SHREWSBURY WATER AUDIT REPORT

TH No. 2614

February 2014

TATA & HOWARD

Water Audit Report
Shrewsbury, Massachusetts

Prepared by:

TATA & HOWARD

February 2014

TATA & HOWARD

February 20, 2014

Mr. Robert Tozeski, Superintendent
Town of Shrewsbury, Water & Sewer
Richard D. Carney Municipal Office Building
100 Maple Avenue
Shrewsbury, MA 01545

Subject: Water Audit Report
Shrewsbury, Massachusetts
T&H No. 2614

Dear Mr. Tozeski,

In accordance with our agreement, Tata & Howard is pleased to present you with four copies of the Water Audit Report. The report includes assessing the amount of unaccounted-for water, identifying sources of lost water, and completing water audit worksheets with calculated water losses, infrastructure leakage index (ILI), Unavoidable Annual Real Losses (UARL), and Current Annual Real Losses (CARL).

The results using both Water Management Act (WMA) and American Water Works Association (AWWA) water audit forms and procedures are presented and discussed in Section 9 of the draft report. Recommendations are discussed in Section 10. These recommendations will improve record keeping and increase the validity score for the data as shown in the AWWA water audit. They will also assist in lowering the Town's unaccounted-for water as shown in the WMA water audit. The recommendations include performing leak detection surveys, documenting breaks, leaks, and all unmetered water usage, testing and calibrating the master meters, completing the service meter replacement program for both residential and commercial meters, testing new customer meters prior to installation, developing procedures to identify and address discrepancies in billing results, continued implementation of water conservation measures, continuing to review SCADA data to highlight anomalies, and updating the Water Audit Report to include 2013 data.

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During the course of this project, Ms. Justine Carroll, P.E. served as Project Manager and Ms. Victoria Zabierek served as Project Engineer, with the undersigned as Project Officer. Ms. Stephen Rupar, P.E. provided technical reviews.

At this time, we wish to express our appreciation to the Town for their participation in this report and for their help in collecting information and data. Special thanks are given to Mr. Robert Tozeski and Mr. Steve Johnson for contributions to this report. We appreciate the opportunity to assist the Town on this important project.

Sincerely,

TATA & HOWARD, INC.

Paul B. Howard, P.E.
Senior Vice President

Enclosure

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SECTION 1

TATA & HOWARD

SECTION 1 – Executive Summary

1.1 General

Tata & Howard, Inc. was retained by the Town of Shrewsbury (Town) to complete a water audit of Shrewsbury's water distribution system. The project included assessing the amount of unaccounted-for water, identifying sources of lost water, and completing water audit worksheets with calculated water losses, infrastructure leakage index (ILI), Unavoidable Annual Real Losses (UARL), and Current Annual Real Losses (CARL).

1.2 Purpose of Water Audit

The purpose of a water audit is to review and analyze the volume pumped from each source, source meter errors/calibration, the volume of imported and exported water, billed and unbilled consumption, recorded leakage, main breaks, and unauthorized consumption. There are two separate guidelines that can be used to complete a water audit. The first is the Massachusetts Department of Environmental Protection's (MassDEP) *Water Management Act Program Guidance Document for a Water Audit and Leak Detection Survey.* The forms associated with the Water Management Act (WMA) Program water audit were completed using the Town's data from 2010, 2011, and 2012 and are attached in Appendix A. The second is the American Water Works Association's (AWWA) *Water Audits and Loss Control Programs, Manual of Water Supply Practices – M36, Third Edition,* published in 2009. The AWWA M36 worksheets were completed using Town data from 2012 and are in included in Appendix B.

Water Management Act Program – Water Audit

A water audit, as outlined in the WMA program, identifies the discrepancy between the volume of water pumped into the system and the volume of water sold. This volume of water is known as unaccounted-for water. The WMA water audit examines master meter and service meter records, billing procedures, and record keeping, and identifies potential sources of unaccounted-for water. Known water use that is not metered and not billed is broken into two categories; unmetered authorized public uses and unmetered miscellaneous losses. These are discussed in greater detail in Section 5 and Section 6 of this report. The unaccounted-for water is then adjusted to reflect these known losses of water.

The most significant component of the WMA water audit is the assessment of the quantity of unaccounted-for water. Sources of unaccounted-for water include:

- Inaccurate Master Meters – This can lead a community to believe they are pumping more water than they actually are.
- Inaccurate Industrial and Commercial Meters – It is important that all service meters are properly sized and installed. A meter that is too large may not register low flows, and a meter that is too small may produce excessive drops in pressure, causing it to wear out in a short period of time.

- Inaccurate Domestic Meters – The older a meter is, the less accurate it becomes.
- Unmetered Authorized Uses – These include water used for water and sewer main testing and flushing, fire fighting and fire fighting training.
- Unmetered Miscellaneous Losses – These include bleeders, backwash waters, unauthorized connections, and theft.
- Underground Leakage – Underground leakage, as determined by a leak detection survey, is principally caused by soil movement or corrosive soil conditions in the ground around a water transmission main. Leakage also tends to occur more in the older pipes in the system.

American Water Works Association – Water Audit

The AWWA water audit is a top down approach that allows for more comprehensive quantification of both consumption and losses within the distribution system. This approach helps to identify system components that may require further investigation and validation in future audits. Properly performing the AWWA water audit and executing the recommended loss control programs provides benefits in four key areas: water resource management, financial performance, operational performance and system integrity by reducing the potential for contamination within the system. Improvements in these areas help reduce unnecessary or wasteful water withdrawals, optimize revenue recovery, reduce system interruptions, increase efficiency, increase the reliability of the system data, and reduce the potential for contamination within the distribution system.

The AWWA water audit uses a water balance calculation summarizing system inputs, consumption, and losses. There is no unaccounted-for water component with this approach. All water is considered either revenue or nonrevenue water. Revenue water is that which is billed to a customer. Nonrevenue water is the water produced that is not billed and produces no revenue and includes unbilled metered water, unbilled unmetered water, and both apparent and real water losses. The Infrastructure Leakage Index (ILI) is the ratio of current annual real losses (CARL) to the unavoidable annual real losses (UARL), the theoretical minimal real losses that a system could achieve using best current technology and management practices. Estimation of ILI allows water utilities to benchmark performance and compare it to other utilities, both locally and nationally.

Apparent losses are losses associated with the distribution system that occur when water is successfully delivered to the customer but is not measured or recorded accurately. These losses have two major impacts for the utility. First, by under billing a customer, the utility does not collect all the revenue it is entitled to and, second, by under recording the amount of customer consumption, the utility is not able to properly make decisions regarding the appropriate capacity of its water supply infrastructure and evaluate conservation practices. There are three components of apparent losses: customer meter inaccuracy, consumption data handling errors, and unauthorized consumption. These components are discussed in further detail in Section 5.

Real losses are physical losses of water from the distribution system and occur because of breaks and leaks in water mains, service connection pipes, joints, and fittings.

Additionally, real losses can also occur because of leaks or overflows at storage facilities. Real losses have two major impacts on the utility. The first is the additional cost to treat and deliver water throughout the distribution system that does not provide any benefit to the utility or its customers. The second is the additional cost to build and maintain additional or larger capacity treatment facilities, storage facilities, and pumping facilities designed and constructed to accommodate the water that will be lost.

Results and Recommendations

The results using both WMA and AWWA water audit forms and procedures are presented and discussed in Section 9. The unaccounted-for water using the WMA water audit forms is approximately 13.5 percent. According to the AWWA water audit, UARL is 88.5 million gallons (mg), CARL is 295.8 mg, and the system ILI is 3.34.

Recommendations are discussed in Section 10. These recommendations will improve record keeping and increase the validity score for the data as shown in the AWWA water audit. They will also assist in lowering the Town's unaccounted-for water as shown in the WMA water audit. The recommendations include performing leak detection surveys, documenting breaks, leaks, and all unmetered water usage, testing and calibrating the master meters, completing the service meter replacement program for both residential and commercial meters, testing new customer meters prior to installation, developing procedures to identify and address discrepancies in billing results, continued implementation of water conservation measures, continuing to review SCADA data to highlight anomalies, and updating the Water Audit Report to include 2013 data.

SECTION 2

TATA & HOWARD

SECTION 2 – System Description and Operations

2.1 System Description

The Shrewsbury water distribution system services approximately 35,600 residents with approximately 11,234 services and is 100 percent metered. The current system is comprised of approximately 200 miles of water mains. The pipe diameters range from four to 16 inches. These mains are constructed of various materials including cement lined ductile iron (CLDI), cast iron (CI), asbestos cement (AC), and polyvinyl chloride (PVC). The water distribution system contains seven active groundwater supply sources at three locations, six water storage facilities, three booster pump stations, a water treatment facility, and two emergency interconnections. The distribution system is divided into three separate pressure service areas, the Low (LSA), High (HSA) and Reduced High Service Areas (RHSA).

2.2 System Operations

The LSA has a hydraulic gradeline elevation (HGL) of approximately 600 feet. Ground elevations range from approximately 350 feet to 535 feet. The LSA constitutes approximately 35 percent of the overall system demands. The RHSA has a HGL of approximately 680 feet and ground elevations range from approximately 360 feet to 595 feet. The RHSA constitutes approximately 33 percent of the overall demand. The HSA has a HGL of approximately 800 feet and ground elevations range from approximately 425 feet to 740 feet. The HSA constitutes approximately 32 percent of the overall demand.

Home Farm Water Treatment Plant

The Home Farm Water Treatment Plant (WTP) was constructed in the early 1990's with a design capacity of approximately 6.0 mgd for VOC removal using air strippers. Water from the Home Farm Wells and Lamberts Wells are treated through the air strippers. The air strippers also effectively remove a percentage of the carbon dioxide in the water, thereby increasing the pH and reducing the amount of potassium hydroxide needed for pH adjustment. A sequestering agent is added to the supply for the sequestering of iron and manganese, potassium hydroxide is added for further pH adjustment, chlorine gas is added for disinfection, and hydrofluosilicic acid is used for fluoride treatment.

A 12-inch transmission main conveys water from Sewall Well No. 4 to the Home Farm WTP. The Sewall transmission main is connected to the finished water transmission main outside of the WTP. The treated water from the Home Farm and Lamberts wells is mixed with raw water from the Sewall supply.

Water Storage Facilities

The Town currently operates three water storage facilities in the LSA, two water storage facilities in the HSA, and one water storage facility in the RHSA. Information about the water storage facilities is summarized in Table No. 2-1.

Table No. 2-1
Water Storage Facility Summary

Name	Service Area	Overflow Elevation (ft)	Capacity (MG)
Browning Street Tank	LSA	600	1.0
Oak Street Tank	LSA	598	0.45
Hillside Drive Tank	LSA	596	1.0
Masonic Hill Tank No. 3	HSA	800	1.25
Masonic Hill Tank No. 4	HSA	800	1.0
Temple Hill Tank	RHSA	680	1.25

Booster Pump Stations

There are three booster pump stations in Shrewsbury. The West Main Street Booster Pump Station and the Gulf Street Booster Pump Station pump water from the LSA to the HSA. The Oak Street Booster Pump Station pumps water from the LSA to the RHSA.

Emergency Interconnections

The Town of Shrewsbury has two emergency interconnections with the City of Worcester, on Hartford Turnpike (Route 20) and on West Main Street. The West Main Street interconnection requires a temporary connection from hydrant to hydrant. The Hartford Turnpike interconnection is a metered connection. Due to the HGL in the City of Worcester, Shrewsbury can receive water from Worcester in an emergency, but Worcester cannot receive water from Shrewsbury.

Water Conservation Efforts

The Town has been committed to promoting water conservation and educating consumers. Water conservation tips are incorporated into newsletters that are distributed throughout the community, are available at the Towns offices, and are sent out with the water bills. The Town has teamed up with the Great American Rain Barrel Company to offer discounted rain barrels to all its customers. The program was initiated in February 2014. The rain barrels are made from recycled 55 gallon food grade plastic drums and come equipped with a five foot hose and shutoff valve. The program allows the community to manage its natural water resources, prevent storm water runoff, and save money. The Town's website also features links and information regarding their Water Conservation Project and the Rain Barrel Program.

SECTION 3

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SECTION 3 - Water Supplied to Distribution System

3.1 Sources

In accordance with their most recent Water Management Act (WMA) permit (Permit No. 9P4-2-12-271.01), issued in January 2014, the Town is currently authorized to withdraw a maximum daily rate of 7.87 million gallons per day (mgd) and an annual average day rate of 4.17 mgd from their seven supply sources. A summary of the maximum withdrawal volumes for each source is shown in Table No. 3-1.

Table No. 3-1
Approved Well Withdrawal Volumes

Source Name	Permitted Withdrawal Volumes (mgd)
Home Farm Well No. 6-1	4.32
Home Farm Well No. 6-2	3.02
Home Farm Well No. 6-3	*
Home Farm Well No. 6-4	*
Home Farm Wells Total:	**5.4**
Lamberts Well No. 3-1	0.75**
Lamberts Well No. 3-2	0.58
Sewell Well No. 4	1.14
Total:	**7.8*** **

*Home Farm Wells Nos. 6-3 and 6-4 were installed as supplemental wells. The combined withdrawal rate for Home Farm Well No. 6-1, 6-3, and 6-4 cannot exceed 4.32 mgd and the total maximum withdrawal volume from all of the Home Farm Wells cannot exceed a maximum daily pumping rate of 5.4 mg.
**The existing Lamberts Well No. 3-1 is currently not utilized due to a collapsed well screen. A replacement well is currently under construction.
*** The total amount pumped from all of the Town's sources cannot exceed 7.8 mgd based on Shrewsbury's interbasin transfer limit.

3.2 Master Meters

Home Farm Wells No. 6-1 and 6-4, Lamberts Wells No. 3-1 and 3-2, and Sewell Well No. 4 have individual master meters. A flow meter inside the meter vault at the WTP measures the combined flow from Home Farm Wells No. 6-2 and 6-4. Flow from Home Farm Well No. 6-2 is calculated by deducting the total flow from Home Farm Well No. 6-4 from the total flow from Home Farm Wells No. 6-2 and 6-4. A second master meter in the meter vault measures the total raw water flow into the treatment plant from the four Home Farm Wells and the two Lamberts Wells. The flow from Home Farm Well No. 6-3 is calculated by deducting the total flow from the other three Home Farm Wells and the two Lambert Wells from the total flow from the Home Farm and Lambert Wells entering the air strippers at the Water Treatment Plant. There is also a finished water master meter

that records the flow entering the distribution system from the WTP. Master meters are a potential source of large errors in the water system due to the high volumes of water each meter registers every day. Sewall Well No. 4 was upgraded and the master meter was replaced in 2012. The master meter at Home Farm Well No. 6-4 was installed with the well in 2012. A new master meter will be installed at the Lamberts Well No. 3-1 replacement well. The existing well and master meter will be properly abandoned when the replacement well is completed. The Town uses a Supervisory Control and Data Acquisition system (SCADA) to record the locally measured quantities continuously. Each day's SCADA readings are generally reviewed and manually checked for any obvious anomalies and for reasonableness.

The MassDEP recommends that master meters be calibrated once a year. The Town's master meters are tested annually for accuracy and, if necessary, calibrated to within American Water Works Association (AWWA) accuracy limits. The master meters are tested and calibrated by Control Systems Services. The testing results for 2010, 2011, and 2012 are shown on Form 4 in Appendix A. The average master meter error adjustment over the three years is shown on Form 6 in Appendix A. The master meter error adjustment for 2012 is shown in Appendix B.

Based on the review of the Annual Statistical Reports (ASR), the Town has supplied an average of approximately 1,334 mg of water per year over the past three years. The total uncorrected water supply volumes are shown in Table No. 3-2, in Figure No. 3-1, and are also reported in Form 1 of the water audit forms located in Appendix A. In 2010, 2011, and 2012, the average day demands for the Town's system were 3.64 mgd, 3.69 mgd, and 3.66 mgd, respectively. The annual fluctuations in demand and volumes pumped from the Town's sources by month in 2010, 2011, and 2012 are shown on Figures Nos. 3-2, 3-3, and 3-4. Pumpage totals for each well are based on SCADA recordings from the Town's master meters.

Table No. 3-2
Uncorrected Total Water Supply*

Well	2010	2011	2012
Home Farm Well No. 6-1	366.25	358.64	119.36
Home Farm Well No. 6-2	420.31	324.84	277.06
Home Farm Well No. 6-3	141.17	262.72	241.18
Home Farm Well No. 6-4	-	-	295.28
Lamberts Well No. 3-1	99.35	67.23	54.36
Lamberts Well No. 3-2	70.27	41.88	56.61
Sewall Well No. 4	230.65	284.72	291.36
Total Water Supplied:	**1,328.00**	**1,340.02**	**1,335.19**

*Values are reported in mg.

Figure No. 3-1
Historical Water Production
Water Audit Report
Shrewsbury, Massachusetts

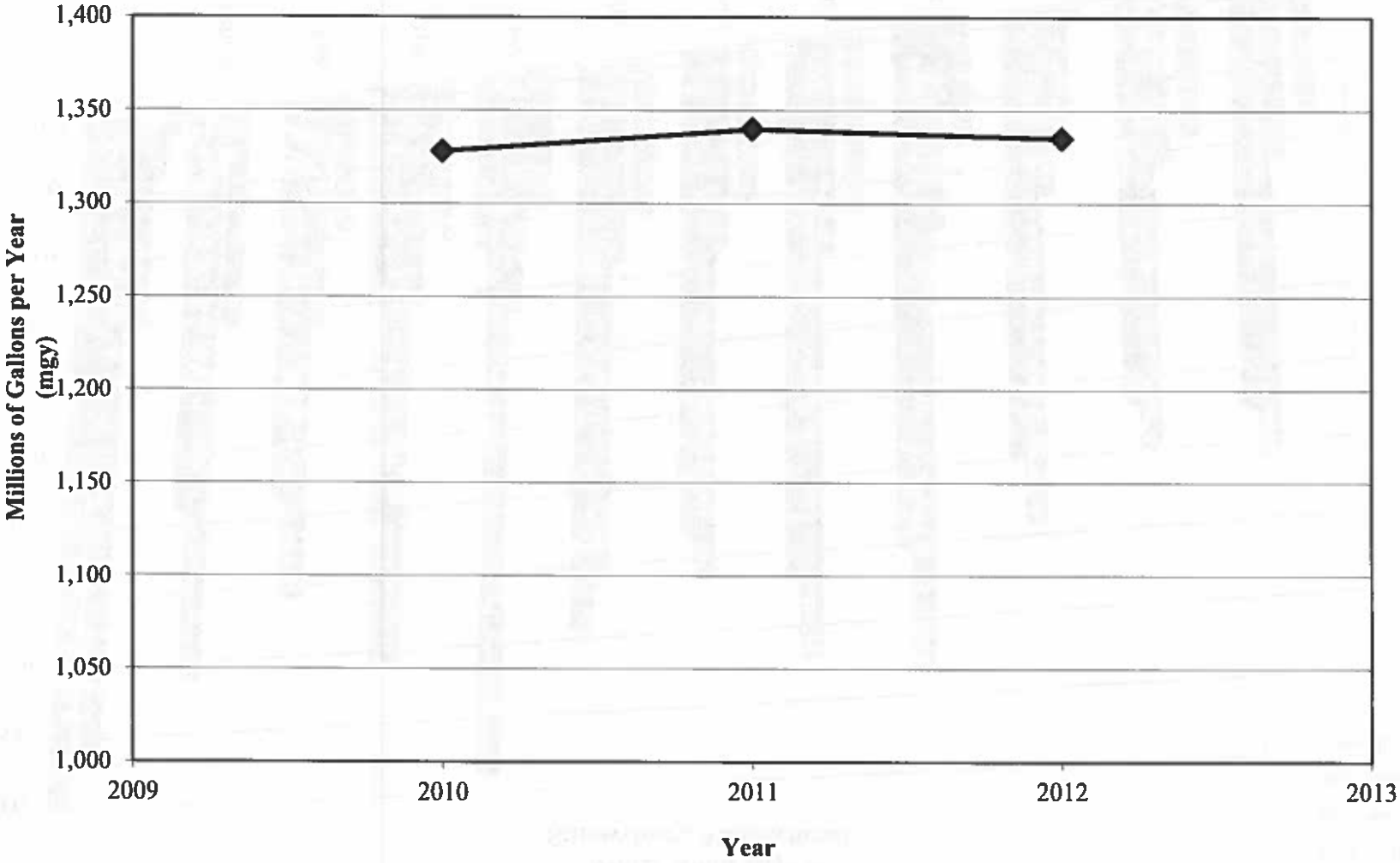

Figure No. 2-2
2009 Water Production
Water Audit Report
Shrewsbury, Massachusetts

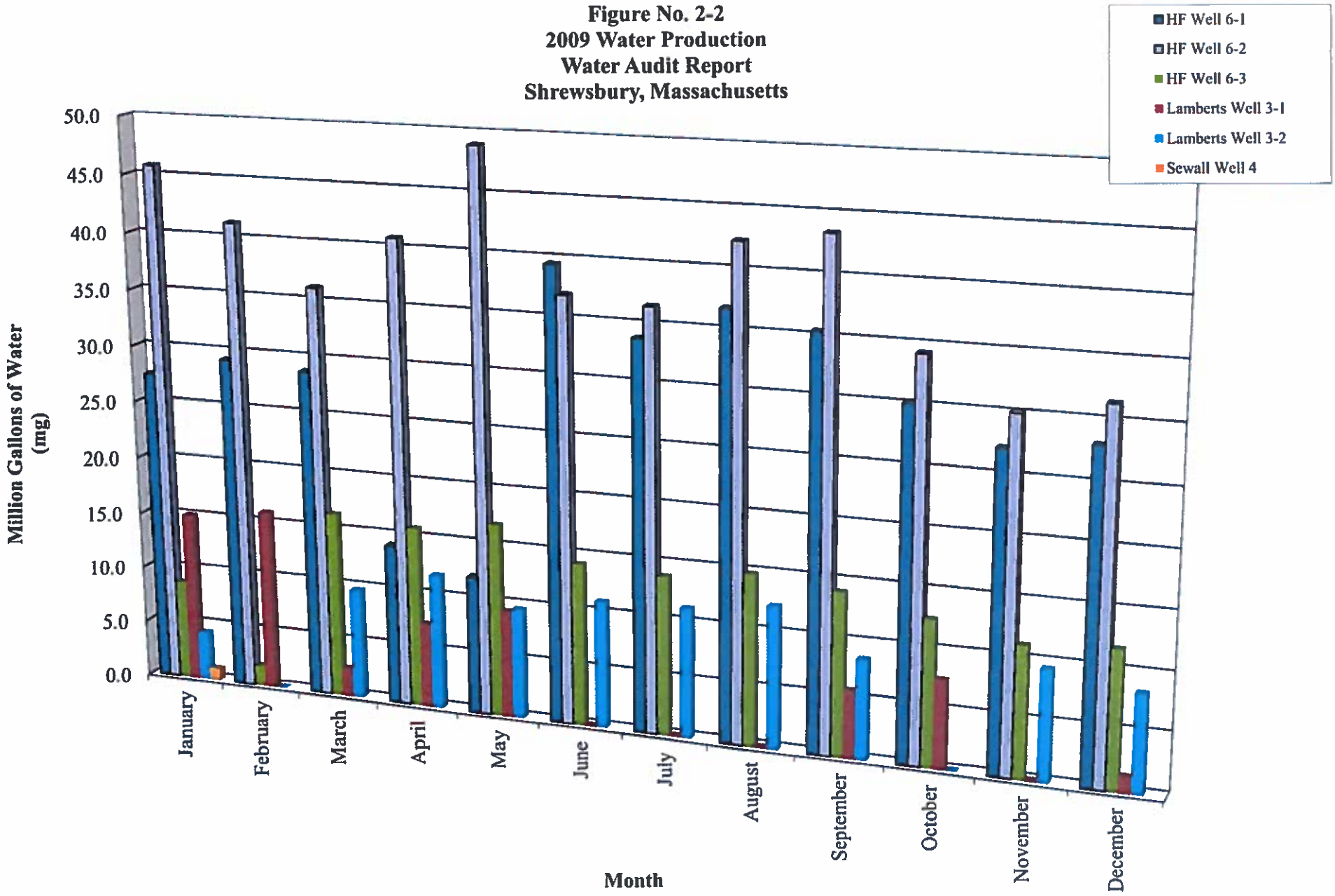

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Figure No. 3-2
2010 Water Production
Water Audit Report
Shrewsbury, Massachusetts

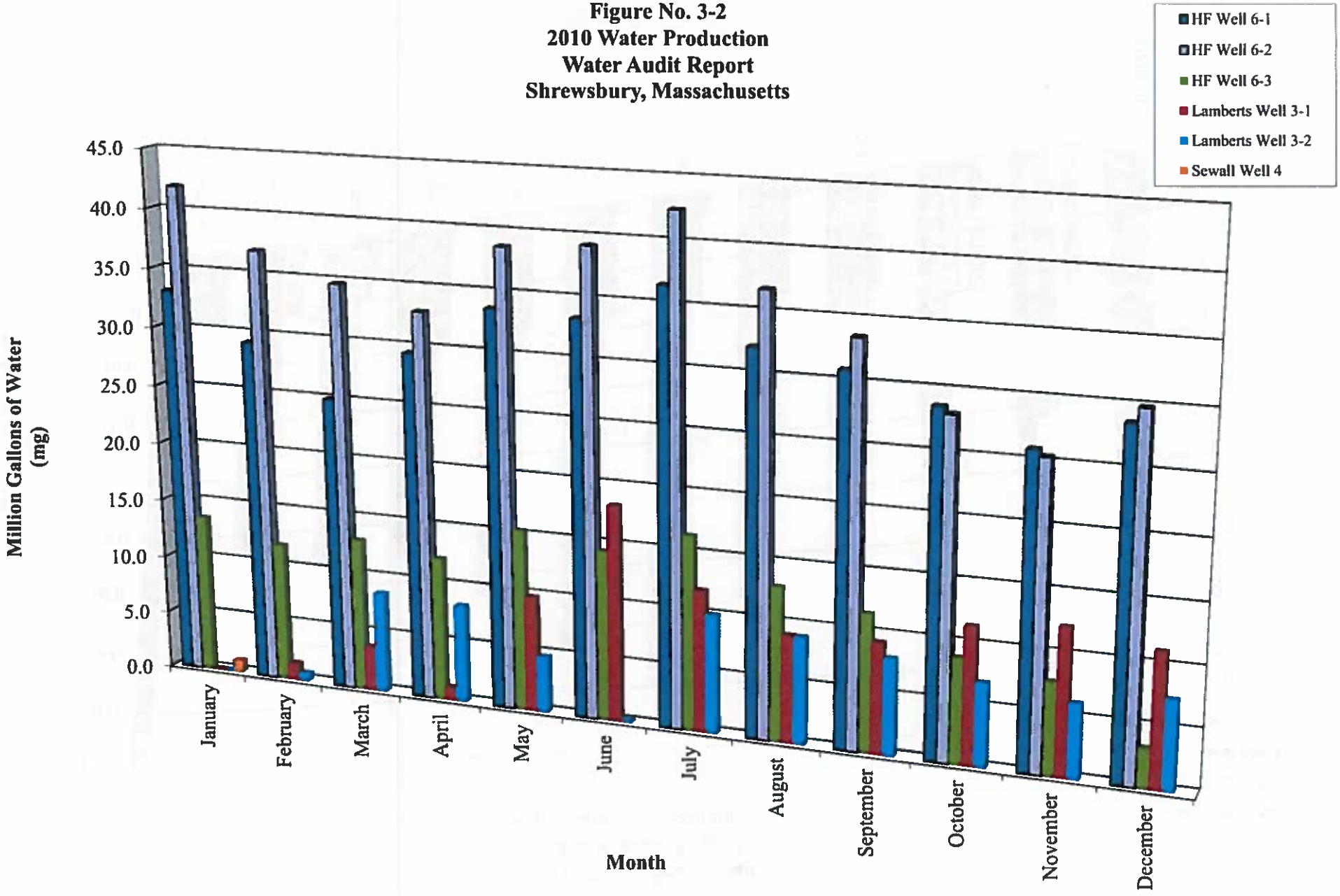
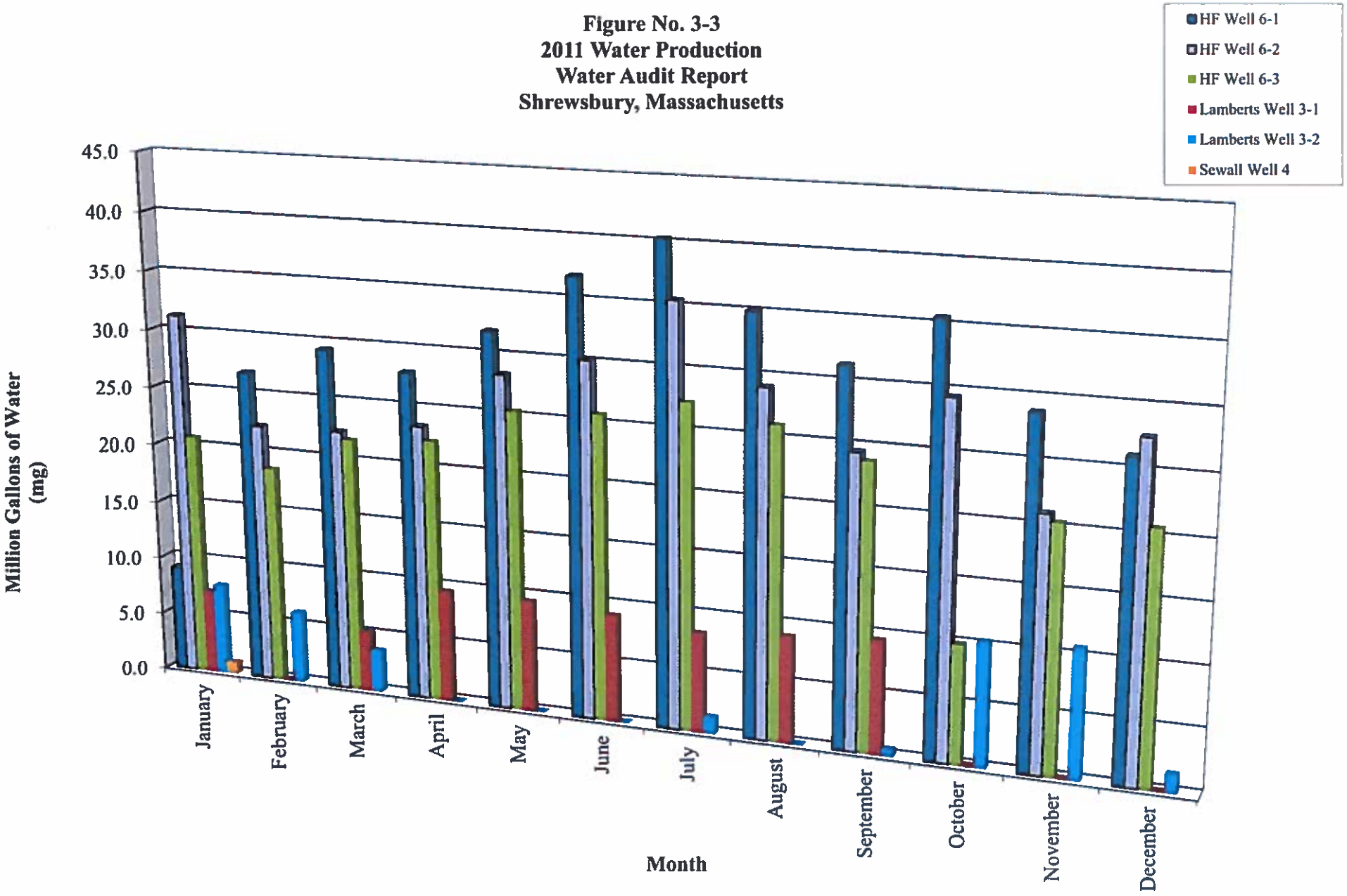


Figure No. 3-3
2011 Water Production
Water Audit Report
Shrewsbury, Massachusetts



3.3 SCADA

There are several anomalies that can occur from SCADA. Below is a list of these potential anomolies:

- Negative values for items like tank levels,
- Zero values for items like tank levels which are not empty,
- Missing time periods,
- Tank levels reading higher than the tank,
- Repeat values,
- Duplicate dates and times,
- Impossible values,
- Missing data or data not recorded,
- Values in tables not matching what is shown on the SCADA screen,
- Multiple flow descriptions,
- Minor variations between data recorded by redundant PLCs
- Values, such as flow rate, remaining constant,
- Averaging errors.

As the errors do not appear to be systematic and are more likely random, a corresponding value cannot be assigned. Currently, the Town does not have a standard operating procedure to address SCADA errors.

3.4 Purchased Water

The Town does not currently purchase water from any other towns or cities. There is an emergency connection with the City of Worcester on Route 20 that has been updated to include a new meter if the need to purchase water on an emergency basis occurs in the future.

SECTION 4

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SECTION 4 - Metered Consumption

4.1 Service Meters and Billing

According to the Town, 100 percent of the distribution system is metered and this includes the publicly owned buildings. All customers are grouped into three separate billing sections. Each month one section's meters are read and the customer is billed. All meters are billed and read on a quarterly basis. The meter usage for each month can not be compared to the volume pumped from the sources each month because only a third of the meters are read each month. The Town's current meter reading and billing cycle does not allow the Town to accurately compare metered usage with pumping records. The Town has an ascending block rate structure for each of its ten billing categories. The billing categories and associated water rates are shown in Appendix C.

The Town is currently in the final year of a commercial meter replacement program. To date, approximately 85 percent of the commercial meters have been replaced with remote read meters. Some of the meters have been downsized for better accuracy. Scheduling is being coordinated with the remaining property owners and the Town plans to have 100 percent of the commercial meters replaced by summer 2014.

Approximately 40 percent of the residential meters have been replaced with remote read meters since 2004. The remote read meters are either Hersey or Badger meters. Hersey meters were installed for the first phase of the remote read meter installation program. In 2011, the program changed and Badger meters were installed. These meters all use the same remote read system. There are approximately 2,100 Neptune meters that are read using a handheld unit and a probe to connect to a touch pad. These meters were installed between 1998 and 2004. The remaining meters (approximately 4,400 meters) were installed prior to 1998 with some meters dating back to the 1970s. Many of these meters have been fitted with probes and are scanned using handheld units, but there are still a small percentage of older, visual inspection meters remaining. The Town has funding allocated to contract the replacement of approximately 5,000 meters in 2014. The Town is planning to replace the remaining meters within the next year. By 2015 the Town plans to have all meters be remote read meters. Once the meter replacement is complete the Town plans to read the meters and bill customers monthly. The Town has spent approximately $4 million in the last two to three years as part of their ongoing meter replacement program.

Service meters can also be examined to determine if they are accurately registering the amount of water used. Inaccuracies in service meters are usually due to meters that are worn, damaged or improperly sized. The billing software gives a warning if a reading is significantly higher or lower than the previous billing cycle. Some variation in billings can be due to demand variation quarter to quarter. The software does not compare readings from the same billing cycle to readings from previous years.

Water Department personnel attempt to review all meters with low recorded usage in a billing cycle. As part of the review process, the Water Department will consider historic

usage, determine if the house/business is now vacant, contact the customer to identify any recent changes that could account for the decrease in usage, and if the usage continues to be low, the Water Department will replace the meter. When a zero reading is recorded, the customer is billed the minimum amount. Once multiple zero readings are recorded, the Water Department will send a letter to the customer to try to get the meter replaced. There is a faster response time to replace the meters from the residential customers. The commercial meters are the responsibility of the owner and it is more difficult to get the customer to replace these meters. The Town's current commercial meter replacement program should address all outstanding issues with commercial meters. The Water Department does have an easier time tracking abnormal high readings. Customers will typically report higher than normal bills, but not lower than normal bills.

The Water Department has recently identified several other issues with a few of the commercial users. For example, a car wash had been reading the incorrect usage amount for an unknown period of time. The meter was a compound meter and one side was not reading. The owner had been unresponsive to a request to change the meters. The meter has now been replaced and the Water Department will compare the current usage rates to past usage rates once a few billing cycles have been completed. Also, the Water Department has historically believed that the Shaw's Supermarket was reading high. The meter at the Shaw's is a 2-inch compound manual read meter. A recent comparison between the three markets in Town suggests that perhaps the Shaw's is not reading high, but the Stop & Shop may be reading low. The Stop & Shop meter is a larger meter. Once these meters are replaced and a few cycles of billing data is available, the Water Department plans to review the usage.

The Town primarily serves residential users. However, there are several municipal, institutional, industrial and commercial customers that are among the top water users in Town. The top ten water users in 2011 are listed in Table No. 4-1:

Table No. 4-1
2011 Top Water Users

Identification	Assessment Type	Usage (million gallons per year)
UMass Medical School	Institutional	21.09
Green at Shrewsbury	Residential	19.94
Wheelabrator Millbury, Inc.	Commercial	9.43
Southgate at Shrewsbury	Residential/Nursing Home	4.97
Shrewsbury Nursing & Rehab.	Institutional	4.24
Albertsons Inc.	Commercial	3.94
BMA Worcester - FMC	Commercial	3.52
DJP Hospitality, Inc.	Commercial	3.43
Arbor Commons Realty	Commercial	3.16
United States Postal Service	Federal	2.77

The available service meter records and billing information for 2010, 2011, and 2012 were reviewed and the results are summarized in Table No. 4-2. As indicated, the reported number of service connections has increased from 11,105 connections in 2010 to 11,234 connections in 2012. The uncorrected total amount of metered water has ranged from approximately 947 mg in 2011 to approximately 1,022 mg in 2012. The residential per capita consumption was calculated by dividing the metered residential volume by the population as reported in the ASR for that year. The results are shown in Table No. 4-3. The reported residential per capita consumption for the Town for 2010, 2011, and 2012 was approximately 55, 53, and 54 gallons per capita per day (gpcd), respectively. In general, the MassDEP, in conjunction with the Department of Conservation and Recreation (DCR), require communities to keep their per capita consumption at or below 65 gpcd. The Town is currently below the recommended per capita consumption due to extensive water conservation efforts implemented by the Town. The uncorrected total amount of metered water for 2010, 2011, and 2012 is reported in Form 2 found in Appendix A. The uncorrected total amount of metered water for 2012 is reported in Appendix B.

4.2 Unmetered Water Sold

Unmetered water sold is water that is delivered to customers but is not metered. This could be due to a non-functioning meter or that a meter has not been installed. Since there are no records of the number of non-functioning meters per cycle, there is no estimated quantity of unmetered sold water on Line 6 of the water audit form 6 included in Appendix A or in Appendix B.

Table No. 4-2
Uncorrected Total of Metered Water

Service Type	2010		2011		2012	
	Million Gallons	Connections	Million Gallons	Connections	Million Gallons	Connections
Residential	716.11	10,602	695.03	10,657	695.87	10,726
Commercial	286.26	474	236.63	475	248.70	479
Municipality	19.17	29	15.72	29	18.41	29
Total:	**1,021.54**	**11,105**	**947.38**	**11,161**	~~926.98~~ 962.98	**11,234**

Table No. 4-3
Residential Per Capita Consumption

Year	Million Gallons	Population	Consumption (gpcd)
2010	716.11	35,608	55
2011	695.03	35,608	53
2012	695.87	35,608	54

SECTION 5

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SECTION 5 - Unmetered Unbilled Authorized Consumption

5.1 General

There are numerous unmetered unbilled but authorized uses of water in a public water system including water for periodic maintenance of hydrants, fire flow tests, and water main flushing programs. The construction of new water mains uses unmetered water for testing and disinfection purposes. Unmetered water may also be used by the local Fire Department for firefighting and training.

In Shrewsbury, the average quantity of unmetered authorized public and miscellaneous uses of water was approximately 7.84 mg during the water audit period. This represents approximately 0.6 percent of the average water supplied over the audit period. This quantity is based on information included in Shrewsbury's records and in their ASRs. The authorized unmetered uses of water, which could be reasonably estimated using available records, are related to fire protection and training, hydrant and water main flushing, flow testing, bleeders and blow offs, sewer and stormwater flushing, and street cleaning. A breakdown of the contributing components for years 2010 through 2012 is provided herein and summarized in Table No. 5-1. The average total volume of unmetered unbilled authorized water uses for 2010, 2011, and 2012 is reported on Line 9 of Form 6 located in Appendix A. The volume of unmetered unbilled authorized water uses for 2012 is shown in Appendix B.

Table No. 5-1
Unmetered Authorized Uses of Water*

Unmetered Authorizes Public Uses	2010	2011	2012
Fire Protection & Training	2.95	2.43	2.71
Hydrant/Water Main Flushing	5.29	3.41	6.09
Flow Testing	0.09	0.06	0.11
Sewer & Stormwater Flushing	0.08	0.02	-
Street Cleaning	0.10	0.10	0.10
Total:	**8.51**	**6.02**	**9.00**
Average:		**7.84**	

*Usage reported in million gallons per year

5.2 Fire Protection & Training

The Town reported the amount of water used during fire protection and training in their ASR's for 2010, 2011, and 2012. These amounts are listed in Table No. 5-1. There are no records indicating how these values were estimated.

5.3 Hydrant/Water Main Flushing

The Town flushes the entire distribution system once each year. Information used in reporting volumes attributed to hydrant flushing is based on flow data collected and recorded by Shrewsbury Water Department personnel. During each flushing sequence, the Shrewsbury personnel note defective hydrants and valves and made observations regarding pressure and water quality. It should be noted that flushing is also conducted if there are water quality complaints. A flushing log is maintained by the Shrewsbury Water Department personnel. In addition to the annual flushing program and water quality complaints, this component includes miscellaneous flushing of dead ends, flushing after water main break repairs, and flushing for chlorination. The total amounts attributed to hydrant and water main flushing for 2010, 2011, and 2012 are listed in Table No. 5-1.

5.4 Flow Testing

The Town estimated approximately 0..09 mg of water was used for flow testing in 2010, 0.06 mg of water was used for flow testing in 2011, and 0.11 mg of water was used for flow testing in 2012. The flow tests were conducted by Shrewsbury personnel. There were no calculations or documentation for flow testing attached to the Town's ASRs. These values are listed in Table No. 5-1.

5.5 Sewer and Stormwater Flushing

The Town estimated approximately 0.08 mg and 0.02 mg of water was used for sewer and stormwater flushing in 2010 and 2011, respectively. Water Department personnel conducted the flushing and recorded the amount of water used. These values were reported in the ASRs and are listed in Table No. 5-1. The Town did not report any water used for sewer and stormwater flushing in 2012.

5.6 Street Cleaning

The Town estimated approximately 0.10 mg of water was used for street cleaning in 2010, 2011, and 2012. These values are reported in the ASRs and are listed in Table No. 4-1.

SECTION 6

TATA & HOWARD

SECTION 6 - Unmetered System Water Losses

6.1 WMA Water Audit

The WMA Program water audit categorizes unmetered water losses in a public water system as any unauthorized uses. This can include unauthorized/unmetered service connections, backwash waters, water main breaks, and water system leaks. Shrewsbury utilizes several different operation and maintenance methods to manage these losses. Valuable information which would indicate signs of leakage is often obtained from water customers. This information includes complaints from customers who hear water running in their house plumbing, observe sudden increases in metered consumption, or experience low pressure. In the event a leak or break is discovered, they are repaired at the earliest possible date by Shrewsbury personnel. A summary of these losses in 2010, 2011, and 2012 is shown in Table No. 6-1.

Table No. 6-1
Unmetered System Water Losses - WMA Water Audit

Unmetered System Water Losses	2010	2011	2012
Water Main Breaks	72.69	80.69	129.25
Leak Detection Survey Results	131.40	*	*
Total:	**204.09**	**80.69**	**129.25**
Average:	**138.01**		

*Values for these categories were reported in million gallons per year in the ASR. There were no reports or calculation worksheets indicating how the values were estimated. As a result the values were not used in this report.

The Town keeps records on all reported water main/service breaks and leaks. These records include information regarding location, date, the condition of the break/leak, who reported the break/leak, the work required to repair the break/leak, and the method used to calculate the volume of water lost. Leaks or breaks are repaired at the earliest possible time during normal working hours unless emergency or safety concerns required immediate attention. The continued use of the leak/break detection repair log could further improve recordkeeping and would be helpful for documenting problem areas within the distribution system.

The average total volume of unmetered water losses for the audit period is estimated to be 138.01 mg. This represents approximately 10.3 percent of the average water supplied during the Water Audit Period. These losses include the leaks and breaks identified by the Town discussed above. The volume of unmetered water losses is entered on line 10 of Form 6 included in Appendix A.

6.2 AWWA Water Audit

The AWWA method classifies unmetered system water losses differently than the WMA method. These losses are broken down into two major categories, apparent losses and

real losses. Apparent losses include meter inaccuracy, data handling errors, and unauthorized usage. Real losses include water main breaks and leaks.

Apparent Losses – Customer Meter Inaccuracy

Customer meters can be a major source of apparent losses. Under registering meters result in lost water revenues. In addition to providing information used for billing purposes, data from customer meters can be used to evaluate consumption trends, which can be used for long term planning and to evaluate loss control and conservation programs. The three main components of meter accuracy are physical accuracy, appropriate meter size, and meter type.

The physical accuracy relates to a meter functioning properly. Past practices attributed meter inaccuracies to the age of the meters. A study titled, "Accuracy of In-Service Water Meters at Low and High Flow Rates," was published in 2011 and was sponsored by the American Water Works Association's (AWWA) Water Research Foundation and the U.S. Environmental Protection Agency (EPA). The study identified inaccuracies based on meter type and rate of flow. Additionally, inaccuracies in service meters were reportedly due to the type and size of the meter, water quality, and low flow conditions. Meters should be periodically tested and repaired or replaced, if necessary, to maximize accuracy.

Approximately 60 percent of the service meters are more than 10 years old. The Town's meter replacement program is ongoing. As part of this water audit, the Town has begun testing some of the service meters using a Master-Meter datalogger to verify the accuracy of the meter. To date, eight service meters have been tested. The results are shown in Table No. 6-2. All but two of the meters were identified as recording lower flow rates. On average, the meters tested were recording approximately eight percent low. The selection of meters tested is too small to observe trends in meter usage and is to too small to be representative of all residential meters. The Water Department is continuing to test additional meters. The results of the additional testing will be included in an update to this report.

Meter size should be based on the most common flow rate for each customer. AWWA Manual M22, *Sizing of Water Service Lines and Meters* can be utilized to help determine meter size. This methodology is based on the flow requirements of all fixtures installed in a building. This may lead to meters being oversized as meters that accurately register the larger flows may not be as accurate during lower more common flows at a customer location.

The appropriate meter type is another factor in determining the accuracy of a customer meter. Different meters are designed for different flow rates and flow patterns. Turbine meters are accurate at high flows but much less accurate at measuring lower flows. Compound meters are capable of measuring both high and low flows accurately. Another example of the need for proper meter type is having a separate meter for fire connections. Fire service connections will be seldom used, but will have a high flow rate when in use. Smaller meters also operate over a range of flows but need to be able to measure much

lower flow rates, including leakage inside of customer's homes. The above mentioned study by the Water Research Foundation also noted that nutating disc meters appear to be able to register very low flows, which may be caused by small leaks at a customer location, at a much higher accuracy than other types of meters.

Based on the small number of residential meters tested, the Town is unable to calculate an amount of water associated with meter inaccuracies. A default value of five percent of the total water supplied was used to estimate the apparent losses due to customer meter inaccuracy. This percentage should be updated as more residential meter testing results become available.

Table No. 6-2
Customer Meter Inaccuracy - WMA Water Audit

Test No.	Meter Manufacturer	Meter Installation Date	Meter Size	Recorded Usage (gallons)	Datalogged Usage (gallons)	Percent Error
1	Neptune	-	5/8-inch	270	290	7.4
2	Neptune	-	5/8-inch	130	131	0.8
3	Hersey	July 2005	5/8-inch	290	338	16.6
4	Badger	-	5/8-inch	300	381	27.0
5	Hersey	August 2005	1-inch	1,030	1,095	6.3
6	Neptune	August 2000	1-inch	1,090	828	-24.0
7	Hersey	-	5/8-inch	180	209	16.1
8	Hersey	-	5/8-inch	330	383	16.1

Apparent Losses – Systematic Data Handling Errors

Data handling errors are those that occur during the data transfer, billing or archival processes and result in an incorrect accounting of the customer consumption. System wide data handling errors can result in large discrepancies for the distribution system. The systematic data handling errors for 2012 were estimated to be one percent of the total water supplied, approximately 13.4 mg and is shown in Appendix B. Table No. 6-3 illustrates ways customer consumption data may be compromised.

Table No. 6-3
Potential Data Handling Errors

Data Transfer Errors	Manual meter reading errors.
	AMR or AMI equipment failure.
	Procedural/data entry errors during meter change-outs.
Data Analysis Errors	Poorly estimating volumes in place of meter readings.
	Customer billing adjustments given by altering actual metered consumption data.
	Poor customer account management. Accounts not activated, lost or transferred incorrectly.
Policy and Procedure Shortcomings	Some customers left unmeasured or unread.
	Customer accounts allowed to be made non-billed.
	Adjustment policies that allow manipulation of actual customer data.
	Bureaucratic regulations or performance lapses that cause delays in permitting, metering or billing operations.
	Organizational divisions that prevent data to be accessed by all appropriate personnel.

Apparent Losses – Unauthorized Consumption

Unauthorized consumption usually occurs when customers or other persons deliberately take water without paying for it and occurs in virtually all drinking water systems. Unauthorized consumption can occur in many ways, including:

- Illegal connections,
- Open bypasses,
- Buried or obscured meters,
- Misuse of fire hydrants and fire-fighting systems (unmetered fire lines),
- Meter tampering,
- Illegally opening intentionally closed valves or curb stops at customer service locations that have been shut off or discontinued for nonpayment,
- Illegally opening intentionally closed valves to neighboring water distribution systems designed for emergency or special use,
- Failing to notify the utility to activate a billing account after water use has been initiated.

No data was available for 2012 for unauthorized consumption. The default value of 0.25 percent of the total water supplied was used and is approximately 3.34 mg.

Real Losses

The majority of real losses occur because of leakage from the pipes in the distribution network. These losses occur underground and are not seen until the water either becomes visible on the surface or causes damage that can be seen at the ground surface. Leakage can be categorized into three basic types; surfacing leaks, non-surfacing leaks and background leakage. Background leakage is leakage that occurs at very low rates of flow and is usually not considered economically worth fixing individually compared with the larger surfacing and non-surfacing leaks. Pressure reduction is a means of reducing background leakage where that is possible. Leakage within the distribution system can be caused by several different factors including; inferior or defective materials, pipe breaks due to poor craftsmanship or materials, operational errors, corrosion (both external and internal), seasonal stresses, poor quality of repair work, poorly aligned fittings and appurtenances, and accidental or deliberate damage to the distribution system.

The total real losses on the audit form are approximately 295.8 mg. It should be noted that unlike the WMA water audit, the AWWA audit method does not consider Shrewsbury's records regarding leak detection, water main breaks, etc. in estimating real losses. Real losses are the total water losses subtracted from the apparent losses. This amount is reported in Appendix B.

Shrewsbury has many ongoing projects to limit real losses throughout the distribution system. These projects include leak detection and main replacement. The Town reportedly performed a leakage survey on the entire water distribution system in 2010 and found a total of 24 leaks. Another complete leak detection survey is scheduled for spring 2014.

SECTION 7

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SECTION 7 - Cost of Losses

To properly assess the impact that water losses have on the Shrewsbury system, a value or cost must be applied to both real losses and apparent losses. The value associated with the lost water demonstrates the cost to the utility for real losses and the lost revenue for apparent losses.

7.1 System Operating Costs

In general, there are two components that make up the costs needed to supply customers with water. The first component includes the costs associated with personnel salaries, water system operation and maintenance, capital costs for system improvements, technical services, supplies, and equipment. The second component includes the costs associated with pumping and treating the water supplies. Based upon review of the Town's water expenditures, this component includes yearly costs for chemicals, fuel and electricity.

The costs associated with pumping and treating during 2010, 2011, and 2012 were reviewed and are summarized in Table No. 7-1. Based on Shrewsbury's records, the average cost to pump and treat the water was approximately $346,614. The average cost to supply water was $0.26 per 1,000 gallons.

Table No. 7-1
Pumping and Treating Cost 2010-2012

Item	2010 Expenditures	2011 Expenditures	2012 Expenditures
Chemical	$144,151	$159,626	$138,364
Fuel	$14,396	$16,570	$5,904
Electrical	$150,687	$134,211	$266,934
Purchasing Water	N/A	N/A	N/A
Total:	**$309,234**	**$310,407**	**$411,202**
Average:		**$346,614**	

The total cost of operating the water system, including all non-production costs on the audit form in Appendix B, is approximately $1,791,289. Non-production costs includes those for operations, maintenance, and any annually incurred costs for long-term upkeep of the system, such as repayment and 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 do not include any costs to operate wastewater, biosolids, or other systems outside of drinking water.

7.2 Apparent Losses

Apparent losses are valued at the retail rate charged to customers, as these losses represent water that reached the customer, but was not billed to the customer. Service charges, connection fees, and other fees are disregarded since they are not dependent on the volume of water a customer uses. As previously discussed, the Town bills their consumers through multiple rate classifications.

On average, customers are billed approximately $35.00 a quarter while using approximately 8,000 gallons. Therefore, the base rate of $4.83 per 1,000 gallons was used to value apparent losses. Apparent losses within the distribution system for the audit period are estimated to be approximately 67.4 mg and valued at approximately $295,086.

7.3 Real Losses

Real losses are valued at their production costs. Production costs include the variable costs to extract, treat, and deliver water to the customer. Since labor costs are not dependent on the volume of water produced, they are not factored into the value of real losses. The volume of real losses including unavoidable background losses is estimated to be approximately 295.8 mg for the audit period and valued at approximately $76,177.

SECTION 8

TATA & HOWARD

SECTION 8 - Key Performance Indicators

The AWWA recommends two types of performance indicators: financial and operational. These can be used to assess the performance of the water system. Table No. 8-1 provides a list of the performance indicators evaluated in the audit. The AWWA divides the performance indicators into three levels: Levels 1 (Basic), 2 (Intermediate) and 3 (Detailed). The performance indicators should be used as a benchmark to allow the Town to track performance and help determine the effectiveness of any improvements made to the water system. The ILI is a dimensionless indicator that can be used when comparing one water system to another.

Table No. 8-1
Performance Indicators

Performance Indicator	Level	Description
Financial		
Nonrevenue Water by Volume	1	Volume of nonrevenue water as a percentage of water system input volume.
Nonrevenue Water by Cost	3	Value of nonrevenue water as a percentage of annual cost of running the water system.
Operational		
Apparent Losses	1	Gallons per service connection per day.
Real Losses	2	Gallons per service connection per day.
Unavoidable Annual Real Losses (UARL)	3	The technical low limit of leakage that can be achieved if all current technology is successfully applied (mg/year).
Infrastructure Leakage Index	3	Ratio of Current Annual Real Losses to Unavoidable Annual Real Losses.

8.1 Financial Indicators

The two financial indicators which are useful in assessing the fiscal cost of the nonrevenue water use in the Town's system include Nonrevenue Water by Volume and Nonrevenue Water by Cost. Nonrevenue Water by Volume allows the Town to track the percentage of water produced that does not generate revenue. Nonrevenue water includes bleeder usage, construction projects, system maintenance, hydrant sprinkler usage, water used by the Town at its treatment plants and other facilities, and real and apparent losses. The Nonrevenue Water by Cost performance indicator gives a monetary value to the nonrevenue water and is expressed as a percentage of the annual costs of operating the water system. This indicator provides insight into the real cost of water used for nonrevenue purposes. Many of these uses are necessary to operate the water system; however, these indicators can be used to help determine if the water can be used more efficiently.

8.2 Operational Indicators

The operational performance indicators examine losses, both apparent and real, that occur throughout the water system. The Town's losses are measured in gallons lost per service connection per day. In addition, the indicator can be multiplied by the billing rate to identify the revenue not being earned by the Town from water delivered to the customer that is not accounted for properly. The Real Loss indicator measures the volume of real losses per service connection per day. This indicator can be multiplied by the production cost of the water to indicate costs for Shrewsbury to produce water that is not reaching its customers.

The UARL is the theoretical value that represents the technical low limit of leakage that can be achieved if all current technology is successfully applied. The UARL equation was developed by the International Water Association's Water Loss Task Force published in 2000. The calculation is based on leakage data gathered from well-maintained and well-managed systems. The UARL equation is as follows:

$$UARL\ (gal) = (5.41Lm + 0.15Nc + 7.5Lc) \times P$$

Lm = length of water mains (miles)
Nc = number of service connections
Lc = total length of private pipe (miles) = Nc x average distance from curb stop to customer meter, Lp
P = average system pressure (psi)

The ILI is used as a benchmarking tool to compare leakage among different utilities. It is a ratio of the Current Annual Real Losses (CARL) to the UARL and quantifies how well a water system is managed for leakage control. The UARL for the Town's system is estimated to be approximately 88.48 mg. The ILI for the Town's system is estimated to be 3.34.

In a study published by the AWWA in 2003, Committee Report: Applying Worldwide BMPs in Water Loss Control, *AWWA*, 95:8:65, the ILI for 34 water systems from around the world, including seven from North America, were compared. Of the systems compared, twelve had an ILI under 2.0 and the remaining 22 had an ILI between 2.0 and 13.1. Of the seven North American systems, all had an ILI greater than 2.0 including the City of Philadelphia which had an ILI of 13.1. Since that time, Philadelphia has worked to lower their 2009 ILI to 8.9. The Louisville Water Company is another utility using ILI as a benchmarking tool. In 2009 their ILI was 2.50.

SECTION 9

TATA & HOWARD

SECTION 9 - Water Audit Results

9.1 WMA Audit Results

Shrewsbury continues to increase their efforts to reduce the amount of unaccounted-for water within the distribution system and meet or exceed the MassDEP recommended residential per capita consumption. The results of this water audit report show that the unaccounted-for water within the system is actually lower than the volume indicated on the Town's Annual Statistical Reports. The average unaccounted-for water value for the audit period is approximately 13.5 percent. Based on this information, it is apparent that the Town has made substantial progress in reducing the system unaccounted-for water over the last several years. In addition to the completion of this water audit report and its associated components, the following items have been completed by the Town to date:

- A leak detection survey was completed in April 2010. The Town has scheduled to conduct a leak detection survey in Spring 2014.
- Water conservation tips are provided to customers with their bills and annually in Shrewsbury's Consumer Confidence Report and on their website.
- The master meters within the Town's system are calibrated annually.
- The Town has currently replaced 85 percent of the commercial meters and approximately 40 percent of the residential meters with radio read meters. The Town has allocated additional funding to replace the remaining residential and commercial meters by 2015.

This water audit will assist the Town in recognizing areas for future improvements and provide suggestions to further reduce the unaccounted-for water and maintain the recommended residential per capita consumption of 65 gpcd. The water audit report has resulted in the following conclusions and recommendations.

9.2 AWWA Audit Results

During 2010, Shrewsbury supplied 1,335 mg from the sources to the distribution system. Approximately 27.9 percent of this water is classified as nonrevenue.

The results for the Performance Indicators on the audit form are summarized in Table No. 9-1.

Table No. 9-1
Performance Indicator Results

Performance Indicator	Result	Description
Financial		
Nonrevenue Water by Volume	27.9%	Volume of nonrevenue water as a percentage of water system input volume.
Nonrevenue Water by Cost	20.9%	Value of nonrevenue water as a percentage of annual cost of running the water system.
Operational		
Apparent Losses	67.4	Gallons per service connection per day.
Real Losses	295.8	Gallons per service connection per day.
Unavoidable Annual Real Losses (UARL)	88.5	The technical low limit of leakage that can be achieved if all current technology is successfully applied (mg/year).
Infrastructure Leakage Index	3.34	Ratio of Current Annual Real Losses to Unavoidable Annual Real Losses.

Data Validity

The data from each category is given a validity score. Table No. 9-2 summarizes the grade for each category. The grading matrix, which explains in general how the validity score for each category is arrived at, can be found in Appendix C. For example, the category 'volume from own sources' received a score of six. The score was arrived because 75 percent to 100 percent of Shrewsbury's sources are metered and the master meters are tested on an annual basis.

The data validity score on the audit form is 62 out of 100 giving the Town a Data Validity Level of III. Both the data validly score and Data Validity Level do not have a direct effect on the ILI. The data validity score is a confidence factor for how accurate the water audit is. The Data Validity Level provides a guideline for water loss control planning. The Water Loss Control Planning Guide, which includes the Data Validity Level, is included in Appendix B.

Table No. 9-2
Data Validity Scores

Category	Score	Reason for Score	Recommendation to Improve Score
Volume From Own Source	6	Five of the sources have master meters that are calibrated annually.	Remaining sources should have a master meter installed. Volumetrically test and calibrate all master meters on an annual basis.
Master Meter Error Adjustment	8	Meter data is not adjusted for known master meter errors. Daily SCADA totals are available for each source. The known errors were applied to the daily flow, but this does not take into consideration higher and lower flows during the course of the day	Volumetrically test and calibrate all master meters on an annual basis. Compare and track distribution flow to raw water flow on a daily basis.
Water Imported	N/A		
Water Exported	N/A		
Billed Metered	6	All customers are metered. There are a few visual read meters left in the system.	Finish upgrading all meters to radio read meters..
Billed Unmetered	N/A		
Unbilled metered	N/A		
Unbilled unmetered	6	Some of unbilled unmetered water use is documented and estimated, however much of the water use is not tracked and only estimated.	Add meters wherever possible, work with local fire departments and water department personnel to document unmetered water usage. Water lost during water main failures should be better estimated by recording duration of water flowing before the water main is shut down and estimated flow rate.

Table No. 9-2
Data Validity Scores (continued)

Category	Score	Reason for Score	Recommendation to Improve Score
Customer Metering Inaccuracies	5	Customer meters have historically been only tested when an issue arises.	Test meters for accuracy on low flow accounts. Ensure larger meters are sized and typed properly for each customer. Implement routine customer meter testing program.
Systematic Data Handling Error	6	The Town currently uses a computerized billing system. Internal checks of billing data error conducted periodically.	Formalize regular auditing process to reveal scope of data handling error.
Length of Mains	10	Accurate data kept in GIS database.	
Number of Active and Inactive Service Connections	8	Database updated periodically to maintain accurate database.	Perform periodic field checks to verify accuracy, and compare billing system vs. GIS data.
Average Length of Customer Service Line	5	Records regarding length of service lines are available by paper record only. The written records were not able to be used to estimate an average length of customer service lines.	Research and collect paper records of service line installations. Inspect in the field to determine length of service line, if necessary Add customer service lines to GIS. Review policies on customer service line ownership.
Average Operating Pressure	8	Full scale SCADA system monitors pressure in system. A hydraulic model has also been calibrated using field measurements.	Deploy additional pressure monitoring throughout distribution system.
Total Annual Cost of Operating Water System	6	Data has not been audited by a third party.	Perform water audit on fiscal year basis so data can be verified.
Customer Retail Unit Cost	8	The water rates were last updated in 2012.	Determine retail unit cost based on weighted average of consumption for each billing category.
Variable Production Cost	7	Data has not been audited by a third party.	Perform water audit on fiscal year basis so data can be verified.

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SECTION 10

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SECTION 10 - Recommendations

10.1 Recommendations

The following recommendations are a result of this water audit report. These recommendations will improve record keeping and increase the validity score for the data as shown in the AWWA water audit. They will also assist in lowering the Town's unaccounted-for water as shown in the WMAP water audit.

1. Continue to conduct partial leak detection surveys of the entire system every year according to the standard operating procedures for leak detection surveys.

2. Continue to document leaks found during the survey and in everyday operation by staff and customers. Leak records should include the location, date and time the leak was found, the approximate size of the leak, the type of leak (hydrant, main, service, etc.) and an estimate of approximately how long it has been leaking.

3. Leaks should continue to be repaired in accordance with the established priority system:
    - All leaks of 3 gpm or more shall be repaired as soon as possible and no later than within 12 months of detection.
    - Leaks of less than 3 gpm at hydrants and appurtenances shall be repaired promptly and no later than within 12 months of detection.
    - Leaks of less 3 gpm in local roadways, arterial or collector roadways shall be repaired when related work on the roadway is being performed.

4. It is recommended that at a minimum, monies for a full leak detection survey be completed and budgeted every three years. The estimated cost of a leak detection survey is approximately $120 per mile of main or approximately $24,000 for the Shrewsbury distribution system.

5. It is recommended that the Town continue to test and calibrate the master meters for the main sources of water on a yearly basis in accordance with MassDEP recommendations.

6. Shrewsbury should continue with their ongoing service meter replacement program. Once all service meters are replaced with radio read meters, the meters should be read and customers billed monthly. Reading all meters on a monthly basis will allow the Town to compare the water pumped and water billed on a monthly basis and allow the Town to better track meter anomalies and errors.

7. The Town should continue to keep well written records regarding unmetered water uses so that the volume of such usage can be reasonably estimated. One component of this recordkeeping program includes reporting the time of discovery and/or how a leak was reported, as well as the estimated volume of lost water. By reporting when leaks are discovered and/or reported, Shrewsbury can

keep an accurate record of how long it takes for the leak to be repaired and the related costs. This information is and will continue to be useful in identifying problem areas within the distribution system and coordinating and managing personnel time. Other recordkeeping components Shrewsbury may consider include documentation of areas of Town requiring additional water quality flushing. The Town should meter the amount of water used during any authorized municipal use, such as construction, street cleaning, etc., whenever possible. This will enable Shrewsbury to more precisely quantify the amount of water used.

8. The Town should continue with its efforts to promote water conservation within the community through water conservation outreach and educational programs. These include implementing additional water use restriction bylaws, distributing water conservation education information through various outlets and formats, visiting local schools, increased public service announcements, producing local cable or newspaper announcements, and low water use concepts to agricultural, commercial, industrial, and residential consumers. The Town should continue to implement their Rain Barrel Program, update their website with indoor and outdoor conservation tips, and update links to conservation related websites.

9. The Town should continue to effectively and accurately record all miscellaneous water losses and authorized water uses. MassDEP has calculation worksheets for estimating water lost due to flow testing, street cleaning, and water main breaks. These worksheets are located in Appendix D and should be completed and attached to the Town's ASR.

10. The Town should investigate whether master meter venturis and transmitters are regularly subjected to flows which are either higher than or lower than their operating range.

11. Test customer meters with zero or low flow readings. These meters should be repaired or replaced if found to not be registering properly.

12. For all meters that are 1 1/2-inches and larger, continue to identify the highest and lowest registering meters and begin a process of data logging those meters to establish they are the proper meter type and size. Replacement of oversized and incorrectly typed meters can significantly increase revenues and reduce apparent losses.

13. The Water Research Foundation Project No. 4028 also found that while meter manufactures claim that their new meters meet AWWA accuracy requirements they in fact often do not. Shrewsbury should consider testing all new meters themselves in accordance with AWWA M6 prior to field installation.

14. Regularly review and consider new meter technology which provides economic benefit to the Town.

15. Establish a program for the local fire departments to track location and the length of time a hydrant was flowed and an estimate of the flow rate. This will give Shrewsbury the ability to estimate the quantity of water used each year for fire protection and training. This will improve the data validity score for the unbilled unmetered category.

16. The Town should perform periodic checks on accounts that have been terminated for nonpayment. Curb stops that have been closed should be checked to ensure that they have not illegally been reopened.

17. The Town should perform regular internal audits of the data trail from data read at the customer meter to the creation of the customer bill. This will determine the accuracy of the consumption data.

18. The Town should field verify all water storage tank level instrumentation equipment and compare to SCADA readings to prevent tank overflows.

19. It is recommended that SCADA data be periodically evaluated over a four to five day period at approximately five minute intervals to look for anomalies or errors. The analysis will be included in an update to the Water Audit Report.

20. We recommend Shrewsbury continue to review the SCADA data each day and highlight anomalies and provide a summary report for review. In this way, errors may be corrected on a systematic and timely basis.

21. The Water Audit Report should be updated to include 2013 data once it is available.

APPENDIX A

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Shrewsbury, MA
FORM 1 - UNCORRECTED TOTAL WATER SUPPLY FROM SOURCES OF SUPPLY MASTER METER READINGS

TOTAL ANNUAL AMOUNT **(in million gallons per year)**

YEAR	SOURCE	SOURCE	SOURCE	SOURCE	SOURCE	SOURCE	SOURCE			TOTAL	Comment
	HF Well 6.1 (07G)	HF Well 6.2 (08G)	HF Well 6.3 (09G)	HF Well 6.4 (10G)	Lamberts Well 3.1 (04G)	Lamberts Well 3.2 (05G)	Sewall Well 4 (02G)				
2012	119.36	277.06	241.18	295.28	54.36	56.61	291.36			1,335.19	
2011	358.64	324.84	262.72		67.23	41.88	284.72			1,340.02	
2010	366.25	420.31	141.17	0.00	99.35	70.27	230.65			1,328.00	

TOTAL 4,003.21

Enter Annual or Avg. = Total divided by 3 = 1,334.40 **Enter on Line 1 - Form 6 and Enter on Line 1 - Form 3**

FORM 2 - UNCORRECTED CUSTOMER METER RECORDS

TOTAL WATER SOLD

YEAR	RESIDENTIAL	INDUSTRIAL	COMMERCIAL	AGRICULTURAL	INSTITUTIONAL	OTHER	TOTAL
2012	695.9	0.00	248.70	0.000	18.41	0.000	962.98
2011	695.0	0.00	236.63	0.000	15.72	0.000	947.38
2010	716.1	0.00	286.26	0.000	19.168		1,021.5
					Line a TOTAL		2,931.90
				Annual or Average	**Line b = Total divided by 3 =**		977.30
					Enter on Line 4 - Form 6		

CALCULATIONS

1	Total amount of water metered in system over the past three years (Line a _____)	2,931.90
2	Average total amount of water metered over past 3 years (Line b = Line a/3 =_____)	977.30
3	Estimate of total amount of water sold but not metered in past 3 years (Line c _____)	0.0000
4	Average of the total amount of water sold but not metered over past 3 yrs. (Div. Line c by 3 = ___ **Enter on Line 6 - Form 6**	0.0000

FORM 3 - PUMPING AND TREATMENT COSTS - Shrewsbury, MA

Annual Costs for the past three (3) years

No.	Category	Year 2012 $	Year 2011 $	Year 2010 $	Total	Average = Total Divided by 3 $
1	Chemicals	$138,364.00	$159,626.00	$144,151.00	$442,141.00	$147,380.33
2	Fuel - Gas	$5,904.00	$16,570.00	$14,396.00	$36,870.00	$12,290.00
3	Electricity	$266,934.00	$134,211.00	$150,687.00	$551,832.00	$183,944.00
5	Other	$	$	$	$0.00	$0.00
				TOTALS	Line a =	$343,614.33

CALCULATIONS

Line 1	Average of the total amount of treated and pumped water supplied to the system over the past three years **Form Line a - Form 1**	**1,334.40**	
Line 2	If water is purchased, average of the amount purchased over the past three years **See Page 4**		
Line 3	Total amount of water supplied from total of sources and total purchased **Add Lines 1 and 2**	**1,334.40**	
Line 4	Average pumping and treating divided by the purchasing cost of water **Divide Totals - Line a (from above) by** Line 3	**0.00026**	**Enter Annual or Avg. Line 15 on Form 6**

FORM 4 - SOURCE METER ERROR ADJUSTMENTS TO THE TOTAL AMOUNT OF WATER SUPPLIED TO THE SYSTEM - Shrewsbury, MA

Year 2012

No.	Meter Location	Meter Test Date	Calibration/Test	Meter Error % (+ or -)	times	Total Metered (gallons)		Adjustment in gallons (+ or -)
1	HF Well 6-1	12/18/2012	Discrepancy in Test		x	119.36	=	0.0000
2	HF Well 6-2				x	277.06	=	0.0000
3	HF Well 6-3				x	241.18	=	0.0000
4	HF Well 6-4				x	295.28	=	0.0000
5	Lamberts Well 3-1				x	54.36	=	0.0000
6	Lamberts Well 3-2				x	56.61	=	0.0000
7	Sewall Well 4				x	291.36	=	0.0000
8					x		=	
9					x		=	
10					x		=	
11					x		=	

AVERAGE PERCENT: 0 TOTAL ADJUSTMENTS: 0.000

Year 2011

No.	Meter Location	Meter Test Date	Calibration/Test	Meter Error % (+ or -)	times	Total Metered (gallons)		Adjustment in gallons (+ or -)
1	HF Well 6-1	10/18/2011		0	x	358.64	=	0.0000
2	HF Well 6-2	10/18/2011		-15.5	x	324.84	=	-50.350
3	HF Well 6-3	Not listed in calibration report.			x	262.72	=	0.000
4	Lamberts Well 3-1	10/18/2011		0	x	67.23	=	0.000
5	Lamberts Well 3-2	Not required.			x	41.88	=	0.000
6	Sewall Well 4	Not required well upgrade in process.			x	284.72	=	0.000
7					x		=	
8					x		=	
9					x		=	
10					x		=	
11					x		=	

AVERAGE PERCENT: -5.17 TOTAL ADJUSTMENTS: -50.350

Year 2010

No.	Meter Location	Meter Test Date	Calibration/Test	Meter Error % (+ or -)	times	Total Metered (gallons)		Adjustment in gallons (+ or -)
1	HF Well 6-1	10/7/2010		0		366.25		0.0000
2	HF Well 6-2	10/7/2010		-13.6		420.31		-57.1623
3	HF Well 6-3	Not listed in calibration report.			x	141.17	=	0.0000
4	Lamberts Well 3-1	10/7/2010		0	x	99.35	=	0.0000
5	Lamberts Well 3-2	Not required.			x	70.27	=	0.0000
6	Sewall Well 4	Not required well upgrade in process.			x	230.65	=	0.0000
7					x		=	
8					x		=	
9					x		=	
10					x		=	
11					x		=	

AVERAGE PERCENT: -4.53 TOTAL ADJUSTMENTS: -57.162

CALCULATION

AVERAGE ADJUSTMENT - Enter Annual or Add total adjustments for each of the three years and divide by 3 | -35.837

ENTER ALSO ON LINE 2a OF FORM 6

FORM 5 - DISTRIBUTION SYSTEM LARGE SERVICE METER ADJUSTMENTS

Shrewsbury, MA

Year 2012

No.	Meter Location	Meter Test Date	Meter Size	Meter Error % (+ or -)		Total Metered (gallons)		Adjustment in gallons (+ or -)
1					x		=	
2					x		=	
3					x		=	
4					x		=	
5					x		=	
6					x		=	
7					x		=	
8					x		=	
9					x		=	
10					x		=	
11					x		=	
12					x		=	

AVERAGE PERCENT: **TOTAL ADJUSTMENTS:**

Year 2011

No.	Meter Location	Meter Test Date	Meter Size	Meter Error % (+ or -)		Total Metered (gallons)		Adjustment in gallons (+ or -)
1					x		=	
2					x		=	
3					x		=	
4					x		=	
5					x		=	
6					x		=	
7					x		=	
8					x		=	
9					x		=	
10					x		=	
11					x		=	
12					x		=	

AVERAGE PERCENT: **TOTAL ADJUSTMENTS:**

Year 2010

No.	Meter Location	Meter Test Date	Meter Size	Meter Error % (+ or -)		Total Metered (gallons)		Adjustment in gallons (+ or -)
1					x		=	
2					x		=	
3					x		=	
4					x		=	
5					x		=	
6					x		=	
7					x		=	
8					x		=	
9					x		=	
10					x		=	
11					x		=	
12					x		=	

AVERAGE PERCENT: **TOTAL ADJUSTMENTS:**

CALCULATION

Enter Annual or AVG. = Add Total Adjust. for each year and divide by 3

Enter on Line 5a - Form 6

Line No.	DESCRIPTION		FORM	(+ or -)	RESULTS
1	Uncorrected Total Water Pumped From Sources of Supply		1		1,334.404
2a	Adjustments toTotal Water Supply Master Meter Error		4		-35.8373
2b	Faulty Valve Controlling Devices		Pg. 4		
3	Corrected Total Water Supply	**Add Lines 1, 2a and 2b)**	**Unadjusted Total**	-	1,298.6
4	Uncorrected Customer Meter Records Total Amount Sold		**2**		977.30
5a	Adjustments to Metered Water Sales - meter error		5		0
5b	Billing Procedure error		Pg. 6		
6	Uncorrected Customer Meter Records		2		0
7	Corrected Total Quantity of WaterSold	**Add Lines 4, 5a, 5b and 6**	**Adjusted Total**	-	977.3
8	Total amount of water not sold	**Subtract Line 7 from Line 3**	**Unmetered**	-	321.27
9	Total Unmetered Authorized Public Uses of Water	**See Page 5**	Pg. 5		7.839
10	Total Unmetered Miscellaneous Losses	**See Page 5**	Pg. 5		138.011
11	Total Identified Water Losses	**Add Lines 9 and 10**	**Estimated**	-	145.851
12	Total Unidentified Water Losses-	**Subtract Line 11 from Line 8**	**UAW**	-	175.4173
13	Potential water system leakage in gpd per mile of watermain. **Divide Line 12 by 365 then divide by total system miles of watermain**		**Leakage/mile**	-	2,363.39
14	Percentage of unaccounted for water that may be attributed to leakage -	**Divide Line 12 by Line 3**	**UAW leakage %**	-	**13.5%**
15	Pumping and treating cost per gallon of water	**Line 4 on Form 3**	**Cost/gallon**	3	0.00026
16	Annual Expenditure Due to Unidentified Water Losses **Multipy Line 12 by 15**		**UAW Cost**		$45,170.64

APPENDIX B

TATA & HOWARD

AWWA Water Loss Control Committee (WLCC) Free Water Audit Software v4.2

WAS v4.2

PURPOSE: This spreadsheet-based water audit tool is designed to help quantify and track water losses associated with water distribution systems and identify areas for improved efficiency and cost recovery. It provides a "top-down" summary water audit format, and is not meant to take the place of a full-scale, comprehensive water audit format.

USE: The spreadsheet contains several separate worksheets. Sheets can be accessed using the tabs towards the bottom of the screen, or by clicking the buttons on the left below. Descriptions of each sheet are also given below.

THE FOLLOWING KEY APPLIES THROUGHOUT:

- Value can be entered by user
- Value calculated based on input data
- These cells contain recommended default values

Please begin by providing the following information, then proceed through each sheet in the workbook:

NAME OF CITY OR UTILITY:	Shrewsbury Water Department			COUNTRY:	USA
REPORTING YEAR:	2012	START DATE(MM/YYYY):	01/2012	END DATE(MM/YYYY):	12/2012
NAME OF CONTACT PERSON:	Robert ToTozeski	E-MAIL:	rtozeski@th.ci.shrewsbury.ma.us	TELEPHONE:	508-414-2114
				Ext.	

PLEASE SELECT PREFERRED REPORTING UNITS FOR WATER VOLUME: Million gallons (US)

Click to advance to sheet... Click here: ? for help about units and conversions

Instructions	The current sheet
Reporting Worksheet	Enter the required data on this worksheet to calculate the water balance
Water Balance	The values entered in the Reporting Worksheet are used to populate the water balance
Grading Matrix	Depending on the confidence of audit inputs, a grading is assigned to the audit score
Service Connections	Diagrams depicting possible customer service connection configurations
Definitions	Use this sheet to understand terms used in the audit process
Loss Control Planning	Use this sheet to interpret the results of the audit validity score and performance indicators

Comments:

Add comments here to track additional supporting information, sources or names of participants

If you have questions or comments regarding the software please contact us at: wlc@awwa.org

AWWA WLCC Free Water Audit Software: Reporting Worksheet

Back to Instructions

Click to access definition

Water Audit Report for: Shrewsbury Water Department
Reporting Year: 2012 1/2012 - 12/2012

Please enter data in the white cells below. Where available, metered values should be used; if metered values are unavailable please estimate a value. Indicate your confidence in the accuracy of the input data by grading each component (1-10) using the drop-down list to the left of the input cell. Hover the mouse over the cell to obtain a description of the grades

All volumes to be entered as: MILLION GALLONS (US) PER YEAR

WATER SUPPLIED << Enter grading in column 'E'

Volume from own sources:	6	1,335.190	Million gallons (US)/yr (MG/Yr)	
Master meter error adjustment (enter positive value):	8	0.000	under-registered	MG/Yr
Water imported:	n/a	0.000	MG/Yr	
Water exported:	n/a	0.000	MG/Yr	
WATER SUPPLIED:		1,335.190	MG/Yr	

AUTHORIZED CONSUMPTION

Click here: for help using option buttons below

Billed metered:	6	962.980	MG/Yr	
Billed unmetered:	n/a	0.000	MG/Yr	
Unbilled metered:	n/a	0.000	MG/Yr	
Unbilled unmetered:	6	9.007	MG/Yr	Pcnt: ○ ● Value: 9.007
AUTHORIZED CONSUMPTION:		971.987	MG/Yr	

Use buttons to select percentage of water supplied OR value

WATER LOSSES (Water Supplied - Authorized Consumption) 363.203 MG/Yr

Apparent Losses

Unauthorized consumption:		3.338	MG/Yr	Pcnt: 0.25% ● ○ Value:
Default option selected for unauthorized consumption - a grading of 5 is applied but not displayed				
Customer metering inaccuracies:	5	50.683	MG/Yr	5.00% ● ○
Systematic data handling errors:	6	13.350	MG/Yr	
Apparent Losses:		67.371		

Choose this option to enter a percentage of billed metered consumption. This is NOT a default value

Real Losses (Current Annual Real Losses or CARL)

Real Losses = Water Losses - Apparent Losses:		295.832	MG/Yr	
WATER LOSSES:		363.203	MG/Yr	

NON-REVENUE WATER

NON-REVENUE WATER:		372.210	MG/Yr	

= Total Water Loss + Unbilled Metered + Unbilled Unmetered

SYSTEM DATA

Length of mains:	10	203.4	miles	
Number of active AND inactive service connections:	8	11,234		
Connection density:		55	conn./mile main	
Average length of customer service line:	5	28.0	ft	(pipe length between curbstop and customer meter or property boundary)
Average operating pressure:	8	75.0	psi	

COST DATA

Total annual cost of operating water system:	6	$1,791,289	$/Year	
Customer retail unit cost (applied to Apparent Losses):	8	$4.38	$/1000 gallons (US)	
Variable production cost (applied to Real Losses):	7	$257.50	$/Million gallons	

PERFORMANCE INDICATORS

Financial Indicators

Non-revenue water as percent by volume of Water Supplied:	27.9%	
Non-revenue water as percent by cost of operating system:	20.9%	
Annual cost of Apparent Losses:	$295,086	
Annual cost of Real Losses:	$76,177	

Operational Efficiency Indicators

Apparent Losses per service connection per day:	16.43	gallons/connection/day
Real Losses per service connection per day*:	72.15	gallons/connection/day
Real Losses per length of main per day*:	N/A	
Real Losses per service connection per day per psi pressure:	0.96	gallons/connection/day/psi
Unavoidable Annual Real Losses (UARL):	88.48	million gallons/year
From Above, Real Losses = Current Annual Real Losses (CARL):	295.83	million gallons/year
Infrastructure Leakage Index (ILI) [CARL/UARL]:	3.34	

* only the most applicable of these two indicators will be calculated

WATER AUDIT DATA VALIDITY SCORE:

***** YOUR SCORE IS: 62 out of 100 *****

A weighted scale for the components of consumption and water loss is included in the calculation of the Water Audit Data Validity Score

PRIORITY AREAS FOR ATTENTION:

Based on the information provided, audit accuracy can be improved by addressing the following components:

1: Volume from own sources
2: Billed metered
3: Customer metering inaccuracies

For more information, click here to see the Grading Matrix worksheet

AWWA WLCC Free Water Audit Software: Water Balance

WAS v4.2

Water Audit Report For:	Report Yr:
Shrewsbury Water Department	2012

Own Sources (Adjusted for known errors): 1,335.190

Water Imported: 0.000

Water Supplied: 1,335.190

Water Exported: 0.000

Authorized Consumption: 971.987

Billed Water Exported

Billed Authorized Consumption: 962.980

- Billed Metered Consumption (inc. water exported): 962.980
- Billed Unmetered Consumption: 0.000

Revenue Water: 962.980

Unbilled Authorized Consumption: 9.007

- Unbilled Metered Consumption: 0.000
- Unbilled Unmetered Consumption: 9.007

Water Losses: 363.203

Apparent Losses: 67.371

- Unauthorized Consumption: 3.338
- Customer Metering Inaccuracies: 50.683
- Systematic Data Handling Errors: 13.350

Real Losses: 295.832

- Leakage on Transmission and/or Distribution Mains: Not broken down
- Leakage and Overflows at Utility's Storage Tanks: Not broken down
- Leakage on Service Connections: Not broken down

Non-Revenue Water (NRW): 372.210

AWWA WLCC Free Water Audit Software: Grading Matrix

V4.0 R1.2

Back to Instructions

In the Reporting Worksheet, grades were assigned to each component of the audit to describe the confidence and accuracy of the input data. The grading assigned to each audit component and the corresponding recommended improvements and actions are highlighted in yellow. Audit accuracy is likely to be improved by prioritizing those items shown in red

Grading

	n/a	1	2	3	4	5	6	7	8	9	10
Volume from own sources	Select this grading only if the water utility purchases/imports all of its water resources (i.e. has no sources of its own)	Less than 25% of water production sources are metered, remaining sources are estimated. No regular meter accuracy testing	25% - 50% of treated water production sources are metered, other sources estimated. No regular meter accuracy testing	Conditions between 2 and 4	50% - 75% of treated water production sources are metered, other sources estimated. Occasional meter accuracy testing	Conditions between 4 and 6	At least 75% of treated water production sources are metered, or at least 90% of the source flow is derived from metered sources. Meter accuracy testing and/or electronic calibration conducted annually. Less than 25% of tested meters are found outside of +/- 6% accuracy.	Conditions between 6 and 8	100% of treated water production sources are metered, meter accuracy testing and electronic calibration conducted annually, less than 10% of meters are found outside of +/- 6% accuracy	Conditions between 8 and 10	100% of treated water production sources are metered, meter accuracy testing and electronic calibration conducted semi-annually, with less than 10% found outside of +/- 3% accuracy.
Improvements to attain higher data grading for "Volume from own Sources" component:		To qualify for 2: Organize efforts to begin to collect data for determining volume from own sources	To qualify for 4: Locate all water production sources on maps and in field, launch meter accuracy testing for existing meters, begin to install meters on unmetered water production sources and replace any obsolete/defective meters		To qualify for 6: Formalize annual meter accuracy testing for all source meters. Complete installation of meters on unmetered water production sources and complete replacement of all obsolete/defective meters.		To qualify for 8: Conduct annual meter accuracy testing on all meters. Complete project to install new, or replace defective existing, meters so that entire production meter population is metered. Repair or replace meters outside of +/- 6% accuracy		To qualify for 10: Maintain annual meter accuracy testing for all meters. Repair or replace meters outside of +/- 6% accuracy. Investigate new meter technology; pilot one or more replacements with innovative meters in attempt to improve meter accuracy.		To maintain 10: Standardize meter accuracy test frequency to semi-annual, or more frequent, for all meters. Repair or replace meters outside of +/- 3% accuracy. Continually investigate/pilot improving metering technology.
Master meter error adjustment	Select n/a only if the water utility fails to have meters on its sources of supply, either its own source, and/or imported (purchased) water sources	Inventory information on meters and paper records of measured volumes in crude condition; data error cannot be determined	No automatic datalogging of production volumes; daily readings are scribed on paper records. Tank/storage elevation changes are not employed in calculating "Volume from own sources" component. Data is adjusted only when grossly evident data error occurs	Conditions between 2 and 4	Production meter data is logged automatically in electronic format and reviewed at least on a monthly basis. "Volume from own sources" tabulations include estimate of daily changes in tanks/storage facilities. Meter data is adjusted when gross data errors occur, or occasional meter testing deems this necessary.	Conditions between 4 and 6	Hourly production meter data logged automatically & reviewed on at least a weekly basis. Data adjusted to correct gross error from equipment malfunction and error confirmed by meter accuracy testing. Tank/storage facility elevation changes are automatically used in calculating a balanced "Volume from own sources" component.	Conditions between 6 and 8	Continuous production meter data logged automatically & reviewed daily. Data adjusted to correct gross error from equipment malfunction & results of meter accuracy testing. Tank/storage facility elevation changes are automatically used in "Volume from own sources" tabulations.	Conditions between 8 and 10	Computerized system (SCADA or similar) automatically balances flows from all sources and storages, results reviewed daily. Mass balance technique compares production meter data to raw (untreated) water and treatment volumes to detect anomalies. Regular calibrations between SCADA and sources meters ensures minimal data transfer error.
Improvements to attain higher data grading for "Master meter error adjustment" component:		To qualify for 2: Develop plan to restructure record/keeping system to capture all flow data; set procedure to review data daily to detect input errors	To qualify for 4: Install automatic datalogging equipment on production meters. Identify tanks/storage facilities and include estimated daily volume of water added to, or subtracted from, "Water Supplied" volume based upon changes in storage		To qualify for 6: Review hourly production meter data for gross error on, at least, a weekly basis. Begin to install instrumentation on tanks/storage facilities to record elevation changes. Use daily net storage change to balance flows in calculating "Water Supplied" volume.		To qualify for 8: Complete installation of elevation instrumentation on all tanks/storage facilities. Continue to use daily net storage change in calculating balanced "Volume from own sources" component. Adjust production meter data for gross error and inaccuracy confirmed by testing.		To qualify for 10: Link all production and tank/storage facility elevation change data to a Supervisory Control & Data Acquisition (SCADA) System, or similar computerized monitoring/control system, and establish automatic flow balancing algorithm and regularly calibrate between SCADA and source meters.		To maintain 10: Monitor meter innovations for development of more accurate and less expensive flowmeters. Continue to replace or repair meters as they perform outside of desired accuracy limits.
Water Imported	Select n/a if the water utility's supply is exclusively from its own water resources (no bulk purchased/ imported water)	Less than 25% of imported water sources are metered, remaining sources are estimated. No regular meter accuracy testing	25% - 50% of imported water sources are metered, other sources estimated. No regular meter accuracy testing	Conditions between 2 and 4	50% - 75% of imported water sources are metered, other sources estimated. Occasional meter accuracy testing	Conditions between 4 and 6	At least 75% of imported water sources are metered, meter accuracy testing and/or electronic calibration conducted annually. Less than 25% of tested meters are found outside of +/- 6% accuracy.	Conditions between 6 and 8	100% of imported water sources are metered, meter accuracy testing and/or electronic calibration conducted annually, less than 10% of meters are found outside of +/- 6% accuracy.	Conditions between 8 and 10	100% of imported water sources are metered, meter accuracy testing and/or electronic calibration conducted semi-annually, with less than 10% found outside of +/- 3% accuracy.
Improvements to attain higher data grading for "Water Imported Volume" component:		To qualify for 2: Review bulk water purchase agreements with partner suppliers, confirm requirements for use and maintenance of accurate metering. Identify needs for new or replacement meters with goal to meter all imported water sources.	To qualify for 4: Locate all imported water sources on maps and in field, launch meter accuracy testing for existing meters, begin to install meters on unmetered imported water interconnections and replace obsolete/defective meters		To qualify for 6: Formalize annual meter accuracy testing for all imported water meters. Continue installation of meters on unmetered exported water interconnections and replacement of obsolete/defective meters.		To qualify for 8: Complete project to install new, or replace defective, meters on all imported water interconnections. Maintain annual meter accuracy testing for all imported water meters. Repair or replace meters outside of +/- 6% accuracy.		To qualify for 10: Maintain annual meter accuracy testing for all meters. Repair or replace meters outside of +/- 6% accuracy. Investigate new meter technology; pilot one or more replacements with innovative meters in attempt to improve meter accuracy.		To maintain 10: Standardize meter accuracy test frequency to semi-annual, or more frequent, for all meters. Repair or replace meters outside of +/- 3% accuracy. Continually investigate/pilot improving metering technology.

Grading											
	n/a	1	2	3	4	5	6	7	8	9	10
Water Exported	Select n/a if the water utility sells no bulk water to neighboring water utilities (no exported water sales)	Less than 25% of exported water sources are metered, remaining sources are estimated. No regular meter accuracy testing	25% - 50% of exported water sources are metered, other sources estimated. No regular meter accuracy testing	Conditions between 2 and 4	50% - 75% of exported water sources are metered, other sources estimated. Occasional meter accuracy testing	Conditions between 4 and 6	At least 75% of exported water sources are metered, meter accuracy testing and/or electronic calibration conducted annually. Less than 25% of tested meters are found outside of +/- 6% accuracy	Conditions between 6 and 8	100% of exported water sources are metered, meter accuracy testing and/or electronic calibration conducted annually, less than 10% of meters are found outside of +/- 6% accuracy	Conditions between 8 and 10	100% of exported water sources are metered, meter accuracy testing and/or electronic calibration conducted semi-annually, with less than 10% found outside of +/- 3% accuracy.
Improvements to attain higher data grading for "Water Exported Volume" component:		to qualify for 2: Review bulk water sales agreements with partner suppliers; confirm requirements for use & upkeep of accurate metering. Identify needs to install new, or replace defective meters as needed.	To qualify for 4: Locate all exported water sources on maps and in field, launch meter accuracy testing for existing meters, begin to install meters on unmetered exported water interconnections and replace obsolete/defective meters		to qualify for 6: Formalize annual meter accuracy testing for all exported water meters. Continue installation of meters on unmetered exported water interconnections and replacement of obsolete/defective meters.		to qualify for 8: Complete project to install new, or replace defective, meters on all exported water interconnections. Maintain annual meter accuracy testing for all imported water meters. Repair or replace meters outside of +/- 6% accuracy		to qualify for 10: Maintain annual meter accuracy testing for all meters. Repair or replace meters outside of +/- 6% accuracy. Investigate new meter technology; pilot one or more replacements with innovative meters in attempt to improve meter accuracy.		to maintain 10: Standardize meter accuracy test frequency to semi-annual, or more frequent, for all meters. Repair or replace meters outside of +/- 3% accuracy. Continually investigate/pilot improving metering technology.
AUTHORIZED CONSUMPTION											
Billed metered:	n/a (not applicable) Select n/a only if the entire customer population is not metered and is billed for water service on a flat or fixed rate basis. In such a case the volume entered must be zero	Less than 50% of customers with volume-based billings from meter readings, flat or fixed rate billed for the majority of the customer population	At least 50% of customers with volume-based billing from meter reads; flat rate billed for others. Manual meter reading, under 50% read success rate, remainder estimated. Limited meter records, no regular meter testing or replacement. Billing data maintained on paper records, with no auditing	Conditions between 2 and 4	At least 75% of customers with volume-based billing from meter reads, flat or fixed rate billed for remainder. Manual meter reading used, at least 50% meter read success rate, failed reads are estimated. Purchase records verify age of customer meters, only very limited meter accuracy testing is conducted. Customer meters replaced only upon complete failure. Computerized billing records, but only periodic internal auditing conducted	Conditions between 4 and 6	At least 90% of customers with volume-based billing from meter reads, remaining accounts are estimated. Manual customer meter reading gives at least 80% customer meter reading success rate, failed reads are estimated. Good customer meter records, limited meter accuracy testing, regular replacement of oldest meters. Computerized billing records with routine auditing of global statistics	Conditions between 6 and 8	At least 97% of customers with volume-based billing from meter reads. At least 90% customer meter read success rate, or minimum 80% read success rate with planning and budgeting for trials of Automatic Metering Reading (AMR) in one or more pilot areas. Good customer meter records. Regular meter accuracy testing guides replacement of statistically significant number of meters each year. Routine auditing of computerized billing records for global and detailed statistics, verified periodically by third party	Conditions between 8 and 10	At least 99% of customers with volume-based billing from meter reads. At least 95% customer meter reading success rate; or minimum 80% meter reading success rate, with Automatic Meter Reading (AMR) trials underway. Statistically significant customer meter testing and replacement program in place. Computerized billing with routine, detailed auditing, including field investigation of representative sample of accounts. Annual audit verification by third party
Improvements to attain higher data grading for "Billed Metered Consumption" component:	If n/a is selected because the customer meter population is unmetered, consider establishing a new policy to meter the customer population and employ water rates based upon metered volumes.	to qualify for 2: Conduct investigations or trials of customer meters to select appropriate meter models. Budget funding for meter installations. Investigate volume based water rate structures.	to qualify for 4: Purchase and install meters on unmetered accounts. Implement policies to improve meter reading success. Catalog meter information during meter read visits to identify age/model of existing meters. Test a minimal number of meters for accuracy. Install computerized billing system.		to qualify for 6: Purchase and install meters on unmetered accounts. Eliminate flat fee billing and establish appropriate water rate structure based upon measured consumption. Continue to achieve verifiable success in removing manual meter reading barriers. Expand meter accuracy testing. Launch regular meter replacement program. Conduct routine audit of global statistics.		to qualify for 8: Purchase and install meters on unmetered accounts. Assess cost-effectiveness of Automatic Meter Reading (AMR) system for portion or entire system, or achieve ongoing improvements in manual meter reading success rate. Refine meter accuracy testing program. Set meter replacement goals based upon accuracy test results. Refine routine auditing procedures based upon third party guidance		to qualify for 10: Purchase and install meters on unmetered accounts. Launch Automatic Meter Reading (AMR) system trials if manual meter reading success rate of at least 95% is not achieved within a five-year program. Continue meter accuracy testing program. Conduct planning and budgeting for large scale meter replacement based upon meter life cycle analysis using cumulative flow target. Continue routine auditing and require annual third party review.		to maintain 10: Regular internal and third party auditing, and meter accuracy testing ensures that accurate customer meter readings are obtained and entered as the basis for volume based billing. Stay abreast of improvements in Advanced Metering Infrastructure (AMI) and information management. Plan and budget for justified upgrades in metering, meter reading and billing data management.
Billed unmetered	Select n/a if it is the policy of the water utility to meter all customer connections and it has been confirmed by detailed auditing that all customers do indeed have a water meter. I.e. no unmetered accounts exist	Water utility policy does not require customer metering, flat or fixed fee billed. No data collected on customer consumption. Only estimates available are derived from data estimation methods using average fixture count multiplied by number of connections, or similar approach	Water utility policy does not require customer metering, flat or fixed fee billed. Some metered accounts exist in parts of the system (pilot areas or District Metered Areas) with consumption recorded on portable dataloggers. Data from these sample meters are used to infer consumption for the total customer population. Site specific estimation methods are used for unusual buildings/water uses	Conditions between 2 and 4	Water utility policy does require metering and volume based billing but lacks written procedures and employs casual oversight, resulting in upto 20% of billed accounts believed to be unmetered. A rough estimate of the annual consumption for all unmetered accounts is included in the annual water audit, with no inspection of individual unmetered accounts	Conditions between 4 and 6	Water utility policy does require metering and volume based billing but exemption exist for a portion of accounts such as municipal buildings. As many as 15% of billed accounts are unmetered due to this exemption or meter installation difficulties. Only a group estimate of annual consumption for all unmetered accounts is included in the annual water audit, with no inspection of individual unmetered accounts	Conditions between 6 and 8	Water utility policy requires metering and volume based billing for all customer accounts. However, less than 5% of billed accounts remain unmetered because because installation is hindered by unusual circumstances. The goal is to minimize the number of unmetered accounts. Reliable estimates of consumption are obtained for unmetered accounts via site specific estimation methods	Conditions between 8 and 10	Water utility policy requires metering and volume based billing for all customer accounts. Less than 2% of billed accounts are unmetered and exist because meter installation is hindered by unusual circumstances. The goal exists to minimize the number of unmetered accounts to the extent that is economical. Reliable estimates of consumption are obtained at these accounts via site specific estimation methods.

Grading											
	n/a	1	2	3	4	5	6	7	8	9	10
Improvements to attain higher data grading for "Billed Unmetered Consumption" component:		to qualify for 2: Investigate a new water utility policy to require metering of the customer population, and a reduction of unmetered accounts. Conduct pilot metering project by installing water meters in small sample of customer accounts and datalogging the water consumption.	to qualify for 4: Implement a new water utility policy requiring customer metering. Expand pilot metering study to include several different meter types, which will provide data for economic assessment of full scale metering options. Assess sites with access difficulties to devise means to obtain water consumption volumes.		to qualify for 6: Budget for staff resources to review billing records to identify unmetered properties. Specify metering needs and funding requirements to install sufficient meters to significant reduce the number of unmetered accounts		to qualify for 8: Install customer meters on a full scale basis. Refine metering policy and procedures to ensure that all accounts, including municipal properties, are designated for meters. Implement procedures to obtain reliable consumption estimate for unmetered accounts awaiting meter installation.		to qualify for 10: Continue customer meter installation throughout the service area, with a goal to minimize unmetered accounts. Sustain the effort to investigate accounts with access difficulties to devise means to install water meters or otherwise measure water consumption.		to maintain 10: Continue to refine estimation methods for unmetered consumption and explore means to establish metering, for as many billed unmetered accounts as is economically feasible.
Unbilled metered	select n/a if all billing-exempt consumption is unmetered.	Billing practices exempt certain accounts, such as municipal buildings, but written policies do not exist; and a reliable count of unbilled metered accounts is unavailable. Meter upkeep and meter reading on these accounts is rare and not considered a priority. Due to poor recordkeeping and lack of auditing, water consumption for all such accounts is purely guessimated.	Billing practices exempt certain accounts, such as municipal buildings, but only scattered, dated written directives exist to justify this practice. A reliable count of unbilled metered accounts is unavailable. Sporadic meter replacement and meter reading occurs on an as-needed basis. The total annual water consumption for all unbilled, metered accounts is estimated based upon approximating the number of accounts and assigning consumption from actively billed accounts of same meter size.	Conditions between 2 and 4	Dated written procedures permit billing exemption for specific accounts, such as municipal properties, but are unclear regarding certain other types of accounts. Meter reading is given low priority and is sporadic. Consumption is quantified from meter readings where available. The total number of unbilled, unmetered accounts must be estimated along with consumption volumes	Conditions between 4 and 6	Written policies regarding billing exemptions exist but adherence in practice is questionable. Metering and meter reading for municipal buildings is reliable but sporadic for other unbilled metered accounts. Periodic auditing of such accounts is conducted. Water consumption is quantified directly from meter readings where available, but the majority of the consumption is estimated	Conditions between 6 and 8	Written policy identifies the types of accounts granted a billing exemption. Customer meter management and meter reading are considered secondary priorities, but meter reading is conducted at least annually to obtain consumption volumes for the annual water audit. High level auditing of billing records ensures that a reliable census of such accounts exists.	Conditions between 8 and 10	Clearly written policy identifies the types of accounts given a billing exemption, with emphasis on keeping such accounts to a minimum. Customer meter management and meter reading for these accounts is given proper priority and is reliably conducted. Regular auditing confirms this. Total water consumption for these accounts is taken from reliable readings from accurate meters.
Improvements to attain higher data grading for "Unbilled metered Consumption" component:		to qualify for 2: Reassess the water utility's policy allowing certain accounts to be granted a billing exemption. Draft an outline of a new written policy for billing exemptions, with clear justification as to why any accounts should be exempt from billing, and with the intention to keep the number of such accounts to a minimum.	to qualify for 4: Review historic written directives and policy documents allowing certain accounts to be billing-exempt. Draft an outline of a written policy for billing exemptions, identify criteria that grants an exemption, with a goal of keeping this number of accounts to a minimum.		to qualify for 6: Draft a new written policy regarding billing exemptions based upon consensus criteria allowing this occurrence. Assign resources to audit meter records and billing records to obtain census of unbilled metered accounts		to qualify for 8: Communicate billing exemption policy throughout the organization and implement procedures that ensure proper account management. Conduct inspections of accounts confirmed in unbilled metered status and verify that accurate meters exist and are scheduled for routine meter readings.		to qualify for 10: Ensure that meter management (meter accuracy testing, meter replacement) and meter reading activities are accorded the same priority as billed accounts. Establish ongoing annual auditing process to ensure that water consumption is reliably collected and provided to the annual water audit process.		to maintain 10: Reassess philosophy in allowing any water uses to go "unbilled". It is possible to meter and bill all accounts, even if the fee charged for water consumption is discounted or waived. Metering and billing all accounts ensures that water consumption is tracked and water waste from plumbing leaks is detected and minimized.
Unbilled unmetered		Extent of unbilled, unmetered consumption is unknown due to unclear policies and poor recordkeeping. Total consumption is quantified based upon a purely subjective estimate.	Clear extent of unbilled, unmetered consumption is unknown, but a number of events are randomly documented each year, confirming existence of such consumption, but without sufficient documentation to quantify an accurate estimate of the annual volume consumed	Conditions between 2 and 4	Extent of unbilled, unmetered consumption is partially known, and procedures exist to document certain events such as miscellaneous fire hydrant uses. Formulae is used to quantify the consumption from such events (time running x typical flowrate x number of events)	Default value of 1.25% of system input volume is employed	Coherent policies exist for some forms of unbilled, unmetered consumption but others await closer evaluation. Reasonable recordkeeping for the managed uses exists and allows for annual volumes to be quantified by inference, but unsupervised uses are guesstimated	Conditions between 6 and 8	Clear policies and good recordkeeping exist for some uses (ex: unmetered fire connections registering consumption), but others uses (ex: miscellaneous uses of fire hydrants) have limited oversight. Total consumption is a mix of well quantified use such as from formulae (time x typical flow) or temporary meters, and relatively subjective estimates of less regulated use.	Conditions between 8 and 10	Clear policies exist to identify permitted use of water in unbilled, unmetered fashion, with the intention of minimizing this type of consumption. Good records document each occurrence and consumption is quantified via formulae (time x typical flow) or use of temporary meters
Improvements to attain higher data grading for "Unbilled Unmetered Consumption" component:		to qualify for 5: Utilize accepted default value of 1.25% of system input volume as an expedient means to gain a reasonable quantification of this use to qualify for 2: Establish a policy regarding what water uses should be allowed as unbilled and unmetered. Consider tracking a small sample of one such use (ex: fire hydrant flushings)	to qualify for 5: Utilize accepted default value of 1.25% of system input volume as an expedient means to gain a reasonable quantification of this use to qualify for 4: Evaluate the documentation of events that have been observed. Meet with user groups (ex: for fire hydrants - fire departments, contractors to ascertain their need for water from fire hydrants)		to qualify for 6: Utilize accepted default value of 1.25% of system input volume as expedient means to gain a reasonable quantification of all such use. This is particularly appropriate for water utilities who are in the early stages of the water auditing process.	to qualify for 6 or greater: Finalize policy and do field checks. Proceed if top-down audit exists and/or a great volume of such use is suspected.	to qualify for 8: Assess water utility policy and procedures to ensure that fire hydrant permits are issued for use by persons outside of the utility. Create written procedures for use and documentation of fire hydrants by water utility personnel.		to qualify for 10: Refine written procedures to ensure that all uses of unbilled, unmetered water are overseen by a structured permitting process managed by water utility personnel. Reassess policy to determine if some of these uses have value in being converted to billed and/or metered status.		to maintain 10: Continue to refine policy and procedures with intention of reducing the number of allowable uses of water in unbilled and unmetered fashion. Any uses that can feasibly become billed and metered should be converted eventually.

Grading											
	n/a	1	2	3	4	5	6	7	8	9	10
APPARENT LOSSES											
Unauthorized consumption		Extent of unauthorized consumption is unknown due to unclear policies and poor recordkeeping. Total unauthorized consumption is guesstimated	Unauthorized consumption is a known occurrence, but its extent is a mystery. There are no requirements to document observed events, but periodic field reports capture some of these occurrences. Total unauthorized consumption is approximated from this limited data	conditions between 2 and 4	Procedures exist to document some unauthorized consumption such as observed unauthorized fire hydrant openings. Use formulae to quantify this consumption (time running x typical flowrate x number of events)	Default value of 0.25% of system input volume is employed	Coherent policies exist for some forms of unauthorized consumption but others await closer evaluation. Reasonable surveillance and recordkeeping exist for occurrences that fall under the policy. Volumes quantified by inference from these records. Unsupervised uses are guesstimated	Conditions between 6 and 8	Clear policies and good recordkeeping exist for certain events (ex. tampering with water meters); other occurrences have limited oversight. Total consumption is a combination of volumes from formulae (time x typical flow) and subjective estimates of unconfirmed consumption	Conditions between 8 and 10	Clear policies exist to identify all known unauthorized uses of water. Staff and procedures exist to provide enforcement of policies and detect violations. Each occurrence is quantified via formulae (time x typical flow) or similar methods.
Improvements to attain higher data grading for "Unauthorized Consumption" component:		to qualify for 5: Use accepted default of 0.25% of system input volume. to qualify for 2: Review utility policy regarding what water uses are considered unauthorized, and consider tracking a small sample of one such occurrence (ex: unauthorized fire hydrant openings)	to qualify for 5: Use accepted default of 0.25% of system input volume to qualify for 4: Review utility policy regarding what water uses are considered unauthorized, and consider tracking a small sample of one such occurrence (ex: unauthorized fire hydrant openings)		to qualify for 5: Utilize accepted default value of 0.25% of system input volume as expedient means to gain a reasonable quantification of all such use. This is particularly appropriate for water utilities who are in the early stages of the water auditing process.	to qualify for 6 or greater: Finalize policy and do field checks. Proceed if top-down audit exists and/or a great volume of such use is suspected	to qualify for 8: Assess water utility policies to ensure that all known occurrences of unauthorized consumption are outlawed, and that appropriate penalties are prescribed. Create written procedures for use and documentation of various occurrences of unauthorized consumption as they are uncovered.		to qualify for 10: Refine written procedures and assign staff to seek out likely occurrences of unauthorized consumption. Explore new locking devices, monitors and other technologies designed to detect and thwart unauthorized consumption.		to maintain 10: Continue to refine policy and procedures to eliminate any loopholes that allow or tacitly encourage unauthorized consumption. Continue to be vigilant in documentation and enforcement efforts.
Customer metering inaccuracies:	select n/a only if the entire customer population is unmetered. In such a case the volume entered must be zero	Customer meters exist, but with unorganized paper records on meters; no meter accuracy testing or meter replacement program. Workflow is driven chaotically by customer complaints with no proactive management. Loss volume due to aggregate meter inaccuracy is guesstimated	Poor recordkeeping and meter oversight is recognized by water utility management who has allotted staff and funding resources to organize improved recordkeeping and start meter accuracy testing. Existing paper records gathered and organized to provide cursory disposition of meter population	Conditions between 2 and 4	Reliable recordkeeping exists, meter information is improving as meters are replaced. Meter accuracy testing is conducted annually for a small number of meters. Limited number of oldest meters replaced each year. Inaccuracy volume is largely an estimate, but refined based upon limited testing data	Conditions between 4 and 6	A reliable electronic recordkeeping system for meters exists. Population includes a mix of new high performing meters and dated meters with suspect accuracy. Routine, but limited, meter accuracy testing and meter replacement occur. Inaccuracy volume is quantified using a mix of reliable and less certain data	Conditions between 6 and 8	Ongoing meter replacement and accuracy testing result in highly accurate customer meter population. Testing is conducted on samples of meters at varying lifespans to determine optimum replacement time for various types of meters	Conditions between 8 and 10	Good records of number, type and size of customer meters; ongoing meter replacement occurs. Regular meter accuracy testing gives reliable measure of composite inaccuracy volume for the system. New metering technology is embraced to keep overall accuracy improving
Improvements to attain higher data grading for "Customer meter inaccuracy volume" component:	If n/a is selected because the customer meter population is unmetered, consider establishing a new policy to meter the customer population and employ water rates based upon metered volumes.	to qualify for 2: Gather available meter purchase records. Conduct testing on a small number of meters believed to be the most inaccurate. Review staffing needs of metering group and budget for necessary resources to better organize meter management.	to qualify for 4: Implement a reliable record keeping system for customer meter histories, preferably using electronic methods typically linked to, or part of, the Customer Billing System or Customer Information System. Expand meter accuracy testing to a larger group of meters.		to qualify for 6: Standardize procedures for meter recordkeeping with the electronic information system. Accelerate meter accuracy testing and meter replacements guided by testing results		to qualify for 8: Expand annual meter accuracy testing to evaluate a statistically significant number of meter makes/models. Expand meter replacement program to replace statistically significant number of poor performing meters each year.		to qualify for 10: Continue efforts to manage meter population with reliable recordkeeping, meter testing and replacement. Evaluate new meter types and install one or more types in 5-10 customer accounts each year in order to pilot improving metering technology.		to maintain 10: Increase the number of meters tested and replaced as justified by meter accuracy test data. Continually monitor development of new technology in Advanced Metering Infrastructure (AMI) to grasp opportunities for greater accuracy in metering and customer consumption data.
Systematic Data Handling Error:	Note: all water utilities incur some amount of this error. Even in water utilities with unmetered customer populations and fixed rate billing, errors occur in annual billing tabulations. Enter a positive value for the volume and select a grading	Vague policy for permitting (creating new customer accounts) and billing. Billing data maintained on paper records which are in disarray. No audits conducted to confirm billing data handling efficiency. Unknown number of customers escape routine billing due to lack of billing process oversight.	Policy for permitting and billing exists but needs refinement. Billing data maintained on paper records or insufficiently capable electronic database. Only periodic unstructured auditing work conducted to confirm billing data handling efficiency. Volume of unbilled water due to billing lapses is a guess	Conditions between 2 and 4	Policy and procedures for permitting and billing exist but needs refinement. Computerized billing system exists, but is dated or lacks needed functionality. Periodic, limited internal audits conducted and confirm with approximate accuracy the consumption volumes lost to billing lapses	Conditions between 4 and 6	Policy for permitting and billing is adequate and reviewed periodically. Computerized billing system in use with basic reporting available. Any effect of billing adjustments on measured consumption volumes is well understood. Internal checks of billing data error conducted annually. Reasonably accurate quantification of consumption volume lost to billing lapses is obtained	Conditions between 6 and 8	Permitting and billing policy reviewed at least biannually. Computerized billing system includes an array of reports to confirm billing data and system functionality. Annual internal checks conducted with periodic third party audit. Accountability checks flag billing lapses. Consumption lost to billing lapses is well quantified and reducing year-by-year.	Conditions between 8 and 10	Sound policy exists for permitting of all customer billing accounts. Robust computerized billing system gives high functionality and reporting capabilities. Assessment of policy and data handling errors conducted internally and audited by third party annually, ensuring consumption lost to billing lapses is minimized and detected as it occurs.

Grading										
	n/a	1	2	3	4	5	6	7	8	9	10
Improvements to attain higher data grading for "Systematic Data Handling Error volume" component:		To qualify for 2: Draft written policy for permitting and billing. Investigate and budget for computerized customer billing system. Conduct initial audit of billing records by flow-charting the basic business processes of the customer account/billing function.	To qualify for 4: Finalize written policy for permitting and billing. Implement a computerized customer billing system. Conduct initial audit of billing records as part of this process.		To qualify for 6: Refine permitting and billing procedures and ensure consistency with the utility policy regarding billing, and minimize opportunity for missed billings. Upgrade or replace customer billing system for needed functionality - ensure that billing adjustments don't corrupt the value of consumption volumes. Proceduritze internal annual audit process.		To qualify for 8: Formalize regular review of permitting and billing practices. Enhance reporting capability of computerized billing system. Formalize regular auditing process to reveal scope of data handling error.		To qualify for 10: Close policy/procedure loopholes that allow some customer accounts to go unbilled, or data handling errors to exist.] Ensure that internal and third party audits are conducted annually.		To maintain 10: Stay abreast of customer information management developments and innovations. Monitor developments of Advanced Metering Infrastructure (AMI) and integrate technology to ensure that customer endpoint information is well-monitored and errors/lapses are at an economic minimum.
SYSTEM DATA											
Length of mains		Poorly assembled and maintained paper as-built records of existing water main installations makes accurate determination of system pipe length impossible. Length of mains is guesstimated.	Paper records in poor condition (no annual tracking of installations & abandonments) Poor procedures to ensure that new water mains installed by developers are accurately documented	Conditions between 2 and 4	Sound policy and procedures for permitting and documenting new water main installations, but gaps in management result in a uncertain degree of error in tabulation of mains length.	Conditions between 4 and 6	Sound policy and procedures exist for permitting and commissioning new water mains. Highly accurate paper records with regular field validation, or electronic records and asset management system in good condition. Includes system backup.	Conditions between 6 and 8	Sound policy and procedures exist for permitting and commissioning new water mains. Electronic recordkeeping and asset management system are used to store and manage data.	Conditions between 8 and 10	Sound policy exists for managing water mains extensions and replacements. Geographic Information System (GIS) data and asset management database agree and random field validation proves truth of databases
Improvements to attain higher data grading for "Length of Water Mains" component:		To qualify for 2: Assign personnel to inventory current as-built records and compare with customer billing system records and highway plans. Assemble policy documents regarding permitting and documentation of water main installations by the utility and building developers; identify gaps in procedure that result in poor documentation.	To qualify for 4: Complete inventory of paper records of water main installations & abandonments for a number of years prior to audit year. Review policy and procedures for commissioning and documenting new water main installation and abandonments.		To qualify for 6: Finalize updates/improvements to policy and procedures for permitting/commissioning new main installations. Confirm inventory of records for five years prior to audit year; correct any errors or omissions.		To qualify for 8: Launch random field checks of limited number of locations. Convert to electronic databases with backup as justified.		To qualify for 10: Link Geographic Information System (GIS) and asset management databases, conduct field verification of data.		To maintain 10: Continue with standardization and random field validation to improve knowledge of system
Number of active AND inactive service connections		Vague permitting (of new service connections) policy and poor paper recordkeeping of customer connections/billings result in suspect determination of the number of service connections, which may be 10-15% in error from actual count.	General permitting policy exists but paper records, procedural gaps, and weak oversight result in questionable total for number of connections, which may vary 5-10% of actual count.	Conditions between 2 and 4	Permitting policy and procedures exist, but with some gaps in performance and oversight. Computerized information management system is being brought online to replace dated paper recordkeeping system. Reasonably accurate tracking of service connection installations & abandonments, but count can be up to 5% in error from actual total.	Conditions between 4 and 6	Permitting policy and procedures are adequate and reviewed periodically. Computerized information management system is in use with annual installations & abandonments totaled. Very limited field verifications and audits. Error in count of number of service connections is believed to be no more that 3%	Conditions between 6 and 8	Permitting policy and procedures reviewed at least biannually. Well-managed computerized information management system and routine, periodic field checks and internal system audits allows counts of connections that is no more than 2% in error.	Conditions between 8 and 10	Sound permitting policy and well managed and audited procedures ensure reliable management of service connection population. Computerized information management system and Geographic Information System (GIS) information agree; field validation proves truth of databases. Count of connections believed to be in error by less than 1%.
Improvements to attain higher data grading for "Number of Active and Inactive customer service connections" component:		To qualify for 2: Draft new policy and procedures for permitting and billing. Research and collect paper records of installations & abandonments for several years prior to audit year.	To qualify for 4: Refine policy and procedures for permitting and billing. Research computerized recordkeeping system (Customer Information System or Customer Billing System) to improve documentation format for service connections.		To qualify for 6: Refine procedures to ensure consistency with permitting policy to establish new service connections or decommission existing connections. Improve process to include all totals for at least five years prior to audit year.		To qualify for 8: Formalize regular review of permitting policy and procedures. Launch random field checks of limited number of locations. Develop reports and auditing mechanisms for computerized information management system.		To qualify for 10: Close any procedural loopholes that allow installations to go undocumented. Link computerized information management system with Geographic Information System (GIS) and formalize field inspection and information system auditing processes. Documentation of new or decommissioned service connections encounters several levels of checks and balances.		To maintain 10: Continue with standardization and random field validation to improve knowledge of system.
	Note: If customer	Gradings 1-9 apply if customer properties are unmetered, if customer meters exist and are located inside the customer building premises, or if the water utility owns and is responsible for the entire service connection piping from the water main to the customer building. In any of these cases the average distance between the curbstop or boundary separating utility/customer responsibility for service connection piping, and the typical first point of use (ex: faucet) or the customer meter must be quantified. Gradings of 1-9 are used to grade the validity of the means to quantify this value (See the "Service Connection Diagram" worksheet)									Either of two conditions can be met to obtain a grading of 10

Grading											
	n/a	1	2	3	4	5	6	7	8	9	10
Average length of customer service line:	water meters are located outside of the customer building next to the curbstop or boundary separating utility/customer responsibility, follow the grading description for 10(a) Also see the Service Connection Diagram worksheet	Vague policy exists to define the delineation of water utility ownership and customer ownership of the service connection piping. Curbstops are perceived as the breakpoint but these have not been well-maintained or documented. Most are buried or obscured. Their location varies widely from site-to-site, and estimating this distance is arbitrary due to the unknown location of many curbstops	Policy requires that the curbstop serves as the delineation point between water utility ownership and customer ownership of the service connection piping. The piping from the water main to the curbstop is the property of the water utility, and the piping from the curbstop to the customer building is owned by the customer. Curbstop locations are not well documented and the average distance is based upon a limited number of locations measured in the field	Conditions between 2 and 4	Good policy requires that the curbstop serves as the delineation point between water utility ownership and customer ownership of the service connection piping. Curbstops are generally installed as needed and are reasonably documented. Their location varies widely from site-to-site, and an estimate of this distance is hindered by the availability of paper records.	Conditions between 4 and 6	Clear policy exists to define utility/customer responsibility for service connection piping. Accurate, well-maintained paper or basic electronic recordkeeping system exists. Periodic field checks confirm piping lengths for a sample of customer properties	Conditions between 6 and 8	Clearly worded policy standardizes the location of curbstops and meters, which are inspected upon installation. Accurate and well maintained electronic records exist with periodic field checks to confirm locations of service lines, curbstops and customer meter pits. An accurate number of customer properties from the customer billing system allows for reliable averaging of this length.	Conditions between 8 and 10	a) The customer water meter is located outside of the customer building adjacent to the curbstop or boundary separating utility/customer responsibility for the service connection piping. In this case enter a value of zero in the Reporting Worksheet with a grading of 10. b) Customer water meters are located inside customer buildings, or the properties are unmetered. In either case the distance is highly reliable since data is drawn from a Geographic Information System (GIS) and confirmed by routine field checks.
Improvements to attain higher data grading for "Average Length of Customer Service Line" component:		to qualify for 2: Research and collect paper records of service line installations. Inspect several sites in the field using pipe locators to locate curbstops. Obtain the length of this small sample of connections in this manner.	to qualify for 4: Formalize and communicate policy delineating utility/customer responsibilities for service connection piping. Assess accuracy of paper records by field inspection of a small sample of service connections using pipe locators as needed. Research the potential migration to a computerized information management system to store service connection data.		to qualify for 6: Establish coherent procedures to ensure that policy for curbstop, meter installation and documentation is followed. Gain consensus within the water utility for the establishment of a computerized information management system.		to qualify for 8: Implement an electronic means of recordkeeping, typically via a customer information system or customer billing system. Standardize the process to conduct field checks of limited number of locations.		to qualify for 10: Link customer information management system and Geographic Information System (GIS), standardize process for field verification of data.		to maintain 10: Continue with standardization and random field validation to improve knowledge of system.
Average operating pressure:		Available records are poorly assembled and maintained paper records of supply pump characteristics and water distribution system operating conditions. Average pressure is guesstimated based upon this information and ground elevations from crude topographical maps. Widely varying distribution system pressures due to undulating terrain, high system head loss and weak/erratic pressure controls further compromise the validity of the average pressure calculation.	Limited telemetry monitoring of scattered sites provides some static pressure data, which is recorded in handwritten logbooks. Pressure data is gathered at individual sites only when low pressure complaints arise. Average pressure is determined by averaging relatively crude data, and is affected by significant variation in ground elevations, system head loss and gaps in pressure controls in the distribution system.	Conditions between 2 and 4	Effective pressure controls separate different pressure zones, moderate pressure variation across the system, occasional open boundary valves are discovered that breech pressure zones. Basic telemetry monitoring of the distribution system logs pressure data electronically. Pressure data gathered by gauges or dataloggers at fire hydrants or buildings when low pressure complaints arise, and during fire flow tests and system flushing. Reliable topographical data exists. Average pressure is calculated using this mix of data.	Conditions between 4 and 6	Reliable pressure controls separate distinct pressure zones, only very occasional open boundary valves are encountered that breech pressure zones. Well-covered telemetry monitoring of the distribution system logs extensive pressure data electronically. Pressure gathered by gauges/dataloggers at fire hydrants and buildings when low pressure complaints arise, and during fire flow tests and system flushing. Average pressure is determined by using this mix of reliable data.	Conditions between 6 and 8	Well-managed, discrete pressure zones exist with generally predictable pressure fluctuations. A current full-scale SCADA System exists to monitor the water distribution system and collect data, including real time pressure readings at representative sites across the system. The average system pressure is determined from reliable SCADA System data.	Conditions between 8 and 10	Well-managed pressure districts/zones, SCADA System and hydraulic model exist to give very precise pressure data across the water distribution system. Average system pressure is reliably calculated from extensive, reliable, and cross-checked data.
Improvements to attain higher data grading for "Average Operating Pressure" component:		to qualify for 2: Employ pressure gauging and/or datalogging equipment to obtain pressure measurements from fire hydrants. Locate accurate topographical maps of service area in order to confirm ground elevations. Research pump data sheets to find pump pressure/flow characteristics.	to qualify for 4: Formalize a procedure to use pressure gauging/datalogging equipment to gather pressure data during various system events such as low pressure complaints; or operational testing. Gather pump pressure and flow data at different flow regimes. Identify faulty pressure controls (pressure reducing valves, altitude valves, partially open boundary valves) and plan to properly configure pressure zones. Make all pressure data from these efforts available to generate system-wide average pressure.		to qualify for 6: Expand the use of pressure gauging/datalogging equipment to gather scattered pressure data at a representative set of sites, based upon pressure zones or areas. Utilize pump pressure and flow data to determine supply head entering each pressure zone or district. Correct any faulty pressure controls (pressure reducing valves, altitude valves, partially open boundary valves) to ensure properly configured pressure zones. Use expanded pressure dataset from these activities to generate system-wide average pressure.		to qualify for 8: Install a Supervisory Control and Data Acquisition (SCADA) System to monitor system parameters and control operations. Set regular calibration schedule for instrumentation to insure data accuracy. Obtain accurate topographical data and utilize pressure data gathered from field surveys to provide extensive, reliable data for pressure averaging.		to qualify for 10: Obtain average pressure data from hydraulic model of the distribution system that has been calibrated via field measurements in the water distribution system and confirmed in comparisons with SCADA System data.		to maintain 10: Continue to refine the hydraulic model of the distribution system and consider linking it with SCADA System for real-time pressure data calibration, and averaging.

Grading											
	n/a	1	2	3	4	5	6	7	8	9	10
COST DATA											
Total annual cost of operating water system		Incomplete paper records and lack of documentation on many operating functions making calculation of water system operating costs a pure guesstimate	Reasonably maintained, but incomplete, paper or electronic accounting provides data to estimate the major portion of water system operating costs	Conditions between 2 and 4	Electronic, industry-standard cost accounting system in place. Gaps in data known to exist, periodic internal reviews conducted but not a structured audit.	Conditions between 4 and 6	Reliable electronic, industry-standard cost accounting system in place, with all pertinent water system operating costs tracked. Data audited periodically by utility personnel, not a Certified Public Accountant (CPA)	Conditions between 6 and 8	Reliable electronic, industry-standard cost accounting system in place, with all pertinent water system operating costs tracked. Data audited at least annually by utility personnel, and periodically by third-party CPA.	Conditions between 8 and 10	Reliable electronic, industry-standard cost accounting system in place, with all pertinent water system operating costs tracked. Data audited annually by utility personnel and by third-party CPA
Improvements to attain higher data grading for "Total Annual Cost of Operating the Water System" component:		to qualify for 2: Gather available records, institute new procedures to regularly collect and audit basic cost data of most important operations functions.	to qualify for 4: Implement an electronic cost accounting system, structured according to accounting standards for water utilities		to qualify for 6: Establish process for periodic internal audit of water system operating costs; identify cost data gaps and institute procedures for tracking these outstanding costs.		to qualify for 8: Standardize the process to conduct routine financial audit on an annual basis.		to qualify for 10: Standardize the process to conduct a third-party financial audit by a CPA on an annual basis.		to maintain 10: Maintain program, stay abreast of expenses subject to erratic cost changes and budget/track costs proactively
Customer retail unit cost (applied to Apparent Losses)		Antiquated, cumbersome water rate structure is use, with periodic historic amendments that were poorly documented and implemented, resulting in classes of customers being billed inconsistent charges. The actual composite billing rate likely differs significantly from the published water rate structure, but a lack of auditing leaves the degree of error indeterminate	Dated, cumbersome water rate structure, not always employed consistently in actual billing operations. The actual composite billing rate is known to differ from the published water rate structure, and a reasonably accurate estimate of the degree of error is determined, allowing a composite billing rate to be quantified	Conditions between 2 and 4	Straight-forward water rate structure in use, but not updated in several years. Billing operations reliably employ the rate structure. The composite billing rate is derived from a single customer class such as residential customer accounts, neglecting the effect of different rates from varying customer classes	Customer population unmetered. Fixed fee charged, single composite number derived from multiple customer classes	Clearly written, up-to-date water rate structure is in force and is applied reliably in billing operations. Composite customer rate is determined using a weighted average residential rate using volumes of water in each rate block.	Conditions between 6 and 8	Effective water rate structure is in force and is applied reliably in billing operations. Composite customer rate is determined using a weighted average composite consumption rate, including residential, commercial, industrial and any other customer classes within the water rate structure.	Conditions between 8 and 10	Third party reviewed weighted average composite consumption rate (includes residential, commercial, industrial, etc.)
Improvements to attain higher data grading for "Customer Retail Unit Cost" component:		to qualify for 2: Formalize the process to implement water rates, including a secure documentation procedure. Create a current, formal water rate document and gain approval from all stakeholders.	to qualify for 4: Review the water rate structure and update/formalize as needed. Assess billing operations to ensure that actual billing operations incorporate the established water rate structure.		to qualify for 6: Evaluate volume of water used in each usage block by residential users. Multiply volumes by full rate structure.	Meter customers and charge rates based upon water volumes	to qualify for 8: Evaluate volume of water used in each usage block by all classifications of users. Multiply volumes by full rate structure.		to qualify for 10: Conduct a periodic third-party audit of water used in each usage block by all classifications of users. Multiply volumes by full rate structure.		to maintain 10: Keep water rate structure current in addressing the water utility's revenue needs. Update the calculation of the customer unit rate as new rate components, customer classes, or other components are modified.
Variable production cost (applied to Real Losses)	Note: if the water utility purchases/imports its entire water supply, then enter the unit purchase cost of the bulk water supply in the Reporting Worksheet with a grading of 10	Incomplete paper records and lack of documentation on primary operating functions (electric power and treatment costs most importantly) makes calculation of variable production costs a pure guesstimate	Reasonably maintained, but incomplete, paper or electronic accounting provides data to roughly estimate the basic operations costs (pumping power costs and treatment costs) and calculate a unit variable production cost	Conditions between 2 and 4	Electronic, industry-standard cost accounting system in place. Electric power and treatment costs are reliably tracked and allow accurate calculation of unit variable production costs based on these two inputs only. All costs are audited internally on a periodic basis	Conditions between 4 and 6	Reliable electronic, industry-standard cost accounting system in place, with all pertinent water system operating costs tracked. Pertinent additional costs beyond power and treatment (ex: liability, residuals management, etc.) are included in the unit variable production cost. Data audited at least annually by utility personnel.	Conditions between 6 and 8	Reliable electronic, industry-standard cost accounting system in place, with all pertinent variable production costs tracked. Data audited at least annually by utility personnel, and periodically by third-party.	Conditions between 8 and 10	Either of two conditions can be met to obtain a grading of 10: 1) Third party CPA audit of all primary and secondary cost components on an annual basis or; 2) Water supply is entirely purchased as bulk imported water, and unit purchase cost serves as the variable production cost
Improvements to attain higher data grading for "Variable Production Cost" component:		to qualify for 2: Gather available records, institute new procedures to regularly collect and audit basic cost data and most important operations functions.	to qualify for 4: Implement an electronic cost accounting system, structured according to accounting standards for water utilities		to qualify for 6: Formalize process for regular internal audits of production costs. Assess whether additional costs (liability, residuals management, etc.) should be included to calculate a more accurate variable production cost.		to qualify for 8: Formalize the accounting process to include primary cost components (power, treatment) as well as secondary components (liability, residuals management, etc.) Conduct periodic third-party audits		to qualify for 10: Standardize the process to conduct a third-party financial audit by a CPA on an annual basis.		to maintain 10: Maintain program, stay abreast of expenses subject to erratic cost changes and budget/track costs proactively

AWWA WLCC Free Water Audit Software: Customer Service Line Diagrams

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Average Length of Customer Service Line

The three figures shown on this worksheet display the assignment of the Average Length of Customer Service Line, Lp, for the three most common piping configurations.

Figure 1 shows the configuration of the water meter outside of the customer building next to the curbstop valve. In this configuration Lp = 0 since the distance between the curbstop and the customer metering point is essentially zero.

Figure 2 shows the configuration of the customer water meter located inside the customer building, where Lp is the distance from the curbstop to the water meter.

Figure 3 shows the configuration of an unmetered customer building , where Lp is the distance from the curbstop to the first point of customer water consumption, or, more simply, the building line.

In any water system the Lp will vary notably in a community of different structures, therefore the average Lp value is used and this should be approximated or calculated if a sample of service line measurements has been gathered.

Click for more information

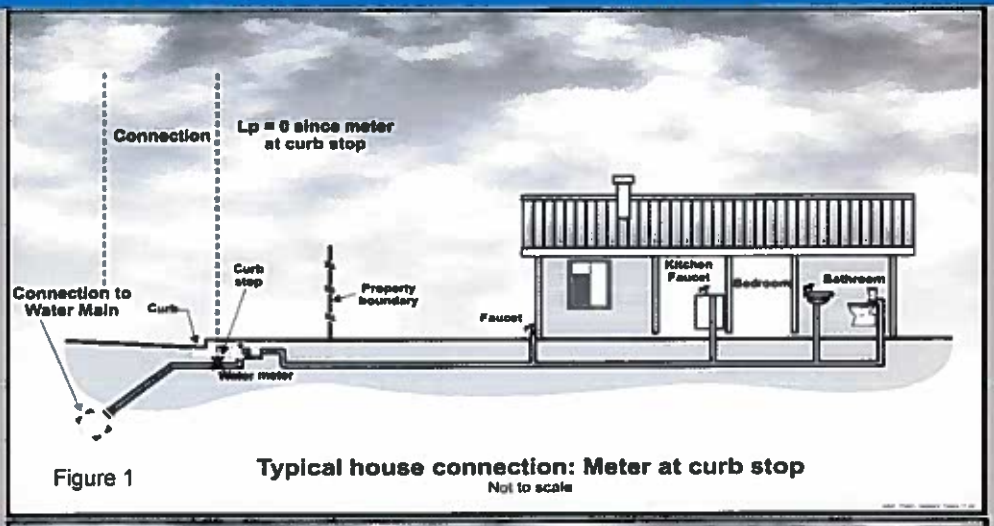

Figure 1 **Typical house connection: Meter at curb stop**
Not to scale

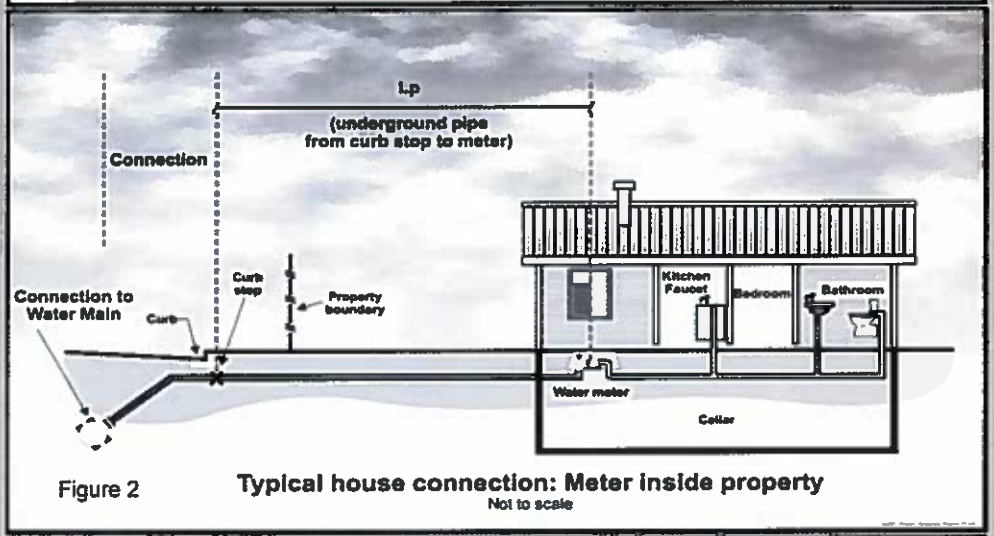

Figure 2 **Typical house connection: Meter inside property**
Not to scale

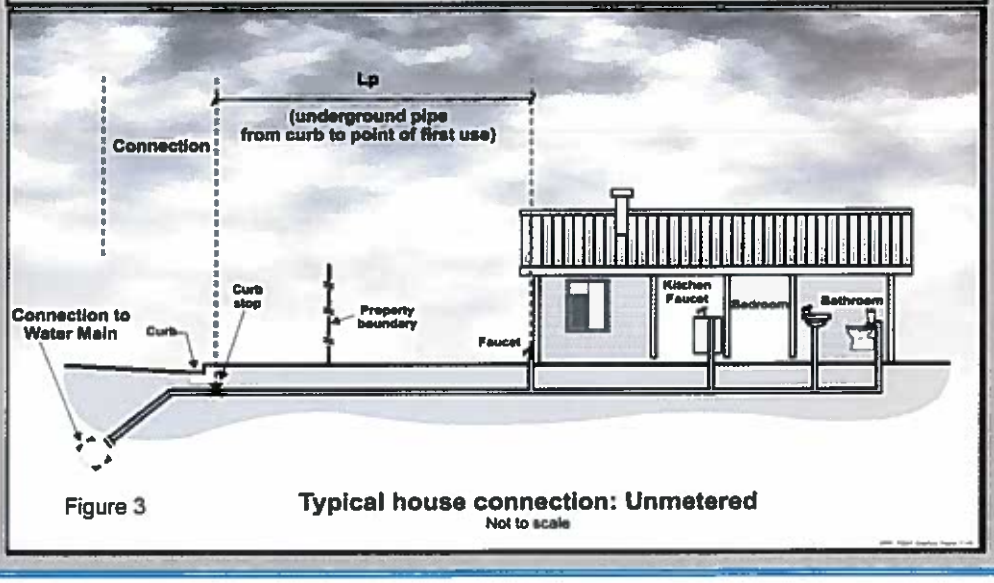

Figure 3 **Typical house connection: Unmetered**
Not to scale

AWWA WLCC Free Water Audit Software: Definitions

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Item Name		Description
Apparent Losses	Find	= unauthorized consumption + meter under-registration + data handling errors Includes all types of inaccuracies associated with customer metering as well as data handling errors (meter reading and billing), plus unauthorized consumption (theft or illegal use). NOTE: Over-registration of customer meters, leads to under-estimation of Real Losses. Under-registration of customer meters, leads to over-estimation of Real Losses.
AUTHORIZED CONSUMPTION	Find	= billed metered + billed unmetered + unbilled metered + unbilled unmetered The volume of metered and/or unmetered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorized to do so by the water supplier, for residential, commercial and industrial purposes. This does NOT include water sold to neighboring utilities (water exported). Authorized consumption may include items such as fire fighting and training, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, frost protection, building water, etc. These may be billed or unbilled, metered or unmetered.
Average length of customer service line	Find	This is entered for unmetered services and in cold or other areas where meters are installed inside homes and buildings. It is the length of customer service line either between the utility's service connection (often at the curbstop) and the meter, or to the building line (first point of customer consumption) if customers are unmetered. Note that the length of service connection between the main and customer service line is owned by the utility and its length and potential leakage is accounted for in the UARL formula by the number of service connections. **What role does the "Average Length of Customer Service Line" parameter serve in the Water Audit?** In many water distribution systems the water utility has maintenance responsibility for a portion of the customer service piping from its connection point at the water main to the curbstop valve located midway to the customer building. The customer is responsible to maintain the customer service piping from the curbstop to the building premises. When leaks arise on customer service piping, water utilities respond faster to repair leaks than customers when the leak is on piping under their responsibility. Leak durations are longer on the customer-maintained piping than the utility-maintained piping. The total length of pipe maintained by customers is one of the components of the Unavoidable Annual Real Loss (UARL) equation and is determined by multiplying the average length of customer maintained pipe, Lp by the number of customer service connections. Therefore this parameter is important to the calculation of the UARL and the Infrastructure leakage Index (ILI). Click to see Service Connection Diagram
Average operating pressure	Find	The average pressure may be approximated when compiling the preliminary water audit. Once routine water auditing has been established, a more accurate assessment of average pressure should be pursued. If the water utility infrastructure is recorded in a Geographical Information System (GIS) the average pressure at many locations in the distribution system can be readily obtained. If a GIS does not exist, a weighted average of pressure data can be calculated from water pressure measured at various fire hydrants scattered across the water distribution system.
Billed Authorized Consumption		All consumption that is billed and authorized by the utility. This may include both metered and unmetered consumption. See "Authorized Consumption" for more information.
Billed metered consumption	Find	All metered consumption which is billed. This includes all groups of customers such as domestic, commercial, industrial or institutional. It does NOT include water sold to neighboring utilities (water exported) which is metered and billed. The metered consumption data can be taken directly from billing records for the water audit period. The accuracy of yearly metered consumption data can be refined by including an adjustment to account for customer meter reading lagtime, however additional analysis is necessary to determine the adjustment value, which may or may not be significant.
Billed unmetered consumption	Find	All billed consumption which is calculated based on estimates or norms but is not metered. This might be a very small component in fully metered systems (for example billing based on estimates for the period a customer meter is out of order) but can be the key consumption component in systems without universal metering. It does NOT include water sold to neighboring utilities (water exported) which is unmetered but billed.
Connection density		=number of connections / length of mains

Item Name		Description
Customer metering inaccuracies	Find	Apparent water losses caused by the collective under-registration of customer water meters. Many customer water meters will wear as large cumulative volumes of water are passed through them over time. This causes the meters to under-register. The auditor has two options for entering data for this component of the audit. The auditor can enter a percentage under-registration (typically an estimated value), this will apply the selected percentage to the two categories of metered consumption to determine the volume of water not recorded due to customer meter inaccuracy. Alternatively, if the auditor has substantial data from meter testing to arrive at their own volumes of such losses, this volume may be entered directly. Note that a value of zero will be accepted but an alert will appear asking if the customer population is unmetered. Since all metered systems have some degree of inaccuracy, then a positive value should be entered. A value of zero in this component is valid only if the water utility does not meter its customer population.
Customer retail unit cost	Find	The Customer Retail Unit Cost represents the charge that customers pay for water service. This unit cost is applied to the components of apparent loss, since these losses represent water reaching customers but not (fully) paid for. It is important to compile these costs per the same unit cost basis as the volume measure included in the water audit. For example, if all water volumes are measured in million gallons, then the unit cost should be dollars per million gallon ($/mil gal). The software allows the user to select the units that are charged to customers (either $/1,000 gallons, $/hundred cubic feet or $/1,000 litres) and automatically converts these units to the units that appear in the "WATER SUPPLIED" box. Since most water utilities have a rate structure that includes a variety of different costs based upon class of customer, a weighted average of individual costs and number of customer accounts in each class can be calculated to determine a single composite cost that should be entered into this cell. Finally, the weighted average cost should also include additional charges for sewer, stormwater or biosolids processing, if these charges are based upon the volume of potable water consumed.
Infrastructure Leakage Index (ILI)	Find	The ratio of the Current Annual Real Losses (Real Losses) to the Unavoidable Annual Real Losses (UARL). The ILI is a highly effective performance indicator for comparing (benchmarking) the performance of utilities in operational management of real losses.
Length of mains	Find	Length of all pipelines (except service connections) in the system starting from the point of system input metering (for example at the outlet of the treatment plant). It is also recommended to include in this measure the total length of fire hydrant lead pipe. Hydrant lead pipe is the pipe branching from the water main to the fire hydrant. Fire hydrant leads are typically of a sufficiently large size that is more representative of a pipeline than a service connection. The average length of hydrant leads across the entire system can be assumed if not known, and multiplied by the number of fire hydrants in the system, which can also be assumed if not known. This value can then be added to the total pipeline length. Total length of mains can therefore be calculated as: Length of Mains, miles = (total pipeline length, miles) + [{(average fire hydrant lead length, ft) x (number of fire hydrants)} / 5,280 ft/mile] or Length of Mains, kilometres = (total pipeline length, kilometres) + [{(average fire hydrant lead length, metres) x (number of fire hydrants)} / 1,000 metres/kilometre]
Master meter error adjustment	Find	An estimate or measure of the degree of any inaccuracy that exists in the master meters measuring the Volume from own sources. Please also indicate if this adjustment is because the master meters under-registered (did not capture all the flow) or over-registered (overstated the actual flow). All systems encounter some degree of error in their Master Meter data. Please enter a positive value.
NON-REVENUE WATER	Find	= Apparent Losses + Real Losses + Unbilled Metered + Unbilled Unmetered Water which does not provide any revenue to the utility
Number of active AND inactive service connections	Find	Number of service connections, main to curb stop. Please note that this includes the actual number of distinct piping connections including fire connections whether active or inactive. This may differ substantially from the number of Customers (or number of accounts)
Real Losses	Find	Physical water losses from the pressurized system and the utility's storage tanks, up to the point of customer consumption. In metered systems this is the customer meter, in unmetered situations this is the first point of consumption (stop tap/tap) within the property. The annual volume lost through all types of leaks, breaks and overflows depends on frequencies, flow rates, and average duration of individual leaks, breaks and overflows.
Revenue Water		Water which is charged to customers to provide revenue to the utility.
Systematic data handling errors	Find	Apparent water losses caused by systematic data handling errors in the meter reading and billing system.
Total annual cost of operating the water system	Find	These costs include those for operations, maintenance and any annually incurred costs for long-term upkeep of the system, such as repayment of 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.

Item Name		Description
Unauthorized Consumption	Find	Includes water illegally withdrawn from hydrants, illegal connections, bypasses to consumption meter or meter reading equipment tampering. While this component has a direct impact on revenue, in most water utilities the volume is low and it is recommended that the auditor apply a default value of 0.25% of the volume from own sources. If the auditor has well validated data that indicates the volume from unauthorized consumption is substantially higher or lower than that generated by the default value then this value can be entered. However, for most water utilities it is recommended to apply the default value. Note that a value of zero will not be accepted since all water utilities have some volume of unauthorized consumption occurring in their system.
Unavoidable Annual Real Losses (UARL)	Find	UARL (gallons/day) = (5.41Lm + 0.15Nc + 7.5Lc) xP, or UARL (litres/day) = (18.0Lm + 0.8Nc + 25.0Lc) xP where: Lm = length of mains (miles or kilometres) Nc = number of service connections Lc = total length of customer service lines (miles or km) = Nc multiplied by the average distance of customer service line, Lp (miles or km) P = Pressure (psi or metres) Click to see Service Connection Diagram The UARL is 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. It is a key variable in the calculation of the Infrastructure Leakage Index (ILI). It is not necessary that water utilities set this level as the target level of leakage, unless water is unusually expensive, scarce or both. NOTE: The UARL calculation has not yet been fully proven as effective for very small, or low pressure water distribution systems. If, in gallons per day: (Lm x 32) + Nc < 3000 or P <35psi in litres per day: (Lm x 20) + Nc < 3000 or P < 25m then the calculated UARL value may not be valid. The software does not display a value of UARL or ILI if either of these conditions is true.
Unbilled Authorized Consumption		All consumption that is unbilled, but still authorized by the utility. See "Authorized Consumption" for more information.
Unbilled metered consumption	Find	Metered Consumption which is for any reason unbilled. This might for example include metered consumption of the utility itself or water provided to institutions free of charge. It does NOT include water sold to neighboring utilities (water exported) which is metered but unbilled.
Unbilled unmetered consumption	Find	Any kind of Authorized Consumption which is neither billed nor metered. This component typically includes items such as fire fighting, flushing of mains and sewers, street cleaning, frost protection, etc. In most water utilities it is a small component which is very often substantially overestimated. It does NOT include water sold to neighboring utilities (water exported) which is unmetered and unbilled - an unlikely case. This component has many sub-components of water use which are often tedious to identify and quantify. Because of this, and the fact that it is usually a small portion of the water supplied, it is recommended that the auditor apply the default value of 1.25% of the volume from own sources. Select the default percentage to enter this value. If the water utility already has well validated data that gives a value substantially higher or lower than the default volume, then the auditor should enter their own volume. However the default approach is recommended for most water utilities. Note that a value of zero is not permitted, since all water utilities have some volume of water in this component occurring in their system.
Units and Conversions	Find	The user may develop an audit based on one of three unit selections: 1) Million Gallons (US) 2) Megalitres (Thousand Cubic Metres) 3) Acre-feet Once this selection has been made in the instructions sheet, all calculations are made on the basis of the chosen units. Should the user wish to make additional conversions, a unit converter is provided below (use drop down menus to select units from the yellow unit boxes): Enter Units: 1 — Convert From... Million Gallons (US) = Converts to..... 3.06888 Acre-feet (conversion factor = 3.06888328973723)

Item Name		Description
Use of Option Buttons	Find	To use the percent value choose this button To enter a value choose this button and enter the value in the cell to the right  NOTE: For unbilled unmetered consumption and unauthorized consumption, a recommended default value can be applied by selecting the Percent option. The default values are based on fixed percentages of water supplied and are recommended for use in this audit unless the auditor has well validated data for their system. Default values are shown by purple cells, as shown in the example above. If a default value is selected, the user does not need to grade the item; a grading value of 3 is automatically applied (however, this grade will not be displayed).
Variable production cost (applied to Real Losses)	Find	The cost to produce and supply the next unit of water. (E.g., $/million gallons) This cost is determined by calculating the summed unit costs for ground and surface water treatment and all power used for pumping from the source to the customer. It should also include the unit cost of bulk water purchased as an import if applicable.
Volume from own sources	Find	The volume of treated water input to system from own production facilities
Water exported	Find	Bulk water sold and conveyed out of the water distribution system. Typically this is water sold to a neighboring water utility. Be sure to account for any export meter inaccuracy in reporting this volume
Water imported	Find	Bulk water purchased to become part of the water supplied. Typically this is water purchased from a neighboring water utility or regional water authority. Be sure to account for any import meter inaccuracy in reporting this volume
WATER LOSSES	Find	= apparent losses + real losses The difference between System Input and Authorized Consumption. Water losses can be considered as a total volume for the whole system, or for partial systems such as transmission or distribution systems, or individual zones. Water Losses consist of Real Losses and Apparent Losses.

AWWA WLCC Free Water Audit Software: Determining Water Loss Standing

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Water Loss Control Planning Guide

Functional Focus Area	Water Audit Data Validity Level / Score				
	Level I (0-25)	Level II (26-50)	Level III (51-70)	Level IV (71-90)	Level V (91-100)
Audit Data Collection	Launch auditing and loss control team; address production metering deficiencies	Analyze business process for customer metering and billing functions and water supply operations. Identify data gaps.	Establish/revise policies and procedures for data collection	Refine data collection practices and establish as routine business process	Annual water audit is a reliable gauge of year-to-year water efficiency standing
Short-term loss control	Research information on leak detection programs. Begin flowcharting analysis of customer billing system	Conduct loss assessment investigations on a sample portion of the system: customer meter testing, leak survey, unauthorized consumption, etc.	Establish ongoing mechanisms for customer meter accuracy testing, active leakage control and infrastructure monitoring	Refine, enhance or expand ongoing programs based upon economic justification	Stay abreast of improvements in metering, meter reading, billing, leakage management and infrastructure rehabilitation
Long-term loss control		Begin to assess long-term needs requiring large expenditure: customer meter replacement, water main replacement program, new customer billing system or Automatic Meter Reading (AMR) system.	Begin to assemble economic business case for long-term needs based upon improved data becoming available through the water audit process.	Conduct detailed planning, budgeting and launch of comprehensive improvements for metering, billing or infrastructure management	Continue incremental improvements in short-term and long-term loss control interventions
Target-setting			Establish long-term apparent and real loss reduction goals (+10 year horizon)	Establish mid-range (5 year horizon) apparent and real loss reduction goals	Evaluate and refine loss control goals on a yearly basis
Benchmarking			Preliminary Comparisons - can begin to rely upon the Infrastructure Leakage Index (ILI) for performance comparisons for real losses (see below table)	Performance Benchmarking - ILI is meaningful in comparing real loss standing	Identify Best Practices/ Best in class - the ILI is very reliable as a real loss performance indicator for best in class service

For validity scores of 50 or below, the shaded blocks should not be focus areas until better data validity is achieved.

Once data has been entered into the Reporting Worksheet, the performance indicators are automatically calculated. How does a water utility operator know how well his or her system is performing? The AWWA Water Loss Control Committee provided the following table to assist water utilities is gauging an approximate Infrastructure Leakage Index (ILI) that is appropriate for their water system and local conditions. The lower the amount of leakage and real losses that exist in the system, then the lower the ILI value will be.

Note: this table offers an approximate guideline for leakage reduction target-setting. The best means of setting such targets include performing an economic assessment of various loss control methods. However, this table is useful if such an assessment is not possible.

General Guidelines for Setting a Target ILI
(without doing a full economic analysis of leakage control options)

Target ILI 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, water conservation) are included in the long-term planning.
>5.0 - 8.0	Cost to purchase or obtain/treat water is low, as are rates charged 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 ILI greater than 8.0, such a level of leakage is not an effective utilization 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 calculated Infrastructure Leakage Index (ILI) value for your system is 1.0 or less, two possibilities exist. a) you are maintaining your leakage at low levels in a class with the top worldwide performers in leakage control. b) A portion of your data may be flawed, causing your losses to be greatly understated. This is likely if you calculate a low ILI 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.		

APPENDIX C

TATA & HOWARD

WATER RATES AND STRUCTURES EFFECTIVE NOVEMBER 1, 2012

RESIDENTIAL

Minimum (0 to 5,000 gallons)	$21.00 base charge
5,001 to 25,000 gallons	$ 3.40/thousand gallons
25,001 to 60,000 gallons	$6.30/thousand gallons
Over 60,000 gallons	$10.00/thousand gallons

CONDOMINIUMS

Minimum (0 to 5,000 gallons)	$21.00 base charge
5,001 to 25,000 gallons	$ 3.40/thousand gallons
25,001 to 60,000 gallons	$ 6.30/thousand gallons
Over 60,000 gallons	$10.00/thousand gallons

COMMERCIAL

Minimum (0 to 5,000 gallons)	$36.00 base charge
5,001 to 25,000 gallons	$ 2.80/thousand gallons
25,001 to 50,000 gallons	$ 3.80/thousand gallons
Over 50,000 gallons	$ 3.80/thousand gallons

APARTMENTS

Flat rate/thousand	$4.25/thousand gallons

RESIDENTIAL LAWN

Minimum	$21.00 base charge
0 to 60,000 gallons	$ 6.30 /thousand gallons
Over 60,000 gallons	$10.00/thousand gallons

SUMMER SERVICE

Minimum	$21.00 base charge
0 to 60,000 gallons	$ 6.30/thousand gallons

Over 60,000 gallons	$10.00/thousand gallons
APARTMENT LAWN	
Minimum	$21.00 base charge
0 to 60,000 gallons	$ 6.30/thousand gallons
Over 60,000 gallons	$10.00/thousand gallons
COMMERCIAL LAWN	
Minimum	$21.00 base charge
0 to 60,000 gallons	$ 6.30/thousand gallons
Over 60,000 gallons	$10.00/thousand gallons
CONDO LAWN	
Minimum	$ 21.00 base charge
0 to 60,000 gallons	$ 6.30/thousand gallons
Over 60,000 gallons	$ 10.00 /thousand gallons
MUNICIPAL	
Minimum (0 to 5,000 gals)	$36.00 base charge
5,001 to 50,000 gallons	$ 2.30/thousand gallons
Over 50,000 gallons	$ 3.40/thousand gallons
SCHOOLS	
Minimum(0 to 5,000 gals)	$36.00 base charge
5,001 to 50,000 gallons	$ 2.30 /thousand gallons
Over 50,000 gallons	$ 3.40 /thousand gallons
SCHOOL LAWN	
Flat rate/ thousand	$ 3.50/thousand gallons

APPENDIX D

TATA & HOWARD

PWSID#: ______________________

Name: ______________________

Town: ______________________

Year: ____________

Flow Testing Water Use Log

Location of Flow test	Date	Time on	Time off	Total minutes	GPM	Gallons Used

Total Gallons: 0

Use as many of these sheets as necessary to account for all the water used for flow testing each year.
Include total Flow Testing volume for the entire year in UAW Table 3 in Section G of the ASR.
Attach this sheet to Annual Statistical Report

PWSID#: ______________________ Year: ______________

Name: ______________________

Town: ______________________

Hydrant / water main flushing record

Street	Hydrant no.	Date	time on	time off	Total minutes	GPM	Gallons Flushed
						Total Gallons:	0

Use as many of these sheets as necessary to account for all the water used for flushing each year.
Include total Hydrant/Water Main Flushing volume for the entire year in UAW Table 3 in Section G of the ASR
Attach this sheet to Annual Statistical Report.

PWSID#: _____ Year: _____

Name: _____

Town: _____

Street Cleaning Water Use Log

Date	Tank Size (gallons)	No. of tank fills	Total Gallons
		Total Gallons Used:	0

Use as many of these sheets as necessary to account for all the water used for street cleaning each year.
Include total street cleaning volume for the entire year in UAW Table 3 in Section G of the ASR
Attach this sheet to Annual Statistical Report.

PWSID#: _____ Year: _____

Name: _____

Town: _____

Major Water Main Break Water Use Log

Street/Location	Date	Duration of Break (minutes)	Estimated GPM	Total Gallons
				0

This is to be used for large, unexpected breaks requiring emergency action on the part of the PWS. If another method of estimating water lost through the break is more appropriate (tank level decline, pumping records, etc.) please provide records and/or calculations showing how the volume of water lost was estimated.

Losses of water found through leak detection and repair are not to be included under main break losses. Leak detection losses are included in unaccounted for water (UAW).

Use as many of these sheets as necessary to account for all the water lost to water main breaks each year. Include volume of water lost to water main breaks for the entire year in UAW Table 3 in Section G of the ASR. Attach this sheet to Annual Statistical Report.

TATA & HOWARD

OFFICE LOCATIONS:
MA | NH | CT | ME | VT | AZ

800-366-5760
www.tataandhoward.com