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MEMORANDUM

Date: December 30, 2023

To Kenan Connell, Director, Town of Weymouth, Department of Public Works

From Ryan J. Allgrove, PE, Principal, Environmental Partners

Subject **Town of Weymouth Water Audit Report (Redacted)**
CY 2022

Introduction and Background

The Town of Weymouth (the Town) supplies residents and businesses with drinking water supplied by the Great Pond surface water supply via the Great Pond Water Treatment Plant and the Mill River aquifer groundwater well supplies via the Arthur J. Bilodeau Water Treatment Plant. Water enters the Town's distribution system via the respective treatment plants and travels along approximately 245 miles of pipe to reach customers across three service zones. Four storage tanks also maintain distribution system pressure in the Town and provide fire storage.

Recent evaluations of the total amount of water supplied to the system versus the total metered consumption in the system suggest that a significant amount of water entering the distribution system is considered non-revenue water. In 2022, approximately 414 million gallons (MG), or 26% of the Town's 1,595 MG of water supplied is considered non-revenue. Non-revenue water includes any volume of water that cannot be quantified or confidently estimated as a component of authorized consumption. Non-revenue water may be attributed to both real and apparent losses. Excessive losses in a distribution system can lead to wasted water, lost revenue, and operational disruptions. Consequently, the Town of Weymouth retained the services of Environmental Partners Group, LLC (EP) to conduct a water audit to help provide recommendations for minimizing water losses.

This memorandum documents the results of the water audit. The first section discusses the top-down distribution system water audit conducted by EP following the latest water industry best practices. The subsequent section of the report focuses on leak detection surveys. Finally, the memorandum concludes with a summary of the audit.

AWWA Top-Down Water Audit Results

EP conducted a top-down water audit of the Town of Weymouth's water system for calendar year 2022 following the principles and procedures outlined in Chapter 2 of the 4rd Edition of the *American Water Works Association (AWWA) Manual M36 – Water Audits and Loss Control Programs*. The AWWA produces worksheets and software to assist water systems with conducting the top-down audit. EP

utilized the AWWA Free Water Audit Software v6.0, released in 2020. Printouts associated with this audit from the AWWA Free Water Audit Software are provided in Attachment A. This attachment includes an extensive list of definitions for key water audit terminology.

The software's Reporting Worksheet includes fields for water supplied, authorized consumption, meter inaccuracies, system data, and cost data. Comment fields for each input are provided in the software to allow the auditor to document the source of all data. The auditor also provides a "Data Validity Score" from 1 to 10 for each input based on a grading matrix in the software. In general, a score of 1 represents data presented with little confidence or accuracy while a grade of 10 represents data that is presented with a high degree of confidence. By focusing on improving the items with low scores, a water utility can improve the accuracy of its audit. Lastly, the software provides a water balance sheet detailing water losses.

The following text highlights the results, conclusions, and recommendations of the water audit.

Water Supplied

The Town currently produces all of its water with two finished water entry points into the distribution system at the respective water treatment plants. EP acquired documentation on finished water meter testing indicating that the Town calibrates source meters annually, including cross-checking reads with the SCADA system. Testing results show that metered finished water was under registered by less than 1%. However, translation to SCADA resulted in an under registration of 3.4% at the GPWTP.

Authorized Consumption

The Town collects meter reads on a quarterly and monthly frequency, depending on the customer. About 521 higher demand customers are read monthly while the remaining customers are read quarterly. The Town then imports the wirelessly transmitted reads into an electronic file and then into the Town's billing software, MUNIS by Tyler Technologies. MUNIS then generates a bill for each customer.

The Water Department is responsible for the billing process in Weymouth. Billing review includes a manual review of overall total for all customers as well as an in-depth spot check of trends and totals for some targeted accounts and a random sample of accounts. The Town scans for anomalous, non-zero consumption, but there is no formal process for flagging all bills with anomalous consumption outside of a certain threshold. If there is a bill with a zero read, the software will automatically estimate this bill based on an average of the previous readings. Customers who receive an estimated bill as the result of a zero read also receive a request to replace the meter.

It is the Town's policy to meter and bill all customers, including Town facilities, schools, and even the water department. The Town offers abatements to customers on a case-by-case basis. Customers may request abatements for anomalous bills; requests are reviewed, and abatements are granted at the discretion of the water department.

The Town's unbilled unmetered consumption is equivalent to the Confidently Estimated Municipal Use (CEMU) as reported on the 2022 ASR. A summary of the CEMU calculation is presented in Table 1.

Table 1: 2022 Confidently Estimated Municipal Use (CEMU) Calculation

Category	2022 ASR Volumes (MGY)
Fire Protection & Training	2.555
Hydrant/Water Main Flushing/Main Construction	2.279
Flow Testing	0.038
Bleeders/Blow Offs	8.935
Tank Overflow & Drainage	3.852
Sewer & Stormwater Flushing	0.035
Street Cleaning	0.156
Source Meter Calibration Adjustments	0
Major Water Main Breaks (not leak detection)	4.884
Total CEMU	**22.734**

The Town provided supporting documentation within the 2022 ASR detailing usage calculations for fire protection and training use, the flushing program, flow testing and construction usage, bleeders and blow offs (treatment plant losses), tank overflows, sewer jetting, street paving and sweeping, and water main breaks. The total CEMU value is an essential value in the determination of overall UAW in a municipal water system and the documentation performed by the Town allows them to provide an estimate that is refined to the greatest extent possible.

Customer Metering

It is the Town's policy to meter all consumption. According to the Town's meter inventory data, as of July 24, 2023, approximately 97.5% of installed service meters are manufactured by Neptune, and the remaining are a blend of other meter brands. EP prepared a histogram of meter installation by year this century to review the age of system meters using the same meter inventory data. Based on the information in Figure 1, about 16% of the meters are 20 years or older, while the remaining 84% were installed in the last 20 years. Industry standards suggest that water meters be replaced after 15-20 years, especially meters larger than 1-inch. Generally, older meters tend to lose accuracy and should be tested and/or replaced. If inaccurate or not properly sized for correct flows, large meters can lead to lost revenue and unaccounted-for water. The Town of Weymouth does not have a meter testing program, but meters are replaced in response to customer complaints about inaccurate meter readings in addition to the Town's annual replacement program. No conclusion can be made on average accuracy of existing meters without the necessary data. As presented in the below figure, EP prepared a histogram of meter installation by year this century to review the age of system meters. Based on the information in this figure, the majority of meters were installed in the last 7 to 8 years;

however, there are still approximately 1,000 meters that are about 20 years old. In addition, there are very few meters remaining from the 2001 to 2012 period.

Figure 1: Meters Installed by Year

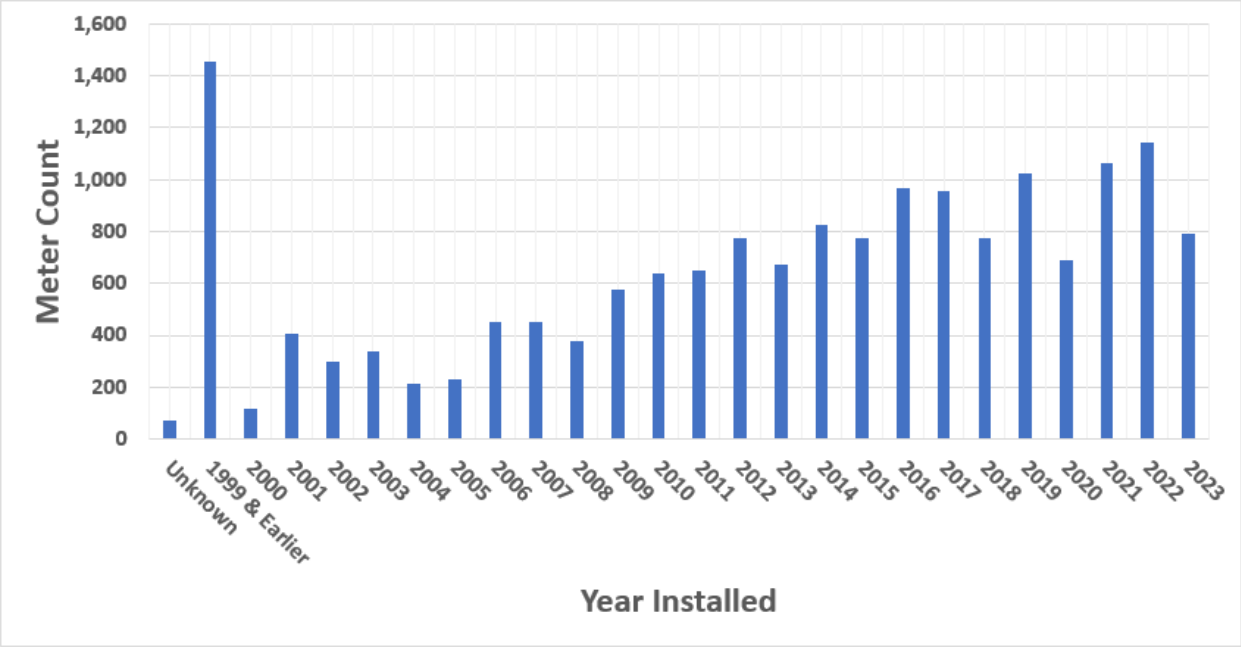


Figure 1 shows the Town is actively replacing meters throughout its distribution system. From 2013 to 2022, the Town installed an average of nearly 900 new meters per year. About 150 of the new meters were attributed to new water services added to the system, while the remaining 750 were old meter replacements. Some meter configurations include a supply valve upstream of the customer meter, which leaves them vulnerable to tampering and water theft. EP recommends continuing to prioritize replacement of these old meters with new ultrasonic meters that offer wider range of low and high flow measurement capabilities and new meter configurations. 1-inch or smaller ultrasonic meters are warrantied to last 20 years while larger ultrasonic meters have a 10-15 year warranty, depending on the manufacturer. Additional ultrasonic meters offer features like reverse flow, no flow, and tampering detections that can help deter, identify, and reduce water theft. After all existing meters have been replaced by ultrasonic meters, the Town can implement an annual meter replacement program to replace approximately one-twentieth of all meters every year, which results in a complete system replaced every 20 years. For the current number of meters, this equates to approximately 870 meter replacements per year.

Table 2 summarizes the meter sizes currently in service according to Town provided 2022 water usage data. Almost 94% of the meters within the Town are 5/8-inch, a size commonly installed for residential applications. Nearly 5% of the meters are 1-inch or larger while there is no meter size data for a little over 1% of all meters. EP recommends identifying 199 meters of unknown sizes for a complete meter size inventory.

Table 2: Water Accounts by Meter Size

Meter Size	Service Meters	Percent of Total Meters
5/8"	16,359	93.91%
1"	445	2.55%
1.5"	171	0.98%
2"	215	1.23%
3"	16	0.09%
4"	13	0.07%
6"	2	0.01%
Other/Unknown	199	1.14%
Total	**17,420**	**100.0%**

System Data

EP calculated an average operating pressure of [redacted] psi using the Town's hydraulic model. The total number of service connections reported on the audit is the same as what was reported on the 2022 ASR: 16,773. The total length of water mains, 240.7 miles, is based on the Town's GIS database which is updated annually at a minimum. The average length of customer service lines reported on the audit is 30 feet, which is an estimate based on a sample survey of representative neighborhood services. The Town also indicated that service records have been maintained by service logbooks and are updated regularly.

Water Losses

Water losses include *real losses* and *apparent losses*. In general, real losses are physical losses from the system, such as leakage, while apparent losses are "paper" losses, such as customer metering inaccuracies. (Precise definitions of these terms are provided in Attachment A.) Total water losses represent the difference between water supplied and authorized consumption. Apparent losses are individually estimated and added together. The remainder is real losses. Table 3 provides a summary of water losses for the Town of Weymouth in 2022.

Table 3: 2022 Water Loss Summary, in million gallons (MG)

<table>
<tr><td rowspan="6">Water Losses
391.754</td><td rowspan="3">Apparent Losses
7.920</td><td>Unauthorized Consumption
1.000</td></tr>
<tr><td>Customer Metering Inaccuracies
4.000</td></tr>
<tr><td>Systematic Data Handling Errors
2.920</td></tr>
<tr><td rowspan="3">Real Losses
383.834</td><td>Leak Detection Surveys
49.669</td></tr>
<tr><td>Water Main Breaks
4.884</td></tr>
<tr><td>Other Real Losses
329.281</td></tr>
</table>

The largest source of water loss is Real Losses. EP attempted to quantify real losses when possible. The 49.669 million gallons attributed to leak detection is based on estimated leakage of 94.5 gallons per minute (GPM) over the course of the year as reported in the 2023 Comprehensive Leak Detection Survey Report provided by New England Water Distribution Services, LLC in March 2023. The 4.884 million gallons of reported water main breaks is based on a Town estimation of leakage from repaired main breaks, as reported in the ASR. After accounting for these detected leaks, there are still approximately 329.281 million gallons of other unidentified real losses. The Town of Weymouth is above the 70th percentile for unit real losses by miles of mains; the Town has approximately 4,369 gallons per mile per day of real losses. The Leak Mapping section discusses recommendations for real loss reduction.

The largest sources of apparent losses are likely customer metering inaccuracies and water theft. As discussed previously, this could be an underestimation of water usage due to metering inaccuracies from the lack of accuracy testing data. EP recommends that the Town focus heavily on improving the accuracy of its customer meters to help reduce losses and tackling water theft.

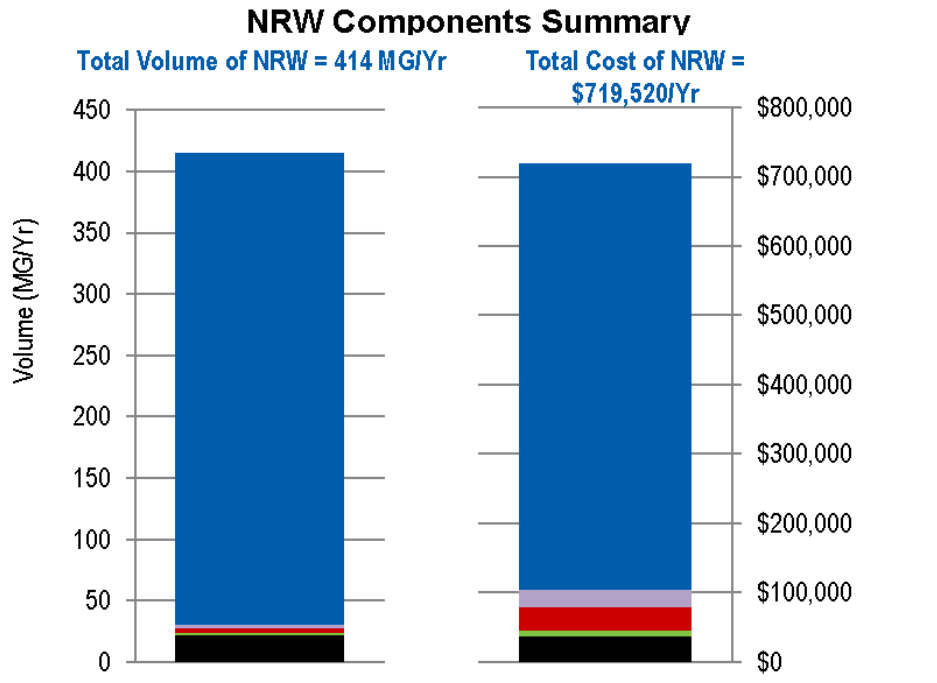
EP selected the default AWWA audit option for unauthorized consumption, 0.25% of total water supplied. This calculates to 2.92 MG, higher than the value of 1.0 MG that the Town input for the 2022 ASR. Town staff report suspected tampering on several occasions. In addition to the recommendations of this report, the Town of Weymouth should consider implementing a process to document all known incidents of unauthorized withdrawals from the system. Similarly, EP selected the default value (0.25%) for systematic data handling errors.

Costs & Performance Indicators

Cost data is broken down into two components: *customer retail unit charge* and *variable production cost*. Customer retail unit charge represents the volumetric portion of the total charges that customers pay. Derived from the Town's rate structure, the customer retail unit charge is applied to apparent losses because these losses typically represent lost billing revenue. Based on the water audit software calculations, apparent losses cost the Town approximately $68,000 in 2022.

Variable production cost is the cost to produce and supply water per unit. For the Town of Weymouth, it is calculated based on the cost of pumping and treating the water as well as maintaining treatment plant operations. In an AWWA water audit, variable production cost is applied to real losses in the system and unbilled authorized consumption. Based on the water audit software calculations, real losses cost the Town approximately $615,000 in 2022 and unbilled authorized consumption cost the Town approximately $36,000 in 2022. Figure 2 provides a graphical depiction of the scale of system losses from the AWWA audit software dashboard.

Figure 2: 2022 Non-revenue Water (NRW) Cost and Volume Summary



	Volume MG/Yr	Value $/Yr	Basis of Valuation
Apparent Losses	7.9	$68,236	CRUC
Real Losses	383.8	$614,865	VPC
Unbilled Authorized Cons	22.7	$36,420	VPC
Non-Revenue Water	414.5	$719,520	Blended

As presented in Figure 2, non-revenue water costs the Town of Weymouth approximately $720,000 in 2022. The largest share of financial loss is real losses which cost the Town approximately $615,000 per year.

The water audit software presents key performance indicators (KPIs) and percentiles to help interpret the results of the audit and provide benchmarks. The results of the audit suggest that the Town of Weymouth is between the 75th and 90th percentile among water systems at total loss cost rate of approximately $40.73 per connection per year. Unit real losses are similarly between the 75th and 90th percentile at 4,369 gallons per mile per day.

Leak Mapping

As previously referenced, the Town has most recently contracted leak detection surveys of the water distribution system in 2020, 2022 and in 2023. EP mapped leak locations to identify geospatial patterns in the leak occurrences, which the Town could use to inform further leak detection and distribution pipe repairs and replacement. To generate the maps, EP utilized all identified leaks as reported in the Water Leak Detection Survey provided by Water & Waste Pipe Testing, Inc. in 2020, and Comprehensive Leak Detection Survey Report provided by New England Water Distribution Services, LLC in 2022 and 2023. The 2020 report surveyed about 210 miles of the distribution system and discovered 24 leaks, while the 2022 and 2023 reports surveyed about 238 miles of the distribution system and discovered 8 leaks and 5 leaks, respectively. Estimated annual real losses for the 2020, 2022 and 2023 leak detection were 123 MG, 64 MG and 50 MG, respectively. EP overlaid these leaks on a map of the Town of Weymouth. Attachment B contains the map of these leaks.

Given the limited number of data points, it is not possible to draw definitive conclusions from the mapping efforts. Leaks do appear to be generally located in areas of higher static pressure which could indicate a correlation between leak occurrence and pressure. As the amount of water lost from a leak increases with an increase in pressure. replacement of water mains in areas of high static pressure should be considered as part of the Town's water main replacement program.

The water balance sheet shown as Table 3 indicated a high volume of real losses that were not captured by previous leak detection efforts. The Town should continue its leak detection program at an annual frequency at a minimum.

Based on the AWWA software and leak mapping, EP recommends the following strategies to reduce real losses:

- Expand the breadth of leak detection vendors and technologies. Increase frequency until real losses are minimized.
- Research water main replacement options in high static pressure areas to reduce potential for continued failures and leaks.
- Consider District metering in the future if previously recommended strategies do not improve water losses. District metering would include separating accounts into meter districts by service zone (High, Intermediate and Low) and adding flow meters to the zone boundaries. This would allow the Town to prioritize loss prevention efforts in zones with higher losses.

Summary

EP systematically evaluated the Town of Weymouth's water supply system for potential sources of water loss. The results of the audit reveal that inaccurate metering and leaks are major potential sources of water loss. Water losses cost the Town of Weymouth approximately $719,000 per year.

The Town can reduce losses by diversifying their use of leak detection technologies, implementing a meter testing program and replacing meters as needed, improving accuracy and documentation of water theft, and initiating a regular 3rd party review of billing practices. The Town could also improve the accuracy and utility of its recordkeeping through digitizing service logs and establishing a modern water system asset management program.

Attachments

Attachment A: AWWA Water Audit Software Worksheets

Attachment B: Leak Map

AWWA Free Water Audit Software v6.0

FWAS v6.0

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. Auditors are strongly encouraged to refer to the most current edition of AWWA M36 Manual for Water Audits for detailed guidance on the water auditing process and targeting loss reduction levels. This tool contains several separate worksheets. Sheets can be accessed using the tabs at the bottom of the screen, or by clicking the TOC links below.

Table of Contents (TOC)

AWWA Web Resources for Water Loss Control

https://www.awwa.org/Resources-Tools/Resource-Topics/Water-Loss-Control

Items referenced in the Free Water Audit Software v6.0 on the web:

- Data Grading Matrix v6.0
- Example Water Audit v6.0
- Water Audit Compiler v6.0
- AWWA Reports on Performance Indicators
- M36 Manual

Enter Basic Information

Name of Utility:	Water Division
Name of Contact Person:	Braydon Marot, P.E.
Email:	bmarot@weymouth.ma.us
Telephone | Ext.:	(781) 927-0847
City/Town/Municipality:	Town of Weymouth
State / Province:	Massachusetts (MA)
Country:	USA
Audit Preparation Date:	Aug 30 2023
Audit Year:	2022
Audit Year Label:	2022 (Fiscal, Calendar, etc)
Audit Period Start Date:	Jan 01 2022
Audit Period End Date:	Dec 01 2022
Volume Reporting Units:	Million gallons (US)
Water System Structure:	Retail
Water Type:	Potable Water
System ID Number:	3336000
Validator Name/ID:	
Validator Email:	
Estimated Total Population Served by Water Utility:	55,998

Key of Input Acronyms

In order of appearance in the Worksheet

VOS	Volume from Own Sources
VOSEA	VOS Error Adjustment
WI	Water Imported
WIEA	WI Error Adjustment
WE	Water Exported
WEEA	WE Error Adjustment
BMAC	Billed Metered Authorized Consumption
BUAC	Billed Unmetered Authorized Consumption
UMAC	Unbilled Metered Authorized Consumption
UUAC	Unbilled Unmetered Authorized Consumption
SDHE	Systematic Data Handling Errors
CMI	Customer Metering Inaccuracies
UC	Unauthorized Consumption
Lm	Length of mains
Nc	Number of service connections
Lp	Average length of (private) customer service line
AOP	Average Operating Pressure
CRUC	Customer Retail Unit Charge
VPC	Variable Production Cost

Color Key User input | Calculated | Optional default

Guidance for the Worksheet

Choosing to enter unit of **percent** or **volume** (applies to VOSEA, WIEA, WEEA, CMI) choose entry option:

1.00%	percent	*or*	
	volume		25.000

Choosing to enter **default** or **custom input** (applies to UUAC, SDHE, UC) choose entry option:

0.25%	default	*or*	
	custom		75.000

Guidance for the Interactive Data Grading

Use acronym buttons in IDG header to navigate among inputs. Acronym Key above. White = needs answers, orange = complete, clear = not required. Example below.

VOS	VOSEA	WI	WIEA	WE	WEEA	BMAC	BUAC	UMAC	UUAC
SDHE	CMI	UC	Lm	Nc	Lp	AOP	CRUC	VPC	

After clicking an acronym button, answer all visible questions in the order they're presented, choosing best-fit answer

Grade will populate when all visible questions are complete for an input: **7**

The limiting criteria will be labeled along the right. If only 1 limiting criterion is shown, improving on that criterion will achieve a higher data grade. If multiple limiting criteria are shown, improving on *each* limiting criterion is necessary to achieve a higher data grade. A complete inventory of data grading criteria is available in the Data Grading Matrix v6.0 (see web resources)

Limiting

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

AWWA Free Water Audit Software: Worksheet

FWAS v6.0
American Water Works Association.

Water Audit Report for: Water Division
Audit Year: 2022 | Jan 01 2022 - Dec 01 2022 | 2022

Click 'n' to add notes
Click 'g' to determine data validity grade
To edit water system info: go to start page

To access definitions, click the input name

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

Water Supplied Error Adjustments

WATER SUPPLIED

choose entry option:

		n	g				n	g				
VOS	Volume from Own Sources:	n	g	7	1,594.952	MG/Yr	n	g	8	0.19% percent	over-registration	VOSEA
WI	Water Imported:	n	g	n/a	0.000	MG/Yr						WIEA
WE	Water Exported:	n	g	n/a	0.000	MG/Yr						WEEA
	WATER SUPPLIED:				1,591.927	MG/Yr						

AUTHORIZED CONSUMPTION

choose entry option:

BMAC	Billed Metered:	n	g	7	1,177.439	MG/Yr				
BUAC	Billed Unmetered:	n	g	n/a		MG/Yr				
UMAC	Unbilled Metered:	n	g	n/a		MG/Yr				
UUAC	Unbilled Unmetered:	n	g	8	22.734	MG/Yr	custom	22.734	MG/Yr	
	AUTHORIZED CONSUMPTION:				1,200.173	MG/Yr				

WATER LOSSES

391.754 MG/Yr

Apparent Losses

Default option selected for Systematic Data Handling Errors, with automatic data grading of 3

choose entry option:

SDHE	Systematic Data Handling Errors:	n	g	3	2.944	MG/Yr	0.25%	default		
CMI	Customer Metering Inaccuracies:	n	g	1	4.000	MG/Yr	volume	4.000	MG/Yr	under-registration
UC	Unauthorized Consumption:	n	g	1	1.000	MG/Yr	custom	1.000	MG/Yr	
	Apparent Losses:				7.944	MG/Yr				

Real Losses

	Real Losses:				383.811	MG/Yr
	WATER LOSSES:				391.754	MG/Yr

NON-REVENUE WATER

	NON-REVENUE WATER:				414.488	MG/Yr

SYSTEM DATA

Lm	Length of mains:	n	g	8	240.7	miles	(including fire hydrant lead lengths)
Nc	Number of service connections:	n	g	8	16,773		(active *and* inactive)
	Service connection density:				70	conn./mile main	
	Are customer meters typically located at the curbstop/property line?				No		
Lp	Average length of (private) customer service line:	n	g	1	30.0	ft	(average distance between property line and meter)
AOP	Average Operating Pressure:	n	g	8	64.0	psi	

COST DATA

CRUC	Customer Retail Unit Charge:	n	g	7	$8.59	$/1000 gallons (US)	Total Annual Operating Cost	
VPC	Variable Production Cost:	n	g	9	$1,602.00	$/Million gallons	$10,800,000	$/yr (optional input)

WATER AUDIT DATA VALIDITY TIER:

***** The Water Audit Data Validity Score is in Tier III (51-70). See Dashboard tab for additional outputs. *****

go to dashboard

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

PRIORITY AREAS FOR ATTENTION TO IMPROVE DATA VALIDITY:

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

1: Volume from Own Sources (VOS)
2: Customer Metering Inaccuracies (CMI)
3: Billed Metered (BMAC)

KEY PERFORMANCE INDICATOR TARGETS:

OPTIONAL: If targets exist for the operational performance indicators, they can be input below:

Unit Total Losses:		gal/conn/day
Unit Apparent Losses:		gal/conn/day
Unit Real Losses[A]:		gal/conn/day
Unit Real Losses[B]:		gal/mile/day

If entered above by user, targets will display on KPI gauges (see Dashboard)

2022

White = incomplete
Orange = complete
Use acronyms for navigation

VOS | VOSEA | WI | WIEA | WE | WEEA | BMAC | BUAC | UMAC | UUAC
SDHE | CMI | UC | Lm | Nc | Lp | AOP | CRUC | VPC

Limiting criteria (see Start Page for details)

go to input

Volume from Own Sources (VOS) - Data Grading Criteria

go to notes

vos	Criteria Question	Select Best-Fit Answers to All Visible Questions	
vos.0	Did the water utility supply any water from its own sources during the audit year?	Yes	
vos.1	What percent of own supply volume is metered?	>99%	

For questions 2-10 below: Choose the answer that applies for those meters that measure >90% of the finished water volume.
In-situ flow accuracy testing = a test process that confirms the flow measuring accuracy of the primary device (the flowmeter), in its installed location, using an independent reference volume.
Electronic calibration = a process that checks for error in the metering secondary device(s) and/or the tertiary device(s).
Secondary device can include conversion to mA, meter transmitter or similar instrumentation.
Tertiary device can include SCADA, historian or other computerized archival system.

vos.2	What is the frequency of electronic calibration?	Annually	Limiting
vos.3	What level of data transfer errors are checked as part of the electronic calibration process?	Data transfer errors are checked at secondary device(s), but no tertiary device(s) exist	
vos.4	Is the most recent electronic calibration documentation available for review?	Yes	
vos.5	What is the frequency of in-situ flow accuracy testing?	Less than annual but within last 5 years	Limiting
vos.6	Is the most recent in-situ flow accuracy testing documentation available for review?	Yes	
vos.7	What are the total volume-weighted average results of in-situ flow accuracy testing (during or closest to audit year)?	At or within ±3%	
vos.8	Have testing and calibration procedures been closely scrutinized for compliance with procedures described in the AWWA M36 and/or M33 Manual(s)?	No	
vos.9	Which best describes the frequency of finished water meter readings?	Continuous	
vos.10	Which best describes the frequency of data review for anomalies/errors? These can include numbers that are outside of typical patterns, and zero or 'null' values that may reflect a gap in data recording.	Daily	
	FINAL DATA GRADE FOR THIS AUDIT INPUT:	7	

go to input

Volume from Own Sources Error Adjustment (VOSEA) - Data Grading Criteria

go to notes

vosea	Criteria Question	Select Best-Fit Answers to All Visible Questions	
vosea.1	Are tank levels monitored automatically & recorded daily?	Yes	
vosea.2	Are daily changes of stored water volumes in distribution system tanks included in the tabulation of the daily "Volume from Own Sources" quantity?	No	Limiting
vosea.3	Is the annual net distribution storage change included in either the VOS input or the VOSEA input?	No	
vosea.4	Are the flow accuracy test and/or electronic calibration results included in the VOSEA input in the water audit?	Yes, results are analyzed and incorporated	
	FINAL DATA GRADE FOR THIS AUDIT INPUT:	**8**	

go to input

Water Imported (WI) - Data Grading Criteria

go to notes

wi	Criteria Question	Select Best-Fit Answers to All Visible Questions
wi.0	Did the water utility import any water during the audit year?	No
wi.1		

For questions 2-10 below: Choose the answer that applies for those meters that measure >90% of the water imported volume.
In-situ flow accuracy testing = a test process that confirms the flow measuring accuracy of the primary device (the flowmeter), in its installed location, using an independent reference volume.
Electronic calibration = a process that checks for error in the metering secondary device(s) and/or the tertiary device(s).
Secondary device can include conversion to mA, meter transmitter or similar instrumentation.
Tertiary device can include SCADA, historian or other computerized archival system.

wi.2		
wi.3		
wi.4		
wi.5		
wi.6		
wi.7		
wi.8		
wi.9		
wi.10		
	FINAL DATA GRADE FOR THIS AUDIT INPUT:	**n/a**

go to input

Water Imported Error Adjustment (WIEA) - Data Grading Criteria

go to notes

wiea	Criteria Question	Select Best-Fit Answers to All Visible Questions
wiea.1		
wiea.2		
wiea.3		
wiea.4		
	FINAL DATA GRADE FOR THIS AUDIT INPUT:	**n/a**

go to input

Water Exported (WE) - Data Grading Criteria

go to notes

we	Criteria Question	Select Best-Fit Answers to All Visible Questions
we.0	Did the water utility export any water during the audit year?	No
we.1		

For questions 2-10 below: Choose the answer that applies for those meters that measure >90% of the water exported volume.
In-situ flow accuracy testing = a test process that confirms the flow measuring accuracy of the primary device (the flowmeter), in its installed location, using an independent reference volume.
Electronic calibration = a process that checks for error in the metering secondary device(s) and/or the tertiary device(s).
Secondary device can include conversion to mA, meter transmitter or similar instrumentation.
Tertiary device can include SCADA, historian or other computerized archival system.

we.2		
we.3		
we.4		
we.5		
we.6		
we.7		
we.8		
we.9		
we.10		
	FINAL DATA GRADE FOR THIS AUDIT INPUT:	**n/a**

go to input

Water Exported Error Adjustment (WEEA) - Data Grading Criteria

go to notes

weea	Criteria Question	Select Best-Fit Answers to All Visible Questions
weea.1		
weea.2		
weea.3		
weea.4		
	FINAL DATA GRADE FOR THIS AUDIT INPUT:	**n/a**

go to input

Billed Metered Authorized Consumption (BMAC) - Data Grading Criteria

go to notes

bmac	Criteria Question	Select Best-Fit Answers to All Visible Questions	
bmac.0	Were any customers metered in the audit year?	Yes	
bmac.1	For billed metered accounts, what % of bills are estimated in a typical billing cycle?	5% or less	
bmac.2	How often does the utility read its customer meters? For systems with multiple read frequencies, select the reading frequency that describes the majority of your customers.	Quarterly	Limiting
bmac.3	Is the BMAC volume pro-rated to represent consumption occuring exactly during the audit period?	No	
bmac.4	How frequently does internal review by utility staff of the BMAC volumes occur?	Every billing cycle	
bmac.5	What level of detail is examined in the internal review of BMAC volumes?	Totals grouped by use type or customer class and specific accounts flagged for anomalous consumption	
bmac.6	When was the most recent billing data review by someone who is independent of the utility billing process?	More than 5 years ago, or not sure	
bmac.7			
	FINAL DATA GRADE FOR THIS AUDIT INPUT:	**7**	

go to input

Billed Unmetered Authorized Consumption (BUAC) - Data Grading Criteria

go to notes

buac	Criteria Question	Select Best-Fit Answers to All Visible Questions
buac.0	Was there any billed consumption on unmetered accounts in the audit year?	No
buac.1		
buac.2		
buac.3		
	FINAL DATA GRADE FOR THIS AUDIT INPUT:	**n/a**

go to input

Unbilled Metered Authorized Consumption (UMAC) - Data Grading Criteria

go to notes

umac	Criteria Question	Select Best-Fit Answers to All Visible Questions
umac.0	Did the water utility have any unbilled-metered consumption in the audit year?	No
umac.1		
umac.2		
umac.3		
umac.4		
	FINAL DATA GRADE FOR THIS AUDIT INPUT:	**n/a**

go to input

Unbilled Unmetered Authorized Consumption (UUAC) - Data Grading Criteria

go to notes

uuac	Criteria Question	Select Best-Fit Answers to All Visible Questions	
uuac.0	On the Worksheet, the status of the default option is:	A system specific volume has been entered	
uuac.1	How well-understood is the extent of unbilled unmetered use?	Complete inventory exists	
uuac.2	Which best describes the records that are kept for events of unbilled unmetered use?	Each event is documented	
uuac.3	How is the majority of unbilled unmetered use estimated?	By number of events multiplied by typical use estimates	Limiting
	FINAL DATA GRADE FOR THIS AUDIT INPUT:	**8**	

go to input

Systematic Data Handling Error (SDHE) - Data Grading Criteria

go to notes

This Data Grading Criteria is hidden when the 'default' input is used on the Worksheet

FINAL DATA GRADE FOR THIS AUDIT INPUT:	3

go to input

Customer Metering Inaccuracies (CMI) - Data Grading Criteria

go to notes

cmi	Criteria Question	Select Best-Fit Answers to All Visible Questions	
cmi.0	Was there any metered customer usage during the audit period?	Yes	
cmi.1	Do you test meters reactively (when triggered by customer complaint or billing/consumption flag)?	No reactive testing conducted	Limiting
cmi.2	For small size customer meters, which best describes the frequency of proactive testing (effort beyond when triggered by customer complaint or billing/consumption flags)?	Not recurring, last effort conducted more than 5 years prior to audit period	
cmi.3			
cmi.4	For mid and large size customer meters, which best describes the frequency of the proactive testing program?	Not recurring, last testing effort occurred more than 5 years prior to audit period	
cmi.5			
cmi.6	Which best describes how the input was derived?	Guesstimated without any customer meter testing data as a reference	
cmi.7	Has the input derivation been reviewed by someone with expert knowledge in the M36 methodology?	No	
cmi.8	To what extent does meter replacement occur and for which meters?	Annual proactive replacement of subset of meters (i.e. by age or throughput)	
cmi.9	Which best describes the reliability of meter installation records?	Records are kept for meter installations, and they include data on installation date, type, size, and manufacturer	
	FINAL DATA GRADE FOR THIS AUDIT INPUT:	**1**	

go to input

Unauthorized Consumption (UC) - Data Grading Criteria

go to notes

uc	Criteria Question	Select Best-Fit Answers to All Visible Questions	
uc.0	On the Worksheet, the status of the default option is:	A system specific volume has been entered	
uc.1	Which best describes how the input was derived?	Guesstimated	Limiting
uc.2	Which best describes the extent of unauthorized consumption tracking and oversight?	All discovered events are recorded	
	FINAL DATA GRADE FOR THIS AUDIT INPUT:	**1**	

go to input

Length of Mains (Lm) - Data Grading Criteria

go to notes

Lm	Criteria Question	Select Best-Fit Answers to All Visible Questions	
Lm.1	How was the input derived?	Derived directly from Mains inventory (GIS, ledger, etc)	
Lm.2	Are hydrant laterals included in the input derivation?	No	Limiting
Lm.3	Which best describes how the Mains inventory (GIS, ledger, etc) is kept up to date?	Additions or subtractions are updated in the mains inventory (GIS, ledger, etc), at least annually	
Lm.4	Which best describes how the Mains inventory (GIS, ledger, etc) is field validated to confirm field conditions match the inventory?	Field validation is accomplished (i.e. in daily operations or specific validation projects)	
	FINAL DATA GRADE FOR THIS AUDIT INPUT:	**8**	

go to input

Number of Service Connections (Nc) - Data Grading Criteria

go to notes

Nc	Criteria Question	Select Best-Fit Answers to All Visible Questions	
Nc.1	How was the input derived?	Extracted from Services inventory (GIS, billing system, etc)	
Nc.2	What is the count of services based on?	Non-premise based, i.e. meter count, customer count	Limiting
Nc.3	Are inactive (but still pressurized) service lines included in the input? These may be metered or unmetered.	Yes	
Nc.4	Which best describes how the inventory of service connections (GIS, billing system, etc) is kept up to date?	Additions or subtractions are updated in the service line inventory (GIS, billing system, etc), at least annually	
Nc.5	Which best describes how the inventory of service connections (GIS, billing system, etc) is field validated to confirm field conditions match the inventory?	Field validation is accomplished for the entire system (i.e. in daily operations or specific validation projects)	
	FINAL DATA GRADE FOR THIS AUDIT INPUT:	**8**	

go to input

Average Length of (Private) Customer Service Line (Lp) - Data Grading Criteria

go to notes

Lp	Criteria Question	Select Best-Fit Answers to All Visible Questions	
Lp.0	Are customer meters typically located at the curbstop or property line?	No	
Lp.1	How was the input derived?	Guesstimated	Limiting
Lp.2	Which best describes how the Customer Service Line and Meter Locations mapping is kept up to date?	Customer Service Line and Meter Locations inventory is not maintained or updated	Limiting
Lp.3			
Lp.4	Which best describes the policy to define where the utility's ownership of the service line ends, and the customer's ownership of the service line begins?	Policy is clear, but adherence in practice is uncertain	
	FINAL DATA GRADE FOR THIS AUDIT INPUT:	**1**	

go to input

Average Operating Pressure (AOP) - Data Grading Criteria

go to notes

aop	Criteria Question	Select Best-Fit Answers to All Visible Questions	
aop.1	Which best describes checks on the boundary integrity for the system's pressure zone(s)?	Normally-closed boundary valves between zones have been confirmed within the past 3 years to be fully closed	
aop.2	Which best describes how one-time pressure readings (i.e. from hydrants) are collected?	Collected only if there are low pressure complaints, or new development requests	Limiting
aop.3	Which best describes where continuous pressure data (via temporary data loggers or permanent telemetry) is collected?	At zone boundary conditions only (i.e. supply entry points, PRVs, booster stations)	Limiting
aop.4	Which best describes how continuous pressure data is collected?	Year-round data collection via permanent monitoring	
aop.5	How was the input derived?	Derived from hydraulic model, where model has not been field calibrated in the last 5 years	
	FINAL DATA GRADE FOR THIS AUDIT INPUT:	**8**	

go to input

Customer Retail Unit Charge (CRUC) - Data Grading Criteria

go to notes

cruc	Criteria Question	Select Best-Fit Answers to All Visible Questions	
cruc.0	Was any metered consumption billed on a volumetric basis in the audit period?	Yes	
cruc.1	Which best describes the use and reliability of the current rate structure?	Customer bill calculations have been checked to confirm the rate structure is correctly implemented	
cruc.2	Choose the option that best describes how the input was derived	A volume-weighted average of all rates was calculated	
cruc.3	Is there any additional volumetric revenue the utility receives that depends on water meter readings, such as sewer?	Yes, but this has not been incorporated into the volume-weighted average calculation	Limiting
cruc.4	Has the input derivation been reviewed by someone with expert knowledge in the M36 methodology?	No	
	FINAL DATA GRADE FOR THIS AUDIT INPUT:	**7**	

go to input

Variable Production Cost (VPC) - Data Grading Criteria

go to notes

vpc	Criteria Question	Select Best-Fit Answers to All Visible Questions	
vpc.1	Choose the option that best describes how the input was derived	Multiple sources of water exist, and a volume-weighted average was calculated for all sources	
vpc.2	Choose the option that best describes which short-run marginal costs have been included in the input, using the definitions below for reference. Short-run marginal costs can include the following: - chemicals + power for treatment, typically applicable if the utility is producing/treating water - power for distribution, typically applicable if pumps exist in the distribution network - water acquisition costs, typically applicable if the utility is purchasing water or incurs any extraction costs for withdrawing from a source Some short-run marginal costs may not be applicable. The auditor should analyze the system characteristics to determine which costs are applicable for inclusion in the VPC input derivation. See also the latest AWWA M36 Manual for further guidance.	All applicable short-run marginal costs are included	
vpc.3	Choose the option that best describes which long-run marginal costs have been included in the input, using the definitions below for reference. Long-run marginal costs can include the following: - water treatment residuals management, typically applicable if solids are produced from water treatment process - accelerated wear & tear on dynamic equipment, typically applicable if pumps exist for treatment and/or distribution, or any other equipment exists that wears out as a function of use instead of time (i.e. filter media, chemical dosing pumps, uv disinfection bulbs, etc) - payouts for damage claims from main and service line breaks, typically applicable if damage claims are paid by the utility - accelerated expansion of supply capacity, typically applicable if the utility is at or nearing supply capacity, or scarecity costs in water scarce areas - full cost pricing that includes all lifecycle costs and externalities (internalized or not) Some long-run marginal costs may not be applicable. The auditor should analyze the system characteristics to determine which costs are applicable for inclusion in the VPC input derivation. See also the latest AWWA M36 Manual for further guidance.	Long-run marginal costs have been evaluated for applicability, and all applicable costs are included	
vpc.4	Has the input derivation been reviewed by someone with expert knowledge in the M36 methodology?	No	Limiting
	FINAL DATA GRADE FOR THIS AUDIT INPUT:	**9**	

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AWWA Free Water Audit Software: Dashboard

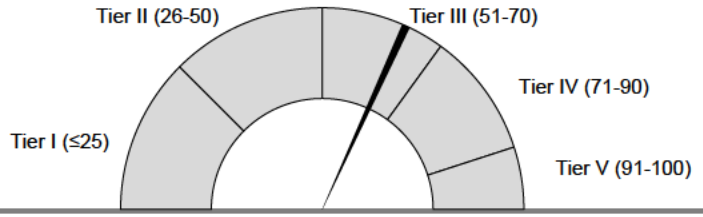
go to worksheet | go to grading | go to references

Water Audit Report for: Water Division **Audit Year: 2022 ##** **Jan 01 2022 - Dec 01 2022**

Data Validity

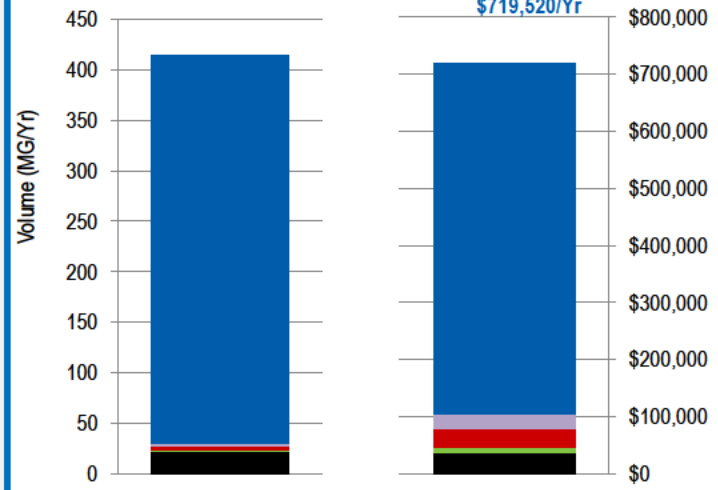
Data Validity Score: 63 **Data Validity Tier:** Tier III (51-70)

See Loss Control Planning for Tier Details



NRW Components Summary

Total Volume of NRW = 414 MG/Yr **Total Cost of NRW = $719,520/Yr**



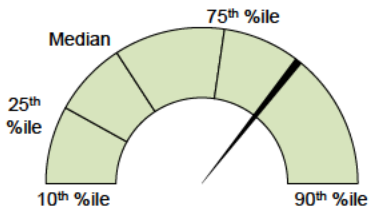
Real Losses
Systematic Data Handling Errors
Customer Metering Inaccuracies
Unauthorized Consumption
Unbilled Unmetered Auth Cons
Unbilled Metered Authorized Cons

	Volume MG/Yr	Value $/Yr	Basis of Valuation
Apparent Losses	7.9	$68,236	CRUC
Real Losses	383.8	$614,865	VPC
Unbilled Authorized Cons	22.7	$36,420	VPC
Non-Revenue Water	414.5	$719,520	Blended

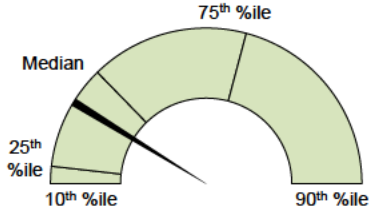
Key Performance Indicators

Actual KPI result — Target (see Worksheet)

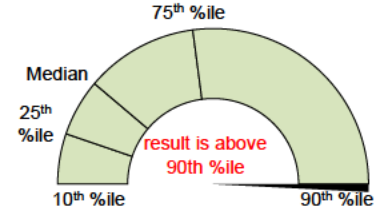
gauge %iles per validated industry ranges[2]



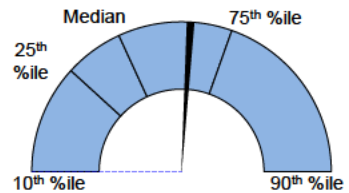
Total Loss Cost Rate
40.73 $/conn/year



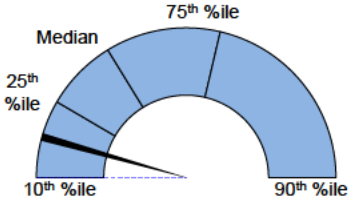
Apparent Loss Cost Rate
4.07 $/conn/year



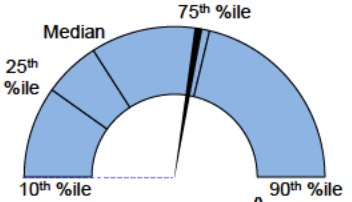
Real Loss Cost Rate
36.66 $/conn/year



Unit Total Losses
64.0 gal/conn/day

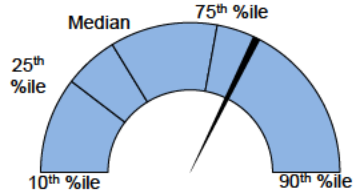


Unit Apparent Losses
1.3 gal/conn/day

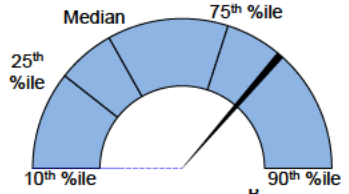


Unit Real Losses[A]
62.7 gal/conn/day

Average Operating Pressure
64 psi
90th %ile
75th %ile
Median
25th %ile
10th %ile



Infrastructure Leakage Index (ILI)
3.6 dimensionless



Unit Real Losses[B]
4,369 gal/mile/day

See UARL definition for additional guidance on the ILI

(UARL) Unavoidable Annual Real Losses 105.9 MG/Yr 17.3 gal/conn/day

Guidance Information for Key Performance

- The eight indicators shown are the recommended suite per the AWWA Water Loss Control Committee 2020 Position on KPIs[1].
- A suite of KPIs is necessary, as no single KPI can holistically communicate water loss performance for a given water system.
- See Table 1 below for Uses and Limitations for each KPI, excerpted from the AWWA Water Loss Control Committee Report (2020)[1], with naming conventions updated.
- Percentiles (%iles) shown on KPI gauges come from Level 1 validated data in the AWWA WLCC Reference Water Audit Dataset (2020)[2].
- KPI %iles shown above are not segregated by cohorts. Limited KPI data by cohorts may be found in WRF 4695 Guidance Manual, Appendix B (2019)[5].
- Actual KPI results that fall below 10th %ile or above 90th %ile do not necessarily imply error, but should be viewed with scrutiny.
- Percentiles not intended to imply targets. Targets may be input by user for operational KPIs, if desired, on Worksheet.
- See UARL and ILI in Definitions tab for discussion of size and pressure limitations.
- Systems that fall on the extreme ends of size or connection density should use caution when interpreting Unit Losses KPIs.

Water Audit Report for: Water Division
Audit Year: 2022

2022
Jan 01 2022 - Dec 01 2022

General Notes:	

	Audit Item	Notes on Input Derivation	Notes on Data Validity Grading
go to worksheet / go to grading	**Volume from Own Sources (VOS)**		Meter calibration and accuracy testing performed annually but not 100% of meters.
go to worksheet / go to grading	**Volume from Own Sources Error Adjustment (VOSEA)**		
go to worksheet / go to grading	**Water Imported (WI)**		
go to worksheet / go to grading	**Water Imported Error Adjustment (WIEA)**		
go to worksheet / go to grading	**Water Exported (WE)**		

		Audit Item	Notes on Input Derivation	Notes on Data Validity Grading
go to worksheet	go to grading	**Water Exported Error Adjustment (WEIA)**		
go to worksheet	go to grading	**Billed Metered Authorized Consumption (BMAC)**		
go to worksheet	go to grading	**Billed Unmetered Authorized Consumption (BUAC)**		
go to worksheet	go to grading	**Unbilled Metered Authorized Consumption (UMAC)**		
go to worksheet	go to grading	**Unbilled Unmetered Authorized Consumption (UUAC)**		
go to worksheet	go to grading	**Systematic Data Handling Errors (SDHE)**		
go to worksheet	go to grading	**Customer Metering Inaccuracies (CMI)**		Large meter testing and replacment program initiated in 2023.

		Audit Item	Notes on Input Derivation	Notes on Data Validity Grading
go to worksheet	go to grading	**Unauthorized Consumption (UC)**		
go to worksheet	go to grading	**Length of Mains (Lm)**		
go to worksheet	go to grading	**Number of Service Connections (Nc)**		
go to worksheet	go to grading	**Average Length of (private) Customer Service Line (Lp)**		
go to worksheet	go to grading	**Average Operating Pressure (AOP)**		
go to worksheet	go to grading	**Customer Retail Unit Charge (CRUC)**		
go to worksheet	go to grading	**Variable Production Cost (VPC)**		

Hello, I am a blank sheet, at your service.

AWWA Free Water Audit Software
Water Balance

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Water Audit Report for: Water Division
Audit Year: 2022 (Jan 01 2022 - Dec 01 2022)
Data Validity Tier: Tier III (51-70)

Volume from Own Sources (VOS) (corrected for known errors) *1,591.927*	System Input Volume *1,591.927*	Water Exported (WE) (corrected for known errors) *0.000*	Billed Water Exported			Revenue Water (Exported) 0.000
		Water Supplied *1,591.927*	Authorized Consumption *1,200.173*	Billed Authorized Consumption *1,177.439*	Billed Metered Consumption (BMAC) (water exported is removed) *1,177.439*	Revenue Water 1,177.439
					Billed Unmetered Consumption (BUAC) *0.000*	
				Unbilled Authorized Consumption *22.734*	Unbilled Metered Consumption (UMAC) *0.000*	Non-Revenue Water (NRW) *414.488*
					Unbilled Unmetered Consumption (UUAC) *22.734*	
			Water Losses *391.754*	Apparent Losses *7.944*	Systematic Data Handling Errors (SDHE) *2.944*	
					Customer Metering Inaccuracies (CMI) *4.000*	
					Unauthorized Consumption (UC) *1.000*	
Water Imported (WI) (corrected for known errors) *0.000*				Real Losses *383.811*	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*	

AWWA Free Water Audit Software:
Determining Water Loss Standing

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Water Audit Report for: **Water Division**
Audit Year: **2022** **Jan 01 2022 - Dec 01 2022**
Data Validity Tier: **Tier III (51-70)**

Water Loss Control Planning Guide

	Water Audit Data Validity Tier (Score Range)				
Functional Focus Area	**Tier I (1-25)**	**Tier II (26-50)**	**Tier III (51-70)**	**Tier IV (71-90)**	**Tier V (91-100)**
Audit Data Collection	Launch auditing and loss control team; address supply metering deficiencies	Analyze business process for customer metering and billing functions and water supply operations; Identify data gaps; improve supply metering	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 AMR/AMI 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 with PIs for performance comparisons for real losses	Performance Benchmarking with PIs is meaningful in comparing real loss standing	Identify Best Practices/ Best in class; PIs are very reliable as real loss performance indicators 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.

AWWA Free Water Audit Software: Definitions

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Item Name	Description
Apparent Losses Find	= systematic data handling errors + customer metering inaccuracies + unauthorized consumption Apparent Losses include all types of inaccuracies associated with customer metering (worn meters as well as improperly sized meters or wrong type of meter for the water usage profile) as well as systematic data handling errors (meter reading, billing, archiving and reporting), plus unauthorized consumption (theft or illegal use). NOTE: Over-estimation of Apparent Losses results in under-estimation of Real Losses. Under-estimation of Apparent Losses results in over-estimation of Real Losses.
AUTHORIZED CONSUMPTION Find	= billed metered + billed unmetered + unbilled metered + unbilled unmetered consumption The volume of metered and/or unmetered water taken by registered customers, the water utility's own uses, and uses of others who are implicitly or explicitly authorized to do so by the water utility; for residential, commercial, industrial and public-minded purposes. Typical retail customers' consumption is tabulated usually from established customer accounts as billed metered consumption, or - for unmetered customers - billed unmetered consumption. These types of consumption, along with billed water exported, provide revenue potential for the water utility. Typically a lag will exist between timing for reading of supply meters and reading of customer meters. A lag-time correction should typically be calculated to account for this. **Be certain to tabulate the water exported volume as a separate component and do not "double-count" it by including in the billed metered consumption component as well as the water exported component.** Unbilled authorized consumption occurs typically in non-account uses, including water for fire fighting and training, flushing of water mains and sewers, street cleaning, watering of municipal gardens, public fountains, or similar public-minded uses. Occasionally these uses may be metered and billed (or charged a flat fee), but usually they are unmetered and unbilled. In the latter case, the water auditor may use a default value to estimate this quantity, or implement procedures for the reliable quantification of these uses. This starts with documenting usage events as they occur and estimating the amount of water used in each event. (See Unbilled Unmetered Authorized Consumption)
View Service Connection Diagram **Average Length of (private) Customer Service Line (Lp)** Find	This is the average length of underground customer service line, Lp, that is owned and maintained by the customer; from the point of ownership transfer to the customer water meter, or building line (if unmetered). The quantity is one of the data inputs for the calculation of Unavoidable Annual Real Losses (UARL), which serves as the denominator of the performance indicator: Infrastructure Leakage Index (ILI). The value of Lp is multiplied by the number of customer service connections to obtain a total length of customer owned piping in the system. The purpose of this parameter is to account for the unmetered service line infrastructure that is the responsibility of the customer for arranging repairs of leaks that occur on their lines. In many cases leak repairs arranged by customers take longer to be executed than leak repairs arranged by the water utility on utility-maintained piping. Leaks run longer - and lose more water - on customer-owned service piping, than utility owned piping. If the customer water meter exists near the ownership transfer point (usually the curb stop located between the water main and the customer premises) this distance is zero because the meter and transfer point are the same. This is the often encountered configuration of customer water meters located in an underground meter box or "pit" outside of the customer's building. The Free Water Audit Software asks a "Yes/No" question about the meter at this location. If the auditor selects "Yes" then this distance is set to zero and the data grading score for this component is set to 10. If water meters are typically located inside the customer premise/building, or properties are unmetered, it is up to the water auditor to estimate a system-wide average Lp length based upon the various customer land parcel sizes and building locations in the service area. Lp will be a shorter length in areas of high density housing, and a longer length in areas of low density housing and varied commercial and industrial buildings. General parcel demographics should be employed to obtain a total Lp length (Lc) and subsequently a weighted average Lp length for the entire system. Refer to the "Service Connection Diagram" worksheet for a depiction of the service line/metering configurations that typically exist in water utilities. This worksheet gives guidance on the determination of the Average Length, Lp, for each configuration.
Average Operating Pressure (AOP) Find	This is the average pressure in the distribution system that is the subject of the water audit. If the water utility is compiling the water audit for the first time, the average pressure can be approximated, but with a low data grading. In subsequent years of auditing, effort should be made to improve the accuracy of the average pressure quantity. This will then qualify the value for a higher data grading. In the absence of a hydraulic model, the average pressure may be approximated by obtaining readings of static water pressure from a representative sample of fire hydrants or other system access points evenly located across the system. A weighted average of the pressure can be assembled; but be sure to take into account the elevation of the fire hydrants, which typically exist several feet higher than the level of buried water pipelines. If your water utility has an up-to-date and calibrated hydraulic model of the water distribution system, it can be utilized to obtain a very accurate quantity of average pressure. However using the average pressure of all "nodes" in the system model is not necessarily the most accurate way to calculate the average operating pressure. This is especially true if there are significant pressure differences throughout the system, and the "nodes" are not evenly distributed throughout the distribution system. The most accurate calculation is to obtain the average pressure that each pipe segment experiences. The way to do this is to calculate the pressure at each end of the pipe. Then calculate the average of those two values and multiply this average value by the length of that pipe. This must be calculated for all pipe segments in the model. Finally calculate the sum of all of these values and and divide by the total pipe length. This effectively calculates a weighted average of pressure over the total pipe length. For low density systems (<32 connections/mile), average mains pressures at the service connection or curb stop may have greater influence and should be considered.
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.

Item Name	Description
Billed Metered Authorized Consumption (BMAC) Find	All metered consumption which is billed to retail customers, including all groups of customers such as domestic, commercial, industrial or institutional. **It does NOT include water supplied to neighboring utilities (water exported) which is metered and billed. Be sure to subtract any consumption for exported water sales that may be included in these billing roles. Water supplied as exports to neighboring water utilities should be included only in the Water Exported component.** 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 lag time since not all customer meters are read on the same day of the meter reading period. However additional analysis is necessary to determine the lag time adjustment value, which may or may not be significant.
Billed Unmetered Authorized Consumption (BUAC) Find	All billed consumption which is calculated based on estimates or norms from water usage sites that have been determined by utility policy to be left unmetered. This is typically a very small component in systems that maintain a policy to meter their customer population. However, this quantity can be the key consumption component in utilities that have not adopted a universal metering policy. **This component should NOT include any water that is supplied to neighboring utilities (water exported) which is unmetered but billed. Water supplied as exports to neighboring water utilities should be included only in the Water Exported component.**
Customer Metering Inaccuracies (CMI) Find	Apparent water losses caused by the collective under-registration of customer water meters. Many customer water meters gradually wear as large cumulative volumes of water are passed through them over time. This causes the meters to under-register the flow of water. This occurrence is common with smaller residential meters of sizes 5/8-inch and 3/4 inch after they have registered very large cumulative volumes of water, which generally occurs only after periods of years. For meters sized 1-inch and larger - typical of multi-unit residential, commercial, institutional and industrial accounts - meter under-registration can occur from wear or from the improper application of the meter; i.e. installing the wrong type of meter or the wrong size of meter, for the flow pattern (profile) of the consumer. For instance, many larger meters have reduced accuracy at low flows. If an oversized meter is installed, most of the time the routine flow will occur in the low flow range of the meter, and a significant portion of it may not be registered. It is important to properly select and install all meters, but particularly large customer meters, size 1-inch and larger. 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. Note that this percentage is a composite average inaccuracy for all customer meters in the entire meter population. The percentage will be multiplied by the sum of the volumes in the Billed Metered and Unbilled Metered components. Alternatively, if the auditor has substantial data from meter testing activities, he or she can calculate their own loss volumes, and this volume may be entered directly. Note that a value of zero will be accepted but is not recommended, as all metered systems tend to have some degree of inaccuracy. A positive value should be entered. A value of zero in this component is generally valid only if the water utility does not meter its customer population. The formula for caculating a volume of CMI from a percentage input is as follows: CMI volume = (BMAC+UMAC)/(1-CMI%)-(BMAC+UMAC)
Customer Retail Unit Charge (CRUC) Find	The Customer Retail Unit Charge represents the volumetric portion of the total charges that customers pay for water service. The CRUC does not include fixed charges. This unit charge cost is applied routinely to the components of Apparent Loss, since these losses represent water reaching customers but not (fully) paid for. Since most water utilities have a rate structure that includes a variety of different charges costs based upon class of customer, a volume-weighted average of water sold at each unique rate should be calculated to determine a single composite charge that should be entered into this cell. Finally, the weighted average charge should also include additional charges for sewer, storm water or biosolids processing, but only if these charges are based upon the volume of potable water consumed. For water utilities in regions with limited water resources and a questionable ability to meet the drinking water demands in the future, the Customer Retail Unit Charge Cost might also be applied to value the Real Losses; instead of applying the Variable Production Cost to Real Losses. In this way, it is assumed that every unit volume of leakage reduced by leakage management activities will be sold to a customer. Note: the Free Water Audit 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 for purpose of calculating Apparent Loss valuations. The monetary units are United States dollars, $.
Infrastructure Leakage Index (ILI) Find	The ratio of the Current Annual Real Losses (Real Losses) to the Unavoidable Annual Real Losses (UARL). This performance indicator is dimensionless. **NOTES ON THE UARL AND ILI:** 1. This Free Water Audit Software version 6 presents the calculated UARL and ILI for systems of all sizes and all pressures. Some published research is now available on predicting how UARL is likely to be modified when modeling low leakage limits in systems that are very small (< 3000 conn), or have very low average pressures, or have very high pressures (aka boundary cases). Inherent over- or under- estimation of UARL volume may exist in these boundary cases, as they operate at or near the limits of the UARL model assumptions. More widespread application and understanding of system specific corrections to the UARL model in these boundary cases is now likely to occur, but are not included in the FWAS at the time of this publication. Caution is advised when using the standard UARL modeled value (and subsequently the ILI) for boundary cases. In boundary cases, the ILI may still be considered a general Performance Indicator, but not used as an absolute performance measurement or for benchmark comparisons. 2. The UARL term is based on average operating pressure in a given audit year, and a utility's current pressure conditions may not be optimized. Thus, ILI should always be interpreted with some measure of pressure, and only used for tracking progress if all justifiable pressure management has already been completed.

Item Name	Description
Length of Mains (Lm) 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]
NON-REVENUE WATER Find	= Apparent Losses + Real Losses + Unbilled Metered Consumption + Unbilled Unmetered Consumption. This is water which does not provide revenue potential to the utility.
Number of Service Connections (Nc) Find	Number of customer service connections, extending from the water main to supply water to a customer. This includes the actual number of pressurized piping connections, including fire connections, **whether active or inactive**. This may differ substantially from the number of customers (or number of accounts). **Note: this number does not include the pipeline leads to fire hydrants. The total length of piping supplying fire hydrants should be included in the "Length of mains" input, and excluded from the Number of service connections input.**
Real Losses Find	Physical water losses from the pressurized system (water mains and customer service connections) 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	Those components of System Input Volume that are billed and have the potential to produce revenue.
Service Connection Density Find	=number of customer service connections / length of mains
Systematic Data Handling Errors (SDHE) Find	Apparent losses caused by accounting omissions, errant computer programming, gaps in policy, procedure, and permitting/activation of new accounts; and any type of data lapse that results in under-stated customer water consumption in summary billing reports. **Systematic Data Handling Errors occur as a customer consumption volume and can result in a direct loss of revenue potential. Water utilities can find "lost" revenue by keying on this component.** Utilities typically measure water consumption volumes registered by water meters at customer premises. The meter should be read routinely (ex: monthly) and the data transferred to the Customer Billing System, which generates and sends a bill to the customer. Data Transfer Errors result in the registered consumption volume value being less than the actual consumption volume, creating an apparent loss. Such error might occur from illegible and mis-recorded hand-written readings compiled by meter readers, inputting an incorrect meter register unit conversion factor in the automatic meter reading equipment, or a variety of similar errors. Apparent losses also occur from Data Analysis Errors in the archival and data reporting processes of the Customer Billing System. Inaccurate estimates used for accounts that fail to produce a meter reading are a common source of error. Billing adjustments may award customers a rightful monetary credit, but do so by creating a negative value of consumption volume, thus under-stating the actual consumption. Account activation lapses may allow new buildings to begin using water for months without meter readings and billing. Poor permitting and construction inspection practices can result in a new building water service commencing without a billing account, a water meter and meter reading; i.e., the customer is unknown to the utility's billing system. Close auditing of the permitting, metering, meter reading, billing and reporting processes of the water consumption data trail can uncover data management gaps that create volumes of systematic data handling error. Utilities should routinely analyze customer billing records to detect data anomalies and quantify these losses. For example, a billing account that registers zero consumption for two or more billing cycles should be checked to explain why usage has seemingly halted. Given the revenue loss impacts of these losses, water utilities are well-justified in providing continuous oversight and timely correction of data transfer errors & data handling errors. If the water auditor has not yet gathered detailed data or assessment of systematic data handling error, it is recommended that the auditor apply the default value of 0.25% of the Billed Authorized Consumption volume. However, if the auditor has investigated the billing system and its controls, and has well validated data that indicates the volume from systematic data handling error is substantially higher or lower than that generated by the default value, then the auditor should enter a quantity that was derived from the utility investigations and select an appropriate grading. Negative or zero values are not allowed for this audit component. Note: occasionally billed consumption volumes for a customer account may be over-stated due to issues of double-counting an account or applying an over-stated meter multiplier. The possibility of such occurrences should be explored in the data validation process, particularly if billed authorized consumption volumes for the year, or for any sub-group of customers (by classification or meter size), appears to be inordinately high. It is recommended to correct any
Total annual operating cost (optional input) Find	*This input has been made optional, as it is no longer used in calculating a Performance Indicator. Auditors are welcome to continue to track this input as desired.* These costs include those for operations, maintenance and any annually incurred costs for long-term upkeep of the drinking water supply and distribution system. It should include the costs of day-to-day upkeep and long-term financing 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. Depending upon water utility accounting procedures or regulatory agency requirements, it may be appropriate to include depreciation in the total of this cost. This cost should not include any costs to operate wastewater, biosolids or other systems outside of drinking water.

Item Name	Description
Unauthorized Consumption (UC) Find	Includes water illegally withdrawn from fire hydrants, illegal connections, bypasses to customer consumption meters, or tampering with metering or meter reading equipment; as well as any other ways to receive water while thwarting the water utility's ability to collect revenue for the water. Unauthorized consumption results in uncaptured revenue and creates an error that understates customer consumption. In most water utilities this volume is low and, if the water auditor has not yet gathered detailed data for these loss occurrences, it is recommended to use the default value of 0.25% of the Billed Authorized Consumption volume. However, if the auditor has investigated unauthorized occurrences, and has well validated data that indicates the volume from unauthorized consumption is substantially higher or lower than that generated by the default value, then the auditor should enter a quantity that was derived from the utility investigations. Note that a value of zero will not be accepted since all water utilities tend to have some volume of unauthorized consumption occurring in their system.
Unavoidable Annual Real Losses (UARL) Find	The UARL is a theoretical reference value representing the technical low limit of leakage for well managed systems in good condition, with aggressive active leakage control. It is a key variable in the calculation of the Infrastructure Leakage Index (ILI). UARL (gallons) = (5.41Lm + 0.15Nc + 7.5Lc) x P x 365 d/year, or UARL (litres) = (18.0Lm + 0.8Nc + 25.0Lc) x P x 365 d/year where: Lm = length of mains (miles or kilometres) Nc = number of customer service connections Lp = the average length of customer service connection piping (feet or metres) (see the Worksheet "Service Connection Diagram" for guidance on deterring the value of Lp) Lc = total length of customer service connection piping (miles or km) Lc = Nc X Lp (miles or kilometres) P = Average operating pressure (psi or metres) (see Average Operating Pressure definition) **NOTES ON THE UARL AND ILI:** 1. This Free Water Audit Software version 6 presents the calculated UARL and ILI for systems of all sizes and all pressures. Some published research is now available on predicting how UARL is likely to be modified when modeling low leakage limits in systems that are very small (< 3000 conn), or have very low average pressures, or have very high pressures (aka boundary cases). Inherent over- or under- estimation of UARL volume may exist in these boundary cases, as they operate at or near the limits of the UARL model assumptions. More widespread application and understanding of system specific corrections to the UARL model in these boundary cases is now likely to occur, but are not included in the FWAS at the time of this publication. Caution is advised when using the standard UARL modeled value (and subsequently the ILI) for boundary cases. In boundary cases, the ILI may still be considered a general Performance Indicator, but not used as an absolute performance measurement or for benchmark comparisons. 2. The UARL term is based on average operating pressure in a given audit year, and a utility's current pressure conditions may not be optimized. Thus, ILI should always be interpreted with some measure of pressure, and only used for tracking progress if all justifiable pressure management has already been completed.
Unbilled Authorized Consumption	All consumption that is unbilled, but still authorized by the utility. This includes Unbilled Metered Authorized Consumption (UMAC) + Unbilled Unmetered Authorized Consumption (UUAC). See "Authorized Consumption" for more information.
Unbilled Metered Authorized Consumption (UMAC) Find	Metered consumption which is authorized by the water utility, but, for any reason, is deemed by utility policy to be unbilled. This might for example include metered water consumed by the utility itself in treatment or distribution operations, or metered water provided to civic institutions free of charge. **It does not include water supplied to neighboring utilities (water exported) which may be metered but not billed.**
Unbilled Unmetered Authorized Consumption (UUAC) Find	Any kind of Authorized Consumption which is neither billed nor metered. This component typically includes water used in activities such as fire fighting, flushing of water mains and sewers, street cleaning, fire flow tests conducted by the water utility, etc. In most water utilities it is a small component. This component does NOT include water supplied to neighboring utilities (water exported) which is unmetered and unbilled – an unlikely case. Also, if any potable water used at a water treatment plant is tapped from a location upstream of the meter(s) used to determine the Volume from Own Sources in the audit, this is outside of the boundary of the audit and should therefore not be included as part of Unbilled, Unmetered Authorized Consumption. This component has many sub-components of water use which may not yet be quantified. The default is 0.25% of the Billed Authorized Consumption volume (BMAC + BUAC), and is recommended for temporary use if customized estimates are not yet available, with recommendation to begin tracking and estimating these volumes for the next audit. Note that a value of zero is not permitted, since all water utilities likely have some volume of water in this component occurring in their system.
Units and Conversions	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):

Enter Units:	Convert From…		Converts to…..	
100	**Million Gallons (US)**	=	**306.888329**	**Acre-feet**

Item Name	Description
	(conversion factor = 3.0689)
Variable Production Cost (VPC) (applied to Real Losses) Find	The cost to produce and supply the next unit of water (e.g., $/million gallons). This cost can include both short-run and long-run marginal costs. See the VPC data grading questions on IDG tab for examples of short-run and long-run marginal costs that may be included. It is common to apply the VPC unit cost to the volume of Real Losses. However, if water resources are strained and the ability to meet future drinking water demands is in question, then the water auditor may be justified in applying the Customer Retail Unit Charge to the Real Loss volume, rather than applying the Variable Production Cost.
Volume from Own Sources (VOS) Find	The volume of water withdrawn (abstracted) from water resources (rivers, lakes, streams, wells, etc) controlled by the water utility, and then treated for potable water distribution. Most water audits are compiled for utility retail water distribution systems, so this volume should reflect the amount of treated drinking water that entered the distribution system. Often the volume of water measured as treated effluent of the treatment works is slightly less than the volume measured at the raw water source, since some of the water is used in the treatment process. Thus, it is useful if flows are metered at the effluent of the treatment works. Water treatment plants are also often supplied potable drinking water and therefore are a "customer" of the water utility. If the service connection line serving the water treatment plant is downstream of treated water effluent flowmeters, this water should be metered and billed as billed authorized consumption. In this case, this volume of water does not enter into any calculations for Volume from Own Sources. If the service connection line suppling potable water to the treatment plant is upstream of treated water effluent flowmeters, then this water is considered "process" water and included with calculations accounting for process water use. If metering exists only at the raw water source, an adjustment for water used in the treatment process should be included to account for water consumed in treatment operations such as filter backwashing, basin flushing and cleaning, plant potable water consumption (if the supply is drawn upstream of effluent flowmetering.) and similar uses. If the audit is conducted for a wholesale water agency that sells untreated water, then this quantity reflects the measure of the raw water, typically metered at the source.
Volume from own sources: error adjustment Find	An estimate or measure of the degree of inaccuracy that exists in the master (production) meters measuring the annual Volume from own Sources, and any error in the data trail that exists to collect, store and report the summary production data. This adjustment is a weighted average number that represents the collective error for all master meters for all days of the audit year and any errors identified in the data trail. Meter error can occur in different ways. A meter or meters may be inaccurate by under-registering flow (did not capture all the flow), or by over-registering flow (overstated the actual flow). Data error can occur due to data gaps caused by temporary outages of the meter or related instrumentation. All water utilities encounter some degree of inaccuracy in master meters and data errors in archival systems are common. Enter a positive percentage or volume, then select 'under-registration' or 'over-registration' from the drop-down immediately adjacent. **See Water Supplied Error Adjustments definition for guidance on how to calculate this input.**
Water Exported (WE) Find	The Water Exported volume is the bulk water conveyed or sold by the water utility to neighboring water systems that exists outside of their service area. Typically this water is metered at the custody transfer point of interconnection between the two water utilities. Usually the meter(s) are owned by the water utility that is selling or transfering the water: i.e. the exporter. If the water utility who is compiling the annual water audit sells or transfers bulk water in this manner, they are an exporter of water. Note: The Water Exported volume is typically sold to wholesale customers who are charged a wholesale rate that is different than retail rates charged to the retail customers existing within the service area. Many state regulatory agencies require that the Water Exported volume be reported to them as a quantity separate and distinct from the retail customer billed consumption. For these reasons - and others - the Water Exported volume is always quantified separately from Billed Authorized Consumption in the standard water audit. **Be certain not to "double-count" this quantity by including it in both the Water Exported box and the Billed Metered Consumption box of the water audit Worksheet. This volume should be included only in the Water Exported box.**
Water Exported: Error Adjustment (WEEA) Find	An estimate or measure of the volume by which the Water Exported volume is incorrect. This adjustment is a weighted average that represents the collective error for all of the metered and archived exported flow for all days of the audit year. Meter error can occur in different ways. A meter may be inaccurate by under-registering flow (did not capture all the flow), or by over-registering flow (overstated the actual flow). Error in the metered, archived data can also occur due to data gaps caused by temporary outages of the meter or related instrumentation. All water utilities encounter some degree of error in their metered data, particularly if meters are aged and infrequently tested. Occasional errors also occur in the archived data. Enter a positive percentage or volume, then select 'under-registration' or 'over-registration' from the drop-down immediately adjacent. If regular meter accuracy testing is conducted on the meter(s) - which is usually conducted by the water utility selling the water - then the results of this testing can be used to help quantify the meter error adjustment. Corrections to data gaps or other errors found in the archived data should also be included as a portion of this meter error adjustment. **See Water Supplied Error Adjustments definition for guidance on how to calculate this input.**
Water Imported (WI) Find	The Water Imported volume is the bulk water purchased to become part of the Water Supplied volume. Typically this is water purchased from a neighboring water utility or regional water wholesale supplier, and is metered at the custody transfer point of interconnection between the two water utilities. Usually the meter(s) are owned by the water supplier selling the water to the utility conducting the water audit. The water supplier selling the bulk water usually charges the receiving utility based upon a wholesale water rate.
Water Imported: Error Adjustment (WIEA) Find	An estimate or measure of the volume by which the Water Imported volume is incorrect. This adjustment is a weighted average that represents the collective error for all of the metered and archived imported flow for all days of the audit year. Meter error can occur in different ways. A meter may be inaccurate by under-registering flow (did not capture all the flow), or by over-registering flow (overstated the actual flow). Error in the metered, archived data can also occur due to data gaps caused by temporary outages of the meter or related instrumentation. All water utilities encounter some level of meter inaccuracy, particularly if meters are aged and infrequently tested. Occasional errors also occur in the archived metered data. Enter a positive percentage or volume, then select 'under-registration' or 'over-registration' from the drop-down immediately adjacent. If regular meter accuracy testing is conducted on the meter(s) - which is usually conducted by the water utility selling the water - then the results of this testing can be used to help quantify the meter error adjustment. **See Water Supplied Error Adjustments definition for guidance on how to calculate this input.**

Item Name	Description
Water Supplied Error Adjustments Find	**Disclaimer**: The guidance provided below should be considered general, representing a typical approach to determining Error Adjustment. Supply metering setups, metering technologies, instrumentation, data recording/archival, and data management systems can vary significantly from one water utility to the next. Inherent margins of error will also vary among different testing and calibration methods and the measurement systems being tested. Other factors that may be important include, but are not limited to, frequency of testing and calibration practices, data communication outages in the audit period, tested flowrates versus typical operating flowrates, and test durations. All of these factors must be considered when assessing Error Adjustment for the Water Supplied inputs. Each specific situation should be carefully analyzed to determine the most appropriate approach for determining the Error Adjustment to input, if any. **General**: For the Water Supplied inputs, there are three typical sources of error that may warrant an Error Adjustment on the Worksheet. 1. **Meter error:** measurement inaccuracy in the meter(s) used to derive the input volume, typically identified through in-situ flow accuracy testing. Applicable for VOS, WI and WE. If no such testing has been performed, adjustment for meter error is not typically recommended. 2. **Data transfer error**: inaccuracy in archived volumes, typically due to gaps in data, programming errors impacting unit conversions, and/or programming errors impacting totalization of measured volumes over the audit period. Applicable for VOS, WI and WE. These errors are typically identified through electronic calibration to verify data transfer at the secondary device (i.e. conversion to mA, meter transmitter or similar instrumentation) and/or the tertiary device (i.e. SCADA, historian or other computerized archival system). 3. **Net distribution storage change**: The difference between end of audit period and beginning of audit period for total finished water stored, downstream of the system input meter(s). Typically applicable for VOS or WI. This volume is typically derived by comparing distribution storage tank water levels at end and beginning of the water audit period and using approximate tank geometry to convert levels to volumes. **Derivation Guidance**: If an Error Adjustment input is being calculated as a volume, each source of error (described above) may be separately calculated, with careful consideration of under- vs over-registration, then added together to determine the composite volume to input. The composite input should be entered on the Worksheet as a positive number, then under- or over-registration selected on the adjacent dropdown. If an Error Adjustment input is being calculated as a percent, some very general guidance for calculating each error source (described above) is provided below. The auditor is again cautioned that each specific water supply setup needs to be evaluated closely as noted in the Disclaimer. Refer to the latest AWWA M36 Manual for additional discussion and guidance on this matter. 1. Meter error: If in-situ flow accuracy testing has been performed, and inherent testing method error is understood, first the *meter accuracy %* may be determined as follows: *meter accuracy % = System input meter(s) volume / Reference volume* Then, the *meter error %* may be determined as follows: *meter error % = meter accuracy % - 100%* 2. Data transfer error: If electronic calibration at the secondary (i.e. conversion to mA, meter transmitter or similar instrumentation) and/or tertiary (i.e. SCADA, historian or other computerized archival system) devices has been performed, first the *data transfer accuracy %* may be determined as follows: *data transfer accuracy % = Tertiary device volume / Reference volume (typically at Secondary device)* Then, the *data transfer error %* may be determined as follows: *data transfer error % = data transfer accuracy % - 100%* If no error is identified, or if electronic calibration has not been performed, or if no secondary or tertiary devices exist, a *data transfer error %* adjustment is not typically recommended. 3. Net distribution storage change. If meter error and/or data transfer error are being calculated as a %, it is recommended to make the adjustment for net distribution storage change as a volume adjustment, directly in the VOS or WI input, as applicable. The final step is to add *meter error %* and *data transfer error %:* *Error Adjustment % = meter accuracy % + data transfer error %* If the total Error Adjustment % calculates out as a negative number, it represents an under-registration. Vice versa, if positive. The composite input should be entered on the Worksheet as a positive number, then under- or over-registration selected on the adjacent dropdown.
WATER LOSSES Find	= apparent losses + real losses = water supplied - authorized consumption Water Losses are the difference between Water Supplied and Authorized Consumption. Water losses can be considered as a total volume for the whole system, or for partial systems such as transmission systems, pressure zones or district metered areas (DMA), if one of these configurations are the basis of the water audit.

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.

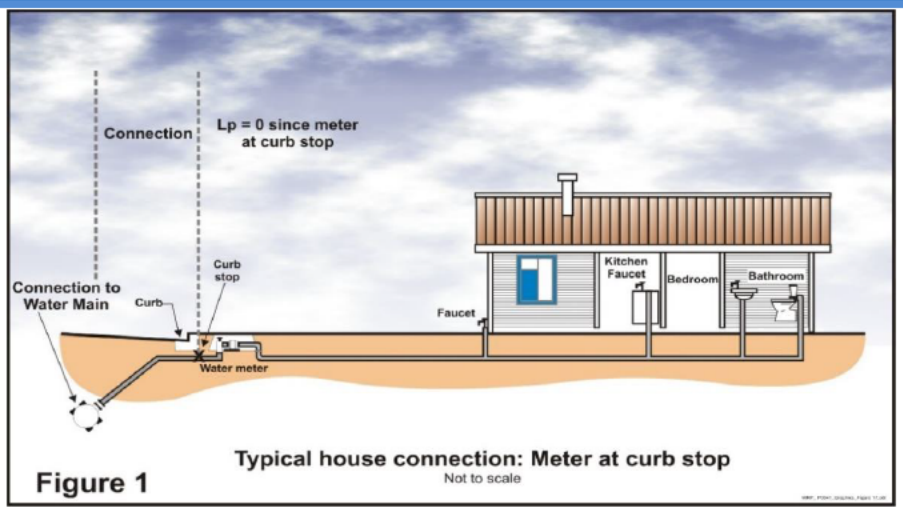
Figure 1 shows the configuration of the water meter outside of the customer building next to the curb stop valve. In this configuration Lp = 0 since the distance between the curb stop and the customer metering point is essentially zero.

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

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

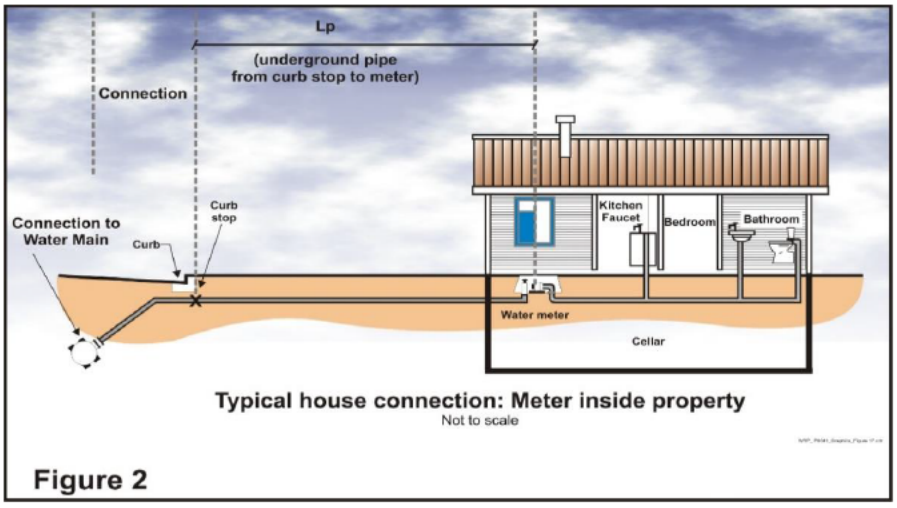
In any water system the Lp will vary notably in a community of different structures, therefore the average Lp value is used and this should be approximated or calculated if a sample of service line measurements has been gathered.

Click for more information



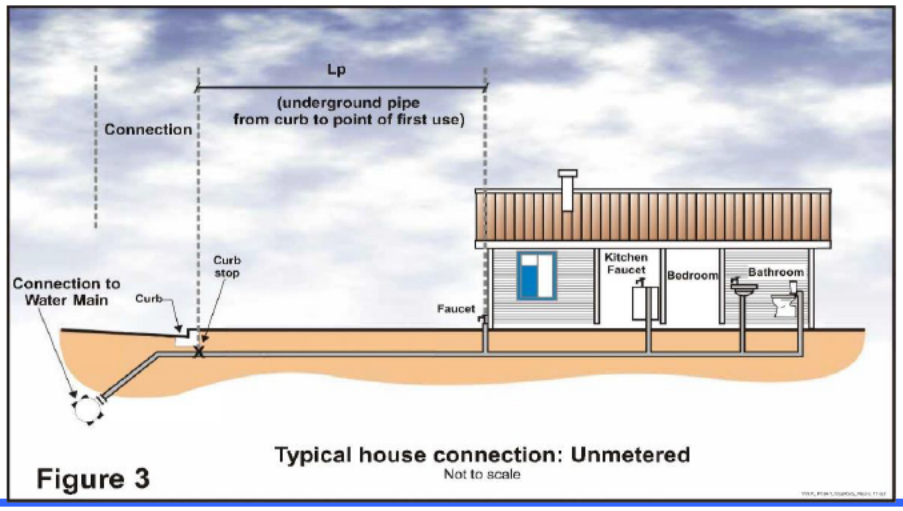
Typical house connection: Meter at curb stop
Not to scale

Figure 1



Typical house connection: Meter inside property
Not to scale

Figure 2



Typical house connection: Unmetered
Not to scale

Figure 3

American Water Works Association
Dedicated to the World's Most Important Resource®

AWWA Free Water Audit Software - Version 6.0
developed by the
Water Loss Control Committee of the American Water Works Association
December 2020

World Water Loss Day
4th December

This software is intended to serve as a basic tool to compile a preliminary, or "top-down", water audit. It is recommended that users also refer to the current edition of the AWWA M36 Publication, Water Audits and Loss Control Programs, for detailed guidance on compiling a comprehensive, or "bottom-up", water audit using the same water audit methodology.

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A special thanks to those members of the AWWA Water Loss Control Committee and other water industry stakeholders who assisted in the review and testing of this software.

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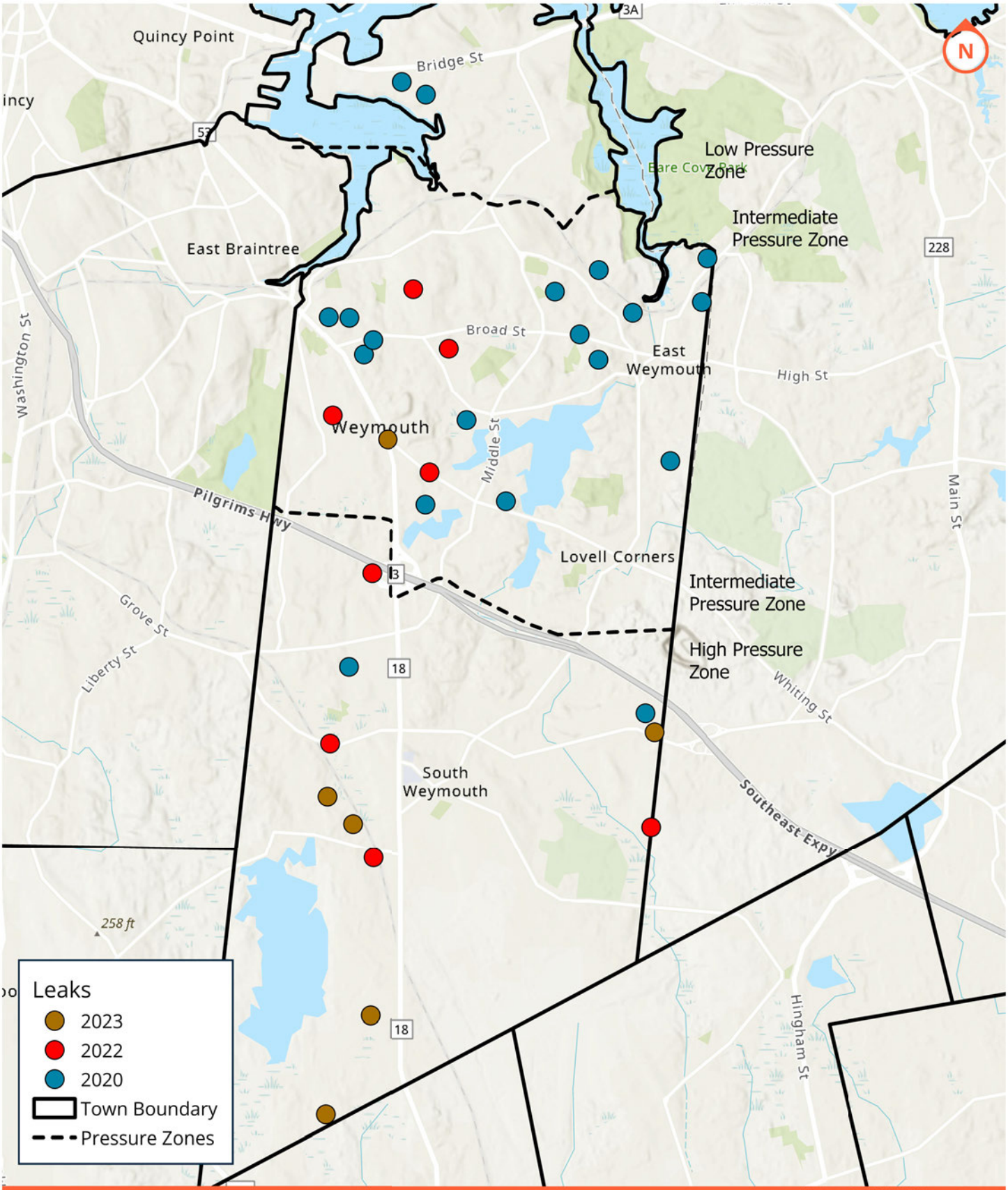
VERSION HISTORY:

Version:	Release Date:	Number of Worksheets:	Key Features and Developments
v1	2005/ 2006	5	The AWWA Water Audit Software was piloted in 2005 (v1.0 beta). The early versions (1.x) of the software restricted data entry to units of Million Gallons per year. For each entry into the audit, users identified whether the input was measured or estimated.
v2	2006	5	The most significant enhancement in v2 of the software was to allow the user to choose the volumetric units to be used in the audit, Million Gallons or Thousand Cubic Metres (megalitres) per year. Two financial performance indicators were added to provide feedback to the user on the cost of Real and Apparent losses.
v3	2007	7	In v3, the option to report volumetric units in acre-feet was added. Another new feature in v3 was the inclusion of default values for two water audit components (unbilled unmetered and unauthorized consumption). v3 also included two examples of completed audits in units of million gallons and Megalitres. Several checks were added into v3 to provide instant feedback to the user on common data entry problems, in order to help the user complete an accurate water audit.
v4 - v4.2	2010	10	v4 (and versions 4.x) of the software included a new approach to data grading. The simple "estimated" or "measured" approach was replaced with a more granular scale (typically 1-10) that reflected descriptions of utility practices and served to describe the confidence and accuracy of the input data. Each input value had a corresponding scale fully described in the Grading Matrix tab. The Grading Matrix also showed the actions required to move to a higher grading score. Grading descriptions were available on the Reporting Worksheet via a pop-up box next to each water audit input. A water audit data validity score is generated (max = 100) and priority areas for attention (to improve audit accuracy) are identified, once a user completes the requied data grading. A service connection diagram was also added to help users understand the impact of customer service line configurations on water losses and how this information should be entered into the water audit software. An acknoweldgements section was also added. Minor bug fixes resulted in the release of versions 4.1 and 4.2. A French language version was also made available for v4.2.
v5	2014	12	In v5, changes were made to the way Water Supplied information is entered into software, with each major component having a corresponding Master Meter Error Adjustment entry (and data grading requirement). This required changes to the data validity score calculation; v5 of the software uses a weighting system that is, in part, proportional to the volume of input components. The Grading Matrix was updated to reflect the new audit inputs and also to include clarifications and additions to the scale descriptions. The appearance of the software was updated in v5 to make the software more user-friendly and several new features were added to provide more feedback to the user. Notably, a dashboard tab has been added to provide more visual feedback on the water audit results and associated costs of Non-Revenue Water. A comments sheet was added to allow the user to track notes, comments and to cite sources used.
v6	2020	11	v6 brings an overhaul to the user interface for data grading, now presented as a series of questions on the Interactive Data Grading (IDG) tab for each input that, when answered (by selecting best-fit answer from a dropdown menu), automically determines the data grade for the given input. This provides transparency to the data practices selected and which specifically are limiting, removes subjectivity in data grade assignments, and provides clarity on candidate next steps for data validity improvements. IDG tab includes navigation buttons across top banner for ease of movement between inputs, and color signals for completion. The Worksheet (fka Reporting Worksheet) includes overt designation of error adjustment as "under" or "over" for the 3 Water Supplied inputs, as well as Customer Metering Inaccuracies. This makes the convention consistent, transparent, and reduces chance of user error. A Blank Sheet has been added allowing the user to, as desired, perform supplemental calculations or capture additional relevant information. The Dashboard has been overhauled to include Data Validity, NRW Components and Key Performance Indicators (KPIs). KPIs are presented in gauge format, depicting the specific KPI result against the range of results from Level 1 validated data in North America (see Web Resources, Start Page). Percentage-based indicators (% of supply, % of cost) removed as these indicators were deemed unreliable and sunset by the AWWA Water Loss Control Committee, subsequent to research and reporting from its NRW Performance Indicators Task Force.

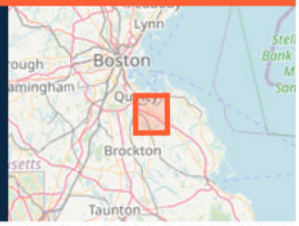
If you have questions or comments regarding the software please contact us via email at: wlc@awwa.org



ENVIRONMENTAL PARTNERS
— An Apex Company —

Figure 1:
Leak Map
Weymouth, Massachusetts
December 2023

0 5,100 10,200 20,400 Feet



\\apexcos.local\Offices\Quincy\Projects\Weymouth.144\Water System\WEY003-0632071-22010424 MWRA Entrance Permitting\Background\Weymouth Documents\Leak Detection\GIS

Disclaimer: This map is intended for planning purposes