Water Loss Control

THE CHALLENGE

A crucial aspect of infrastructure management for drinking water utilities is the efficiency of distribution systems, which means fully capturing sales and reducing non-revenue water. Non-revenue water includes real losses (leaks), apparent losses (unauthorized use, metering inaccuracies, or systematic data handling errors), and unbilled authorized consumption. Water utilities are increasingly implementing water loss control efforts to enhance water supply reliability, increase revenue generation, and accurately account for water usage. Whether a utility is in the initial stages of a water loss control program or has been working on these efforts for many years, there are WRF resources that will help the utility define and meet its goals.

THE RESEARCH

Since the 1980s, WRF has undertaken nearly 30 research projects on various aspects of water loss control. The 1987 project, *Water and Revenue Losses: Unaccounted-For Water* (90531) was an early effort to address the lack of standardized definitions and approaches to water audits and water loss control. Since then, great strides have been made in water loss control worldwide. Early advancements in water loss control were realized by many water utilities in the United Kingdom that were pursuing proactive leakage management strategies. One of WRF's first water loss control projects investigated whether these UK strategies could be successfully applied in North America. Published in 2007, *Leakage Management Technologies* (2928) gave North American utilities guidance on conducting water audits, using district metered areas, implementing pressure management strategies, and more.

Over the last 15 years, WRF's research in this area has been conducted in coordination with the American Water Works Association (AWWA) Water Loss Control Committee, helping to further advance the field. AWWA's *Manual 36, Water Audits and Loss Control Programs* provides a comprehensive overview of everything a utility needs to know to improve their water loss program. Now in its fourth edition, the manual lays out standardized definitions, water audit methodology, and an overview of loss control techniques.

Regulatory Context

For many utilities, regulations are the primary driver to engage in water loss control, and in many states the regulations continue to evolve. In the United States, 30 states and territories had some form of water loss control regulation as of March 2019, ranging from rudimentary water loss reporting to system-specific, volume-based performance benchmarking. California and Georgia have the most stringent regulations, requiring annual water loss reporting with AWWA standard terminology, annual use of the AWWA Free Water Audit Software, validation of water loss audit data, and volume-based performance benchmarking.

Water Audits

An initial and proactive step for improving distribution system efficiency is conducting a water audit—a thorough

FIGURE 1. CALCULATING A "TOP-DOWN" WATER AUDIT

System Input Volume (Corrected for Known Errors)									
Authorized Consumption				Water Losses					
Billed Authorized Consumption		Unbilled Authorized Consumption		Apparent Losses			Real Losses		
Billed Metered Consumption (including exported water)	Billed Unmetered Consumption	Unbilled Metered Consumption	Unbilled Unmetered Consumption	Unauthorized Consumption	Customer Metering Inaccuracies	Systematic Data Handling Errors	Leakage on Transmission and Distribution Mains	Leakage and Overflows at Utility's Storage Tanks	Leakage on Service Connections Up to Point of Customer Metering
Revenue Water		Non-Revenue Water							

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examination of a water utility's data, records, accounts, and procedures regarding the volumes of water that are moved from system input through the distribution system to the customer (i.e., a "top-down" water audit, Figure 1). Water audits are essential for assessing the efficiency of a water utility's resources and operational and financial impacts.

In 2015, WRF released *Water Audits in the United States: A Review of Water Losses and Data Validity* (4372b), one of the first analyses of a large batch of water audits. The research team analyzed more than 4,500 water audits, and found that 21% of the water audits did not pass basic checks of plausibility, underscoring the importance of education, training, and data validation for improving the quality of a water audit.

Published in 2016, WRF's first edition of the *Level 1 Water Audit Validation Guidance Manual* (4639a) provides North American water utilities and regulatory entities with a standardized methodology for validating water audit data when using AWWA Free Water Audit Software version 5. The second edition was published in 2021 (5057) for use with AWWA Software version 6. Water audit validation is the process of examining water audit inputs to improve the audit's accuracy and document the uncertainty associated with water audit data. Level 1 water audit validation confirms that AWWA's water audit methodology was correctly applied to a utility's specific situation, identifies inaccuracies in summary water audit data, and verifies that data validity grades accurately reflect utility practices. While some uncertainty may persist in the water audit, the water audit is more reliable for having been Level 1 validated.

Apparent Losses

One of the first recommendations after completing a water audit is to double-check meter data. Apparent water losses are caused by revenue meter under-registration, water theft, and billing errors. It is not so much that water is being "lost," but rather that utilities are losing potential revenue. One way to cut down on apparent losses is to ensure that water meters are sized appropriately and collecting accurate measurements. WRF has a range of research to help in this area.

For over 100 years, AWWA has published standards for water meters, which detail minimum requirements for design, installation, performance, and manufacturing. *Accuracy of In-Service Water Meters at Low and High Flow Rates* (4028), published in 2011, tested meters for accuracy and endurance. Meter types evaluated included fluidic oscillator, nutating disc, piston, multi-jet, and single-jet. The results illustrated that a larger-than-expected number of new meters do not meet the AWWA flow registry standard applicable to that meter type. Some meter types passed the AWWA registry standard tests more consistently than other meter types. Test results illustrate that some meter types were capable of accurately measuring flow at flow rates well below and well above the AWWA standard flow rates and that other meter types were not capable of measuring these same flows.

WRF research has also addressed oversized water meters, a common problem for utilities across North America, especially considering increased water conservation and more efficient plumbing fixtures. When meters are oversized, they cannot accurately capture low flows. The recent release of *Assessing Water Demand Patterns to Improve Sizing of Water Meters and Service Lines* (4689) improved understanding of correct meter sizing and performance to help prevent inaccurate meter registration at low flow regimes and underreporting of delivered water. More accurately sized meters will ultimately help increase recurring utility revenue.

As a growing number of water utilities implement advanced metering infrastructure (AMI) to capture detailed information from customer meters, WRF research also helps realize the full potential of this data. With this new information, utilities can better respond to customer billing questions, enforce policies for water usage, and better quantify and ultimately reduce the level of non-revenue water in their distribution systems. Released in 2020, *AMI Meter Data Analytics* (4741) improved understanding of the benefits of correct meter sizing and meter performance. The research identified strategies for AMI data analyses and used case studies to demonstrate the value of using AMI data. The research resulted in a meter performance index, which allows utilities with AMI data to define their meter maintenance and replacement strategies based on actual meter performance.

Real Losses

The quest to control non-revenue water in North America frequently focuses on identifying and efficiently minimizing water distribution leakage (real losses). WRF has published a range of projects to help utilities identify leaks. *Continuous System Leak Monitoring: From Start to Repair* (3183), a 2011 publication, found that continuous acoustic monitoring (CAM) systems could detect about 65% of leaks earlier (prior to leaks surfacing), thereby reducing real losses. Leaks that were not detected by the CAM system were likely not "heard" because of the inability of leak noise to travel through certain pipe materials (i.e., Acoustic noise sensors can more easily detect leak sounds from metal/ferrous pipes than plastic pipes).

To prevent real losses, water utilities must also manage pressure within the distribution system. Persistent pressure fluctuations may contribute to long-term weakening of distribution system piping. A 2010 report, *Criteria for Optimized Distribution Systems* (4109), sought to identify the key optimization criteria for distribution system performance. Pressure management was found to be a critical barrier in maintaining distribution system integrity, since it directly influences so many other operational parameters.

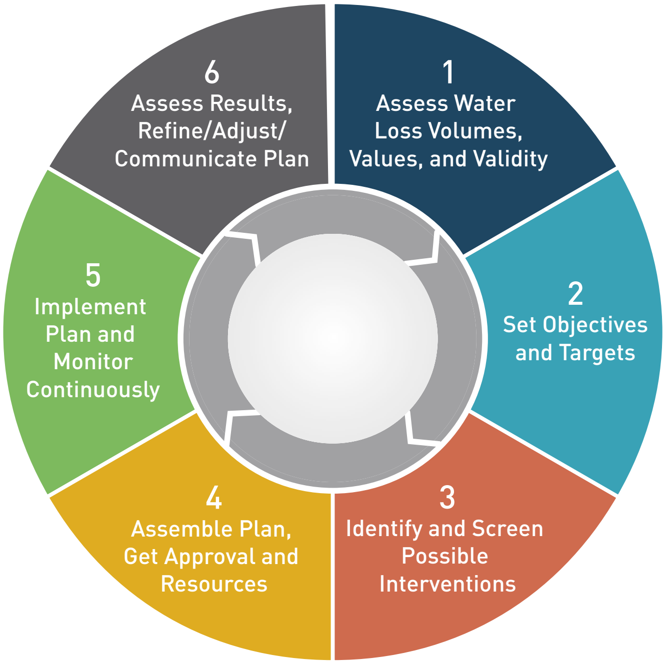
Susceptibility of Distribution Systems to Negative Pressure Transients (3008), released in 2006, recommended surge

SOLUTIONS IN THE FIELD: CALIFORNIA WATER AUDIT VALIDATOR TRAINING

After facing its worst drought on record, in 2017, the State of California began requiring urban retail water suppliers to submit validated distribution system water audits each year—a first step in understanding and preventing water loss. To help utility personnel prepare for and comply with this development, the California-Nevada Section of AWWA sponsored a training series, conducted by Water Systems Optimization Inc. and Cavanaugh & Associates. The Water Audit Validator course is a two-day program designed to qualify individuals to perform Level 1 water audit validations in California. Water audit validators examine water loss audit inputs to consider the water audit's accuracy and document sources of uncertainty.

The training materials for this course drew heavily on WRF's *Level 1 Water Audit Validation Guidance Manual* (4639a). The use of this research in the training materials furthered the project goals—getting clear guidance and standard methods for water audit validation into the hands of water utilities and regulatory entities. It is likely that WRF's *Level 1 Water Audit Validation Guidance Manual, Second Edition* (5057), published in 2021, will be utilized for future training efforts.

FIGURE 2. WATER LOSS CONTROL PROGRAM PLANNING



Source: WRF Project #4695

models, a type of computer modeling approach that allows operators to identify locations in the distribution system that might be susceptible to low or negative pressure surges. These models can then be monitored to verify the surge model. Once these vulnerable areas of the distribution system are identified, various mitigation strategies can be pursued: slowing the rate of flow control operations, increasing pump inertia, prolonging valve opening and closing times, and more.

Pressure Management: Industry Practices and Monitoring Procedures (4321), published in 2014, developed best practices for continuous pressure improvement programs. Proactive pressure monitoring is recommended and collecting pressure readings only every hour was found to be inadequate—accelerated monitoring, known as "impulse recordings," are recommended, where sensors automatically record data when significant changes in pressure occur. For best results, utilities must consider pressure management optimization along with other distribution system performance indicators: leakage, breaks, and energy usage.

Another approach to calculating real losses is to perform a real loss component analysis or leak component analysis, which requires detailed annual leak and repair data as well as the top-down water audit. *The Real Loss Component Analysis: A Tool for Economic Water Loss Control* (4372a) developed the Real Loss or Leakage Component Analysis Model, a utility-tested, user-friendly tool to help utilities better understand the sources of their real losses (reported, unreported, or background) and analyze their economic intervention strategies. The need to provide clear guidance on failure data collection and documenting was addressed by the research team through the development of a Leak Repair Data Collection Guide, an open-source MS Office Excel spreadsheet.

Water Loss Control Plans

More recently, WRF research has also focused on strategically integrating water loss control activities and plans with broader institutional goals, objectives, and spending programs. Published in 2019, *Guidance on Implementing an Effective Water Loss Control Plan* (4695) provides advice on how to analyze more than three years of water audits to set performance targets, offering material that complements AWWA M36. This project created a guidance manual and decision framework to help North American water utilities develop actionable, cost-effective, and defensible water loss reduction and control plans.

WHAT'S NEXT

AWWA's 2017 *State of the Water Industry* cited deteriorating infrastructure as the top concern among utilities, and pressure has been implicated in pipe failure in several studies. In many case studies, pressure reductions apparently correlated with reduced pipe breaks. Lowering pressure, consistent with water quality protection, may provide significant reductions in pipe breaks, leakage, and energy costs—and certain smart water technologies are applicable for measuring and managing pressure with the direct result of reduced stress on pipes and water loss. Ongoing WRF research is already exploring this issue. *Utilizing Smart Water Networks to Manage Pressure and Flow for Reduction of Water Loss and Pipe Breaks* (4917) will use network solutions to help water utilities better manage pressure and flows in their water distribution networks to extend the life of pipes and reduce water loss.