IMPLEMENTATION OF INTELLIGENT WATER NETWORKS SOLUTIONS – EXPERIENCES FROM AUSTRALIA

E.M. Skowron
Jacobs

ABSTRACT

Intelligent Water Network (IWN) systems integrate time-series information collected from a water network (flow, pressure, storage level, customer demand, and water quality) and apply analytics to provide insights into network behaviour and optimise operations, strategy, planning and investment.

They require adequate network data (quantity, location, type, accuracy, polling frequency, transmission frequency and system reliability) to reliably and consistently process information, apply algorithms, enable a utility to apply insights, increase understanding of network behaviours, reduce losses and optimise operations.

IWN technologies, features and services are diverse. Many IWN providers offer a suite of products and services that together can provide a comprehensive solution. Technologies continue to rapidly evolve with no two products offering an identical solution.

Initially developed to identify when leaks or bursts are occurring, IWN solutions are becoming more sophisticated. In addition to identifying leaks and bursts, they are being used to identify changes in performance of pump stations, pressure reduction valves or bulk flow meters in real time. They can verify that repairs and changes in network operation have been properly completed, optimise asset management programs, monitor water quality and identify gradual changes in network performance.

Where flow meters are implemented for large customers, IWN solutions can be used to identify behaviours from large customers that adversely impact the network and identify post-meter customer leakage. This paper summarises the evolution of IWN technologies from simple, static and reactive systems to comprehensive event management solutions for water utilities.

It is acknowledged that eventually IWN technologies will become widely adopted in the industry; however they remain subject to economic considerations and business objectives. Jacobs has assisted utilities going through this process.

Some early preparation for future IWN implementation can be integrated into 'business as usual' activities. This paper provides a summary of insights gained while supporting utilities through integration of IWN technologies, including:

- Streamline asset IDs between systems during planned upgrades of SCADA, GIS, ERP /P and network monitoring infrastructure;
- Prioritise technology for upgrades subject to obsolete technologies (closure of 2G network); and
- Identify utility objectives for implementing IWN technologies.

The paper also presents a summary of findings from three water utilities in Australia that have implemented the TaKaDu IWN technology, including:

- Management pressure management programs through IWN monitoring;
- Quantifying benefits, costs and establishing performance KPIs for establishment of an IWN solution;
- Automation of reporting processes for water balance calculations and other business metrics;
- Tracking of unauthorised consumption;

- Optimisation of maintenance strategies: from reactive to scheduling maintenance when changes in behaviours observed;
- Verification of proper resolution of normal network operation after network maintenance or repair requiring implementation of contingency plans; and
- Return on investment from TaKaDu implementation.

KEYWORDS

Event Management Intelligent Water Networks, Internet of Things, IOT, Intelligent Water Networks, IWN, Location Based Services, LBS, Non-Revenue Water, NRW, TaKaDu

1 INTRODUCTION

Intelligent Water Network (IWN) systems integrate time-series information collected from a water network (flow, pressure, storage level, customer demand, and water quality) and apply analytics to provide insights into network behaviour and optimise operations, strategy, planning and investment.

IWN technologies, features and services are diverse. Many IWN providers offer a suite of products and services that together can provide a comprehensive solution. Technologies continue to rapidly evolve with no two products offering an identical solution.

With so many IWN solutions available with rapidly evolving technologies, individual vendors are best placed to present the benefits, costs, use of the product (or service) and infrastructure and resource requirements.

As network monitoring, telemetry, big data systems, cloud computing and SCADA technologies continue to advance, IWN solutions become more plentiful and diverse in purpose and application. Some IWN solutions are intended for identifying bursts, leaks and reducing background leakage while others are intended to monitor water quality parameters in network storages and in far reaches of the network where water quality can be of greater concern. Some are intended to identify unauthorised consumption and post-customer connection leakage while others are intended to optimise efficiency and maintenance regimes of pumps, pressure reduction valves and other network control elements. Others are intended to optimise availability of asset, network performance and event information with operational staff and repair crews to improve efficiency of response and repair efforts.

While many IWN solutions are intended for specific purposes, others are designed to provide several of these functions and some are customisable to customer needs and system requirements.

This paper introduces the concepts of the ‘smart city’ (of which IWN solutions are a part of) and identifies considerations to be mindful of prior to implementing an IWN solution. The paper concludes with case studies from three Australian water utilities whom have implemented and are using the TaKaDu software-as-a-service (SaaS) IWN solution.

2 SMART CITIES, SMART NETWORKS

Developments in big data solutions, information and communications technology (ICT) and internet of things (IoT) solutions have enabled implementation of the ‘smart city’ concept.

There are many definitions of the smart city. Since its first use in the 1990s, the term smart city has held several meanings (some inconsistent) as technologies evolved and integration of technology for monitoring and management of city assets, utilities and infrastructure has advanced.

Organisations such as the Seattle-based Smart Cities Council have been established, providing guidance on technologies, benefits, guidelines and case studies. The Smart Cities Council has prepared the *Smart Cities Readiness Guide*, which presents information on the many aspects of smart cities including the topic of water and wastewater.

In New Zealand, the topic of smart cities is gaining visibility. In 2010, a smart cities summit was held in New Zealand and the New Zealand Planning Institute conference in 2015 was heavily focused on smart cities concepts.

The rebuilding efforts following the Christchurch earthquakes have incorporated smart cities technologies as part of reconstruction and repair tasks.

Companies including Oracle, Cisco, IBM and others are developing technologies and platforms for smart city initiatives including lighting, parking, operations, safety, traffic, community engagement and water/wastewater.

2.1 SMART CITIES: INTELLIGENT WATER NETWORKS

Over the past 10 years, there have been significant advancements in technology and analytics in the water industry.

The Smart Cities Council has estimated that an average of 7% of the world's total energy consumption is used to pump and treat water and wastewater. They have referred to the energy consumption for the provision of water and wastewater services as the *energy-water nexus*.

As water utilities begin to adopt smart cities concepts and technologies, early efforts often include improvements to mapping of physical infrastructure, upgrading asset databases, upgrading network monitoring plans and infrastructure, ICT infrastructure and SCADA systems.

Evolution of smart metering technologies, telemetry, network monitoring, SCADA systems, 'big data' solutions, cloud computing and products and services with detailed algorithms for assessment, planning and event management continue to increase the possibilities of what water authorities can do to more efficiently plan, operate and manage their infrastructure. Collectively, these systems are referred to as Intelligent Water Networks (IWN).

The term Intelligent Water Networks is defined by the Smart Water Research Centre as the integration of intelligent devices including water meters, pressure sensors, meter data into all relevant business practices and systems, and using this information to guide strategy and investment (Beal, C.D and Flynn, J., 2013).

IWN solutions can enable automated monitoring, identification of unexpected changes in network behaviours, improvements to operational, asset management and event management efforts. Insights learned from analysis of network information can enable utilities to optimise business functions in other parts of the organisation including finance, asset management and planning.

Many cities remain in early stages of their smart city journey as they focus on provision of reliable, safe and efficient water and wastewater service delivery to the community. Rapid changes in technology can complicate business cases for implementation of new technologies. Often the implementation of smart technologies occurs as part of required upgrades to existing systems and implementation of water security strategies.

There are few external sources of funding for new technology initiatives, frequently leaving local authorities to self-fund intelligent water networks initiatives.

In 2013, the Smart Water Research Centre in Australia conducted an online survey of 48 water businesses in Australia and New Zealand and found that 80% of them were actively pursuing Smart Water Metering (SWM) or IWN projects and 66% had initiated IWN projects or intended to within 12 months (Beal, C.D and Flynn, J., 2013).

Trials of intelligent water network technologies are often implemented to trial the ability of new technologies to achieve trial objectives and KPIs while minimizing financial risk and commitment of resources.

Jacobs has supported water utilities through the implementation of IWN solutions in Australia over the past six years. This paper summarises lessons learned through this process, important points for utilities to consider and examples from implementation of the TaKaDu solution at four water authorities.

3 WATER IN NEW ZEALAND

According to the Water New Zealand National Performance Review (NPR) for 2014-2015, the average per capita water consumption in New Zealand is 275 L/person/day. The NPR suggested this was the highest of all international benchmarks included in the review (average residential consumption from international benchmark studies ranged between 119 L/person/day in the Netherlands to 195 L/person/day in Australia).

In Southeast Queensland, Australia, a 'Target 140' initiative was introduced following a period of extensive drought in the mid-2000's to reduce daily residential consumption to less than 140 liters per person (through strict water restrictions and other water conservation measures).

As the drought eased, permanent water conservation measures were implemented and a target of 200 L/p/d for average residential consumption was introduced.

Seqwater, the bulk water authority in South East Queensland monitors residential per capita water consumption on a fortnightly basis. Average per capita residential water consumption figures have been gradually increasing since Target 140 was initiated, however consumption figures for the 14-day period remain well below the 200 L/p/d target. The average residential consumption for week ending August 24, 2016 residential consumption was 157 L/p/d (Water New Zealand, 2015).

Average residential consumption is difficult to quantify for many New Zealand water authorities because many do not meter all residential customers. The 2014-15 NPR assessment indicated that of participants in the study, only seven had implemented metering of all residential customers and 22 have not implemented residential meters (or had implemented 'very low levels' of residential metering).

Yet according to the NPR study, two-thirds of participants issued water restrictions in the 2014-2015 financial year indicating that water availability is of concern in New Zealand (Water New Zealand, 2015).

Even with efforts to reduce per capita residential consumption, pressure on water resources in New Zealand will continue to increase as population increases. Intelligent Water Network technologies could assist New Zealand water utilities seeking to further optimise water network operations, reduce non-revenue water and provide insight for customer engagement and demand management initiatives.

4 IMPLEMENTING INTELLINGENT WATER NETWORKS

IWN technologies, features, services and infrastructure requirements are diverse and the technologies continue to rapidly evolve. There are many IWN products and solutions available, most of which have vastly different purposes and infrastructure, investment and support requirements. Generally, all IWN solutions apply analytics to data collected from many sources including network monitoring (pressure, flow, water quality, storage level, operational state, etc.), customer metering and satellite imagery.

Most IWN solutions have different requirements for field monitoring equipment, personnel resources and infrastructure requirements. Implementation and operating costs can vary significantly depending on what objectives the water utility intends to achieve by using the technology.

Some solutions require specific data formats, monitoring equipment and network structure with the intention for medium to long term management of an overall water supply network. Others are short term solutions, intended to analyse data collected for a specific purpose using monitoring equipment that is temporarily placed in the network.

In addition, some solutions require detailed monitoring programs, communications infrastructure, data storage, upgrades to current systems and support staff. Others use cloud computing and offer a Software-as-a-Service (SaaS) approach.

It is common for utilities to use multiple IWN solutions, some which perform entirely independent functions and others that share function and purpose. Others trial multiple technologies to determine which are best suited for business requirements and operational objectives.

Considerations to be mindful of prior to implementing an IWN solution are presented in the following sections. They are in general presented in chronological order but will vary in order and relevance depending on the utility and intended use of IWN technologies.

4.1 REVIEW OF NETWORKS, SYSTEMS, PRACTICES & IDENTIFY BUSINESS NEED

A review of and practices, a process to determine necessary upgrades to existing systems, infrastructure, practices and resourcing will be required to ensure that the results of implementing an IWN solution is consistent with identified objectives and required outcomes.

Data is reviewed for accuracy, completeness, quality and suitability, while systems and practices are reviewed for functionality, condition, compatibility, effectiveness and risk of obsolescence.

Data inputs include network structure data, time-series 'live' data from network flow meters, pressure gauges, reservoir level sensors, water quality sensors, smart customer meters and repair and asset records for network assets.

Typically, GIS, SCADA, ERP/P, customer metering, asset management and hydraulic modelling systems and practices are reviewed as part of data and systems review.

It is important to review current systems, networks and practices to determine which objectives can be achieved through improvements to existing systems and processes and which will require the use of new technologies or approaches to deliver water services consistent with the ongoing strategy and vision of the business. Through this process, it may be concluded that required improvements to the business in the short term can be achieved with modification to existing systems or processes enabling more time to plan for implementation of new technologies as part of medium or long-term business objectives.

Some organisational practices are beneficial for implementation and use of IWN solutions including:

- Support and encouragement at management level for the use of IWN solutions to achieve business objectives;
- Active leakage detection and reduction programs;
- Network data analyst staff included in the Operations team (for identifying and responding to network events);
- Active programs for updating systems and data as required;
- Maintaining consistent unique identifiers between systems (or maintaining 'bridging' files that identify different identifiers between systems and enable systems and resources to link assets through different platforms; and
- Availability of knowledgeable field resources for responding to network events and resolving data logging and telemetry issues.

The outcome of this step is to assess the current state of business systems and practices and establish the need for implementing an IWN solution.

4.2 REVIEW OF NETWORK DATA

There are multiple data inputs required for many IWN solutions. The different types of data are detailed below.

4.2.1 GIS

Geospatial, asset and repair information on all water assets within the network (including pipes, reservoirs, pump stations, control valves, boundary valves and monitoring points) is often required. The asset information should include identification of relationships between asset records and all systems that manage network data (and should include unique identifiers, locations, repair history, units of measurement for monitoring assets and condition).

The type (e.g. stop, scour, boundary, etc.) and normal operating state (open/closed) of all valves should be included in the GIS data extract. The valve state provides information that will enable establishment of zone boundaries during network configuration, visual display of boundary valves that should be closed and will allow for quick identification of boundary valves that have been inadvertently left open after repair or network maintenance when reviewing network data after an event has been raised.

All GIS data needs to be established on an appropriate coordinate system (datum) and projection.

Common problems with GIS data include missing attribute fields, missing assets, inconsistent population of attribute fields, spatial data not connected at endpoints (hydraulic connectivity), inaccurate coordinates of elements or inconsistent data (meters not located on mains, wrong valve states, etc.)

Unique asset identifiers that link monitoring points with network assets are required to spatially locate each monitoring point within the network.

4.2.2 NETWORK STRUCTURE

Some IWN solutions are well-suited where District Metered Areas (DMAs) or Pressure Managed Areas (PMAs) are configured and where flow and pressure monitoring is active on each zone inlet (and at critical points within the zone). Without segregating the distribution network into DMAs (or PMAs), analysis of zone performance for leakage, mains breaks, changes in network behaviour, changes of zone consumption, and other events within the network is limited and generally ineffective. For non-segregated sections of a network, flow, pressure and water quality monitoring could be distributed to create 'virtual' zones for assessment and monitoring. If the IWN solution requires network segmentation into DMAs, information on each zone including extraction of boundary valves, sources of supply and monitoring points are usually required.

For network structure data, hierarchy 'mapping' is generally required to identify naming conventions of unique identifiers for all assets within the network. Differences in unique identifiers between systems need to be mapped to enable assignment of 'live' data to the appropriate asset (and location) within the network for configuration within the IWN solution.

DMA configuration and the relationships of associated flow meters must be understood to develop flow calculation formulas (including all inputs and outputs to a water supply zone and location of all monitoring points).

4.2.3 RESERVOIR DATA AND WATER QUALITY

Reservoir level values can provide the ability to compare and observe trends in reservoir operation, filling and volume calculations for wholesale supply and consumption. Reservoir levels also provide a mechanism to verify data from related flow meters. Further, flow and depletion rates (if available) can help derive a flow value where reservoir outflow data is unavailable.

Water quality data including chlorine, pH, temperature and turbidity can be analysed in many IWN solutions. While they do not directly contribute to the identification of leaks or bursts, some IWN solutions can monitor this data to verify conformance with water quality guidelines or service agreements. In some cases, unexpected variances in water quality data can lead to investigations that ultimately reveal hidden leaks.

Works performed registers and/or asset information systems can provide a historical perspective for the typical leakage or main breaks profile of an area/zone. This information includes the works and asset management schedules as well as registers of completed works. This allows for tuning of the IWN solution's algorithms and matching of profiles of flows to system changes.

4.2.4 CUSTOMER DATA

If water balance, post-customer meter leakage and consumption assessments are available functions and intended uses for an IWN solution, customer consumption data will be required. The customer consumption data may be in the form of total volume metered per billing period for each customer connection, or ideally as time-series consumption data from smart metering systems that is available continuously.

Total consumption and volume information from the billing information system is used for the calculation of water balance for the water supply network without using private customer information. Generally, water balance is determined by calculating the difference between the total volume of water supplied to a network (through network flow meters) and the total volume of water consumed (through billing/metering data).

The analysis of water balance figures can help a water utility determine the poor performing zones, thereby more efficiently utilise limited field resources and allocate funding for capital expenditure.

4.2.5 HISTORIC NETWORK PERFORMANCE

For IWN solutions that provide events and alerts based on anomalies with reference to normal network behaviour, historic network data is required in order for the system to learn the network and compile a historic pattern against which real-time data can be compared. Typically, 18 months or more of historic network data is recommended to develop an expected network behavior, identify and remove erroneous data and identify changes due to seasonality, holidays or specific events. This period of data will generally capture seasonal variations in water consumption, effects of changing weather and variations and changes in consumption patterns.

While more historic data could result in better predictions, assessment of larger data sets could result in greater cost and resource requirements while providing reduced benefit to establishment of baseline network behaviours.

Significant system changes (such as SCADA system upgrades) that have occurred during the historic data period should be reviewed to identify data errors that have occurred or discrepancies in location or unique identifiers for network monitoring equipment from when historic data was collected and current points that will be used to provide real-time data to the IWN solution.

4.3 ESTABLISH OBJECTIVES FOR IWN TECHNOLOGIES

Prior to determining which specific technology is best suited for a water utility, the intended purpose of pursuing an IWN solution should be well-established. The objectives on how the technology will be implemented, used and assessed should be clearly defined and understood.

Establishment of objectives should be consistent with water security strategies, demand management initiatives, pressure and leakage management programs, short and long term planning strategies, corporate vision and other relevant initiatives.

Common considerations for establishing objectives for implementation of an IWN solution include (but are not limited to):

- Current state of data, monitorability, availability of SCADA systems, asset databases and other relevant systems;
- Data and knowledge retention practices and expectations;
- Financial considerations (including cost of upgrades to/replacement of current systems, staffing and human resources, infrastructure resources, initial implementation of the IWN solution, ongoing operational costs of maintaining the usage of the IWN solution and anticipated impacts to Operational and Capital budgets);
- Required return on investment and return period;
- Compatibility and flexibility with corporate systems, practices and strategies;
- Accuracy, compliance and adherence to standards;
- Customer engagement and accessibility (including customer access portal/user interface);
- Data security (including local legal and legislative requirements);
- Water system / supply network efficiency; and
- Operational practices and requirements.

4.4 REVIEW AVAILABLE TECHNOLOGIES

Because of the diversity, quantity and rapidly evolving nature of available IWN solutions, product (and service) vendors are best placed to present the benefits, costs, use of the product (or service) and infrastructure and resource requirements.

Some are stand-alone solutions that do not communicate with other systems already established in the utility, intended for a particular purpose or for specific locations in the network.

Other IWN solutions are integrated systems relying on numerous inputs from the water distribution network to identify changes in behaviour, classify event types to categorise and automate event response and report outcomes to multiple business functions, either independently or through central business intelligence (BI) systems.

While some solutions can be integrated with other systems, can use data from multiple sources and can be used to address broader business objectives (such as resource management), others are developed with specific operations purposes (such as monitoring water quality parameters, monitoring pump operational characteristics, tracking of water haulers using GPS technology).

There are also IWN technologies that apply algorithms to satellite imagery to identify changes in vegetation, locations (and changes in volume of) fresh water, soil moisture content and other variables. The imagery is typically then applied to mapping of water distribution networks to determine where leaks may be present.

Other IWN technologies measure vibrations and sounds of water pipes to detect leaks through sensors installed in the network. Vibrations and sounds in water pipes can vary when leaks are present and can be used to approximate the location of the leak.

Hydraulic modelling and predictive tools are incorporated in some IWN solutions, using ‘live’ network flow and pressure data to predict where failures are likely to occur by estimating both likelihood and consequence for failures of individual pipes. Some also include asset data (such as age of a water pipe) and network data (such as history of failures) to predict and provide notifications of locations where failures are more likely to occur.

Furthermore, there are other IWN solutions integrate data from smart water metering programs with network flow data to correlate zone flow behavior with customer consumption to more accurately identify changes in network behaviours.

Experiences gained through supporting and working with Australian water utilities who have adopted IWN solutions have demonstrated that there are steps that water utilities should follow when considering IWN technologies and which specific solution is most suitable. These steps include assessing current systems, evaluating their state of operations, determining opportunities for reduced water loss and improved operational efficiency, establishing business and operational objectives and desire outcomes considering financial and resource implications and understanding systems requirements.

Outcomes of the technology review should be compiled with outcomes of the review of utility systems and practices and determination of the desired objectives from implementation of an IWN solution to be used as part of tender documentation as part of a procurement strategy for selecting an IWN solution.

The following should be considered when reviewing IWN solutions and their applicability to the corporate strategy and vision.

Most IWN vendors are willing to give presentations and live demonstrations of their products and how they can be used to achieve particular business objectives.

4.4.1 IWN CAPABILITIES

IWN systems integrate time-series ‘live’ data collected from the water network (flow, pressure, storage level, customer demand, and water quality) and apply analytics to provide insights into network behaviour, system performance and optimise operations, business strategy, planning, risk management and investment.

Despite IWN technologies rapidly evolving, capabilities of such solutions typically include:

- Provision of consistent and reliable data more efficiently to make effective decisions on planning, asset management, operations;

- Enhancement of understanding of network demand characteristics at different levels (i.e. customer, DMA, Water Supply Zone, Region);
- Automation of manual processes (i.e. event detection, DMA reporting);
- Elimination of the need for personnel to access dangerous spaces (automated asset management);
- Automation of alerts when networks or assets are not performing;
- Provision of accurate information on asset condition, resulting in more efficient asset maintenance;
- Optimisation of water consumption and demand management programs;
- Enhancement of existing water infrastructure;
- Improvement in capital planning;
- Collation of data from multiple sources, formats and frequencies;
- Extraction of data from multiple sources into a single consolidated output;
- Facilitation of knowledge sharing and development;
- Reduction of risk by reducing the likelihood of major events through early detection (i.e. contamination, pipe bursts); and
- Reduction in leakage and NRW.

Often, Smart Water Metering (SWM) technologies functionality forms part of an IWN solution.

4.4.2 NETWORK MONITORING INFRASTRUCTURE

Some IWN solutions provide greater benefit through additional monitoring information from the network. The current network monitoring plan and monitoring data should be reviewed for consistency, completeness and accuracy to confirm it can be used with the IWN technology being considered.

In the event that additional network monitoring is anticipated to support the preferred IWN solution, advancements in monitoring and telemetry technologies should be considered carefully to select current technologies that can provide more functionality and longevity in compatibility (and in some cases lower cost options).

Advancements in ultrasonic metering technologies can enable additional flow monitoring points for ‘virtually’ segmenting a large distribution zone or DMA into smaller areas for greater monitoring resolution without further physically segmenting the network with boundary valves.

4.4.3 SECURITY

Security of data and systems is an important consideration when considering IWN solutions.

Many IWN solutions are stand-alone platforms that are installed on and operate within a utility’s IT operating environment (and are therefore subject to existing security protocols). IWN solutions are typically not intended to automatically alter or influence network control.

However, some IWN solutions can enable two-way communication or the ability to directly influence network control. These solutions should be carefully reviewed with respect to security protocols to confirm that the solution is compatible with IT and data security requirements.

There are also IWN solutions that are based on a SaaS delivery model which require minimal capital investment because SaaS solutions do not require additional hardware or big data infrastructure. SaaS solutions are typically accessed through web browsers offering ease of use and accessibility to multiple users.

Further, IWN solutions are considered ICT infrastructure. In some parts of Australia, these are subject to government ICT requirements for use at public water utilities.

4.5 CONSULTATION OF PEERS

Most utilities are happy to share thoughts and experiences about their journey to improve efficiency and integrate innovation into their business practices. Water utilities whom are considering IWN technologies should consult with industry peers to learn about what they have done and what they would do differently if going through the journey again.

4.6 RESOURCES

When considering an IWN solution, utilities should identify current resources within the organisation that will take ownership of use and implementation of the product. The utility should carefully consider what tasks they would like to be performed by resources within the business and which should be outsourced (to a consultant or as part of an SaaS solution).

Implementation of IWN technologies typically have greatest success when supported and endorsed by key stakeholders at all levels in the utility including executive, operations, engineering, IT and field staff.

Key resources to consider are summarised below.

4.6.1 NETWORK ANALYST

Regardless of the specific IWN solution selected, a network data analyst will be required to review the outputs and generated events from the technology and determine the response required to address events. The network analyst should have strong background and understanding in the water supply network that IWN solution has been implemented in, as well as the experience in analysing data in network/asset behaviour.

4.6.2 OPERATIONS

Operations staff typically provide data and information for configuring an IWN solution.

Often, network analysts on IWN projects are part of the operations team. Their knowledge of the network and day-to-day management (such as valve operations, water quality analysis and planned maintenance) can often aid in the use of the technology.

4.6.3 LEAK DETECTION

Leak detection crews often complement an IWN solution by completing the cycle of network event management. IWN technologies that identify events or alerts often require field crews to perform leak detection activities to precisely confirm where leaks or bursts are located (particularly where water from a leak does not come to surface or the location is otherwise known by the utility through customer complaints or other notification).

4.6.4 SCADA

SCADA operators often assist with extraction of historic data, defining the water network and establishing the location of (and unique identifiers for) network monitoring points. SCADA operators can assist with verification of the network and resolving network configuration queries when implementing IWN solutions.

4.6.5 IT

IT staff assist with installation and configuration of software based IWN solutions, extraction of data from existing systems (in appropriate format and frequency) and compliance with network security requirements. IT staff also assist with establishing scripts to enable automated transfer of data to SaaS solutions operating outside of the client network.

4.6.6 BILLING

Billing staff provide historical customer consumption data for use with water balance calculations, post-customer meter leakage and consumption assessments. To facilitate the use of these functions, billing officers often assist with the extraction of data from existing systems in the format and frequency during set-up stages as required by the IWN solution.

4.7 BUSINESS CASE

After reviewing current systems, establishing objectives for an IWN solution and reviewing available technologies, a Business Case should be prepared to justify the undertaking of an IWN program based on consistency with the business strategy, expected benefits, costs and perceived risks. The business case should also determine the source of available funding and establish whether funds for implementation and use of IWN solutions will be considered a capital expense, operational expense or both.

4.8 PROCUREMENT

Consistent with outcomes of the business case, when the business decision has been made to proceed with an IWN solution, it is important to consider how an IWN solution will be selected, consistent with procurement policies and requirements.

Because of the diversity of IWN solutions, it is recommended that as part of the review of IWN solutions, determination of objectives and review of current systems and practices that IWN vendors are short-listed to identify those that are consistent with the business case for proceeding to procurement.

Appropriate procurement methods will be subject to applicable regulations and requirements but typically include open tender, tendering to shortlisted vendors or direct source. Shortlisted vendors are typically selected as part of an expression of interest process during assessment of market technologies.

4.9 IMPLEMENTATION AND SETUP

While each specific IWN solution has different requirements for setup and implementation, there are three general stages for setup of IWN solutions that rely on network data, historical performance data and 'live' (real-time) network performance data.

The first stage requires definition of the water supply network. This typically requires updated network asset data, including spatial and attribute information on water mains, valves, control elements (pumps, valves), storages, DMAs, bulk meters, customer meters and all monitoring points within the network. This information is typically provided in GIS format with SCADA schematics of network configuration. Information to identify the location of monitoring points and enable calculation of flows for unmetered water supply zones (or zones supplied from storages with unmetered outlets) using data from metered points is usually collected during this stage.

The second stage includes the extraction of historical time-series data for all required network monitoring points. This is often extracted from SCADA systems or proprietary systems where real-time data from network monitoring infrastructure is transferred to or stored. This typically requires the setup of a sound and reliable data transfer process that is usually facilitated through secure FTP servers. In some cases, engagement with third-party entities is required to retrieve historical data where third-party data services providers have been commissioned to provide monitoring equipment or provision of data to the water utility.

The third stage includes configuration of access to (or automated transfer of) performance data from the network. This typically includes flow data, pressure data, water quality data, water storage level data and customer demand data (where used, typically for large commercial customers). Ideally higher data resolution and frequency of transmission (between every four hours and hourly) will enable an IWN solution to provide a more detailed assessment of network performance and a more reliable and timely identification of network events.

Once data is received continuously the network is configured within the IWN solution and the transfer (or access to) live data has been established, validation processes are applied to confirm correct setup and configuration prior to implementation and integration of outputs into business systems and practices.

4.10 TRAINING AND ENGAGEMENT

Resources identified for the implementation and use of an IWN solution should be identified (and secured if necessary) prior to starting to use the technology.

Some IWN vendors provide ongoing support and training throughout the use of the product (or service). The terms of training and support should be established as part of negotiations with the preferred IWN vendor.

5 CLIENT EXPERIENCES

Since 2012, Jacobs has been working with water utilities in Australia with the assessment, evaluation, selection and implementation of IWN solutions. Jacobs has assisted clients with the review of networks, systems and practices, available technologies, determination of IWN KPIs, setup and use of IWN solutions and continued support and data analysis through ongoing collaborative engagements.

The following sections summarise the experiences of Unitywater, Queensland Urban Utilities and Sydney Water with implementation and use of TaKaDu including some examples of events detected, operational response and some of the benefits that have been realised.

5.1 UNITYWATER

Unitywater implemented TaKaDu in 2013 as an events management tool to optimise the operation of its water supply network and business practices. A summary of how Unitywater has implemented and benefited from the use of TaKaDu is presented in the following sections.

5.1.1 EARLY LEAK DETECTION

Unitywater has achieved a reduction in time required to discover and classify leak and burst events through the implementation of TaKaDu. These tasks were previously achieved through cyclic leak detection sweeps or manual analysis of available network data. Over the past three years, the average notification time for hidden leakage and water main bursts has been reduced to within an hour by automating identification and notification processes using TaKaDu.

Leakage events identified in TaKaDu are reviewed to determine if the observed increase in flow was as a result of unexpected demand or a genuine break or leak. If the flow increase does not return to expected levels within reasonable time, the leak is then investigated further through a desktop assessment, followed by deployment of field resources. This approach has enabled Unitywater to identify large leaks earlier that otherwise would remain undetected compared to before the deployment of TaKaDu.

Early detection and notification has reduced water loss, impacts to customers and risk of further network damage.

5.1.2 ASSET CONDITION & MAINTENANCE PROGRAMS

The use of TaKaDu has provided Unitywater with greater visibility of DMAs, assets and bulk meter performance. This has enabled Unitywater to replace a traditionally scheduled maintenance program to a 'just in time' maintenance program, which translates to more effective resource management while maintaining an acceptable risk profile.

Previously, Unitywater scheduled maintenance and major service of PRVs, pump stations and flow meters based on asset lifecycle and manufacturers specifications. Monitoring asset performance through TaKaDu has allowed Unitywater to respond early as changes in performance are observed, reducing resource investment required when compared to regularly scheduled maintenance and servicing practices.

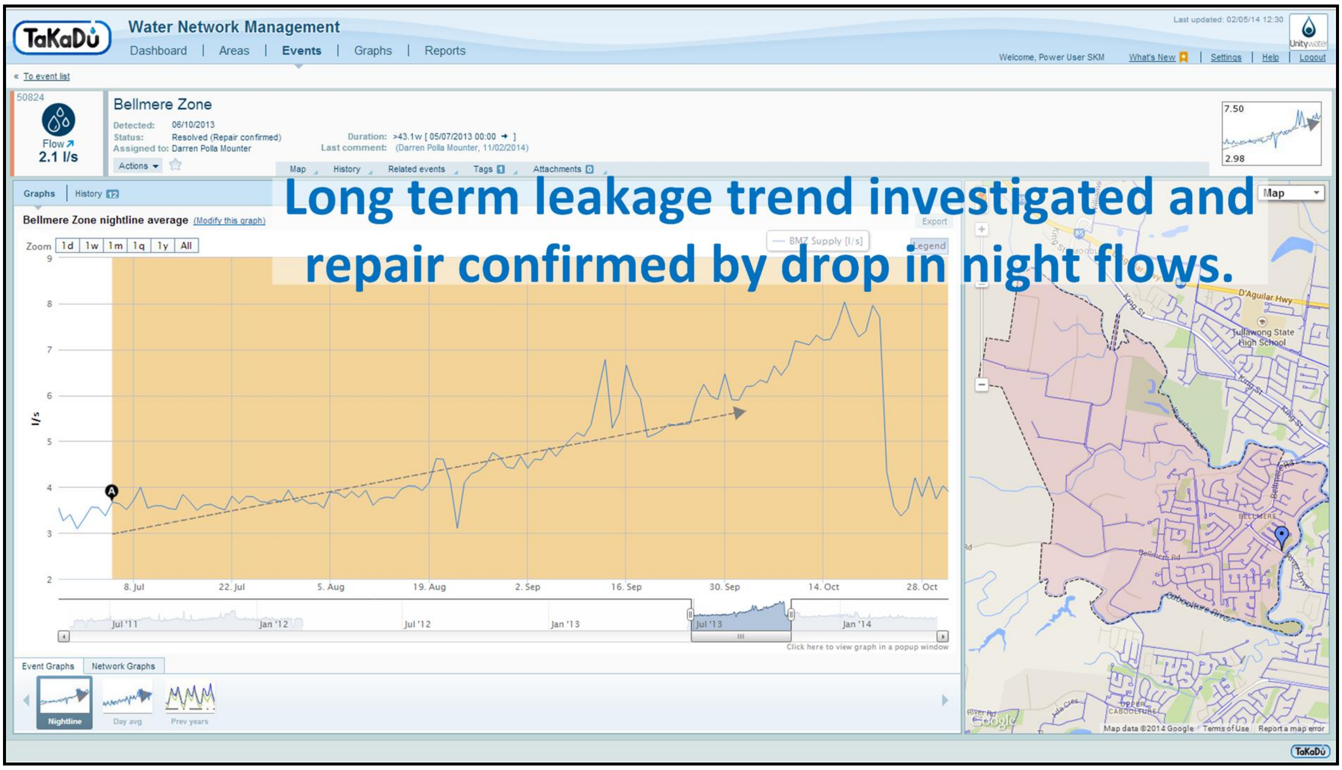
5.1.3 TREND EVENTS

Leak events in TaKaDu correspond to instantaneous increases in flow. This is the most common type of leakage event identified in TaKaDu.

Flow trend events occur less frequently than leak events and indicate detection of a gradual increase in flow (particularly night flow) over a longer period of time. Flow trend events are typically due to evolving and/or compounding leaks or an increase in the quantity of small leaks.

In October 2013 during the initial trial of TaKaDu at Unitywater, a flow trend event was identified with an estimated start time in July 2013, resulting in an increase in night flow from less than 4 L/s to 8 L/s. After field crews were dispatched, a leak was identified and repaired. This resulted in night flows returning to pre-event levels that matched target night flow levels. This flow trend event was subsequently analysed and was estimated to have avoided approximately 132 ML of further water loss if it remained undetected.

Figure 1: Example of leakage trend event in TaKaDu - Unitywater

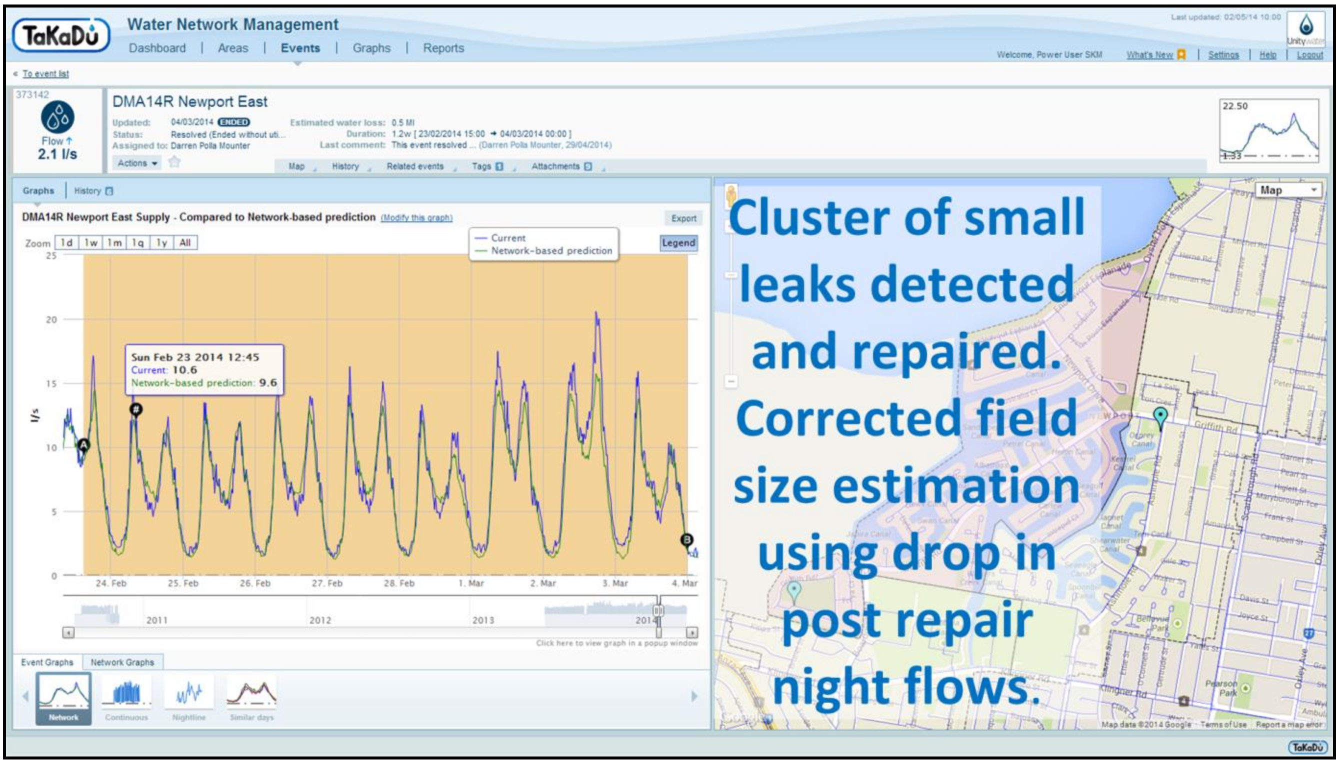


Less than half a year later in early 2014, Unitywater identified potential background leakage through notification of a leak event and a flow trend event in the Newport East zone.

After identification of the flow trend event and leak event, a leak detection team was dispatched to locate the leaks using acoustic detection techniques. The investigation found a cluster of small leaks within the zone (resulting in a cumulative flow of 2.1 L/s).

Following the repairs, the background night flow returned to historic levels. The detection and repair of the cluster of leaks resulted in an estimated avoided loss of 66.15 ML.

Figure 2: Example of Cluster of leakage events in TaKaDu - Unitywater



5.2 QUEENSLAND URBAN UTILITIES

Since 2013, Queensland Urban Utilities has used TaKaDu for integrated event management of its water supply network to identify leakage, operational faults and post-customer meter leakage using existing monitoring locations in its network.

The Queensland Urban Utilities network was well suited for implementation of TaKaDu as DMAs, flow and pressure monitoring was implemented as part of their Pressure and Leakage Management Program (PLMP) beginning in the 2000s when the water supply levels were critically low. The PLMP involved a significant investment in PRVs, electromagnetic network flow meters, water pipe upgrades and the creation of district metered areas (DMAs) in order to reduce water loss.

The creation of DMAs allowed Queensland Urban Utilities to start actively managing the pressure and leakage levels in smaller discrete zones within the overall water network.

However, with over 300 DMAs across the entire Queensland Urban Utilities water supply network service area, there was a requirement for ongoing management of them. Active monitoring of flow and pressure data points across each DMA became increasingly resource intensive.

As a result, the performance of many DMAs declined and leakage levels began to increase. With an ongoing need to preserve natural resources, increasing costs of treatment and transport of drinking water, and drivers for efficiency and innovation measures, Queensland Urban Utilities sought a solution to efficiently manage their DMAs by automating the monitoring of water pressure and leakage levels across the network. There was a necessity for increased efficiency and automation of network event identification, detection, repair verification and reporting.

Queensland Urban Utilities undertook a procurement process that involved the development of a needs specification, intensive market engagement, products evaluation and associated budget challenges. In late 2013, Queensland Urban Utilities decided to implement TaKaDu. This began with a 12-month trial of the system that included monitoring of 83 DMAs comprising 2,000km of water mains in the water supply network. The trial yielded water savings of 1,235 ML (annualised), equating to a cost avoidance of approximately AU$2.9 million over the 12-month trial period (Queensland Urban Utilities, 2015). Following a successful trial, Queensland Urban Utilities implemented TaKaDu permanently.

Queensland Urban Utilities has since expanded the use of TaKaDu to cover 233 zones and over 4,000km of water mains. The expanded coverage includes the city of Ipswich, the regional area of Lockyer Valley, as well as additional parts of Brisbane. To date, the implementation of TaKaDu at Queensland Urban Utilities has saved over 4,000 ML of water (annualised). This is equivalent to a potential cost avoidance of approximately AU$11 million.

The project team who was involved in the implementation of TaKaDu consisted of key stakeholders from teams across the business including project management, information services, control systems, network operations and asset maintenance.

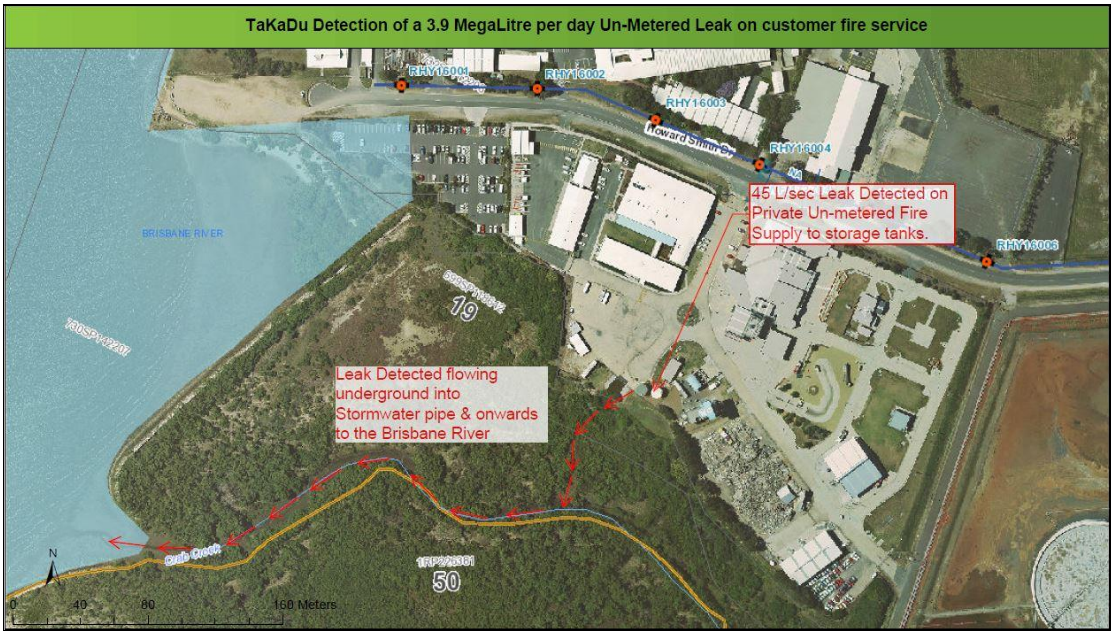
TaKaDu business as usual (BAU) operations now belongs to the Network Control team under the Network Operations branch. The analysis team consists of a primary network analyst, a secondary analyst for Brisbane and another secondary analyst specifically for Ipswich and Lockyer Valley. Schedule/dispatch officers and control room officers from the Queensland Urban Utilities Control Centre are critical stakeholders in the initiation of work orders and repair process for actions raised as a result of TaKaDu events.

5.2.1 POST CUSTOMER METER LEAK IDENTIFICATION

In early 2016, TaKaDu detected a substantial hidden leak on a large industrial customer's private water main without actually having data from the customer meter. This began with a leak event detected and raised by TaKaDu. The primary analyst deemed that this event was worthy for further investigation and dispatched network operators to the field to locate the leak. However, the network operators were unable to locate any visible leakage within the Queensland Urban Utilities network that corresponded to the location of the leak event raised by TaKaDu.

After confirming that the unexpected increase in flow in this DMA was sustained beyond normal operating hours, specialist leak detection crews were deployed for further field investigation. Ultimately, a 45 L/s leak was identified within a customer property. Water being lost through the leak was found to be flowing directly into stormwater drainage infrastructure as shown in Figure 3. This hidden leak would have likely remained undetected until the customer received their water bill which could have extended for another three months due to the billing cycle being quarterly.

Figure 3: Post-customer leakage identified from customer fire service main – Queensland Urban Utilities



While Queensland Urban Utilities is in the process of implementing smart metering of their top commercial customers, this particular customer for which this event was raised is not yet monitored in TaKaDu. This leak was identified through analysis of data from the zone flow meter supplying the network that included the large industrial customer.

This leak event, illustrated in Figure 4, highlighted that even major leaks can remain undetected by the customer and the utility. The use of TaKaDu as an integrated event management system has enabled Queensland Urban Utilities to identify post-customer meter leakage and help customers reduce water and financial losses from leaks. If this leak was left undetected, it would have resulted in the loss of 353 ML (equivalent to AU$0.94 million) over a full quarterly billing cycle.

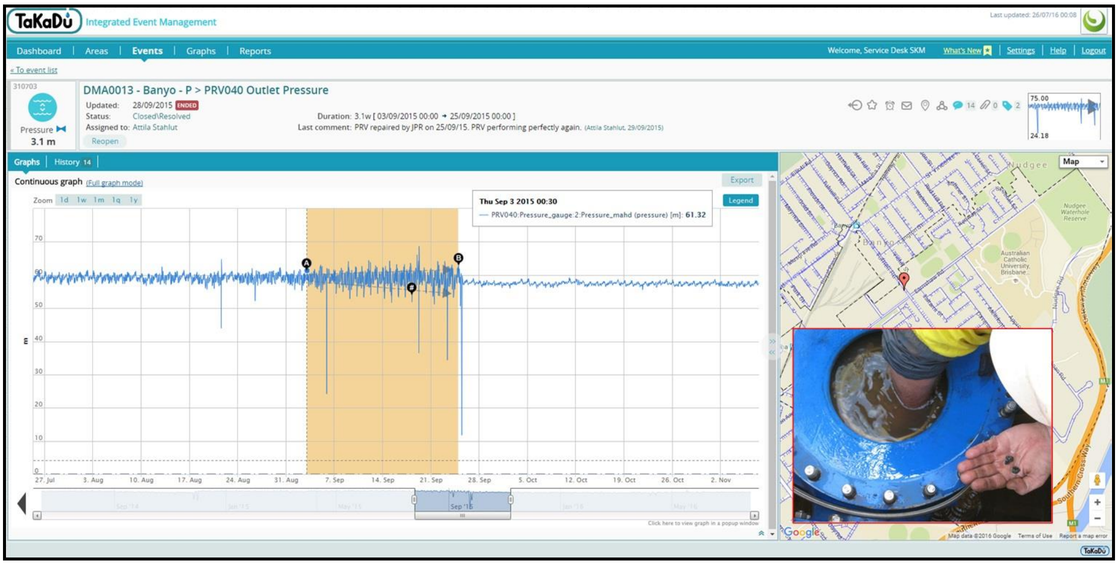
5.2.2 IDENTIFICATION OF PRV FAULT

TaKaDu detected and raised a PRV Fault event for a PRV supplying a zone of 1,300 customers and 30km of main because of increasingly variable outlet pressure. Irregular pressure fluctuation and increasing PRV outlet pressure behaviours were observed, as illustrated in Figure 6. Due to the increase in variability being gradual and small in magnitude, it was initially thought to be as a result of a rezoning in the area that had been recently commissioned.

Shortly after the PRV Fault event had been identified, a large burst of 35 L/s occurred within the zone, coinciding with a 10m drop in the PRV outlet pressure. Further observations showed that the PRV was not maintaining a constant downstream pressure during both high and low demand periods as expected. Subsequently, Queensland Urban Utilities confirmed the PRV fault.

A review of event data resulted in a responsive work order to repair the asset. The PRV was found to have multiple small rocks from the upstream trunk main lodged inside, preventing the PRV from functioning appropriately.

Figure 4: Example of PRV fault event – Queensland Urban Utilities



After repair of the PRV was carried out, the outlet pressure can be observed in TaKaDu to have returned to a level of stability that could not be seen in historic data for over two months prior to the event, indicating the debris was likely in the PRV chamber over this period. Because of this, Queensland Urban Utilities concluded that the PRV behaviour prior to the repair that was thought to be normal was in fact not normal for that PRV.

Post-event analysis carried out by Queensland Urban Utilities concluded that had the PRV Fault event not been raised by TaKaDu, the large burst would have been repaired without knowledge that the root cause was in fact failure of the PRV. The PRV fault would have been left unrepaired, which would likely result in further bursts within the zone before the root cause was finally found.

5.3 SYDNEY WATER

Sydney Water initiated a 12-month trial of TaKaDu on 2,000km of main within the Sydney Water network in May of 2015 to assist with reduction of water loss and improvement of operational efficiency. Water loss reduction and improved operational efficiency are part of an ongoing commitment at Sydney Water to providing valued water solutions to customers and maintaining high levels of customer satisfaction.

The trial included approximately 10% of the total Sydney Water operational area, all of which was located in the south region.

Through the trial, Sydney Water has detected events of different type, significance and potential consequence.

Savings to Sydney Water from the trial were determined by quantifying the avoided water loss from leakage and burst events detected with TaKaDu. A positive return on investment was realised within the first quarter of the trial, resulting in an extension after the conclusion of the initial trial in May of 2016.

Intangible benefits acknowledged by Sydney Water included identification of opportunities for improvement to their internal event detection practices, verification and quality assurance of network repairs by contractors, improved understanding of the monitorability of water supply zones (based on size) and identification of operational deficiencies that would have otherwise remained undetected.

The trial extension is focused on smaller DMAs with a single source of supply where Sydney Water had realised the most benefit from the initial trial. The renewal also includes zones not included in the original trial and includes zones in the north and west regions in the Sydney Water network.

5.3.1 IDENTIFICATION OF OPEN ZONE BOUNDARY VALVE

Sydney Water used information from TaKaDu to identify a breached zone boundary after what would have otherwise been a routine leak repair. In November 2015, a flow trend increase event was raised in TaKaDu, identifying a gradual increase in flow within the Loftus Reduced 1 pressure zone.

The cause of the flow increase was unclear as there was not any scheduled maintenance within the zone and there were not any customer reports of water leaks or sightings of bursts.

The operations team investigated the event and asked field staff to perform acoustic leak detection within the zone. The field staff found and repaired a leak however the event remained open in TaKaDu because of continued flow increase within the zone.

In response to the continued flow increase in the Loftus zone, correspondence from customers and work orders were reviewed to determine if any repairs or planned maintenance corresponded with the increased flow.

A report of discoloured water in a small pocket of the zone had been raised on the day that the flow increase began. Discoloured water can result from a repair or change in operational state in the network.

As there was no record of pipe repairs within the Loftus zone when the increased flow had begun, verification of the state of all zone boundary valves was initiated. An open boundary valve was discovered between the Loftus zone and an adjacent zone (with lower pressure under normal operating conditions). This resulted in increased flow through the Loftus to the adjacent zone and higher than normal pressure in the adjacent zone (increasing risk of leakage or bursts). Furthermore, because the Loftus zone is supplied by a pump station, there is a higher cost of water supply to the adjacent zone when supplied through the Loftus zone.

The valve had remained open after completion of repairs in the adjacent zone in August of 2015. Both the Loftus and adjacent zones were not monitored in TaKaDu at the time of the breach in August 2015, so the flow increase in the Loftus zone was not identified at that time.

After closure of the boundary valve, the Loftus zone had returned to expected normal operating behaviour.

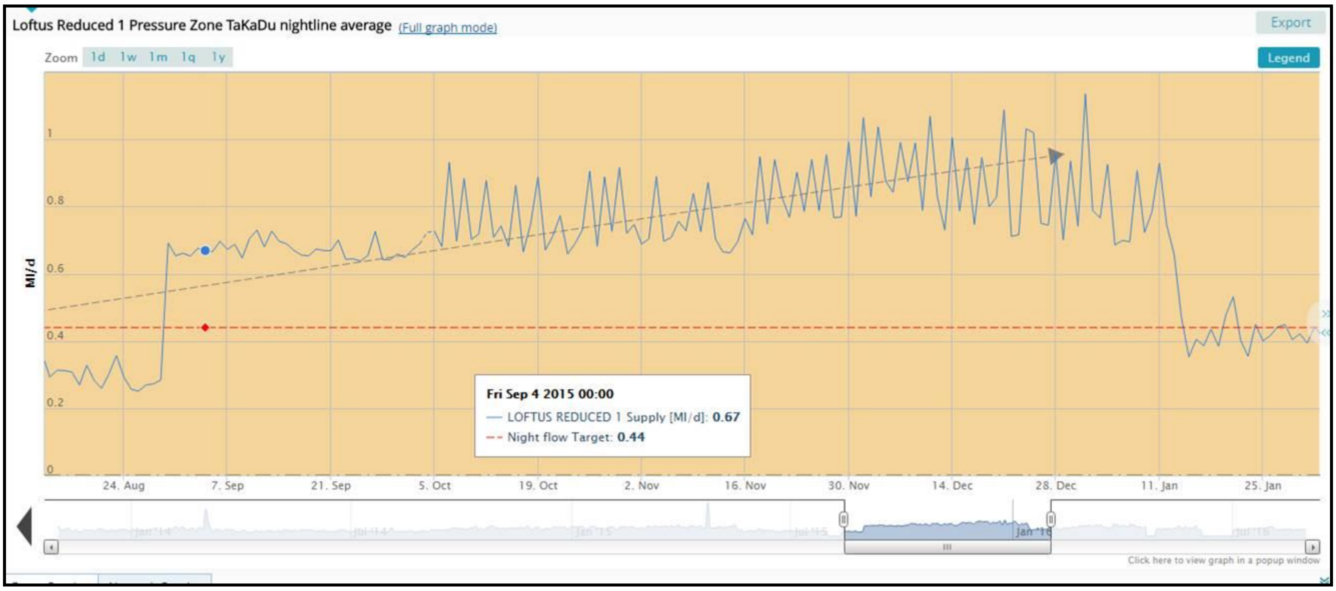
Typically, TaKaDu will raise a Breach event if a zone experiences an increased flow while an adjacent zone experiences a decrease of flow of similar magnitude. However, in this example the zone adjacent to Loftus is a complex zone over a large geographical area with multiple offtakes and variable customer demand. Both zones were also not actively monitored in TaKaDu during the time when the boundary breach had first occurred.

During post-event analysis, Sydney Water had estimated that closure of the boundary valve resulted in savings of AU$10,000 over three years (based on an average cost of their pumping station calculated at $18/ML with around 0.5ML/d unnecessarily supplied to the adjacent zone from the Loftus zone). The estimated savings did not include increased background leakage and risk of bursts as a result of higher pressure in the adjacent zone because of the supply through the Loftus zone.

TaKaDu enabled Sydney Water to detect the irregular flow event quickly, monitor the flow trend, identify the root cause and make an informed decision on the more appropriate cause of remedial action.

The event is illustrated in Figure 5.

Figure 5: Example of flow trend event in TaKaDu – Sydney Water



6 CONCLUSION

Australian water utilities are increasingly using IWN technologies to better understand the operation of their networks, optimise operations, reduce non-revenue water and use insights from IWN solutions to enhance other business functions.

While different from Australia, water availability is also of concern in New Zealand and there are opportunities to optimise water utility operations through adoption of new technologies and IWN solutions.

IWN solutions are gaining greater awareness in New Zealand as technologies evolve, water utilities continue implementing innovative and efficiency measures and examples of how water utilities in other parts of the world use IWN technologies become more prevalent.

Through working with water utilities in Australia with the implementation and use of IWN solutions including TaKaDu, there are measures that should be considered when implementing an IWN solution.

Objectives (KPIs) for implementation, use and assessment of benefits from IWN technologies should be determined before reviewing available technologies, preparing a business case and selecting an IWN solution. Systems and practices should then be reviewed to determine what improvements are required prior to implementation.

If proper planning has occurred prior to the implementation of an IWN solution, it has been observed that successful project outcomes and both tangible benefits (financial savings through avoided water loss, optimised maintenance programs and avoided repair or replacement of infrastructure) and intangible benefits (verification of repair, monitoring of meter accuracy, capture of data for modelling programs, and insights for improved management of assets) can be realised.

ACKNOWLEDGEMENTS

Jacobs thanks Unitywater, Queensland Urban Utilities and Sydney Water and TaKaDu for their efforts and contributions to this report.

REFERENCES

Beal, C.D. & Flynn, J. (2014) The 2014 Review of Smart Metering and Intelligent Water Networks in Australia and New Zealand. Report prepared for WSAA by the Smart Water Research Centre, Griffith University, November, 2014.

Deakin, Mark; Al Waer, Husam. (2011) From Intelligent to Smart Cities. *Journal of Intelligent Buildings International*, Vol 3, Issue 3.

Feltham, C. (2011). Freshwater Use in New Zealand. Parliamentary Library Research Paper. Retrieved from https://www.parliament.nz/resource/en-NZ/00PlibCIP151/431c33c3cf20b98103fa36e28a1dee1185801174

Klein Leichman, A. (2015) Spotting Water Leaks by Satellite. Retrieved from http://www.israel21c.org/spotting-water-leaks-by-satellite/

Pioneering British business uses satellite data analytics to detect and predict water pipeline leaks in Australia. (2016, August 23). Retrieved from http://www.realwire.com/releases/Pioneering-British-business-uses-satellite-data-analytics

Sorbello, J. and Marck, R. (2014). Applications for Intelligent Water Network Systems: Case studies to demonstrate how water utilities can use smart systems to tackle a diverse range of water issues. *Water Journal*, **82**, 75-80.

South East Queensland Water Strategy (2010). Retrieved from https://www.dews.qld.gov.au/__data/assets/pdf_file/0019/32734/seqws.pdf

Stahlut, A., Tung, I. and Skowron, E. (2016) Integrated Event Management at QUU Using TaKaDu. IWA WWCE 2016 Conference paper.

Water New Zealand (2015). National Performance Review 2014-15.

Water Security and Consumption Update – 26 August 2016 (2016). Retrieved from http://www.seqwater.com.au/water-security-and-consumption-update