Condition Assessment of Pipelines –
Helping Municipalities Reduce Long-Term Costs

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The Challenge:

Municipalities across North America are faced with aging water infrastructures that, if not managed properly, may turn into major political, financial and economic issues. Although municipalities understand the predicament, the linear water infrastructure has taken a back seat to other, more pressing services and social issues. Moreover, public officials and utility managers have been skeptical about raising rates to the levels necessary to sustain the infrastructure in fear of the potential economic impact to their customers. This quandary has resulted in many utilities being uncertain about the condition and future performance of their water system assets.

Overcoming the Challenge:

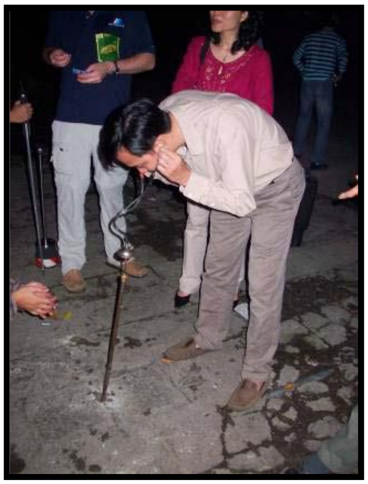
In order to avoid this adverse situation, utilities are implementing asset management strategies, with a combination of common sense practices that provide the required level of service in a cost effective manner. Utilities are considering a strategy that begins with identifying, locating, and assessing the condition of the water infrastructure and proceeds with determining the appropriate levels of service and the criticality of the assets and culminates with establishing a funding strategy. The strategy seeks answers to these basic questions:

1. What is the current state of the assets?
2. Which assets are critical to sustain performance?
3. What are the best O&M and Capital Improvement Program strategies?

It is no longer adequate to complete a desktop study of pipeline assets to determine a repair or replacement priority. Recent studies from Australia have shown that age is NOT a useful factor in prioritizing pipelines for repair, or replacement. Better information from the field is necessary. However this information needs to be obtained in a cost effective manner. There are innovative technologies being used in the UK and USA to assess the actual condition of small diameter water pipelines and to provide information to calibrate Capital Improvement Programs.

Condition Assessment of pipelines allows the operator to extend the life of the asset and invest where investment is needed, therefore, reducing costs and expenditures.

[1]Ferrous water mains represent two thirds of the installed network. It unavoidably leaks and, over time, it will leak more. Leaks have a lifecycle. Small leaks grow into larger leaks that surface and continue to grow until water is visibly streaming up until the point they are re-classified as a main break, which will damage the area around the rapidly streaming leak. In other instances, pipe fails catastrophically and the lifecycle is seemingly invisible. In the former case, the challenge is to identify leaks in their earliest stage whereas in the latter case, the challenge is to identify where corrosion, manufacturing defects, human error and unexpected pipe loading are allowing some applied force to overcome the residual strength of the pipe.



The tendency within the water industry is to replace entire pipe segments at some point after the first failure. This is particularly true with regard to small diameter mains. In the process, two mistakes are commonly made: replacing too much pipe and doing so while it remains economical to continue repairing it. Since small diameter mains make up two thirds, or more, of all water pipe then it is a logical conclusion that the tendency has been to over spend on pipeline replacement. This was due to the prohibitive cost of condition assessment for small diameter mains.

Low flow conditions, water quality complaints, age and service histories are reactionary data points that convey the general condition of pipe. The lack of specificity is a primary contributor to the tendency for utilities to replace more pipe than is necessary. In an operational environment where the apparent cost of condition assessment remains very high, 10%, or greater of replacement cost, then collecting general condition data points will continue to be the norm. To that end, the goal moving forward, from a technological perspective, is to develop low cost condition assessment technologies, which will deliver specific actionable data about the conditions of pipe.

Pipeline failures often take place in multiple stages, rather than as a single event. For instance, circumferential breaks caused by bending forces on the pipe are frequently combined with spiraling cracks caused by transient pressures. At the most basic level, pipe failures are caused by applied forces exceeding the residual strength of the metal. These forces can be classified as five groups; those produced by internal water pressure, bending forces, crushing forces, soil-movement induced tensile forces and temperature induced expansive forces. Cast iron pipe was generally designed to withstand internal water pressure and crushing forces. Combining internal transient pressures with unexpected external forces can trigger multiple failure modes. The probability of a given failure mode occurring varies significantly by pipe size. Makar, Desnoyers, McDonald, 2001, points out that small diameter pipes are more prone to longitudinal bending forces because they have a smaller moment of inertia due to thinner pipe walls. Bending forces cause pipe failures by way of circumferential cracking. The same force on large diameter pipe tends to cause bell shearing and this means that since smaller diameter pipes are more susceptible to bending forces that circumferential cracking is a more common failure mode than bell cracking regardless of the pipe size. This emphasizes the need to identify bending force on small diameter water mains.

In many instances the bending force that causes circumferential cracking can be seen from inside the pipe. Bending forces on pipe occur when the pipe is installed incorrectly and when the soil around the pipe moves. Bending forces can cause the pipe to kink or for joints to become misaligned.

While it may be the case that neither visible kinks nor misaligned joints are leaking, the probability of a failure at this location is very high. That probability increases dramatically in the presence of frequent transient pressures.
Bending forces are visible in cast iron pipes as deformation, cracking and crumbling lining. It is visible at misaligned joints and subtle longitudinal bending between joints.

Many municipalities attempt to measure the amount of leaking in a system and then use tools to locate leaks. In another paper we will review leak detection tools. But how useful are the industry standards that municipalities compare themselves against?

The degree to which all water distribution systems leak is known as the system's Unavoidable Annual Real Losses (UARL). It is calculated as a function of the length of pipe, the number of customers, the typical configuration of meters relative to the curb stop and the system's operating pressure. The AWWA has adopted the ratio of Current Annual Real Losses (CARL) to UARL as a benchmark for utilities' leak management. This ratio is the water systems Infrastructure Leakage Index (ILI). ILI = CARL / UARL.

In practical terms, an ILI close to 1.0 would mean that "world-class" leakage management is ensuring that CARL is close to the UARL or the "technical minimum" value at the current operating pressure. ILI is equal to 1.0 when all of the CARL is due to UARL; an improbability. It was furthermore noted (Lambert & McKenzie, 2004) that from a sample of 27 utilities located in 20 countries that the average ILI was 4.38. The most probable ILI, however, was 2.94. This means that worldwide, a utility should expect their current annual real losses to be about three times the unavoidable annual real losses.

ILI as a benchmark, however, can be counterintuitive; this isn't a one size fits all measurement. In large municipal water systems that are designed to supply a predominately manufacturing based economy, there is much greater redundancy, there is a greater quantity of large diameter water mains and the end result is that UARL becomes skewed because leakage at service connections is understated. In these systems, large services represent nearly half of water consumption. To complicate matters, when calculating UARL, the leakage in gallons per minute per mile of pipe and leakage per customers is summed and then multiplied by the average pressure of the system. This is the largest influence on UARL and it is usually a guess – the middle of the hydraulic grade line. This causes the UARL to be substantially understated in large utilities and municipalities, sometimes by as much as 50%.

When UARL is significantly understated, the ILI by definition is significantly overstated. An overstated ILI could trigger widespread unsuccessful leak detection. In terms of water balance, unsuccessful leak detection could easily lead to the conclusion that Current Annual Real Losses were overstated. An overstatement of CARL would typically mean that apparent losses were understated. While the first place to look would be large meters, at some point, the municipality could conclude that small diameter meters are the culprit and this could be a $200MM price tag associated with overstated ILI due to errors creating the UARL whose largest numbers are entirely based on speculation – pressure and leakage per customer.

So municipalities need to be careful when using measures such as ILI, CARL and UARL as indicators of performance.

CONCLUSIONS:

Municipalities nationwide are making pipeline replacement decisions based on a general lack of specific data. It results in the replacement of too much pipe with low probability of failure. They are making financial decisions related to non-revenue water based on a general lacking of specific data. It results in chasing revenues that don’t exist and wasting energy resources that our country desperately needs. Water utilities want for a solution which would cost effectively and without risk provide specificity with regard to pipeline conditions in terms of both the probability of failure and real water loss.

Recent data is confirming that age is NOT a key indicator of which pipelines need to be replaced.

However, the aging of water mains, coupled with the continuous stress placed on these systems by operational and environmental conditions, has led to their deterioration. This deterioration can be classified into two categories: (1) structural deterioration, which diminishes the structural resiliency of the pipes and their ability to withstand various types of stress, and (2) deterioration of pipe inner surfaces, resulting in diminished hydraulic capacity, degradation of water quality and even diminishing structural resiliency in cases of severe internal corrosion. This deterioration manifests itself in the following ways:

- Increased rate of pipe breakage due to deterioration in pipe structural integrity. This, in turn, causes increased operation and maintenance (O&M) costs, increased loss of (treated) water and social costs such as property damage, loss of service, disruption of traffic, disruption of business and industrial processes, disruption of residential life, public safety hazard, and loss of landscape vegetation. In addition, pipe breakage events increase the risk of water quality failure through intrusion of contaminants into the system.

- Decreased hydraulic capacity of pipes in the systems, which results in increased energy consumption and disrupts the quality of service to the public. This includes drinking water as well as fire extinguishing needs.

- Deterioration of water quality in the distribution system due to the condition of inner surfaces of pipes, which may result in taste, odor, and aesthetic problems in the supply water and even public health problems in extreme cases.

The structural deterioration of water mains and their subsequent failure are complex processes, which are affected by many factors, both static (e.g., pipe material, size, soil type) and dynamic (e.g., age, climate, cathodic protection, pressure zone changes). The physical mechanisms that lead to pipe breakage are often very complex and not completely understood. The facts that most pipes are buried, and that relatively little data are available about their breakage modes also contribute to this incomplete knowledge.

It appears that while physical modeling of the structural deterioration of water mains may be scientifically more robust, it is, to date, limited by existing knowledge and available data. Some of the data that are required for the physical models can be obtained albeit at significant costs. These costs may currently be justified only for major transmission water mains, where the consequences of failure are significant. In contrast, statistically-derived empirical models can be applied with various levels of input data and may therefore be useful for small diameter water mains for which low cost of failure does not justify expensive data acquisition campaigns. The statistical analysis of breakage patterns of water mains has thus been a cost effective way to model this deterioration, particularly when available data are scarce. However, this effectiveness is higher at high-level planning (i.e., regional or network level) and diminishes to a certain degree when applied to individual water mains. Information on the current structural condition of the individual water main, combined with good understanding of failure modes and deterioration models, will greatly enhance the ability of water utilities to manage these assets in a cost-effective manner.

Advantages of Working with OCWA:

The bottom line is that you need more information to prioritize your linear assets, and you need to use the most appropriate tools to obtain that information.

OCWA can work with your municipality to help you prioritize your pipelines. OCWA can work with your municipality to offer the most up-to-date tools and condition assessment options. We have working relationships with major condition assessment companies such as, PURe, PICA, Echologics, Genivar, Utility Services, Syrinix, etc. and would work with you to select the most appropriate technology for the process.

OCWA also offers leak detection services and partners with other leak detection companies. An OCWA representative would happy to discuss our range of service offerings with you. Please visit http://www.ocwa.com/en/contact to find a sales representative in your community (or click here for a detailed territory map).

Cliff Jones joined OCWA as Vice President Sales, Marketing and Engineering Services in August 2012 with a wealth of experience in the water industry, including his role as Vice President of Sales, Marketing and Pipeline Services for Wachs Water Services, a leader in the assessment of pipelines and underground assets in North America. He is Chair of the Pipeline Committee for the National Association of Sewer Service Companies, is Education Chair for the Centre for Advancement of Trenchless Technologies, and is the International Chair for the American Society of Civil Engineers' Pipelines 2012 Committee. He has also published many papers and articles focused on condition assessment of pipelines, water distribution efficiency and asset management.