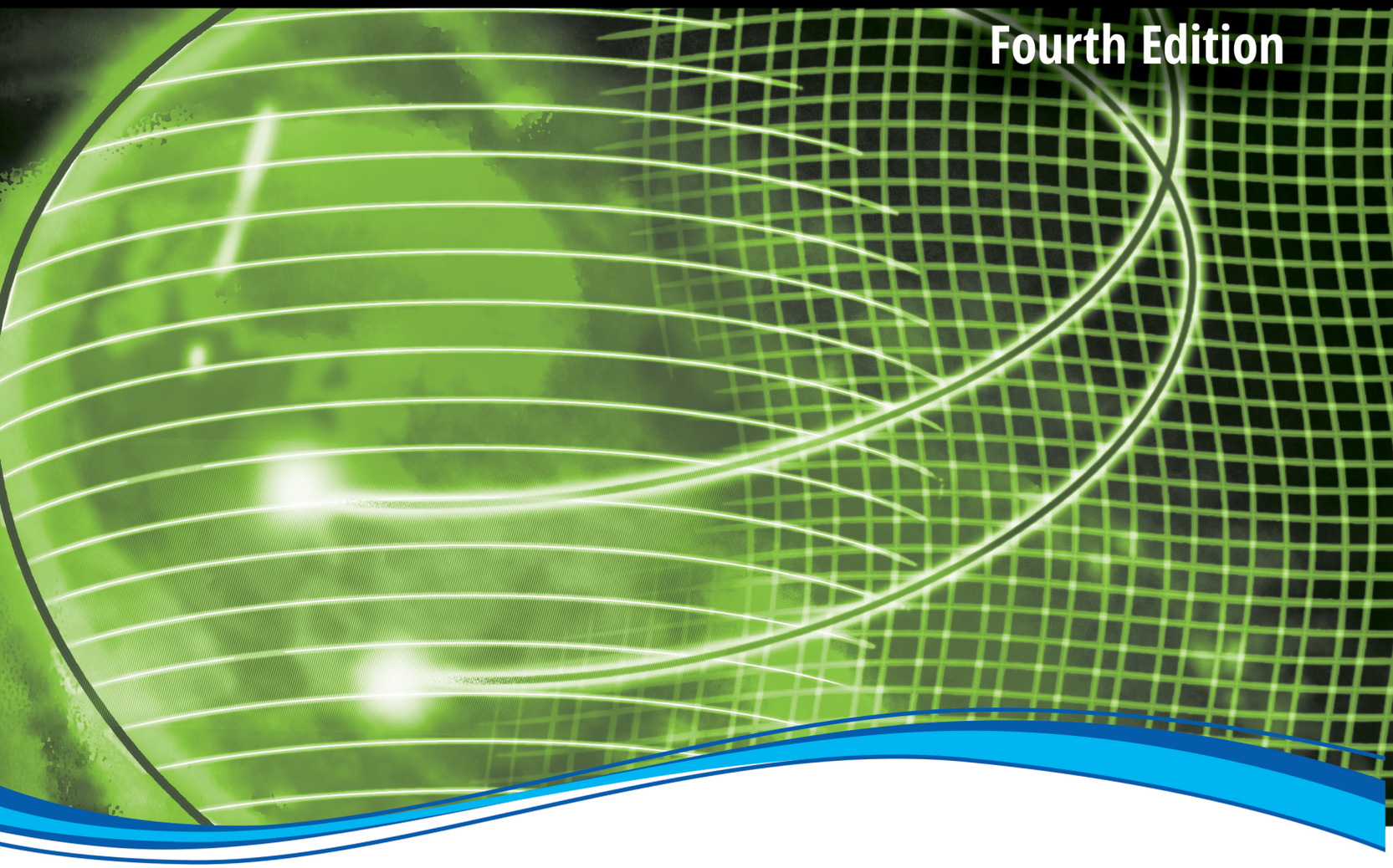
Manual of Water Supply Practices

M36

Water Audits and Loss Control Programs

Fourth Edition



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Water Audits and Loss Control Programs

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Managing Editor: Melissa Valentine
Production: Glacier Publishing Services

If you find errors in this manual, please email books@awwa.org. Possible errata will be posted at www.awwa.org/resources-tools/resource.development.groups/manuals-program.aspx.

Library of Congress Cataloging-in-Publication Data

Names: Kunkel, George A., Jr., author. | American Water Works Association.
Title: Water audits and loss control programs / by George A. Kunkel, Jr.
Other titles: M36, Water audits and loss control programs
Description: Fourth edition. | Denver : American Water Works Association, 2016. | Series: AWWA manual ; M36 | Based on: Water audits and loss control programs. 3rd ed. c2009.
Identifiers: LCCN 2015037692 | ISBN 9781625761002
Subjects: LCSH: Water consumption--Measurement. | Water--Waste--Measurement. | Water leakage--Prevention. | Loss control.
Classification: LCC TD499 .W38 2016 | DDC 628.1/440287--dc23
LC record available at http://lccn.loc.gov/2015037692

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ISBN-13 978-1-62576-100-2
eISBN-13 978-1-61300-339-8

Printed in the United States of America
American Water Works Association
6666 West Quincy Avenue
Denver, CO 80235-3098
awwa.org

Printed on recycled paper

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Preface

Accountable Water Management—Progressive Thinking and Solutions

North American water utilities have been highly successful in providing safe, reliable water supplies that have been a foundation for growth and prosperity. Benefiting from abundant natural resources, suppliers have succeeded in establishing high expectations for quality water service. In the closing years of the 20th century, however, changes not seen before on the continent were witnessed. Some of the fastest growing cities in the United States are located in sunbelt areas with limited water resources and a reliance on water supplies that have been developed and conveyed from distant water sources.

Multiyear periods of drought have begun to plague many areas of the United States. Water restrictions and shortages have become routine in many areas as a result of these circumstances, sometimes coupled with poor infrastructure reliability of individual water systems. For many water systems in the older parts of North America, aging infrastructure is exerting a toll as failures and high leakage rates increase and compromise system efficiency, frequently disrupting the reliable provision of services. Enhanced water quality and environmental protections along with funding constraints make development of new water resources more difficult, costlier, and less attractive than in prior eras.

In North America, a growing focus on *water conservation* has evolved to address these challenges. Conservation efforts have been successful in stemming customer water demand via the use of water efficiency measures such as low-flow plumbing fixtures, conservation water rates, and public education. It is essential that these successful efforts continue because all water users have a responsibility to use water wisely. In the broader context of water supply management, water suppliers also have a responsibility to manage valuable water resources wisely. This tenet—*the accountable and efficient management of water supplies by utilities*—is the central focus of the water audit methodology and water loss control programs described in this manual.

While successfully delivering quality water supplies for up to two centuries, the North American water industry has often done so with uncertain accountability controls and high losses of both treated drinking water, mostly from leakage, and revenue caused by inaccurate metering, errant billing, and unauthorized consumption. Because the seemingly endless water resources of yesteryear are no longer available in many regions, water suppliers must manage water resources with a greater sense of stewardship and efficiency than in the past.

The first edition of this manual was published in 1990 and detailed the water audit method advocated by the California Department of Water Resources and adopted by the California-Nevada Section of the American Water Works Association (AWWA). The second edition was published in 1999 and provided relatively minor updates to the first edition. The third edition (2009) included a major advancement in water audit methodology, giving water utilities greater guidance in improving accountability and economically controlling water and revenue losses. This fourth edition significantly enhances all the chapters and outlines new details on production meter testing, real (leakage) loss reduction, descriptions of several free software tools, and examples of regulatory approaches.

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Historically, standard methods to audit water supplies and control losses were lacking throughout most of the world. In 2001, a survey of U.S. state and regional water oversight agencies revealed that inconsistent definitions for water loss existed with few reliable water auditing or loss control measures in place. Regulatory requirements were sparse on this issue in the United States. However, available data along with many case study and anecdotal accounts suggested that the occurrence of high-loss water supplies is widespread.

Improvement in this state of affairs emerged in the 1990s. The United Kingdom's National Leakage Initiative brought forth valuable research findings that were applied in new policies and practices leading to significant leakage reductions. From 1997 to 2000, AWWA participated on the Water Loss Task Force organized by the International Water Association (IWA). The Water Loss Task Force (now the Water Loss Specialist Group) drew on the best practices included in the various water audit methods in use worldwide, including the United States, to assemble a *best management practice* methodology that features a set of rational terms and definitions, and an array of robust performance indicators that allows an objective gauging of loss levels. In 2003, AWWA's Water Loss Control Committee published the report "Applying Worldwide Best Management Practices in Water Loss Control" in *Journal AWWA*. In this report, AWWA advocates the use of the IWA/AWWA method and performance indicators.

This manual explains the IWA/AWWA water audit methodology in a user-friendly manner and provides an overview of some of the best loss control techniques that can currently be implemented for a sustainable water loss control program. Chapter 1 provides a brief introduction while chapter 2 discusses the regulatory approaches within North America. Chapter 3 gives detailed instruction on the water audit process and highlights use of the AWWA Free Water Audit Software. Chapters 4 and 5 describe the impacts and the methods to control apparent losses, respectively. This includes ways to recoup missing revenues by controlling these nonphysical losses. Chapters 6 and 7 discuss the impacts of real (physical) losses, which are largely leakage, and the methods to control these losses, including proactive leakage detection and pressure management. Chapter 8 gives guidance on the organizational steps a water utility can take to manage and sustain the water loss control program, while Chapter 9 offers valuable insights for small systems in managing their losses.

A glossary of terms and definitions is also provided. Appendices include a new section on production meter testing and data management, blank forms, water resources considerations, a detailed description of the AWWA Free Water Audit Software, and analysis of water audit data from several hundred North American water utilities. For water utilities just getting started, the AWWA Free Water Audit Software can be downloaded directly from the AWWA Web site and used to obtain a preliminary quantity of losses and their costs. This can be followed up by field measurements and investigations to gradually enhance and validate the water audit, and these steps are clearly described throughout this manual. Examples are included within the manual for the fictitious County Water Company, illustrating the means to compile the water audit and initiate control of both apparent and real losses.

Water utilities now have effective tools and methods to promote accountability and efficiency in their supply operations. Water utility managers will be called on to assess their inefficiencies and take corrective action, and the methods contained in this manual will help them do it reliably.

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Acknowledgments

The AWWA Technical & Educational Council, the Distribution & Plant Operations Division, and the Water Loss Control Committee gratefully acknowledge the contributions made by those volunteers who drafted, edited, and provided the significant and critical commentary essential to updating M36. The Technical Review Board members dedicated many hours in the final stages of preparation for this fourth edition to ensure the overall technical quality, consistency, and accuracy of the manual.

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Chapter 1

Introduction: Auditing Water Supply Operations and Controlling Losses

Community water supply systems around the world have been instrumental in improving the human condition by providing essential water to promote public health and safety and to serve as a basis for economic development. For hundreds of years, societies have constructed infrastructure to withdraw water from available sources, to treat it to an acceptable standard, and to distribute it to communities, typically through buried piping distribution systems. Yet, for all their success in quenching human needs, many water utilities operate with considerable inefficiencies in terms of water and revenue losses. As the world grapples with the dilemma of a growing population but a finite amount of water, these inefficiencies need to be brought under a reasonable level of control. This manual offers water utilities a set of tools and approaches to instill accountability and control losses, including

- step-by-step procedures to conduct a water audit to assess the efficiency of the water distribution system and water accounting practices;
- definitions and implications of apparent (nonphysical) losses and real (physical) losses;
- specific techniques to identify, measure, and verify all water sources, consumption, and losses;
- example data inputs and sample calculations for each step of the water audit;
- references to freely available software tools to compile the water audit and plan leakage management activities;
- a road map to control apparent losses in metering and billing operations and to recover missed revenues;

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- steps to implement a leakage and pressure management program to control real losses and preserve source water resources;
- planning steps to assemble the proper resources, information, and equipment to launch and sustain the accountability and loss control program;
- approaches for short-term and long-term goal setting for the loss control program;
- considerations for small water systems; and
- discussions and listings of actual water audit data and descriptions of successful water loss control being applied by North American water utilities.

Many water utilities suffer a variety of losses. Most operators recognize distribution system leakage, categorized under the heading *Real Losses*, as a primary type of loss. However, water suppliers also suffer losses from poor accounting, customer metering inaccuracies, and unauthorized consumption. These losses are collectively labeled *Apparent Losses* and have a negative impact on utility revenue and consumption data accuracy. While it is essential that system operators employ means to control such losses, the initial step is to assemble a water audit to identify the nature and volumes of losses existing in a water utility, and the water resources and financial impacts that these losses exert.

THE WATER AUDIT AND WATER BALANCE

Good management of any resource requires that the supplier maintain accurate records of transactions and deliveries of the commodity provided to its customers. The *audit* is a common function in the world of finance and accounting, and it typically denotes activities that systematically review an organization's financial records and accounts to confirm their accuracy. Similarly, the *water audit* involves a review of records and data that traces the flow of water from its source and treatment, through the water distribution system, and into customer properties. The water audit usually exists in the form of a worksheet or spreadsheet that details the variety of supply, consumption, and loss components that exist in a community water system. The *water balance* summarizes these components and provides accountability, as all of the water placed into a distribution system should, in theory, equal all of the water taken out of the distribution system.

In 2000, the International Water Association (IWA) published the manual *Performance Indicators for Water Supply Services* (Alegre et al. 2000). This publication includes a description of a water audit method developed during the period of 1997–2000 by the IWA Water Loss Task Force (now called the Water Loss Specialist Group), which at the time was a five-country group that included participation by the American Water Works Association (AWWA).* Until then, a multitude of different water auditing practices had existed around the world, and the primary focus of the task force was to draw on the best practices of the various approaches and craft them into a single, standard best management practice methodology. The method needed to be applicable worldwide, across the spectrum of differing system characteristics and units of measure. Many of the features of the resulting best practice methodology were drawn from the original AWWA Manual M36, *Water Audits and Leak Detection*, published in 1990 and revised in 1999. Shortly after the task force published its new methodology, the AWWA Water Loss Control Committee (WLCC) voiced support for the method in its committee report "Applying Worldwide Best Management Practices in Water Loss Control" published in the August 2003 edition of *Journal AWWA* (Kunkel et al. 2003). In support of this approach, the WLCC comprehensively revised and expanded Manual M36 in creating the third edition (2009). This edition carefully detailed

* The IWA Water Loss Task Force has grown considerably and was elevated to become the IWA Water Loss Specialist Group in 2011.

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the best practice water audit method and provided significant guidance on innovative loss control technologies and approaches for planning the loss control program.

This fourth edition of Manual M36 continues to promote the standard, best practice water audit method created by IWA and AWWA, and the method is explained in detail in chapter 3. The WLCC recommends this method as the current best management practice structure for water utilities to compile a water audit of their operations. In addition to reliably tracking water consumption and losses using this method, water utilities also have a variety of effective means to economically control apparent and real losses. Great innovation in loss control approaches and technologies has occurred since the early 1990s. Many of these techniques are explained in chapters 5 and 7. The final chapters of this manual provide guidance on planning and sustaining the loss control program and considerations for small systems.

This fourth edition improves on the third edition manual in several ways. First, the AWWA Free Water Audit Software (2014), which was briefly mentioned in the third edition, is now fully integrated into the guidance and examples of this edition and is the tool of choice recommended by the WLCC for water utilities to conduct the annual water audit. The WLCC created and issued the Audit Software in 2006 and has since issued several upgraded versions. Version 5.0 was issued in 2014.

Second, an entirely new section (appendix A) has been included to detail the methods to ensure valid, accurate water production data and to identify best practices to accurately quantify the *Volume of Water Supplied* to the water distribution system. Production water volumes, which are the supply volumes at the water source or supply leaving water treatment plants, represent the largest and most important quantities in the water audit, and the fourth edition provides highly detailed guidance in ensuring reliability in these quantities. A third major addition to the manual is a comprehensive description on the use of a free software tool known as the Leakage Component Analysis Model (LCA Model). This model became available to the water industry in 2014 as part of a research project administered by the Water Research Foundation and sponsored by the US Environmental Protection Agency (WRF 2014). The LCA Model offers a clear and concise method to analyze data on leak and water main break events occurring in a water utility, and uses the data to define the parameters of an economic leakage and pressure management program tailored for the needs of the individual water utility. The LCA Model offers a user-friendly instrument to automatically execute the calculations that were merely listed in the third edition.

Finally, the fourth edition includes numerous examples and data of validated water audits from hundreds of North American water utilities. The use of the AWWA water audit has increased dramatically since the release of the third edition of Manual M36 in 2009; and the fourth edition provides a representative glimpse into the validated data that is fast being compiled by the North American water industry. The fourth edition offers updated and improved content that supersedes the third edition, and readers will find this new edition to be invaluable in their efforts to establish sound accountability and efficiency in their water supply operations.

THE IMPORTANCE OF WATER AUDITS AND LOSS CONTROL

Strong water loss control produces benefits in four primary ways:

1. Through water resources management, by limiting unnecessary or wasteful source water withdrawals
2. Financially, by optimizing revenue recovery and promoting equity among ratepayers

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3. Operationally, by minimizing distribution system disruptions, optimizing supply efficiency, and generating reliable performance data
4. Through system integrity, by reducing the potential for contamination in the water distribution system

Water suppliers have obligations in all of these areas: they must act as stewards of the valuable water resources they manage; they must be fiscally responsible to their customers, shareholders, and bondholders; and they must maintain safe, reliable operations that provide quality water service to their communities. Properly executed water auditing and loss control programs help water utilities meet their obligations in all of these areas, to the benefit of their customers and their own bottom line. The specific benefits of water auditing and loss control include the following:

- *Reduced apparent losses*. Reducing apparent losses creates a financial improvement by recovering lost revenues from customers who have been undercharged or have gained water in an unauthorized manner.
- *Reduced real losses*. Reducing real losses saves water purchase and operating costs including power, maintenance, and treatment costs. Because leakage volumes are a considerable portion of system input for many water utilities, expansion of water supply infrastructure might be deferred if successful leakage control is achieved. Likewise, better use of existing resources may ease drought restrictions or allow economic development to occur without exploiting new water resources. Reducing leakage volumes results in a corresponding reduction in the operation of equipment, thereby extending the interval between scheduled maintenance.
- *Improved data integrity*. Sound water auditing improves the accuracy and integrity of water system input volumes and customer consumption. Knowing true water consumption patterns promotes better water resources management, confirms water conservation benefits, and aids long-term planning.
- *Better use of available water resources*. Controlling losses helps stretch existing supplies to meet increasing needs, thus avoiding the exploitation of new water sources. Environmental impacts are limited given that no more water is withdrawn from sources than is absolutely needed.
- *Increased knowledge of the distribution system*. During the water auditing process, distribution personnel become familiar with the distribution system, including the location of mains and valves, pressure levels, and demand variations. This familiarity helps the utility to respond quickly to emergencies, such as water main breaks, and provides a basis for optimization of supply operations.
- *Increased knowledge of the customer metering and billing systems*. The water auditing process provides the auditor the opportunity to review the workings of the customer billing system. For many water utilities, inadvertent procedural or programming gaps exist in billing operations, allowing certain customers to receive water without paying for it.
- *Safeguarding of public health and property*. Improved maintenance of the water distribution system helps reduce the likelihood of property damage and safeguards public health.
- *Improved public relations*. Consumers appreciate maintenance of the water distribution system. Field teams performing loss control activities provide visual assurance that the distribution system is being maintained. Consumers also appreciate value for their money. They expect high-quality service at a reasonable price.

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Efficient delivery of high-quality water, along with affordable, equitable water rates, creates a strong reputation for the water utility in the minds of its customers.

- *Reduced liability*. By protecting public property and health and providing detailed information about the distribution system, water audits and loss control programs help protect the utility from expensive lawsuits.
- *Reduced disruption to customers*. More leaks are repaired on a proactive basis rather than developing into large leaks or main breaks that disrupt service and cause damage and customer ill will.
- *Improved asset management*. By effectively managing leakage and optimizing pressure in the water distribution system, water main and service connection leakage can be reduced and pipeline asset life can be extended.
- *Favorable reviews from the financial community*. Effective operations and accountability instill credibility for the water utility in the eyes of the financial community, helping the utility to secure funding to sustain sound upkeep of the operation well into the future.

In summary, water and revenue losses are wasteful to the water utility, its customers, the environment, and society at large, while good accountability and loss control offer many benefits. It is likely that many, if not most, North American water utilities can strongly benefit from improvements in their level of accountability and loss control practices. In this way, this manual serves as a valuable guide for water utilities.

GETTING STARTED

Just as a proactive water utility carefully tracks its finances, effective utilities should also track the water supply that they manage. Historically, the motivation for a water utility to compile the annual water audit was strictly voluntary. However, since 2000, several American states have enacted requirements for annual water audits, and the number of water utilities routinely compiling water audits is growing. For most water utilities, getting started is the largest hurdle. Perhaps in prior generations, utility personnel did not know where to turn for guidance on how to get started in the water audit process. However, today's water utilities have available to them the detailed guidance provided in this manual: the AWWA Free Water Audit Software (2014), the LCA Model, and information on AWWA's Web site (www.awwa.org). Hence, utility personnel can readily obtain and employ the tools and guidance to quickly identify and quantify their losses and the impacts. In as little as several hours, readily available data can be accessed and input into the standard water audit format, revealing preliminary loss control standing and cost impacts. *The most important step is to just get started, and the guidance and tools provided in this manual give utilities everything they need to do this!*

THE FUTURE OF WATER SUPPLY EFFICIENCY

In 2001, AWWA commissioned an extensive survey of state and regional water resource and environmental agencies in the United States to uncover the extent and usefulness of their water accountability statutes and regulations. The project, titled *Survey of State Agency Water Loss Reporting Practices* or the "States Survey Project," was successful in garnering valuable information from 46 jurisdictions, including 43 state agencies and 3 regional agencies (Beecher 2002). The results of the survey found that widely varying language existed throughout many regulations and statutes of these agencies. Many organizations defined water losses as some form of *unaccounted-for* water but left the components

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Table 1-1 Guidance for the use of proper terminology in the standardized water audit methodology

Non-Preferred Term	Preferred Term	Reason
Unaccounted-for water (UFW)	Non-revenue water (NRW)	All water entering a distribution system can be defined as a component of either authorized consumption or water loss.
Percentage of system input volume to measure water loss performance	Suite of key indicators for water loss as outlined in AWWA audit method in chapter 3 (e.g., gal/service connection/d)	A percentage-based expression obscures the underlying causes of water loss and impedes realistic solutions based on system specifics.

included in this parameter subject to interpretation *and manipulation*. As an example of the latter, some utilities included volumes from known leaks in "accounted-for" water categories, thus underestimating actual leakage volumes, which are a loss. In attempting to gather voluntary data from large water utilities, one state agency found that water utilities that earnestly attempted to audit their supplies reported figures that appeared less flattering than counterparts who reported unrealistically low losses, with no substantiation of their data (McNamee 2002). This type of gamesmanship reflects poorly on the US water industry, which has proven itself up to any challenge, including that of reliable water auditing and loss control. The final report of the States Survey Project was astute in its recommendation that "a better system of accounting is necessary if accountability is to be instilled in water utilities" (Beecher 2002).

The WLCC supports the methods offered in this manual as the "better system of accounting" called for in the States Survey Project report. Since 2003, AWWA has recommended against the use of the imprecise term *unaccounted-for water* because it does not exist in the best practice water audit method, and its use creates more confusion than guidance to water utilities. Instead, the precisely defined term *non-revenue water* should be employed, as given in this guidance. The use of non-preferred and preferred terminology is given in Table 1-1.

The WLCC holds that the methods in this manual are workable, meaningful, and offer the greatest potential to bring about improved accountability and water efficiency in water utilities. The methods can enhance service for water customers, improve the bottom line for water utilities, and better manage water resources for the common good. It is recommended that these methods become the model approach for quantitative management of water resources in North America for water utilities, professional organizations, regulatory agencies, and all stakeholders who support safe and reliable water.

Across North America, several state, provincial, and regional agencies have enacted water auditing requirements applying the methodology first advocated by the AWWA WLCC in 2003. Although the movement toward routine, standardized water auditing is still in the early stages, validated data for hundreds of water utilities have been compiled, allowing water managers, regulators, and policy analysts to gain the first truly representative assessment of the quantitative management of water supplies in North America. This will allow for strategic targeting of loss control efforts by individual water utilities and coherent policy and statutory decisions by water resource managers and regulators. The number of states and provinces enacting new water auditing requirements will undoubtedly grow in coming years, and water utilities must be prepared to assess their water supply management in a more comprehensive manner.

Water accountability and loss control is garnering increasing prominence in water resources management, particularly as limitations in available water resources are

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occurring in many parts of the world. New water sources will continue to become more difficult and costly to develop, water quality regulations and customer expectations will increase the value of water, and growing populations and economies will need adequate water supplies on a continuous basis. All of these drivers will combine to create an increased focus on water accountability, efficiency, and conservation. By employing the methods included in this manual, water utilities will have the tools to meet these growing challenges.

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Chapter 2

Implementation of Water Loss Control Regulatory Approaches in North America

Considerable advancement has occurred in water auditing and loss control methodology and policy since the early 1990s. Water auditing methodology and innovative technologies for water and revenue loss control are explained in great detail in this manual, starting in chapter 3. Since the advent of the best practice methods described herein, many water utilities throughout North America have launched or refined efforts to audit their water supplies and manage losses in a more proactive manner. At the same time, drinking water and water resource agencies have also taken note of the benefits of these approaches.

This chapter discusses the evolution of policy and regulatory developments in water loss control, most of which have occurred since the year 2000. Readers will find the descriptions included in this chapter useful in discerning how the efforts of individual water utilities can collectively promote the long-term stability of a region's water resources when programmatic requirements are put in place via a sound, consensus-based process.

AWWA's Water Loss Control Committee (WLCC) has been very active in both developing tools and methods for effective water loss control and in conducting outreach to educate and promote the use of these methods. The prominent initiatives of the WLCC are described in this chapter. Early in the development of these approaches, AWWA conducted the project that led to the publication of the States Survey Project report on regulatory policies and guidance for water loss control in 2002. The report detailed the findings of an extensive survey of United States state and regional water agencies and found that requirements for water auditing and loss control varied widely and were of mixed degrees of effectiveness. The survey report concluded that "a better system of accounting is needed if accountability is to be established in water utilities" (Beecher 2002).

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The WLCC followed the States Survey Project with its 2003 committee report *Applying Worldwide Best Management Practices in Water Loss Control*" (Kunkel et al. 2003), which included recommendations for water utilities to adopt new best management practices for water loss control. Since the publication of these reports, there has been increased recognition of the need for and value of implementing improved practices for effective water loss control. Drinking water utilities gain the benefits of reduced operating costs and increased revenues that can be applied to better sustain water system assets. Valuable water resources are better preserved, while allowing economic growth to continue. Water utility customers benefit from quality water supplies that are reliably provided at affordable rates. Drinking water regulatory agencies are better able to oversee responsible water resources management and incentivize programs where utilities can leverage funding of projects that ensure their sustainability. Bond rating agencies can more favorably rate utility debt issuance, thus lowering the cost of borrowing for capital programs and offsetting upward pressure on water rates. Furthermore, as a result of increased public discourse on the benefits of water use efficiency and sustainability, drinking water regulatory agencies are finding that a consensus-based stakeholder involvement process for policy development is effective and more likely to be readily accepted across the spectrum of stakeholders.

Table 2-1 is a listing of North American regulatory or water resources agencies that (as of 2014) have adopted (or are close to adopting) water auditing and loss control requirements that feature the AWWA Water Audit Methodology as the foundation for accountability. This table lists 10 state agencies, one regional river basin commission, and one Canadian province that have requirements for the routine submittal of water audit data by water utilities in the form of the AWWA Water Audit Methodology. These requirements exist with varying degrees of compliance enforcement measures. Several regulatory agencies have implemented programs on a multiyear, phased approach with the largest water utilities required to comply first. Varying performance thresholds are employed as "triggers" for followup activities in some agencies. These activities can include assistance with leak detection surveys of the water distribution system or robust meter accuracy testing and replacement programs. In some cases, notices of violation can be issued, fines can be imposed, extensions of existing—or granting of new—water supply permits can be withheld, or permitted allocations can be reduced if the performance thresholds are not met. However, in general, the regulatory approaches have keyed largely on data collection and identifying water utilities that appear to have the greatest need for improved water loss management.

This chapter presents what are believed to be the essential elements of water auditing and loss control programs that should be carefully considered by regulatory or water resource agencies when undertaking rulemaking processes or setting regulatory guidance. This discussion also provides examples of recently developed federal, state/provincial, and regional regulatory programs that encourage drinking water utilities to implement best practices for water loss control.

ESSENTIAL ELEMENTS OF THE RULEMAKING PROCESS AND REGULATORY GUIDANCE

Most water utilities can benefit by adopting the practices and tools contained in this manual. It is also recognized that flexibility to employ other approaches can advance the body of knowledge in the drinking water industry. *The AWWA WLCC recommends that water utilities should routinely compile water audit data on an annual basis as a standard business practice. This serves as the fundamental activity to promote efficient management of water in the drinking water sector.* Thus, collection of standardized, validated water audit data should be the starting basis for water utilities voluntarily launching a water loss control program, and

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Table 2-1 Water loss requirements of regulatory agencies in North America (2014)

These are state/provincial and regional regulatory agencies with a water loss control program and requirements based on the AWWA Water Audit Methodology*

State/ Province	Agency	Water Audit Data Submission Requirement	Water Audit Methodology in Use	Water Audit Data Collection Format	Performance Target Requirement
California	California Urban Water Conservation Council (CUWCC)	Incentivized (SB 1240 makes this mandatory in 2016)	AWWA	AWWA Free Water Audit Software	Leakage control; by year 5 of program, show improvement or obtain top 20% level, or below benchmark leakage level.
	Department of Water Resources	Mandatory	AWWA	AWWA Free Water Audit Software	Urban water systems required to quantify and report water loss and description of water loss management program measures. No performance targets for urban water systems that are not a signatory utility to CUWCC Memorandum of Understanding.
Delaware, New York, Pennsylvania, New Jersey	Delaware River Basin Commission	Mandatory	AWWA	AWWA Free Water Audit Software	15% Non-revenue water (NRW) used as a benchmark of performance; additional reporting may be required by systems in excess of this value.
Georgia	Department of Natural Resources–Environmental Protection Division, Georgia Environmental Finance Authority	Mandatory	AWWA	AWWA Free Water Audit Software	No performance target, but Georgia offers training and employs a mandatory water audit data validation process funded via State Revolving Funds.
Illinois	Illinois Department of Natural Resources	Mandatory	AWWA		Previously 8% "unaccounted-for water"; however, the State adopted a comprehensive program change to the AWWA Water Audit Methodology with an NRW standard of 12%, declining to 10% in Water Year 2019.
New Mexico	Office of the State Engineer	Incentivized	AWWA	AWWA Free Water Audit Software	Detailed water audits and case studies were assembled for several water utilities.

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Table 2-1 Water loss requirements of regulatory agencies in North America (2014) (continued)

State/ Province	Agency	Water Audit Data Submission Requirement	Water Audit Methodology In Use	Water Audit Data Collection Format	Performance Target Requirement
Pennsylvania	Public Utility Commission	Mandatory	AWWA	AWWA Free Water Audit Software	None.
Tennessee	Office of the Comptroller	Mandatory	AWWA	AWWA Free Water Audit Software	Threshold levels set for graduated Data Validity Score (65–80), and NRW by cost 30%, to 20% by 2020. Water utilities exceeding these thresholds are offered assistance.
Texas	Texas Water Development Board (TWDB)	Mandatory	AWWA	TWDB format	An Infrastructure Leakage Index of 3 for large systems. Real losses of 50 gal/ connection/d or 1,600 gal/mi/d for small systems (density dependent), 5.5% apparent loss for all systems.
Washington	Department of Health (DOH)	Mandatory	AWWA modified	DOH format	10% Leakage, three-year average
Wisconsin	Public Service Commission & Department of Natural Resources	Mandatory	AWWA modified	Wisconsin format	25% Water loss for small utilities, 15% water loss for large utilities. Currently investigating use of the AWWA Free Water Audit Software with training and validation.
Quebec	Ministry of Municipal Affairs, Regions & Territorial Occupation	Incentivized	AWWA modified	Quebec format	20% Water loss, <15 m^3/ km/d of water mains (6,400 gal/mi/d)

*This is not necessarily a complete listing. Other state and regional agencies may have developed, or intend to develop, water loss control requirements substantially based on the AWWA Water Audit Methodology.

for regulatory agencies to assess water loss management performance. Regulatory agencies may also consider requirements for loss control activities; however, these activities cannot be reliably planned, or tracked, if a sound water auditing structure with valid water audit data is not first in use.

A majority of the agencies listed in Table 2-1 have adopted the AWWA Water Audit Methodology virtually in its entirety as a basis for regulatory requirements. In some cases, the water loss control requirements are imposed as part of a broader water use efficiency context that includes more conventional water conservation programs that are intended to aid in managing water resources in areas experiencing water shortages. In other cases, requirements are intended to specifically address operational concerns or issues of financial viability. Either approach can be effective when the affected water utilities are afforded the opportunity to provide input to the rulemaking process.

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The following elements are considered to be important for engaging drinking water utilities in the process of setting objectives of a water loss control regulatory program.

- Stakeholder participation process:
  - The agency proposing rules for water auditing and loss control practices should engage as wide a group of potential stakeholders as possible to participate in the rulemaking process.
  - Stakeholders should be given sufficient time to review proposed language and provide comments and feedback to the agency proposing the rules.
- Statement of desired objectives, policies, and approaches for achieving the objectives:
  - The process should clearly state the applicable water loss policies and definitions, desired objectives, and rationale for use of the practices and tools detailed in this manual, along with the means by which results will be measured. This should include a clear description of the water audit methodology and format to be employed.
  - The outdated and imprecise term *unaccounted-for water* should be replaced with the specifically defined term *non-revenue water*. This is an important modification that promotes meaningful expression of water accountability and water loss management performance.
  - The water utilities to be included under the regulatory program should be clearly identified.
  - This manual describes numerous approaches to the effective control of apparent and real losses. Not all of these approaches are applicable and useful to all water systems, since varying conditions exist among the large number of water utilities in operation today. Thus, rulemaking should take into account specific regional or local conditions that exist for water utilities and determine whether specific approaches detailed in this manual are, or are not, applicable.
  - Strongly consider the establishment of a structured training program to instruct water utility personnel on the water audit process. Effective training will produce more reliable water audit data and ultimately save utility personnel time in the data collection and review process.
- Appropriate application of the best practice water audit performance indicators and Data Validity Score (DVS) of the AWWA Free Water Audit Software:
  - The AWWA Free Water Audit Software is the standard tool recommended for water utilities to compile the annual water audit. It is described in detail in chapter 3 of this manual. The Audit Software includes the array of standardized output-based performance indicators that serve as performance-based metrics to guide water utilities in tracking their performance and making valid comparisons with peer water utilities.
  - In 2010, the AWWA Free Water Audit Software was updated with a system of process-based metrics to give water utilities a sense of the validity of their water audit data as related to the day-to-day practices that they employ. Utility auditors assign a numeric grading value to each input quantity in the water audit, with low values for more questionable data and higher values for well-validated data. The Audit Software then calculates a composite DVS that reflects the overall validity, or trustworthiness, of the water audit data. The DVS is also an indirect measure of the process integrity of the water utility's

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practices. Several agencies have keyed on the DVS in particular to promote a focus on the use of recommended best practices in water utility operations.

  - Independent review and validation of the water audit data ("auditing the audit") is strongly encouraged to confirm that objective data gradings are assigned and the DVS is representative of water utility performance. Programs that include both training for utility personnel on the water audit process and independent validation of the water audit data have shown the greatest success in producing representative data.
  - The water audit performance indicators should be applied only in the manner for which they are intended. Certain indicators are intended to track the year-to-year performance of the water utility and not to make comparisons with other water utilities. Performance indicators for the normalized measure of real (leakage) losses are different for water systems having a low density of service connections and those with a more typical density of connections. The Infrastructure Leakage Index (ILI) is performance indicator designed for comparisons among water utilities and for benchmarking performance. However, the ILI is best suited for utilities with well-validated water audit data and all justifiable pressure management already implemented. The ILI has not been proven valid for very small water utilities; hence, it cannot be applied in all cases.
  - There are other options for utilities to use when analyzing these performance indicators to assist in understanding the underlying factors contributing to the water audit results. Water audit data can be segregated into groups of similar system attributes or regional characteristics, such as population, number of customer service connections, average operating pressure, annual precipitation, and temperature range. This type of analysis can allow more precise comparisons, but it is not as relevant for regulatory purposes. AWWA's Water Audit Data Initiative (WADI) collects and validates water audit data annually, and, in 2011, this effort included detailed analysis of data from 21 water utilities. This analysis segregated utilities by system size, with those serving a population of less than 50,000 as one group and systems serving more than 50,000 as a separate group (AWWA 2011). This type of analysis provided greater context for interpretation of the performance indicators of the water utilities in the WADI dataset.

- Appropriate caution in target-setting for loss control interventions:
  - The water audit process is the fundamental water efficiency activity that water utilities should conduct on an annual basis to track their use of water resources. At this time, it is likely best for regulatory or water resources agencies to focus primarily within the practice of water auditing for water utilities and thus promote the collection of reliable, comparable utility data.
  - Several agencies have also set rules for loss reduction, keying on real (leakage) losses, financial management, or other aspects of non-revenue water (NRW). Setting water or revenue loss reduction targets, however, is a complicated undertaking that should be derived only from well-validated water audit data from a large pool of water utilities. To date, however, only a limited pool of well-validated data exists. Regulatory agencies should be well aware of several fundamental concepts of water utility operations before proceeding to establish goals and targets for water loss control. The components, volume, and financial impacts of NRW occurring in a water utility are system-specific characteristics. Setting goals and targets to reduce apparent

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and real losses in a water utility is therefore a system-specific endeavor, and it is not generally effective to establish singular output targets for all utilities in a region or state. Managing NRW is akin to the utility rate-setting process: the individual factors and costs of the water utility go into setting a system-specific water rate structure. No one would expect multiple water utilities in a given region to employ the same water rate structure and charge the same rates for water. Thus, loss reduction goals and programs should also be set in a system-specific manner, and it is difficult for regulatory agencies to attempt to set singular loss reduction goals for water utilities.

- Defining compliance/noncompliance provisions of prospective water auditing and loss control rules:
  - Care should be taken when defining remedies for noncompliance with regulatory approaches that are based on the best practices defined in this manual. As previously noted, this publication is a guidance manual and is not written as a regulatory instrument. While a variety of means to audit supplies and control losses are detailed herein, it is not necessary that all water utilities employ all of the loss control interventions. Corrective measures that are based on steps detailed in this manual should be restricted to those that encourage improvement and compliance rather than those that produce financial or other penalties without additional guidance.
- Guidance for compliance with prospective water auditing and loss control rules:
  - The regulatory agency should clearly communicate the schedule for water audit data submittal, and how the information will be compiled and shared. The agency should also identify, as applicable, which types of proposed water utility programs (e.g., water supply and other growth-induced treatment and conveyance projects) are subject to compliance with water audit data submittal requirements.
  - Thresholds for compliance should be based on well-founded rationales that yield actionable information and recognize benefit–cost analysis to evaluate alternative activities for achieving compliance, such as those described in this manual. Such rationales are preferred over arbitrary, less meaningful parameters like universal or percentage-based triggers. The method of calculation for the applicable parameters should be clearly stated.
  - As previously noted, the proposed schedule under which water utilities would begin submitting required information to the regulatory agency should be discussed with the affected utilities, recognizing that smaller systems may need more time to install needed data collection equipment, collect and validate the required data, and assemble the data for submittal.
  - It is important to also identify additional guidance documents that the regulatory agency believes will complement methods detailed in this manual. Agencies should also provide contact information to which water utilities can turn for technical assistance.
- Obtaining financial support for relevant projects:
  - The regulatory agency should clearly communicate the availability of, and requirements to receive, financial support for water auditing or loss control functions or projects undertaken by water utilities. Such efforts might include water auditing training and data validation, leak detection assistance, customer meter testing, and occasionally water pipeline replacement. Agencies should investigate the availability of State Revolving Fund monies as a possible source of such programs' funding for water efficiency purposes.

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RECENT RULEMAKING PROCESSES AND REGULATORY PROGRAM DEVELOPMENT

Several states, one regional water management commission, and one Canadian province have promulgated water loss control–related protocols that align with the approaches included in this manual. Typically, these emerging types of programs require water utilities to submit data in the form of the best practice annual water audit structure. This goes well beyond the traditional gathering of basic monthly or annual water supply and consumption data, and noting the difference between these two volumes. In the sections that follow, the structures employed in these agencies are highlighted, and they reflect the momentum that is growing around the implementation of AWWA's best practice methods.

Additional information on evolving regulatory requirements for water loss control is available in *The Water Efficiency and Conservation State Scorecard*, published by the Alliance for Water Efficiency and the Environmental Law Institute (AWE and ELI 2012). This compendium of state agency responses to a 20-question survey provides an indication of how regulatory agencies are incorporating water loss control policies within the broader context of water use efficiency. *The Scorecard* includes responses to a specific question on policies or regulations for water utilities regarding water loss in the utility distribution system, as well as excerpts from certain state regulations for comprehensive water conservation plans that include water loss control program–related provisions.

The US Environmental Protection Agency (USEPA) sets national drinking water regulations in the United States and has extensive regulatory structures in place for clean streams and rivers and for utility drinking water quality. USEPA has taken an interest in water loss control and issued the guidance manual *Control and Mitigation of Drinking Water Losses in Distribution Systems* (2010a). At least one region of the United States (Region 4–Southeast) has included recognition of the need for utilities to have a water loss control plan when coordinating the review process for the permitting of water supply reservoirs (USEPA 2010b). USEPA continues to monitor the progress for implementation of improved water auditing and loss control methods by US water utilities.

A summary of a representative mix of regulatory approaches that is now in place for water loss control policy follows, in alphabetical order.

State of California

The California Urban Water Conservation Council (CUWCC) is a consortium of more than 200 metropolitan water utilities (signatory utilities) and other stakeholders who are dedicated to the promotion of water efficiency. The CUWCC was created to increase efficient water use statewide through partnerships among urban water agencies, public interest organizations, and private entities. The council's goal is to integrate a series of defined urban water conservation best management practices (BMPs) into the planning and management of California's water resources.

Best practices for water loss control programs in California primarily comprise one of four subcategories of the Water Utility Operations component of the Memorandum of Understanding (MOU; last revised on Sept. 16, 2009) issued by the CUWCC. "Foundational" BMP 1.2–*Water Loss Control* and the related BMP 1.3–*Metering With Commodity Rates and Retrofit of Existing Connections* establish a reporting system for the signatory utilities. Under these BMPs, water utilities should annually compile and submit water audits in accordance with the AWWA Water Audit Methodology, using the AWWA Free Water Audit Software. Additionally, utilities should submit reports detailing their progress in installing meters on all new construction and retrofitting of meters to existing service lines (including outdoor irrigation systems but not fire suppression lines). Water utilities should also conduct billing on a volume basis, conduct regular testing and repair of customer meters, and implement a program of regular customer meter replacement.

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Background and basis for a revised BMP for water accountability and loss control. The CUWCC is not a regulatory agency. The CUWCC provides annual reports to the California State Water Resources Control Board and the governing bodies of the signatory water utilities on the progress of implementation of the several BMPs relating to water efficiency.

Stakeholder involvement. Membership of the CUWCC includes representatives from the signatory water utilities, public advocacy groups, and other interested stakeholders. Only the first two groups are eligible to serve on the board of directors and to vote on matters relating to the MOU (including modifications to the BMPs) and the organization's bylaws. Nonvoting members of the board of directors include representatives of the other interested stakeholders and representatives of certain state and federal agencies involved with the allotment of California water resources.

Applicability and implementation. BMP 1.2 incorporates the water loss management procedures embodied in AWWA Manual M36, and the signatory water utilities are expected to use the AWWA Free Water Audit Software to compile and submit their standard water audit annually.

The signatory water utilities are assigned the first four years of water audit data collection as a period to gradually improve the quality of their water audit data, with the goal of achieving a DVS of at least 66 by year 4 submittal. Utilities are designated to achieve a DVS of 71 or higher (Level IV of the Water Loss Control Planning Guide worksheet included in the Audit Software) by the fifth year of data submittal. Utilities should follow recommendations on the Audit Software's Grading Matrix worksheet to improve their practices and produce more reliable data.

The CUWCC established a progressive program in that it includes both the water audit data submittal process and a requirement to track and manage real (leakage) losses to achievable low levels. The economic value assigned to real losses recovery is based on the signatory water utility's avoided cost of water as calculated by the CUWCC's adopted Avoided Cost Model, or other signatory water utility's model consistent with the CUWCC's Avoided Cost Model.

Signatory water utilities are required to conduct a leakage component analysis at least once every four years. *Leakage component analysis* is defined as a means to analyze real losses and their causes by quantity and type. The goal is to identify volumes of water loss, the cause of the water loss, and the value of the water loss for each component. Knowing these parameters, the utility has the inputs for the Leakage Component Analysis (LCA) Model that provides information needed to support the economic analysis and selection of intervention tools. The LCA Model is explained in detail in chapter 7 of this manual. This model follows the bursts and background estimates (BABE) model (Lambert 1994), which assesses leakage occurring in a water distribution system by its components of background losses, reported leaks, and unreported leaks. The nature, extent, and value of the leakage losses occurring in a water utility are unique to each utility's water distribution system. The leakage component analysis provides information to set a realistic, achievable level of leakage to target. Signatory water utilities are required under BMP 1.2 to reduce real losses to the extent that it is cost-effective.

A phased implementation schedule was established beginning on July 1, 2009, with the first BMP 1.2 report due by Dec. 1, 2010, for the periods of 2008–2009 and 2009–2010 for those signatories as of Dec. 31, 2008. Subsequent signatories are required to begin implementation no later than July 1 of the year following the year that they executed the MOU. While the signatory water utilities have largely met the data submittal goals, results of these efforts are not yet available.

Signatory water utilities are also required to test source, import, and production meters annually, beginning in the second year of implementation.

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Consequences of noncompliance. Because a benchmark performance indicator was to be determined after the first four years of data collection from the signatory water utilities, and voted on by the council by year 6 of the revised MOU implementation schedule, the CUWCC has yet to establish such an indicator and determine the consequences of noncompliance.

The leakage component analysis of real losses is required to be updated every four years. Beginning with the fifth year of implementation and carrying through the tenth year, progress in water loss control performance as measured by the performance indicator "gallons per day per service connection" or "gallons per day per mile of mains," or another appropriate indicator, must be demonstrated through achievement of

- a score lower than the prior year's score, or
- a score less than the 3-year running average, or
- a score in the top quintile (20 percent) of all signatory water utilities reporting such performance with a Data Validity Level IV, or
- in year 6 and beyond, reducing real losses to or below the benchmark determined in the CUWCC's process noted previously.

Signatory water utilities are also required to repair all reported leaks and breaks to the extent they are cost-effective. By the end of the second year of implementation, a record-keeping system for these repairs must be established, including time of report, leak location, type of leaking pipe segment or fitting, and leak running time from report to repair. By the end of the fourth year, the report must include the estimated leakage volume from report to repair and the cost of repair (including pavement restoration costs and paid-out damage claims, if any). Unreported leaks shall also be located and repaired to the extent they are cost-effective. All of the data serve as inputs to the leakage component analysis and allow water utilities to continue to refine and improve their leakage management efforts.

Documentation of the foregoing data must be maintained, including the economic value assigned to the apparent and real losses, miles of mains surveyed for leaks, pressure reduction undertaken for real loss reduction, infrastructure rehabilitation and renewal, volumes of water saved, and costs of intervention(s). Such documentation must be submitted to the CUWCC annually during years 2 through 5 of implementation.

Financial and technical support mechanisms. Training in water auditing and the LCA method was required and offered to the signatory water utilities by AWWA and the CUWCC within the first four-year implementation period. Funding of projects related to improved management of apparent and real water losses has been supported through other state programs, such as the Drinking Water State Revolving Fund, as well as recent federal programs intended to enhance economic recovery.

On Sept. 19, 2014, California amended Section 10631 of the State Water Code to require all urban water systems, including those not signatory to the CUWCC MOU, to quantify and report distribution system water loss using the water system balance methodology developed by AWWA (State of California 2014). Urban water systems are also required to include this information, together with descriptions of water demand management measures (including water loss management), in updates to their urban water management plans beginning with the 2015 plan updates, which are to be submitted by July 1, 2016. There are no water loss performance targets in the amended Section 10631 for water systems that are not a signatory to the CUWCC MOU.

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Delaware River Basin Commission

The Delaware River Basin Commission (DRBC) was formed in 1961 when President Kennedy and the governors of Delaware, New Jersey, Pennsylvania, and New York signed concurrent compact legislation into law. The compact's signing marked the first time since the nation's birth that the federal government and a group of states joined together as equal partners in a river basin planning, development, and regulatory agency to oversee a unified approach to managing a river system without regard to political boundaries. The members of this regional body include the four-basin state governors and the division engineer of the US Army Corps of Engineers North Atlantic Division who serves as the federal representative. Commission programs include water quality protection, water supply allocation, regulatory review (permitting), water conservation initiatives, watershed planning, drought management, flood loss reduction, and recreation.

Background and basis for an amendment to DRBC's Water Code. For several decades, the DRBC has employed a comprehensive water efficiency program, which has formed an integral component of its broader strategy to manage water resources throughout the basin. In 2009, the DRBC amended its Comprehensive Plan and Water Code to implement an updated water audit approach to identify and control water loss in the basin. The new approach requires water utilities to prepare and submit an annual water audit conforming to the AWWA Water Audit Methodology and using the AWWA Free Water Audit Software as the data collection tool. The impetus for the rule change was that DRBC determined that then-current methods to account for, track, and reduce physical water losses from public water supply distribution systems in the Delaware River Basin—estimated to be as much as 150 mgd (million gallons per day)—were inadequate. In recognizing such problems and proactively seeking best management solutions, the DRBC is one of a handful of regulatory agencies in the United States that has changed its regulations to reflect the improved approach to water loss accounting made possible by the AWWA Water Audit Methodology. On Sept. 1, 2008, the DRBC announced its intention to revise provisions of its Water Code relating to efficiency for water utilities who serve the public with sources located within the Delaware River Basin. By Resolution No. 2009-01 on Mar. 11, 2009, the DRBC approved amendments to its Water Code and Comprehensive Plan calling for a phased program of water auditing and reporting in accordance with the audit structure established by AWWA (DRBC 2009).

Stakeholder participation. Potential modifications to the DRBC's policies and regulations on water loss control were considered and drafted by the DRBC's Water Management Advisory Committee (WMAC). WMAC is comprised of 20 members representing a wide range of interests in the water resources of the Delaware River Basin. The committee concluded that the AWWA water audit approach offered multiple benefits over the existing regulations through the use of more precise definitions, rational accounting procedures, and a consistent methodology. Upon publication of the Notice of Proposed Amendments in the participating states' legal publications and in the *Federal Register*, a public hearing was held on Sept. 25, 2008, and written comments were accepted through Oct. 3, 2008. The DRBC made minor clarifying revisions and published a detailed comment and response document simultaneously with adoption of the final rule.

Applicability and implementation. The 2009 DRBC rule change required the AWWA reporting format to be used for the 2012 calendar year water audit and annually thereafter. In the interval between the passing of the resolution and the implementation of the new reporting format, the DRBC promoted voluntary use of the new format and focused its efforts on raising awareness of the new approach and requirements through efforts such as:

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- presentations and outreach to the regulated community;
- a one-day water audit training workshop held by DRBC in partnership with water utilities in the basin; and
- new DRBC Web pages dedicated to water audits, hosting materials from the workshop, and other supporting information.

The water audit requirement applies to all public water suppliers within the Delaware River Basin who have been issued approvals by the DRBC to withdraw and use in excess of an average of 100,000 gpd (gallons per day) of water during any 30-day period. Through an extensive outreach effort, DRBC notified the regulated community, subject to the new water audit requirement, that the first report would cover the period of calendar year 2012 and would be due to DRBC by Mar. 31, 2013, with subsequent reporting required annually thereafter. An important aspect of the new DRBC water audit program was an emphasis on electronic reporting and processing of water audit reports. As previously noted, the AWWA Free Water Audit Software is the specified tool for water audit data collection and submittal. This method provides for a consistent reporting format and enables the AWWA Water Audit Software Compiler Tool (another tool freely available from the AWWA Web site) to be used to rapidly assemble water audit data for analysis.

Prior to adoption of the new regulations, a 15 percent "unaccounted for water" performance standard was utilized by DRBC. Until a sufficient body of data exists to indicate that a more meaningful measure of system performance can be established, DRBC will look at NRW as a key indicator of system performance.

In addition to compiling the annual water audit, water purveyors (utilities) distributing more than 100,000 gpd are required to develop and undertake a systematic program to monitor and control leakage within their system. Such a program shall, at a minimum, include periodic surveys to identify leakage, enumerate NRW, and determine the current status of system infrastructure, recommendations to monitor and control leakage, and a schedule for the implementation of such recommendations.

Consequences of noncompliance. Each program to monitor and control leakage is subject to review by the applicable state agency where the water system is located and must be updated at a frequency not less than every three years. A more frequent submittal may be required if NRW as a percentage by volume of water supplied exceeds 15 percent.

Financial and technical support mechanisms. The DRBC has hosted workshops describing the revised regulations, including outreach to smaller water systems, and collaboration with state and local water industry organizations and training programs. DRBC staff has also led the development of the AWWA Free Water Audit Software and complementary tools. More information about the DRBC's water audit program can be found on the DRBC Web site at www.state.nj.us/drbc/programs/supply/audits/.

State of Georgia

The State of Georgia's program focuses not only on a rational structure for the program, but also dedicates considerable resources to the training and education of the water utilities, and validation of the water audit data submitted by the water utilities. Its ability to leverage State Revolving Funds to assist these purposes is groundbreaking. According to the *Georgia Water System Audits and Water Loss Control Manual*, published by the Georgia Department of Natural Resources, the Georgia Environmental Protection Division (GA EPD), and the Georgia Association of Water Professionals (GAWP), the primary impetus for adopting a comprehensive water loss control regulatory system was the recognition that demonstrating strong stewardship of the state's water resources would be very beneficial for improving water use efficiency in the face of potential shortages in many regions of the state (GA DNR, GA EPD, and GAWP 2014). Water system audits and water loss control

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are considered valuable water management strategies that can improve the efficiency of water production and delivery within all water systems in the state.

Background and basis for Georgia's Water Stewardship Act. The State of Georgia moved proactively to create a stronger water efficiency ethic throughout the state by passing the Water Stewardship Act of 2010 (SB 370). The state's water loss control program is embodied in this legislation and is applicable to water systems serving at least 3,300 persons. These water systems must conduct and submit a standardized annual water system audit (according to the AWWA methodology) to GA EPD and implement a water loss control program. The water audit data undergoes an extensive data validation process, is finalized, and the summary results are posted on the GA EPD Web site.

Stakeholder involvement. Stakeholder input was obtained through a series of public comment periods, with technical support provided by the GAWP. The three entities that created the *Georgia Water System Audits and Water Loss Control Manual* also enlisted the assistance of key stakeholders and a number of nationally recognized experts to participate in the creation and review of this publication, which serves as the primary training tool for water utilities in Georgia.

Applicability and implementation. A phased approach was adopted by GA EPD, which required systems serving more than 10,000 individuals to electronically submit their audit by March 2012 for the period Jan. 1, 2011, to Dec. 31, 2011. Systems serving fewer than 10,000 persons but at least 3,300 persons were required to submit their 2012 calendar year audits by March 2013. Annual reporting for all systems serving at least 3,300 persons continues thereafter.

Consequences of noncompliance. It is intended by GA EPD that water withdrawal permits, water treatment plant production increases, and loan issuance by the Drinking Water State Revolving Fund/Georgia Environmental Finance Authority (GEFA) may take into consideration water audit results and the development and implementation of water loss control programs.

Audit results are evaluated by the state, and utilities are required to demonstrate progress using a suite of performance indicators that includes data validity and real and apparent loss per connection per day. Percentages are not used as a performance indicator to track improvement over time. Performance targets are the system-specific Economic Level of Leakage, which, once achieved, are to be maintained.

Financial and technical support mechanisms. GEFA leverages State Revolving Funds for water efficiency purposes, providing funding for training, technical assistance, data validation, and water loss control grants to small systems serving less than 10,000 persons. Grants are awarded depending on the level of water audit data validity, performance indicator values, and the utility's ability to achieve a meaningful reduction in water loss. With these functions in place, Georgia has ensured that water utilities are knowledgeable and active participants in the water audit data collection process and are fully engaged in launching efforts to better control losses. The *Georgia Water System Audits and Water Loss Control Manual* defines and describes best practices for compliance and improving water audit data validity, and provides guidance for use of the AWWA Free Water Audit Software, which is the defined method of data collection for the program. Updated information and technical resources on the Water System Audit and Loss Control Program can be found at the GAWP Web site at www.gawp.org.

A series of workshops is conducted on a periodic basis to provide training to utility personnel on compiling the water audit, review results of the previous round of audit data collection, and assess performance indicator data to better develop improvement programs. These training sessions also key on in-depth practices for managing water loss, updates to the regulatory and administrative requirements and technical tools, and other aspects of evolving technical guidance, such as recent research findings from organizations such as the Water Research Foundation.

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Georgia's Water Loss Control Program Successes

The State of Georgia implemented a water loss control program that keys primarily on the collection and validation of utility water audit data. While requiring the use of the AWWA Water Audit Methodology, considerable resources are dedicated to the training and education of the water utilities in the data collection process. An effective collaboration of the Georgia Department of Natural Resources (GA DNR), the Georgia Environmental Protection Division (GA EPD), and the Georgia Association of Water Professionals (GAWP) resulted in several training tools, including the *Georgia Water System Audits and Water Loss Control Manual* (GA DNR, GA EPD, and GAWP 2014).

Training workshops were held across the state prior to the initial data collection, and a comprehensive data validation process was conducted on the submitted water audit data. The above-mentioned agencies worked closely with the Georgia Environmental Finance Authority to leverage State Revolving Funds to pay for consulting services to conduct training and data validation. The validation process includes one-on-one data review and revision as needed with each of the water utilities submitting data.

The State of Georgia has taken a very comprehensive approach in launching its water loss control program and benefits from its growing pool of well-validated data to more reliably identify the extent of losses in water utilities and the appropriate controls to cost-effectively control the losses.

As previously noted, a distinct data validation effort was included in the Georgia program to ensure that all collected data was objectively represented in terms of its validity, but also as an additional educational process for utility personnel to become familiar with the integrity of their data sources and data management processes. To accomplish this, GA EPD implemented a third-party review process of all submitted water audits. For the first year that water audits were submitted by water systems serving 10,000 persons or more, a validation process was performed using contracted services of consultants versed in the water audit validation process. The validation team interviewed the water utility auditors to review their data inputs and the basis for their data grading assignments. Where applicable, water utilities systems submitted revised water audits before GA EPD finalized and then posted the summary water audit data to their Web site. GA EPD is planning to continue this validation process with future water audit submissions prior to posting on the Internet. While the water audit data validation process demands additional resources of time and funding, this process is invaluable to the success of the water audit data collection process, as the assessments and judgments made about the results of the water audit are only as valid as the trustworthiness of the audit data inputs.

State of Illinois

As a result of a 1967 US Supreme Court Decree (amended in 1980), the Illinois Department of Natural Resources (IDNR) administers the allocation of water supply from Lake Michigan to more than 50 water utilities in the Metropolitan Chicago area. The decree and Illinois state law mandate that "all feasible means reasonably available to the State and its municipalities, political subdivisions agencies and instrumentalities shall be employed to conserve and manage the water resources of the region and the use of water therein in accordance with the best modern scientific knowledge and engineering practice" [Level of Lake Michigan Act (615 ILCS 5O/5)]. IDNR's water-needs criteria require these water utilities to indicate their existing sources of supply, water use and population served, projections of future consumption and water supply needs, and to demonstrate their implementation of conservation practices and reduction of NRW.

Background and basis for a rule change. Title 17, Chapter I, Subchapter h, Part 3730, Section 3730.304 of the Illinois Joint Committee on Administrative Rules–Administrative Code describes the water-needs criteria that these water utilities (permittees) must document, which includes descriptions as to the extent of customer metering, expenditures for

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maintenance and repair of water distribution systems, groundwater conservation levels if applicable, and conventional elements of conservation-related programs (Illinois Joint Committee on Administrative Rules 2015).

Until 2014, with specific regard to water loss management, threshold percentages of "unaccounted-for flows" (UFFs) were also indicated, above which holders of Lake Michigan water allocation permits would be considered in violation and subject to fines and possibly review of their allocation permits. Furthermore, Section 3730.307 mandated that all permittees must reduce or eliminate wasteful water use and reduce UFFs (expressed as a maximum unavoidable leakage [MUL] allowance) to 8 percent of net annual pumpage or less (having previously been required to meet a 12 percent threshold). Permittees must also determine the efficiency of water metering or accounting in their system and, subject to practical difficulties, limit hydrant uses (excluding fire-fighting needs) to 1 percent of net annual pumpage or less. Annual reporting requirements described in Section 3730.309 include summaries of results and recommendations for leak detection surveys performed during the reporting period.

As described throughout this manual, IDNR has recognized that the use of the term *unaccounted-for* water is imprecise, and the sole reliance on simple percentage performance indicators, such as the "unaccounted-for" water percentage, is misleading. Thus, a good opportunity existed to improve beyond the existing requirements of the traditional rule defined above.

Stakeholder participation. In February 2013, IDNR announced proposed changes to its rules for permitting allocations of Lake Michigan water, consistent with the above obligations to "require that all feasible means reasonably available be employed." The initially proposed rules would have modified the protocol for evaluating the water loss control performance of regulated water systems and would have included provisions for managing demand through submetering of new multifamily construction, updating low-flow plumbing fixture specifications to labeled WaterSense products, updating lawn-sprinkling ordinances to require time-of-day restrictions, not on consecutive days, and would recommend that water rates reflect full-cost pricing.

In September 2013, in response to numerous comments received from many water systems that would be affected by the proposed changes and from other stakeholders, IDNR announced that it was considering modifications to its original proposal. IDNR then proposed phased-in compliance while moving its traditional reporting form (LMO-2) submittal process toward completion of a water audit methodology resembling that of the AWWA Water Audit Methodology. The modified rules, if approved, would change the "Unaccounted-For Flow" Standard to a Non-Revenue Water Standard (12 percent in Water Year 2015, decreasing to 10 percent by Water Year 2019), without a MUL allowance.

The proposed rules would also require a valuation of utility water losses based on the water utilities' wholesale cost of water purchased (conservatively assuming that all loss is real loss rather than apparent loss), thus enabling permittees to translate their water loss volume data to a monetary amount and thereby illustrate the value of undertaking infrastructure improvement to their water systems. The modified rules would also require preparation and submittal to IDNR of a water system improvement plan for noncompliant water systems that enables these systems to make necessary improvements over time.

Under the modified rule, implementation of submetering of multifamily service connections would also be included as a recommended, not mandatory, practice. The final proposed rules were submitted for approval by the Joint Committee on Administrative Rules with additional time needed to complete the process and promulgate the revised rules.

Applicability and implementation. All water utilities with or seeking allocations of water supply from Lake Michigan are subject to the described rules. There are no comparable requirements for water utilities in other parts of Illinois. The implementation process

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under the proposed rules was promulgated on Nov. 18, 2014 (Illinois Joint Committee on Administrative Rules 2014). The State of Illinois has taken strong, positive steps to improve its structures for utility water accountability and loss control and preservation of Lake Michigan's waters.

Consequences of noncompliance. Failure to comply with the requirements of the existing and proposed rules may result in issuance of a notice of violation, fines, and/or reduction of an existing allocation, or a denial of application for an allocation or renewed allocation of water supply from Lake Michigan.

Financial and technical support mechanisms. Financial assistance is available through the Illinois Environmental Protection Agency (IEPA), which administers the state's Public Water Supply Loan Program. Funding through this program was recently expanded through integration with the governor's Clean Water Initiative. Assistance can support projects such as renewal or replacement of water mains. The state does not directly provide technical assistance to water utilities for water loss management. However, IDNR has worked with several organizations, including the Illinois Section of AWWA, IEPA, Chicago Metropolitan Agency for Planning, the Metropolitan Planning Council, and the Center for Neighborhood Technology, to conduct a series of water loss audit workshops and otherwise make available guidance to communities to help them better understand the nature of their particular water loss issues and how their particular infrastructure needs can be clarified and an investment strategy developed. The workshops were held at several locations within the Lake Michigan allocation area throughout the state of Illinois.

State of New Mexico

New Mexico does not have a discrete regulatory system in place for water auditing and reporting, although it has conducted a pilot AWWA water audit for several water utilities in the state. Water auditing and water loss control are promoted by the state through guidance to those water rights applicants who are public water suppliers, for preparation of a water conservation plan that can be used to demonstrate the applicant's stewardship of water resources.

Background and basis for rule changes. Under Title 19, Chapter 25, Part 13 of the New Mexico Administrative Code, and as authorized by Article XVI of the New Mexico State Constitution, the New Mexico Office of the State Engineer (NMOSE) adopts rules and regulations to supervise the physical distribution of water, to prevent waste, and to administer the supply of water by priority date or by alternative administration, as appropriate. Accordingly, subject to court adjudication, NMOSE may deny a permit sought by applicants for rights to such water supplies, within the framework of a system of water master districts, if the applicants do not meet the requirements of these rules and regulations. One of the requirements is for the applicant to demonstrate that the permit will not be contrary to the conservation of water.

Stakeholder participation. In addition to promoting the conservation of water by facilitating the formation and operation of water rights groups, NMOSE provides assistance to applicants who are public water suppliers in the form of a resource guide titled *Water Conservation Planning Guide for Public Water Suppliers* (NMOSE 2013). This planning guide includes extensive discussion of how to apply the AWWA Water Audit Methodology and make use of the AWWA Free Water Audit Software, together with NMOSE's GPCD (gallons per capita per day) Calculator, to assist in the development of a water conservation plan.

Applicability and implementation. In particular for assessment of water loss management performance, the *Water Conservation Planning Guide* recommends that the water audit approach be employed to organize water diversion data and track its path through the distribution system. Users are encouraged to examine the DVS that is generated by the

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AWWA Free Water Audit Software before proceeding with water loss control program planning. Provided the underlying data are sufficiently valid, this auditing process determines the volume of NRW and assigns a cost to the components of NRW, particularly apparent and real (leakage) losses. Additionally, water utilities can assess their performance by reviewing the performance indicator values calculated by the Audit Software.

Once the results of the water audit are known, users are advised to establish realistic goals for the water conservation plan, which may comprise short-term actions to improve water audit data validity and achieve early success in reducing NRW. This can be followed by longer-term activities that will achieve further improvements in water loss management.

Consequences of noncompliance. Applications for water rights permits may be denied by NMOSE if the applicant is unable to demonstrate consistency with the principles of water conservation.

Financial and technical support mechanisms. *The Water Conservation Planning Guide* includes several potential sources of funding for projects related to water loss management and water conservation, including the US Bureau of Reclamation and the New Mexico Environment Department. In particular, the New Mexico General Services Department provides statewide price agreements for water meters and installation components. These contracts allow public entities to avoid the public bidding process. Various types of meters are available with a variety of features.

The New Mexico Rural Water Association (NMRWA) is a nonprofit membership organization committed to helping communities provide safe drinking water and wastewater services through onsite technical assistance, specialized training, and legislative support. NMRWA partners with community utilities across the state to create sustainable systems and build local expertise. It provides leadership, technical assistance, and training for utility professionals who serve rural New Mexico families. The NMRWA has published several management and sustainability guides, including *Water Use Auditing: A Guide to Accurately Measure Water Use and Water Loss* (Holmes 2007), and also provides a list of funding sources.

The *Water Conservation Planning Guide* includes detailed instructions for completing a water audit using the AWWA Free Water Audit Software and interpreting the results to establish an improvement program.

Pennsylvania Public Utility Commission

In partnership with the implementation of the water auditing program of the Delaware River Basin Commission (DRBC), the Pennsylvania Public Utility Commission (PAPUC) launched a two-year water audit pilot program in 2009 with five of the largest private water companies in Pennsylvania. (The PAPUC is a financial regulator that has oversight of Pennsylvania's privately held water utilities, but not publicly held utilities.) Water audits were compiled for several individual water systems operated by these companies using the AWWA Free Water Audit Software, and an assessment of the program was conducted in 2011. PAPUC judged the pilot program to be a successful demonstration of the AWWA Water Audit Methodology and moved to make the pilot program a permanent requirement. The following excerpt of the Advance Notice of Proposed Rulemaking Order appeared in the *Pennsylvania Bulletin* on Feb. 9, 2013 (*Pennsylvania Bulletin* 2013).

> On November 10, 2011, the Commission [PAPUC] issued a Tentative Opinion and Order at M-2008-2062697 (2011 Tentative Order) wherein the Commission ordered all Class A water utilities (over $1,000,000 in annual revenues) to implement the Water Audit methodology. The Tentative Opinion and Order became final January 27, 2012 (2012 Order). [A Secretarial Letter finalizing the 2011

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Tentative Order was issued on January 27, 2012, at Docket No. M-2008-2062697, after the only comments filed to the 2011 Tentative Order was withdrawn.] Specifically, the Commission concluded:

> Based upon this Commission's tradition of establishing ground-breaking regulatory tools, such as the DSIC or single tariff pricing, we will order the implementation of this Water Audit methodology which will help achieve a number of public interest benefits, such as increased infrastructure reliability, help preserve water resources, limit water leakage, reduce overall company risk, and enhance customer service. We believe that this practice is a better tool than the current unaccounted-for-water method and in the public interest.

To this end, the Commission ordered the five participating water utilities, namely, Aqua Pennsylvania, Inc., Pennsylvania-American Water Company, Superior Water Company, York Water Company and United Water Pennsylvania, Inc., to file annual Water Audit summaries with the Secretary of the Commission for the year ended December 31, 2011, no later than April 30, 2012, and on subsequent years no later than April 30.

In addition to ordering the five participating water utilities to file annual Water Audit summaries by April 30, 2012, the Commission specifically directed in the 2012 Order:

> That all other Class A water utilities (over $1,000,000 in annual revenues) commence to file the annual Water Audit summaries with the Secretary of the Commission for the year ended December 31, 2012, no later than April 30, 2013, and on subsequent years no later than April 30. These other Class A water utilities presently include Columbia Water Company, Newtown Artesian Water Company, CAN DO, Inc.-Water Division, United Water Bethel, Inc., and Audubon Water Company.

Accordingly, the Water Audit methodology has now been adopted by this Commission and all Class A water utilities are now required to file the annual Water Audit summaries with the Secretary of the Commission no later than April 30 of each year.

While the Commission has formally adopted the Water Audit methodology and also has directed all Class A water utilities to file the annual Water Audit summaries no later than April 30th of each year, a remaining question going forward for the Commission and the water industry is whether the Commission should revise its existing regulations regarding unaccounted-for-water at 52 Pa. Code § 65.20, or, whether it is necessary for the Commission to adopt new regulations regarding the Water Audit methodology.

Section 65.20 of the Code states, in pertinent part:

> § 65.20. Water conservation measures—statement of policy.
>
> In rate proceedings of water utilities, the Commission intends to examine specific factors regarding the action or failure to act

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> to encourage cost-effective conservation by their customers. Specifically, the Commission will review utilities' efforts to meet the criteria in this section when determining just and reasonable rates and may consider those efforts in other proceedings instituted by the Commission.
>
> Subsection (4) of this section, which specifically addresses unaccounted-for-water, states:
>
> Levels of unaccounted-for-water should be kept within reasonable amounts. Levels above 20% have been considered by the Commission to be excessive…."

Additionally, the Commission, as was requested in the 2012 Order, invited comments from the regulated community (particularly the participants in the pilot project and the other Class A water utilities designated to file their first annual Water Audit by April 30, 2013) and other interested parties on the experienced benefits and costs of the Water Audit methodology.

PAPUC also invited comments as to whether the Water Audit methodology should be extended to the other jurisdictional water utilities. PAPUC has since issued an Advance Notice of Proposed Rulemaking for comment (PAPUC 2013). At the time of publication for this manual, a final decision on the new rulemaking is awaited. PAPUC has taken a progressive stand to require a defensible, best practice methodology to collect water audit data from private water utilities in the Commonwealth of Pennsylvania. AWWA continues to assist PAPUC in its efforts to improve water efficiency.

Province of Quebec, Canada

Quebec's Water Efficiency Strategy (2011) is rooted in the Quebec Water Policy of 2002 (Government of Quebec Province, Canada 2002). It renders the allocation of financial assistance to municipalities for water infrastructure projects contingent upon the adoption of specific measures to conserve water and reduce leakage rates. While water resources are abundant in Quebec, the policy recognizes the importance of efficient management and responsible water use. The goal of the strategy relevant for water loss management is to achieve, by 2017, a reduction of water loss rates to a maximum of 20 percent of water distributed and a maximum of 15 m^3/km/d (cubic metres per kilometre per day) of water main, or approximately 6,400 gal/mi/d (gallons per mile per day). As of early 2014, Quebec stood as the only Canadian province to implement a requirement for reporting of water loss volumes via the compilation of the annual water audits.

Background and basis for new rulemaking. The Water Efficiency Strategy is administered by the Ministere des Affaires municipales, des Regions et de l'Occupation du territoire (Ministry of Municipal Affairs, Regions and Territorial Occupation).

Stakeholder involvement. The various elements contained in the Water Efficiency Strategy were developed through a close collaboration between the provincial government and the participating municipalities. The Province of Quebec's strong interest in the water loss methods being advanced by AWWA led to the creation of French language versions of both the third edition of AWWA Manual M36 and the AWWA Free Water Audit Software (version 4.2).

Applicability and implementation. Each participating municipality must, annually, as of 2012:

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- Measure water distributed and complete a water balance using data loggers on flowmeters to determine minimum night flows and estimate water losses. (Note: many municipalities in Quebec do not meter individual water customers, thus the data-logging requirement was implemented as a means to obtain a representative sample of customer consumption.) As of 2016, accuracy must be within 5 percent of true flow with onsite verification of flows at low, intermediate, and high flow rates.
- Complete/update an action plan that includes
  - a proactive leak detection and repair program if water losses exceed the strategy's maximum values,
  - public education programs designed to inform about water efficiency,
  - adoption of a municipal bylaw on water use, and
  - evaluation of the full cost of water service provision.
- Submit a water use report to the Municipal Council.

And, as of 2014: Install meters in the nonresidential sector, and estimate (with an acknowledged uncertainty) residential consumption, if the quantity of water distributed per person is not reduced by 10 percent from 2001 levels or if the strategy's leakage rate limits are exceeded.

And, as of 2017: Implement adequate water pricing, if the quantity of water distributed per person is not reduced by 20 percent from 2001 levels or if the strategy's leakage rate limits are exceeded.

As of late 2013, more than 750 municipalities, representing 99 percent of the population connected to a drinking water system, participated in the strategy. Approximately 400 municipalities, representing 90 percent of the population connected to a drinking water system, had implemented or planned to implement a proactive leak detection program. Approximately 8,000 leaks were repaired by municipalities in 2012. Approximately 30 percent of nonresidential buildings and 10 percent of residential buildings have a water meter that is now read on a regular basis.

Consequences of noncompliance. Participation in the annual reporting program is voluntary. Municipalities who participate are eligible for financial assistance for water infrastructure upgrades from the Ministry of Municipal Affairs, Regions and Territorial Occupation.

Financial and technical support mechanisms. The government has made a commitment to provide conditional financial assistance to municipalities, make revisions to the Building Code to prohibit the sale of inefficient plumbing fixtures, pursue water efficiency programs in government buildings, produce tools to assist municipalities and building owners, and establish three committees (technical, municipal, and ministerial) to monitor and report results of the program.

The cost of eligible equipment and studies may be reimbursed through a grant program. Forms and technical guidance are available to assist municipalities in the preparation of the annual reports to be submitted to the Municipal Council and to the Quebec Ministry of Municipal Affairs. (For more information, see www.mamrot.gouv.qc.ca/grands-dossiers/strategie-quebecoise-deconomie-deau-potable/.)

State of Tennessee

The Tennessee Code Annotated (TCA) includes provisions for a regulatory system for water loss reporting and control adopted by the state legislature in 2007 (Public Chapter 243, HB 743). The regulatory system is administered by the Comptroller of the Treasury–Utility Management Review Board (UMRB) and the Water and Wastewater Financing Board

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(WWFB). These entities provide assistance to utility districts, municipal water systems, water authorities, and county water systems, including establishment of guidelines for water loss reporting and control. Similar to a public utility commission, the focus of the UMRB is the financial protection of the water consumer.

Background and basis for new rulemaking. "The Tennessee UMRB supports natural gas, water and wastewater public utility districts by assuring that they are financially self-supporting and by requiring appropriate action by those districts that have financial deficiencies" (Tennessee Comptroller of the Treasury 2015). On Oct. 7, 2010, acting under authorization of TCA Section 7-82-702, a joint meeting of the UMRB and the WWFB established a percentage for excessive water loss at 35 percent using the then-current method of calculation and required a transition in reporting and calculation methods for water loss (Tennessee Association of Utility Districts 2010). Prior to Jan. 1, 2013, subject to amendment of the TCA to allow the UMRB and WWFB to adopt water loss standards, water utilities were required to submit the original calculation method and reporting form for water loss. If the system has excessive water loss, then it must resubmit using the AWWA Water Audit Methodology. On Jan. 1, 2013, the AWWA Water Audit Methodology became the operative protocol. The term *unaccounted-for water* was removed from the TCA and replaced with *water loss* throughout.

Stakeholder participation. A key stakeholder in the development of the Tennessee regulatory system for water loss control is the Tennessee Association of Utility Districts (TAUD, www.taud.org). TAUD recommended adoption of the AWWA Water Audit Methodology for calculating water loss and an implementation strategy for compliance.

Applicability and implementation. Water utilities regulated by the UMRB and WWFB are required to electronically submit annually the completed water audit via the AWWA Free Water Audit Software together with the water utility's audited financial statements. The spreadsheet submittal is in addition to a single Reporting Worksheet that summarizes water treated and purchased, water sold and other authorized uses, and other financial information for revenues as well as electrical and chemical costs.

The audit information submitted using the AWWA Free Water Audit Software includes the DVS determined according to data input gradings entered by the auditor as guided by the Grading Matrix worksheet within the Audit Software. Water utilities must demonstrate that their DVS is

- greater than 65 for audits received between Jan. 1, 2013, and Dec. 31, 2014;
- greater than 70 for audits received between Jan. 1, 2015, and Dec. 31, 2016;
- greater than 75 for audits received between Jan. 1, 2017, and Dec. 31, 2018; and
- greater than 80 for audits received between Jan. 1, 2019, and Dec. 31, 2020.

A concurrent milestone-based requirement applies for demonstration of improved NRW performance. This performance is assessed using the NRW-by-cost performance indicator. The initial threshold for acceptable performance was 30 percent through Dec. 31, 2014. This threshold declines to less than 25 percent through Dec. 31, 2016, and settles at less than 20 percent through Dec. 31, 2020. For this purpose, "Total Annual Cost of Operating the Water System" is defined to include all costs for operation, maintenance, debt service (principal and interest), and depreciation. The thresholds are subject to change by approval of the UMRB and WWFB.

Consequences of noncompliance. Failure by the water utility to submit the required audit information results in a referral to the appropriate board (UMRB or WWFB), as does a reported NRW-by-cost level that exceeds the designated standard and failure to achieve improvement in the DVS by the milestones noted previously. Referrals are primarily required to substantiate the financial viability of the water utility. The referral is made by

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Tennessee's System for Water Loss Reporting and Control

Tennessee's water loss control program is administered by the Comptroller of the Treasury–Utility Management Review Board and the Water and Wastewater Financing Board. These boards operate as financial regulators of water systems in Tennessee. As such, the boards hold the interests of water ratepayers and strive to ensure that water utilities provide reliable service at reasonable cost. Tennessee requires use of the AWWA Water Audit Methodology and data collection via the AWWA Free Water Audit Software. In applying assessments of the software's performance indicators, Tennessee has taken a unique approach. Instead of setting a low target level of non-revenue water (NRW) that all water utilities should meet, Tennessee identified high threshold levels of the water audit Data Validity Score and the NRW-by-cost indicator. Water utilities that exist beyond these high threshold levels are referred to the appropriate authorities to help them gain the proper assistance to improve their performance in a focused manner. This avoids a punitive approach toward utilities and ensures that needed attention is directed to the relatively few utilities that may be struggling to maintain acceptable water loss performance.

the Office of the Comptroller within 60 days of the failure to file or a filing where results do not meet the designated performance standard.

It is important to note Tennessee's progressive approach toward water utilities. Instead of setting a low threshold for NRW that all water utilities should meet, Tennessee identified high threshold levels of water audit data validity and NRW by cost. Water utilities that operate with parameters beyond these high threshold levels are referred to the appropriate authorities to help them gain the proper assistance to improve their performance in a focused manner. This avoids a punitive approach toward utilities and ensures that needed attention is directed to the relatively few utilities that may be struggling to maintain acceptable water loss and/or financial performance.

Financial and technical support mechanisms. TAUD has provided several workshops to assist water utilities with gaining knowledge of the applicable state policies and underlying principles of the AWWA Water Audit Methodology, issues that arise in analyzing the data utilized for the audit, and the process for completion of the audit.

Tennessee's Drinking Water State Revolving Fund awards priority points for offering low-interest loans to eligible water loss control–related projects (intended to reduce leakage) on a sliding scale. Higher priority is assigned to projects submitted by water utilities demonstrating poorer water loss performance (between 80 and 20 points for water loss in increments of 20 points for water loss increments of 10 percentage points, correspondingly ranging between 50 percent or greater and 20 percent or greater).

State of Texas

Texas was the first state to implement legislation that included a water auditing requirement and, very recently, has tightened its requirements for water auditing and loss control. As a result of state legislation (House Bill 3338 passed in 2003, and House Bills 857, 1461, and 3605 passed in 2013), utility companies are required to conduct annual water audits to quantify water loss, to inform customers of water audit results, and to use a portion of state assistance funds to conduct conservation that can include water loss control. HB 857 requires water utilities to conduct annual water loss audits. HB 1461 requires customer notification of the audit results. HB 3605 requires utilities that receive board financial assistance to use a portion of that financial assistance to mitigate the utility's system water loss if, based on a water audit filed by the utility, the water loss meets or exceeds a threshold established by rule. The three recent bills were enacted during the year following the worst period of drought in the history of Texas.

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The Texas Water Development Board (TWDB) began requiring submittal of standardized water audits using a water audit worksheet to be filed by retail public water utilities beginning in 2005 at five-year intervals. The methodology, guidance, and worksheet were forerunners of the AWWA Free Water Audit Software, embedded data validity scoring matrix, and technical guidance for data entry and calculation of performance indicators. TWDB still employs these internally developed forms, which are similar to—but not the same as—the AWWA tools.

Background and basis for legislative activity. House Bill 3338 was enacted to help conserve the state's water resources by reducing water loss occurring in the systems of drinking water utilities. In response to the legislation, approximately half of the public water utilities serving approximately 84 percent of the population in Texas reported their water loss data. House Bills 857, 1461, and 3605 were enacted to request that utilities receiving any funding from the TWDB need to submit audits annually. Another objective of House Bill 3605 was to develop water loss thresholds. Rules were adopted on Dec. 5, 2014, and published (*Texas Register* 2014). The adopted rules provide the following thresholds (*Texas Register* 2014):

- For a retail public utility with a population more than 10,000:
  - Apparent loss expressed as gallons per connection per day must be less than the allowed apparent loss, consisting of a unique number calculated for each utility.
  - Real loss expressed as gallons per connection per day must be less than three times the unavoidable annual real loss, consisting of a unique number calculated for each utility.
- For a retail public utility with a population less than or equal to 10,000 and a service connection density more than or equal to 32 connections per mile:
  - Apparent loss expressed as gallons per connection per day must be less than the allowed apparent loss, consisting of a unique number calculated for each utility.
  - Real loss expressed as gallons per connection per day must be less than 50 gal/connection/d.
- For a retail public utility with a population less than or equal to 10,000 and a service connection density less than 32 connections per mile:
  - Apparent loss expressed as gallons per connection per day must be less than the allowed apparent loss, consisting of a unique number calculated for each utility.
  - Real loss expressed as gallons per mile per day must be less than 1,600 gal/mi/d.

Stakeholder participation. Although stakeholder participation in the development of the TWDB's *Water Loss Audit Manual for Texas Utilities* (Mathis et al. 2008) was somewhat limited, a subsequent survey on municipal water loss management practices was conducted in 2009 with the objective of achieving a more consistent representation of water use accounting and water loss management. Approximately 300 water systems responded to the survey. The consensus of the responses confirmed the need for consistency of reporting and management, particularly for methods of leak detection, leak repair response, and meter management, as well as assistance to smaller systems in the state. The final rulemaking process that established the above thresholds received comments from the City of Houston, City of Austin, and Texas Rural Water Association, along with two environmental groups.

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Applicability and implementation. Any retail water supplier that is financially obligated to the TWDB and retail water suppliers that serve more than 3,300 service connections are required to file an annual water audit with the TWDB. All retail public water suppliers are required to file a water audit every five years (the next audit is due on May 1, 2016, for the 2015 reporting year). The TWDB encourages all retail public water suppliers to prepare an annual audit as a best practice for proactive identification and resolution of water loss management issues.

The standardized approach, technical guidance for data entry and interpretation of results, data validity scoring system, and data entry forms are described in the TWDB's *Water Loss Audit Manual for Texas Utilities* (Mathis et al. 2008). A drawback to the TWDB's approach was the incorporation of a "balancing adjustment" that allowed some water use to be unclassified. This adjustment has been removed in the most recent versions. Also, although the TWDB uses a data grading system, it does not align with the system used in the AWWA Free Water Audit Software; hence, the DVSs of Texas utilities cannot be compared directly with those of the many other state and regional agencies that employ the AWWA tools.

All public drinking water utilities are required to submit a water conservation plan that includes best practices relevant to water loss management. These practices include supply metering with an accuracy of ±5 percent; universal metering of public uses of water, meter testing and repair as well as periodic meter replacement; periodic visual inspections along distribution lines; and audits of customer service lines. Additionally, public drinking water suppliers who serve or will serve—within 10 years from the effective date of the plan—5,000 or more persons must include a program of leak detection, repair, and water loss accounting for the transmission, delivery and distribution system, documentation of water pumpage, delivery, sales, and loss volumes. These plan requirements also apply to the wholesale customers of these systems.

Consequences of noncompliance. The TWDB is a nonregulatory state agency. However, failure to comply with the audit submittal requirements will preclude a water utility from receiving financial assistance for water supply projects.

Financial and technical support mechanisms. The TWDB maintains a robust capability for providing technical guidance to drinking water utilities. This capability includes staff consultation, Web portals with considerable technical guidance (most also available in Spanish), an outreach program that includes workshops for water utilities—the content of which is eligible for licensure credits to water utility operators offered by the Texas Commission on Environmental Quality, free equipment on loan for acoustical sounding devices for leak detection and pinpointing, and ultrasonic flow-measuring devices to verify metered flow rates through source or master meters.

In early 2014, the TWDB discussed publishing a new Water Loss Reduction Implementation Manual that would include details of apparent and real loss management programs, and discussion of benchmarks and ranges of water audit data collected during the audit reporting program. Technical assistance can be accessed through the TWDB's Water Conservation Division. Financial assistance for projects related to water loss control should be available in 2015 through low-interest loan funding from House Bill 4 (2013) where up to $2 billion of the Texas Rainy Day Fund can be used to provide low-interest loans to aid with implementation of the state's 50-year water supply plan.

MOVING FORWARD THROUGH CONTINUOUS IMPROVEMENT

It is evident from the foregoing examples of regulatory and voluntary systems for water auditing and water loss control programs that a nexus exists between conventional water conservation (demand side) activities and actions that can be undertaken by water

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purveyors or utilities (supply side). Synergies that are likely to arise from continued implementation of such programs will lead to operating cost reduction, revenue recovery, and improved sustainability of water resources for the water utilities that participate.

In many cases, the quality of data submitted to the administering agencies must be improved and validated so that actionable information is generated for use in planning effective water loss control programs. In other cases, the legal authority of some agencies may need strengthening to achieve greater participation, or the latest methodologies need to be adopted to achieve greater consistency in reporting and improved ability to compare performance against other water utilities with similar characteristics.

The AWWA Water Audit Methodology and companion software tools offer water utilities a standardized approach for assessing and reporting water loss performance. Continued dialogue between the drinking water industry, the regulatory community, and interested stakeholders will assist the process to better understand the components of water loss and how to manage them to economic levels. A collaborative rulemaking process can produce benefits for water utilities, their customers, water management agencies, and other involved stakeholders.

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