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A Call for Water Utility Reliability Standards: Regulating Water Utilities' Infrastructure Programs to Achieve a Balance of Safety, Risk, and Cost

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Executive Summary

The catastrophic gas pipeline failure that occurred in California on September 9, 2010 tragically reminds us that a public utility's most important function is the safe operation, maintenance, repair, and management of its infrastructure. Like every other human endeavor, however, it is impossible to reduce the risk of failure to zero.

Numerous national studies estimate that water utilities will need to invest tens, or even hundreds, of billions of dollars in water infrastructure during the next 20 years. But no national study can identify the specific assets that need to be repaired or replaced at any particular utility, the appropriate time period for undertaking that work, how the work should be prioritized, or the risks that will be faced if the work is not performed.

The process of studying infrastructure and developing plans for its maintenance, repair, and replacement is generally known as *asset management*, which has been defined as "a combination of management, financial, economic, engineering, and other practices applied to physical assets with the objective of maximizing the value derived from an asset stock over the whole life cycle, within the context of delivering appropriate levels of service to customers, communities, and the environment at an acceptable level of risk."

Neither the water utility industry nor the commissions that regulate those utilities, however, has developed definitions or standards of the "appropriate levels of service to customers" or the "acceptable level of risk" of pipeline failure. Such standards are urgently needed. This paper calls upon regulatory commissions to establish reliability standards for water utilities before we spend billions of dollars to replace aging infrastructure.

These standards are critically important because pipeline assets of the same age and type fail at different rates. In fact, some newer generations of water pipes actually fail sooner than pipes of an earlier vintage. Spending money to reduce the average age of water mains or to reduce the number of main breaks—without quantifying the types of mains that are breaking and the number of customers they serve—can result in the waste of scarce capital resources and the failure to improve service to customers.

The potential savings from this type of effort can be substantial. One study estimated that changing the reliability target by less than 12 percent could defer a multi-million-dollar construction program by as much as ten years.

Too much money already has been spent on infrastructure "improvement" in the water industry without a demonstration that customer service has improved. Utility commissions should apply their knowledge of reliability standards from the electric distribution industry (standards such as SAIDI and SAIFI) to the water utility industry so that we can ensure that infrastructure management and investments are improving customer service.

Table of Contents

Introduction

The catastrophic gas pipeline failure that occurred in California on September 9, 2010 tragically reminds us that a public utility's most important function is the safe operation, maintenance, repair, and management of its infrastructure. Like every other human endeavor, however, it is impossible to reduce the risk of failure to zero. And even approaching that utopian zero-risk state would result in utility service being so expensive that only a privileged few could afford it. The provision of water service is essential for the safe development and habitation of our cities and towns—turning the service into a luxury is neither feasible nor desirable. But neither is it acceptable to allow our infrastructure to deteriorate or to spend money on that infrastructure without understanding the benefits likely to be obtained.

Utility regulators must require water utilities to answer a critically important question: How do we achieve the optimal level of infrastructure performance? The answer is not simple and cannot be determined with a single study or equation. Rather, the answer lies in a *process*: an optimization process that includes understanding the causes of water infrastructure failure, determining an acceptable level of failure risk, evaluating the cost of reducing that risk, and implementing a continuous-improvement process (or feedback loop) to continually re-evaluate and improve the process.

I. The Water Infrastructure Challenge: Asset Management

A. The challenge: managing multi-billion-dollar infrastructure networks

Numerous national studies have defined the infrastructure challenge in broad terms.[1] Those studies estimate that water utilities will need to invest tens, or even hundreds, of billions of dollars in water infrastructure during the next 20 years. But no national study can identify the specific assets that need to be repaired or replaced at any particular utility, the appropriate time period for undertaking that work, how the work should be prioritized, or the risks that will be faced if the work is not performed.

There is no question that water infrastructure assets, particularly the buried assets (pipes and valves), are aging. The United States' oldest water systems were built during the 1800s. But age alone is not sufficient to identify assets that pose an imminent risk of failure. Age, pipe material, and population growth are important factors in determining a utility's overall asset profile. Every depreciation study ever conducted documents that all assets of the same age and material do not fail at the same time. One study of water infrastructure summarized the phenomenon as follows:

> As in any population, age is not the only determinant of the length of a life. All the pipes that are "born" in a given year will not "die" in the same year in the future. For example, pipes placed in corrosive soils or in locations where they are subject to adverse stresses have a decreased life expectancy. The number of years of service for a group of pipes installed in the same year will take the form of a statistical distribution, such as a bell-shaped curve. Within this distribution, the average life of most pipes makes up the middle of the distribution and the extremes—represented by the "tails" of the distribution curve—are either shorter or longer than the average.[2]

B. Asset management: a multifaceted problem with no single solution

The process of studying infrastructure and developing plans for its maintenance, repair, and replacement is generally known as *asset management*. Marlow and Burn provide the following comprehensive definition of asset management:

> Asset management is a combination of management, financial, economic, engineering, and other practices applied to physical assets with the objective of maximizing the value derived from an asset stock over the whole life cycle,

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[1] See Gregory M. Baird, "How to Eat an Elephant: The Infrastructure Investment Gap," *Journal AWWA* 102:6:26-33 (June 2010), for a summary of the various studies.

[2] John E. Cromwell III, *et al.*, "The Infrastructure 'Crisis'?," *Journal AWWA,* 99:4:109-115 (Apr. 2007).

> within the context of delivering appropriate levels of service to customers, communities, and the environment at an acceptable level of risk.[3]

Not only do assets of the same age and type fail at different rates, but some newer generations of water pipes actually fail sooner than pipes of an earlier vintage. For example, the American Water Works Association (AWWA) notes that, "In the United States, many of the oldest cast-iron pipes installed in the late 19th century still are serving us well. Owing to uncertainties in the engineering science of the day, many of these pipes were over-designed by a factor of five."[4] Similarly, a metallurgical study of different generations of cast iron water pipe found significant differences in the physical properties and expected life of what would seem to the layperson to be the same material.[5] Differences in manufacturing methods appear to account for at least some of the differences in the pipes' useful lives and physical properties.

In addition to manufacturing processes, installation practices, soil conditions, earth disturbance, and numerous other factors can affect a pipe's useful life. The seminal risk-management manual for pipeline systems identifies dozens of factors that can affect the integrity and life of the components in a water (or natural gas) distribution network, including pipe material and coating, pipe diameter, soil corrosivity (including factors such as moisture content, acidity, and the presence of chemicals such as chlorides and sulfates), joint type, pressure, tree locations, traffic, nearby excavation, level of activity above ground, cathodic protection, type of joint, land movements, maintenance and inspection practices, and construction methods.[6] Over the past 30 years, numerous studies have confirmed that the age of a pipeline segment is not sufficient to estimate its useful life or determine when it should be replaced.[7]

C. Utilities should get started: Perfect data are not necessary

Just because age is not a valid predictor of a pipeline's useful life does not mean that utilities should do nothing to identify and manage their risks until they have built the perfect pipe database. Quite the contrary is true, as Cromwell and Speranza explain:

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[3] David R. Marlow and Stewart Burn, "Effective Use of Condition Assessment within Asset Management," *Journal AWWA,* 100:1:54-63 (Jan. 2008).

[4] AWWA, *Water Infrastructure at a Turning Point: The Road to Sustainable Asset Management* (2006), p. 6.

[5] J.M. Makar and S.E. McDonald, "Mechanical Behavior of Spun-Cast Gray Iron Pipe," *Journal of Materials in Civil Engineering*, 19:10:826-833 (Oct. 2007).

[6] W. Kent Muhlbauer, *Pipeline Risk Management Manual: Ideas, Techniques, and Resources* (3rd ed. 2004), Chap. 11.

[7] See, e.g., K. O'Day, "Organizing and Analyzing Leak and Break Data for Making Main Replacement Decisions," *Opflow*, 74:11:589-594; Robert M. Clark, et al., "Condition Assessment Modeling for Distribution Systems Using Shared Frailty Analysis," *Journal AWWA,* 102:7:81-91 (July 2010).

> Many utilities have hesitated to implement asset management because they view their data systems as inadequate to the task. It is neither necessary nor desirable, however, to try to perfect a database in order to begin asset management. It is advisable to start with what exists and improve moving forward.… Until asset management begins, [asset failure] risks aren't being managed. Moreover, the risk management character of the asset management process will tell what details are important to understand and help prioritize information systems improvements accordingly.[8]

Those authors also suggest that an asset management process should begin in phases, "starting with the highest-priority asset classes and extending the practice as work progresses."[9]

Davis and Marlow echo that concern and suggest that water utilities should focus first on their largest pipelines. While the management of smaller pipelines is important, those authors note that individual small water mains "can still be allowed to fail because of the relatively low consequences incurred per pipe break, relative to the cost of preventing such breaks across a network. In contrast, because of the higher consequences associated with failure of large-diameter mains, most water authorities would prefer to prevent and/or avoid such failures whenever possible."[10]

In sum, water utilities need to have asset management programs to evaluate and manage the maintenance, repair, and replacement of their buried infrastructure. But that leaves an important question: How should regulators evaluate an asset management program and determine whether a utility's maintenance, repair, and replacement expenditures were prudently incurred?

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[8] John E. Cromwell III and Elisa Speranza, "Asset Management Too Complicated? Just Think About Your Car," *Journal AWWA*, 99:1:46-51 (Jan. 2007).

[9] *Id.*

[10] Paul Davis and David Marlow, "Asset Management: Quantifying Economic Lifetime of Large-Diameter Pipelines," *Journal AWWA*, 100:7:110-119 (July 2008).

II. The Regulatory Challenge: Setting Reliability Goals that Quantify the Risk of Failure and the Value of Reliability

One of the most important inputs into asset management decisions is a matter of public policy that regulators are uniquely qualified to address: What is the appropriate goal of the water system? As we stated at the outset, an appropriate goal for a human endeavor cannot be perfect performance. Such a level of performance is neither achievable nor cost-effective. So how much imperfection is tolerable in a public water supply system, and how do we measure it?

Rogers and Grigg note that a 2002 AWWA study found that during the previous few years a sample of water utilities averaged 36 main breaks per year for each 100 km (61 miles) of pipeline.[11] More recently, the author of the AWWA study, John Cromwell, reports that his work during the past decade shows that most water utilities experience between 0.1 and 0.3 breaks per mile, with smaller mains (ten inches or smaller) breaking five to ten times more frequently than larger mains.[12] While these data provide strong evidence that the reliability level in the water industry is not 100% available, it does little to help water regulators develop an appropriate reliability target for water utilities.

A study by Dandy and Engelhardt properly characterizes the asset management problem as being a trade-off between economics and reliability.[13] They define these two objectives (that is, perfect performance) as follows:

- Economic objective: "minimize the present value of the system cost."
- Reliability objective: maximize "the ability [of the utility] … to meet the demands [of customers] at all locations at acceptable pressures" at all times.

Obviously, neither of these objectives is fully achievable in reality, but the goal is to approach an optimal solution: achieving an acceptable level of reliability at the lowest reasonable present value of system cost.

Dandy and Engelhardt suggest that the reliability goal should be based on the number of annual customer interruptions, which they call the "total expected number of customer interruptions" (TENCI). Some utilities will have actual data on the number of customers for each pipe segment (a section of water main between valves), while others will not have such specific data. In the absence of actual data, the authors made simplifying assumptions based on land-use data, such as that a rural road would have three customers per pipe segment while a main supplying a residential area would have 50 customers per segment.

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[11] *Id.*

[12] John E. Cromwell, III, personal communication, October 2010.

[13] G.C. Dandy and M.O. Engelhardt, "Multi-Objective Trade-Offs Between Cost and Reliability in the Replacement of Water Mains," *Journal of Water Resources Planning and Management*, 132:2:79-88 (Mar. 2006).

Determining the reliability goal should be the province of utility regulators. It is hard to imagine a decision that is more closely related to the public interest than deciding the level of safety and reliability a utility must provide.

This concept should sound familiar to utility regulators. The idea of determining an acceptable level of reliability based on customer interruptions is well-recognized in the electric industry. Utility commissions commonly set electric reliability standards based on CAIFI (customer average interruption frequency index) and CAIDI (customer average interruption duration index), or on similar system-wide measures (SAIFI and SAIDI). These indexes measure the likelihood that a customer suffered an outage during a given year (or whatever time period is being measured) and the average length of each customer's outage.

Water utilities' asset management plans should incorporate similar reliability standards—and those standards should be established by regulators.

In addition, given the public-health implications of a water outage, utilities and regulators should consider reliability standards that vary for different types of customers. For example, an industrial plant with access to a private well as a backup water supply for its manufacturing process might require a lower level of reliability from the water utility than a typical residential customer. On the other hand, a hospital or nursing home that must have water to maintain sanitation might require a higher level of reliability than a typical residential customer.

While regulators are used to dealing with critical care facilities' needs (for example, in determining priorities for restoring electricity outages), there is an important difference when water is involved. Most critical facilities have backup energy supplies, such as diesel-powered emergency generators. But backup water supplies are rarely if ever available. And without access to clean water for sanitation and consumption, hospitals, nursing homes, and schools must shut down. Thus, in regulating water system reliability, critical facilities are not limited to large-diameter pipelines that serve thousands of customers. Critical facilities also can be smaller facilities that serve critical community needs that do not have alternate sources of water.

In summary, utility regulators cannot evaluate the reliability of a water utility by looking at the average age of pipelines or the raw number of main breaks. A more robust analysis is required to determine the number (and type) of customers experiencing outages, the duration of those outages, and the potential economic and public health costs to the community of those outages. A main break in a 6-inch line on a rural road with three homes does not have the same impact as a main break on a 16-inch line that might serve a hospital, a school, and hundreds of homes.

As described in the next section, regulators need to work with utilities, consumers, local government officials, and others to develop water utility reliability standards. Those standards then should be used as the target output of utilities' asset management programs, and would become the way in which the asset management program is evaluated and recalibrated.

III. A Call to Action: Infrastructure Planning Based on Reliability Standards

A water utility's asset management plan is an optimization process that attempts to meet the competing objectives of cost minimization and reliability maximization. The goal cannot be to develop a perfect plan or to achieve 100 percent reliability for every customer. Rather, the goal is to achieve an appropriate level of reliability, given regulatory requirements and the needs of the community, in a cost-effective manner. That cost-effective manner recognizes that certain large-capacity, high-value assets are critical and require a great deal more "care and feeding" (and earlier replacement) than do lower-capacity, lower-value assets. An asset management plan also recognizes reality: Outages (both planned and unplanned) will occur; water mains will fail unexpectedly. And the plan is dynamic—it must change in response to new data, cost increases, and the changing needs of the utility's service area.

For example, between 2004 and 2005, the average cost for 12-inch ductile iron pipe suitable for a water system increased by more than 14 percent, or about four times faster than the rate of inflation.[14] Such a dramatic change in materials prices is likely to alter a utility's economic evaluation of the relative merits of repairing versus replacing a water main. Similarly, on the other side of the equation (reliability), if a new housing development is built where there used to be a farm, the reliability risk associated with every water main that serves that location must be changed.

The key concept is to establish a process by which to collect and analyze data, develop and implement plans, and then dynamically modify those plans as more data are received and analyzed. Pipes may behave differently than we expect as they age. Earth movement in an area (as a result of construction or natural causes) might affect the life of a pipeline. New construction will change the reliability value of each pipeline segment. Materials costs and labor costs will change. The world is dynamic, and a utility's asset management plan must be flexible enough to model major changes taking place in the communities it serves.

Reliability targets also need to be revisited as the needs of the community change. For example, as a community ages and more people retire, their reliance on water to the home might become more critical than it was when most people were away at work during the day. An aging population also might face mobility challenges that could limit their ability to leave the home to eat, bathe, or wash laundry.

A 2008 order of the Connecticut Department of Public Utility Control (DPUC) illustrates how utility regulators can require water utilities to approach the asset management challenge.[15] In that order, the DPUC stated that before allowing a utility to recover costs through an

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[14] "Construction Economics," *ENR: Engineering News-Record*, 254:18:23-24 (May 9, 2005).

[15] *DPUC Review and Investigation of the Requirements for Implementation of a Water Infrastructure and Conservation Adjustment*, Docket No. 07-09-09, 264 PUR4th 441 (April 30, 2008).

infrastructure surcharge "it will require that prudent engineering and objectively determined system needs be considered that will benefit reliability of service to customers at reasonable rates and insure that companies do not become overly aggressive in prematurely investing in main renewal or other projects of questionable benefit." The DPUC then stated that the purpose of an infrastructure surcharge, known as WICA, "is to rehabilitate or replace aging underground infrastructure, in particular decaying pipe and valves. The WICA program is not intended to be a substitute for ongoing maintenance of system infrastructure."

The DPUC then listed more than 20 factors that utilities should use to prioritize their infrastructure investment (see appendix), including measures of both cost and reliability. That order represents an important step forward for regulators of the water industry, but it does not go far enough. What that order does not do is quantify an actual reliability standard.

Connecticut is not alone in this regard. Our search of nationwide databases of utility commission decisions and regulations has located no state utility commissions that have water reliability goals, standards, or reporting requirements. Some regulatory commissions or environmental regulators may have a reliability goal for water supply sources, but no such goals were located for an entire water distribution utility.[16]

[16] See, e.g., *Application of Valencia Water Company*, Decision No. 01-11-048, 2001 Cal. PUC LEXIS 1017 (Nov. 29, 2001) ("Valencia's water reliability goal, … as part of its effort to balance the provision of reliable service with economical operations, is to meet water demands (unadjusted for conservation) 95% of the time, or in 19 out of 20 years. In the remaining 5% of the time, the maximum contemplated supply shortage is 10%—the presumed level of conservation.").

Conclusion

In conclusion, before the United States commits to spending tens or hundreds of billions of dollars on water infrastructure, it is essential that we have a way to set priorities, measure progress, and revisit plans as new information is received. An essential part of that process is establishing performance goals for water distribution systems. As is common with electric utilities, those goals should be based on the reliability of service received by customers, as measured by outage frequency and duration.

Utility commissions need to lead the way for the water industry by using their substantial expertise in evaluating the reliability of electricity distribution networks. Utility commissions have the unique combination of legal authority, expertise, and impartiality that is needed to develop water utility reliability standards.

The potential savings from this type of effort can be significant. One study estimated that changing the reliability target for a water system by less than 12 percent (from 1,700 customers interrupted per year to 1,900 interruptions per year) could defer a multi-million-dollar construction program by as much as ten years.[17]

Too much money already has been spent on infrastructure "improvement" in the water industry without a demonstration that customer service has improved. Utility commissions should apply their knowledge of reliability standards from the electric distribution industry (standards such as SAIDI and SAIFI) to the water utility industry so that we can ensure that infrastructure management and investments are improving customer service.

[17] G.C. Dandy and M.O. Engelhardt, "Multi-Objective Trade-Offs Between Cost and Reliability in the Replacement of Water Mains," *Journal of Water Resources Planning and Management*, 132:2:79-88 (Mar. 2006).

Appendix

Asset Management Data Required by Connecticut DPUC

1. Main Breaks

a. Main break history
   - Break frequency
   - Break repair cost

b. Outage impact history
   - Duration of outage
   - Customer impact, including number and type of customers, need for extraordinary flushing, disinfection, complaints, etc.

2. Pipe Age / Useful Life

a. Approaching or exceeding expected useful life
b. Range of expected useful life
c. Material, e.g., cast iron, cement, steel, ductile iron
d. Location or conditions of installation
e. Installation date / age
f. Pressure or other factors known to affect useful life

3. Material Integrity

a. Undesirable materials
b. Known internal or external corrosion
c. Batch, vintage, or manufacturer with known problems
d. Unaccounted for water losses
e. Leaks identified by survey activity

4. Critical System Impact

a. Transmission or other large-diameter main

b. Potential failure impact on customers
   - Total number and type of customer(s) affected
   - Priority customers (schools, health / day care, senior center, hospital, significant commercial or industrial users)
   - Nature and magnitude of impact of failure (low pressure, no water)

c. Valve operation/location issues

5. Water Quality Issues

a. Customer complaints related to water quality (dirty / rusty water)
b. More frequent flushing needs
c. Mains utilizing bleeders for quality control
d. Pipe material contributing to water quality problems

6. Hydraulic Capacity

a. Does not meet hydraulic needs of the system
b. Customer complaints or operational issues related to flow and/or pressure
c. Hydrants on mains less than desired diameter
d. Fire flow adequacy

7. Scheduled Work Coordination

a. State or town or other government agency project
b. Required government agency relocations
c. Potential for restoration/paving savings due to third-party work

8. Other (To be Specified by the Applicant)

a. Unique customer or community considerations
b. Other mitigating or unanticipated factors or conditions

Source: *DPUC Review and Investigation of the Requirements for Implementation of a Water Infrastructure and Conservation Adjustment*, Docket No. 07-09-09, 264 PUR4th 441 (Conn. DPUC April 30, 2008).