Water Loss Audit Manual for Texas Utilities

by Mark Mathis • George Kunkel, P.E. • Andrew Chastain Howley

Report 367
March 2008

Texas Water Development Board
www.twdb.state.tx.us

Texas Water Development Board
Report 367

Water Loss Audit Manual for Texas Utilities

by
Mark Mathis
Texas Water Development Board

George Kunkel, P.E.
American Water Works Association
Water Loss Control Committee, Active Member

Andrew Chastain Howley
American Water Works Association
Water Loss Control Committee, Active Member

March 2008

This project was funded in part by the U.S. Bureau of Reclamation's Water 2025 Challenge Grants for States and by the Texas Water Development Board.

Cover photo courtesy of City of Austin Water Utility

Texas Water Development Board

Published and distributed by the
Texas Water Development Board
P.O. Box 13231, Capitol Station
Austin, Texas 78711-3231

March 2008
(Printed on recycled paper)

This page is intentionally blank.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

This page is intentionally blank.

Executive Summary

In 2003, the 78th Texas Legislature, Regular Session, enacted House Bill 3338 to help conserve the state's water resources by reducing water loss occurring in the systems of drinking water utilities. This statute requires that retail public utilities providing water within Texas file a standardized water audit once every five years with the Texas Water Development Board (TWDB). In response to the mandates of House Bill 3338, TWDB developed a water audit methodology for utilities that measures efficiency, encourages water accountability, quantifies water losses, and standardizes water loss reporting across the state.

The water audit worksheet developed by TWDB is comprised of data typically required for a water supply utility to conduct an internal "top-down" water audit approach, which is largely a desktop exercise gathering data and information from water consumption and loss reports already commonly compiled by many water utilities. However, utilities seeking to gain further efficiencies can perform additional field auditing tasks in a more comprehensive "bottom-up" manner. Bottom-up practices can determine more precisely where losses are occurring, thus better validating the accuracy of the water audit and guiding the utilities' strategies for loss control efforts. To assist water utilities in undertaking their top-down water audit, this manual provides guidance on the specific data and information that should be gathered to assemble a realistic assessment of water loss. *The most important step in the auditing process is to begin.*

This standardized approach to auditing water loss provides utilities with a reliable means to analyze their water loss performance. By reducing water loss, utilities can increase their efficiency, improve their financial status, minimize their need for additional water resources, and assist long-term water sustainability.

1 *Introduction*

Water is one of our most precious resources, yet within North America only a few states have begun to implement proactive water accountability policies for their utilities. Water auditing and loss control are emerging as significant conservation measures because as utilities minimize water loss, they increase their efficiency and reduce the need to search for additional water sources. For utilities to effectively identify losses in their systems, they must first employ water auditing as a routine business practice, using a method that has clearly defined terms and meaningful performance indicators. In recognizing the need for such a reliable method, the Water Loss Control Committee of the American Water Works Association adopted (AWWA, 2003) the method published by the International Water Association's Water Loss Task Force (Alegre and others, 2000). This methodology not only assists utilities in identifying where their losses are occurring, but also expresses by volume how much is lost and associates a cost to those losses. It also standardizes the water audit reporting process for water utilities.

The Texas Water Development Board (TWDB) water audit program begins with an examination of the water utility's business practices and procedures. It uses the terms from the International Water Association and American Water Works Association Water Audit Method (hence referred to as the Water Audit Method)—system input volume, authorized consumption, real and apparent loss—as well as the performance indicators included in this method. Since all water is essentially accounted for in this approach, the term "unaccounted-for" water is discouraged. The Water Audit Worksheet (Appendix 1.1) is the audit form developed by TWDB, based on the Water Audit Method. The approach defined in this manual also asks water utilities to assess the validity of the data that they enter into the water audit. A scale is provided for all components of water consumption and loss, assigning low assessment scores to data that are mere approximations and high assessment scores for components that are derived from well-calibrated meters or other well-substantiated means.

2 *Implementing Water Audits as the Foundation of the Water Loss Control Program*

For utilities to operate efficiently, they should use recommended practices to monitor and control water and revenue losses. These include active leakage control, as well as metering production flows and customer consumption. Consumption data serve as the basis for billing and revenue collection for most water utilities, but the data are also critical to water demand management. Customer billing systems, which are commonly used to archive customer account and consumption data, should be configured so that consumption volumes are not distorted by billing adjustments or inconsistent procedures. By correcting deficiencies in archiving customer consumption in billing systems, utilities can often recover significant uncaptured revenue. Today's water utilities can also use other advanced technologies, such as automatic meter reading technologies, Advanced Metering Infrastructure, Supervisory Control and Data Acquisition (SCADA) Systems, Geographic Information Systems (GIS), hydraulic modeling, and sophisticated leak detection technologies, such as leak correlators and leak noise loggers. Many of these technologies help reduce real loss, which saves water resources.

By using the above technologies, water utilities can address a variety of losses; however, the foundation of the water loss control program is the compilation of the water audit on a routine basis as a standard business practice. Water utilities should compile a regular water audit in a fashion similar to how an accounting firm routinely examines the finances of a business: by tracking volumes of water supplied by the water utility from source to customer, just as accountants track a firm's finances throughout its business path. The water audit quantifies production flows, customer consumption, and a number of different loss volumes and assigns costs to these volumes. Throughout the audit process, utilities determine specific areas of water loss, examine deficiencies in their overall performance, review current practices and procedures for developing data, and calculate the costs of water loss. The Water Audit Worksheet (Appendix 1.1) uses a standard set of terms and definitions so that all utilities in the state are measuring water loss in the same way. Because many water utilities historically used water accounting practices that fell short in accurately determining where losses occurred and how to recover lost revenues, the water audit provides a tool for systematically evaluating those losses. The methods included in this manual follow a standard, best management practice approach advocated by the American Water Works Association, and TWDB encourages all water utilities to implement this method. Although House Bill 3338 requires that water utilities file a water audit only once every five years, TWDB recommends that water utilities compile a water audit annually on the same business year frequency as the financial audits that many water utilities perform.

Water loss programs should be planned based upon validated water audit data. The self-assessment feature described in this publication guides water utilities in taking steps to first obtain sufficiently validated data before making important loss control program decisions on the data produced by the water audit. An internal top-down water audit approach is largely a desktop exercise gathering data and information from water consumption and loss reports already commonly compiled by many utilities. Once a water utility produces this top-down water audit with sufficiently validated data, it can begin bottom-up field auditing activities to better validate the initial data. Bottom-up activities are longer term in nature and can be implemented incrementally over periods of months or years. These activities typically involve some investment, but the projected costs of these activities can be objectively weighed against the inherent costs of the losses, as detailed in the validated top-down water audit. In the long run, investment in bottom-up activities will likely save the utility from costly, ineffective programs that may not provide a substantial return on investment. Bottom-up practices are discussed in Chapter 5.

Utilities should use the Water Audit Worksheet to compile the top-down water audit. To assist in this process, TWDB has provided a worksheet designed as a software application for utilities to download to their computers, so they can continue to use the methodology.

3 *Understanding the Water Audit Method*

The Water Audit Method takes the approach that all water is accounted for and quantified as either a component of beneficial consumption or wasteful loss by measuring (metering) or estimating water quantities. Under this approach, no water is "unaccounted for," and this flawed term and the flawed indicator "unaccounted-for-water percentage" should be avoided. Figure 3.1 shows the Water Balance of the Water Audit Method. All quantities of water fit into one of the boxes of the water balance. The sum of the quantities of each column in the water balance is the same; hence, all quantities balance.

Standard terms and definitions that accompany the components shown in Figure 3.1 are given in Table 3-1, and TWDB recommends reviewing these definitions before filling out the Water Audit Worksheet.

3.1 How much are losses costing the utility?

All losses impart a cost impact to the water utility and the communities they serve. By accurately assessing where and how much water is being lost, utilities can determine how much water loss is costing. These costs can then be compared to potential investments in loss control activities to determine cost-benefit ratios for effective loss reduction. When water utilities reduce losses, they may also improve their financial bottom line. All component volumes of

<table>
<tr><td rowspan="7">Corrected input volume</td><td rowspan="4">Authorized consumption</td><td rowspan="2">Billed authorized consumption</td><td>Billed metered consumption</td><td rowspan="2">Revenue water</td></tr>
<tr><td>Billed unmetered consumption</td></tr>
<tr><td rowspan="2">Unbilled authorized consumption</td><td>Unbilled metered consumption</td><td rowspan="7">Non-revenue Water</td></tr>
<tr><td>Unbilled unmetered consumption</td></tr>
<tr><td rowspan="5">Water losses</td><td rowspan="3">Apparent losses</td><td>Unauthorized consumption</td></tr>
<tr><td>Customer meter under-registering</td></tr>
<tr><td>Billing adjustment and waivers</td></tr>
<tr><td rowspan="2">Wholesale water imported</td><td rowspan="2">Real losses</td><td>Reported leaks</td></tr>
<tr><td>Unreported loss</td></tr>
</table>

Figure 3.1. Water Balance

Table 3-1. Standard Definitions of the Water Audit Method

Definitions
System Input Volume: The total water supplied to the water distribution system, corrected for any error in the production meters. It includes the sum total of purchased surface or groundwater, water obtained through the utility's own wells, water purchased through contracted interconnections with other water suppliers, or water obtained from other sources. This is the total of all production meter readings for the entire audit year from all sources. • **Production Meter Accuracy**—All production and bulk purchase volumes should be metered. Meters should be well maintained and calibrated to ensure a high degree of accuracy. For any given water utility, one or more production meters may incur a degree of inaccuracy due to wear, malfunction, or improper installation. • **Corrected System Input Volume**—The level of production meter accuracy is usually a percentage. To calculate corrected system input volume, divide the system input volume by the percentage of accuracy to achieve the corrected system input volume—the volume actually placed into the distribution system. Since inaccurate meters often under-register, this number will usually be larger than the reported system input volume.
Authorized Consumption: This category consists of all water that has been authorized for use by the utility and its customers. Authorized consumption includes, but is not limited to, water used for residential and commercial uses, fire fighting, public fountains, golf courses, municipal landscape watering, line flushing, city offices, water treatment facility use, dust control, and construction practices. Authorized consumption is all the water the utility gave permission to a business, individual, or itself to use. It may be billed or unbilled, metered or unmetered. • **Billed Metered**—Water that is appropriately metered and billed. • **Billed Unmetered**—Estimated water that has been sold but not metered; for example, dust-control trucks and types of businesses using authorized water drawn from fire hydrants or other unmetered uses. • **Unbilled Metered**—Water that is metered but not billed, such as city/government offices, city park irrigation, water treatment facility use, some fire department use, and line flushing. • **Unbilled Unmetered**— Estimated water that is not billed or metered, such as most line flushing (see Form D in Appendix 2). Estimations may also be entered for this category. Installing meters on any of the sources of significant unmetered water represents bottom-up activity to improve the accuracy of the top-down water audit and better manage these water uses.
Water Losses: This is derived by subtracting authorized consumption from corrected system input volume. Water losses exist in two major classifications: apparent losses and real losses. Both are considered types of water loss. Apparent loss is valued at the customer retail rate because it had the opportunity to be sold. Real loss, however, is calculated at the variable production cost of water. • **Apparent Losses**—These are "paper" losses that occur when water reaches a customer, but the volume is not accurately measured and/or recorded due to customer meter inaccuracy, systematic data handling discrepancies, or unauthorized consumption. Apparent loss is water that has been consumed but not paid for due to error in quantifying the volume of water. These losses cost water utilities revenue and understate the collective measure of customer consumption in the water utility's service area. Valued at the customer retail (revenue) rate, these losses are often very cost effective to recover. • **Real Losses**—These are the "physical" losses, largely leakage, from the infrastructure: mains, valves, service lines, and tank overflows. Leakage occurrences are categorized as "reported" (visible) events or "unreported" (nonvisible—found only by active leak detection) events. Real losses occur prior to reaching customers and effectively force the water utility to treat and deliver more water than its customer population actually requires. These losses are typically valued at the variable production rate (costs for water treatment, pumping, or bulk water purchase); however, if the utility is experiencing a water shortage, then real losses may be valued at the customer retail rate because recovered leakage could be viewed as water that can be sold to customers.
Revenue Water: Revenue water consists of billed wholesale water exported and billed metered and unmetered water. These are usually the primary categories through which the utility can generate revenue.
Non-revenue Water: This term is the sum of apparent loss, real loss, and unbilled authorized consumption. Non-revenue water is clearly defined as all water for which no revenue is received.

non-revenue water (unbilled authorized consumption, apparent loss, and real loss) should be assigned a cost value.[1]

Apparent losses differ from real losses in the manner in which they occur but, perhaps more dramatically, in the financial impact that they impart to the water utility. Apparent losses occur when water has reached the customer, but by not accurately recording the consumption, a portion of the revenue is not captured. Apparent losses are, therefore, valued at the customer retail rate. Water utilities often use rate structures with different rates for different customer classes, such as residential and industrial, and for different tiers of water consumption. For purposes of simplicity in compiling the water audit, utilities can use a single, composite rate for all customer classes to determine the cost impact of apparent losses.

Real losses cause a portion of the treated, pressurized water to be lost from the distribution system before customer use. In effect, the utility treats a greater volume than its customer base requires, hence incurring excess production costs. The cost for real losses is, therefore, typically valued at the variable production cost and/or the purchase cost of imported bulk water supply. The variable production cost is defined as the cost of raw water, electricity to treat and distribute water, and chemicals to treat the water for the year. One way to calculate the variable production cost is to divide the sum of the raw water, energy, and chemical costs by the corrected input volume. In cases of water shortage where any real loss reduction results in additional customer sales, then the real losses should be valued at the customer retail rate.

1 When compiling the water audit, utilities should use consistent volume units throughout the audit. Often water utilities measure their water supply in one unit (for example, gallons) and their customer consumption in another unit (for example, cubic feet). Typically, the customer consumption values must be converted to align with the units of measurement for the water supplied

3.2 PERFORMANCE INDICATORS

The water audit method features a number of performance indicators that allow water utilities to reliably assess their water loss standing and track their performance. The performance indicators are designed specifically to

- track the water utility's progress on a year-to-year basis,
- set performance targets, and
- benchmark performance with other water utilities.

The complete list of performance indicators is shown in Table 3-2. The indicators are categorized as operational or financial in nature. The level of detail they project is also identified as 1) basic level indicators, 2) intermediate indicators, and 3) detailed indicators. An array of operational performance indicators exists—one for apparent losses and four for real losses. The operational performance indicators are well suited to evaluate operational efficiency, track progress, and benchmark with other water utilities. Also shown are financial performance indicators included in the International Water Association and American Water Works Association Water Audit Method, including non-revenue water by volume and non-revenue water by cost.

Water utilities can track their performance in controlling apparent losses by using the apparent loss indicator (Op23), which reflects the volume of apparent losses quantified in the water audit, normalized by dividing this volume by the number of service connections per day.

For real losses, the water utility can likewise track performance using two normalized indicators of real losses (Op24). Dividing the quantity of real losses from the water audit by the number of service connections (or miles of pipe for low density systems) per day gives the Op24 indicator. A second variation of this indicator can also be calculated by dividing the result by the average pressure across the system. These performance indicators are good for setting specific leakage reduction targets and tracking performance.

The unavoidable annual real losses are another performance indicator. These losses are a theoretical reference for low-level leakage that recognizes even the best maintained water distribution systems in the world have some leakage. Unavoidable annual real losses are calculated from the equation in Table 3-2 by using the most influential factors in system leakage: length of piping in the water distribution system, number of customer service connections, and average system pressure. Note that age of the piping is not an influential factor.

The primary performance indicator used for comparing performance with other water utilities (benchmarking) is the infrastructure leakage index. This index provides utility managers with the ability to weigh leakage efficiency relative to the ideal low level that might exist in the water utility (Appendix 1.4). The Water Loss Control Committee of the American Water Works Association also gives guidelines for using the infrastructure leakage index as a preliminary leakage reduction target-setting tool.

The index takes into account system-specific attributes, including the length of mains, number of customer service connections, and average pressure; therefore, leakage efficiency can be compared among water utilities in an objective manner. This avoids a "one size fits all" approach to target setting. The infrastructure leakage index is the ratio of the real loss volume from the water audit over the level of unavoidable annual real losses as calculated for each system using the equation shown in Table 3-2 (Op25). As a ratio, the lower the value of the infrastructure leakage index, the closer the actual level of real losses is to the unavoidable annual real losses. The index represents how efficiently the system's infrastructure upkeep, leakage management, and repair activities are operating at the current pressure, with a validated low infrastructure leakage index value implying that the utility is very efficient.

Table 3-2. International Water Association and American Water Works Association Water Audit Method—Performance Indicators

Function	Level*	Code*	Performance Indicator	Comments
Operational: Apparent losses	1 Basic	Op23	[gallons/service connection/day]	Basic but meaningful performance indicator for apparent losses. Easy to calculate once apparent losses are quantified.
Operational: Real losses	1 Basic	Op24	[gallons/service connection/day] or [gallons/mile of mains/day] (only if service connection density is less than 32/mile)	Best of the simple "traditional" performance indicators. Useful for target setting. Limited use for comparisons between systems.
Operational: Real losses	2 Intermediate	Op24	[gallons/service connection/day/pressure] or [gallons/mile of mains/day/pressure] (only if service connection density is < 32/mile)	Easy to calculate this indicator if the infrastructure leakage index is not yet known. Useful for comparisons between systems.
Operational: Unavoidable annual real losses	3 Detailed	UARL[a]	UARL (gallons) = (5.41Lm + 0.15Nc) x P, (Eq. 1) where Lm = length of water mains, miles Nc = number of service connections P = average pressure in the system	A theoretical reference value representing the technical low limit of leakage that could be achieved if all of today's best technology could be successfully applied. A key variable in calculating the infrastructure leakage index. The calculation for unavoidable annual real losses is not valid for systems with less than 3,000 service connections.
Operational: Real losses	3 Detailed	Op25	Infrastructure leakage index (dimensionless) = Real loss volume/UARL[a]	Ratio of real loss volume to unavoidable annual real losses). Best indicator for comparisons between systems.
Financial: Non-revenue water by volume	1 Basic	Fi36	Volume of non-revenue water as % of corrected system input volume	Easily calculated from the water balance. Has limited value in high-level, financial terms only. Misleading to use this as a measure of operational efficiency.
Financial: Non-revenue water by cost	3 Detailed	Fi37	Value of non-revenue water as a percentage of the annual cost of running the system	Incorporates different unit costs for non-revenue components. Good financial indicator. These costs include operations, maintenance, and any annually incurred costs for long-term upkeep of the system, such as repaying capital bonds for infrastructure expansion or improvement. Typical costs include employee salaries and benefits, materials, equipment, insurance, fees, administrative costs, and all other costs that exist to sustain the drinking water supply. These costs should not include any costs to operate wastewater, biosolids, or other systems outside of drinking water.

* Descriptors assigned to the performance indicators from Alegre and others (2000).
[a]UARL=unavoidable annual real losses

4 *Validating and Interpreting the Water Audit Data*

Assembling a basic top-down water audit is the first step a water utility should take to establish accountability and manage water and revenue losses. The main advantage of the top-down approach is that it is relatively quick, using existing data from records routinely compiled by most water utilities and estimates for components where data do not exist. The top-down approach allows the water utility to get the process started.

The drawback to the top-down approach, particularly for the first time auditor, is that some of the data may be of suspect quality or estimates may be relatively crude. In such cases, utilities should interpret the validity of the water audit results cautiously. If many of the water audit quantities are derived from estimates, new data collection procedures and/or bottom-up field activities should ultimately be instituted over the course of time to generate more accurate and realistic data that better validate the water audit results and lead to better loss control program decisions.

Validation is defined as the process by which water audit data is confirmed to reflect the actual operating conditions of the water utility within a reasonable degree of accuracy. Water is indestructible; it can be neither created nor destroyed. Therefore, the quantities in the Water Balance (Figure 3.1) *must* balance, with each column adding to the same amount. All of the water managed by a utility can be assigned to the components shown in the balance, but it is frequently difficult to ascertain how accurate the quantities are in each of the boxes. Often some of the data, such as billed metered consumption, is very accurate because it is usually derived from customer meter data. However, other components, such as unauthorized consumption, may be much less valid if the water utility has not collected data from individual investigations of unauthorized consumption, instead merely entering an estimate or "best guess" for this quantity. For most utilities, some of the components of the water audit have data that are more accurate, or "valid," than other data. Since the sum of each column has to balance, overestimating one component means one or more of the other components are underestimated. But which components are over- or understated and by how much?

Another uncertainty in the top-down Water Audit Method is the unreported leaks. It is quantified as a "catch-all" component, meaning that the volume of real losses is the quantity that remains after authorized consumption, apparent losses, and reported leakage have been subtracted from the corrected input volume. Although this approach allows the top-down audit to be completed quickly, it results in assigning to unreported loss the collective inaccuracies in quantifying authorized consumption, apparent losses, and reported leakage. As a consequence

1) understating the quantity of authorized consumption, apparent losses, and reported leakage effectively overstates the volume of unreported loss; and

2) overstating the quantity of authorized consumption, apparent losses, and reported leakage effectively understates the volume of unreported loss.

Although the audit worksheet does not require a breakdown of leakage rates between leaks on water mains, leaks on customer services, or tank overflows, it is good practice if records are kept to this level of detail.

The reason that unreported loss is quantified in a "catch-all" method is that a true assessment of all leakage occurring in a distribution system often requires extensive bottom-up work to quantify, which is beyond the scope of the top-down intentions expressed in this publication.

4.1 INDICATING THE LEVEL OF VALIDATION

Since this publication's Water Audit Method uses a top-down approach for expediency, it is important for utilities to not only obtain the results of the water audit, but also a sense of how reliable, or valid, their data are. In order to rate the degree of validity, a scale is included on the worksheet to allow water utilities to assess the various components of the water audit. A composite is then calculated to represent the relative degree of validity of the water audit results.

An assessment table (Appendix 1.3) has been developed using a 1-5 scale for the assignable components of the water audit. A score of 1 represents the lowest degree of certainty of a component. A purely arbitrary estimate of unauthorized consumption that amounts to a "rough guess" is an example of a component that should be assessed with a 1. Conversely, a score of 5 indicates a high degree of accuracy, an example of which might be system input volume derived from measured data gathered from current model, well-calibrated production meters and reliable data management. Assessments of 2, 3, and 4 represent incrementally greater levels of accuracy or validity of the data.

In the drinking water industry, a high level of data accuracy is achieved typically by

- metering water quantities to the greatest extent possible;
- accurately cataloging metered flow data in a billing system or other database; and
- conducting regular maintenance or auditing functions, such as meter testing and calibration, and audits of billing records to detect unauthorized consumption from meter tampering, or similar activities.

Water utilities that carry out all three levels of scrutiny for a given component should assign a high degree of validation to their quantities in the water audit. Systems that perform none of these activities for a given component have poor validity; hence, an assessment of 1 would apply.

Not all components of the water audit can be feasibly metered. Metering production flows and customer consumption is recommended as a minimum. In the absence of meters, estimates must be used.

Water utilities can improve the validity of their water audit data incrementally over time by instituting improvements that raise their scores. If production sources are unmetered, installing meters is a major step to move the utility from low validity to a higher validity. Improvements such as this can be identified from the recommendations listed in Appendix 1.3. A water audit should be compiled annually on the utility's business year frequency and improvements in data validity be incorporated incrementally over time.

4.2 INTERPRETING AND COMPARING WATER AUDIT DATA

The validity assessments on the Water Audit Worksheet are also used to calculate a composite for the entire water audit based on a scale of 85. This composite rates the level of validation for the water audit.

If a water utility is conducting a water audit for the first time and has a collective validation score of less than 40, then the results of the water audit should be viewed as preliminary, and the water utility should begin to carry out activities that improve the validation of the water audit. Improving the measured data from the system's production meters is the recommended starting point. Since data from water audits with a composite at 40 or less are viewed as preliminary, this data should not be benchmarked with other utilities. Likewise, it would be premature to design long-term loss reduction programs and targets on such preliminary data. The water audit data can be best used for tracking performance within the water utility from year to year, until the validity of the water audit is upgraded.

A composite between 40 and 70 represents progressively greater validity in the water audit data. Utilities with assessments in this range can place greater faith in the water audit results, which can be reliably used for planning and developing targeted loss control efforts. Water audits in this range have sufficient validity so that their data can be compared with data from similarly assessed water audits of other water utilities. This also opens the door for performance benchmarking. The utility should continue to address lower assessments in any individual components of the water audit by upgrading procedures or practices in order to improve validation in these areas.

Water audits with an assessment between 70 and 85 reflect mature programs of auditing and loss control with a high level of confidence in the water audit results. Data from these water audits are highly reliable in guiding and tracking advanced programs in apparent and real loss control. Performance tracking within the water utility and benchmarking with similar water audits can be carried out in a reliable manner.

The validation of water audits is an important tool necessary for distinguishing data that are preliminary and approximate in nature versus data that are refined and accurate. The best actions for water utilities to take to improve their water accountability depend to a large degree on the level of validity of their water audit. Appendix 1.3 provides “improvement” guidance for each component in the water audit to allow water utilities to determine the next step to a higher level of validity.

5 *Using Bottom-up Activities to Better Validate the Water Audit Data*

Once water utilities have completed a preliminary, top-down water audit, they will have at least a general assessment of the level of apparent and real loss occurring. If the composite validation of the water audit is below 40, the utility should seek bottom-up activities in those specific audit components that have low scores of 2 or less. If the composite is higher, the utility can seek bottom-up activities that control the larger components of loss. Below are brief descriptions of the most important validation and bottom-up activities that utilities can undertake. (See Appendix 1.3 for additional information.)

5.1 SYSTEM INPUT VOLUME AND CONSUMPTION

5.1.1 Production and Wholesale Meters

Production and wholesale meters measure the large bulk supply volumes, such as source water or purchased water. The collective water from all such meters is entered into the Water Audit Worksheet as the first number under system input volume (line 12). Any notable degree of error in this quantity carries throughout the entire worksheet and can have an unduly negative influence on the accuracy of the water audit. Production and wholesale meters should be current, well calibrated, and continuously monitored, with measured data stored in a reliable billing system or database. Calibrating these meters is relatively inexpensive since they are typically few in number.

5.1.2 Customer Metering for Reliable Billed Consumption Data

The American Water Works Association recommends that water utilities meter all water withdrawn from their distribution system at the customer's point of service. Water utilities that do not meter their customers should seek to establish metering along with billing based upon consumed volumes of water. Billed metered and unbilled metered consumption can then be reliably derived.

5.1.3 Unmetered Consumption

Although utilities should strive to meter all customer consumption, some volume of water will always be withdrawn from the distribution system in unmetered fashion. Water used for fire fighting is a prime example, as well as water taken from fire hydrants for distribution system maintenance and testing. These uses can be metered to the extent possible; however, on an annual basis the total water used as unbilled authorized consumption is usually small. The utility should assign this component secondary priority for bottom-up assessments unless there is a very strong reason to believe that large, continuous uses of water are being consumed in unmetered fashion. In that case, the utility should launch a bottom-up investigation to confirm the existence and quantity of such use.

5.2 APPARENT LOSSES

5.2.1 Customer Meter Accuracy

Standard customer meters used in the United States are generally highly accurate and reliable, with long service lives, some over 20 years. Even with proper sizing and installation all meters will eventually lose accuracy and under-register flow at a rate influenced by the amount of cumulative consumption passed through the meter. Chemically aggressive water may also shorten the lifespan of meter accuracy. Water utilities should monitor the demographics of their customer meter population (for example, age, size, and number) and perform testing on random and targeted samples of customer meters on a periodic basis to project when the limits of acceptable accuracy are expected to be reached. Irrigation meters and commercial meters should be tested first because these meters usually generate the majority of the revenue for the utility. In this way, a high level of accuracy will be ensured throughout the meter population.

5.2.2
Systematic Data Handling Error in Customer Billing Systems

Customer water meters generate readings that allow a water utility to measure the amount of water consumption occurring in a given period of time. However, the meter reading must be accurately transmitted and stored to a proper database, typically a customer billing system. Systematic and random errors can occur in the data transfer and archiving process. For example, when meters are read by humans, numbers can be transposed or viewed incorrectly. A fast-growing number of water utilities have installed automatic meter reading technologies to better allocate human resources, improve safety, and reduce data transfer error in the customer meter reading process. This progressive technology also improves customer service by reducing billing errors related to the above problems.

Most water utilities store customer consumption data in a customer billing system. Although such systems are designed for financial (billing) purposes, they have also become the de facto operational database for tracking customer usage patterns. Many billing systems have incorporated data adjustment and estimate procedures in order to address the variety of billing issues that occur. Unfortunately, sometimes these procedures unduly modify the consumption values in the process of making financial adjustments. An example is a billing routine that generates a credit to a customer by artificially reducing consumption. Although such a routine achieves the desired billing result, it distorts the measure of customer consumption. Utilities should analyze the information flow path in the billing system by flowcharting the process. Such an exercise can often reveal procedures that result in consumption values being understated. Fortunately, such issues are often easily corrected by relatively minor procedural and/or programming changes.

5.2.3
Unauthorized Consumption

There is a certain percentage of any population that will maliciously seek to obtain water service without paying for it. Typical examples include taking water illegally from fire hydrants, tampering with customer meters or meter reading equipment, and illegally tapping into service connections or fire service lines. There are limitless ways to take water in an unauthorized fashion, and every water utility should have in place at least minimal policies and safeguards to thwart, detect, and abate unauthorized consumption. For most systems, the total water lost to unauthorized consumption is small relative to the system input volume, and an approximate estimate should be used in the top-down water audit. Bottom-up activities should include examination of billing data for suspicious consumption patterns (successive periods of zero or lower than average consumption, for example) and follow-up investigation of individual customer properties to confirm evidence of tampering or similar illegal activity. Enforcement policies may need to be strengthened if patterns of unauthorized consumption are chronic and widespread. Such policies could include service discontinuance and criminal judgments.

5.3
REAL LOSSES

All water utilities incur leakage losses; only the amount varies. Leaks and most visible main breaks occur for a variety of reasons, including poor installation workmanship or materials, corrosion, external forces, environmental extremes, and other causes. Leakage is always occurring, and only grows worse if left unchecked. Therefore, all water utilities should provide system maintenance and upkeep functions that include appropriate components of leakage management: active leakage control, timely quality repair, water main rehabilitation, and pressure management.

5.4
ACTIVE LEAKAGE CONTROL

Active leakage control is defined as any water utility program that proactively seeks nonvisible leakage. The most typical functions of active leakage control are routine leak detection surveys and the use of minimum hour flow measurement in District Metered Areas or pressure zones. District Metered Areas are zones or metered areas created within the distribution system to isolate flow to monitor water loss. Large meters are installed on the main lines, and with the aid of "radio read" or similar automated meter technology, the utility is able to compare customer usage to the actual main line flow meter. Although this effort will not pinpoint leaks, it will aid utilities in locating high loss sections so they can begin leak detection surveys with more accuracy.

Leaks and water main breaks that surface and are visible are defined as "reported' since they usually come to the water utility's attention by a report from a customer, police, or other citizen. Most water utilities are effective in addressing reported leaks since these events represent emergency or nuisance conditions. These leaks are addressed quickly so the duration of the leak event is short and volume of water lost is relatively small, even if the leak is spraying at a high rate of flow. Unfortunately, many water utilities respond only to reported leaks and operate no active leakage control programs to identify and control unreported leaks. Unreported leaks usually account for the majority of annual real loss volumes in most water utilities because they are numerous and run undetected for long periods of time. All water utilities should operate an active leakage control program, even if this involves conducting a leak detection survey once every several years. Utilities with extensive and/or aging water distribution systems should operate an ongoing program, with constant leak detection and possible use of District Metered Areas to monitor flows closely and respond to new leakage shortly after it arises. Even for systems that have a good active leakage control program, it is likely that a portion of the leakage will go undetected and, thus, unreported. This volume and the background leakage are collectively labeled "unreported loss" in the Water Audit Worksheet. The top-down Water Audit Method (Appendix 1.1) quantifies unreported loss as a "catch-all" component, meaning that this volume of real losses is the quantity that remains after authorized consumption, apparent losses, and reported leakage have been subtracted from the system input volume.

5.4.1
Timely, Quality Leak Repair Policies and Functions

This practice appears to be straightforward: once a leak or break is known to the water utility, respond quickly and make the repair. This function, however, can be more complicated than it seems. On some occasions, utilities use a "band-aid" repair approach that does not identify the underlying cause of the failure and execute a repair that addresses that root cause. Unfortunately, many leaks occur at the site of previous repairs. Utility policy also plays a role in repair functions. When water utilities play a stronger role in customer service connection leak repairs, leak run time is usually reduced and quality repairs are implemented. Water utility managers should review their leak repair practices and look for ways to ensure that timely, quality repairs are implemented.

5.4.2 Water Main Rehabilitation and Replacement

All infrastructure eventually reaches the limits of its useful service life and must be renewed or replaced. This holds true for water infrastructure, such as pumps, pipelines, valves, hydrants, and appurtenances. In order to capture as much of the original investment in an asset as possible, most utilities want to ensure that the asset remains in service for its entire life. This is achieved by proper maintenance, such as that provided by active leakage control programs and timely repair efforts. At the time in which a water asset reaches the end of its useful life, a number of different options exist. Historically, water utilities relied upon outright replacement as the sole option once an asset reached this stage. Although replacement is the most comprehensive means of renewing an asset, it is also the most expensive option and often requires considerable disruption, such as full trench excavation to replace pipelines. More recently, "trenchless" technologies are providing means to renew pipeline assets without as much above-ground disruption and sometimes at lesser cost than full pipe replacement. All water utilities should have in place a capital program to renew water infrastructure as needed. This program should take into account the variety of options that can efficiently and economically maintain infrastructure integrity.

5.4.3 Pressure Management

Because more water is lost under high pressure conditions than low pressure, pressure management is a recent innovation that strives to reduce water loss. Where appropriate, it reduces excessive background leakage, inhibits the growth of new leakage, and limits the risk of breaks due to pressure transients. Evaluations of water distribution systems across the world have found that 1) many water utilities operate systems with very high pressure; and 2) in many systems, the condition of the piping makes the infrastructure very susceptible to high pressure, particularly poor infrastructure, plastic pipe, and poor service connection piping. Regarding the former, many water utilities have not set realistic upper limits for operating pressures. Additionally, in many distribution systems, pressure may rise during night or minimum consumption hours when customer demand drops. Conversely, when customer consumption is high during the day, pressure drops. Pressure management schemes now exist to regulate night or minimum consumption periods to reduce pressure and save water lost to leakage. During the high demand daytime periods, pressures rise to provide sufficient volume to meet demand. Not all water utilities operate with excessive pressure or have strong pressure management potential. However, all water utilities should understand the range of pressures within their water distribution system, including the occurrence of pressure transients, to judge the feasibility of pressure management to reduce leakage and sustain infrastructure.

6 *Conclusion*

As water utilities incorporate routine water audits as part of their standard business practices, they can expect to become more efficient by focusing on problem areas that were identified in the top-down audits. With decreasing water availability and rising costs for water treatment or purchase, auditing water supplies is essential for water utilities to ensure efficiency in their operations and preserve water resources.

The water audit method featured in this manual is designed to guide water utilities in identifying and quantifying components of water supply, customer consumption, and loss, so they can effectively focus their resources on priority areas of water loss. By implementing appropriate water management programs, these water utilities can extend existing supply resources and minimize the search for additional water resources to supply growing populations.

With routine water auditing and targeted loss control efforts, water utilities can anticipate incremental drops in water loss each year. As with any business plan, it may take several years for utilities to begin to see the effects of implementing this water loss management program. Therefore, goals can be long term but certainly achievable.

7 References

Alegre, H., Baptista, J.M., Cabrera, E., Jr., Cubillo, F., Duarte, P., Hirner, W., Merkel, W., Parena, R., 2000, Performance indicators for water supply services (1st ed.): IWA Publishing, 312 p.

AWWA (American Water Works Association), 2003, Water loss control committee report—Applying BMPs in water loss control: Journal AWWA, vol. 95, no. 8.

8 Acknowledgments

This report was developed by the Texas Water Development Board. Special thanks to TWDB staff John Sutton, Comer Tuck, Mike Parcher, Merry Klonower, and JoAnn Estrada for their knowledge and assistance and to Bill Mullican and Kevin Ward for their management support.

Appendix 1

This page is intentionally blank.

Texas Water Development Board
Water Audit Worksheet

A. Water Utility General Information

1. Water Utility Name: ______________________________

2. Contact: Name ______________________________

   Telephone# ____________ Email Address ______________________

3. Reporting Period: From _____/_____/_____ to _____/_____/_____

4. Source Water Utilization, percentage: Surface Water ______% Groundwater ______%

5. Population Served:

   a. Retail Population Served ____________

   b. Wholesale Population Served ____________

		Assessment Scale
6. Utility's Length of Main Lines, miles	____________	______
7. Number of Wholesale Connections Served	____________	
8. Number of Retail Service Connections Served	____________	
9. Service Connection Density *(Number of retail service connections/Miles of main lines)*	____________	
10. Average Yearly System Operating Pressure (psi)	____________	______

11. Volume Units of Measure (check one):
    _____ acre-ft _____ million gallons ______ thousand gallons ______ gallons

B. System Input Volume

12. Water Volume from own Sources	____________	______
13. Production Meter Accuracy (enter percentage)	____________%	______
14. Corrected Input Volume	____________	
15. Wholesale Water Imported	____________	______
16. Wholesale Water Exported	____________	______
17. **System Input Volume** *(Corrected input volume, plus imported water, minus exported water)*	____________	

		Assessment Scale
C. Authorized Consumption		
18. Billed Metered	____________	____
19. Billed Unmetered	____________	____
20. Unbilled Metered	____________	____
21. Unbilled Unmetered	____________	____
22. Total Authorized Consumption	____________	
D. Water Losses		
23. Water Losses *(Line 17 minus Line 22)*	____________	
E. Apparent Losses		
24. Average Customer Meter Accuracy *(Enter percentage)*	____________%	____
25. Customer Meter Accuracy Loss	____________	
26. Systematic Data Handling Discrepancy	____________	____
27. Unauthorized Consumption	____________	____
28. Total Apparent Losses	____________	
F. Real Losses		
29. Reported Breaks and Leaks *(Estimated volume of leaks and breaks repaired during the audit period)*	____________	____
30. Unreported Loss *(Includes all unknown water loss)*	____________	____
31. Total Real Losses *(Line 29, plus Line 30)*	____________	
32. Water Losses (Apparent + Real) *(Line 28 plus Line 31) = Line 23*	____________	
33. Non-revenue Water (Water Losses + Unbilled Authorized Consumption) *(Line 32, plus Line 20, plus Line 21)*	____________	

Assessment Scale

G. Technical Performance Indicator for Apparent Loss

34. Apparent Losses Normalized
(Apparent Loss Volume/# of Retail Service Connections/365) ______________

H. Technical Performance Indicators for Real Loss

35. Real Loss Volume *(Line 31)* ______________

36. Unavoidable Annual Real Losses, volume (calculated) ______________

37. Infrastructure Leakage Index (calculated) ______________
(Equals real loss volume divided by unavoidable annual real losses)

38. Real Losses Normalized
(Real Loss Volume/# of Service Connections/365) ______________
(This indicator applies if service connection density is greater than 32/mile)

39. Real Losses Normalized
(Real Loss Volume/Miles of Main Lines/365) ______________
(This indicator applies if service connection density is less than 32/mile)

I. Financial Performance Indicators

40. Total Apparent Losses *(Line 28)* ______________

41. Retail Price of Water ______________ _____

42. Cost of Apparent Losses ______________
(Apparent loss volume multiplied by retail cost of water, Line 40 x Line 41)

43. Total Real Losses *(Line 31)* ______________

44. Variable Production Cost of Water* ______________ _____
*(*Note: In case of water shortage, real losses might be valued at the retail price of water instead of the variable production cost.)*

45. Cost of Real Losses ______________
(Real loss multiplied by variable production cost of water, Line 43 x Line 44)

46. Total Assessment Score _____

47. Total Cost Impact of Apparent and Real Losses ______________

This page is intentionally blank.

Appendix 1.2

Water Audit Worksheet Instructions

(All numbers used in this worksheet are for example purposes only)

The following instructions can be used in completing the Water Audit Worksheet. The instructions are labeled by line number shown on the worksheet. The Water Audit Worksheet requests that the water utility enter general information and water supply, consumption, and loss quantities. It also requests assessment scores representing the degree of validation of individual components. For those components that include an assessment line, enter a number between 1 and 5. (See Appendix 1.3 for more information.) If a component does not apply, then enter 0 (for example, if the water utility does not import any water, enter 0 for wholesale water imported). You may visit the TWDB Web site for the online version of the water audit:

http://www.twdb.state.tx.us/assistance/conservation/Municipal/Water_Audit/wald.asp

A. Water Utility Information

1. **Water Utility Name:** List the formal name of the water utility for which the water audit exists.
2. **Contact:** List the name of the primary contact person responsible for completing the water audit for the water utility, the telephone number, and email address.
3. **Reporting Period:** Enter calendar year or fiscal year dates for the reporting period.
4. **Source Water Utilization:** Enter percentages to represent the proportions of surface water and groundwater withdrawn for source water supply. Remember that the total of the two percentages must equal 100%.
5. **Population Served:** List separately the retail and wholesale populations served. You may multiply the number of connections by three if needed to estimate the retail population.
6. **Utility's Length of Main Lines, miles:** List the total length of pipeline in the water distribution system in miles.
7. **Number of Wholesale Connections Served:** List the number of wholesale interconnections supplying water to other water utilities.
8. **Number of Retail Service Connections Served:** List the number of retail customer service connections served by the utility's water distribution system.
9. **Service Connection Density:** Calculate the service connection density by dividing the number of retail customer service connections by the length of miles of pipeline in the water distribution system.
10. **Average Yearly System Operating Pressure:** List the average pressure across the entire water distribution systems for the audit period. If a hydraulic model of the network exists, the average pressure can be calculated by the model; otherwise, an estimate can be used.
11. **Volume Units of Measure:** Select the volume units of measure for the water audit. The units must be consistent throughout the entire water audit. If choosing million gallons for system input (from production meters), then authorized consumption (billed and unbilled) and all other entries must also be entered in million gallons. This typically requires a conversion for billed metered consumption.

B. System Input Volume: The total water supplied to the infrastructure. It is the total of all production meter readings for the entire year. List the volume or percentage requested in each item, along with the scores from Appendix 1.3 that in your judgment best represent the degree of validation of the data.

12. **Water Volume from own Sources:** Includes all water taken as source water from permitted sources, such as rivers, lakes, streams, and wells.
13. **Production Meter Accuracy (enter a percentage):** Achieved by calibrating or verifying the accuracy level (expressed as a percentage) of production meters. For example purposes, if the meter over-registered by 4 percent, enter 1.04; if it under-registered by 4 percent, enter .96.
14. **Corrected Input Volume (calculated automatically online):** The sum obtained when the production meter adjustment is either added to or subtracted from the system input volume. Divide "water volume from own sources" by the production meter accuracy. You must add the decimal point when the calculation is done manually (for example, to .96).

    Example: If "water volume from own sources" registered 1.8 MG/year through two production meters, which were found to be collectively under-registering flow by 4 percent, then the corrected input volume (CIV) is:

Corrected Input Volume = (1,800,000)/(0.96) = 1,875,000

15. **Wholesale Water Imported:** Amount of purchased wholesale water transferred into the utility's water distribution system from other water suppliers.
16. **Wholesale Water Exported:** Amount of wholesale water transferred out of the utility's distribution system. It may be put into the system initially but is only in the system for a brief time for conveyance reasons.
17. **System Input Volume:** Calculated as the corrected input volume plus water imported minus water exported (Line 14, plus Line 15, minus Line 16).

C. Authorized Consumption: All water that has been authorized for use or consumption by the utility or its customers. Remember to convert these volumes into the same units as the water delivery volume. Note: Any type of legitimate consumption should be classified in one of the four components of authorized consumption.

18. **Billed Metered:** All retail water sold and metered.
19. **Billed Unmetered:** All water sold but not metered.
20. **Unbilled Metered:** All water metered but not billed, such as back flushing water, parks, golf courses, and municipal government offices.
21. **Unbilled Unmetered:** All water not billed or metered, such as flushing fire hydrants.
22. **Total Authorized Consumption:** The total of the above four components, automatically calculated in the online worksheet.

D. Water Losses: Water delivered to the distribution system that does not appear as authorized consumption.

23. Calculated as the difference of the system input volume and total authorized consumption (Line 17 minus Line 22).

E. **Apparent Losses:** Water that has been consumed but not properly measured or billed. These losses represent under-registered or under-billed water that occurs via customer meter inaccuracy, systematic data handling error in the customer billing system, and unauthorized consumption:

24. **Average Customer Meter Accuracy:** List the composite accuracy percentage for your customer's meters. This percentage is typically derived from meter testing results. A representative assessment of customer meter accuracy can be obtained by testing as few as 50 meters.
25. **Customer Meter Accuracy Loss:** Obtained by dividing the billed metered water volume by the degree of average customer meter accuracy (Line 18 ÷ Line 24).

    Example: If billed metered (line 18) consumption registered 1.5 MG/year and random meter testing found customer meters to be collectively under-registering flow by 8 percent (so they are 92 percent accurate), then the customer meter accuracy loss is:

    Custom Meter Accuracy = [(1,500,000)/(0.92) – 1,500,000] = 130,434.78 gallons

26. **Systematic Data Handling Discrepancy:** List the estimated volume of water recorded by customer meters but distorted by meter reading or billing system error.
27. **Unauthorized Consumption (theft):** Estimate amount of water loss due to theft. Include an estimate of water taken illegally from fire hydrants, as well as water loss at the customer service connection. Theft at the customer connection can include tampering with meters or meter reading equipment, in addition to illegal taps and other similar occurrences.
28. **Total Apparent Losses:** This value is calculated automatically online as the sum of customer meter accuracy loss, systematic data handling error, and unauthorized consumption.

F. **Real Losses:** These are physical losses from the pressurized water distribution system, including water mains and all appurtenances (for example, valves and hydrants) and customer service connection piping. Real losses represent water that is lost from the distribution system prior to reaching the customer destination.

29. **Reported Breaks and Leaks:** Reported breaks and leaks are brought to the attention of the water utility by customers, public safety officials, other utilities, or other members of the general public. Usually these visible water main breaks are very disruptive and water utilities respond quickly to these events, so the run duration of the break or leak is relatively short. Estimate the total volume of water loss during the water audit period from reported breaks and leaks that were repaired during the year. Leakage flow rates must be estimated for various types of breaks and leaks, as well as the approximate duration of the breaks or leaks prior to repair.
30. **Unreported Loss:** This is a "catch-all" volume, meaning that this volume of real losses is the quantity that remains after authorized consumption, apparent losses, and reported leakage have been subtracted from the system input volume. In every water distribution system, even those employing effective active leakage control programs, there exists some amount of undetected leakage. Some of this loss is comprised of unreported leakage that has not yet been detected in leak surveys. It also includes a subcomponent known as background leakage, which is the collective weeps and seeps at pipe joints and on customer service connections that cannot be detected with acoustic sounding devices. Any degree of error in quantifying metered and estimated volumes in the water audit results in error in this component. As the validation of the water audit improves over time, so will the level of validation of the unreported loss volume.

31. **Total Real Losses:** This value is calculated automatically online as the sum of reported breaks and leaks and unreported loss.

32. **Water Losses:** Calculated as the sum of apparent losses and real losses. This value should equal the value of Line 23. This line is included as a balancing check.

33. **Non-revenue Water:** Calculated as the sum of apparent losses, plus real losses, plus unbilled metered consumption and unbilled unmetered consumption. This is the water that does not contribute to the water utility billings.

G. **Technical Performance Indicator for Apparent Loss:** Performance indicators are quantitative measures of key aspects within the utility. Using these indicators, the utility will have a history to track its performance from year to year. One performance indicator exists for apparent loss.

34. **Apparent Losses Normalized:** Calculated as the volume of apparent loss, divided by the number of retail customer service connections, divided by 365 days. This performance indicator allows for reliable performance tracking in the water utility's efforts to reduce apparent losses.

H. **Technical Performance Indicator for Real Loss:** Several performance indicators exist for real loss.

35. **Real Loss Volume:** This is the quantity from Line 31.

36. **Unavoidable Annual Real Losses:** Calculated reference value using the equation shown in Table 3-2. This is a theoretical value of the technical low level of leakage that might be attained in a given water utility, based upon several system specific parameters.

37. **Infrastructure Leakage Index:** This performance indicator is calculated as the ratio of real losses over the unavoidable annual real losses. The index measures the water utility's leakage management effectiveness and is an excellent performance indicator for comparing performance among water utilities. The lower the value of the infrastructure leakage index, the closer the utility is operating to the theoretical low level of the unavoidable annual real loss. Appendix 1.4 gives general guidance on setting preliminary leakage reduction targets using the infrastructure leakage index without changing water pressure.

38. **Real Losses Normalized:** Calculated as the real loss volume, divided by the number of retail service connections, divided by 365. Use this calculation if the service connection density is greater than, or equal to, 32 per mile. This indicator allows for reliable performance tracking in the water utility's efforts to reduce real losses.

39. **Real Losses Normalized:** Calculated as the real loss volume, divided by the number of miles of pipeline, divided by 365. Use this calculation if the service connection density is less than 32 per mile. This indicator allows for reliable performance tracking in the water utility's efforts to reduce real losses.

I. Financial Performance Indicators

40. **Total Apparent Losses:** List the volume from line 28.
41. **Retail Price of Water:** Water utility rate structures usually feature multiple tiers of pricing based upon volume consumed. For the water audit, it is best to use a single composite price rate to represent the retail cost of water, which is used to place a value on the apparent losses. The largest number of accounts in most utilities is residential accounts; therefore, the residential pricing tier may be used in place of weighted calculations to determine a composite rate.
42. **Cost of Apparent Losses:** Calculated by multiplying the apparent loss volume by the retail price of water. This represents the potential amount of missed revenue due to apparent losses.
43. **Total Real Losses:** List the volume from line 31.
44. **Variable Production Cost of Water:** Marginal production cost including variable costs, which are typically the costs of raw water, energy, and chemicals. If applicable, the cost of raw water should include the price of take or pay contracts. These costs are applied to determine the cost impact of real losses. In cases of water shortage, real losses might be valued at the retail price of water instead of the variable production cost.
45. **Cost of Real Losses:** Calculated by multiplying the real loss volume by the variable production cost of water. These costs represent the additional operating costs incurred by the water utility due to the real losses (in other words, leakage).
46. **Total Assessment Score:** Add the individual assessment scores to obtain a total.
47. **Total Cost Impact of Apparent and Real Losses:** Calculated by adding lines 42 and 45. This amount indicates the cost inefficiency encountered by the water utility for losses. This cost value can be objectively weighed against potential loss control programs to determine the cost effectiveness of such programs.

If you or the utility has any software application questions, please call Mark Mathis at 512-463-0987 or email: mark.mathis@twdb.state.tx.us

For more information on water audits, visit the American Water Works Association Web site: http://www.awwa.org/Resources/topicspecific.cfm?ItemNumber=3653&navItemNumber=1583

Appendix 1.3

Guidance Matrix for Assigning Scores to Components of the Water Audit

COMPONENT	ASSESSMENT TABLE				
SYSTEM DATA	**1**	**2**	**3**	**4**	**5**
Length of mains	Estimates only	Paper records in poor condition (no totals from year to year)	Good annual paper records	Electronic records and asset management system in good condition; includes system backup	GIS data and asset management database in agreement; random field checks validate databases
Improvements in quantifying the length of mains	Research and collect paper records for a number of years prior to audit year	Improve to include all totals for at least five years prior to audit year	Convert to electronic databases with backup	Link GIS and asset management databases; conduct field verification of data	Continue with standardization and random field validation to improve knowledge of system
Average operating pressure	Estimates only	Random pressure testing and averaging	Pressure testing through system standardized on annual basis	Combine pressure testing to calibrate hydraulic model to develop average system pressure	District testing and averaging matching data from hydraulic model
Improvements in quantifying the average operating pressure	Develop total system pressure by averaging known pressure from hydrant and random pressure tests	Improve standardization of pressure testing and recording	Analyze SCADA pressure data and assess average system pressure through hydraulic network modeling	Conduct standardized pressure testing as part of calibration process for developing hydraulic model	Continue with standardization and random field validation to improve knowledge of system; refine hydraulic model
System Data					**10**
WATER SUPPLIED	**1**	**2**	**3**	**4**	**5**
Volume from own sources	No meters; volume quantified by estimates only	Partially metered; several supply sources metered but not all	Fully metered; no regular testing or calibration of meters	Fully metered; partial testing or electronic calibration; no meters greater than 15 years old	Fully metered; annual electronic calibration and flow testing; no meters greater than 15 years old
Improvements in quantifying volume from own sources	Install meters	Complete 100% metering	Initiate testing of meters	Reduce age of meters unless able to prove accuracy of all old meters through flow testing	No new work; standardize calibration, testing, and replacement to ensure this high level of service continues

Appendix 1.3 continued

Production meter accuracy	No testing of production meters; estimated adjustment used only as needed	Testing of production meters only where problems suspected	Systematic testing of meters; underperforming meters not always replaced	Systematic testing of all meters within at least a five-year cycle; all meters over standards replaced or repaired and retested	Testing of all production meters conducted in year of audit; replacement of all meters outside standard accuracy range
Improvements to master meter error adjustment	Start testing program	Develop systematic testing program	Replace or repair all non-standard meters	Test all production meters annually; repair or replace all underperforming meters	No new work; standardize calibration, testing, and replacement to ensure this high level of service continues
Water imported	No meters; volume quantified by estimates only	Partially metered; several supply sources metered but not all	Fully metered; no regular testing or calibration of meters	Fully metered; partial testing or electronic calibration; no meters greater than 15 years old	Fully metered; annual electronic calibration and flow testing; no meters greater than 15 years old
Improvements in quantifying volume of water imported	Install meters	Complete 100% metering	Initiate testing of meters	Reduce age of meters unless able to prove accuracy of all old meters through flow testing	No new work; standardize calibration, testing, and replacement to maintain this high level of service
Water exported	No meters; volume quantified by estimates only	Partially metered; several interconnections metered but not all	Fully metered; no regular testing or calibration	Fully metered; partial testing or electronic calibration; no meters greater than 15 years old	Fully metered; annual electronic calibration and flow testing; no meters greater than 15 years old
Improvements in quantifying volume of water exported	Install meters	Complete 100% metering	Initiate testing of meters	Reduce age of meters unless able to prove accuracy of all old meters through flow testing	No new work; standardize calibration, testing, and replacement to ensure this high level of service continues
Water Supplied					**20**
AUTHORIZED CONSUMPTION	**1**	**2**	**3**	**4**	**5**
Billed metered	No consumption data gathered; flat or fixed rate in use only	Manual meter reads and billings; no regular audits of customer billing data	Automated billing system; no annual checks of data	Automated meter reading and billing system; internally checked or checked by third party on less than annual basis	Automated meter reading and billing system audited by third party on annual basis
Improvements in quantifying volume of billed metered consumption	Start meter reading and volume-based billing; plan computerized billing system	Develop computerized billing system; consider automatic meter reading	Conduct internal checks of billing data; install automatic meter reading	Conduct third-party audit of billed data	Continue and standardize program

Appendix 1.3 continued

Billed unmetered	Estimates of consumption used	Production meters used to determine consumption; all areas not monitored	Production meters used to determine consumption; all areas monitored	District meters (each 3,000 or fewer connections) used to determine consumption; No total coverage; rest use production meters	District meters (each covers 3,000 connections or less) throughout system used to determine consumption
Improvements in quantifying volume of billed unmetered consumption	Develop methods to meter at a higher level (production or district level)	Improve level of monitoring to all areas or consider metering any unmetered accounts	Reduce size of monitored areas or meter unmetered accounts	Reduce size of monitored areas and standardize system analysis, or meter unmetered accounts	Continue and standardize program; all customers who can feasibly be metered are metered
Unbilled metered	No testing; estimates only	Testing only where problems suspected	Systematic testing of all meters; underperforming meters not always replaced	Systematic testing of all meters within at least a five-year cycle; all meters over standards replaced or repaired and retested	Testing of all production meters conducted in year of audit; replacement of all meters outside standard accuracy range
Improvements in quantifying volume of unbilled metered consumption	Start testing program and regular meter readings	Develop systematic testing program; consider automatic meter reading	Replace or repair all non-standard meters; install automatic meter reading	Test all meters annually; repair or replace all underperforming meters	No new work; standardize calibration, testing, and replacement to ensure this high level of service continues
Unbilled unmetered	Overall estimates throughout system	Partial estimates for some of variables; basic estimates for others	Estimates using formulae (for example, time x gallons per flush) for known events	Partial estimates using test data; other estimates using formulae from known number of events	Estimates using previous metered testing to determine overall estimated values
Improvements in quantifying volume of unbilled unmetered consumption	Develop estimates for various unbilled metered events; use default of 1.25% of input volume; change to metered values	Record number of events and develop standard formula for calculating volume, or change to metered values	Conduct test studies of defined duration to determine actual versus estimated volumes, or change to metered values	Conduct test studies on all variables to determine actual versus estimated volumes, or change to metered values	Change to metered values; use of diffuser to accurately determine flushing volume
Authorized Consumption					**20**

Appendix 1.3 continued

APPARENT LOSSES	1	2	3	4	5
Average customer meter accuracy	No testing or replacement; estimates only	Testing or replacement of 1 to 5% of meters in year of audit	Analysis of test data finds meters meeting specs, or testing or replacement of 5 to 10% of meters per year	Previous test data analyzed and all meters in specifications, or testing or replacement of 10 to 50% of meters in year of audit	Previous test data analyzed and all meters in specifications, or testing or replacement of over 50% of meters in year of audit
Improvements in quantifying loss due to customer meter inaccuracies	Conduct testing regime on small number of meters targeted to suspected problem areas such as meter age or type	Standardize testing and test or replace 5 to 10% of meters; consider increasing number of meters tested or replaced after review of test data	Consider increasing number of meters tested or replaced after review of test data	Consider increasing number of meters tested or replaced after review of test data	Consider increasing number of meters tested or replaced after review of test data
Systematic data handling discrepancy	No review of billing system	Automated system but no checks of data validity	Automated system; less than annual checks of data	Automated system; internally checked on at least annual basis	Assessment of data handling errors conducted internally and audited by third party on annual basis
Improvements in quantifying losses due to systematic data handling error	Conduct internal review of meter reading and billing systems	Conduct internal checks on data validity and meter reading procedures	Conduct annual internal checks of billing data	Conduct third party audit of billed data with specific review of possible data handling and meter reading errors	Continue and standardize program
Unauthorized consumption	Arbitrary volume estimates	Default of 0.25% of input volume	Number of events of each type evaluated; multiply by estimated gallons lost per event	Number of occurrences evaluated; monitoring and enforcement program started	Monitoring and enforcement program well established with analyzed losses less than 0.25% and declining from previous years
Improvements in quantifying volume of unauthorized consumption	Develop estimates for likely major incidents of unauthorized consumption; use default of 0.25% of input volume	Evaluate number of occurrences of each of major incidents of unauthorized consumption	Identify losses and aim to reduce; audit areas of suspected losses; examine policy and procedures for gaps allowing fraud	Put in place a monitoring and enforcement plan to show reductions in water lost; implement improved policy and procedures for better policing	Continue with monitoring and enforcement program; review at least annually; consider new regulations to thwart specific incidents of unauthorized consumption
Apparent Losses					**15**

Appendix 1.3 continued

REAL LOSSES	1	2	3	4	5
Reported leaks	Arbitrary estimates; repairs of reported leaks and breaks not documented	Only visual leaks and breaks from customer calls fixed; no known duration before fixing; cursory records	Visual leaks and breaks reported by customers and city staff; call-to-repair times known (greater than one week average); good records	Visual leaks and breaks reported by customers and city staff; call-to-repair times average less than one week; computerized maintenance management system used to document leak repair trends	Visual leaks and breaks reported by customers and city staff; call-to-repair times average less than two days; outstanding computer maintenance records track system deficiencies and repair crew performance
Improvements in quantifying reported leaks	Report leaks and breaks and develop standards to find, repair, and document leaks and breaks	Standardize recording of leak location and repair data	Continue to standardize recordkeeping process; plan computerized maintenance management system; cut average leak run time to less than one week	Implement computerized maintenance management system to document repairs; reduce leak run time average to less than two days; plan proactive leak detection	Use capabilities of computerized maintenance management system to track failure trends in distribution system and repair crew activity costs; conduct proactive leak detection
Unreported loss	If no active leakage control activities exist, unreported leaks are undetected and quantity is zero	Limited leak detection using basic sounding performed for a portion of the distribution system; no detailed records/database	Proactive leak detection using basic sounding, correlation, and detailed leak detection records; one or more District Metered Areas in use	Proactive leak detection using basic sounding, correlation, flow monitoring, and detailed leak detection and asset condition records; detailed component analysis results	Fully integrated flow monitoring and leak detection program with continuous reporting and analysis of system leakage; integration with asset management, GIS, and economic level of leakage
Improvements in quantifying unreported loss	Plan proactive leak detection, and/or evaluate the feasibility of continuous flow monitoring in one or more District Metered Areas	Upgrade leak detection capabilities using electronic correlation; set structured leak survey schedule; improve detail of records/database	Improve sonic leak detection and flow monitoring capabilities; improve records to include analysis of asset condition; conduct a component analysis by estimating leak run times and repair times	Fully integrate all leak detection and asset management functions; continue to install District Metered Areas as economically feasible; start to analyze economic level of leakage	Continue to standardize and audit on regular basis
Real Losses					**10**

Appendix 1.3 continued

COST DATA	1	2	3	4	5
Customer retail unit cost (applied to apparent losses)	Estimates only	Residential rate only	Weighted average residential rate using volumes in each rate block	Weighted average combination usage rate (includes residential, commercial, and industrial)	Third-party reviewed; weighted average combination usage rate (includes residential, commercial, and industrial)
Improvements in quantifying the annual retail unit costs	Conduct structured audit	Evaluate volume of water used in each usage block by residential users; multiply volumes by full rate structure	Evaluate volume of water used in each usage block by all classifications of users; multiply volumes by full rate structure	Conduct a third-party audit of water used in each usage block by all classifications of users; multiply volumes by full rate structure	Continue with this program
Variable production cost (applied to real losses)	Estimates only	Extrapolated from evaluation of partial system electric and chemicals costs	Non-audited evaluation of total system electric and chemical costs	Internally audited wholesale, electric, and chemical costs	Third party audited wholesale, electric, chemical, and detailed support costs annually
Improvements in quantifying the variable production costs	Conduct structured audit	Conduct cost evaluation of total system electric and chemical costs	Conduct an annual internal audit	Conduct a third-party audit	Continue with this program
Cost Data					**10**
				Total Score	**85**

Appendix 1.4

American Water Works Association General Guidelines for Setting a Target Infrastructure Leakage Index

(without a full economic analysis of leakage control options*)

Once data has been entered into the Water Audit Worksheet, the performance indicators are automatically calculated. The Water Loss Control Committee of the American Water Works Association provided the following table to assist water utilities in gauging an approximate infrastructure leakage index that is appropriate for their water system and local conditions. The lower the amount of leakage and real losses that exist in the system, the lower the infrastructure leakage index will be.

Target Infrastructure Leakage Index Range	**Financial Considerations**	**Operational Considerations**	**Water Resources Considerations**
1.0 - 3.0	Water resources are costly to develop or purchase; ability to increase revenues via water rates is greatly limited because of regulation or low ratepayer affordability.	Operating with system leakage above this level would require expansion of existing infrastructure and/or additional water resources to meet the demand.	Available resources are greatly limited and are very difficult and/or environmentally unsound to develop.
>3.0 - 5.0	Water resources can be developed or purchased at reasonable expense; periodic water rate increases can be feasibly imposed and are tolerated by the customer population.	Existing water supply infrastructure capability is sufficient to meet long-term demand as long as reasonable leakage management controls are in place.	Water resources are believed to be sufficient to meet long-term needs, but demand management interventions (leakage management and water conservation) are included in the long-term plan.
>5.0 - 8.0	Cost to purchase or obtain/treat water is low, as are rates charge to customers.	Superior reliability, capacity, and integrity of the water supply infrastructure make it relatively immune to supply shortages.	Water resources are plentiful, reliable, and easily extracted.
Greater than 8.0	Although operational and financial considerations may allow a long-term infrastructure leakage index greater than 8.0, such a level of leakage is not an effective use of water as a resource. Setting a target level greater than 8.0 other than as an incremental goal to a smaller long-term target is discouraged.		
Less than 1.0	If the value of the infrastructure leakage index for your system is 1.0 or less, two possibilities exist: 1) You are maintaining your leakage at low levels in a class with the top worldwide performers in leakage control; or 2) A portion of your data may be flawed, causing your losses to be greatly understated. This is likely if you calculate a low value but do not employ extensive leakage control practices in your operations. In such cases, it is beneficial to validate the data by performing field measurements to confirm the accuracy of production and customer meters or to identify any other potential sources of error in the data.		

**Note:* This table offers an approximate guideline for setting leakage reduction targets. The best means of setting such targets include performing economic assessments of various loss control methods. However, this table is useful if such assessments are not possible or a preliminary target is desired.

Appendix 2

This page is intentionally blank.

Form A

Leak Detection and Repair Field Guide

Utility Name: ______________________________________ Date:______________________________

A. Area to be Surveyed

1. The area in the distribution system to be surveyed should be mapped using the results of the water audit. Give higher priority to areas with high leak potential. (Items to consider include records of previous leaks, type of pipe, age of pipe, soil conditions, pressures, ground settlement, and installation procedures.)

2. Estimate the total miles of main to be surveyed (excluding service lines).

3. Estimate the average number of miles of main to be surveyed per day.

4. Describe the equipment and procedures that will be used to detect leaks.

5. Estimate the number of working days needed to complete the survey.

B. Procedures and Equipment

1. Experience has shown that the best results have been obtained by listening for leaks at all system contact points, such as water meters, valves, hydrants, and blow-offs.

2. The average two-person survey crew can survey about two miles of main per day if the main is located in a city or subdivision and all valves, hydrants, and meters are checked.

3. Items to consider include distances between services and total number of listening points.

4. If not listening for leaks at all available listening points, what plans will be made for checking missed points later? A portable listening device, field notebook, hammer, screwdriver, flashlight, and cover key are essential items. The leak surveyor should note broken valves, hydrants, meters, or other unserviceable equipment in addition to location, size and type of leak, or other water loss condition observed.

5. Describe how the leak detection team and the leak repair crew will work together. A leak is normally reported by a citizen or utility employee who sees the water leaking out of the ground or building. The leak detection team should be called in first or at the same time as the repair crew to pinpoint the leak. In other cases, the leak detection crew might discover a leak, pinpoint it, and initiate the work order.

6. What measures will be used to minimize the chance of digging "dry holes"?

7. Describe the methods that will be used to determine the flow rates for excavated leaks. Formulas for calculating approximate flow rates for typical leaks are presented in Appendix 2.1.

C. Leak Detection Survey Budget

	Number of Days	$/Day	Cost
Utility Crew Cost			
Consultant Crew Cost			
Vehicle Cost			
Cost of Leak Detection Equipment			
Supervision and Administration			
Other Costs			
Total Estimated Costs			

D. Leak Survey and Repair Schedule

Indicate realistic, practical dates.

	Start Dates		Completion Dates
Phase 1			
Area 1		Area 1	
Area 2		Area 2	
Area 3		Area 3	
Phase 2			
Area 1		Area 1	
Area 2		Area 2	
Area 3		Area 3	

Prepared by ______________________________ Date _____/_____/_____

Title ______________________________

Form B

Leak Detection Survey Daily Log

Date:____________________ Crew:____________________________ Survey Time:______________

Area:____________________________________ Vehicle:_____________________________________

Weather:____

Starting Address: ____

Ending Address: ____

Route:____

Miles Surveyed:____

Brief description of each leak discovered/suspected (size and location):

1)

2)

3)

4)

5)

6)

Notes:

Signed (Crew Chief):

This page is intentionally blank.

Form C

Leak Repair Summary Report

By:______________________________ Date: ___________________________________

Work Order #: ______________Crew: _________ Date Completed:______________

Area/Location: ____

Found per Leak Detection Survey (Attached)? _______________________________

LEAK TYPE				PIPE MATERIAL			
	Meter Leak		Fire Hydrant		Galvanized Iron		A.C.P.
	Meter Spud		Meter Yoke		Black Iron		Steel
	Valve		Joint		Ductile Iron		PVC
	Curb Stop		Main		Cast Iron		Copper
	Service		Other		Polybutylene		Transite

OTHER INFORMATION

Depth to top of pipe ____ (ft) Type of bedding_______ Type of backfill________________

Leakage rate __________ (gpm) (___Measured ___Estimated) Estimated age of leak __________

Estimated water lost _________ (gal) Previous repairs? ___________________________

How was leak repaired (previous/this time)?____

____(Attach "Before" and "After" Photos)

Shape and dimensions ___________________ Original wall thickness of pipe __________(in)

System pressure measured__________ ? Corrosion ________? Outside_________ Inside ______

COST OF REPAIRS

Labor Costs:

Total hours worked _____________ x Average hourly rate $ _____________ = $ _____________

Equipment Cost:

Equipment Used	Hours Used	X	Cost of Equipment	=	Total Equipment Cost
1. ________________	________	X	$ ____________	=	$ ______________
2. ________________	________	X	$ ____________	=	$ ______________
3. ________________	________	X	$ ____________	=	$ ______________
4. ________________	________	X	$ ____________	=	$ ______________

Material used____ Cost $ ______________

Administrative/Supervisory/Other Cost __________________ $ ______________

Total Cost of Repairs $ ______________

Follow-up listing test?__________________________(date) OK? ______________

Supervisor's Signature ____

This page is intentionally blank.

Form D

Line Flushing Report

Date	Location	GPM		Time	Gallons
			X		
			X		
			X		
			X		
			X		
			X		
			X		
			X		
			X		
			X		
			X		
			X		
		Total Gallons			

Remarks: ______________________________

____

____

____

____

Signature: ______________________________

This page is intentionally blank.

Form E

Water for Fire Fighting and Training

Fire Department Name: ____________________

City or System Name: ____________________

Month: ____________________ Tank Size: ____________________ (gal)

1 ____________	16 ____________
2 ____________	17 ____________
3 ____________	18 ____________
4 ____________	19 ____________
5 ____________	20 ____________
6 ____________	21 ____________
7 ____________	22 ____________
8 ____________	23 ____________
9 ____________	24 ____________
10 ____________	25 ____________
11 ____________	26 ____________
12 ____________	27 ____________
13 ____________	28 ____________
14 ____________	29 ____________
15 ____________	30 ____________
	31 ____________

Monthly Total: ____________________

This page is intentionally blank.

Appendix 2.1

Leak Rates from Holes of Known Sizes

Gallons per minute (gpm)						
Area of leak square inches	Pressure pounds per square inch (psi)					
	10	20	40	60	80	100
0.005	0.5	0.8	1.1	1.3	1.5	1.7
0.010	1.1	1.5	2.2	2.6	3.1	3.4
0.025	2.7	3.8	5.4	6.6	7.6	8.5
0.050	5.4	7.6	11	13	15	17
0.075	8.1	11	16	20	23	26
0.100	11	15	22	26	31	34
0.200	22	31	43	53	61	68
0.300	32	46	65	79	92	102
0.400	43	61	86	106	122	136
0.500	54	76	108	132	153	171
0.600	65	92	129	159	183	205
0.700	76	107	151	185	214	239
0.800	86	122	173	211	244	273
0.900	97	137	194	238	275	307
1.000	108	153	216	264	305	341
1.100	119	168	237	291	336	375
1.200	129	183	259	317	366	409
1.300	140	198	280	343	397	443
1.400	151	214	302	370	427	478
1.500	162	229	324	396	458	512
1.600	173	244	345	423	488	546
1.700	183	259	367	449	519	580
1.800	194	275	388	476	549	614
1.900	205	290	410	502	580	648
2.000	216	305	431	528	610	682
2.500	270	381	539	661	763	853
3.000	324	458	647	793	915	1,023
4.000	431	610	863	1,057	1,220	1,364

The above table is based on the following formula:

Flow = 2.8 x Area x Square Root of (148 x Pressure)
Flow – gallons per minute (gpm), Area – square inches, Pressure – pounds per square inch (psi)

Example use of Appendix 2.1:
A hole 1/8 inch by 1¼ inch in size at 50 pounds per square inch
First calculate the area:
1/8 inch = 0.125 inches, 1¼ inch = 1.25 inches, Area = 0.125 x 1.25 = 0.156 square inch
From the table, the size that is closest is 0.1 and 0.2 square inches, and the pressure is between 40 and 60 pounds per square inch. The flow rate is going to be about 36 gallons per minute.

Texas Water Development Board
Brochures, Services, and Leak Detection Equipment

The Texas Water Development Board is a nonregulatory state agency that provides many services to water utilities around the state. These services include providing brochures, conducting Water Audit/ Leak Detector Workshops, and loaning leak detectors and ultrasonic flow meter equipment free for 30 days.

BROCHURES

The brochures we provide cover numerous topics, including lawn irrigation, water wise plants, and utility information. Most of these are available in Spanish. A complete list of brochures can be found on our Web site, http://www.twdb.state.tx.us/assistance/conservation/pubs.asp. We are able to send up to 500 brochures per year at no charge to water utilities, river authorities, and other governmental agencies.

WORKSHOPS

Water Audit/Leak Detector Workshops are available anytime of the year. This is a Texas Commission on Environmental Quality-approved workshop that entitles each operator four hours of credit toward renewing their operator's license. This workshop discusses how a system can achieve maximum efficiency by implementing a leak detection program and conducting a comprehensive water audit. The Texas Water Development Board presenter will travel to your system and conduct the workshop; all necessary training materials will be provided. To be eligible for this workshop, the sponsoring system is responsible for providing a training room and scheduling with other systems to ensure a class size of no less than 10 attendees. Workshop agendas and other relevant information are available by contacting Mark Mathis, 512-463-0987 or by accessing our Web site:

http://www.twdb.state.tx.us/assistance/conservation/Municipal/Water_Audit/Leak_Detection/LeakDetection_Workshop.asp

ASSISTANCE

TWDB staff is also available to consult with utility personnel regarding water loss and in completing the Water Audit Worksheet.

EQUIPMENT

Our free equipment, an LD-12 and Panametrics, are both available for loan for 30 days. The LD-12 is an acoustical sounding device that helps pinpoint leaks and ruptured pipes. The device has headphones and a ground microphone. The Panametrics (an ultrasonic device) works with transducers that are placed onto the pipe near the master meter. This equipment will verify the flow rates going through the master or source meters.

Once again, all of this information is provided without cost to your utility. To implement one or all of these services, call Mark Mathis at 512-463-0987 or access our Web site:

http://www.twdb.state.tx.us/assistance/conservation/consindex.asp

Texas Water Development Board
P.O. Box 13231, Capitol Station
Austin, Texas 78711-3231