not affected by the velocity profile. Less space needed for their installation.
 - Great variety of models, metrologies and prices.
 - Excellent sensitivity at low flow rates.
 - Available in Class D.
 - Almost unaffected by the installation position.
 - Error is always on the negative side of the curve (under-registration) avoiding problems with users.

- Disadvantages:
 - Affected by suspended solids. This is the main argument posed by users for not using them.
 - Noisy at high flow rates.
 - Larger and heavier than equivalent meters of other technologies.
 - More expensive than equivalent meters of other technologies.

Nutating Disc Meter

- Advantages:
 - Very reliable technology used for decades.
 - Not affected by the velocity profile. Less space needed for their installation.
 - Excellent sensitivity at low flow rates.
 - Almost unaffected by the installation position.
 - Error is always on the negative side of the curve (under-registration) avoiding problems with users.
- Disadvantages:
 - Affected by suspended solids. This is the main argument posed by users for not using them.
 - Larger and heavier than equivalent meters of other technologies, even oscillating piston meters.
 - More expensive than equivalent meters of other technologies.

Woltmann Meter (Horizontal Vane)

- Advantages:
 - Woltmann meters resist difficult working conditions. A moderate amount of solids in suspension can even be tolerated.
 - The measuring range is very wide, and the ratio between the minimum and maximum flow can be of 1:100 or even 1:200.
 - The metering module may be replaced without affecting the meter accuracy, keeping the meter housing in-situ.
 - Can be installed at virtually any position.
 - The totalisers included in these meters, allow the installation of different types of pulse emitters so they can be used as flow meters.
- Disadvantages:
 - The error curve is sensitive to the velocity profile quality. The use of tranquillising lengths of pipe upstream of the meter is often necessary. The effective space needed for their installation is therefore quite larger than the length of the meter itself.
 - Low sensitivity for low flow rates. Currently, there are no Class C meters available in this technology.
 - The impact of large suspended solids could damage the metering module, making the installation of a stone strainer, a recommended option.

Woltmann Meter (Vertical Vane)

- Advantages:
 - Good behaviour at low flow rates.
 - Reduced sensitivity to the quality of the velocity profile, and almost no need for additional space.

- Disadvantages:
 - Expensive.
 - Less capacity than an equivalent diameter horizontal vane meter.
 - Fixed installation position.

Combined (compound) Meter

- Advantages:
 - Very wide measuring range.
- Disadvantages:
 - Need for maintenance
 - High probability of failures in the changeover valve leading to important metering errors.
 - Many models use separate totalisers for the main and the secondary meters.
 - Expensive
 - Not suitable for “dirty” waters, especially those carrying suspended solids.

Paddle Wheel Meter

- Advantages:
 - Low cost, especially in large diameters.
 - Great flow capacity
 - Low-pressure losses.
 - Able to function with dirty water and suspended solids without damage. Suitable to meter water from bore holes (the internal meter cross-section is almost completely free).
- Disadvantages:
 - Very sensitive to the quality of the velocity profile.
 - Only a few ISO 4064:1993 certified models. Normally found in Class A, and exceptionally Class B.
 - Narrow measuring range. Limited metering capacity at low flows.

Proportional Meter

- Advantages:
 - Low cost.
 - Great flow capacity.
 - Low-pressure losses.
 - Suitable for “dirty” water. May be used in bore holes.
- Disadvantages:
 - Unreliable technology.
 - There are no ISO4064 certified models.
 - Small measuring range. Very limited at low flows.
 - Limited accuracy. Manufacturers usually only guarantee errors within $\pm 5\%$.

Ultrasonic Transit-time Meter

- Advantages:
 - High accuracy and linear response.
 - Great reliability. No mobile parts subject to wear.
 - Small head losses.

- Operation as a flow meter and a registering meter in the same device.
- Moderate cost. Price is not linear with diameter increases.
- Disadvantages:
 - High sensitivity to flow distortions.
 - Need for electricity supply.
 - Not suitable for “dirty” waters.
 - Not suitable for billing (for the time being). This may change in the future with the publication of newer standards.

Ultrasonic Doppler Meter

- Advantages:
 - Great reliability. No mobile parts subject to wear.
 - Small head losses.
 - Operation as a flow meter and a registering meter in the same device.
 - Suitable to operate in slurry waters.
- Disadvantages:
 - Poor accuracy.
 - High sensitivity to flow distortions.
 - Need for electricity supply.
 - Not suitable for clean waters.

Electromagnetic Flow Meter

- Advantages:
 - High accuracy and linear response.
 - Great reliability. No mobile parts subject to wear.
 - Small friction losses. Low operation cost.
 - Can register flow rate and volume in one instrument.
 - Can be used in loaded waters.
 - Low sensitivity to flow profile distortions.
 - Moderate cost.
- Disadvantages:
 - Need for electricity supply. Some devices available in the market are autonomous and can operate for up to two years without replacing the batteries.
 - Need to be grounded.
 - Cannot legally be used for billing, although new standards will change this in the future.
 - Need protection against storms. Failures due to lightning strikes are frequent.

Insertion Flow Meter

- Advantages:
 - Low cost, especially for large diameters. The probe’s cost is almost independent of the pipe diameter.
 - Some technologies can be used in water with suspended solids with no risk of deteriorating the device. They can be used to control groundwater extraction.
 - A single insertion probe can be used in several points of the distribution network.

- Small head losses.
- Disadvantages:
 - Low reliability in the measurements compared to other technologies.
 - Extremely sensitive to the quality of the velocity profile. The required length of straight pipe upstream of the meter may be over 50 diameters.
 - Need to drill a hole in the pipe.
 - Narrow range of measurement (Usually 1:10 or lower)

2.8.2 Meter Installation

The accuracy of water meters is determined by the actual flow rate passing and correct meter installation, to enable the measurement mechanism to function correctly.

Most meters are designed to operate in a horizontal position. Other meter positions such as vertical or inclined meter installations, may cause reading errors, unless the meters are specifically designed and approved (by the manufacturer) for operation at these orientations.

Contaminated water may also cause the meter mechanisms to foul or block due to the debris, therefore strainers (which can be cleaned during scheduled maintenance routines) may also need to be fitted in the supply line, before the meter inlet.

Water turbulence, swirl or entrapped gases (such as air) are also known to cause meters to register incorrect flows. Therefore, installations should also be designed to ensure the required minimum straight lengths entering and exiting the meter are achieved. Air release valves may be required to remove pockets of air.

2.8.3 Meter Maintenance, Repair and Replacement

Meter accuracy deteriorates with age and wear, due to the volume of water measured. Meter management programs must allow for regular maintenance and defined meter replacement timeframes, in order to ensure continuing meter accuracy and the ongoing reliability of measurements taken.

Arregui et al, (2006) notes the following factors to be considered when determining the optimum replacement period for meters within a water distribution system:

- Cost of acquiring the meter
- Selling price of the old meter
- Depreciation rate of the meter
- Rate of decay of the meter error curve (meter registration inaccuracy)
- Water consumption / flow rate experienced (especially at low flow rates)
- Installation costs
- Extraction and removal costs

2.9 Manual Meter Reading

Manual meter reading (MMR) consists of meter reading personnel (meter readers) who visit each customer's premises, for the purposes of visually collecting meter readings. These reads are conducted on a pre-determined meter route on a monthly (commercial and industrial customers) or three-monthly (residential users) basis. This method is still by far, the most common method for obtaining meter data and is still generally effective for billing purposes, by many water providers.

Manual meter reading can work reliably, but it encounters a number of difficulties, which can hamper its efficiency and cost-effectiveness. Some issues include; meter readers having difficulty when attempting to gain access to meters, particularly inside customer buildings or when meter access blocked or restricted by other equipment, debris, vegetation, animals (eg. Dogs), hostile customers, or poorly maintained meter spaces. Employees can become bogged down with managing customer keys. Many customers are often unwilling to hand over keys to their property.

When meter access is not possible, meter-reading estimates are made, or provided by the customer, this introduces potential data errors into the process. Manual meter reading is inherently labour-intensive with associated high staffing and deployment costs and issues. Weather conditions, adversity, inattention, monotony, fatigue, illness, injury, staff turnover and transcription errors all contribute to erroneous consumption recording.

Due to the age of most water supply networks within Australia, the task of obtaining water use readings (in order to bill customers) is performed manually, by an employee, who

visits each utility meter individually (in a pre-determined sequence) to visually read the totaliser value and enter this data into a hand-held data-logger. At the end of the day, this data-logger is returned to the billing centre, where it is connected to the processing computer system to download the meter readings and generate invoices for delivery to the customers, for payment. This system occurs on a three monthly cycle for residential customers (four meter reads per year) and monthly for commercial customers (12 meter reads per year).

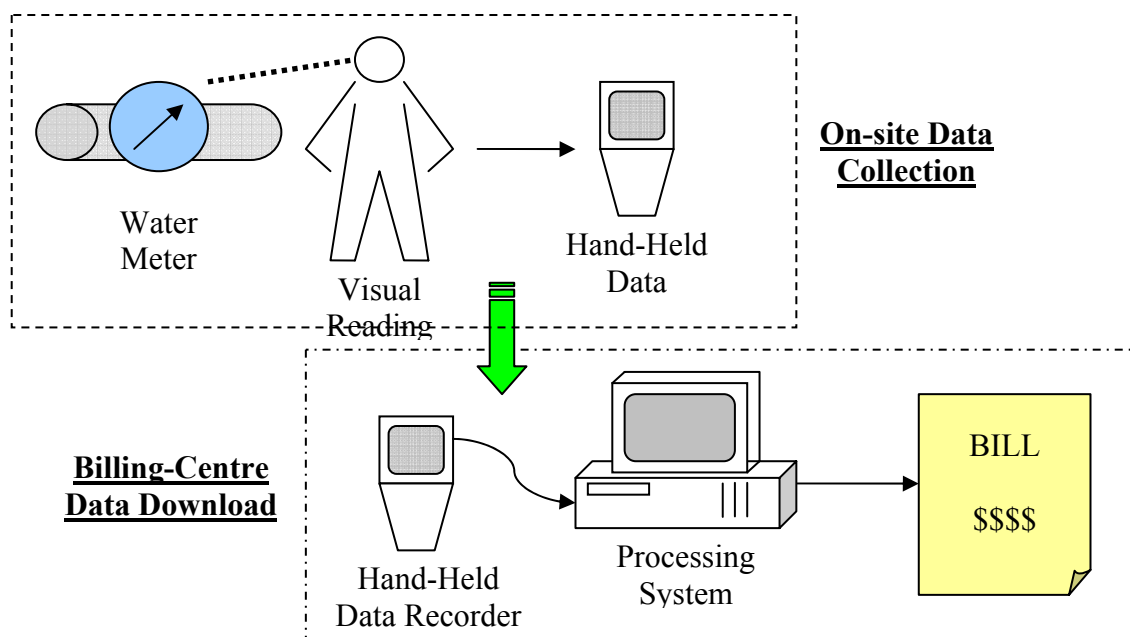


Figure 7: Manual Meter Reading (MMR) Process

MMR is prone to errors, due to the nature of this process, incorrect data entry (transcription errors), infrequent reads (4-12 times a year), errors due to estimated readings when meters are un-able to be read due to accessibility or unreadable problems. The MMR process is very labour intensive and relatively slow.

2.10 Automatic Meter Reading

A *Smart meter* generally refers to a type of advanced meter that identifies consumption in more detail than a conventional meter; and has the capability to communicate that information, via some network, back to the local utility for monitoring and billing purposes.

Automatic Meter Reading (AMR) refers to the process which enables utility meter readings can be obtained automatically, generally at pre-determined times or intervals. There are two methods of providing data via a one- or two-way communications route:

- The Data Collector's system 'polls' the Meter for its data routinely; and
- The Meter 'sends' its readings automatically to the Data Collector or a central location for processing.

At a basic level, AMR technology enables accurate and timely meter reading with unprecedented efficiency. This is accomplished through the installation of a radio-based meter module called an ERT module on a new or existing water meter. Readings are then collected by a meter reader using a handheld or vehicle-based radio device, or by a fixed network system.

No matter what collection method is used, AMR is exponentially faster and more efficient than the old method of manually reading each meter. For example, a meter reader using a handheld computer and walking a route can typically read up to 300 meters during an eight-hour shift. In contrast, a single meter reader equipped with a vehicle-based mobile computer can read up to 15,000 meters during an eight-hour shift. (Hengesh, 2001)

Because of difficulties and short-comings encountered in manual meter reading programs, many water providers (world-wide) have installed AMR systems, which include benefits such as :

- Improves data accuracy and reliability
- Less labour intensive (reduced labour costs)
- Improves employee safety
- Typically more cost effective than manual meter reading
- Eliminates access problems
- Improved efficiency
- Increased cost-effectiveness
- Improved billing accuracy
- Eliminates estimated meter reads
- Reduces customer complaints, Improves customer satisfaction
- Improves management of delinquent and disputed accounts
- Accelerates cash flow based on monthly billing

- Improves ability to perform off-cycle reads
- Reduces cost and time to gather, manipulate and reconcile meter data
- Provides central repository of meter data for multiple users
- Streamlines data collection of meter data, from diverse source, for many users
- Combines data and systems for efficient reporting and analysis purposes
- Addresses the costly habit of individual departments sourcing their own solutions
- Reduces the potential for errors and confusion as the frequency of data collection and intervals increase
- Accelerates the revenue cycle and cash flow, thereby reducing financial risk
- Provides theft and tamper detection
- Provides data for analysing capital expenditures
- Creates opportunities for new services
- Improves the accuracy of sales and revenue forecasts
- Improves distribution reliability
- Improves management of conservation programs
- Improves leak detection
- Provides ability to design conservation-oriented rate structures

AMR has a successful history in the electricity and gas utility industries, which began in the late 1980s, while implementation in the water industry commenced in the mid-1990s. Thornton reports “AMR market penetration in the US water sector at greater than 25% of customer accounts in 2007 and is expected to reach over 40% by 2012”.

AMR systems consist of a device (“endpoint”) mounted to the customer meter. This endpoint device has the ability to read the meter register (totaliser) and either store this information electronically or transmit it to a receiver via several communication mechanisms.

An AMR system typically consists of the following components:

- Consumption (Flow) Measurement
 - Meter
 - Totaliser (AMR compatible)
- Data Acquisition
 - Pulse Emitter
 - Data-Logger

- Transmitter
- Receiver
- Processing / Monitoring Software
 - Processing / Billing System.

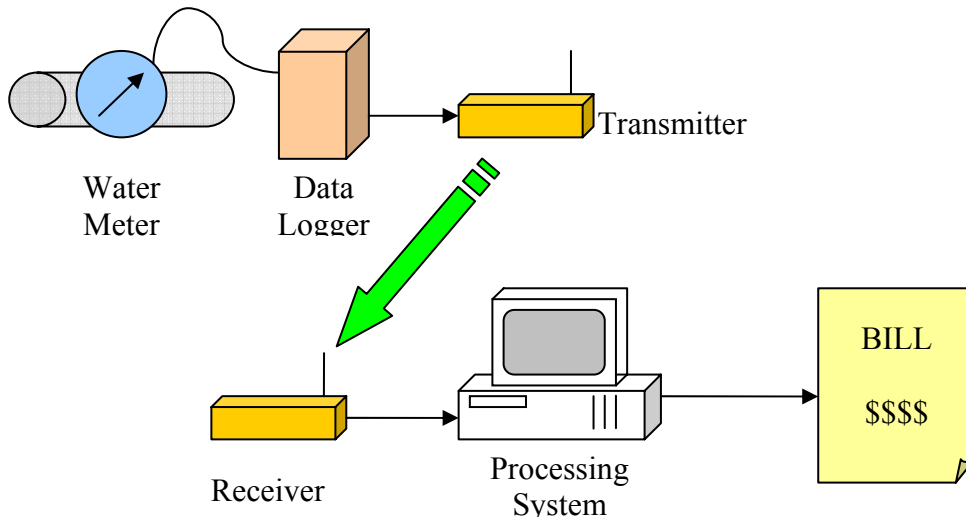


Figure 8: Automatic Meter Reading (AMR) Process

The purpose of AMR systems is to reduce the likelihood of Apparent Losses by identifying leakage patterns and reducing data transfer errors. AMR systems offer additional “best-practice” methods for efficiently and cost-effectively collecting customer consumption data, at more frequent intervals, and on demand. Access to this level of data provides water providers with the ability of being able to monitor their systems in “real-time” for additional leakage detection processes such as:

- Tampering with metering and AMR equipment
- Consumption trend analysis that sends alerts for leakage on customer piping
- Acoustic leak detection
- Backflow (flow-reversal) detection
- Night-reads to determine system leakage during periods of minimum system flows

2.10.1 AMR-Meter Interface

Meters are required to be fitted or compatible with AMR pulse emitters, in order to be connected to AMR equipment.

Automatic Meter Reading manufacturers have developed pulse or encoder registers to produce electronic output for radio transmitters, reading storage devices, and data logging devices. Pulse meters send a digital or analog electronic pulse to a recording device. Encoder registers have an electronic connection for an external device to interrogate the register for either; odometer wheel position or stored electronic readings. Frequent transmissions of consumption can be used to give smart meter functionality. There are also some specialized types of registers such as LCD display instead of mechanical odometers, and registers to output data or pulses to a variety of recording and controller devices. For industrial applications, output is often 4-20 mA analog, for the recording or control of different flow rates, in addition to totalisation.

2.10.2 First Generation – Handheld (“Walk-By”)

The first generation of AMR systems (a step forward from traditional MMR) improves meter reading accuracy, reducing data handling errors. This form of AMR is referred to as “Walk-by” meter reading.

This AMR system communicates the reading signal to a meter reader as they walk from property to property (meter to meter) in order to obtain (via electronic download) individual meter readings either wirelessly or by plugging a handheld device into an exterior port (probe) connection located on the customer meter or metered building. This handheld data collection method eliminates the need to gain access inside the customer property, but still requires the services of a meter reader to step along the designated meter route. This provides improved meter reading accuracy and efficiency, but still incurs similar labour costs. Meter readers are generally able to achieve 300 reads per day.

2.10.3 Second Generation – Mobile (“Drive-By”)

The second generation of AMR systems further improve the meter reading process by increasing the speed and reliability of obtaining meter readings, thereby reducing the time taken to obtain readings from the entire meter population. This form of AMR is referred to as “Drive-by” meter reading.

The Drive-By method of meter reading collection involves the process of meter readers patrolling the meter route in vehicles, which are equipped with communication devices wirelessly collecting meter readings as they pass each property (meter). Meter readers do

not leave the vehicle in order to collect the readings. Dozens of readings can be quickly collected, virtually at the same time, as the patrol vehicle drives slowly down a street.

Equipment in the vehicle sends out radio signals to awaken the AMR endpoint devices attached to the meter, which then transmit meter readings to the vehicle. This Drive-By method offers the advantage of not requiring physical access customer properties for the purposes of collecting meter reads, as is required for the handheld method. Drive-By AMR requires fewer meter readers, as a larger number of daily meter reads (generally 15,000 per day) can be achieved.

2.10.4 Third Generation – Fixed Network (Telemetry, SCADA, GSM/GPRS, WiFi)

Handheld and Drive-by meter reading systems have been the most common form of AMR systems in use by the water providers, who have adopted this technology since AMR became widely available in the water industry, throughout the world. However, AMR in the water industry has now caught up to the electricity and gas industries, that is, the next generation of AMR communication system: Fixed Network AMR.

Fixed network AMR refers to AMR systems, which use cable and wireless fixed communication networks (either publicly or privately owned) of established towers, antennae, WiFi (or similar telecommunications networks) to send AMR signals from the meter to the central receiving location, at the programmed times. Establishing fixed network AMR systems is much more involved than mobile communications systems. Initial construction and installation costs are also much higher to set up, compared to Handheld and Drive-By systems. However, this must be weighed against the benefits being sought from the AMR system, such as eliminating the need to have dedicated full-time staff in the field for meter reading, which saves personnel costs and reduces staffing problems. Another benefit sought by installing a fixed network AMR is the ability to obtain customer meter reading at any frequency interval and at any time of the day. This permits sufficient data to be obtained to create customer use profiles from hourly (or shorter periods) data readings and displaying consumption patterns.

The third generation of AMR systems consists of installing data-loggers (which collect and store readings from the AMR endpoint devices) in locations such as water treatment plants, pits or pumping stations managed by the water provider, which may already be equipped

with telemetry devices, which use designated radio frequency bandwidths, to transmit information back to the water provider's central billing and operations centres.

These systems can either be automatically transmitted or 'called up' at pre-determined times, and incorporated with water provider SCADA (Supervisory Control and Data Acquisition) management systems.

The success of telemetry systems is limited to sites with suitable power availability, and signal strength, for the reception and transmitting of data without interference from physical obstacles such as vegetation, terrain, buildings or infrastructure, which interfere and hinder the signal transmission and integrity. Telemetry provides a suitable option for locations close to the central receiving location, due to very short distances with less interference from city obstructions. Telemetry also offers a solution for obtaining readings from more remote locations by relaying the signal through repeater stations and eliminating the need for meter readers to travel long additional distances for the purpose of collecting meter reads.

Further advances in technology development now offer a water provider to ability to avoid the cost of having to install (or have access to) costly fixed communication infrastructure, by using commercially available wireless and mobile communications networks, such as GSM/GPRS, WiFi, Zigbee, for transmitting and receiving AMR data.

3.0 Methodology

I commenced this investigation with a review of the methods currently used by Ipswich Water, for the process of obtaining metered water consumption data. I then analysed billing and customer information from the previous year, to determine system configuration, requirements and customer water-use quantities.

As I progressed with this project, it became clear that the needs and demands on water providers are many, and end-results are important. However, the result sought from my investigation was, to lesser extent, the specification of system components and arrangements. The primary requirement of this project is first and foremost, to provide the water authority with an explanation of currently available process capabilities and requirements. Component selection was secondary, and served only to provide the water authority with a roadmap and destination for their future implementation, because much ground work was still required by the water provider, before an AMR system can be pursued. Much of this work will form the basis of future projects and investigations.

I proceeded to review the methods used by other Australian Water Supply Authorities, and their performance, in relation to managing water-loss. My objective was to determine a benchmark of best practice, against which, a water supply authorities can measure and model their performance in relation to water-loss control, within their water supply distribution systems.

Finally, I conducted a review of commercially available metering and data-acquisition (AMR) technology, which may be installed into existing and future water distribution systems, for the purpose of obtaining frequent and accurate meter readings.

3.1 Water Loss (Non-Revenue Water) Control

The water supply process consists of two basic management functions:

- Supply-Side (Distribution System) Management (Delivery to customer meter)
 - Collecting
 - Treatment
 - Storage
 - Pressure and Leakage Management
 - Delivery to user connections (Customer meters)

- Demand-Side (Customer) Management
 - Consumption patterns of end users (Customers)
 - Consumption data acquisition
 - Customer Billing (for metered water usage)

Demand-side strategies have already been implemented through public awareness campaigns, water restrictions, enforcement and prosecution, pricing. Further strategies, such as “off-peak” tariffs, infrastructure investment planning and deferment, requires an improved and more dynamic method for obtaining usage data and consumption patterns.

Obtaining consumption (Diurnal) and losses, requires a water balance to be performed between water supplied into the system and water consumed (by users) from the system. The gap between these amounts is defined as a loss (leakage), which is a loss for the water authority both financially and physically (environmentally).

I conducted an analysis of recorded annual water usage for each water connection size (Figure 9), which reveals that (on average), consumption by households (typically 20mm connections), is within range of the usage targets set by SEQ Water Restrictions. However, higher levels of usage occur through the larger water connections (greater than 20mm), as these outlets are typically associated with multi-dwellings such as Units, Flats, Offices, Shops, Light Industry, parks and gardens. District metering (multi-dwelling sub-metering) may be utilised for these services.

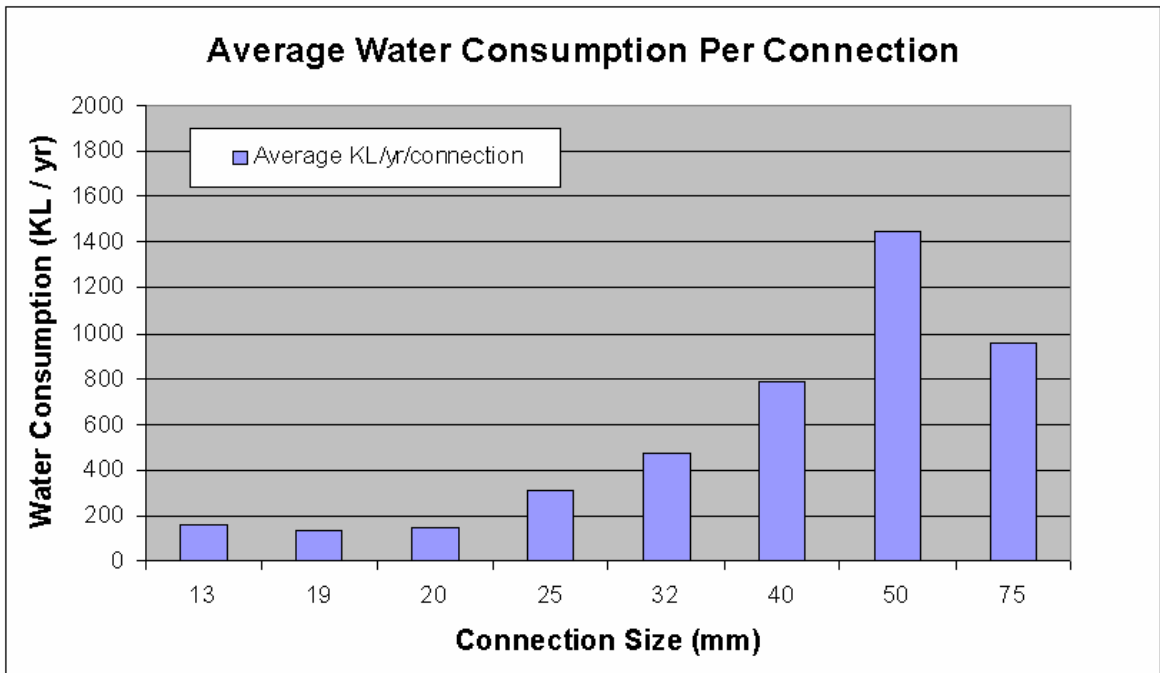


Figure 9: Average Annual Water Consumption by Connection Size.

| Meter Connection Size (NB) | Residential | Commercial | Industrial | Civic Services | Community Organisations | Rural | Vacant | Other | Combined Total |
|----------------------------|-------------|------------|------------|----------------|-------------------------|-------|--------|-------|----------------|
| 13 | 425 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 426 |
| 15 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 19 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21 |
| 20 | 46,705 | 595 | 270 | 166 | 144 | 172 | 586 | 19 | 48,657 |
| 23 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 25 | 316 | 117 | 88 | 52 | 22 | 3 | 12 | 9 | 619 |
| 32 | 164 | 104 | 46 | 21 | 7 | 4 | 3 | 0 | 349 |
| 40 | 315 | 71 | 33 | 32 | 9 | 5 | 12 | 4 | 481 |
| 50 | 332 | 239 | 80 | 92 | 34 | 5 | 10 | 12 | 804 |
| 75 | 11 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 12 |
| 80 | 164 | 11 | 10 | 10 | 5 | 0 | 0 | 0 | 200 |
| 100 | 639 | 58 | 34 | 48 | 13 | 0 | 4 | 0 | 796 |
| 150 | 173 | 13 | 5 | 3 | 1 | 0 | 1 | 0 | 196 |
| 200 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |

Table 1: Number of Meter Connection Sizes supplying each Consumption Group.

Uncertainty is introduced to consumption measures, due to the possibility of meters under-reading during periods of low-flow. Larger connections (and meters) perform a function in the same manner as district metering (such as multi-dwellings). Usage is apportioned to each user in the nominated district, in agreed allocations.

The Water Services Association of Australia (WSAA) collects data, from the reported results of Australian Water Utilities, to compile an annual report on Water Utility performance. An analysis of the water-loss data shows no correlation between reported losses and size of the water distribution network. Therefore, water loss cannot simply be accepted as inevitable (for large systems) because of the physical size of the water distribution system. A similar comparison of the number of customer connections also shows that a larger number of connections do not correspond with higher water loss. The exact cause must be identified, before the problem can be fixed.

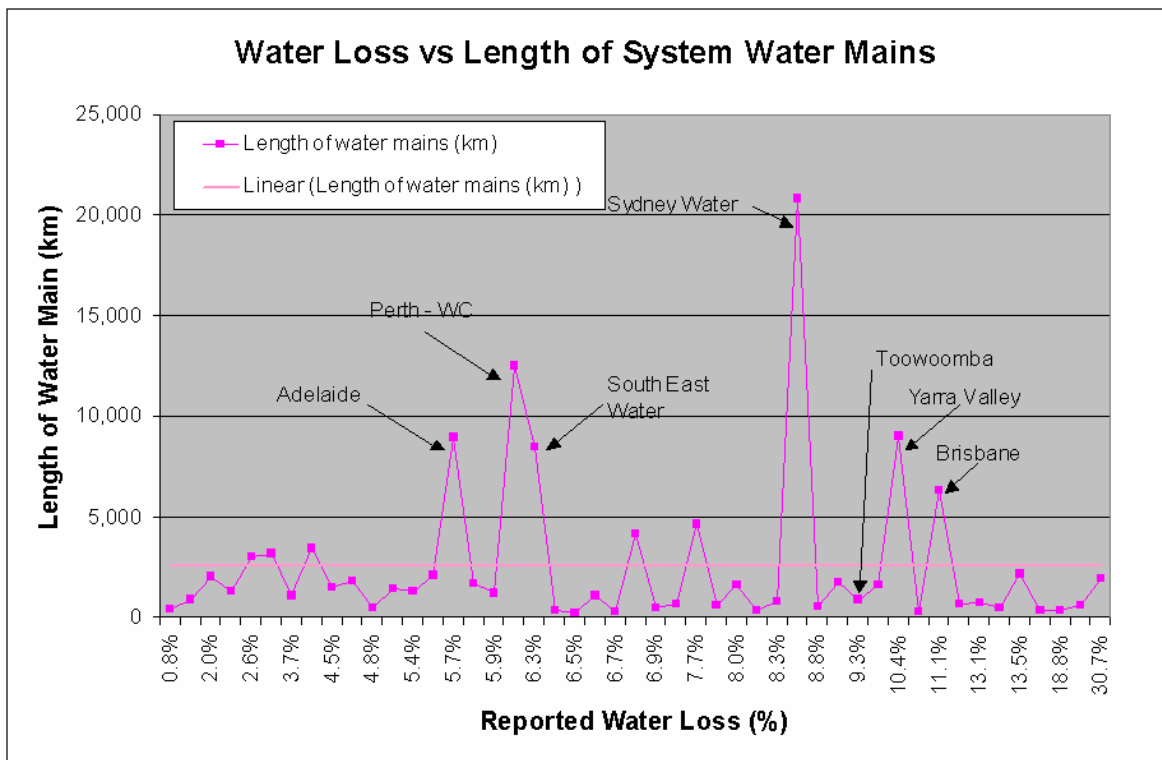


Figure 10: Reported Losses for Australian Water Supply Authorities

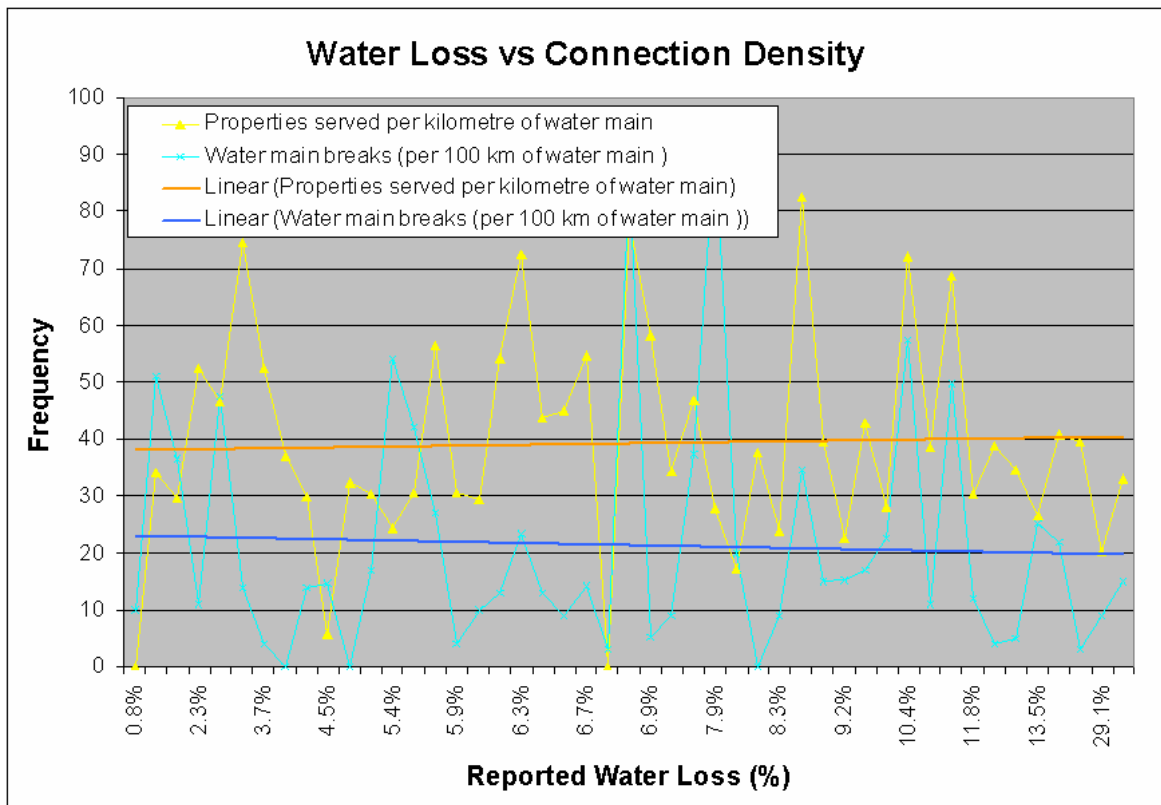


Figure 11: Reported Pipe Breaks for Australian Water Supply Authorities

Several factors may contribute to water loss, such as:

- System Size and number of connections,
- Installation method,
- Bedding material stability,
- Pipe-work material strength,
- Theft (un-authorized use)
- Incorrect meter reads (generally under-reading, due to wear of the meter components, which favours the customer).

Accounting for all water within a system requires accurate usage measurements at nominated moments in time. These measurements are obtained by metering. Therefore, the water meters are the key element in relation to monitoring water movements within a water distribution system. Being able to measure this usage is essential and is a task, which relies completely on the accuracy of the water meter and the ability to easily obtain frequent and reliable readings from these meters.

Three locations are employed within the water supply system, to obtain these measurements (refer Figure 12):

- Production Meters (storage outlets to determine inflow)

- District Metered Areas (DMAs) (installed within the system, identify leakage points)
- Customer Meters (system outlets to determine revenue water)

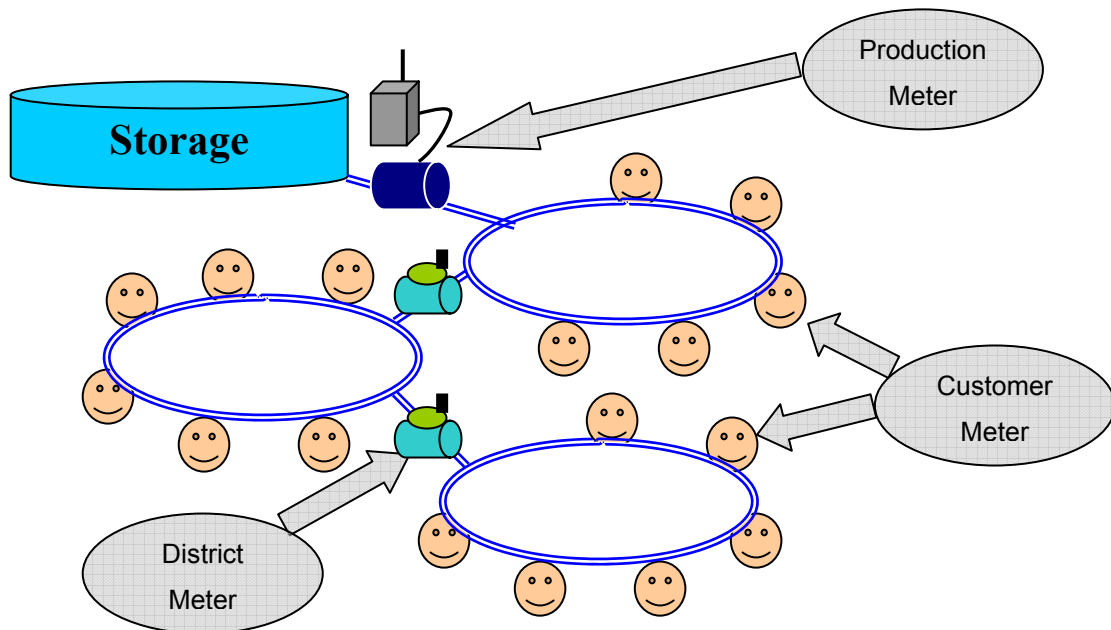


Figure 12: Typical water supply system meter locations

3.2 Data Collection

I analysed the Ipswich Water customer database, which was downloaded from the “PATHWAYS” customer billing system, for the year 2007. This provided four quarterly readings, which, when combined, give me the annual consumption level for each billing meter “assessment” (reading).

This meter list consists of 52,564 assessments (billed, metered consumption readings), which measured a combined annual water consumption of 11,621,350 KL. Water-use for these assessments range from 0L / year to 37,816 KL / year, at an average (mean) of 221 KL / user-connection / year, for all users combined.

In reality, this user population consists of varying consumption behaviours, depending on the water-use purposes, from each of these connections. In order to manage the water-use habits for each user, benchmarks need to be determined on a rate basis, so that acceptable and unacceptable levels of water-use can be identified for the purpose of identifying

leakage, loss and waste components within the water system, for water accounting procedures.

Identifying distribution system losses can be split into two basic categories:

- Losses due to pipe bursts
- Losses resulting from background leakage.

However, these are difficult to determine at this time, without up-to-date meter-readings or expensive and time-consuming leak-detection activities. AMR systems will be recommended for the purposes of monitoring system performance.

Details of burst frequency are available from Ipswich Water records, but it has not been possible for me to correlate these events with specific system performances, due to the lack of frequent and synchronised meter data. The nature of these bursts is a sudden loss of water, for the period of time (which cannot be accurately determined) for which reported and unreported bursts are allowed to discharge. Background losses are characterised by a continual seeping of water from pipe-fittings and from mains which are cracked or perforated through corrosion. Again, lack of frequent meter data intervals does not permit these to be analysed as part of this project.

The quantity of leakage from a water distribution system is related to the system pressure, thus reducing pressures during off-peak hours can reduce leakage. Pressure reduction is achieved through valve operation. Ipswich Water already have pressure reduction programs underway and therefore, this will not be investigated as part of this project.

In addition to water pressure management, active leakage control involves disaggregating of large networks into smaller areas (district metering areas) that can be better monitored (Engelhardt, Skipworth, Savic, Saul and Walters, 2000). DMA areas are currently being investigated and planned to be implemented by utilizing existing system meters which are being located, updated and reviewed by Ipswich Water employees.

Water audits are then used to provide a detailed account of water flow into and out of these portions of the distribution system. This enables areas having excessive leakage, to be identified. Unfortunately they do not provide the specification location of leaks. To

pinpoint leaks, detection surveys are required. A water audit format and model is included as part of this project, based on IWA methodologies and terminologies.

3.3 Modelling

Modelling can be used to help manage leak reduction by determining the effects by disaggregating networks into smaller areas, or by adjusting control valves, which regulates pressure and flow within the system. Using a model to estimate the amount of leakage, is less precise and unreliable. This estimation involves modeling leakage through the use of a flow emitter element or a reservoir connected to the system through small pipe. Modelling and integration with GIS systems is recommended as part of future projects, due to large volume of asset information collection and verification required to be obtained from many IW employees.

Walski et al, (2001) defines two basic approaches (top-down and bottom-up) for filling data gaps within the system between water production meters and customer usage meters. Both of these methods are based on general mass balance concepts and is shown below.

Start: Production Meter Data

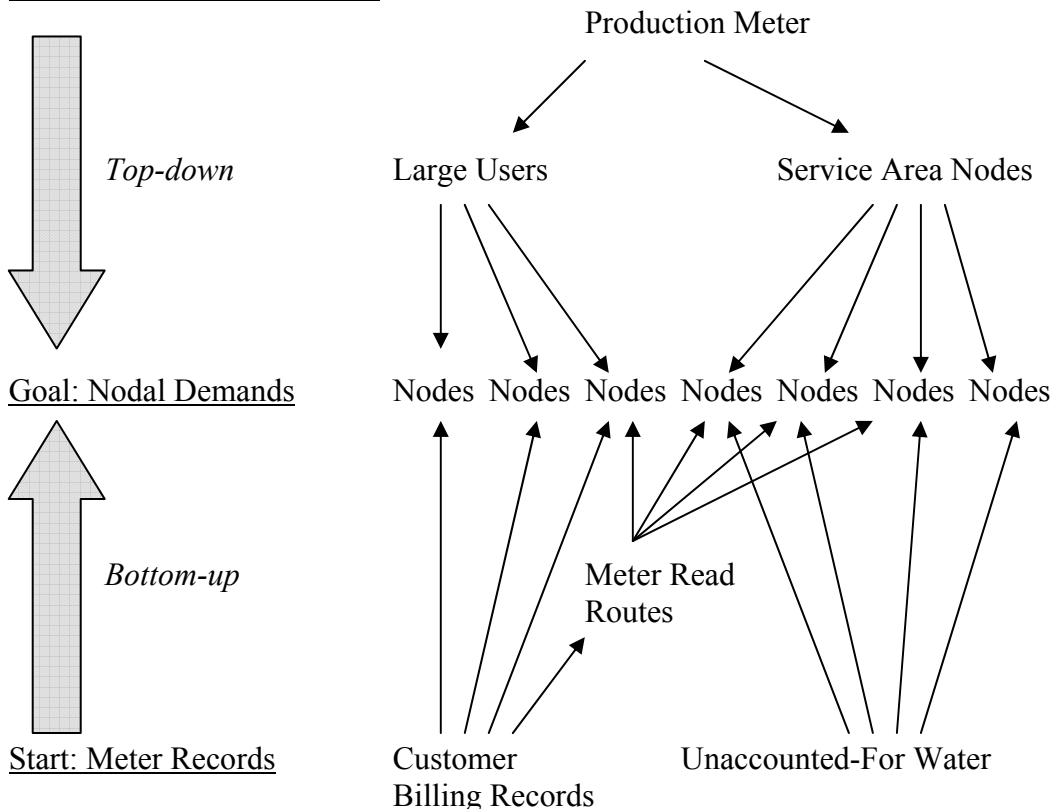


Figure 13: Model Data-Allocation Methods

Tackling Real Losses in the field also requires system maps and plans to be accurate and up to date. Several types of media are used for retaining such information, however, by utilising the latest Geographical Information Systems (GIS), all of this information can be stored electronically in a central storage system, which permits all employees of the water provider, to access the information they need, as well as providing a customer information database for managing complaints, billing, maintenance programs, system upgrades, system modelling and infrastructure planning.

4.0 Results

4.1 Identifying Major Water-Users

The most common, and most widely documented, consumption levels relate to domestic water-use, which has even been regularly measured to an appliance-by-appliance level of accuracy. This enables a reasonable estimation to be made for each residence, based on the number of occupants present (i.e consumption on a per person, per capita, basis). Differing consumption levels and frequency exist for other water-use purposes such as commercial (eg. Offices), industry and public use. However, estimating the consumption patterns for these groups becomes more difficult to generalise as factors can be attributed to a consumption rate based on units such as; per person, per square metre, per machine, per day, per kilogram of product produced, etc. These factors are then all varied depending on seasonal changes in temperature.

Ipswich Water has chosen ninety-one categories to define the expected consumption patterns for each water connection (e.g. dwelling, flats, farming, offices, vacant land, licensed clubs, community clubs, schools, shops, motels, etc). These ninety-one categories are then more broadly grouped into one of eight chosen general categories (Table 2) for the purpose of allocating appropriate pricing structures for revenue collection. I produced the following table to determine a summary of the annual water-use and number of connections per category.

| Consumption Group | Total Consumption (KL / yr) | Total Number of Connections | Average Consumption Per Connection |
|--------------------------|------------------------------------|------------------------------------|---|
| Residential | 9,535,265 | 49,267 | 194 |
| Commercial | 757,827 | 1,209 | 627 |
| Industrial | 509,803 | 567 | 899 |
| Civic Services | 455,727 | 425 | 1,072 |
| Community Organisations | 169,170 | 235 | 720 |
| Rural | 122,440 | 189 | 648 |
| Vacant | 49,215 | 628 | 78 |
| Other | 21,903 | 44 | 498 |
| Combined Total: | 11,621,350 | 52,564 | 221 |

Table 2: Water Consumption-Pattern Categories

From my results with this data, I can determine that residential consumption patterns account for 82% of the total measured water consumed for this period. Therefore, in order to further determine major water-users within this category, I selected several consumption ranges to investigate average water-use values for each group and the distributed usage values in relation to these points, to identify outliers within each group, which in turn identifies major users who may need to have their water-use investigated more closely by Ipswich Water, or to be re-categorised, and billed accordingly, at more appropriate water consumption rates.

To determine the consumption ranges, based on the high level of residential consumption, I used expected residential consumption as the basis for all groups, as a means of broad comparison.

Firstly, at the time of this data collection, Ipswich Water residents were under water restrictions of 140 litres (maximum) per person per day. Therefore, I set the lower consumption range equal to the amount allowed for a one person residence on an annual basis (i.e $1 \text{ person} \times 140 \text{ L/day} \times 365 \text{ days/yr} = 51,100 \text{ L/yr}$), being 0 – 50KL/yr.

I determined the second consumption range, based on the average (mean) Ipswich residence ($144,000 \text{ residents} / 49,000 \text{ connections} = 2.94 \text{ residents per connection}$) of three residents per household connection, this equates to an allowed annual household consumption of (i.e $3 \text{ people} \times 140 \text{ L/day} \times 365 \text{ days/yr} = 153,300 \text{ L/yr}$) 50 – 200KL/yr.

I nominated the third consumption range, based on a large household, say two families making a household of ten residents. This equates to an allowed annual household consumption of (i.e $10 \text{ people} \times 140 \text{ L/day} \times 365 \text{ days/yr} = 511,000 \text{ L/yr}$) 200 – 500KL/yr.

These three ranges account for 50,676 of the connections in the Ipswich Water system. Therefore, I set subsequent consumption ranges in multiples of 1,000 litres, up to and including the maximum reading of 37,816 KL/yr consumption. The graphs below (Figure 14 and Figure 15) show this distribution of user consumption levels. Analysis of residential consumption, based on these consumption ranges, resulted in identifying 1,263 connections, which use well in excess of the allowed consumption levels. This provides Ipswich Water with a list of priority connections to target for closer inspection, with the

objective of gaining potential savings, or pricing structure reviews and category reclassification of these users, based on their actual water use.

Government legislation (Water Act 2007) defines major water-users as those with consumption levels equal to or greater than 10,000 KL (10 ML). These users are required to develop and submit Water Efficiency Management Plans (WEMPs) in order to maintain their connection to the water distribution system. From the customer data, I have identified 41 customers who have consumed greater than 10ML, and therefore can be reviewed for compliance against the Water Act requirements for WEMP implementation and monitoring.

The following graphs (Figure 14 and Figure 15) show that the majority of Ipswich Water users consume much less than the 10 ML / yr level and therefore, are not required to submit WEMPs.

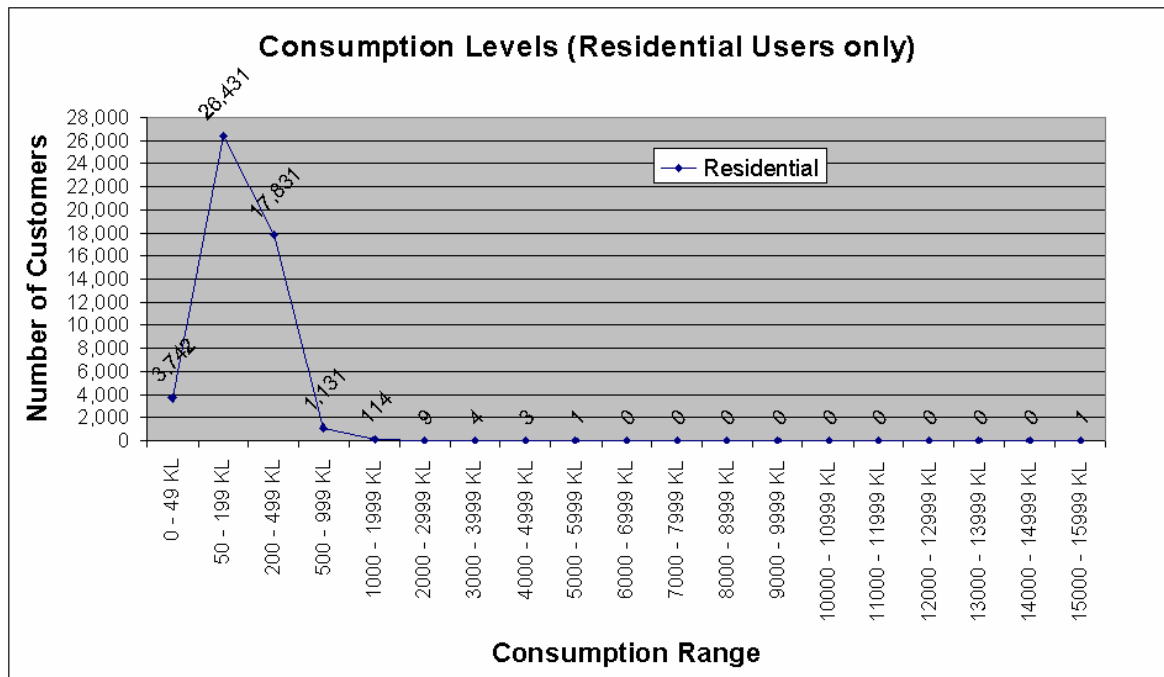


Figure 14: Consumption Levels for Residential User Group Category

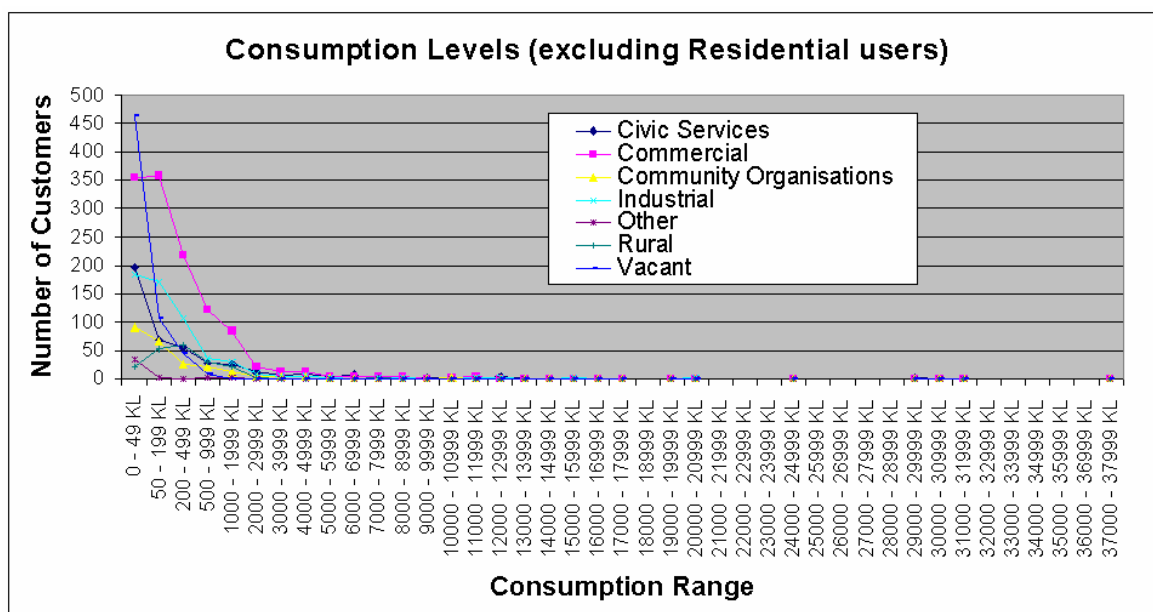


Figure 15: Consumption Levels for User Group Categories (Excluding Residential)

Ipswich Water achieved its goal of 100% metered connections, in March 2007. The requirement now, is the ability to utilise the availability of this meter data in a more effective manner than staggered, 4-12 meter reads per year.

4.2 Meter Product Options

I have conducted a review of suitable meters and identified twelve brands of water meter, as being suitable for billing purposes and compatible with AMR technology. An indicative selection of these meter types, is listed below, based on local (Australian) product support and availability.

| Meter Type | Actaris (+Itron) | AMCO (+Elster) | Badger Meter |
|----------------------------|------------------|----------------|--------------|
| Single Jet Meter | Yes | Yes | |
| Multi-Jet Meter | Yes | Yes | |
| Oscillating Piston Meter | Yes | Yes | |
| Woltmann Meter | Yes | Yes | Yes |
| Combined (Compound) Meter | Yes | Yes | Yes |
| Paddle Wheel Meter | | Yes | |
| Electromagnetic Flow Meter | Yes | Yes | Yes |

Table 3: Selected AMR Meter Suppliers

4.2.1 Single-Jet Meters

ACTARIS – ‘Flostar’ Single Jet Meters



Features:

- Meter Class: Class C
- Nominal Pipe Size: DN15 - 150
- AMR Interface: Cyble

ACTARIS – ‘Flodis’ Single jet turbine type water meter



Features:

- Meter Class: Class C
- Nominal Pipe Size: DN 15 - 32
- AMR Interface: Cyble

ACTARIS – ‘Flostar’ Commercial and Industrial Single Jet



Features:

- Meter Class: Class C
- Nominal Pipe Size: DN 40 - 150
- AMR Interface: Cyble
- No upstream or down stream straight pipe length required
- Horizontal installation required
- Strainer is not required

4.2.2 Multi-Jet Meter

ACTARIS – ‘MultiMag’ Multi-jet Meters



Features:

- Nominal Pipe Size: DN 15 - 50
- AMR Interface: Cyble

ACTARIS – ‘MC’ Multi-jet Meters

Features:

- Meter Class: Class C
- Nominal Pipe Size: DN15 - 20
- AMR Interface: Cyble

ACTARIS – ‘MSD Cyble’ Multi jet turbine type water meter



Features:

- Meter Class: Class B
- Nominal Pipe Size: DN 25-50
- AMR Interface: Cyble

4.2.3 Rotating Piston Meter

ACTARIS – ‘Aquadis’ Rotary Piston volumetric type water meter



Features:

- Meter Class: Class C
- Nominal Pipe Size: DN 15 - 65
- AMR Interface: Cyble

4.2.4 Woltmann (Turbine) Meter

ACTARIS - Woltex Horizontal Turbine Meters



Features:

- Meter Class: Class C
- Nominal Pipe Size: DN 200 - 250
- AMR Interface: Cyble

ACTARIS – ‘Woltex’ Horizontal Woltmann type water meter



Features:

- Meter Class: Class B
- Nominal Pipe Size: DN 50-500
- AMR Interface: Cyble
- Integrated flow straightener, it provides accurate metering whatever the upstream flow conditions
- Accurate metering in any position

4.2.5 Combination (Compound) Meter

ACTARIS – ‘Isoflo’ Combination water meter



Features:

- Meter Class: Class B + Class C
- Nominal Pipe Size: DN 50-150
- AMR Interface: Cyble

4.2.6 Paddle Wheel (Proportional / Irrigation) Meter

ACTARIS – ‘Irrimag’ Proportional water meter



Features:

- Meter Class: Class B
- Nominal Pipe Size: DN 65-200
- AMR Interface: Cyble

4.2.7 Ultrasonic Transit-Time Meter

ACTARIS – ‘Echodis’ Ultrasonic water meter



Features:

- Meter Class: Class C
- AMR Interface: Cyble

4.3 AMR Product Options

I have identified six suppliers of AMR data acquisition products as compatible with AMR water meters and communication technologies.

Five of these suppliers offer the full spectrum of AMR capabilities in terms of data-collection methods and software monitoring and management. These suppliers have been chosen so as to ensure component compatibility. This provides the option of creating ‘hybrid’ systems, and system upgrades, in the future. These manufacturers are shown below:

- Actaris
- Badger Meter
- Datamatic
- Elster
- Itron

| AMR Solution | Actaris (+Itron) | Badger Meter | Datamatic | Elster (+AMCO) | Itron (+Actaris) |
|-------------------------------------|-------------------------|---------------------|------------------|-----------------------|-------------------------|
| AMR-Meter Interface | Yes | Yes | Yes | Yes | Yes |
| Handheld ("Walk-By") | Yes | Yes | Yes | Yes | Yes |
| Mobile ("Drive-By") | | Yes | Yes | Yes | Yes |
| Fixed Communications Network | | | Yes | Yes | Yes |
| Software Monitoring | Yes | Yes | Yes | Yes | Yes |
| Sub-Metering / Mesh Networks | | | Yes | | |

Table 4: Selected AMR Solution Suppliers

AMR systems can achieve a range of meter read rates and can be optimised to suit local conditions:

- Standard meters = 100 – 125 reads per day (with notebook)
- Standard meters = 125 – 175 reads per day (with hand-held unit)
- Absolute encoder register = 175 – 450 reads per day

- Walk-by probe connection = 175 - 450 reads per day
- Walk-by RF = 1,000 – 2,000 reads per day
- Mobile RF = 2,000 – 30,000 reads per day
- Fixed RF system = 96 reads / meter / day (15min intervals)
- Hybrid system = up to 96 reads / meter / day (15min intervals)

AMR system location, functionality and compatibility must be considered in order to select the best option for performing this task. This includes tasks such as:

- Method for data collection
- Frequency (interval) of data results,
- Power, battery life
- Data transfer and storage capacity

Data acquisition from water meters, can be collected by several methods:

- Wireless Communication (Radio Frequency Transmission)
 - Handheld (Walk-By)
 - Mobile (Drive-By)
 - Radio Frequency Network Transmission (RF Telemetry)
 - Global System for Mobile Communications (GSM / GPRS)
 - Satellite Telephone Network
 - Other: eg. Zigbee, Wi-Fi
- Fixed Network (Co-axial and Optic Fibre cable transmission)
 - Hand-Held unit connection via probes.
 - Fixed Line Public Telephone Network (Modem, Coaxial, Optic Fibre cable)
 - SCADA, PLC systems

An AMR system includes a meter interface (referred to by some manufacturers as an ‘Endpoint’ device or ‘Meter Module’), which is configured to provide optimal compatibility, in order to fit all major meter types. Standardisation across AMR technologies (in order to provide maximum compatibility with commercially available communication networks) has resulted in very few compatibility issues between supplier’s and their products. However, some suppliers have been acquired, or have formalised ‘partnership’ agreements, with other suppliers in the industry so as to enable them to provide ‘complete solution’ services and guaranteed performance and reliability. For

example; Actaris (water meters) is a subsidiary of Itron (AMR solutions), and AMCO (water meters) is a division of Elster (communications).

Technology advances now provide AMR battery life, equal to the life expectancy of most meters, this means batteries can be conveniently replaced during normal scheduled meter replacement programs.

A regular ERT module operates in "wake-up" mode, awaiting a radio signal from a reading device, which prompts it to transmit metering data to a collection system. In addition to wake-up mode, the new dual-mode ERT module can operate in "bubble-up" mode, in which no wake-up signal is required. Instead, the ERT sends a continuous stream of data that can be picked up by most collection systems. Dual mode ERTs, operating in 'bubble-up' mode, means an FCC license is not required (which is an additional operating expense), due to the one-way communication process on an unlicensed radio frequency band. This is one less barrier and headache for many smaller utilities and municipalities that do not have the resources available to obtain FCC approval.

An indicative selection of these AMR products is provided below, based on local (Australian) product support and availability.

4.3.1 AMR-Meter Interface

ACTARIS – 'Cyble' M-Bus Coder



This device converts the meter totaliser readings into an electronic signal, which automatically registers the water meter reading and stores the values for data-collection via an AMR collection method. The Cyble module is connected to meters, which are equipped with the standard Cyble target. This enable the modules to be easily fitted to the water meter during installation or at a future date, to adapt with AMR requirements.

The Cyble Coder can be configured for a two or three wire application, making it compatible with all major touch pad and AMR systems.

The Cyble module enclosures are non-magnetic, which prevents tampering. The enclosures are also water-proof which permits operation in flooded pits.

Features:

- Battery life 12 years
- Cable length 1.52m or 7.62m
- Wire connection 3 wires
- Working temperature -15 C to 60 C
- Enclosure Protection IP 68
- Reading distance Up to 152 m
- Output format ASCII
- 3 fixed date readings
- Backflow detection
- Leakage detection

ACTARIS – ‘Cyble’ M-Bus Sensor



This device converts the meter totaliser readings into an electronic signal, which automatically registers the water meter reading and stores the values for data-collection via an AMR collection method. The Cyble module is connected to meters, which are equipped with the standard Cyble target. This enable the modules to be easily fitted to the water meter during installation or at a future date, to adapt with AMR requirements.

The Cyble Sensor is a pulse output device with no polarity requirement and can adapt to a wide variety of remote reading applications. Ten rotations of the Cyble target will cause one pulse to be sent from the Sensor to a remote AMR device. Unlike most reed switch (pulse) type registers, the Cyble Sensor is non-magnetic and therefore, not susceptible to

magnetic tampering. The Sensor provides an accurate and reliable pulse output AMR solution. The enclosures are also water-proof, which permits operation in flooded pits.

Features:

- Battery life 12 years
- Cable length 4.57m
- Wire Connection two wires (no polarity)
- Working temperature -9.4°C to 54.4°C
- Enclosure Protection IP 68
- Max current 100 mA
- Max voltage 30 V
- Output format Pulse output
- 3 fixed date readings
- Backflow detection
- Leakage detection

ITRON – 60W and 50W Series Water Endpoints



Data collection endpoint devices for use with Itron's radio-based G5 and FC200 handhelds, mobile AMR and the Itron Fixed Network are programmed to communicate with Itron meter-reading technologies in either "wake-up" mode or "bubble-up" mode. These provide broad protocol support, from all major water meter manufacturers

Features:

- No field programming required
- Advanced leak detection
- Reverse-flow detection

- Tamper detection
- 20-year battery life
- These water endpoints, work with Itron ‘Choice-Connect’ and ‘Water Save - Source’ radio-based handheld and mobile collection systems.
- Data logging allows for storage and retrieval of 35 days of hourly consumption information
- One watt of radio frequency power
- Remote antenna is available to mitigate the RF signal degradation caused by metal pit lids

4.3.2 Handheld (“Walk-By”)

ACTARIS – ‘Easyco’ Windows CE Handheld Terminal



Features:

- Easyco is designed for mobile metering data collection
- Integrated radio frequency interface
- Colour touch screen
- Low weight
- IP54 Enclosure rating
- Meter-reading associated software, ‘EasyRoute’ Mobile WinCE, offers a wide range of functions: upload/download of routes, easy group reading, fast meter reading mode, graphical display of alarms, consumption profile, leakages

ITRON – ‘G5 & G5R’ Handheld Terminals



Field Collector G5 series (and the 200 series), handheld computers combine accuracy and mobility to facilitate ‘Walk-By’ meter-reading. These handhelds are part of Itron’s ‘ChoiceConnect’ AMR data collection suite and can be used for manual or automatic meter reading (AMR), to simplify reading of water meters, when fitted with radio for AMR systems.

The ‘G5’ handheld computer is a DOS-based meter data collection handheld terminal. The enhanced ‘G5R’ is equipped with a powerful radio transmitter/receiver for walk-by collection of meter readings.

The ChoiceConnect ‘G5’ is a light-weight handheld computer for visual and radio-based (G5R) meter reading. The G5 is a handheld computer which is; rugged, flexible, compact, lightweight, water and dust resistant, and operates in a wide range of temperatures. The G5 integrates the functionality of a modern DOS computer into an ergonomic package that provides all the basic meter data collection functionality required within a single unit. The G5 is used for basic manual key-in data entry, as well as time-of-use (TOU) probing and water or touch pad probing. The G5R combines the G5 features as well as being fitted with a radio transceiver for walk-by meter reading data collection from endpoint-equipped water meters.

The G5 and G5R are compatible with the following Itron data collection software systems: MV-RS, Premiereplus4 and Integrator. Data collection software is used to download route information to the handheld, upload the collected meter data and transfer it to a billing system or meter data management system, such as Itron Enterprise Edition Meter Data Management.

Features:

- Provide meter readers with preprogrammed route and customer account information for better route management.
- Download meter readings directly into your data collection software.
- Reduce operational costs associated with reading hard-to-access meters.
- Eliminate manual data entry errors.
- Increase the number of meters that can be read in a single day.
- Improve customer satisfaction by eliminating intrusive meter reading visits.
- Improve employee and customer safety.

ITRON – ‘FC200’ & ‘FC200SR’ Handheld Terminals



Field Collector 200 series (and the G5 series), handheld computers combine accuracy and mobility to facilitate ‘Walk-By’ meter-reading. These handhelds are part of Itron’s ‘ChoiceConnect’ AMR data collection suite and can be used for manual or automatic meter reading (AMR), to simplify reading of water meters, when fitted with radio for AMR systems.

The FC200 (and enhanced FC200SR features) handheld computer, built on the Microsoft Windows® CE. NET operating system, contains a radio transmitter/receiver for automatic meter reading. The FC200 is designed for manual key-in meter data entry as well as time-of-use (TOU) probing and water or touch pad probing.

The FC200SR (which enables personnel to program, service and read up to 80 endpoint messages simultaneously, with one handheld computer), features Itron’s ‘Sread’ radio technology, (900 MHz radio) for automated meter reading of endpoint-equipped water meters. The ‘Sread’ radio listens across 16MHz frequency and uses 80 channels to capture more endpoint transmissions in a shorter amount of time for greater read efficiency.

This handheld, can be used with Itron MV-RS® or Itron Field Collection System data collection software. They also interface with Itron’s mobile workforce management

applications, Service-Link™, Endpoint-Link® and Endpoint-Link® Pro, for added field service productivity.

Features:

- Pre-programmed route and customer account information for better route management.
- Download meter readings directly into your data collection software.
- Improve meter data accuracy by eliminating manual data entry errors.
- Increase the number of meters that can be read in a single day.
- Reduce operational costs associated with reading hard-to-access meters.
- Improve customer satisfaction by eliminating intrusive meter reading visits.
- Improve employee and customer safety.
- Receive up to 80 ERT messages simultaneously.
- Utilise higher power transmission.
- Expand customer options for use with future technologies.

4.3.3 Mobile (“Drive-By”)

ITRON – ‘MC3’ Mobile Collector



Itron’s ‘MC3’ AMR system, uses a vehicle equipped with a portable radio transceiver and computer to gather consumption and tamper data from water radio-based endpoints. Itron ‘Sread’ radio technology read sensitivity, offers two drive-by solutions:

- Option 1 - For high-density, high-volume meter reading operations
- Option 2 – For diverse meter populations, with lower density.

Both options provide the benefits of mobile AMR: increased operational efficiencies, improved customer satisfaction, enhanced employee and customer safety and GPS technology to optimise drive time.

Mobile AMR is ideally suited for high-density areas, as well as areas with difficult-to-access, or hazardous-to-read meters and can dramatically improve meter reading. A single MC3 is capable of reading up to 100,000 meters in a day, whether reading a single route or reading multiple routes simultaneously (compared to the few hundred meters read per day on a typical walking route).

SRead radio technology offers increased receiver sensitivity and simultaneously listens and acquires readings over 80 channels for improvement in reading times and range. The MC3 supports an optional directional antenna for added read performance and is small enough to be easily moved from vehicle to vehicle.

With mobile AMR, route information is downloaded from the utility billing system and loaded into the radio transceiver. Capable of operating in either wake-up or bubble-up mode, the MC3 reads all meter endpoints. The MC3 can further optimise route drive times and distances with a specialised mapping application. The GPS Mapping System provides a visual indication of endpoint locations and read confirmation. This virtually eliminates the need for re-reads or collecting skipped reads, thereby reducing meter reading times and fuel consumption, and improving worker productivity.

Features:

- Increase operational efficiencies by reading more meters in a shorter amount of time
- Initiate mobile demand resets and time-of-use register collection for commercial accounts
- Eliminate the high operational costs associated with hard-to-read meters or skipped meter reads
- Boost customer satisfaction by eliminating intrusive meter reading visits and providing
- Accurate and up-to-date billing data
- Improve employee and customer safety
- Enhance the quality of your billing data by eliminating manual data entry errors
- Identify energy theft and revenue loss due to meter tamper
- Meet performance-based rate (PBR) criteria

ITRON – ‘Mobile Collector Lite



The ‘ChoiceConnect’ ‘Mobile Collector Lite’ is an easy-to-use, portable Drive-By AMR solution that uses the Itron FC200 handheld with an external radio, to gather consumption and tamper data from water radio-based endpoints. ‘Mobile Collector Lite’ combines Drive-By meter data collection with the flexibility of AMR Handheld units, to achieve AMR benefits at a reduced cost.

Features:

- Increase operational efficiencies by reading more meters in a shorter amount of time.
- Improve customer satisfaction by eliminating intrusive meter reading visits and providing more accurate and up-to-date billing data.
- Improve employee and customer safety.
- Improve the quality of your billing data by eliminating estimated reads and manual data entry errors.
- Identify energy theft and revenue loss due to meter tamper

4.3.4 Fixed Network (Telemetry, SCADA, GSM/GPRS, WiFi)

ITRON – ‘Water SaveSource’



Fixed network technology, and the data it delivers, is increasingly sought by water providers. Utilising its Handheld and Mobile ‘Endpoint’ and meter products, Itron also provides fixed

network AMR systems capabilities as part of its 'Choice Connect' technology. This provides Water Suppliers with the ability to meet their operational and customer demands.

'Water SaveSource' is Itron's Fixed Network technology designed specifically for water utilities. Water SaveSource combines simple fixed network architecture, Itron's proven meter data management software and patented leak detection to offer an effective advanced metering solution for water utilities. This network features a dedicated radio frequency, advanced functionality, data logging to support conservation and leak detection capabilities.

Water SaveSource extends Fixed Network technology, for water utilities, beyond simple monthly consumption data. Water SaveSource can collect daily water meter readings or, through its data-logging functionality, can collect even more frequent consumption data, which can be used for resource management and conservation programs.

Field-proven remote and pit radio-based Water SaveSource Endpoints are compatible with water meters from meter leading manufacturers. The one-watt water endpoint is capable of two-way communications and transmits via the utility-dedicated 1.4 GHz radio signal to one or more Water SaveSource Collectors in the network. The high-powered output requires fewer collectors overall in the network, minimising deployment costs. The Endpoints also have a patented leak detection algorithm for monitoring leaks behind the meter.

Water SaveSource Endpoint Leak Sensor will soon be an addition to the solution, offering unsurpassed leak detection for the distribution system. Utilizing patented acoustic sensor technology and sophisticated sound analysis software, the Water SaveSource Leak Sensor is a permanent and maintenance-free leak detection solution that continuously monitors for system leaks. Water SaveSource Leak Sensor is the first acoustic sensor and meter module technology to be incorporated into a compact form factor.

Meter reads are transmitted to Water SaveSource Collectors according to programmed schedules and endpoints can transmit up to 12 reads per day without reducing their 20-year battery life. Collectors can be mounted on utility infrastructure, such as SCADA antennas and water towers, to maximise coverage range. Communication between the collectors and

the collection engine at the utility is two-way, and is supported by a wide-range of communications backhaul options.

Water SaveSource Network Administrator software manages the incoming flow of consumption, tamper and leak information, and distributes consumption data in standard MV-RS, XML and CSV file formats for use by billing systems, direct access customer care programs, and advanced analysis applications.

Features:

- Manage conservation programs by monitoring compliance and effectiveness
- Affect consumer behaviour by increasing their understanding of consumption
- Curb water flow by enacting pricing programs based upon determined time periods
- Limit exposure to high electricity rates by reducing water demand flow and associated pumping requirements during peak pricing periods
- Reduce non-revenue water losses by proactively detecting system leaks
- Cut water pumping and treatment costs by mitigating leaks in distribution lines
- Proactively notify customers of in-home leaks to avoid subsequent high bill issues and reduce loss
- Enable real-time bill dispute resolution using historical data and on-request meter reads
- Eliminate the cost of sending out field service workers to collect meter reads
- Provide greater revenue assurance with accurate consumption reads and tamper alerts
- Improve customer satisfaction by eliminating intrusive meter reading visits
- Improve employee and customer safety
- Improve the quality of billing data by eliminating manual data entry errors, performing off-cycle reads and eliminating estimated readings.
- Identify revenue loss due to meter tamper

4.3.5 System Performance and Monitoring Software

ACTARIS: M-BusRead

M-BusRead is a windows based software application, which collects and manages the data obtained from Cyble M-Bus units directly from the concentrator unit or, by modem, using a telephone line. Read-outs can be obtained from single meters, groups of meters or the whole installation with just one mouse-click or timer-controlled.

ACTARIS – ‘EasyRoute’ Radio Reading Route management and data evaluation software



The EasyRoute software package allows comfortable, route-based radio reading for utilities. EasyRoute Host manages data transfer between hand held computers and the billing system. It also allows the technical interpretation of the enhanced reading data by graphical display and csv export function. This software also offers functions for high and low consumption warning and the enhanced comment functionalities, which enables the meter-reader to reduce time and cost .

Features:

- Easy to use
- Easy installation of EasyRoute Mobile on the hand held computer
- Managing the data transfer between Handheld terminal and billing system
- Graphical data display of consumption, and leakage days
- User defined display and CSV export filter for further data processing

ITRON - Itron Enterprise Edition (IEE)



Selecting the right meter data management (MDM) solution not only helps a utility to achieve a reasonable return on investment, but it's a prerequisite for utilities considering an advanced metering infrastructure.

Itron Enterprise Edition (IEE) – Meter Data Management delivers an improved IT infrastructure platform that enables massive scaling and improved integration with other legacy utility systems. IEE enables utilities to manage their metering-based data regardless of source, in a single repository that supports easy access for a wide variety of applications.

Itron Enterprise Edition Meter Data Management is an enterprise-wide data management solution for interval, register and event data for residential, commercial and industrial customers. It is a scalable, open-architecture system that manages data from many different collection systems and provides secure, accurate, reliable data to a wide array of billing and analysis systems. Two database platforms are available: Microsoft SQL Server or Oracle. IEE interfaces with existing billing systems and analysis tools, therefore, offering a cost-effective data management system without affecting existing billing processes.

Features:

- Reduce the cost and time to gather and reconcile meter data from multiple collection systems by eliminating patching, integrating and manipulating different source systems.
- Improve overall business processes by providing a single enterprise-wide data repository that eliminates the need for individual departments to source their own data solutions.
- Improve the reliability and consistency of the meter data that you are using for billing and advanced analytics such as forecasting and transformer load management.

- Improve the security of meter data with the ability view audit trails of the validation-estimation-editing process, including change tracking and version control.
- Reduce the potential for errors and confusion as the frequency of data collection and intervals increase.
- Provide an extensible meter data management solution that interfaces to a suite of powerful analytical software applications for complex billing, customer care, demand response, distribution optimisation and design, and revenue assurance.

ITRON – MV-90 xi



MV-90 xi is a proven solution for interval data collection, management and analysis and can be used as a data collection engine that interfaces to existing data management and analysis tools, or as an end-to-end interval data collection and management solution.

Itron's MV-90xi software collects and processes data from the complex metering devices typically used for large commercial and industrial customers. MV-90xi also provides data management and analysis tools that ensure data integrity and process consistency throughout your business.

MV-90xi collects data from over 150 metering devices and supports a wide variety of communications, including PSTN, cellular, RF, handheld file import, Itron C&I Network and TCP/IP. Inbound and outbound calls, 'daisy-chaining' and master/slave communication configurations are also supported. MV-90xi collects meter data from Itron handheld computers with or without radio, as well as from Itron Mobile Collection Systems.

Features:

- Reduce operation and maintenance costs and increase productivity by operating one system for interval data collection and management.
- Improve revenue realisation from improved integrity in interval data used for billing.
- Improve customer service and billing accuracy with the ability to collect off-cycle readings.
- Read more profile meters more often, to provide better data to customers.
- Adapt easily to changing business needs with software that is scaleable.
- Increase the accuracy and reliability of consumption and load data by establishing a single data repository with auditable validating, estimating and editing processes.
- Improve operational efficiencies through the automation of system process such as collecting data and delivering that data to stakeholders throughout the utility.
- Improve management of large amounts of meter data as well as customer and market participant contractual relationships that require direct access to data in a timely and accurate manner.
- Deliver valuable load data via the Internet to customers who can use it to manage their resource costs, optimise their operations, and plan for their future.
- Experience unmatched system performance with MV-90xi's multi-threaded processing, 32-bit Windows application, database, and task manager for all system operations.
- Improve and grow more effectively with MV-90xi's interface to multiple vendors.
- Provide aggregated meter data from any number of meter points or aggregation of meter data up to a settlement point in the market where transactions are tracked—for a higher level of customer service.
- Easily transfer and exchange meter, billing and settlement data with other market participants by using MV-90xi's flexible array of data exchange formats.
- Utilise powerful analytics to provide value-added services to customers, including time of use (TOU), loss calculations, billing determinant calculations, load profiling and forecasting, energy scheduling and bidding, rate and profitability analysis, and more

Itron – Field Collection System



Itron's Field Collection System (FCS) is a data collection engine for handheld and mobile AMR systems. FCS collects data from multiple meter types and provides accurate, reliable meter data to meter data management and customer billing applications.

FCS is a Microsoft Windows-based software solution that uses web services, client/server architecture to provide superior flexibility and ease-of-use. FCS is compatible with Itron collection devices currently on the market, including optical and water probes, and integrates easily with third-party software applications for billing, meter data management and data analysis.

The architecture supports horizontal scaling allowing utilities to grow by adding additional PCs, rather than requiring bigger, more expensive servers. Data collector communications uses TCP/IP technology allowing utilities many options for exchanging route data including LAN, wireless WAN, broadband modem, and telephone modem support for handheld offices and locations. FCS supports two database platforms: Oracle and Microsoft SQL Server.

Features:

- Collect meter data reliably and accurately from an array of endpoint types using Itron's Handheld and Mobile Collection systems.
- Process handheld and mobile collection routes with the speed of a mainframe for far less equipment and maintenance costs.
- Reduce infrastructure costs with Handhelds that perform multiple functions and communicate using existing TCP/IP networks, without the need for intermediate PCs.
- Improve customer satisfaction by providing more information to Handheld and mobile meter readers in the field.

4.3.6 Water Loss Management

Itron water loss management solutions decrease a utility's unaccounted-for water, which maximises the available water and minimises resource costs.

ITRON - MLOG



Minimize water loss throughout the distribution system with a smart grid of innovative leak detecting sensors that integrate seamlessly with the Itron Water Fixed Network and maximises a water provider's revenue recovery.

Leak detecting sensors, or loggers, monitor the entire water distribution system 365 days a year. Each night MLOG sensors analyse sound patterns in their environment, detecting new, evolving and pre-existing leaks automatically. By analysing changes in the level and frequency of pipe sounds, MLOG creates a leak index for each MLOG sensor. Advanced analytical software displays potential leaks on detailed MLOG Color Map™ of your service area. Flexible reports facilitate management of each MLOG device, leak pinpointing and leak investigation. An expanding database of historical information allows water providers to track assets, account for lost water and guide maintenance of their water pipeline network.

MLOG sensors are installed permanently and connect to the Itron Water Fixed Network via the 200W Series Water Endpoint. MLOG sensors record four hours of sound data from the distribution system every night and are maintenance-free. Alternatively, the radio-based MLOG sensors can be deployed stand-alone in a walk-by or drive-by application.

Features:

- Reduce water loss in the distribution system.
- Optimise system maintenance with proactive pinpointing of pipeline leaks.
- Improve effectiveness of water conservation efforts.
- Ensures responsible resource management.

ITRON - ZCorr



Survey and pinpoint water distribution system leaks through the strategic deployment of digital correlating loggers in a simple overnight process.

ZCorr digital correlating loggers can pinpoint the exact locations of leaks in a single overnight surveillance. Strategically placed 100 to 1,000 metres apart, ZCorr enables water providers to plan spot investigations of several kilometres of water pipeline, guide field service personnel in the deployment and retrieval of the loggers, and then analyse and review the results of overnight recording the next day.

ZCorr provides a flexible network of digital correlating loggers (DCL) combined with digital mapping and advanced analysis software for a temporary and strategic deployment of an advanced leak detection system. Water providers work with their own distribution system maps to target areas for investigation. Working with ZCorr software, users can position DCLs and create work orders that assign field personnel to place and then retrieve the DCLs. The data recorded by the DCLs is transferred via serial link to a desktop PC or laptop where ZCorr's analysis software automatically pinpoints the locations of any detected leaks.

The ZCorr system scales from three to an unlimited number of DCLs so it can grow along with your leak detection program. With ZCorr, utilities can conduct leak detection investigations on distribution pipeline networks anywhere in the world. DCLs can be transported ready to deploy, or set up and deprogrammed remotely, with data access and analysis by Internet or email.

Features:

- Reduce water loss in the distribution system.
- Optimise system maintenance with proactive pinpointing of pipeline leaks.
- Improve water conservation.
- Reduce unaccounted-for water.

ITRON - DigiCorr



Using sound processing, digital correlation quickly and accurately pinpoints pipeline leaks of all sizes for effective long-range integrity testing.

DigiCorr, the world's only true digital correlator, uses a patented computerised acoustic technique to accurately pinpoint pipeline leaks. Analysing the pressure waves caused by leak turbulence inside pressurised pipes, DigiCorr can produce the exact location of a leak source.

DigiCorr's digital correlation technology provides on-demand, real-time leak pinpointing, flexible leak analysis and systematic leak survey of a pipe section without taking the pipeline off-line and without exposing large sections of the pipeline.

Features:

- Manage pipeline integrity proactively.
- Optimise the pipeline installation process.
- Reduce outage and recovery time.
- Improve water conservation efforts.
- Reduce unaccounted-for water.

ITRON - UNILOG



Digital sound logger economically surveys a wide area of the distribution system for potential leakage, narrowing the focus for more intensive leak pinpointing efforts.

UNILOG™ is an intelligent digital sensor that is deployed in underground valve chambers to record and analyse sound from the pipeline in order to detect pre-existing, emerging and sudden new leaks.

UNILOG economically surveys a wide area of a distribution system for leakage. It rules out leakage in most areas, allowing leak pin-pointing efforts to be concentrated in areas where leaks are probable.

UNILOG features completely automatic advanced digital signal processing. The digital sound logger has two-way light communication, is affordable and simple to use. The UNILOG Manager software manages the deployment, retrieval and status of each logger, aiding in tracking logger deployments and system leakage.

Features:

- Manage pipeline integrity proactively.
- Improve pipeline installation process.
- Reduce outage and recovery time.
- Improve water conservation efforts.
- Reduce unaccounted-for water.

ITRON – Digital Leak Detector



Lightweight and easy-to-use, Digital Leak Detector provides dynamic range compression, automatic leak detection and precise digital filters to identify leaks that are undetectable with analog leak detectors. Meet noise and stability requirements of the most demanding leak studies with this high-resolution, waterproof accelerometer.

The high-resolution universal sensor is waterproof and provides a contact microphone for meters and fittings, a magnetic base for hydrants and valves, and a ground listening plate

with quick-release accelerometer. Smart volume limiting suppresses clicks, pops and sudden loud noises, providing continuous, automatic volume protection.

Features:

- Pinpoint leaks anywhere in the system day or night.
- Simplify pipeline repair and maintenance.
- Improve water conservation efforts.
- Reduce unaccounted-for water.

4.4 Case Studies

4.4.1 Philadelphia, USA

Prior to the start of AMR installation in 1997, Philadelphia's Water Department and Waster Revenue Bureau encounter such poor meter reading success that only one out of every seven water bills issued was based upon an actual meter reading; six were based upon estimates. The installation of over 425,000 residential AMR units by 2000, resulted in a meter reading success rate of over 98% in its monthly billing process using a mobile drive-by system. A system of mostly estimates was replaced with a system of mostly accurate meter readings. This has greatly improved the confidence of customer consumption data, lessened the number of customer billing complaints and aided the detection of systematic data handling errors and unauthorised consumption in the city of Philadelphia. Meter readers were assigned to new duties; no layoffs or terminations occurred, and the project has been highly cost effective. Philadelphia envisions moving to fixed network AMR as its next generation system. (Thornton, 2001)

The cost of estimated meter reads ripples throughout the utility's revenue cycle. Bills based on estimated reads create unhappy customers who call to complain, thus increasing call center traffic and the associated costs. Prior to the installation of its AMR system, the Philadelphia Water Department received over 175,000 calls related to billing issues in a year. With the AMR system installed and operational, that number has been reduced by more than 20 percent, while the call abandonment rate has been reduced from over 30 percent to less than 10 percent. Billing adjustments are an additional expense attributed to estimated reads. (Hengesh, 2001)

4.4.2 ACTew, Canberra

ActewAGL's Project MIMI (multi-utility integrated metering infrastructure) is aimed at the research, design, developing, piloting and deployment of integrated water, electricity and gas metering linked to two-way communications infrastructure. Its key objectives are to better inform customers of their consumption choices and patterns, offer a range of new products and services, and improve the effectiveness and performance of the ACT's electricity, gas and water assets.

Key drivers of this change are:

- Transformation of communications technologies and reducing costs
- Innovation by meter vendors
- Climate change and less rainfall and peak load capability issues for electricity
- Necessity for more infrastructure and network augmentation to meet consumer demand
- Calls for more demand management responses
- Changing retailer expectations and a desire to offer new products and services
- Changing community attitudes and lifestyle choices in response to climate change
- Decreasing costs and improved capabilities in the mobile phone and broadband markets
- Increasing use of water restrictions as a measure to ensure sustainable water supplies.

Key Features of the ActewAGL Multi-Utility Metering Initiative

Key features of the new metering configuration and infrastructure proposed by the ActewAGL Multi-Utility Integrated Metering initiative are:

- Meters capable of capturing and transmitting multi-utility consumption data in time periods as frequent as hourly or less for electricity, water and gas
- Two-way communication infrastructure
- Information architecture changes including database reconfiguration and software innovation
- Changes to water management systems and processes
- New multi-utility pricing, products and services
- Increased customer participation, interaction and education in water management and usage

- Better water conservation practices
- Government and regulatory support

This works by extracting data remotely and transmitting from meters capable of capturing interval data. This is then relayed to a two-way communications network, where it is distributed to relevant water, electricity and gas network management databases, analysed and then formatted for reporting back to both the customer and to network operations centres. The speed and detail of information captured very much depends on the type of technology used but, more crucially, the ACT community's readiness for new, innovative conservation measures. Consultation with the community, business and key government policy-makers will be key elements of the project.

A water management framework based on analysing and sharing water consumption information between ACTEW / ActewAGL and its customers will allow for the introduction of a number of incentives to improve water delivery and consumption within the ACT, eg leak detection. For example, more frequent extraction of meter data will form the platform for improved water operation and management. It would also then be possible to offer greater customer choice in water usage, such as water allocation per household or business and associated water management tools.

For example, flat water rates could be a thing of the past if tariff reform leads to the introduction of time-of-use pricing as one potential measure to promote more efficient water use and consumption. This would also provide consumers with more choice and product options.

Key to the participation of customers in water, electricity and gas smart metering will be communication with the customer. There are a number of customer communication options including supply of an in-home display, new website portal, mobile SMS, email and increased reporting.

The information communicated and shared with customers can be displayed in interactive formats and graphically represent water, electricity and gas consumption. It is possible to use information portals to communicate current dam and rainfall levels with customers, warn customers of their increased consumption compared to their consumption in other comparative timeframes, and warn when energy usage (and track green house case

emissions) are higher than previous periods, and allow customers to compare daily, weekly, monthly and yearly consumption at the touch of a screen on an in-home display. (ACTewAGL, 2007)

4.4.3 Denver, Colorado, USA

Denver Water, installed ERT modules on 220,000 meters, is a good example. "We just figured out that the way we were doing it, with all of the trucks and the people and the equipment, was too expensive," said Bob Blauvelt, Denver Water's customer services field manager.

As the project progressed, the utility's fleet of 33 meter readers, all in separate vehicles, were reduced to a lone meter reader in a single vehicle. The cost savings from that change alone are significant. In addition, Denver Water anticipates no layoffs, as its workforce will contract through normal attrition. (Hengesh, 2001)

4.4.4 Mankato, Minnesota, US

Older, slow-running meters represent another revenue drain for water utilities. For instance, independent testing conducted by a Minneapolis-based testing firm, discovered that the city of Mankato, Minn., was collecting an average of only 83 cents for every dollar worth of water used by its residents due to slow-running meters. AMR installation offered the perfect opportunity to fix the leak in its revenue cycle caused by inaccurate meters. Mankato combined its AMR installation with a meter change-out program to replace its older, slower-running meters with new Badger water meters equipped with Itron ERT meter modules. Today, with both AMR technology and new meters installed, the city of Mankato and its customers can proceed with confidence that their meter reads and billing, are accurate. (Hengesh, 2001)

4.4.5 Peoria, Arizona, USA

The City of Peoria, Ariz., has peered into its future and has studied issues that must be addressed. Its population is projected to double within the next 10 years, and the supply of water to western states is tenuous. If the city insisted on doing business the same as it always has, its water staff would double along with the population.

However, with an AMR system in place, meter readers will be taken out of the field and put to work in maintenance and customer service. Staffing levels will remain stable despite

an additional 100,000 customers. In addition, customers will actually receive better service because that is where the city will be able to concentrate its resources. "The customer service ramifications of AMR are huge for us," Larry Dobrosky, revenue manager for City of Peoria Water said.

Dobrosky also understands that water is a finite resource, and that utilities and municipalities like his cannot keep watching their business literally go down the drain. As droughts persist and population growth continues, the supply of water grows shorter as well. Therefore, allowing water leaks and irresponsible usage to go unchecked is self-evident in its carelessness. These factors cannot be addressed when there is no information to go on, when a meter is read once every 3 months, once a year or, in a few cases, not at all.

An AMR system enables a utility to stay apprised of where water actually is going. When data shows that a certain area, or even an individual customer, appears to be using too much, the utility can send a crew to find out exactly what is going on. At the scene, a crew can either fix a costly leak or the utility can take steps to lessen excessive usage, either by education, conservation incentives or regulation. "We have to be proactive. It used to take about 30 days from the time leaks or abnormal usage were reported to when we were able to address the problem," Dobrosky said. "With more people freed up for maintenance and the constant availability of information, we'll now be able to fix the problem in a day or two." Studies also show that customers who know their consumption is closely metered actually use less water. (Hengesh, 2001)

4.4.6 Gold Coast, Queensland

Since 2003, Gold Coast Water has engaged Wide Bay Water Corporation to implement one of the largest water-loss management projects in Australia. The savings achieved are as follows.

- Total system input volume declined by 22.22% from 73,751 ML/year to 57.362 ML/year.
- Overall demand has reduced from 1640 to 1091 L/conn/day (saving 549 L/conn/day).
- Current system leakage has dropped from 164 to 46 L/conn/d. (less than the 60L/conn/d regulation requirements)

- The gap between system input and billed consumption has reduced from 9135 to 3638 ML/yr.
- Current total system leakage has reduced by 4951 to 13.6 ML/yr.
- These results have been achieved through:
 - Establishment of district metered areas (50% of services connections)
 - Establishment of leakage test zones (14% of service connection)
 - Pressure management in appropriate zones
 - Reservoir maintenance and repairs
 - Mains replacement
 - Replacement of service connections and water meters
 - Asset condition assessment and replacement
 - Improved burst response time

The implementation of extensive pressure management activities has led to a significant reduction in reported bursts in pressure-managed areas. (Thornton, 2008)

4.4.7 England and Wales

Not all water systems are universally metered. For example, in the United Kingdom, only roughly 10% of the domestic customers are metered.

Instead of metering individual customers, distribution systems in the UK are divided into smaller zones called District metered areas (DMAs), which are isolated by valving and are fed through a smaller number of inlet and outlet meters (WRC, 1985). The number of properties in a DMA is known fairly precisely, and usually varies from 50 to 5,000 properties but can go as high as 10,000. The flows are recorded using data logging technology or telemetered to a central location.

Demand patterns in the UK are similar to most other developed nations, and the patterns can be established by DMA or groups of DMAs. Data logging is used to determine individual demand patterns only for the largest users.

Because most residences are not metered, unaccounted-for water in the UK is large, but most of this water is delivered to legitimate users and can be estimated fairly reasonably. The amount of actual leakage depends on pressure, burst frequency, leakage control policy

and age of pipes. UK system metering data can make calibration of models easier than in locations without pervasive distribution metering. (Thornton, 2008)

4.5 Model Development

I began developing a spreadsheet model based in the IWA Accounting Model. However, during the course of my investigations I discovered a Water Audit spreadsheet, which had recently been created by the AWWA Water Loss Control Committee and is freely available for distribution on their website. This file is suitable for the purposes of Ipswich Water at this current point for the process of identifying water-loss. Further implementation of AMR systems and integration of data-acquisition, billing and GIS software will replace this manual data-entry process, due to real-time water-loss monitoring capabilities.

Creating a spreadsheet model is a simple process of combining the elements of the IWA / AWWA water balance components. After developing such a spreadsheet, I discovered a freely available spreadsheet model, which has been developed by IWA (Appendix C).

This model is built by manually entering data into the fields, relevant to the water balance. The goal for future reporting of the water balance will target automation of the data collection process such as linking this with a GIS and SCADA system which will enable the report to be run on demand, to give real-time system operating and performance details.

5.0 Analysis

Recovering the cost of supplying potable water is achieved by automatically generating invoices from the billing system. However, the task of obtaining the water consumption data (metering) is far from automatic. Similarly, analysing water-use is time-consuming and fraught with errors due to lag between operational supply data and user data. Real-time monitoring is the key to managing demand and monitoring losses.

Full replacement of all meters will take ten years, however, analysis of Ipswich Water consumers indicate that while 20mm connections account for 90% of system consumption, greater benefit would be achieved through targeting larger connection sizes first (25mm and larger) as these show higher average rates of consumption. Due to the large number of 20mm connections, ongoing strategies (such as education, pressure and leakage management using district metering solutions) to achieve even slight incremental reductions in water use will represent significant accumulated water savings. Use of district metering and multi-dwelling metering, will not necessarily generate additional or lost revenue from unrecovered unauthorised use, but can be utilised as leak detection and water saving tools, by providing diurnal planning and usage patterns, enabling infrastructure investment or deferment priorities. Additional savings are therefore achieved through optimising and extending the useful life of existing assets, water use education and pricing incentives ('off-peak' rates).

5.1 Project Implementation Plan

This project budget and time frame, does not permit the capacity to purchase, install and test alternative AMR products. Implementation of Water loss Reduction systems, utilising AMR products, have taken between two and ten years to complete. Results are gained quickly.

I recommend the following AMR product implementation as a suitable strategy for the water provider, in the following order:

- Stage 1 - Handheld AMR using a mesh network for sub-metering
- Stage 2 - Handheld AMR using radio frequency
- Stage 3 - Mobile AMR using radio frequency
- Stage 4 - Fixed Network AMR

An implementation plan, as a future action from this research, would consist of the following process:

- Tendering Process (1-2 months)
- Funding application and Purchasing (6-12 months)
- Trial Planning and Pilot Study (6-12 months)
- Review and Evaluation (2-3 months)
- Community Consultation (1-2 months)
- Stage 1 (Initial) Installation (1-2 years)

5.2 Costing

A costing of AMR alternatives has not been performed due to pre-existing contractual agreements with designated preferred suppliers to Ipswich Water. A review of existing customers, meter locations, communication infrastructure and DMA meter locations has not yet been completed. Therefore, insufficient data is available for determining and a specific AMR solution or hybrid AMR solution.

Future investigation requires a costing of available alternatives on a project by project basis through a competitive tendering process and pilot study for proof of performance. Trials currently being conducted by Wide Bay Water corporation, for walk-by and Drive-by AMR systems, report a cost of \$40 per meter for installation of MMR processes, compared to an installation cost of \$150 per meter for installation of the AMR Walk-by and Drive-By AMR system trial.

Full life-cycle costing comparisons are required between MMR and chosen AMR solutions, in order to properly attribute financial value and payback periods, compared to the benefits obtained from the information gained, as well as the associated ongoing operational and maintenance costs for each method.

The increase in raw data gathered and the associated information generated, requires additional computing storage, backup and data format compatibility both now and into the future.

5.3 Future Work

I recommend the following future work as further development of an AMR implementation strategy:

- Ongoing reduction in data error to decrease the range of the 95% confidence interval for modelling accuracy
- Determining consumption patterns
- GIS integration and modelling development
- Tendering for AMR suppliers and installation
- Conduct AMR product trials
- Evaluation and customer consultation
- Stage 1 implementation - Handheld AMR using a mesh network for sub-metering
- Stage 2 implementation - Handheld AMR using radio frequency
- Stage 3 implementation - Mobile AMR using radio frequency
- Stage 4 implementation - Fixed Network AMR

6.0 Conclusions

Implementation of automatic-meter-reading systems is expensive and a lengthy process. However, in-action toward reducing water-loss is also costly, in terms of infrastructure maintenance, customer satisfaction, water availability for consumers and environment protection and management. Government Funding is currently available for water saving initiatives to help offset the cost of installing such systems.

Selection of AMR solutions for water-loss reduction is based on environmental necessity, rather than simply the cheapest economic solution.

Revenue must be attributed to system water losses, and billed to customers, in order maintain a fair pricing system, while keeping costs at a minimum, or at least to decrease the rate of increasing water charges.

Current AMR technology provides a range of options to enable systems to be customised for optimum performance, and to meet the needs of each water supplier's processes. Integrated systems provide greater flexibility and reliability.

AMR provides real-time monitoring to inform and manage consumption, but must be employed as part of a system wide Demand Management Plan, which comprises the following:

- Public education for water-use consumption targets and efficiency (Water restrictions)
- Proactive system monitoring
- Leakage Management
- Pressure Management

This is expected to also increase customer satisfaction and management, through access to reliable usage information.

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Appendix A – Project Specification

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project PROJECT SPECIFICATION

Student: *Brian Kenna*

Project Topic: ~~Water Leakage Assessment – Ipswich City~~
Assessment of Water Metering and Revenue Protection (I.W.)

Project Supervisor: Dr David Thorpe - University of Southern Queensland,
Senior Lecturer, Springfield Campus

Project Sponsor: Nimish Chand - Ipswich Water,
Manager, Services Planning & Operations

PROJECT AIM:

This project will formulate an improved water accounting system (using available metering technology) for different customer groups, in order to identify and minimise unaccounted water leakages within the Ipswich City Council water reticulation network, which is divided into District Metering Zones.

A model will be developed in order to determine water use within this system. This model will be used to implement an improved accounting and billing system for water-usage.

PROGRAM: (Issue: B, 31st March 2008)

1. Meet with Ipswich Water to discuss project topic.
2. Identify and define the water accounting problem.
3. Conduct a literature review of issues such as leakage and monitoring.
4. Analyse and assess viable options.
5. Develop a water-use model to identify and assess ~~leakage~~ usage in a timely manner.
6. ~~Test and validate model performance.~~
7. Discuss results of the study with Ipswich Water.
8. Prepare and present a report on this project work.

Agreed:

Student: _____
B. Kenna
Date: / / 2008

Supervisor: _____
D. Thorpe (U.S.Q.)
Date: / / 2008

Sponsor: _____
N. Chand (Ipswich Water)
Date: / / 2008

Appendix B – Ipswich Water “Terms of Reference”

Project Name:

Assessment of Water Meter Data Collection and Revenue Protection, from Un-Accounted Water Usage within the Ipswich Water Reticulation System.

Project Purpose:

The purpose of this project is to review the current Water-Metering and data collection system used by Ipswich water, in order to benchmark this process against current best-practice methods employed by a selection of Water Supply organisations.

The result of this investigation will be a set of recommendations for the upgrade of Ipswich Water’s current metering system, in line with operational demands and current technological capabilities.

This project topic was presented to the University of Southern Queensland, by Ipswich Water, as an opportunity for research to be conducted by a Final-year Engineering student. This is a joint-venture whereby a report is produced, which is beneficial for use by Ipswich Water and also serves as an assessment document for the student, in accordance with the Bachelor of Engineering Degree requirements.

Problem Statement:

It is common for water supply authorities to have a considerable amount of unaccounted water-loss through ‘leakage’. This reduces the amount of water supply available for use and has negative economic consequences for Ipswich Water.

It is difficult to clearly identify leakages as the delay between reading water usage, billing customers and receiving payment in a water distribution system with a large customer base make it difficult to accurately report water usage over the short term, and hence, to clearly identify (unaccounted) water leakage.

A project has therefore been identified to improve the water accounting system using strategies such as identifying major water users through market segmentation, improving billing systems and developing improved approaches to the timely data collection and modelling of water use.

Boundaries of this Project:

This project will research current practices utilised by Ipswich Water, in relation to metering of water usage within the Ipswich Water reticulation system, in order to determine un-accounted water in a timely manner. The research is conducted within the student’s own time, in accordance with Ipswich Water requirements.

The results of this research are for information purposes only, for use by Ipswich Water, and do not serve as a directive for actions to be implemented in any form unless approved by Ipswich Water. A copy of this report will also be archived by the University of Southern Queensland, for academic purposes. Any confidential information presented during this research must be raised as such, in order to protect distribution of this information to other parties.

No financial outlay will be incurred by Ipswich Water, unless expressly requested and approved in writing by the Project Sponsor. Ipswich Water will provide resources, at their disposal (for the duration of this project), including personnel, equipment, tools and documentation, as approved by the Project Sponsor.

Desired Outcomes:

- Strategies to address the problem of “Un-accounted For” (Non-Revenue) water usage.
- Suggested improvements in relation to water-usage and Billing of Ipswich Water customers.
- Upgrade options, in relation to available and viable metering and data-collection systems.

Actions to be undertaken:

| Task |
|--|
| 1. Review of Ipswich Water’s current Metering system. |
| 2. Review of Ipswich Water’s current data collection methods and water usage. |
| 3. Review of Ipswich Water’s Customer Services requirements, issues and performance. |
| 4. Review of Ipswich Water’s Billing system and usage, by market segmentation. |
| 5. Review of “Un-Accounted For” (Non-Revenue) water use |
| 6. Research of available metering and data-collection technologies. |

Persons involved:

Researcher:

Brian Kenna (USQ, Engineering Student)

Project Sponsor:

Nimish Chand (Ipswich Water – Manager, Services Planning & Operations)

Project Supervisor:

David Thorpe (University of Southern Queensland, Senior Lecturer, Springfield Campus)

Project Reviewer:

Joseph Tam (Ipswich Water – Operations Engineering Manager)

Steering Committee:

Sandy Veeren (Ipswich Water – Manager, Project Services)
Gary Gilchrist – Water Services Customer Services Manager
Dana Hallet – IW Sustainability Manager
Colin Hester – IW Manager Model Services

Wayne Cross – IW Policy and Compliance Officer
Daniel O’Brien - (IW, ‘Planning’)
Guy Mowat (IW, System Optimisation Manager, Operations)
Punu Gurusinghe, (IW, ‘Strategic Asset Management’)
Chris Sidel (System Operation)
Bruce Penman (IW, System Control & Enforcement Team Leader)
Liam Parslow (System Assistant, Control Room Operator)
Praveen Gaddam (Technical Officer, Systems Operations)

Review Meetings:

- The researcher will be onsite, within the Ipswich Water offices, (generally, once a week on Wednesday mornings), in order to meet with appointed representatives in relation to pre-arranged project topics.
- Reporting and co-ordination of meetings and documentation will be through Joe Tam.
- Additional group meetings will be arranged, as required.

Appendix C – Water-Loss Model

AWWA Water Loss Control Committee – Water Audit Software Definitions

| AWWA WLCC Water Audit Software: Definitions | | Back to Instructions |
|--|------|---|
| Copyright © 2008, American Water Works Association. All Rights Reserved. | | WAS/3.0 |
| Item Name | | Description |
| Volume from own sources | Find | The volume of treated water input to system from own production facilities |
| Master meter error adjustment | Find | An estimate or measure of the degree of any inaccuracy that exists in the master meters measuring the Volume from own sources. Please also indicate if this adjustment is because the master meters under-registered (did not capture all the flow) or over-registered (overstated the actual flow) |
| Water imported | Find | Bulk water purchased to become part of the water supplied. Typically this is water purchased from a neighboring water utility or regional water authority. Be sure to account for any import meter inaccuracy in reporting this volume |
| Water exported | Find | Bulk water sold and conveyed out of the water distribution system. Typically this is water sold to a neighboring water utility. Be sure to account for any export meter inaccuracy in reporting this volume |
| AUTHORIZED CONSUMPTION | | <p>= billed metered + billed unmetered + unbilled metered + unbilled unmetered</p> <p>The volume of metered and/or unmetered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorized to do so by the water supplier, for residential, commercial and industrial purposes. This does NOT include water sold to neighboring utilities (water exported). Authorized consumption may include items such as fire fighting and training, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, frost protection, building water, etc. These may be billed or unbilled, metered or unmetered.</p> |
| Billed Authorized Consumption | | All consumption that is billed and authorized by the utility. This may include both metered and unmetered consumption. See "Authorized Consumption" for more information. |
| Unbilled Authorized Consumption | | All consumption that is unbilled, but still authorized by the utility. See "Authorized Consumption" for more information. |
| Billed metered consumption | Find | All metered consumption which is billed. This includes all groups of customers such as domestic, commercial, industrial or institutional. It does NOT include water sold to neighboring utilities (water exported) which is metered and billed. The metered consumption data can be taken directly from billing records for the water audit period. The accuracy of yearly metered consumption data can be refined by including an adjustment to account for customer meter reading lagtime, however additional analysis is necessary to determine the adjustment value, which may or may not be significant. |
| Billed unmetered consumption | Find | All billed consumption which is calculated based on estimates or norms but is not metered. This might be a very small component in fully metered systems (for example billing based on estimates for the period a customer meter is out of order) but can be the key consumption component in systems without universal metering. It does NOT include water sold to neighboring utilities (water exported) which is unmetered but billed. |
| Unbilled metered consumption | Find | Metered Consumption which is for any reason unbilled. This might for example include metered consumption of the utility itself or water provided to institutions free of charge. It does NOT include water sold to neighboring utilities (water exported) which is metered but unbilled. |
| Unbilled unmetered consumption | Find | Any kind of Authorized Consumption which is neither billed nor metered. This component typically includes items such as fire fighting, flushing of mains and sewers, street cleaning, frost protection, etc. In most water utilities it is a small component which is very often substantially overestimated. It does NOT include water sold to neighboring utilities (water exported) which is unmetered and unbilled - an unlikely case. This component has many sub-components of water use which are often tedious to identify and quantify. Because of this, and the fact that it is usually a small portion of the water supplied, it is recommended that the auditor apply the default value of 1.25% of the volume from own sources. Select the default percentage to enter this value. If the water utility already has well validated data that gives a value substantially higher or lower than the default volume, then the auditor should enter their own volume. However the default approach is recommended for most water utilities. Note that a value of zero is not permitted, since all water utilities have some volume of water in this component of |
| WATER LOSSES | | <p>= apparent losses + real losses</p> <p>The difference between System Input and Authorized Consumption. Water Losses can be considered as a total volume for the whole system, or for partial systems such as transmission or distribution systems, or individual zones. Water Losses consist of Real Losses and Apparent Losses.</p> |

AWWA Water Loss Control Committee – Water Audit Software
Reporting Worksheet

AWWA WLCC Water Audit Software: Reporting Worksheet

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[Back to Instructions](#)

[Click to access definition](#) Water Audit Report for:

Reporting Year:

Please enter data in the white cells below. Where possible, measured values should be used; if measured values are unavailable please estimate a value. Indicate this by selecting a choice from the gray box to the left, where 1 = measured (or accurately known value) and 2 = estimated.

PLEASE CHOOSE REPORTING UNITS FROM THE INSTRUCTIONS SHEET BEFORE ENTERING DATA

WATER SUPPLIED

Volume from own sources: 1 2

Master meter error adjustment: 1 2

Water imported: 1 2

Water exported: 1 2

WATER SUPPLIED:

AUTHORIZED CONSUMPTION

Billed metered: 1 2

Billed unmetered: 1 2

Unbilled metered: 1 2

Unbilled unmetered: 1 2

AUTHORIZED CONSUMPTION:

Click here: 1 2 for help using option buttons below

Percent: Value:

Use buttons to select percentage OR value

WATER LOSSES (Water Supplied - Authorized Consumption)

Apparent Losses

Unauthorized consumption: 1 2

Customer metering inaccuracies: 1 2

Systematic data handling errors: 1 2

Apparent Losses:

Real Losses

Real Losses = (Water Losses - Apparent Losses):

WATER LOSSES:

NON-REVENUE WATER

NON-REVENUE WATER:

SYSTEM DATA

Length of mains: 1 2

Number of active AND inactive service connections: 1 2

Connection density: 1 2

Average length of customer service line: 1 2

Average operating pressure: 1 2

(pipe length between curbtop and customer meter or property boundary)

COST DATA

Total annual cost of operating water system: 1 2 \$/Year

Customer retail unit cost (applied to Apparent Losses): 1 2 \$/

Variable production cost (applied to Real Losses): 1 2 \$/

DATA REVIEW - Please review the following information and make changes above if necessary:

- Input values should be indicated as either measured or estimated. You have entered:
 0 as measured values
 0 as estimated values
 2 as default values
 10 without specifying measured, estimated or default
- Water Supplied Data: Volume of water imported is the same as the volume from own sources, please review and confirm
- Unbilled unmetered consumption: No problems identified
- Unauthorized consumption: No problems identified
- It is important to accurately measure the master meter - you have entered the measurement type as: unspecified
- Cost Data: None to evaluate

PERFORMANCE INDICATORS

Financial Indicators

Non-revenue water as percent by volume:

Non-revenue water as percent by cost:

Annual cost of Apparent Losses:

Annual cost of Real Losses:

Operational Efficiency Indicators

Apparent Losses per service connection per day:

Real Losses per service connection per day*:

Real Losses per length of main per day*:

Real Losses per service connection per day per meter (head) pressure:

Unavoidable Annual Real Losses (UARL):

Infrastructure Leakage Index (ILI) [Real Losses/UARL]:

* only the most applicable of these two indicators will be calculated

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Water Metering and Revenue Protection – 30/10/08

AWWA Water Loss Control Committee – Water Audit Software
Water Balance

| AWWA WLCC Water Audit Software: Water Balance | | Water Audit Report For: | | Report Yr: |
|--|--------------------------|---------------------------------|--|---|
| Copyright © 2006, American Water Works Association. All Rights Reserved. | | WASv3.0 | | |
| Own Sources (Adjusted for known errors) | Water Exported 0.000 | Billed Water Exported | | |
| | 0.000 | Authorized Consumption 0.000 | Billed Authorized Consumption 0.000 | Billed Metered Consumption (inc. water exported) 0.000 |
| Water Supplied 0.000 | | Water Losses 0.000 | Unbilled Authorized Consumption 0.000 | Billed Unmetered Consumption 0.000 |
| | Apparent Losses 0.000 | | Unbilled Metered Consumption 0.000 | |
| Water Imported 0.000 | 0.000 | Real Losses 0.000 | Unbilled Unmetered Consumption 0.000 | Revenue Water 0.000 |
| | | | Leakage on Transmission and/or Distribution Mains Not broken down | Non-Revenue Water (NRW) 0.000 |
| | | | Leakage and Overflows at Utility's Storage Tanks Not broken down | |
| | | | Leakage on Service Connections Not broken down | |
| | | | Unauthorized Consumption 0.000 | |
| | | | Customer Metering Inaccuracies 0.000 | |
| | | | Systematic Data Handling Errors 0.000 | |

AWWA Water Loss Control Committee – Water Audit Software
Determining Performance Indicators – I.L.I.

| AWWA WLCC Water Audit Software: Determining Water Loss Standing? | | | |
|--|---|---|---|
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| <p>Once data has been entered into the Reporting Worksheet, the performance indicators are automatically calculated. How does a water utility operator know how well his or her system is performing? The AWWA Water Loss Control Committee provided the following table to assist water utilities in gauging an approximate Infrastructure Leakage Index (ILI) that is appropriate for their water system and local conditions. The lower the amount of leakage and real losses that exist in the system, then the lower the ILI value will be.</p> <p><u>Note:</u> this table offers an approximate guideline for leakage reduction target-setting. The best means of setting such targets include performing an economic assessment of various loss control methods. However, this table is useful if such an assessment is not possible.</p> | | | |
| General Guidelines for Setting a Target ILI (without doing a full economic analysis of leakage control options) | | | |
| Target ILI Range | Financial Considerations | Operational Considerations | Water Resources Considerations |
| 1.0 - 3.0 | Water resources are costly to develop or purchase; ability to increase revenues via water rates is greatly limited because of regulation or low ratepayer affordability. | Operating with system leakage above this level would require expansion of existing infrastructure and/or additional water resources to meet the demand. | Available resources are greatly limited and are very difficult and/or environmentally unsound to develop. |
| >3.0 -5.0 | Water resources can be developed or purchased at reasonable expense; periodic water rate increases can be feasibly imposed and are tolerated by the customer population. | Existing water supply infrastructure capability is sufficient to meet long-term demand as long as reasonable leakage management controls are in place. | Water resources are believed to be sufficient to meet long-term needs, but demand management interventions (leakage management, water conservation) are included in the long term planning. |
| >5.0 - 8.0 | Cost to purchase or obtain/treat water is low, as are rates charged to customers. | Superior reliability, capacity and integrity of the water supply infrastructure make it relatively immune to supply shortages. | Water resources are plentiful, reliable, and easily extracted. |
| Greater than 8.0 | Although operational and financial considerations may allow a long-term ILI greater than 8.0, such a level of leakage is not an effective utilisation of water as a resource. Setting a target level greater than 8.0 other than as an incremental goal to a smaller long-term target - is discouraged. | | |
| Less than 1.0 | If the calculated Infrastructure Leakage Index (ILI) value for your system is 1.0 or less, two possibilities exist. a) you are maintaining your leakage at low levels in a class with the top worldwide performers in leakage control. b) A portion of your data may be flawed, causing your losses to be greatly understated. This is likely if you calculate a low ILI value but do not employ extensive leakage control practices in your operations. In such cases it is beneficial to validate the data by performing field measurements to confirm the accuracy of production and customer meters, or to identify any other potential sources of error in the data. | | |