DMA Design and Implementation, a North American Context

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System Overview

The infrastructure owned and operated by the Halifax Regional Water Commission [HRWC] is typical of many North American water utilities. The transmission mains are predominantly concrete pressure pipe and the distribution mains are cast iron, ductile iron and PVC with an average age of approximately 50 years old. The HRWC is a large utility as defined by the American Water Works Association [AWWA] serving a population of approximately 320,000 residents within the Halifax Regional Municipality [HRM] through a 1300 km pipe network. Water is delivered from two large treatment plants to the urban/suburban area of HRM; via gravity from the Pockwock plant and boosted from the Lake Major plant. Both plants deliver water to large storage reservoirs after which it is pressure reduced or boosted throughout the distribution system as dictated by local topography. Due to the varying topography in HRM, there are over 50 distinct pressure zones within the distribution system. Although this makes for more complex hydraulics it provides an opportunity to utilize these zones as the backbone for the creation of district metered areas [DMA's].

Objective

The objective in establishing DMA's in a water utility is to identify and control, to some economic or rational level, the real losses within each DMA, and to a greater extent, the utility as a whole. Given that leakage runtime is arguably the most important contributing factor to real losses, early detection and awareness of leakage is critical to the reduction and control of real losses. Once established, a functional DMA can provide the information required to quickly identify unreported leaks and bursts as they occur. With proper metering, night flow patterns can be analysed to reveal night time use, background, and active leakage. Bursts and flow rates can quickly be identified which allows for prioritization of leak detection personnel. Fire flows, system flushing, and other maintenance activities within the DMA, can be identified and quantified for accounting purposes. During significant flow events, system performance can be observed providing necessary information for system enhancements.

Reported bursts are difficult to ignore and typically trigger an immediate utility response. If all bursts were reported, there would be little need for district metering as a tool to control real losses, however, in many utilities, the majority of bursts are unreported. District metering allows utility personnel to be aware of unreported bursts. With the knowledge of how much water is being lost, and approximately where, the unreported bursts can be as compelling as reported bursts.

DMA Design Challenges

For the majority of large water utilities in North America, the dominant factor in determining water main size is the requirement for fire flows. Combined with maximum daily flow requirements and limited maximum velocities, these design criteria demand a need for large diameter transmission and distribution piping which result in very low velocities during normal day, and night time flows. The extremes in design flows, and the resulting low velocities during normal flows, make proper meter selection and location very important if meaningful information is to be obtained from the DMA. When Creating DMA's in Halifax, we are faced with the challenge of preserving the design capacities while trying to create discrete areas which can be metered in a practical and economic way. To accomplish this, in many cases, where there is a pressure differential along a boundary, check valves or pilot controlled hydraulic valves have been used in place of closed gates valves. When fire flows are required, the system pressure will drop within the DMA causing the check valve or hydraulic valve to open introducing additional supply as required.

Where multiple or redundant feeds are often the case, the majority of DMA's will have two or more metering sites that combine to give the total DMA flow. Cascading DMA's are common where; the water entering one DMA must first pass through one or more other DMA's. Under these conditions, capturing the flow data within the same time frame becomes important for accurate accounting of water flow, and calculation of instantaneous flow rates.

Water quality is always a concern. To establish a DMA, system valves will likely have to be closed along DMA boundaries resulting in dead ends and the possibility of taste and odour problems, and or low chlorine residuals. Where water quality issues or complaints arise, routine flushing, valve operation, or fixed rate jumpers across boundary valves may have to be considered. In designing DMA's, positioning large water users at the extremities can help in keeping the water fresh within the DMA.

Creating District Metered Areas

Where Do We Start

Clearly, each water system can be unique in design. Governed by topography, climate, regulatory issues, design standards and many other variables, each system will have its unique features and operating parameters. However, in all cases, the DMA process begins with a review of the system to identify obvious opportunities, utilizing existing pressure zones, pumped systems, or areas that have a single supply line, as possible candidates to form a DMA. Areas that are prone to leakage or where real losses are believed to be high should be identified as priorities. Areas in which leak detection is difficult, such as non metallic systems, or where contact points are limited, should be identified and given consideration. In many cases, identifying the areas where the simple installation of a flow meter without the need for boundary or hydraulic changes can provide immediate benefits to the utility.

When the immediate opportunities have been identified, the remaining piping network should be reviewed and, on paper, divided into logical DMA's. Implementation will ultimately occur on a priority basis that would consider cost, leakage and burst history, or often, when other works or system upgrades provide a convenient and cost shared opportunity.

DMA Size

How do we determine the appropriate size for a DMA? At the Halifax Regional Water Commission, a decision was made to establish a maximum DMA size based on an acceptable leakage run time. After consideration, it was decided that, once there was an awareness of an unreported burst, the DMA would be sized such that, it could be acoustically surveyed for leaks within one day. Under this scenario, awareness would occur on day one, leak surveying and location would occur on day two, and repair on day three providing a maximum run time of three days. To accomplish this, the ideal maximum DMA size was set at 150 -200 hydrants, 2500 customer connections or 30 km of water main. Given the climate and infrastructure in Halifax, this is the area that can be effectively surveyed by a single leak detection team in a single day. Developed around existing boundaries and other system features, many of the District Metered Areas in Halifax are smaller than the ideal maximum and provide for better resolution and shorter leakage run times. There also remain, areas that are much larger which have been targeted for DMA development.

In Halifax, during the late fall and early winter, bursts begin to occur quite regularly in many DMA's. Although there is an awareness of these unreported bursts, often, the leak crews cannot respond quickly enough to maintain the three day run time goal. During these times, the DMA's can provide the necessary information to prioritize the bursts and direct leak crews in the most productive way. When repairs are made, the night flows are analysed to confirm a return to normal.

Boundary Confirmation and Performance Testing

Once a DMA has been designed on paper, all meter locations and valves that must be operated to form the DMA, are identified and the information is submitted to HRWC's engineering department for review and modelling. With approval to proceed, the valves are operated to create a temporary DMA and begin the testing phase. During this phase, the flow rate into the DMA is measured by way of an existing meter or a temporary strap-on ultrasonic meter, to confirm estimated flow rates. To ensure the boundary valves are closed, and there are no open connections with adjacent zones, the pressure within the temporary DMA is reduced creating a pressure differential between zones and across boundary valves. During this test, leak crews sound all boundary valves listening for leakage through the valves. Pressure loggers installed along the boundary of adjacent zones record pressures during the test. Pressures here should not be affected by the pressure drop within the temporary DMA. All data is reviewed, including flow rates into adjacent zones, looking for any indication that there is leakage into the temporary DMA during the pressure drop.

Finally a flow test is performed to ensure the DMA can supply the required fire flows. If all goes well, the meter installation will proceed and the DMA will become permanent.

Meter Selection and Installation

When it comes to meter selection, smaller is better when trying to capture the all important low night flows, however, meters must be able to perform adequately across the total range of flow. At the HRWC, meter size and type are determined on a site by site basis, matching the performance characteristics and features of the meter, with the specific requirements of the site. In-line magnetic flow meters are the preferred choice however ultra sonic meters are considered on pipe larger than 200 mm, and in-line turbines are considered on by pass lines 100 mm and smaller. In any case, meters must be capable of interfacing with the HRWC SCADA system using either a pulse output or a digital protocol.

Accuracy is a concern with all meters and when required, the meters are field calibrated.

The HRWC has standardised the installation of DMA meters. Where pressure control is required, a standard pre-cast vault equipped with a SCADA interface, two pressure reducing valves, a flow meter and pressure transmitters is installed. The larger PRV is sized to provide fire flows and other exceptional demands, the smaller PRV is sized to meet the daily domestic demands. The flow meter is installed in series with the small PRV to meter daily domestic flows only. The larger PRV is monitored and will generate an alarm if opening is detected. This approach keeps the meter size to a minimum for accurate night flow measurement, yet provides the fire flow capacity when required. Where pressure control is not required, the DMA meter and associated piping are assembled in a pre-cast manhole and inserted after a section of water main has been removed. SCADA equipment is mounted on a nearby utility pole which also provides electrical supply.

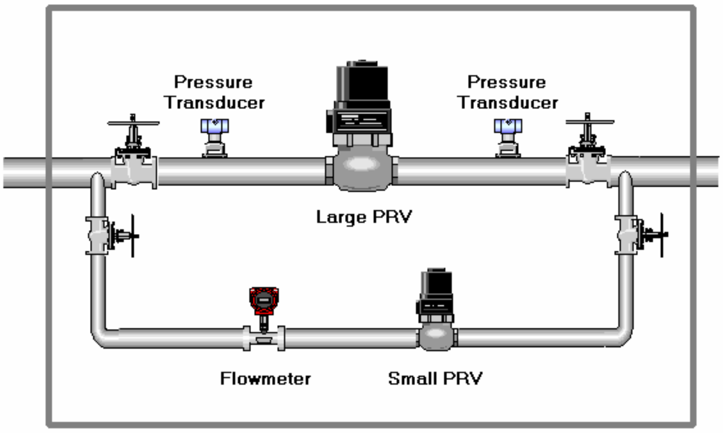

Figure 1 Standard PRV chamber with DMA meter

Collecting, Storing and Using DMA Data

Leveraging off SCADA

For many years, the HRWC has been using a radio frequency (RF) based SCADA system to control and monitor HRWC pumping stations, reservoirs, remote treatment plants and other HRWC facilities. Today, HRWC Technicians construct and maintain all components of the SCADA system which has evolved into a highly flexible, multiple cell system using the latest in RF technology. Agreements with the local power utility allow for low power costs and use of utility poles for mounting SCADA terminals, resulting in low installation and operating costs. Considering the system flexibility and economy of operation, in Halifax, the SCADA system is a practical and cost effective vehicle for collecting DMA data.

The HRWC now has over 60 DMA's including more than 100 metered sites that are monitored by the SCADA system. System input meters provide totaliser readings as well as diagnostic information while DMA meters provide rate of flow. Once collected, the SCADA system deposits the DMA information into a data warehouse, designed for temporal or time based data. The data warehouse stores all plant information, and the data is easily accessible to users for analysis or display.

Getting Value from DMA Data

Once in the data warehouse, the DMA information is readily available for anyone who can use it. Although intended primarily for water loss control, the historical DMA information is routinely used for system design or planning. HRWC engineering staff access the information and view the real time hydraulic grade line for modelling purposes while treatment plant personnel use the historic data for demand forecasting.

Putting reliable and timely information in the hands of those who need it is the foundation for success in controlling leakage. At the HRWC, much of the process has been automated and provides leakage control staff, the information needed to identify leakage and prioritize efforts. The system stores all DMA data, reads system input meters, and records all reservoir levels. With this information, the daily net system input is calculated for each region and posted to the HRWC intranet site for review. Weekly averages are plotted creating an annual trend with previous years overlaid.

The most effective and efficient tool used at HRWC for leakage identification is HRWC's whiteboard. Previously this was a manual process and involved posting flow rates on an actual whiteboard. This is now an automated process that determines the average flow rate for each DMA between 3:00 and 4:00 a.m.. Once calculated, the average night flow rates are compared with established benchmarks for the corresponding DMA's and the difference is calculated. The results form a table that include the benchmarks, the calculated average night flows for five consecutive nights, and the calculated difference between the benchmark and the most recent night flow. Each morning, the whiteboard for each region is updated on the HRWC intranet site while printed copies are produced for leak detection personnel. The whiteboard quickly identifies DMA's with high night flows which can then be analysed in detail to reveal burst time and flow rate.

Clients available with the data warehouse allow quick access to all HRWC DMA and plant data. Powerful graphing tools and long term storage enable staff to review DMA flows over long periods to identify gradual increases in night flows indicating the accumulation of multiple small leaks.

Large customers with sporadic flows can often be mistaken for leakage within a DMA. To prevent this, the HRWC has partnered with some of their large customers and installed flow monitoring equipment at the customer site. Deducting the customer flow from the DMA flow eliminates these false alarms.

Table 2 HRWC Central Region Whiteboard

Central Region Zone Night Flows (m3/h)

District Metered Area	Benchmark	14-Jul	13-Jul	12-Jul	11-Jul	10-Jul	Diff
Bedford Core	7.1	16.2	10.5	19.0	17.9	18.4	+ 9.1
Sackville Green	144.0	166.3	170.6	168.2	156.5	155.6	+ 22.3
Sackville Core	37.0	42.8	42.8	42.3	43.3	46.7	+ 5.8
Beaverbank	8.5	11.0	9.0	10.1	10.3	11.8	+ 2.5
#7 Highway	7.4	6.9	7.4	7.7	8.0	6.9	- 0.5
Crestview	2.2	1.3	1.3	0.7	1.2	1.1	- 0.9
Bedford Village	0.0	0.2	0.2	0.1	0.4	0.2	+ 0.2
Rockmanor	4.0	4.1	4.2	4.0	4.1	4.5	+ 0.1
Bedford High	1.1	5.9	3.5	3.2	3.3	3.2	+ 4.8
Kingswood	6.0	8.3	5.6	6.7	17.5	5.6	+ 2.3
Blue Mtn	2.7	3.4	3.5	3.5	3.5	3.5	+ 0.7
Giles	0.0	0.0	0.0	0.0	0.0	0.0	+ 0.0
Mowatt	1.3	4.1	3.0	4.2	4.1	3.4	+ 2.8

Water Accountability

Since adopting the IWA Standard Water Balance, the HRWC attempts to accurately measure or quantify, whenever possible, all unmetered water. Using DMA data from the data warehouse, the HRWC uses a custom Excel application to determine the volume of water lost from any abnormal event. System flushing, fires, capital work and other maintenance activities are measured using the water loss calculator illustrated in **Figure 3.**

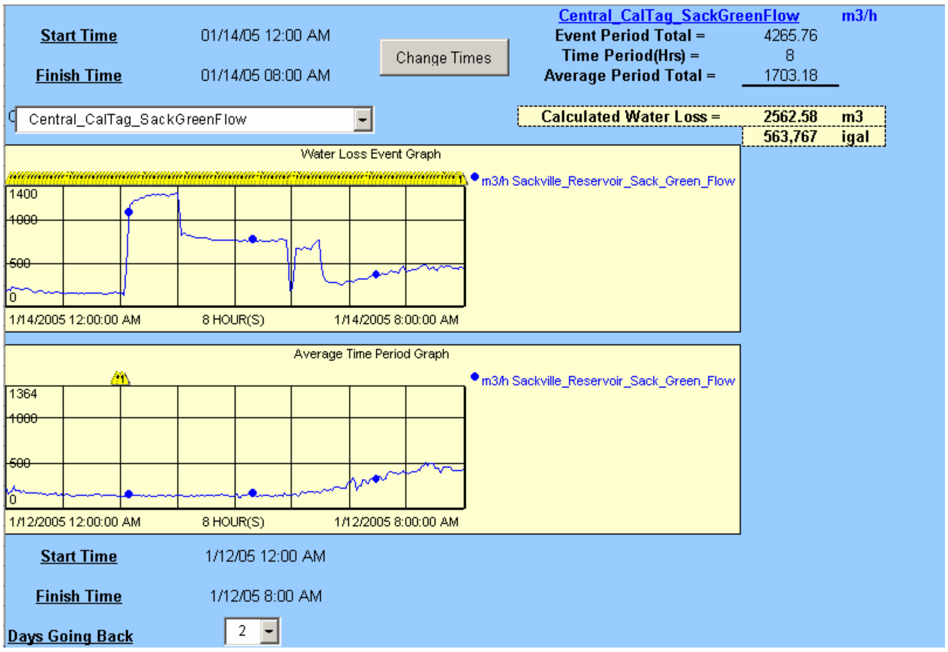

Figure 3 HRWC water loss calculator

The Future at HRWC

At present, the HRWC use the lowest recorded average night flow, per DMA, as a benchmark which is compared with actual night flows to identify leakage. While this does provide indication of bursts, it does not provide an indication of the effectiveness of leak detection efforts, nor the condition of the infrastructure, as it is not known how low the night flow should or could actually be in each DMA. Without knowing the active and background leakage component in each DMA, leak detection and other water loss control efforts could well be misplaced. In light of this, the HRWC has begun a bottom up component based analysis that will identify the background and active leakage levels and calculate the minimum night flow in each DMA as detailed in Figure 4. When complete, it is expected that this detailed analysis will reveal DMA's that are at their lowest technical level of leakage while others may have considerable active leakage. DMA's with high background leakage may be identified and considered as candidates for advanced pressure management. In any case, it is felt that this detailed analysis in each DMA will provide the information necessary to properly manage water loss control efforts.

The vision at the HRWC is to automate as much of the process as possible while providing accessible and meaningful information to leakage control personnel. Using existing applications, the intent is to calculate the minimum night flow for each DMA, determine the active leakage component during the night flow period, then, applying an hour day factor, calculate the leakage over a 24 hr period. With this information, along with the marginal cost of water, the value of lost water in each DMA would be known. This exercise is well underway, and as can be seen in Figure 4, HRWC staff have a very tight DMA in the Mt. Edward zone. Other zones will be analyzed and prioritized for leakage intervention as the program matures.

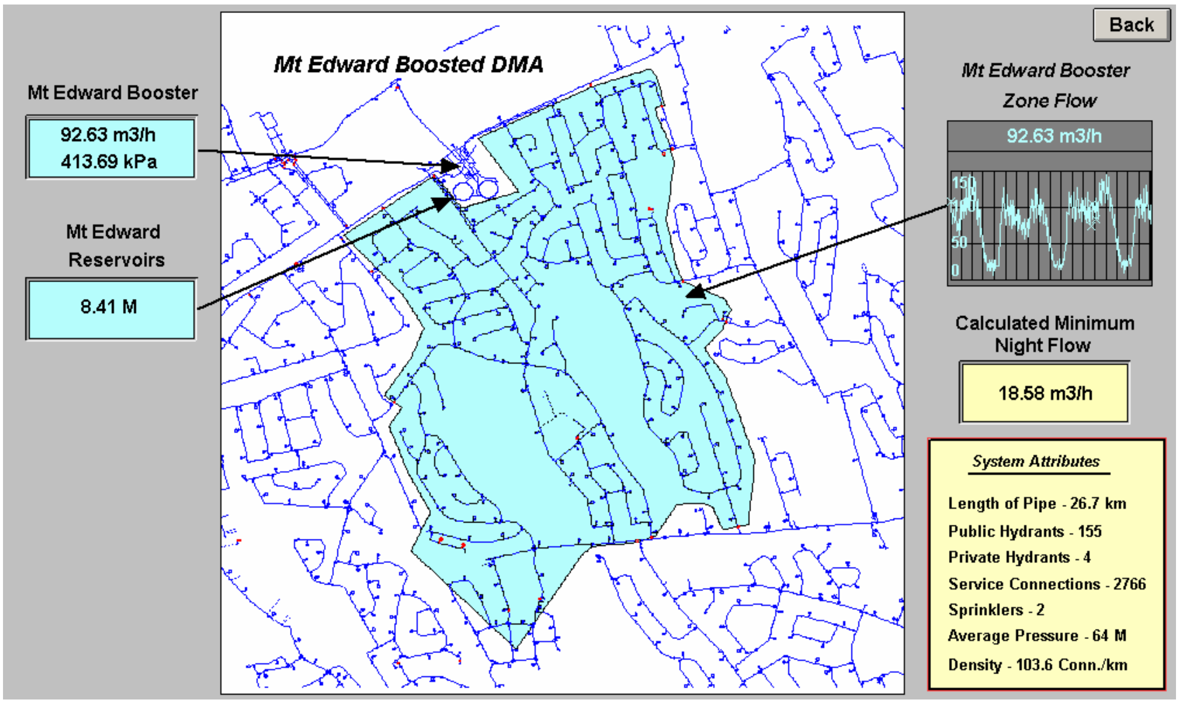

Figure 4 Graphic showing real time DMA data with calculated minimum night flow

Figure 5 shows the Dartmouth East High DMA created by installing an ultrasonic transit time meter on the single 600mm supply to this sector. The transit time meter was field calibrated at 15, 50 and 100 m3/h to ensure accuracy during the expected night flows. The bottom up component analysis suggests a night time flow of 51 m3/h, while measured night flows, following leak detection surveys, have averaged 55m3/h. Although future plans call for breaking the Dartmouth High DMA into smaller DMA's, even at the present size, with proper flow metering, indication of bursts and active leakage is possible.

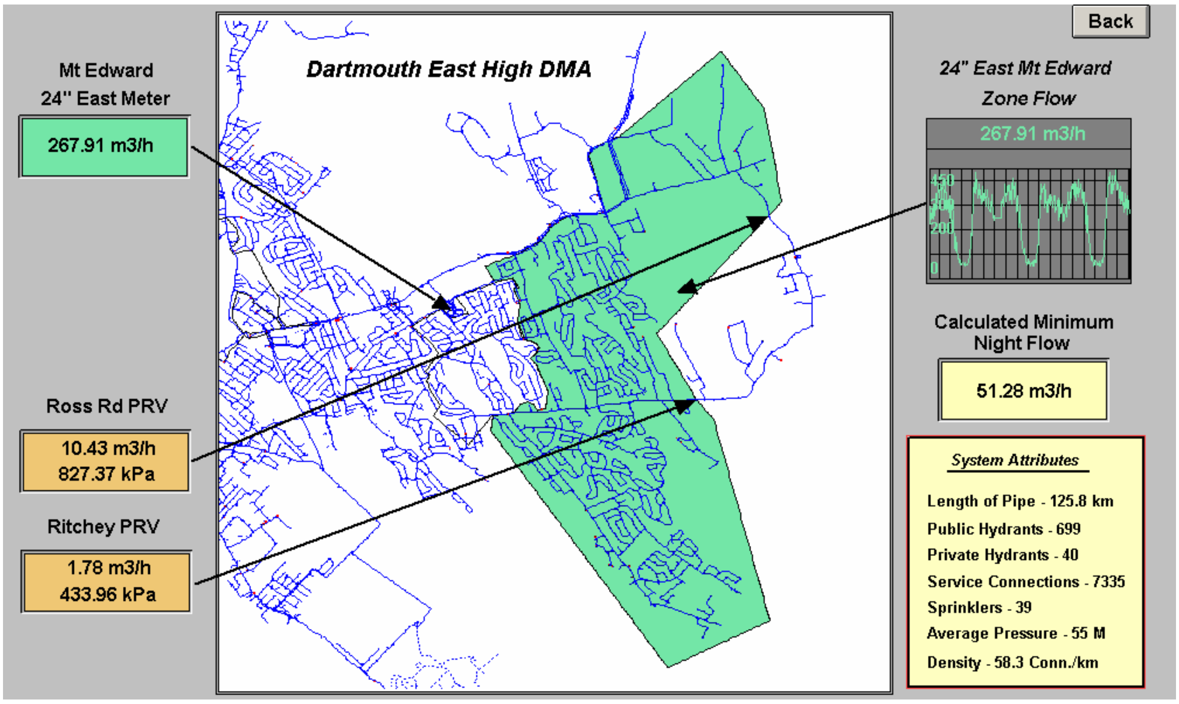

Figure 5 Dartmouth East High DMA

The experience of DMA implementation at HRWC has been nothing short of success. The results from HRWC are well documented as measured through the Infrastructure Leakage Index (ILI). Since 1999, HRWC has reduced its ILI from 9.0 to 3.8 as of March 31, 2005. The utility is not done yet. A target of 3.0 by March 31, 2007, has been established to ensure HRWC is pegged in a world class position.

References

Brothers, K.J., DMA Design and Application for Non-Revenue Water Reduction in Canada, Paper to IWA Leakage Management Conference – A Practical Approach, Presentation, Cyprus, November, 2002, ISBN 9963-8759-0-4

Lambert, A., Timothy G. Brown, M. Takizaw, D. Weimer, A Review of Performance Indicators for Real Losses from Water Supply Systems, IWA/AQUA, 26.01.2000.

Liemberger, Roland, Malcom Farley, A Non-Revenue Water Reduction Strategy – American Water Works Association 2004 Annual Conference

American Water Works Association AWWARF Project 2928, Leakage Management Technologies (In progress).