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REPORT

City of Calgary

Water Metering Review
Residential Metering Technology

January 2018

CANADA'S BEST MANAGED COMPANIES Platinum member

Executive Summary

1 CONTEXT AND PURPOSE

The City of Calgary (The City) has approximately 345,000 water meters installed in residences to measure customer consumption of water. These meters are critical to the operation of the water utility allowing it and the municipality to recover the cost of providing water services, as well as providing customers the assurance that they are being billed in a transparent and fair manner for the water they consume. The reliability and accuracy of this metering infrastructure is therefore important for all stakeholders, and supports or mitigates occasions of unintended or high consumption enquiries.

The City engaged Associated Engineering to provide an independent review of The City's residential water metering technology, and the controls and practices for this technology. This report provides the results, insights and recommendations gained from the review which comprised a comparison of Calgary practices with best practices regarding metering technology, together with a survey and follow-up interviews with other Canadian municipalities.

2 FINDINGS

2.1 Metering Technology

Water metering technology is well proven and has been applied to support billing of water consumption since Roman times. The City uses an industry standard positive displacement meter for residential metering purposes. These meters have a design that is extremely reliable and inherently mitigates over recording. It also provides an accurate record of consumption for many years before requiring replacement. 98% of meters installed in Canada are positive displacement meters. The replacement of these devices is driven by the wear of mechanical parts that leads to the under recording of water consumption. This requires the utility to replace the meter to mitigate potential loss of revenue.

The City is in the upper quartile for most practices and demonstrates many industry leading practices associated with the application, testing and replacement of its metering infrastructure including an industry leading testing facility.

Manual meter reading is a labour-intensive activity that has driven the adoption of smart metering. Smart metering is the application of technology to transmit meter readings to data collectors and utility information systems. Most municipalities have adopted some form of automatic meter reading (AMR) that allows the collection of meter readings by handheld or vehicle mounted data collectors. Many municipalities are going further with the adoption of advanced metering infrastructure (AMI) that provides a fixed network of data collectors and supports continuous provision of meter readings and enhanced customer services. The City currently has approximately 88% of meters read through handheld AMR data collectors.

All participating communities acknowledged the many benefits of AMI however, the transition takes considerable effort with implementation spanning several years. Some communities are struggling to make a supporting business case for the transition due to the capital investment required for meter upgrades, the installation of a fixed data collection network and billing integration impacts.

2.2 High Consumption Investigation and Billing

The results of the review showed that all municipalities are faced with customers concerned about high consumption billing. Most municipalities respond to these concerns through a visit to the customer's home to check for common sources of leaks. Most municipalities have a process whereby a customer can have their meter tested for accuracy. When the meter is found to be accurate, it is common for the customer to pay for the process of meter testing. If the meter is found to be over-registering, the municipality has a process for correcting the billing error. No community reported having had a meter fail by over-registering consumption and needing to utilize the billing correction process.

3 RECOMMENDATIONS

Through the review, a number of practices were identified that could be improved. A full explanation of the rationale in support of the recommendations is contained in the body of the report. The recommendations have been summarized and grouped into three themes listed below.

Strategy Development

a) Review and build on the strategy for smart metering to keep it current with technology trends, and guide decisions made today regarding the selection and installation of technology.

b) Review and document the strategy and guidance for replacing versus refurbishment of water meters that have been removed from customers properties considering both costs and benefits. Include consideration of which components should be salvaged and matched with other components.

Meter Testing

c) In order to minimize the potential for lost revenue, review the weighting of low, medium and high flows in determining overall meter accuracy.

d) Test a sample of meters at different age profiles in order to gain additional sample data to determine the optimal replacement period.

e) Verify the manufacturers' accuracy claims, through the testing of a sample of new meters. Monitor the usefulness of this programme through the evaluation of risks and costs.

f) Ensure the procedure for removal of meters; includes capping the ends of meters at the time of removal to avoid the formation of crystals that could lead to meters testing lower than what they were when installed.

g) In order to duplicate the conditions in which the meter was operating when in service; the order of testing should be changed from *high-to-low* flow to *low-to-high* flow.

h) Review the analysis of flow meter testing results and application in determining optimal replacement strategy.

Meter Installation

i) Review practice of allowing vertical meter installation to confirm the risks associated with potential under reading are acceptable.

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List of Abbreviations

AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading
AWWA	American Water Works Association
ERT	Encoder Receiver Transmitter – Itron brand of MIU
LCD	Liquid Crystal Display
M6	AWWA Manual on Water Meters – Selection, Installation, Testing, and Maintenance
MARS	Meters and Related Services – A company that specialises in water meter testing equipment
MIU	Meter Interface Unit
NWWBI	National Water and Wastewater Benchmarking Initiative
QA/QC	Quality Assurance / Quality Control
RF	Radio Frequency
WHO	World Health Organization

Glossary

Advanced Metering Infrastructure – the transmission of meter readings automatically to fixed network infrastructure (i.e., pole/mast mounted receivers and transmitters).

Automatic Meter Reading – the transmission of meter readings automatically to handheld or vehicle mounted data collectors.

Encoder – a device that converts information from the meter register into another format to support transmission of meter reading to remote reader or via MIU to a remote receiver.

Manual Read Meter - a meter that is read by viewing the register and noting the digits in a notebook or into an electronic device.

Meter Interface Unit – an electronic attachment to a meter allowing the transmission of the meter register readout to a remote receiver using RF technology.

Meter Register – The component of a meter device that registers (and displays) the actual meter reading.

National Water and Wastewater Benchmarking Initiative – a benchmarking initiative created in 1998 to allow Canadian municipalities to measure, track and compare performance across aspects of water and wastewater service provision.

Smart Metering – the principle of using technology to read meters automatically transmitting the signal to the utilities billing systems.

1 Introduction

1.1 CONTEXT, PURPOSE, AND SCOPE

The City of Calgary (The City) has approximately 345,000 water meters installed to measure residential customer consumption of water. Recognizing the importance of water metering and associated billing, and the need to demonstrate to Council and the public, responsible stewardship of the water meter portfolio, The City has engaged Associated Engineering to provide an independent review of The City's application and use of metering technology.

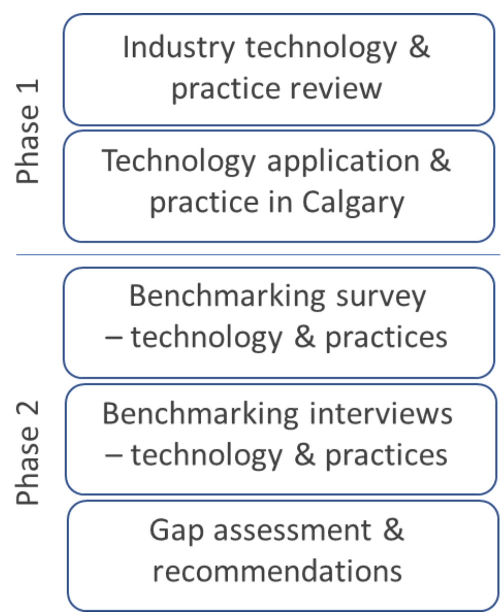
The purpose of this report is to provide the results of the review of metering technology practices, and a comparison with industry standards and practices used by other municipalities across Canada. The review has been focused on residential water meters only. These range in size from 15 mm to 25 mm meters, and therefore excludes any review of practices or technology for industrial, commercial or institutional water metering or network metering.

The scope of the review includes the following elements:

- Trends in water metering including the adoption of smart metering;
- Metering technology including metrology, materials, registers and meter interface units (MIU) including their reliability and accuracy;
- Meter testing and refurbishment including testing standards, use of test bench facilities and refurbishment and replacement strategies;
- High consumption investigations and strategies.

1.2 METHODOLOGY

The approach to undertaking the review has been carried out in two key phases as indicated below.



Phase 1 - The first phase has focussed on understanding the technology applied, and the associated practices for testing and replacement of water meters at The City. The review took the form of reviewing documentation, including standard operating procedures (SOPs) and work instructions, together with an on-site visit to the water meter testing facility, coupled with interviews of key staff. Practices were compared with AWWA standards, industry practices and manufacturers recommendations.

Phase 2 – The second phase has comprised a benchmarking study with other Canadian municipalities. The benchmarking study comprised an initial survey of NWWBI members to respond to questions regarding metering practices and unintended, and high consumption policy and testing practices.

Following the survey, three municipalities were selected for follow-up interviews by telephone to determine more details regarding their practices.

The analysis of these survey results, follow-up interviews, and review of Calgary practices provided validation of many practices and lead to recommendations regarding other practices.

2 High Level Trends in Metering

2.1 INCREASING PUBLIC AWARENESS OF WATER CONSUMPTION

Metering water consumption is a universally accepted means by which water utilities can effectively recover their costs for providing water, encourage conservation of water, and provide data that can be used for analysing consumption patterns that in turn support improved planning for water and wastewater systems.

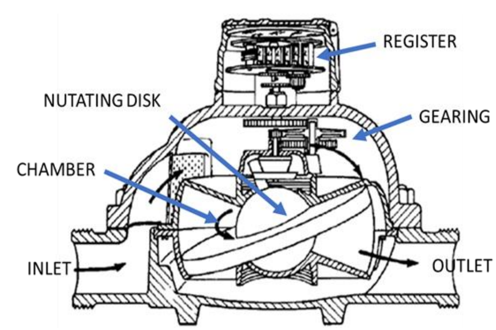
A diverse range of metering devices of different construction, size and performance have been used throughout history. The process of standardizing water metering began in 1913 resulting in a standard being approved by the American Water Works Association (AWWA) in 1921. There have been several revisions to the standard and additional specifications developed as needed over time, typically at least every five years. The AWWA standards on water metering are followed by most, if not all, water utilities that meter their water supplies throughout North America.

Many municipalities have experienced an increase in the cost of treating and pumping water associated with deteriorating raw water quality, increasing water quality regulations, and increasing energy costs. As the increase in the cost of water is passed on to consumers, there has been a corresponding increase in public awareness of water rates and consumption. Consumers are more engaged today than they have been historically. However, there is still generally a lack of understanding of the costs associated with delivering the level of service expected of municipal water supply systems which often causes misunderstanding and occasional disputes between customers and the utility provider. It is essential for utility providers to demonstrate accurate measurement of water provided and fair charges associated with the service. Water metering is the foundation stone of this strategy.

2.2 METER DEVICES

There are a variety of technology choices that a utility can choose from for residential metering. In North America the standard meter in the 50 mm or smaller sizes (residential) has been the positive displacement meter of which there are two variations; the nutating disc and oscillating piston. Essentially equal in performance, these meters have proven by experience to be unrivaled for their combination of accuracy, long life, simple design, moderate cost and easy maintenance.

In a positive displacement meter, a chamber fills with water which then rotates, passing a defined volume of water forward. The volume is calculated based on the number of times these chambers are filled and emptied. The movement of a disc or a piston drives an arrangement of gears that registers and records the volume of water. This registration will be a true representation of flow, assuming the register was appropriately matched to the meter and calibrated. Approximately 98% of small diameter meters installed in municipalities in Canada are positive displacement meters.



2.3 SMART METERING

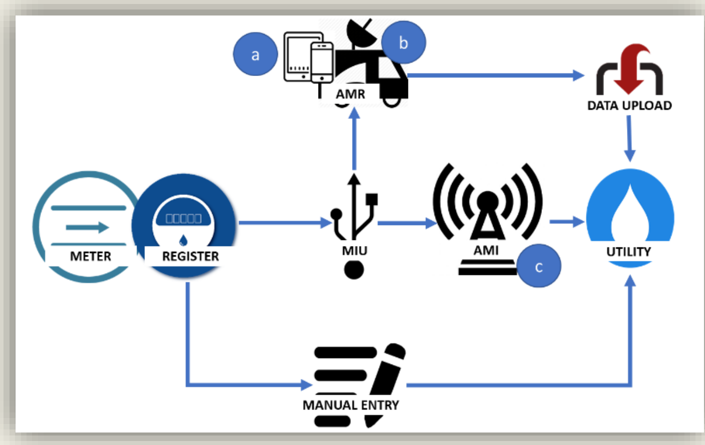
2.3.1 Smart Metering – Industry Practices

Meter reading technology has advanced significantly in recent years. The many disadvantages associated with having to read a meter directly have driven the advancement of technology that allows for the collection of data without going onto a customers' property; this technology became known as Automatic Meter Reading (AMR). For AMR, the mechanical readout of the meter is converted to a digital form by using an encoder. This digital signal is transmitted to a remote device reader. There are two types of encoders, incremental and absolute. The water metering industry refers to meters containing incremental encoders as 'pulse meters' and meters containing absolute encoders as 'encoder meters', although both are encoders. There are fundamental differences between the two types of encoders each with associated advantages and disadvantages. The pulse meter was the first remote reader to be used in the residential water metering industry.

Smart Metering

There are essentially three different approaches to smart metering that revolve around the approach to which the meter reading data is collected:

a) Handheld device data collection
b) Vehicle mounted data collection
c) Fixed network data collection (AMI) – e.g., pole mounted receiver / transmitter.



Once the ability to transmit to a remote reading device was developed, the majority of municipalities in Canada (with meters in basements) quickly moved to have a remote output. There are only a handful of utilities that still use "direct read" meters. In the late 50's and early 60's, most municipalities switched to either a digital pulse meter (outside odometer) or encoder (remote touchpad technology to extract the reading without having to go into the home). Once this was in place, meter reading was carried out more frequently (typically quarterly).

The introduction of digital signals using signal encoder assemblies allowed the development of AMR which has now advanced into a system that can transfer data directly to a central data collection facility with little or no human intervention. This type of AMR is called Advanced Metering Infrastructure (AMI) systems. Both AMR and AMI are now referred to in the industry as Smart Metering.

The key benefits of smart metering include the efficiency opportunity to read meters automatically which speeds up the process of meter reading, and the elimination of typing errors caused by transcribing the observed reading into a log or device.

Furthermore, the adoption of AMR and AMI technology allows the utility to respond to regulatory changes or pressure from the public, customer lobby groups, and watchdogs who are seeking accountability and transparency from utility providers in a climate of increasing costs. This leads to a need for the utility to demonstrate equity in tariff baskets, provide a variety of billing options and provide value added services to customers, a trend that is commonly provided by other utility providers (gas, electric and communications).

The majority of the large water utilities in Canada have moved towards implementing meters with smart metering technology. Five years ago, most utilities viewed AMR as a cost-effective solution, however utilities are now looking at the more advanced technology of AMI for a number of reasons as indicated below.

Benefits of Advanced Metering Infrastructure (AMI)

Meter Reading Improvements – The costs associated with staff having to physically drive or walk by residences is eliminated or significantly reduced. This reduces any safety concerns associated with this activity as staff do not have to mobilize to collect the data. Data collection is more efficient and manual entry errors are reduced, providing the utility with more accurate and frequent data. Costs associated with fleet, fuel and labour are reduced.

Water Conservation and Data Analytics – Conservation measures can be monitored and quantified by the utility supporting reports on program effectiveness. This is a level of transparency much of the public is expecting. The consumption data can also be analysed for trouble shooting and planning purposes.

Early Detection of Leaks – AMI technology supports the creation of District Metering Areas which can be used by municipalities to detect pipe leaks before extensive damage has been caused by the water. This will reduce the likelihood of excessive erosion and infrastructure damage. Early detection allows for a planned response where repair work can be scheduled for an optimal time mitigating the costs associated with reactive or emergency work.

Customer Service Improvements – AMI supports enhanced customer services including allowing customers to understand their water consumption and compare their consumption to others through web portals or apps, provide access to live data to address billing related issues, and provide leak notifications to the customer or utility. The ability for customers to see real time consumption instead of reviewing historical usage will reduce the number of customers challenging their billings. In addition, the ability to read more frequently allows the utility to move to more frequent billing cycles to help homeowners manage the increasing costs of traditional quarterly billing.

System Versatility – AMI systems provide the ability to add other appurtenances to the system in the future such as pressure sensors, remote shut off valves, acoustic leak detection, and other devices.

2.3.2 Smart Metering – City of Calgary Status

Long Term Metering Strategy

The City of Calgary has widely adopted the concept of smart metering. Currently approximately 88% of The City's meters incorporate technology allowing the reading of meters through hand held data collectors. The remaining are read manually and are currently being targeted for exchange. Every year, new AMR capable meters are installed through the lifecycle replacement program. The approach demonstrates the most basic implementation of AMR.

While many municipalities are moving towards AMI systems there are a number of risks for The City to consider such as:

- The older ERTs (50W and 60W) are not AMI capable and would need to be fully replaced. This would result in some meters being replaced before the end of their service life.
- All ERTs are mounted on the meter in the basement which impedes signal transmission to any devices further than a few meters away. While this works adequately with handheld data collectors that are in relative proximity, the location of the ERT could hinder a possible future AMI implementation leading to the requirement for more network infrastructure to support, if possible at all. The Itron ERTs or new chosen AMI System MIUs would need to be moved outside, which in turn would require wire runs through property walls. While most communities that implement AMI do run wires outside successfully, this may be a significant concern for homeowners. A less favourable solution is to mount the ERT on the basement ceiling rather than on the meter device.
- Currently, water meter reading and billing is managed in conjunction with the electrical utility, ENMAX. Calgary would need to consider how an AMI system would be managed with ENMAX as there could be synergies associated with implementing shared AMI infrastructure. However, the majority of water utilities that have a local electricity utility have opted to keep the AMI systems separated. The drivers and use cases for the system are different and it was determined to be difficult to align priorities and manage the relationships.

Recommendation 2.1: The City should review and build on the strategy for smart metering to keep it current with technology trends and guide decisions made today regarding selection and installation of technology.

3 Metering Technology

3.1 METROLOGY

Metrology is the science of measurement and concerns the measuring device component of the water meter. There are two broad groups of devices:

a) mechanical meters e.g., standard positive displacement meters
b) non-mechanical meters such as magnetic flow meters or ultrasonic devices.

3.1.1 Metrology – Industry Practices

The majority of Canadian municipalities continue to use mechanical meters as these provide a number of benefits including:

- **Proven technology** – based on designs over 125 years old.
- **Reliable and long lasting** – Accuracy does decrease over time leading to under reading, especially at low flows, but only nominally at intermediate and high flows. Over time, the internal components of the meter will wear resulting in the meter under-registering the volume of water. The value of lost water at low flow is minimal compared to the cost of meter replacement, but is a key factor that determines meter replacement strategy.
- **Unit Cost** – given that 98% of meters installed in the Canadian market are positive displacement meters, the cost of these devices is relatively inexpensive.
- **Design reliability** – Positive Displacement Meters inherently measure a discreet volume of water. Combined with a mechanical register, the design inherently mitigates over registration. This however, assumes that the correct register is installed (corresponding to meter size) and the data relating to the billing determinants is correct in the billing software.

Although many utilities in Canada have piloted or tried residential non-mechanical flow meters, very few utilities have implemented them as their standard device for a number of reasons:

- **Initial cost** – Higher initial capital cost than for a wholesale implementation; would be a significant impact on the utility. This would be compounded by the need to access customer properties, usually basements, where the majority of meters are located in colder climates.
- **Battery powered** – These devices require the battery to be operational in order to make a reading. The battery is recognized to be the weakest link in the meter assembly. While they are typically expected to have a 20-year life, if they do fail the device stops reading and subsequent usage needs to be estimated.
- **Shorter lifecycle** – The battery life expectancy of approximately 20-years forces the utility to replace the entire metering device within 20-years of installing it, regardless of the condition of the meter. This impacts the cost/benefit or payback associated with meter replacement, and may therefore negate any savings associated with the improved technology. This relatively short replacement cycle does not

compare favorably with conventional mechanical meters which often have an economic life expectancy in excess of 20-years before replacement is required. Mechanical meters will eventually wear with time. There is a break-even point in relation to the rate structure versus accuracy where it makes financial sense to replace the meter. Since the wearing of the aging meter will always favour the customer, with mechanical meters, utilities have the option of altering their replacement strategy if outside factors could potentially delay a replacement program. However, this option is not available with non-mechanical meters that must be replaced to mitigate complete loss of reading.

- **Unproven technology** – Non-mechanical meter technology has not been used for residential water metering for any considerable time to prove battery life. While technology is used in other aspects of water metering, most applications where it is used have power supplies and do not rely on batteries.

However, there are some significant advantages to non-mechanical meters including:

- **Accuracy** – Non-mechanical meters maintains their accuracy curve for the life of the meter. Typically, manufacturers offer a warranty for the 20-year life.
- **Low Flow Accuracy** – Non-mechanical meters maintain their accuracy at low flows for life (typically low flow accuracy degrades more quickly than other flow rates on mechanical meters).

3.1.2 Meters - City of Calgary Status

The City of Calgary uses a mechanical positive displacement meter for its 15 mm to 25 mm residential meters. These meters meet the AWWA guidelines and are an acceptable industry standard for residential billing purposes. The City of Calgary Water Services, has a meter inspection process that ensures meters have the correct register matched to the size of the meter and register configuration is correct to avoid errors when inputting meter information into the billing system.

3.2 MATERIALS

3.2.1 Materials – Industry Practices

The meter casing of both mechanical and non-mechanical meters is predominantly constructed of either bronze or plastic. This is driven by NSF 61 Drinking Water System Component requirements which pertains to the health impacts of materials in contact with water. Many manufacturers now offer lead free bronze alloys which exceed current and potential future Health Canada regulations lead content in water fittings.

Although plastic is less expensive to manufacture only a small percentage of meters installed are plastic. This is partly driven by the relative newness of plastic meters and lack of track record of long term reliability. It is also a function of a preference to use metallic meters to maintain the electrical continuity on metallic pipes negating the requirement for additional grounding straps. Another potential issue with plastic installations is the cracking of the casing when installed on relatively high-pressure systems.

3.2.2 Materials - City of Calgary Status

The mechanical meters used by The City are made of bronze and are entirely consistent with NSF 61 Drinking Water System Component requirements.

3.3 REGISTER

3.3.1 Register – Industry Practices

The register is the component of the device that shows the actual meter reading and has traditionally been made of a series of dials that indicate volume of water passed. Traditional devices are comprised of six dials that indicate down to 100 litre intervals (00000.0 m^3). Higher resolution dials tend to have eight dials and register down to 0.1 litre intervals (0000.0000 m^3). As the technology improves and the need increases for more accurate understanding of consumption, the trend has been towards the higher resolution meter registers. However, the primary driver to increase resolution is the advanced technology of AMR and AMI which provide features that can enhance the detection of leaks and backflow.

The register is generally a mechanical device or a battery operated digital device. Mechanical registers are the most commonly used devices in Canadian utilities and are a well proven technology that is long lasting with low failure rates compared to battery powered devices. In addition, if a mechanical device does stop working it will not lose the last reading, and therefore reduces the risk of lost consumption up to the point of failure detection.

Electronic registers indicate the meter reading on an LCD display that generally requires battery power to operate. These are generally lower cost units, however they face similar issues to non-mechanical meters that require batteries – i.e., they will completely stop recording in the event of battery failure and will lose the meter reading at the time of failure leading to a greater level of estimation of meter reading and potential lost revenue.

The life expectancy of battery operated devices is typically 20-years which can force a meter replacement timeline that may not be optimal given the other meter components. This will also require access to property basements potentially creating more frequent, difficult and costly replacement programs.

3.3.2 Meter Register - City of Calgary Status

The City of Calgary still uses mechanical registers, which are the most reliable and considered current industry best practice in Canada.

3.4 METER INTERFACE UNIT

3.4.1 Meter Interface Units – Industry Practices

The meter interface unit (MIU) is the component that interfaces with the water meter register and transmits a radio frequency (RF) signal to a receiver for the purposes of automatic meter reading. MIUs typically capture and store hourly consumption data for a period of up to about 96 days (3 months). The data is then downloaded to a data collector (hand held or vehicle mounted) in an AMR type system, or can be transmitted to a fixed receiver in an AMI type system.

The use of RF devices in the home has drawn some public attention regarding exposure to RF fields and its effect on humans. However, the World Health Organization (WHO) states that "*Considering the very low exposure levels and research results collected to date, there is no convincing scientific evidence that weak RF signals from base stations or wireless networks cause adverse health effects.*" Smart meter transmissions of RF energy are significantly lower than other types of device such as wireless routers, cell phones or walkie-talkies, and Health Canada concludes that exposure to RF energy from smart meters does not pose a public health risk.

The MIU is usually a programmable device that allows the utility to change meter read intervals, transmission intervals or other parameters. This programming needs to be undertaken carefully as it can impact on battery life and in turn void the warranty on the device, as well as introduce data errors associated with incorrect programming. Most MIUs for AMR applications are shipped pre-programmed reducing the risk of error.

The MIU can be programmed to work with normal AMR (hand held or vehicle mounted data collection) or with AMI systems (fixed network). The trend in MIU deployment is to have a device that can easily be migrated from AMR to AMI to allow for future upgrades while taking advantage of AMR efficiencies today. However, the transmitters need to be powerful enough to make this transmission.

3.4.2 Meter Interface Units – City of Calgary Status

The City of Calgary uses the Itron ERT which is a programmable device that is pre-programmed prior to shipping. In addition to sending the current meter reading to the meter reader, the device stores data for 30 days. While this information can aid high water consumption investigations, the issue will typically not be identified within a 30-day period before the data is overwritten in the ERT.

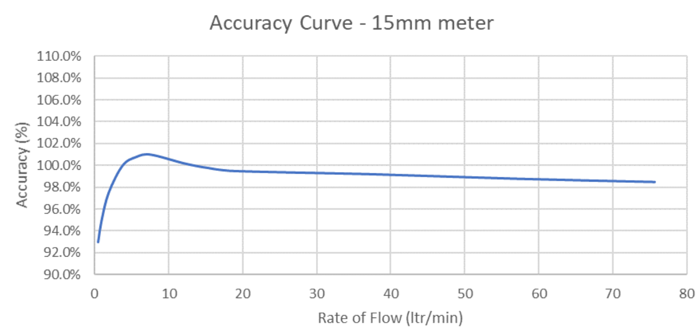
The City has a number of Itron ERT models currently in use, including the 50W, 60W and 100W models. Only the recent version – the 100W – is migratable to an AMI type system should The City wish to move in that direction. The previous ERTs (50W and 60W) are not AMI capable and would need to be fully replaced.

Recommendation 2.1 covers the requirement to review the application of appropriate technology now to support the implementation of technology in line with defined direction of the utility. In the application of new technology, consideration should also be given to the data retention abilities of the MIU.

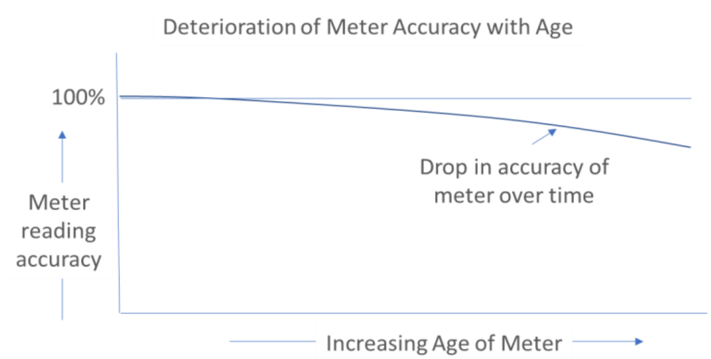
4 Meter Testing & Refurbishment

4.1 METER ACCURACY AND TESTING

Water meters have an inherent variation in accuracy over their design range of flows as indicated in the figure. At low flows, meters in good condition will typically under register. As the flows increase to about 10% of the design capacity of the flow meter, registration of flow increases. At higher flows the accuracy of flow meters reduces. The AWWA sets standards for meter testing accuracy of between 101.5% and 95% of actual volume that passes through the meter compared with what the meter records during testing.



As a mechanical device, water meters are subject to wear and deterioration at a rate that depends on a number of factors including volume of water passed, water quality and rates of flow. The wear and deterioration can also impact on the accuracy of the meter reading and generally leads to a trend of under recording as more flow is able to bypass the worn elements of the device.



Testing of water meters by the manufacturer or utility is of great importance for two main reasons:

a) Prior to installation, to protect customers against meter inaccuracy that could result in over-registration and over charging.

b) to identify inequities and lost revenue that result from under registration of meters and drive meter refurbishment and replacement programs.

The AWWA has developed guidelines for determining the overall accuracy score for water meters. The guidelines weight the accuracy score determined at different flow rates to reflect overall meter accuracy under normal water usage conditions (see Table 4-1 following). While these weightings may be considered suitable and best practice, an alternate weighting framework may be considered.

Prior to shipping all meter manufacturers test their meters and provide a warranty for meter accuracy for a period or volume passed. These warranties are for a level of accuracy at different flow rates as per the accuracy curve in the figure above. While there is no AWWA guidance on validating these manufacturer test results, some utilities choose to conduct their own quality control of new meter shipments through the testing of a sample of new meters.

The warranty information also typically relates to normal recommended installation i.e., horizontal installation of flow meters. The industry standard and best practice is to install meters in a horizontal plane. All meter manufacturers' installation manuals clearly state this and the AWWA M6 Manual states that meters are designed to optimally perform in a horizontal orientation. Some meter designs have shown uneven and faster wear due to orientation which could lead to the potential of under-registration earlier in the meters life. While many manufacturers have provided letters allowing vertical installations, most utilities adhere to horizontal installation guidance as best practice.

Horizontal Setting of Water Meters in Vertical Pipework

(Source: AWWA M6 Manual)

The industry best practice for removing a water meter that has been taken out of service for testing is to cap or plug the ends of the meter when it is removed. It is then delivered to the testing bench in the same condition including moisture levels in the meter chamber, as it was when in service. Allowing the meter to dry before testing allows the crystallization of dissolved solids. This may lead to under recording on the testing facility.

4.1.1 Meter Accuracy and Testing - City of Calgary Status

Meter Test Accuracy Weightings

Water meters removed from service as part of the water meters replacement program are tested on The City's in-house meter test bench. The City also tests water meters at the request of property owners in relation to anomalous readings, complaints or meters extracted for other reasons. The City uses the accuracy guidelines established by AWWA to score meter accuracy. The testing results are analyzed by cumulative meter usage and an overall meter accuracy score determined based on AWWA guidelines (see Table 4-1 below).

Recommendation 4.1: The City should consider an alternate weighting to the flow rates from AWWA guidelines. An extensive study conducted by another municipality led to a revision of the weightings it uses to determine an overall meter accuracy score that puts more emphasis on low flow accuracy. The study found that a higher proportion of flows through the meter are in the low flow profile for the water meter.

Table 4-1
Water Meter Accuracy Testing Weightings

Flowrates	Gallons Per Minute	AWWA Weighting	Revised Weighting
Low	0.25	15%	30%
Intermediate	1.5	70%	59%
High	14	15%	11%

Recommendation 4.2: The City should analyze results by age versus total consumption (usage). The City should also establish an annual testing plan to sample meters in groups from the field to determine when the optimal change out should be, rather than just meters that have been extracted for complaint or event reasons. Many utilities have found that age based replacement of meters is more economical due to the efficiency gains of being able to work in a neighbourhood with similar aged properties and meters.

Testing of New Meters

New shipments of meters are inspected on arrival according to a work instruction and new meter evaluation checklist. This ensures a consistent approach to the inspection of new meters however, it does not include the actual testing or verification of meter accuracy of new meters.

Recommendation 4.3: The City should consider establishing a program to test new incoming meters from the manufacturer to audit the meters against their test certificates. This program can be adjusted based on results over time.

Installation Orientation

The City commonly installs meters in a vertical orientation. While a letter from Badger does indicate that this is an acceptable practice, it also states that the extended low flow accuracy warranty is void in a vertical orientation. Test benches are always orientated in the horizontal plane, including the Calgary test bench, and therefore it is not possible to test and assure the accuracy of meters installed in the vertical orientation. Positive displacement meters installed in a vertical position are likely to under-register earlier in the meters life, resulting in a shorter economic life cycle or present a revenue risk for The City.

Recommendation 4.4: The City should review its practice of allowing vertical meter installation and determine appropriate course of action to mitigate risks of under-registration.

Capping of Removed Meters

The City's standard operating procedure for removing a water meter from a property for testing does not appear to include any reference to the capping of water meters before delivery to the testing facility. Capping the meter preserves the internal moisture conditions of the meter and enables more accurate testing of meters.

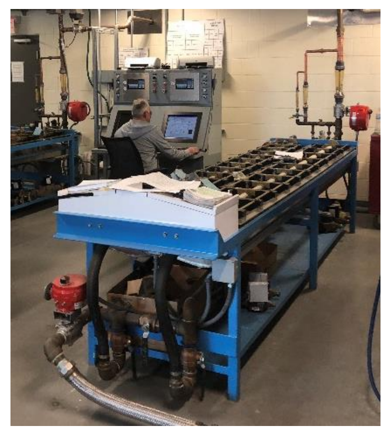
Recommendation 4.5: The City should ensure that the standard operating procedure for removing water meters for testing includes the capping of the meter immediately before conveying to the testing facility.

4.2 TESTING BENCH

4.2.1 Testing Bench – Industry Practices

Most utilities test their water meters either in-house, in a purpose built testing facility, or outsourced, often to the meter supplier. For smaller utilities, the cost of developing an in-house testing facility may be prohibitive and outsourcing this activity will be the preferred approach. However, given the volume of meter testing required by a large utility such as Calgary, it is more cost effective to develop an in-house testing facility.

The AWWA M6 manual provides an indication of best practices in the set-up of a testing facility for small, medium and large-scale operations. This includes the use of defined volumes of water, temperature control and testing process from low-intermediate-high flow rate testing. The industry best practice is to start testing at the low flow first to avoid “cleaning out” the meter base. Typically, a meter will develop build up in the meter chamber area from various minerals in the water (depending on water quality, etc., such as calcium build-up). When the meter is tested at low flow first, the meter is operated in much the same conditions as it was when in service with regards to amount of scale build-up on the internal components. Real in-situ low flow accuracy can only be measured if it is done first. As the flow rate is increased, scale will be dislodged and the in-situ conditions are no longer present.



4.2.2 Test Bench Facility - City of Calgary Status

The City of Calgary test bench is high quality and overall testing practices on old meters are good. The use of the MARS Small Test Bench is well controlled by a standard operating procedure and associated work instruction that provides a clear indication of the required set up and running of the facility including the software. The software, while recognized to be dated, is still adequately functional for the purposes of testing water meters.

Testing Sequence

City staff indicated that the testing of meters begins at high flow rates and then proceeds to intermediate and then low flows, contrary to best practices indicated above.

Recommendation 4.6: Consideration should be given to changing the order of testing to follow AWWA best practices of low-intermediate-high order of testing.

4.3 REFURBISHMENT AND REPLACEMENT OF WATER METERS

4.3.1 Meter Refurbishment and Replacement – Industry Practices

Refurbishment of residential water meters is not common practice and is largely a function of the unit price of a meter versus the labour cost for time spent refurbishing the meter. A number of factors impact on both of these dimensions including the size of the utility (economies of scale), specifications of the meter and the ability to replace individual components of the meter assembly (meter housing, register and MIU).

The lack of cost effectiveness to refurbish a meter drives most utilities into a meter replacement program. At the time of extraction of a meter, typically a new or tested meter will be reinstalled. The extracted meter will be subsequently tested for accuracy, if within age or usage limits, and be shelved or scrapped depending on test results.

Typically, the meter and register would be replaced at the same time. The replacement of the MIU is dependent on the type of register and where it is mounted. MIUs mounted to the exterior of the property would be typically left in place (depending on the age and warranty of the MIU), however an integrated meter-register-MIU assembly would be replaced as a single unit.

Best practice planned replacement programs are developed based on statistical testing results on meter accuracy that would determine an optimum age or volume for meter replacement which balances the cost of replacement with the value of potentially lost revenue to the utility. Industry best practices are to manage meter replacement programs around age to allow for more efficient installation programs by working in neighbourhoods with common installation profiles. This is also supported by easier access to the meter information in the utility meter asset management system. A usage driven program would result in more random locations throughout The City, leading to a relatively inefficient replacement program.

4.3.2 City of Calgary Refurbishment and Replacement Practices

Meter Refurbishment

The City of Calgary has a relatively low unit price for water meters driven by the economies of scale in purchasing meters. The integrally mounted ERT necessitates the replacement of the whole unit at the time of meter extraction. The City does currently undertake limited repairs and refurbishments of approximately 25% of the meters it exchanges. This includes the removal of the transponder and potential redeployment subject to testing success.

Recommendation 4.7: The City should continue to review the cost effectiveness of the number of repairs completed on water meters through the consideration of labour costs, and average accuracy of repaired device versus the cost of new meters and their associated accuracy.

Guidance for Disposal or Refurbishment

The work instruction for repairing meters does not give any indication as to the conditions that should be met for a meter to be repaired.

Recommendations related to this practice would be to decouple the register and ERT, and potentially retrofit to an existing meter that is not too old (i.e., less than 10 years). The shipping combination of register, ERT and base should also be investigated further to clarify if there is a programming issue that prevents older components being coupled with newer components.

Recommendation 4.8: The City should determine and document clear guidance on when meters that have been removed from service should be refurbished. This should also include an indication of the components of the meter assembly that can be redeployed onto a different metering assembly.

Data Analysis

It is clear that the City has undertaken considerable analysis of testing results and financial analysis on optimal timing for replacement of water meters in line with best practices. The analysis of low, medium and high flows on different meter sizes would be considered industry leading. However, a high level review of the statistical regression analysis indicates that more data is needed to support the fit of the trend line of meter accuracy over time. The insight gained may lead to enhancement of optimal lifecycle replacement intervals associated with meter under-registration.

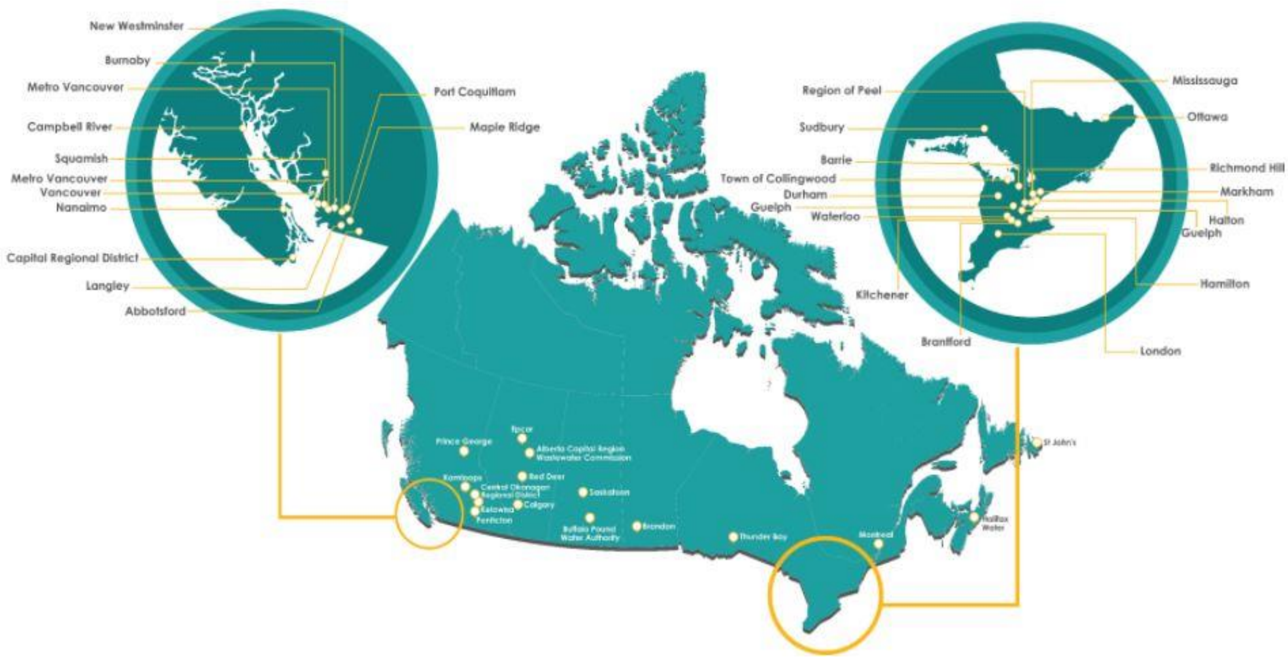
Recommendation 4.9: The analysis of flow meter testing results should be investigated further to confirm the optimal meter replacement strategy. This will be further supplemented by increased testing data that will be gained on the implementation of Recommendation 4.2.

5 Benchmarking Study

5.1 BENCHMARKING APPROACH

The benchmarking study is intended to provide a comparison of The City's metering practices with those of other municipalities. The study does this by comparing a number of metrics such as percentage of types of meter installed, as well as a comparison of processes applied in other municipalities.

The benchmark survey consisted of two components. The initial survey was sent to municipalities using the *National Water and Wastewater Benchmarking Initiative* (NWWBI) network. NWWBI was created in 1998 to allow Canadian municipalities to measure, track, and compare utility performances. It currently consists of 55 municipalities from across Canada as indicated in the figure below.



Questions were sent to the participating municipalities using an online survey provider. This initial phase is a broadcast effort, intended to acquire general information from a broad set of municipalities.

Based on the results from the NWWBI survey, three communities were selected for follow up discussions, allowing for a more detailed review of their metering infrastructure and management practices. The filtering criteria between the two phases was dependent on each municipality's service size, types of meters and registers, maintenance practices, replacement strategies and consumption issues. Discussions were focussed on fine tuning results from the initial NWWBI survey to gain a greater understanding of the key components that Calgary wishes to compare.

5.2 BENCHMARKING SURVEY

The NWWBI survey is split into three sections, focussing on meter and register type, maintenance and replacement strategies and high consumption incidents, respectively. The questions are as follows:

Section 1 – Meter Types and Meter Reading

1. How many small (15 mm - 25 mm) residential meters do you have?
2. What type of small residential water meters do you have in your system? E.g., solid state, positive displacement, multi-jet, other?
    - What is the percentage of total (residential) meters for each type?
    - What type of meter are you currently installing for residential customers?
3. What meter reading systems do you use and what percentage of your customers are on each of those systems? E.g., manually read, AMR or AMI?
    - What is your reading percentage rate for each type?
4. What is the meter reading percentage (monthly/quarterly/annually by breakdown of meter?
5. What type of meter register do you have in your system? E.g., Pulse, encoder, direct read
    - What is the percentage for each type?

Section 2 – Meter Replacement/Accuracy

6. Do you have a small meter replacement strategy or program? Please describe.
7. Do you test your small meters for accuracy after they have been replaced; Do you use this testing information to further develop your replacement strategy?
8. Does technology drive any part of your replacement strategy?

Section 3 – High Customer Consumption

9. For Customers who have a high consumption billing concerns, do you have field staff that will go on-site and investigate the issue? If so, what will they check? E.g., Help customer identify leaks, check meter for signs of damage to the meter, verify meter reading.
10. Do you have a QA/QC program or test for new meters supplied to you?
11. If a customer is disputing the accuracy of the meter, do you have program to test the meter?
12. Does your Utility have fees/charges associated with meter testing for dispute resolution? (YES/NO answer.)
    - If you answered yes, can you please describe the fees/charges included in meter testing?

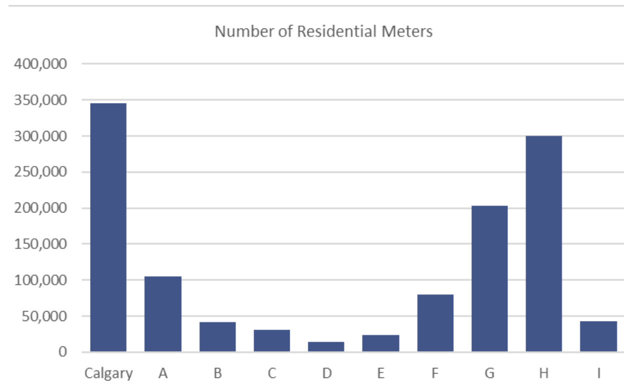
5.3 RESULTS OF BENCHMARKING

A total of 10 municipalities responded to the NWWBI survey. Since all members of the NWWBI enter into a confidentiality agreement that commits to the protection of the identities of the participants, each respondent has been assigned an alpha-numeric identifier in the charts that follow.

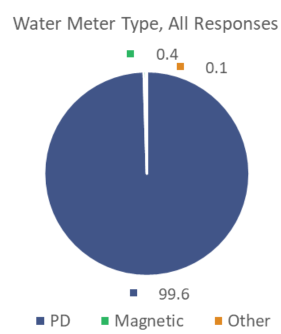
The answers to the questions were tabulated and graphed to determine if there are obvious trends or patterns.

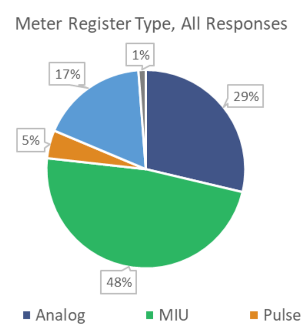
Installed Meter Base

Of the municipalities surveyed the meter base varies significantly. The installed meter numbers ranged from 14,000 meters to 345,000 meters, with Calgary being the largest.



Despite the variation in size of installed meter base, it is clear that all municipalities have a predominance of mechanical positive displacement meters for their residential customers. A small number of magnetic meters are in use and one community is currently installing new magnetic meters.





Most cities had a combination of the older pulse type registers and the newer encoder type. It was not clear from the data if cities were making a concerted effort to move towards one type or the other. As discussed in Section 2.1 the preference for one type over the other is a complex issue and each municipality will make that decision based on a number of factors.

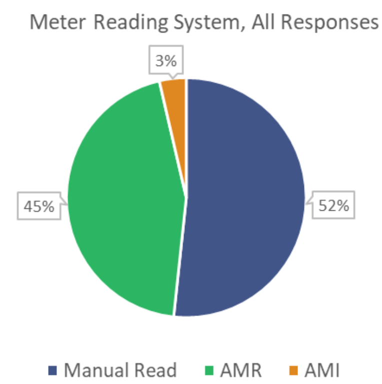
Calgary Summary	Comparison with industry:
Installed meter base: 345,000 Type of meter: 100% positive displacement	Industry standard

Terminology

The results of the survey revealed some differences in the industry in the usage of terminology. In order to verify the data, phone calls were made to some municipalities to clarify information; such as what was meant by ‘manual read’. It was discovered that some people felt ‘manual’ meant a person had to enter a household, read a meter register and write the information down. To others, it meant the meter reading was sent to a touchpad located outside the house which was then read by a person touching a probe to the touchpad. For the purposes of this analysis, AMR included installations where the reading is sent to an MIU and read through the use of a reading device including touchpads.

Smart Metering and Advanced Metering Infrastructure (AMI)

All the municipalities in the survey have installed, or are planning to install, some type of AMR system. The survey indicates that 5 of the 10 municipalities surveyed take meter readings monthly with the remaining bi-monthly or quarterly. There is a strong correlation with reading frequency and application of AMR.

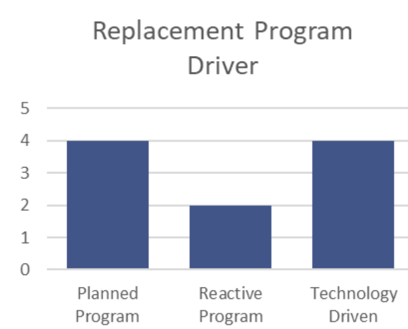


Only two municipalities indicated any use of AMI systems, although a number indicated a plan to move towards AMI. In follow-up phone calls, other municipalities indicated they were also contemplating moving to AMI and some had it written into Master Plan documentation, although this was not reflected in their responses to the survey.

Calgary Summary	Comparison with industry:
Application of Smart Metering: 88% handheld AMR Non-smart meters: 12% direct read	Industry standard

Meter Replacement and Strategy

Four municipalites have a replacement strategy driven by age or usage of the meter. Two municipalities replaced meters only on a reactive basis. The remaining municipalities (four) have either completed or are in the process of a wholesale change of meters in line with a strategy to adopt AMR or AMI.



The majority of the respondent's report using a combination of contracted replacement work for the main replacement programs, and in-house replacements usually on a small scale.

Calgary Summary	Comparison with industry:
Meter replacement program: Planned replacement program based on usage and technology	Industry leading

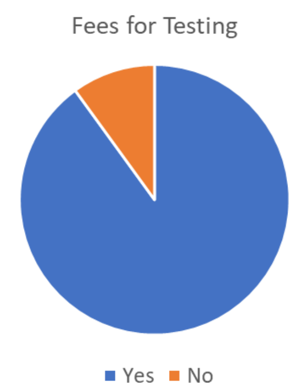
High Customer Consumption

The survey results indicate that all municipalities surveyed offer field services to customers who have high consumption billing concerns. When a customer called in expressing a concern with an unusually high bill, staff would work with the customer to determine if there is an obvious cause. The consistent components include leak checks and detection practices, confirmation of meter operation and accuracy, and discussion points and information to facilitate customer understanding. In follow-up conversations with municipalities one noted they proactively notify customers when their usage is unusually high. In this case, billing is reviewed before being sent out. If a billing varies beyond a threshold amount, it is flagged for a proactive notification. The customer is provided with a package in the mail that notifies them of the anomaly and provides a checklist of potential sources of water leaks for the customer to check. If the usage is extremely high, the utility will call and visit customer's residences. Most municipalities had sent educational brochures in the past; however, few were continuing the practice on an on-going basis. A small number of communities had a Water Conservation group that took on the task of educating the public.

Calgary Summary	Comparison with industry:
Provision of meter checks and leak investigations	Industry standard

Meter Reading Disputes

In cases of disputed meter accuracy, 90% of municipalities in the survey, including Calgary, will have the meter tested for accuracy when a customer disputes the consumption record and make a request. The charges for testing are the responsibility of the customer if the meter is found to be operating within the accuracy guidelines recommended by AWWA or the manufacturer's specifications. Some municipalities' policy is to charge a fee upfront for this service and then refund the money if necessary. Others will charge the customer only when the test shows the meter was the cause of the high consumption record. Fees for testing ranged from $87 to $230.

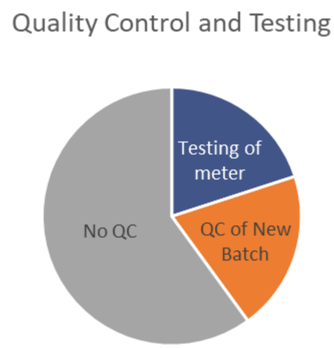


No municipalities reported testing results that showed the meter was over registering. There were some responses that found occasionally errors occurred due to mismatched components or programming errors. Some municipalities indicated they felt a move to AMI would reduce the amount of time and resources required to address the concerns of customers. The quicker response time would also help reduce the amount of revenue lost.

Calgary Summary	Comparison with industry:
Customer initiated meter testing for disputes	Industry standard

New Testing Meter Accuracy

Only one municipality indicated that they tested new, factory supplied meters, although another indicated they had done this in the past. The costs associated with this process were felt to outweigh the benefits. Municipalities made this decision based on the fact that when meters were tested due to high consumption complaints or at the end of its service life, there was a very low incidence of meter failure. Two further municipalities, including Calgary, conduct verification of new batches of meters through inspection and matching of test certificates. The remaining municipalities do not conduct any quality control (QC) on manufacturer supplied meters.



Calgary Summary	Comparison with industry:
QC inspection is carried out on new meter shipments	Industry leading

The review of the survey results indicates that Calgary meets or exceeds standard metering industry practices in identified areas. The results of the survey have been used to help formulate the recommendations indicated in Section 3 and 4 of this report.

6 Summary and Conclusions

Water metering technology is well proven and has been applied to support billing of water consumption since Roman times. The City uses an industry standard positive displacement meter for residential metering purposes. These meters have a design that is extremely reliable, inherently mitigates over recording, and provides an accurate record of consumption for many years before requiring replacement. 98% of meters installed in Canada are positive displacement meters. The replacement of these devices is driven by the wear of mechanical parts that leads to the under recording of water consumption. This requires the utility to replace the meter to mitigate potential loss of revenue.

Most municipalities have already transitioned from manually read meters to smart meters that transmit meter readings automatically to a data collector. There is also an industry trend in support of converting to AMI systems as all survey respondents acknowledged the many benefits of the advanced technology; however, making a business case for the transition has proven to be challenging for most municipalities. Implementation of an AMI system may have a significant impact on the billing process where billing is shared with or carried out by another utility provider.

The results of the survey indicate that most, if not all, municipalities are faced with customers concerned about high consumption billings. Most municipalities respond to these concerns the same way, that is, a visit to the customers home to check for leaks in fixtures most typically at fault, such as toilets and water softeners. Most municipalities have a process whereby a customer can have their meter tested for accuracy. If the meter is found to be over-registering, the municipality has a process for correcting the billing error. When the meter is found to be accurate, the customer pays for all expenses related to the meter testing.

It is also clear that The City is in the upper quartile for most practices including testing and verifying the accuracy of meters, extent of analysis of testing results and determination of optimal replacement strategies for meters.

The problems The City is currently experiencing regarding the public's perception of inaccurate billings is not unique to Calgary; all municipalities that were a part of this survey have the same response from customers. It is also worth noting that other municipalities have not experienced a meter failing by over reading consumption. The experience reported indicated the failure of a meter resulted in it under reading consumption. There were some municipalities that found errors in mismatched components or errors in programming resulted in over billing of customers.

7 Recommendations

Through the review, a number of practices were identified that could be improved. A full explanation of the rationale in support of the recommendations is indicated in the relevant sections of the report including the observation or finding that lead to the recommendation.

The review of the recommendations would indicate that there are three key themes into which they can be categorized:

- **Strategy Development** – This includes recommendations that relate to the development of overall metering strategy or clarification of strategy elements such as repair versus replacement.
- **Meter Testing** – This includes recommendations that relate to the actual meter testing process including obtaining more representative testing results, changing the order of the testing process and improving the interpretation of testing results.
- **Meter Installation** – There is a single recommendation that relates to the physical installation of water meters in customer's homes.

The recommendations from within the document are captured in the three defined categories below.

Strategy Development

Recommendation 2.1: The City should review and build on the strategy for smart metering to keep it current with technology trends and guide decisions made today regarding the selection and installation of technology.

Recommendation 4.7: The City should continue to review the cost effectiveness of the number of repairs completed on water meters through the consideration of labour costs and average accuracy of repaired device versus the cost of new meters and their associated accuracy.

Recommendation 4.8: The City should determine and document clear guidance on when meters that have been removed from service should be refurbished. This should also include an indication of the components of the meter assembly that can be redeployed onto a different metering assembly.

Meter Testing

Recommendation 4.1: The City should consider an alternate weighting to the flow rates from AWWA guidelines. An extensive study conducted by another municipality let to a revision of the weightings it uses to determine the overall meter accuracy score that puts more emphasis on low flow accuracy. The study found that a higher proportion of flows through the meter are in the low flow profile for the water meter.

Recommendation 4.2: The City should analyze results by age versus total consumption (usage). The City should also establish an annual testing plan to sample meters in groups from the field to determine when the optimal change out should be rather than just meters that have been extracted for complaint or event reasons. Many utilities have found that age based replacement of meters is more economical due to the efficiency gains of being able to work in a neighbourhood with similar aged properties and meters.

Recommendation 4.3: The City should consider establishing a program to test new incoming meters from the manufacturer to audit the meter against their test certificates. This program can be adjusted based on results over time.

Recommendation 4.5: The City should ensure that the standard operating procedure for removing water meters for testing includes the capping of the meter immediately before conveying to the testing facility.

Recommendation 4.6: Consideration should be given to changing the order of testing to follow AWWA best practices of low-intermediate-high order of testing.

Recommendation 4.9: The analysis of flow meter testing results should be investigated further to confirm the optimal meter replacement strategy. This will be further supplemented by increased testing data that will be gained in the implementation of Recommendation 4.2.

Meter Installation

Recommendation 4.4: The City should review its practice of allowing vertical meter installation and determine appropriate course of action to mitigate risks of under registration.

Certification Page

This report presents our findings regarding the City of Calgary Water Metering Review Residential Metering Technology.

Respectfully submitted,

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