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Level 1 Water Audit Validation Guidance Manual

Second Edition



Level 1 Water Audit Validation Guidance Manual

Project 5057

Second Edition

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Contents

Acknowledgments	3
Tables	6
Figures	6
Acronyms and Abbreviations	7
What's New in the Second Edition	9
Overview	11
What Is a Water Audit?	11
What Is Water Audit Validation?	11
What Is Water Loss Control?	12
About This Manual.....	13
Chapter 1: What Is a Water Audit?	15
Why Should I Perform a Water Audit?	15
What Tools Can Assist Me in Preparing a Water Audit?	15
AWWA Manual M36: Water Audits and Water Loss Control Programs	16
AWWA Free Water Audit Software	16
AWWA Compiler Software	16
WRF Leakage Component Analysis Model	16
Chapter 2: How Does Data Quality Affect a Water Audit?	19
What Factors Influence Data Quality?	19
Primary Measurement of Raw Data	19
Secondary Data Transfer and Tertiary Summary of Primary Measurements	20
Human Interaction with Data and Methodology, Including Estimation	20
How Does the AWWA Software Assess Data Quality?	20
Chapter 3: What Is New in AWWA Water Audit Software v6?	23
Interface	23
Methodology	23
Data Validity	24
Chapter 4: What Is Water Audit Validation?	27
What Are the Levels of Water Audit Validation?	27
Who Should Validate Water Audits?	28
Chapter 5: What Defines Level 1 Water Audit Validation?	29
What Does Level 1 Water Audit Validation Do?.....	29
What Does Level 1 Water Audit Validation Not Do?	29
How Has Level 1 Validation Impacted Audits in North America?	30
What Is the State of Level 1 Validation Certification Programs in North America?	31
Chapter 6: How Do I Perform Level 1 Validation?	33
Step 1: Receive and Review the Water Audit and supporting Documentation	33
Step 2: Examine Performance Indicators for Evidence of Inaccuracy	34
Unit Apparent Losses.....	35
Unit Real Losses	35

Infrastructure Leakage Index.....	35
Summary.....	36
Step 3: Conduct the Validation Interview	37
Volume from Own Sources — VOS	39
Volume from Own Sources Error Adjustment — VOSEA	42
Water Imported — WI.....	44
Water Imported Error Adjustment — WIEA	47
Water Exported — WE	48
Water Exported Error Adjustment — WEEA	51
Billed Metered Authorized Consumption — BMAC	51
Billed Unmetered Authorized Consumption — BUAC	53
Unbilled Metered Authorized Consumption — UMAC	54
Unbilled Unmetered Authorized Consumption — UUAC.....	56
Systematic Data Handling Errors — SDHE.....	58
Customer Meter Inaccuracy — CMI	59
Unauthorized Consumption — UC	60
Length of Mains — Lm.....	61
Number of Service Connections — Nc	62
Average Length of (Private) Customer Service Line — Lp.....	63
Average Operating Pressure — AOP	64
Total Annual Operating Cost — TAOC.....	65
Customer Retail Unit Cost — CRUC.....	65
Variable Production Cost — VPC.....	66
Step 4: Re-examine Performance Indicators.....	68
Step 5: Document Results	69
Chapter 7: What Are Advanced Validation Options?	71
What Are Examples of Level 2 Water Audit Validation?	71
What Are Examples of Level 3 Water Audit Validation?	72
What Should I Do after Validating My Water Audit?	72
Appendix A: Level 1 Validation Checklist	73
References and Resources.....	77

Tables

Table 1: Default Values in AWWA Software v5 and v6	24
Table 2: Levels of Water Audit Validation	28
Table 3: Performance Indicators to Check for Inaccuracy.....	37
Table 4: Example Supporting Documentation for VOS of System Shown in Figure 10.....	39
Table 5: Example Supporting Documentation for Annual Net Changes in Storage as Shown in Figure 11	40
Table 6: Example Supporting Documentation of VOSEA Calculated as A Volume.....	43
Table 7: Example Supporting Documentation of VOSEA Calculated as a Weighted Average.....	43
Table 8: Example Supporting Documentation for WI of System Shown in Figure 12	45
Table 9: Example Supporting Documentation for WE of System Shown in Figure 13	48
Table 10: Example Supporting Documentation for BMAC	52
Table 11: Example Supporting Documentation for BUAC.....	53
Table 12: Example Supporting Documentation for UMAC.....	55
Table 13: Example Supporting Documentation for UUAC	56
Table 14: Example Supporting Documentation of CMI Calculated as a Weighted Average	59
Table 15: Example Supporting Documentation for Lm	62
Table 16: Example Supporting Documentation for Nc.....	63
Table 17: Example Supporting Documentation for CRUC	65
Table 18: Example Supporting Documentation for VPC.....	66
Table 19: Performance Indicators to Check for Inaccuracy.....	69

Figures

Figure 1: Screenshot of AWWA Free Water Audit Software v6	16
Figure 2: Screenshot of WRF Leakage Component Analysis Model.....	16
Figure 3: Screenshot of the Water Loss Control Planning Guide Featured in AWWA Software v6	22
Figure 4: Publication Timeline of the AWWA Free Water Audit Software.....	23
Figure 5: Screenshot of Worksheet in AWWA Software v6	24
Figure 6: Screenshot of the Interactive Data Grading (IDG) Feature in AWWA Software v6	25
Figure 7: 14 States/Provinces Either Require Level 1 Validation prior to Audit Submission or Feature Level 1 Validation Training (Quebec, Canada Not Illustrated).....	30
Figure 8: Level 1 Validation Certification Programs in North America.....	31
Figure 9: Example Water Audit Boundary	38
Figure 10: Example Water Audit Boundary with Respect to Volume from Own Sources (VOS)	40
Figure 11: Example System with Distribution Storage	41
Figure 12: Example Water Audit Boundary with Respect to Water Imported (WI).....	45
Figure 13: Example Water Audit Boundary with Respect to Water Exported (WE)	49
Figure 14: Example System with Unbilled Metered Authorized Consumption.....	55

Acronyms and Abbreviations

AF	Acre-Feet
AMI	Advanced Metering Infrastructure
AMR	Automated Meter Reading
AOP	Average Operating Pressure
AWWA	American Water Works Association
AWWA Software	American Water Works Association Free Water Audit Software Version 6
BMAC	Billed Metered Authorized Consumption
BUAC	Billed Unmetered Authorized Consumption
CF	Cubic Feet
CCF	100 Cubic Feet
CMI	Customer Metering Inaccuracies
CPA	Certified Public Accountant
CRUC	Customer Retail Unit Charge
CY	Calendar Year
DVG	Data Validity Grade
DVS	Data Validity Score
DVT	Data Validity Tier
FY	Fiscal Year
gal	gallon(s)
GIS	Geographic Information Systems
ILI	Infrastructure Leakage Index
IDG	Interactive Data Grading*
KPI	Key Performance Indicator
Lm	Length of mains
Lp	Average length of (private) customer service line
mA	Milliamp
MG	Million Gallon(s)
MMEA	Master Meter and Supply Error Adjustment
Nc	Number of service connections
NRW	Non-Revenue Water
PSI	pounds per square inch
SCADA	Supervisory Control and Data Acquisition
SDHE	Systematic Data Handling Errors
TAOC	Total Annual Operating Cost
UARL	Unavoidable Annual Real Losses
UC	Unauthorized Consumption
UARL	Unavoidable Real Losses
UMAC	Unbilled Metered Authorized Consumption
UUAC	Unbilled Unmetered Authorized Consumption
VOS	Volume from Own Sources
VOSEA	VOS Error Adjustment
VPC	Variable Production Cost
WE	Water Exported
WEEA	WE Error Adjustment
WI	Water Imported

WIEA	WI Error Adjustment
WLCC	American Water Works Association Water Loss Control Committee
WRF	Water Research Foundation

***Interactive Data Grading (IDG) Question Acronyms**

The new IDG featured in AWWA Free Water Audit Software Version 6 (AWWA Software) uses unique labels to refer to individual data grading criteria questions. Each label is composed of the relevant audit input acronym, a period, and a sequential number. For example, the first question in the Volume from Own Sources (VOS) section of the IDG is labeled “vos.0.”

What's New in the Second Edition

The Water Research Foundation (WRF) published the first edition of the *Level 1 Water Audit Validation: Guidance Manual* in 2016 (Andrews et al. 2016) to provide assistance for audits prepared using version 5 of the American Water Works Association's Free Water Audit Software (AWWA Software v5; Chastain-Howley et al. 2014). Since then, the AWWA Water Loss Control Committee's Software Subcommittee has released version 6 of the AWWA Software (v6; Jernigan et al. 2020), which represents a major evolution of the tool.

The second edition of this manual includes updated content that aligns with the new features of AWWA Software v6. These updates include:

- **New chapter on AWWA Software v6** that describes the major changes from v5 and how they affect the validation process. This manual assumes that the user is validating a water audit completed using the AWWA Software v6.
- **New content related to audit input validation** that emphasizes key points of consideration when reviewing the methodology used to determine specific input values.
- **Examples of supporting documentation** for each audit input to make best practices clear.
- **Updated language** throughout the manual to match AWWA Software v6 and to clarify confusing or ambiguous terminology.
- **Summary of research** related to certification programs and the effect of validation in North America.
- **Revisions based on industry feedback** that was collected from a dedicated advisory group of water loss professionals familiar with the first edition of the manual.

In addition to these updates, the second edition deemphasizes the process of determining data validity grades (DVG) for each audit input. Whereas previous editions of the AWWA Software provided narrative criteria for determining each DVG, v6 introduced an Interactive Data Grading (IDG) feature that simplifies and standardizes this process. As a result, validators will spend less time discussing DVG criteria and more time discussing data completeness, correct application of methodology, and uncertainty related to data validity. More information about IDG is provided in Chapter 3.

Overview

This manual will guide the reader through the process of Level 1 water audit validation using version 6 of the American Water Works Association (AWWA) Free Water Audit Software. It will also highlight the factors that influence water audit data quality and connect you with additional resources related to more advanced levels of validation and water loss auditing and control. The manual was primarily written for validators, but is a useful reference for auditors as well. The best practices for water audit validation can also apply to water audit preparation; however, this manual does not address water audit preparation in complete detail. Instead, it emphasizes key points to consider when assessing whether the correct methodology was used to derive audit input values. Future planned manuals, such as the fifth edition of the AWWA *Manual M36: Water Audits and Loss Control Programs*, will address water audit preparation in complete detail.

Before diving into the details, it is good to understand three fundamental concepts: the AWWA water audit, water audit validation, and water loss control.

What is a water audit?

A water audit accounts for all treated water introduced into a water distribution system and then consumed in order to estimate volumes of water loss. When a utility understands its volumes of water loss, it can act to cost-effectively reduce water loss.

AWWA and the International Water Association (IWA) jointly developed a standard methodology for water auditing used by utilities around the world. The AWWA Free Water Audit Software (AWWA Software) is a digital tool that provides utilities a convenient way to perform a water audit. This manual assumes that the user is validating a water audit completed using the AWWA Software v6.

The water audit is discussed in greater detail in Chapters 1-3.

What is water audit validation?

Water audit validation is the process of examining water audit inputs to improve the water audit's accuracy and document the uncertainty associated with water audit data. There are three levels of validation, which correspond to certain goals, outcomes, and limitations (see Chapter 7 for more details about the levels of validation).

Level 1 validation, which is the focus of this guidance manual, consists primarily of an interview between the person who completes the water audit ("the auditor"), the person who validates the water audit ("the validator"), and any other utility staff who can provide insight into data and operational practices related to the water audit.

According to Sturm et al. (2017), water audit validation is the process of examining water audit inputs in order to:

- Identify and appropriately correct for inaccuracies in water audit data and application of methodology.
- Evaluate and communicate the uncertainty inherent in water audit data.

Without validation, it is possible that estimations of water loss provided by the water audit misrepresent what a utility is actually experiencing. As a result, a water audit that has not been validated can mislead stakeholders, customers, regulators, and utility management in stewarding valuable water and financial resources.

By validating a water audit, you will deepen your understanding of the water distribution system, the data sources available, and the opportunities presented by water loss control.

Water audit validation is discussed in greater detail in Chapters 4-7.

What is water loss control?

This practice of assessing water distribution efficiency, evaluating the economic parameters of water loss management, and then acting to reduce water loss to an economically efficient level is referred to as water loss control. Effective water loss control offers a host of benefits to a water utility, including:

- Water conservation.
- Increased revenue.
- Reduced operating costs.
- Reduced liability.
- Strengthened credibility with stakeholders.
- Improved infrastructure management.
- Improved data accuracy.

A water audit, discussed above, is an effective tool for quantifying water losses and often forms the foundation of water loss control efforts.

About This Manual

This manual has three objectives:

1. Provide step-by-step instruction in Level 1 water audit validation using the AWWA Software v6.
2. Define a standard of care and documentation for Level 1 water audit validation.
3. Highlight the factors that influence water audit data quality and emphasize key points of consideration when assessing if correct methodology was used to determine audit input values.

The manual is organized into the following chapters:

Chapter 1	What is a water audit?
Chapter 2	How does data quality affect a water audit?
Chapter 3	What is new in the AWWA Free Water Audit Software Version 6?
Chapter 4	What is water audit validation?
Chapter 5	What defines Level 1 water audit validation?
Chapter 6	How do I perform Level 1 water audit validation?
Chapter 7	What are advanced validation options?

The first three chapters of the manual focus on defining the water audit, discussing data needs, and exploring some of the tools and resources available. An entire chapter (Chapter 3) is dedicated to highlighting the new features available in AWWA Software v6. The last four chapters focus on defining water audit validation options and describing the step-by-step process of conducting Level 1 validation.

Chapter 1: What Is a Water Audit?

An audit is a systematic examination of records or accounts to confirm their accuracy and ensure the viability of the entity being audited. Audits are common in the world of finance and accounting.

Similar to financial audits, water audits review records and data that trace the flow of water from the point of potable system input, through the distribution system, and to customer delivery. A water audit accounts for all treated water introduced into a water distribution system and then consumed in order to estimate volumes of water loss.

Water auditing is often conducted with a worksheet that tallies annual volumes of potable supply, customer consumption, utility operational use, and water losses. A standard water audit also tracks relevant summary costs and calculates a suite of performance indicators to assess the efficiency of the water utility in supplying drinking water.

The IWA publication, Performance Indicators for Water Supply Services (Alegre et al. 2016), defined the terms and process of the water audit approach discussed in this guidance manual. In North America, AWWA M36 (AWWA 2016) is the adaptation of this work and serves as the authoritative source of terminology for this manual.

In general, a water audit aims to:

- Account for all volumetric inputs and outputs in a distribution system during an audit period to derive volumes of water loss.
- Study the reliability and accuracy of water audit data sources to qualify the potential uncertainty of water audit results.
- Communicate system efficiency with a suite of calculated performance indicators.

Why should I perform a water audit?

Water auditing provides structured accountability to a water utility's operations. Additionally, in performing a water audit, the auditor will:

- Assemble and present information in a standardized format for reliable assessment, tracking, and comparison.
- Provide foundational data and metrics to inform water loss control programs, improve water distribution efficiency, increase revenue, and save water and money.
- Meet regulatory requirements in certain US states and Canadian provinces.
- Improve staff knowledge of utility operations and integration between utility departments.

Water suppliers are stewards of the valuable water resources that they manage, but they must also be fiscally responsible to customers, regulatory agencies, and the stakeholders. Water auditing supports these goals.

What tools can assist me in preparing a water audit?

There are several resources that support water loss control efforts in the drinking water industry. These tools, published by the AWWA and the Water Research Foundation (WRF), promote a standardized, robust approach to water loss assessment and intervention. Because the AWWA and WRF tools are accessible and consistent, a growing number of state, regional, and provincial regulatory agencies have adopted requirements for water auditing that harness these resources.

AWWA Manual M36: Water Audits and Water Loss Control Programs

AWWA promotes water auditing as the best practice for assessing water losses. To facilitate water auditing that follows a standardized methodology, AWWA publishes guidance manual M36: Water Audits and Loss Control Programs. At the time of this manual's publication, the most up-to-date version of M36 is the fourth edition (AWWA 2016). Publication of the fifth edition is expected in 2022.

AWWA Free Water Audit Software

To support utilities in preparing standardized water audits, the Software Subcommittee of the AWWA Water Loss Control Committee (WLCC) created the AWWA Free Water Audit Software (AWWA Software), available for free download from AWWA's website. The AWWA Software is a Microsoft Excel spreadsheet tool that allows users to develop a water balance, access standard definitions, qualify data validity, and calculate performance indicators.

At the time of this manual's publication, the most up-to-date version of the AWWA Software is version 6 (v6). This manual deals specifically with AWWA Software v6, though the philosophy and process of assessing data validity will likely apply to future versions of the Software. Chapter 3 provides more detail on the new features available in v6.

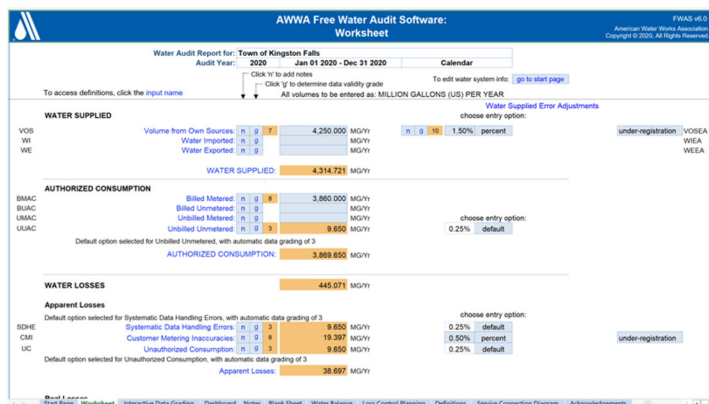


Figure 1: Screenshot of AWWA Free Water Audit Software v6.

Source: Jernigan et al. 2020.

AWWA Compiler Software

The AWWA Software Subcommittee also publishes the Water Audit Compiler (Compiler, AWWA 2014), a Microsoft Excel tool that allows users to assemble multiple water audits in a single database. The Compiler allows benchmarking among utilities and multi-year performance tracking for the same utility. At the time of this manual's publication, the most up-to-date version of the Compiler is v5 and is only compatible with AWWA Software v5. Publication of a v6 Compiler, which will be compatible with AWWA Software v6, is expected in 2021.

WRF Leakage Component Analysis Model

A water audit generates an initial estimate of the total volume of Real Losses, but additional leakage data and analysis are necessary to plan cost-effective Real Loss reduction. To determine the most appropriate interventions against leakage, a utility should complete a Component Analysis of Real Losses after preparing a water audit. A Component Analysis of Real Losses divides the total volume of leakage into distinct types of leakage based on how the leakage can be discovered and reduced.

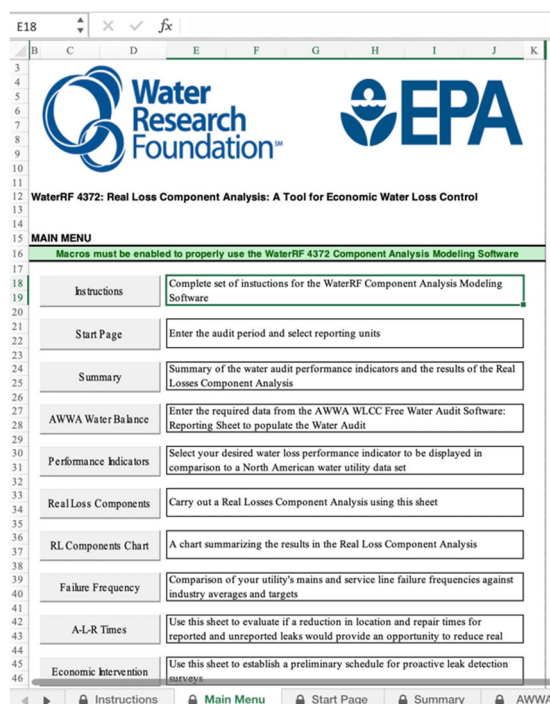


Figure 2: Screenshot of WRF Leakage Component Analysis Model.

Source: Sturm et al. 2014.

WRF offers a free software tool for utilities to conduct a Component Analysis of Real Losses (Sturm et al. 2014). The tool, Leakage Component Analysis software, collates and analyzes leak repair and infrastructure data so that the user can plan cost-effective interventions against leakage. Leakage Component Analysis software can be downloaded from the WRF's project 4372 webpage.

Chapter 2: How Does Data Quality Affect a Water Audit?

The accuracy of each data input directly affects the accuracy of the final water audit. Accurate water audits allow for effective water loss control strategies to be planned. Therefore, it's essential that the quality of data that supports a water audit is examined and understood. By studying the quality of water audit data, a water audit validator will:

- Explore and document uncertainty.
- Minimize inaccuracy.

What factors influence data quality?

To validate water audit data, it's helpful to appreciate how inaccuracy and uncertainty can be introduced into a water audit. Inaccuracy and uncertainty can be introduced into a water audit at three distinct levels of data production (Sturm et al. 2017):

- Primary measurement of raw data.
- Secondary data transfer and summary of primary measurements.
- Human interaction with data and methodology, including estimation.

When validating a water audit, the validator should keep each of these sources of inaccuracy and uncertainty in mind to minimize and document their effects on the overall quality of a water audit.

Primary Measurement of Raw Data

Primary measurements are the raw values recorded by instruments that capture volumes, flow rates, pressure, and other essential facets of utility operations. They form the foundation of a water audit. Inaccuracies in foundational data cumulatively contribute to overall water audit inaccuracy. In the absence of relevant instruments, water audit data can be estimated, as discussed below in the section on human interaction with water audit data.

Careful investigation of the reliability and efficacy of the instruments that produce raw water audit data is necessary to ascertain the accuracy of a water audit.

The validator should consider the factors that influence instrument accuracy, to the extent aligned with the scope of validation. These factors include:

- Maintenance practices.
- Installation conditions.
- Accuracy test practices and results.
- Calibration and programming.
- Measurement resolution.
- Sampling and recording frequency.

To capture inaccuracies in water audit data resulting from instrument performance, Level 2 and/or Level 3 water audit validation (described in Chapter 7) should be performed. Level 1 validation typically will not diagnose inaccuracies due to instrument malfunction.

Secondary Data Transfer and Tertiary Summary of Primary Measurements

Once data has been collected through primary measurement, it is often transferred to permanent data storage. Permanent archival can involve data reformatting and multiple data management systems, which can introduce inaccuracy into the final archived data. Therefore, the validator should study the process of data transfer and storage whenever possible and aligned with the scope of validation.

After data has been archived, inaccuracy and uncertainty can also be introduced when data is accessed and summarized for the purposes of the water audit. Documenting utility operations for an entire year produces many individual data points. As a result, working with a year's worth of data describing a wide range of daily operations can be time intensive. Instead of reckoning with thousands, if not millions, of individual data points, auditors and validators may instead choose to work with summarized datasets. Additionally, because the AWWA Software accepts only a handful of inputs to communicate entire system performance, summary of raw data is necessary.

To condense raw data points into a single descriptive value, an auditor may perform a variety of mathematical operations. Furthermore, the programs and data management systems used to collate water audit data may be programmed to automatically perform mathematical operations in producing an output.

The validator should identify how raw data was selected and summarized to confirm that the summary number in the water audit reflects utility operations as accurately as possible. Potential operations performed include:

- Gain schematic understanding of the data chain from primary measurement to secondary data transfer to permanent archival to retrieval for entry into the water audit.
- Calculating a sum, mean, median, or mode.
- Interpolating or extrapolating.
- Identifying a minimum or maximum.
- Performing a regression.

Whether these operations are performed by the auditor or by data management systems (Supervisory control and data acquisition [SCADA], billing software, geographic information systems [GIS], work order platforms, etc.), it is essential that the data selected for summary is indeed the correct data.

Archival and summarizing functions can introduce inaccuracy or uncertainty into a water audit. To the extent required by the level of validation, it is up to the validator to catch inaccuracy and note the potential for uncertainty introduced by data archival, data management systems, and data summary.

Human Interaction with Data and Methodology, Including Estimation

When conducting a water audit, the auditor may need to choose between multiple sources of data or methodologies to calculate specific audit inputs. During this process, there are many opportunities to introduce human error in data manipulation or interpretation of correct methodology.

To identify potential inaccuracy and uncertainty introduced by the auditor, the validator should note the choices that the auditor made in completing the audit. Where possible and aligned with the scope of validation, the outcomes resulting from other choices should be explored, and alternate data sources should be identified.

How does the AWWA Software assess data quality?

Internationally, water audit data quality has been expressed with a range of techniques, from statistical methods that incorporate confidence intervals to qualitative systems that use alphanumeric scales. In North

America, the AWWA Software is recognized as the standard tool for collecting water audit data and qualitatively communicating the data's quality.

Starting at version 4 in 2010, data validity grades (DVG) were introduced to AWWA Software. In the AWWA Software, each audit input is assigned a DVG on a 1-to-10 scale. For some inputs, a DVG of N/A may also be selected.

- A DVG of 1 indicates lowest validity.
- A DVG of 10 indicates highest validity.

The criteria for assigning a DVG to each input is unique to that input. This acknowledges that the practices that support data integrity for one volume or data point are often distinct from the practices supporting data integrity for a different volume or data point. For example, it is important to maintain supply meter accuracy to accurately calculate the volumes of water supplied, but correctly monitoring and assessing average system pressure requires that attention be paid to pressure models and pressure logging instruments.

In previous versions, the AWWA Software relied on the auditor to interpret a set of narrative criteria outlined in a “Grading Matrix” in order to manually select a DVG. **AWWA Software v6 deemphasizes interpretation of the Grading Matrix and instead prompts the user to answer a series of simplified questions via an “Interactive Data Grading” (IDG) feature that automatically assigns the final DVG** for each input. More information about the IDG and other new features in the AWWA Software v6 are included in Chapter 3.

Once DVGs have been assigned to all water audit inputs, the AWWA Software calculates a composite Data Validity Score (DVS). The DVS reflects the extent to which the water utility employs best practices in collecting, managing, and analyzing water audit data. The DVS is weighted and normalized to 100, with the most weight given to the largest volumes in the water audit.

Lastly, the AWWA Software also includes a Water Loss Control Planning Guide, a table that evaluates the DVS in five ranked Data Validity Tiers (DVT). A DVS falling in a lower DVT prompts a utility to implement practices that promote the collection of more reliable data. A DVS in a higher DVT indicates that water audit data is reliable enough to serve as the basis for water loss intervention planning. Guidance for strategic activities by DVT is included in the AWWA Software (Figure 3).

Water Loss Control Planning Guide					
Functional Focus Area	Water Audit Data Validity Tier (Score Range)				
	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.					

Figure 3: Screenshot of the Water Loss Control Planning Guide featured in AWWA Software v6.

Source: Jernigan et al. 2020.

Chapter 3: What Is New in AWWA Water Audit Software v6?

Version 6 of the AWWA Free Water Audit Software introduced several new features to help auditors complete a comprehensive and accurate water audit. It represents a major evolution in the tool that has continued to grow in complexity and widespread use since its initial release in 2006 (Figure 4).

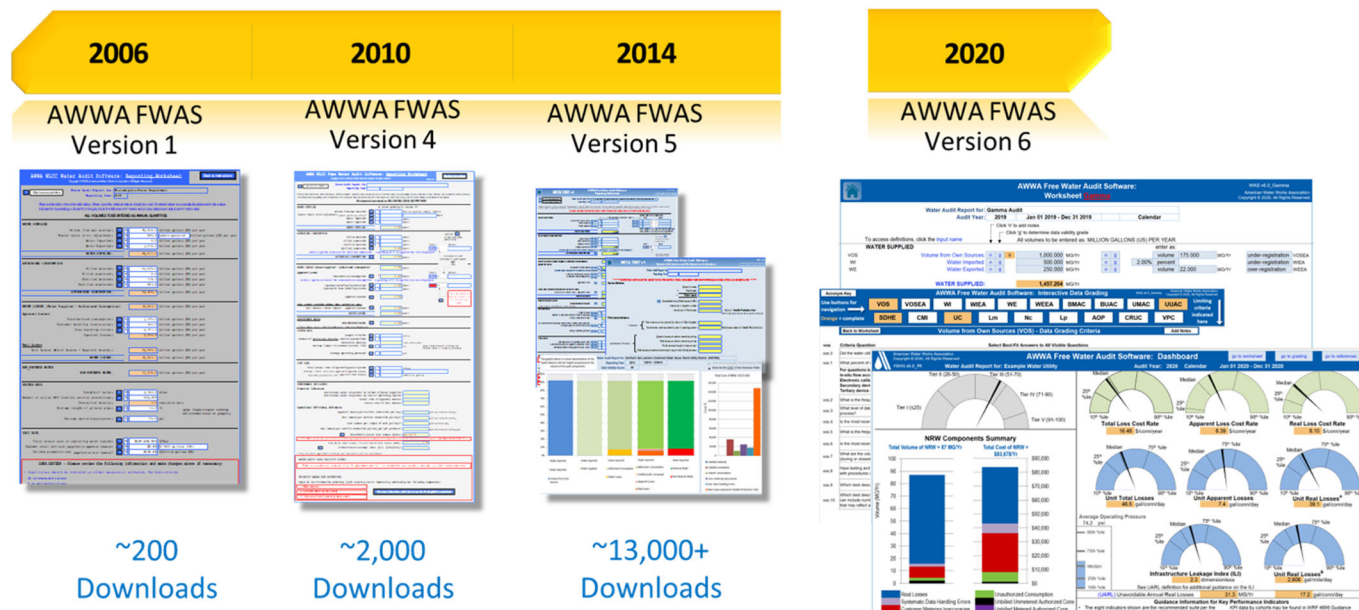


Figure 4: Publication Timeline of the AWWA Free Water Audit Software.

Source: Courtesy of American Water Works Association.

The remainder of this chapter highlights the most important of changes between v5 and v6 and describes how they change the nature of validation. More information about AWWA Software v6 can be found on the AWWA website.

Interface

- **Start Page information:** The Start Page tab prompts the auditor to include more detailed information about their system than in previous versions, including water system structure (e.g., retail, wholesale) and water type (e.g., potable, recycled). Although the AWWA Software can be used to perform audits on non-potable systems, this guidance manual focuses solely on potable systems.
- **Dashboard:** v6 replaces the Performance Indicators tab with a new Dashboard tab that features visualizations of data validity, non-revenue water components, and key performance indicators. More information about key performance indicators in v6 is presented in Chapter 6.

Methodology

- **Water supplied error adjustment specification:** There are three water supplied error adjustment inputs¹ in the AWWA Software that auditors can use to enter adjustments to metered supply volumes based on accuracy testing results that indicate over- or under-registration. In v5, users were required to enter a positive number (either volume or percent) to specify over-registration or a negative number to specify

¹ Volume from Own Sources Error Adjustment (VOSEA), Water Imported Error Adjustment (WIEA), and Water Exported Error Adjustment (WEEA)

under-registration. In v6, users instead always enter a positive number and use a provided drop-down menu to explicitly select over-registration or under-registration (Label A in Figure 5).

- **Customer meter inaccuracy (CMI) specification:** The CMI input is used to enter adjustments to metered consumption volumes based on estimated or calculated inaccuracy. In v5, this input acted in an opposite manner to the water supplied error adjustments: users were required to enter a positive number (representing a volume or percent) to specify under-registration or a negative number to specify over-registration. In v6 this has changed so that users always enter a positive number and use a provided drop-down menu to explicitly select over- or under-registration (Label B in Figure 5).
- **Default values:** Table 1 describes the three audit inputs with default values and how they have changed from v5 to v6. Figure 5 illustrates the location of these inputs in the AWWA Software (Label C). WLCC has learned through statewide validation efforts that the default values needed to be changed to better reflect the volumes as experienced by utilities.

Table 1: Default Values in AWWA Software v5 and v6.

Audit Input	Version 5 Default Value Calculation	Version 6 Default Value Calculation
Unbilled Unmetered (UUAC)	1.25% of Water Supplied	0.25% of Billed Authorized Consumption (BMAC + BUAC) *applies to all three audit inputs
Systematic Data Handling Errors (SDHE)	0.25% of Billed Metered Authorized Consumption (BMAC)	
Unauthorized Consumption (UC)	0.25% of Water Supplied	

Figure 5: Screenshot of Worksheet in AWWA Software v6.

Source: Jernigan et al. 2020.

Data Validity

The mechanism for assigning data validity grades (DVG) in v5 required the user to read a group of narrative criteria spanning gradations from 1 to 10 and make a judgement on the highest data grade where the utility's practices in the audit year met or exceeded all criteria in that grade. This approach brought two key challenges:

- The potential for user subjectivity or error on interpreting the written criteria.
- The lack of visibility as to which of multiple criteria was the limiting criteria for a given input data grade selection.

To address these challenges, v6 introduced two important changes related to data validity:

- **Language clarification:** The data grading criteria for each input were reviewed to identify and refine any language that was deemed potentially subjective. An example of this was refining a descriptor of supply meter testing frequency from “occasional” to “less frequently than annual, but within the last 5 years”.
- **Interactive Data Grading (IDG):** In v6, the data grade for each water audit input is determined not by user assignment, but by an Interactive Data Grading (IDG) process that prompts the auditor with a series of practice-related questions for each input. The user chooses the best-fit answer for each question from a drop-down menu and the software’s algorithm matches the provided answers against the v6 Data Grading Matrix to determine the limiting criteria and resulting DVG for that input (Figure 6). In addition, the answers provided to each criteria question are available as a report output in v6.

The overall DVS, which is calculated as a weighted average of all DVG scores, is automatically calculated and presented in the new Dashboard tab. In v6, there is greater emphasis on what Data Validity Tier (DVT) a utility falls in rather than what exact Data Validity Score (DVS) it achieves.

With the introduction of IDG, the validator will have full visibility on which practices are reported to be applicable, as well as the limiting criteria(on) for data grade selection, prior to the validation interview with the auditor(s). As a result, validators will spend less time discussing DVG criteria and more time discussing data completeness, correct application of methodology, and uncertainty related to data validity. In addition, the validator can more closely review supporting documents and performance indicators. This will further orient the water industry towards increased awareness and adoption of best practices in water auditing and data management as it relates to the water audit. More information about specific IDG questions is provided in Chapter 6.

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	
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 not to tertiary device(s)	Limiting
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?	At least semi-annually	
vos.6	Is the most recent in-situ flow accuracy testing documentation available for review?	No	Limiting
vos.7			
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?	Daily	
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.	More frequently than monthly, but not every day	
FINAL DATA GRADE FOR THIS AUDIT INPUT:		7	

Figure 6: Screenshot of the Interactive Data Grading (IDG) Feature in AWWA Software v6.

Source: Jernigan et al. 2020.

Chapter 4: What Is Water Audit Validation?

Water audit validation is the process of examining water audit inputs to improve the water audit's accuracy and document the uncertainty associated with water audit data. There are three levels of validation, which correspond to certain goals, outcomes, and limitations (see Chapter 7 for more details about the levels of validation).

Water audits are composed of individual data inputs. If water audit data inputs are inaccurate, the water audit results will also be inaccurate. As a result, simply completing a water audit does not guarantee accuracy. As discussed in Chapter 2, primary measurement, secondary data transfer, tertiary data archival and summary, human interpretation of data and methodology, and estimation can introduce inaccuracy and uncertainty into the final water audit. To determine the potential for inaccuracy and uncertainty in a water audit, the audit should be validated.

Level 1 validation, which is the focus of this guidance manual, consists primarily of an interview between the person who completes the water audit ("the auditor"), the person who validates the water audit ("the validator"), and any other utility staff who can provide insight to data and operational practices related to the water audit.

According to Sturm et al. (2017), water audit validation is the process of examining water audit inputs in order to:

- Identify and appropriately correct for inaccuracies in water audit data and application of methodology.
- Evaluate and communicate the uncertainty inherent in water audit data.

Additionally, water audit validation helps ensure that DVGs and the overall DVS reliably represent the operations and practices of the water utility during the audit year.

Without validation, it is possible that estimations of water loss provided by the water audit misrepresent what a utility is actually experiencing. As a result, a water audit that has not been validated can mislead stakeholders, customers, regulators, and utility management in stewarding valuable water and financial resources.

Ultimately, validation provides a utility with more confidence in the results of a water audit so it can effectively plan water loss control efforts, track performance, benchmark indicators, and improve future water audits.

What are the levels of water audit validation?

Water audit validation may be conducted at three different levels. Table 2 provides a brief description of all three levels. See Chapter 5 for more information about Level 1 validation and Chapter 7 for a more information about Level 2 and 3 validation.

Table 2: Levels of Water Audit Validation.
Source: Data from Sturm et al. 2017.

Level of Validation	Description
Level 1	Validated water audits have been examined for inaccuracies evident in summary data and application of methodology for deriving water audit inputs. All answers to IDG questions accurately reflect utility practices and are consistent with supporting documentation.
Level 2	Validated water audits have been corroborated with investigations of raw data and archived reports of instrument accuracy. The best sources of data to inform the water audit have been identified.
Level 3	Validated water audits have been bolstered by field tests of instrument accuracy. The water audit's estimate of Real Losses has been confirmed through pilot leak detection, Component Analysis of Real Losses, and/or minimum night flow analysis.

Who should validate water audits?

When selecting a person to validate a water audit, it is important to consider the validator's relationship to the water audit, knowledge of validation methodology, and overall posture toward data quality and validation.

A water audit validator should not be the person who compiled the water audit. The process of water audit review is made more effective when the validator approaches the water audit with fresh eyes, having not been intimately involved in its assembly. Nonetheless, the validator may be a part of the same organization as the auditor, and a validator may validate the audit of their own utility.

The effectiveness of water audit validation hinges on the knowledge and skills of the validator.

A validator must:

- Be proficient in current AWWA M36 best practices for water audit preparation and validation.
- Have access to the data and people that informed the water audit.
- Be gently skeptical of water audit data and data validity grades, as initially submitted.
- Ask open-ended questions and listen to the answers.
- Document the process and outcomes of the water audit validation.

A water audit validator should be:

- **Objective** in order to appreciate the interplay between instrumentation, data management systems, and utility staff as it affects the water audit.
- **Transparent** in order for validation findings to improve the quality of the water audit.
- **Diplomatic** in order to appreciate the work that went into compiling the water audit but still uncover inaccuracies.
- **Methodical** in order to identify all potential inaccuracies or sources of uncertainty through the validation process.
- **Forward-thinking** in order for the recommendations resulting from validation to improve the water audit and water loss control in subsequent years.

Chapter 5: What Defines Level 1 Water Audit Validation?

What does Level 1 water audit validation do?

As per Sturm et al. (2017) the Level 1 water audit validation aims to:

- Confirm the accurate application of AWWA M36 water audit methodology and terminology to the utility-specific situation.
- Identify evident inaccuracies and correct inaccuracies, where realistic.
- Verify the selection of correct DVGs.²

In meeting these goals, the Level 1 validation process results in:

- DVS that reflects utility practices.
- Identification of macro-level inaccuracies.
- Recommendations for advanced validation activities.

What does Level 1 water audit validation not do?

Level 1 water audit validation is the least rigorous level of validation. The effort and time required to complete Level 1 validation are relatively small. As a result, a Level 1 engagement with data sources and the water audit have limitations.

Level 1 water audit validation does not:

- Correct inaccuracies in raw data that may affect summary data and audit inputs.
- Investigate data processing and handling to identify and correct inaccuracies.
- Study instrument accuracy through field tests to improve the certainty of the water audit.
- Corroborate the volume of Real Losses with bottom-up or field investigations of leakage.

Given these limitations, anyone who wishes to understand the performance of key water audit instruments and data management systems; study raw data for gaps, redundancies, and inaccuracies; or document the translation of data from measurement to summary should perform higher-level validation activities.

The more rigorous the validation, the more likely the water audit is to be accurate and representative of actual utility performance. As a result, Level 1 water audit validation is often only a starting point in the effort to compile reliable water audits. Higher-level validation activities are usually needed to produce and confirm high-quality water audits that inform long-term, cost effective water loss control.

² In AWWA Software v5, the validator helped the auditor interpret the DVG Grading Matrix and select the appropriate score. Now, in AWWA Software v6, the introduction of IDG has shifted the role of the validator to ensuring that the auditor provided answers to the IDG criteria questions which accurately reflect a utility's operational practices.

How has Level 1 validation impacted audits in North America?

As of 2020, there are five North American states and provinces that require Level 1 validation prior to submittal of the AWWA water audit to their respective regulatory agencies: California, Georgia, Hawaii, Indiana, and Quebec. In addition, there are nine other states with volunteer water loss technical assistance programs that feature Level 1 validation training: Arizona, Colorado, Florida, North Carolina, South Carolina, Utah, Washington, Wisconsin, and Wyoming (Figure 7).

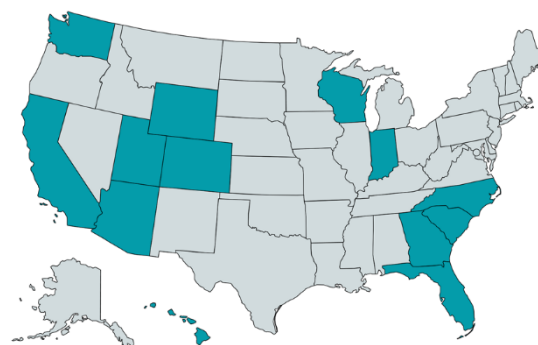


Figure 7: 14 States/Provinces Either Require Level 1 Validation Prior to Audit Submission or Feature Level 1 Validation Training (Quebec, Canada Not Illustrated).

As part of the update to this manual, the project team collected and reviewed pairs of unvalidated audits (“pre-validated”) and Level 1 validated (“post-validated”) water audits data from 734 systems in these states and provinces to determine the impact of validation. The audits were completed using AWWA Software v5. The results from this investigation indicated that Level 1 validation has a substantial impact on both data validity and performance indicators:

- **Identification of macro-level errors:** Pre-validated audits were prone to macro-level errors in audit inputs and performance indicators. For states aggregating self-reported water audit data for hundreds or thousands of water systems each year, these errors may be hidden within summary data and improperly influence water resource planning and related policy decisions. Two common types of macro-level errors were observed:
 - **Unit errors:** Errors that occur when the auditor entered volumetric inputs as the wrong unit (i.e., ‘gallons’ instead of ‘million gallons’). In the research data set, pre-validated water audits contained unit errors that caused the aggregate non-revenue water (NRW) volume to be approximately 717 trillion gallons. Post-validation, these unit errors were corrected and aggregate NRW volume was approximately 717 billion gallons.
 - **Method errors:** Errors that occur when the auditor incorrectly calculates an audit input or incorrectly applies AWWA M36 methodology. Common method errors include duplicating metered volumes, inclusion of raw water, miscalculation of supply meter error adjustment, including estimated leakage in UUAC, and miscalculating CMI.
- **Adjusted data validity scores:** Individual DVG and overall DVS for pre-validated audits were skewed toward higher scores. They included improbably low and high DVS, (0 to 10 and 90 to 100) which likely reflected error in data grading. Post-validation, DVS took on a statistically normal distribution with a lower mean and fewer outliers overall.

With the introduction of the IDG process, AWWA Software v6 automatically assigns DVGs based on reported practices. As a result, improbable DVS scores can be avoided, and validators will be able to focus on identifying macro-level errors.

What is the state of Level 1 validation certification programs in North America?

As of 2020, four formal programs for credentialing Level 1 validators exist in North America (Figure 8). In 2016, the Georgia Association of Water Professionals developed the first validator credentialing program, called the Qualified Water Loss Auditor program, which trained and certified individuals who successfully completed course work and passed an examination testing their competence to perform Level 1 water audit validations. Since then, California, Quebec, and Indiana have initiated similar credentialing programs, each with local adaptations.

Only one program, California, formally developed written methodology for performing a Level 1 validation in greater detail than the first edition of this manual. That methodology primarily offered clarification of specific language the AWWA Software v5 data grading matrix. Now that AWWA Software v6 has addressed these issues (see Chapter 3), lessons learned from the California program have been incorporated in this edition of the manual.

Although Hawaii requires annual water audit submission and validation, there is no certification program in place to become a validator since the State of Hawaii Commission on Water Resource Management is responsible for conducting annual Level 1 validations. Hawaii is evaluating their water audit program to determine if establishing a validator certification program is both feasible and beneficial to the program.

Minimum supporting documentation requirements are generally the same across certification programs and have not changed since the first edition of this manual was published (see Chapter 6). However, existing validator credentialing programs will need to update course materials, in-class exercises, and examination materials to stay consistent with AWWA Software v6 and the current edition of this manual.



Figure 8: Level 1 Validation Certification Programs in North America.

Chapter 6: How Do I Perform Level 1 Validation?

Before a water audit can be validated, it must be prepared. The process of preparing a water audit is distinct from the process of validating a water audit. Though many of the best practices for water audit validation can also apply to water audit preparation, this manual guides validators in performing a Level 1 water audit validation; it does not address water audit preparation in complete detail. Instead, it emphasizes key points of consideration when assessing if the correct methodology was used to derive audit input values. For an in-depth treatment of water audit preparation, please refer to AWWA Manual M36: Water Audits and Loss Control Programs.

Level 1 water audit validation consists of 5 steps over three general phases:

A. Pre-validation interview preparation

1. Receive and review the water audit and supporting documentation.
2. Review performance indicators for evidence of inaccuracy.

B. Validation interview

3. Conduct an interview with the auditor and appropriate utility staff in order to review audit input data, confirm correct application of methodology, and discuss operational practices associated with IDG questions. Adjust Inputs and answers to IDG questions, if necessary.
4. Review performance indicators again for evidence of persisting inaccuracy.

C. Post-validation interview documentation

5. Document results.

Each step is described in greater detail on the following pages.

The validator should keep in mind that the goals of a Level 1 validation effort are to identify evident data inaccuracies, confirm the correct application of methodology, and verify that IDG answers accurately reflect utility practices. Level 1 validation will not correct – or even identify – all inaccuracies that may be present in a water audit. Nonetheless, the potential for uncertainty in a water audit will be better understood following a Level 1 validation.

Step 1: Receive and review the water audit and supporting documentation

When preparing to perform Level 1 water audit validation, the validator should request and receive the water audit and the minimum supporting documentation necessary to corroborate key water audit inputs, methodology, and IDG answers. Though much more data likely supports the water audit, an in-depth examination of all water audit data, analyses, and instrumentation is beyond the scope of Level 1 validation.

At a minimum, the validator should request and receive:

- Completed AWWA Software.
- Minimum required supporting documentation:
 - Volume from Own Sources (VOS) detailed by month and meter, if applicable.
 - Water Imported (WI) detailed by month and meter, if applicable.
 - Water Exported (WE) detailed by month and meter, if applicable.
 - Volume of water sold (BMAC) detailed by month and rate code (e.g., charge status, water type, or customer class).
 - Supply meter testing and/or calibration documentation—this is only required to achieve higher DVG scores, it is not required for Level 1 validation.

If the validator does not receive all required supporting documentation, the water audit cannot be Level 1 validated.

Additional supporting documentation will improve the Level 1 validation process, but such information is not strictly necessary to complete a Level 1 water audit validation. Helpful supplemental documentation includes the calculation or derivation of:

- System Schematic: depicting the water system with relative locations labeled for each of the meters used to derive the volumes entered for VOS, WI, and WE as applicable. Does not need to be to scale, and a sketch is typically adequate.
- Customer Meter Inaccuracy (CMI).
- Operating Pressure (AOP).
- Customer Retail Unit Cost (CRUC).
- Variable Production Cost (VPC).

If a System Schematic is not available, the validator is strongly encouraged to work with the audit team during the validation interview to sketch one out. Additionally, audits from previous years can be collected to examine consistency from one year to the next, if previous audits are available.

Once the validator has received the water audit and supporting documentation, the validator should schedule an interview with the auditor and other utility staff positioned to describe utility practices (see Step 3).

Level 1 validation consists primarily of an interview between the auditor, the validator, and any other utility staff who can provide insight to data and operational practices related to the water audit.

In the interview, the validator should ask open-ended questions to explore the utility practices that maintain the quality of infrastructure, instruments, data, and general operations.

Because each utility operates uniquely, every interview and the collection of supporting documentation must be tailored to the utility. However, some general questions and lines of inquiry that pertain to water audit inputs and data validity grades are provided in this manual for the third step, reviewing water audit inputs.

Once the validator has collected supporting documentation and scheduled a Level 1 validation interview, the validator should examine initial performance indicators for evidence of inaccuracy.

Step 2: Examine performance indicators for evidence of inaccuracy

The Dashboard tab of the AWWA Software v6 displays a suite of key performance indicators (KPI) calculated using the data inputs used by the auditor. Prior to the Level 1 validation interview, each performance indicator can be checked for feasibility as described below to provide an initial assessment of the overall reliability of the water audit. Additionally, by studying initial performance indicators before examining each audit input in the interview, the validator will be positioned to identify potential audit data inaccuracies contributing to questionable performance indicators.

Each KPI is displayed on a gauge which shows the measured KPI value against validated industry benchmarks (Kunkel et al. 2020) of the 10th percentile to 90th percentile ranges for that KPI. This may provide general context for the validator. If a given KPI falls below the 10th or above the 90th percentiles on its gauge, this does not necessarily imply an error, but should be approached with additional scrutiny from the validator. Further guidance by KPI is discussed below.

Unit Apparent Losses

The AWWA Software reports Apparent Losses as a total volume and a normalized performance indicator referred to as:

- Unit Apparent Losses (volume/connection/day).

The AWWA Software normalizes Apparent Losses to service connections by dividing the total Apparent Loss volume by the count of service connections and the number of days in the audit period.

Generally, utilities incur Apparent Losses through theft, meter under-registration, and errors in data handling. As a result, the majority of utilities will have positive values of Unit Apparent Losses.

- Are Unit Apparent Losses greater than 0?

A handful of utilities may experience negative Unit Apparent Losses through meter over-registration and certain errors in data handling, like duplication. However, such a situation is unlikely. Should a utility present negative Unit Apparent Losses, the validator should review the derivation of Apparent Loss volumes for correctness.

Unit Real Losses

The AWWA Software reports Real Losses as a total volume and two normalized performance indicators referred to as:

- Unit Real Losses^A (volume/connection/day).
- Unit Real Losses^B (volume/length of main/day).

The AWWA Software first normalizes Real Losses to service connections. To arrive at Real Losses normalized to service connections, the audit software divides the Real Loss volume by the count of service connections and the number of days in the audit period. Results are presented in volume per connection per day.

The AWWA Software also normalizes Real Losses to the length of mains by dividing the Real Loss volume by the total length of mains and the number of days in the audit period. Results are presented in volume per length of main per day.

In AWWA Software v5, only one of the unit real loss performance indicators (by connection or by mile of main) was presented, depending on system characteristics. In v6, both indicators are presented, regardless of system characteristics.

To verify that the results of the audit are technically feasible, all Unit Real Loss performance indicators should be greater than 0. A Unit Real Loss performance indicator greater than 0 indicates that the utility lost some of the volume it supplied to leakage, as is expected.

- Are both Unit Real Loss indicators greater than 0?

If normalized Real Losses does not pass this check, at least one of the volumetric inputs contains error.

Infrastructure Leakage Index

The Infrastructure Leakage Index (ILI) is a dimensionless ratio calculated by dividing the derived volume of Real Losses by the volume of Unavoidable Annual Real Losses (UARL). The UARL is modeled using the length of mains (Lm), count of service connections (Nc), average length of customer service lines (Lp), and average operating pressure (AOP). 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.

In AWWA Software v5, the ILI and UARL were not presented if a system was very small (<3,000 service connections) or had very low average operating pressure (<35 psi). In v6, the ILI and UARL are presented for systems of all sizes and all pressures.

However, these values should be interpreted with caution when a given system is very small or has very low or very high average operating pressure. Some published research (Lambert 2020) discusses how UARL may be over- or -under-estimated in these systems because they operate at or near the limits of the UARL model assumptions. In exceptional cases such as these, the ILI may still be considered a general performance indicator but may have limited value.

To verify that the results of the audit are technically feasible, ILI should be considered with the following questions:

- Is the water system very small (<3,000 service connections) or does it have very low (<35 psi) or very high average operating pressure (>150 psi)?
 - If yes, the ILI should not be used as a check for validity.
 - If no, is the ILI greater than 1.0?

If the ILI does not pass this check, one or more of the audit inputs may contain errors. A utility with an ILI at or below 1.0, presuming no errors in the water audit inputs, would typically be expected to have newer infrastructure and an aggressive leakage management program. If the utility does not have new infrastructure or an aggressive leakage management program, the validator should investigate for hidden error, with special emphasis placed on reviewing the supply volumes for potential under-stating of Water Supplied and the consumption volumes for potential over-stating of Authorized Consumption.

Summary

Initial performance indicator checks are summarized in Table 3. Should the performance indicator fail the checks, the validator should pay particular attention to the contributing inputs in the process of Level 1 validation.

Once the validator has examined initial performance indicators, they should proceed to assessing the validity of each water audit input and DVG. If the performance indicator review suggests that the water audit is likely inaccurate, the validator should document the relevant performance indicator as well as possible reasons for this inaccuracy.

Table 3: Performance Indicators to Check for Inaccuracy.

Performance Indicator	Unit	Checks	Contributing Inputs
Unit Apparent Losses	volume / connection / day	> 0 Within 10 th to 90 th percentiles of validated industry benchmarks*	Customer Meter Inaccuracy (CMI), Unauthorized Consumption (UC), Systematic Data Handling Error (SDHE)
Unit Real Losses ^A	volume / connection / day	> 0 Within 10 th to 90 th percentiles of validated industry benchmarks*	All volumetric inputs
Unit Real Losses ^B	volume / length of main / day	> 0 Within 10 th to 90 th percentiles of validated industry benchmarks*	All volumetric inputs
Infrastructure leakage index (ILI)	Dimensionless	ILI > 1.0 Within 10 th to 90 th percentiles of validated industry benchmarks*	All volumetric inputs, infrastructure inputs, average system operating pressure

*As depicted on the gauge ranges on the AWWA Software v6 Dashboard

Step 3: Conduct the validation interview

Step 3 is the beginning of the interview portion of the validation process. After examining performance indicators for technical feasibility, the validator should systematically validate each audit input by confirming the supporting documentation and methodology used to derive its value. In addition, the validator should review answers provided in the IDG tab with the auditor as necessary to validate the answers accurately reflect utility practices and are consistent with supporting documentation.

The AWWA Software contains 19 potential data inputs and 1 optional input. For each audit input, the validator should discuss the following broad questions:

- What methodology did the auditor use to derive the water audit input value?
- How did the auditor interpret the water audit input and does that understanding align with the provided supporting documentation?
- Did the auditor have difficulty answering any questions during the IDG process?
- How does the audit input compare to previous years (if applicable)?

As the validator asks these questions, they should remember the following key concepts and review them with the auditor if necessary:

- **Potable water only:** Typically, water audits are conducted on potable distribution systems. With this in mind, the validator should make clear to the auditor that all non-potable supply and consumption should be omitted from the audit.

However, it is possible to complete a water audit on non-potable systems and they can be validated in the same way as potable audits. In fact, v6 of the AWWA Software includes a new selection box in the Start Page tab to indicate which system type the audit refers to (e.g., retail, recycled).

Whether the validator is validating a potable or non-potable water audit, they just need be sure which type of system they are reviewing and confirm that the auditor has excluded any volumes related to the alternate system.

- **Water audit boundary:** When discussing inputs related to water supply—Volume from Own Sources (VOS), Water Imported (WI), and Water Exported (WE)—the validator should work with the utility to clearly identify the water audit “boundary.” The boundary is defined by the metering points that capture all flow going into and out of the distribution system. This is a critical step because it determines which volumes of water should be considered in the audit. All usage outside of the audit boundary can be ignored, while all usage inside the audit boundary needs to be considered.

When validating potable distribution systems, the boundary is defined by metering points that capture treated water entering and leaving the system. For example, effluent meters at treatment plants, import meters from a neighboring supply, and export meters to a neighboring distribution system would all likely be part of the audit boundary. Water utilities may have complicated metering arrangements that make it challenging to correctly identify which meters should be included in the water audit boundary, therefore the validator should be sure to devote enough time to review how and why each meter was selected.

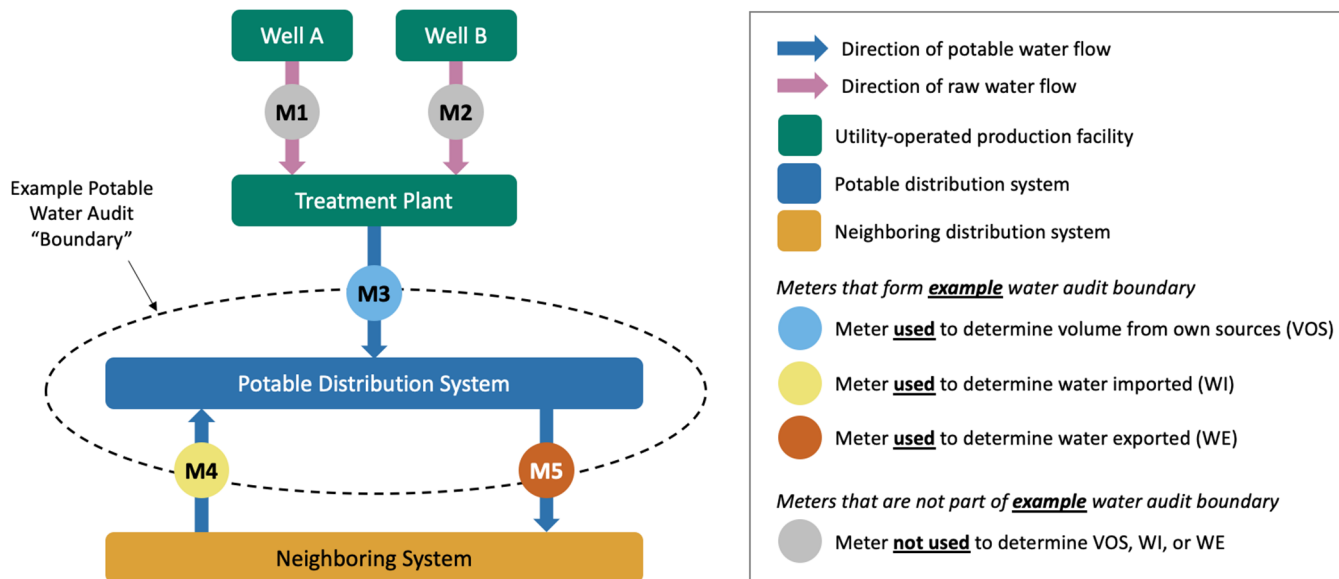


Figure 9: Example Water Audit Boundary.

Figure 9 illustrates a situation where only three meters are used to define the boundary: one for VOS (M3), one for WI (M4) and one for WE (M5). The annual volumes at these meters should be used in the AWWA Software to determine total water supply. Remaining audit inputs dealing with authorized use, apparent loss, and system data should be populated with data related to usage inside of the audit boundary.

An important takeaway from the example in Figure 9 is that not all of the meters should necessarily be included in the audit boundary. Including more meters than necessary increases the risk of error introduced by metering inaccuracy and may incorrectly duplicate supply inputs. More detailed examples for each component of water supply will be discussed in later sections.

- **Units of measure:** The AWWA Software allows the auditor to specify volumetric inputs using the following units: Million gallons (US), Megaliters (thousand cubic meters), and Acre-feet. The validator must confirm with the auditor which units they are using, verify that this was selected on the Start Page

of the AWWA Software, and confirm the correct conversion from supporting documents in different units, if necessary. The audit should use the same units consistently for each volumetric input.

- **Time period:** Most commonly a water audit is conducted on a 12-month period. For most utilities, this coincides with either the calendar year (CY) or the fiscal year (FY). The validator must confirm with the auditor what time period they are considering, verify this was set correctly on the Start Page of the AWWA Software, and ensure supporting documents refer to the same period.

The remainder of this section describes each audit input in greater detail, addressing three of the primary topics the validator will review with the auditor:

- Supporting documentation review
- Input validation and review of methodology
- IDG answer validation
 - Specific IDG questions are referred to with the same labels included in AWWA Software v6. For example, the first question data grading criteria question in the IDG for Volume from Own Sources (VOS) is labeled as vos.0

Volume from Own Sources — VOS

Volume from Own Sources (VOS) is the volume of water withdrawn from water resources (rivers, lakes, streams, wells, etc.) controlled by the water utility and then treated for potable water distribution (AWWA 2016).

Supporting Documentation Review

Supporting documentation for VOS is **required** for Level 1 validation. Utilities commonly track production volumes using:

- **Manual meter reads:** Operations staff physically read meter totalizers and record volumes.
- **SCADA or AMI system:** Flow rates are automatically and continuously logged, totalized, and archived.
- **Estimates:** In some cases, utilities will estimate unmetered sources using, for example, pump run times or portable meters.

Regardless of what system utilities use to collect and store data, it needs to be summarized by month and meter. Table 4 shows example VOS supporting documentation for the system shown in Figure 10:

Table 4: Example Supporting Documentation for VOS of System Shown in Figure 10.

Meter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
M3	131	125	138	149	185	210	256	267	218	202	175	136	2,192
M4	262	250	276	299	370	420	512	534	436	404	350	272	4,385
M6	-	-	-	12	24	34	48	52	23	-	-	-	193
Total (MG)	393	375	414	460	579	664	816	853	677	606	525	408	6,770

In this example, the bolded value in Table 4 (6,770 MG) should be the input for VOS in the water audit Worksheet.

Although documentation of electronic calibration and/or flow accuracy tests is not required for Level 1 validation, it is required to qualify for a VOS DVG above 5.

OPTIONAL SUPPORTING DOCUMENTATION FOR ANNUAL NET CHANGES IN DISTRIBUTION STORAGE

Table 5 shows example supporting documentation for annual net changes in distribution storage for the system shown in Figure 11. Note that this piece of documentation is not required for Level 1 validation.

Table 5: Example Supporting Documentation for Annual Net Changes in Storage as Shown in Figure 11.

Distribution Storage	Volume (MG) at beginning of audit period (Jan 1, 2020)	Volume (MG) at end of audit period (Dec 31, 2020)	Change in Volume (MG)
Reservoir	5.22	5.02	-0.20
Storage Tank A	1.25	1.26	0.01
Storage Tank B	0.80	0.74	-0.06
Overall	7.27	7.02	-0.25

In this example, the bolded value in Table 5 (-0.25 MG) indicates there is overall less water in storage and therefore more water available in the distribution system. As described below, if there is less water in storage at the end of the audit period than at the beginning, the difference should be added to water supply. Therefore, 0.25 MG should be added to VOS or incorporated into Volume from Own Sources Error Adjustment (VOSEA).

Input Validation

VOS should be determined using potable water meters that are part of the water audit boundary (see “Water audit boundary” above for more information). Figure 10 provides an example system for consideration.

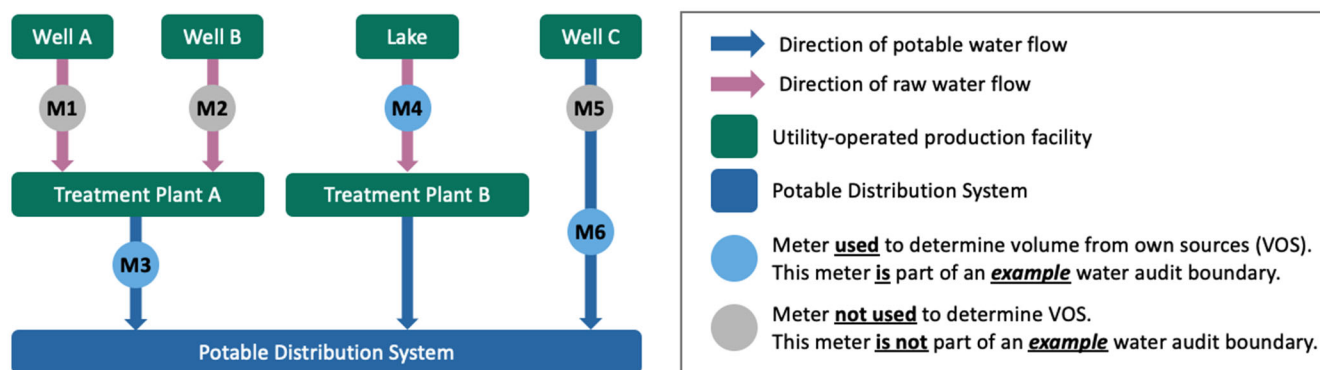


Figure 10: Example Water Audit Boundary with Respect to Volume from Own Sources (VOS).

When reviewing VOS meters included in the water audit boundary with the auditor, the validator should consider the following:

- Simplicity and accuracy:** When there are multiple meters that track water from the same resource, the validator should encourage the auditor to focus on simplicity and accuracy when defining the water audit boundary. For example, meters M1 and M2 (Figure 10) are not included in the example audit boundary because meter M3 captures the same volume of flow from Wells A and B after it is treated at Treatment Plant A. Using a single meter is often preferable because it is simpler to track and reduces the chance of inaccuracy due to instrumentation error.
- Effluent vs influent meters:** Effluent meters are often preferable to influent meters because they track water after treatment processes. This is another good reason to include meter M3 (Figure 10), which is an effluent meter that tracks flow after operational uses at Treatment Plant A. By contrast, Treatment Plant B does not have an effluent meter and therefore the influent meter (M4) is used out of necessity. As a result, the auditor will need to determine usage at Treatment Plant B and include it as unbilled metered or unmetered authorized consumption (UMAC and UUAC)—without doing so, the audit will overestimate water losses.
- In-line meters:** When meters are in-line with one another, the validator should encourage the auditor to select whichever meter is considered to have the most rigorous testing practices. If the meters perform similarly, the auditor should select the meter closest to the distribution system. In Figure 10, meter M6

is selected because it is closer to the distribution system than meter M5 and neither meter has been accuracy tested.

Once the boundary points have been identified, the validator should verify that VOS equals the sum of all volume passing through those points during the audit period by comparing the audit entry to the supporting documentation.

NET CHANGES IN DISTRIBUTION STORAGE

Figure 11 provides an example system for consideration.

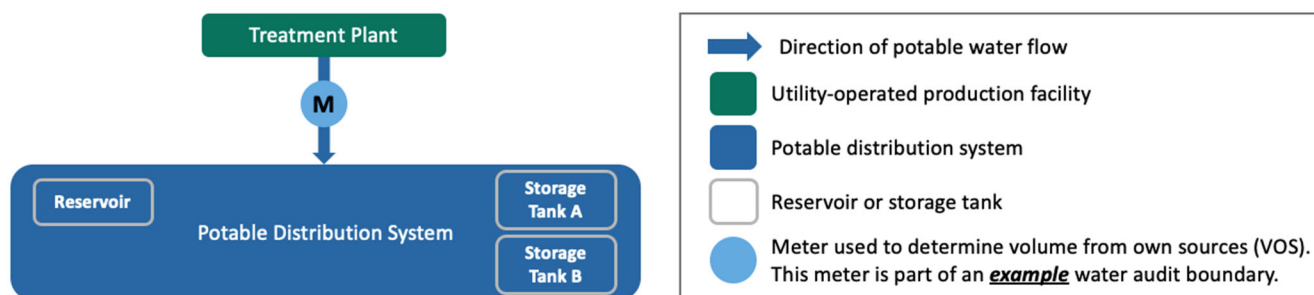


Figure 11: Example System with Distribution Storage.

If there are reservoirs or storage tanks within the potable system and downstream of the audit boundary meters, the validator should confirm the auditor determined the aggregate annual net changes in storage at these locations using the following guidelines:

- If there is **more water in reservoirs and tanks** at the end of the audit period than at the beginning, the difference should be **subtracted from water supply**. This is because supply meters have captured this volume, but it has been temporarily held from the customer. Without subtracting this volume, the auditor will overestimate water losses. The validator should confirm the auditor has calculated the net change in storage correctly.
- If there is **less water in reservoirs and tanks** at the end of the audit period than at the beginning, the difference should be **added to water supply**. This is because the change represents an additional supply of water that is not captured by supply meters within the audit period. Without adding this volume, the auditor will underestimate water losses. The validator should confirm the auditor has calculated the net change in storage correctly.

Incorporating net changes in distribution storage is not a required step but is considered a best practice. The validator should discuss the concept with the auditor to determine if it would have a substantial impact on the volume water supply.

IDG Answer Validation

The validator should consider the following items when reviewing operational practices related to the “Volume from Own Sources — VOS section” (VOS section) of the IDG tab. This list is not exhaustive but includes typical items the validator should be prepared to discuss with the auditor to verify that the IDG answers accurately reflect utility practices and are consistent with supporting documentation.

- **Congruency with supporting documents:** The validator should confirm no conflicts exist between supporting documents and the IDG answers provided. For example, vos.4 and/or vos.6 may indicate that testing and/or calibration documentation is available for review, but none was provided with the

supporting documentation. The validator should discuss this with the auditor and adjust the IDG answers as necessary.

- **Understanding context for answers provided:** It may be important for the validator to have the auditor provide additional context for some answers. For example, if in-situ flow accuracy testing or calibration are indicated, the auditor may describe who these activities are performed by (internal vs. external) and what general procedures are utilized. This may uncover information that would lead the validator to recommend a different answer to one of the IDG questions or provide better context for a validator's improvement recommendation(s) on a limiting criterion.
- **Congruency with supply meter data chain:** The validator should ensure a clear schematic understanding of how supply flow measurement data is managed from the primary measuring device, to secondary data transfer (if applicable), to tertiary data archival and summary (if applicable). For example, vos.3 may indicate "data transfer errors are checked at secondary devices, but not to tertiary devices". If the utility does not use a tertiary archival system (i.e., SCADA), and supply volumes are instead archived and summarized from the secondary device reading (i.e., remote readout recorded daily by operator), the validator should discuss this with the auditor and adjust the IDG answers as necessary.
- **Relevant meter maintenance practices:** Questions in the VOS section of the IDG tab refer specifically to the meters included in the audit boundary and therefore used to determine VOS. Maintenance practices related to meters not selected for the audit boundary are irrelevant to IDG questions.
- **Flow accuracy testing and calibration (vos.2-vos.8):** All answers to questions related to electronic calibration and flow accuracy testing should apply to at least 90% of total VOS. For example, assume that the auditor providing Table 4 above reports annual electronic calibration on meter M3 but no calibration on meters M4 or M6 (these meters are 10 years old). In this case, the auditor should answer "Not within the last 5 years" for question vos.2 because meter M3 represents approximately 32% of total VOS.

Although flow accuracy testing is considered for the VOS DVG, actual adjustments based on these test results are incorporated in the VOSEA audit input.

- **Scrutinized procedures (vos.8):** Discussion between the validator and the audit team regarding testing and calibration procedures with the utility does not constitute the condition of "scrutinized for compliance with procedures described in the AWWA M36 and/or M33 Manual(s)".
- **Limiting criteria review:** The validator should review any criteria which are flagged as "Limiting" in the IDG interface and discuss potential next steps the utility may consider as warranted for improvement. It should be noted that if multiple limiting criteria are shown, improving on each limiting criterion is necessary to achieve a higher data grade for the input.

Volume from Own Sources Error Adjustment — VOSEA

Volume from Own Sources Error Adjustment (VOSEA) is used to adjust for any known meter inaccuracy or data gaps caused by instrumentation outage (AWWA 2016). Additionally, the auditor may incorporate annual net changes in distribution storage in this input (see VOS section). The auditor may choose to enter VOSEA as either a percentage input or total volume.

Supporting Documentation Review

Supporting documentation for VOSEA is **not required** for Level 1 validation. However, it may be helpful to review any calculations the auditor performed to determine VOSEA. In addition, supporting documentation for flow accuracy tests and/or electronic calibration is required to qualify for VOS DVG above 5. Tables 6 and 7 show

example supporting documentation for supply meter inaccuracy calculated as a volume or as a weighted average, respectively.

Table 6: Example Supporting Documentation of VOSEA Calculated as a Volume.

Meter	Uncorrected Volume (MG)	Meter Accuracy	Meter Error (Volume) <i>uncorrected volume – (uncorrected volume/accuracy)</i>	Corrected Volume <i>uncorrected volume – meter error</i>
M3	2,192	102.0%	$2,192 - (2,192/1.02) = 43$	2,149
M4	4,385	96.5%	$4,385 - (4,385/0.965) = -159$	4,544
M6	193	No test	$193 - (193/1) = 0$	193
	6,770		-116 MG*	6,886

*Entered as positive number in AWWA Software v6 with “volume” and “under-registration” selected from the provided drop-down menus

Table 6 shows that flow accuracy tests indicate that water supply was under-registered by 116 MG (bolded). In AWWA Software v6, auditors always enter a positive number and use the provided drop-down menu to explicitly select over- or under-registration.

Table 7: Example Supporting Documentation of VOSEA Calculated as a Weighted Average.

Meter	Uncorrected Volume (MG)	Meter Accuracy	Corrected Volume <i>(Calculations shown in Table 6)</i>	Meter Error (Weighted Average) <i>(accuracy – 1) * (corrected volume of meter/total corrected volume)</i>
M3	2,192	102.0%	2,149	$(1.02 - 1) * (2,149/6,886) = 0.62\%$
M4	4,385	96.5%	4,544	$(0.965 - 1) * (4,544/6,886) = -2.31\%$
M6	193	No test	193	$(1.0 - 1) * (193/6,886) = 0.00\%$
	6,770		6,886	-1.69%*

*Entered as positive number in AWWA Software v6 with “percent” and “under-registration” selected from the provided drop-down menus

Table 7 shows that flow accuracy tests indicate that the water supply was under-registered by –1.69% (bolded). In AWWA Software v6, auditors always enter a positive number and use the provided drop-down menu to explicitly select over- or under-registration.

If a utility uses a third-party to perform accuracy testing, the auditor may provide supporting documentation in its original delivered form (e.g., PDF of results, scanned paper copy). In these cases, it may not be obvious how the auditor determined VOSEA from the provided documentation. The validator should discuss this with the auditor and recommend any necessary corrections.

Input Validation

Every utility has unique metering arrangements, testing and calibration practices, and data management systems that make it difficult to establish a standard approach to estimating an error adjustment volume. However, it is common for auditors to use flow accuracy test results to calculate VOSEA as a result of supply meter inaccuracy.

When discussing how the auditor derived VOSEA from accuracy test results, the validator should consider the following:

- **Flow accuracy testing vs. electronic calibration:** The AWWA Software offers guidance on the difference between accuracy testing and electronic calibration. In most cases, only flow accuracy testing should be incorporated into VOSEA. While calibration is critical for proper meter performance, it does not quantify

accuracy of the primary instrumentation. If the calibration results indicate significant inaccuracy of recorded volumes, then the auditor may consider using the calibration results to make an adjustment to supply volumes.

According to the fourth edition of the AWWA M36 manual, “Water utilities often conduct flowmeter accuracy testing as well as calibration of related instrumentation such as differential pressure cells connected to Venturi meters. Unfortunately, instrument calibration does not confirm the flow measuring accuracy of the primary metering element. Many utilities conduct regular calibration but do not conduct flowmeter accuracy testing. Regular flowmeter accuracy testing in field conditions is necessary for water utilities to ascertain the degree of error in the flowmeter and to warrant a high Data Grading in the Audit Software.” (AWWA 2016)

- **Simple vs weighted inaccuracy for a single meter:** Typically, supply meters are tested at several different flow rates. The validator should discuss how these tests were averaged to determine an overall accuracy for that meter. The best practice is to perform a volume-weighted average so that each test appropriately contributes to the overall accuracy.
- **Meter-by-meter volumetric error adjustment:** If test results were used to derive VOSEA as a volume, the validator should ensure that the auditor determined error adjustment on a meter-by-meter basis. In other words, test results should only be used to adjust the volumes on the meter it was performed on. Table 6 provides example supporting documentation for this type of adjustment.
- **Volume-weighted percentage error adjustment:** If test results were used to derive VOSEA as a percent, the validator should ensure that the auditor determined error adjustment using a volume-weighted approach. Table 7 provides example supporting documentation for this type of adjustment.

IDG Answer Validation

The validator should consider the following items when reviewing operational practices related to the VOSEA section of the IDG tab. This list is not exhaustive but includes typical items the validator should be prepared to discuss with the auditor to verify that the IDG answers accurately reflect utility practices and are consistent with supporting documentation.

- **Relevant meter maintenance practices:** Questions in the VOSEA section of the IDG tab refer specifically to the meters included in the audit boundary and therefore used to determine VOS. Maintenance practices related to meters not selected for the audit boundary are irrelevant to IDG questions.
- **Incorporating net changes in storage:** Whether or not the auditor incorporates annual net changes in distribution storage into water supply affects the VOSEA DVG. However, the AWWA M36 guides the auditor to make the actual volume adjustment in the VOS section of the AWWA Software. Despite this, it is also acceptable to incorporate the adjustment volume in the VOSEA section of the AWWA Software instead by selecting the “volume” option from the drop-down menu and combining it with any meter error adjustment.
- **Limiting criteria review.** The validator should review any criteria which are flagged as “Limiting” in the IDG interface and discuss potential next steps the utility may consider as warranted for improvement. It should be noted that if multiple limiting criteria are shown, improving on each limiting criterion is necessary to achieve a higher data grade for the input.

Water Imported — WI

Water Imported (WI) is the volume of bulk water purchased to supply the distribution system. Typically, WI is purchased from a neighboring water utility or regional water authority and is metered at a point of interconnection between the two utilities (AWWA 2016).

Supporting Documentation Review

Supporting documentation for WI is **required** for Level 1 validation. Utilities commonly track import volumes using:

- **Invoices from exporter:** The importing utility receives periodic invoices from the exporter. In these cases, the validator should ensure that total WI is aligned with the audit period. This is important when invoices are received in the middle of the month. The validator should confirm the auditor has prorated its import volumes to align with the calendar or fiscal year.
- **Manual meter reads:** Operations staff physically read meter totalizers and record volumes from the import meter. It is acceptable for either the importer or the exporter to maintain the meter that provides the data for WI.
- **SCADA or AMI system:** Flow rates are automatically and continuously logged, totalized, and archived. It is acceptable for either the importer or the exporter to maintain the SCADA or AMI system that provides the data for WI.
- **Estimates:** In some cases, utilities will estimate unmetered imports using, for example, historic import volumes.

Regardless of what system utilities use to collect and store data, it needs to be summarized by month and meter. Table 8 shows example WI supporting documentation for the system shown in Figure 12:

Table 8: Example Supporting Documentation for WI of System Shown in Figure 12.

Meter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
M7	-	-	-	12	29	62	128	184	100	43	2	-	560
M8	-	-	-	-	-	-	2	-	-	-	-	-	2
M9	136	190	205	280	292	310	340	330	286	241	199	180	2,989
Total (MG)	136	190	205	292	321	372	470	514	386	284	201	180	3,551

In this example, the bolded value in Table 8 (3,551 MG) should be the input for WI in the water audit Worksheet.

Although documentation of electronic calibration and/or flow accuracy tests is not required for Level 1 validation, it is required to qualify for a WI DVG above 5.

Input Validation

WI should be determined using potable water meters that are part of the water audit boundary (see “Water audit boundary” above for more information). Figure 12 provides an example system for consideration.

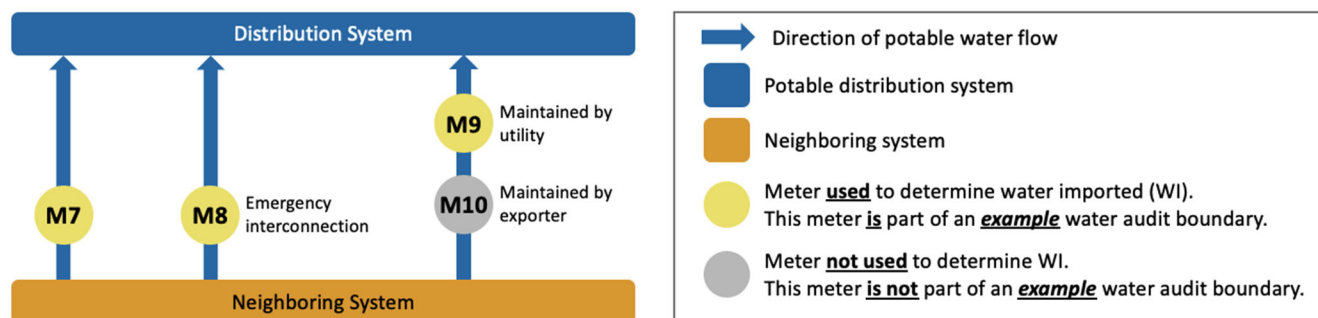


Figure 12: Example Water Audit Boundary with Respect to Water Imported (WI).

When reviewing WI meters included in the water audit boundary with the auditor, the validator should consider the following:

- **Importer vs. exporter meter:** In some cases, the flow of imported water may be captured by multiple meters. The validator should encourage the auditor to select whichever meter is considered to have the most rigorous testing practices. For example, M10 (Figure 12) is an exporter-maintained meter and M9 is a redundant utility-maintained meter. The auditor selects meter M9 because it undergoes annual flow accuracy testing while meter M10 is only tested by the exporter every five years.

Utilities may also be limited by data availability—if the auditor can only furnish monthly totals for one of the meters, they need to include that meter in the audit boundary to meet minimum supporting documentation requirements.

- **Emergency interconnections:** Emergency interconnections with neighboring systems should also be included in the audit boundary, even if they are not active for the entire audit period. For example, M8 (Figure 12) was only active for one month, but it is still included in the audit boundary and supporting documentation (Table 8).
- **Other considerations:** In addition to the previous bullets, the validator may discuss issues common to all water supply meters. These include an emphasis on simplicity and accuracy of meters in the water audit boundary, the merits of effluent vs. influent meters at treatment facilities, and how to select between multiple in-line meters. These points are discussed in greater detail in the VOS section.

Once the boundary points have been identified, the validator should verify that WI equals the sum of all volume passing through those points during the audit period by comparing the audit entry to the supporting documentation.

IDG Answer Validation

The validator should consider the following items when reviewing operational practices related to the WI section of the IDG tab. This list is not exhaustive but includes typical items the validator should be prepared to discuss with the auditor to verify that the IDG answers accurately reflect utility practices and are consistent with supporting documentation.

- **Congruency with supporting documents:** The validator should confirm no conflicts exist between supporting documents and the IDG answers provided. For example, wi.4 and/or wi.6 may indicate that testing and/or calibration documentation is available for review, but none was provided with the supporting documentation. The validator should discuss this with the auditor and adjust the IDG answers as necessary.
- **Understanding context for answers provided:** It may be important for the validator to have the auditor provide additional context for some answers. For example, if in-situ flow accuracy testing or calibration are indicated, the auditor may describe who these activities are performed by (internal vs. external) and what general procedures are utilized. This may uncover information that would lead the validator to recommend a different answer to one of the IDG questions or provide better context for a validator's improvement recommendation(s) on a limiting criterion.
- **Congruency with supply meter data chain:** The validator should ensure a clear schematic understanding of how supply flow measurement data is managed from the primary measuring device, to secondary data transfer (if applicable), to tertiary data archival and summary (if applicable). For example, wi.3 may indicate "data transfer errors are checked at secondary devices, but not to tertiary devices". If the utility does not use a tertiary archival system (i.e., SCADA), and supply volumes are instead archived and

summarized from the secondary device reading (i.e., remote readout recorded daily by operator), the validator should discuss this with the auditor and adjust the IDG answers as necessary.

- **Relevant meter maintenance practices:** Questions in the WI section of the IDG tab refer specifically to the meters included in the audit boundary and therefore used to determine WI. Maintenance practices related to meters not selected for the audit boundary are irrelevant to IDG questions.
- **Flow accuracy testing and calibration (wi.2-wi.8):** All answers to questions related to electronic calibration and flow accuracy testing should apply to at least 90% of total WI. For example, assume that the auditor providing Table 8 above reports annual electronic calibration on meter M9 but no calibration on meters M7 or M8 (these meters are 10 years old). In this case, the auditor should answer “Not within the last 5 years” for question wi.2 because meter M9 represents approximately 84% of total WI.

Although flow accuracy testing is considered for the WI DVG, actual adjustments based on these test results are incorporated in the WIEA audit input.

- **Scrutinized procedures (wi.8):** Discussion between the validator and the audit team regarding testing and calibration procedures with the utility does not constitute the condition of “scrutinized for compliance with procedures described in the AWWA M36 and/or M33 Manual(s)”.
- **Limiting criteria review.** The validator should review any criteria which are flagged as “Limiting” in the IDG interface and discuss potential next steps the utility may consider as warranted for improvement. It should be noted that if multiple limiting criteria are shown, improving on each limiting criterion is necessary to achieve a higher data grade for the input.

Water Imported Error Adjustment — WIEA

Water Imported Error Adjustment (WIEA) is used to adjust for any known meter inaccuracy or data gaps caused by instrumentation outage (AWWA 2016). The auditor may choose to enter WIEA as either a percentage input or total volume.

Supporting Documentation Review

Supporting documentation for WIEA is **not required** for Level 1 validation. However, documentation of accuracy test results and/or electronic calibration is required to qualify for WI DVG above 5.

Additional considerations for supporting documentation related WIEA are generally the same as those for VOSEA and WEEA. Refer to Supporting Documentation Review in the Volume from Own Sources Error Adjustment – VOSEA section for further guidance.

Input Validation

Considerations for WIEA are generally the same as those for VOSEA and WEEA. Refer to Input Validation in the Volume from Own Sources Error Adjustment – VOSEA section for further guidance.

IDG Answer Validation

The validator should consider the following items when reviewing operational practices related to the WIEA section of the IDG tab. This list is not exhaustive but includes typical items the validator should be prepared to discuss with the auditor to verify that the IDG answers accurately reflect utility practices and are consistent with supporting documentation.

- **Relevant meter maintenance practices:** Questions in the WIEA section of the IDG tab refer specifically to the meters included in the audit boundary and therefore used to determine WI. Maintenance practices related to meters not selected for the audit boundary are irrelevant to IDG questions.
- **Flow accuracy testing and calibration (wiew.4):** Although flow accuracy test results are incorporated in the WIEA audit input, wiew.4 is the only question in the WIEA section of the IDG tab related to testing. All other questions related to testing and calibration are included in the WI section of the IDG tab.
- **Limiting criteria review.** The validator should review any criteria which are flagged as “Limiting” in the IDG interface and discuss potential next steps the utility may consider as warranted for improvement. It should be noted that if multiple limiting criteria are shown, improving on each limiting criterion is necessary to achieve a higher data grade for the input.

Water Exported — WE

Water Exported (WE) is the volume of bulk water conveyed and sold by a water utility to neighboring systems that exist outside the utility’s distribution system (AWWA 2016).

Supporting Documentation Review

Supporting documentation for WE is **required** for Level 1 validation. Utilities commonly track export volumes using:

- **Manual meter reads:** Operations staff physically read meter totalizers and record volumes from the export meter. It is acceptable for either the importer or the exporter to maintain the meter that provides the data for WE.
- **SCADA or AMI system:** Flow rates are automatically and continuously logged, totalized, and archived. It is acceptable for either the importer or the exporter to maintain the SCADA or AMI system that provides the data for WE.
- **Estimates:** In some cases, utilities will estimate unmetered exports using, for example, historic export volumes.

Regardless of what system utilities use to collect and store data, it needs to be summarized by month and meter. Table 9 shows example WE supporting documentation for the system shown in Figure 13:

Table 9: Example Supporting Documentation for WE of System Shown in Figure 13.

Meter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
M11	9	11	11	11	11	13	13	13	11	10	10	10	133
M12	-	-	6	-	-	-	-	-	4	1	-	-	11
M13	22	26	30	32	45	78	87	89	72	67	54	36	638
Total (MG)	31	37	47	43	56	91	100	102	87	78	64	46	782

In this example, the bolded value in Table 9 (782 MG) should be the input for WE in the water audit Worksheet.

Although documentation of electronic calibration and/or flow accuracy tests is not required for Level 1 validation, it is required to qualify for a WE DVG above 5.

Input Validation

WE should be determined using potable water meters that are part of the water audit boundary (see “Water audit boundary” above for more information). Figure 13 provides an example system for consideration.

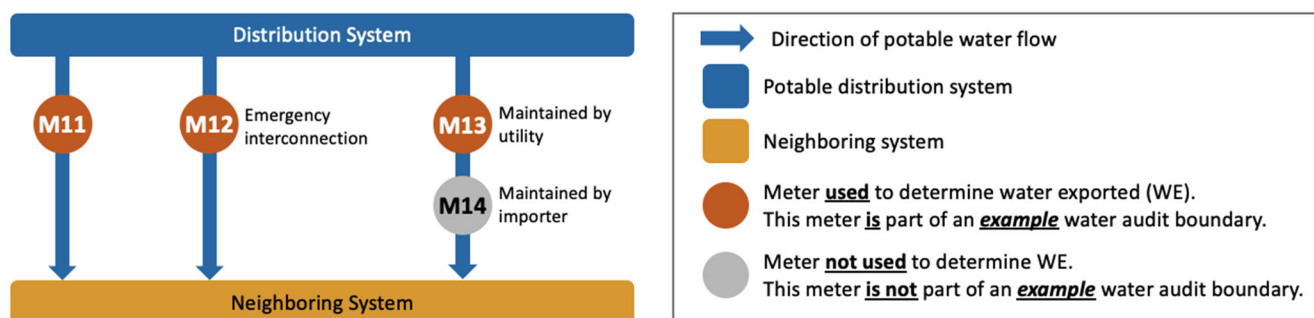


Figure 13: Example Water Audit Boundary with Respect to Water Exported (WE).

When reviewing WE meters included in the water audit boundary with the auditor, the validator should consider the following:

- **Water exported vs. BMAC:** Exported water sold in bulk to agencies are typically charged a wholesale rate that differs from the retail rates charged to customers within a utility’s own distribution system. Therefore, the exported volume should be treated as WE for the determination of water supplied—it should not be manually removed from water supply and recategorized as BMAC. If the customer billing system includes records of wholesale exports to outside agencies, the validator should make sure the auditor has excluded them from the determination of BMAC.
- **Importer vs. exporter meter:** In some cases, the flow of exported water may be captured by multiple meters. The auditor should select whichever meter is considered to have the most rigorous testing practices. For example, M13 (Figure 13) is a utility-maintained meter and M14 is a redundant exporter-maintained meter. The auditor selects meter M13 because it undergoes annual flow accuracy testing while meter M14 is not tested by the exporter.

Utilities may also be limited by data availability—if the auditor can only furnish monthly totals for one of the meters, they need to include that meter in the audit boundary to meet minimum supporting documentation requirements.

- **Emergency interconnections:** Emergency interconnections with neighboring systems should also be included in the audit boundary, even if they are not active for the entire audit period. For example, M12 (Figure 13) was only active for one month, but it is still included in the audit boundary and supporting documentation (Table 9).
- **Other considerations:** In addition to the previous bullets, the validator may discuss issues common to all water supply meters. These include an emphasis on simplicity and accuracy of meters in the water audit boundary, the merits of effluent vs. influent meters at treatment facilities, and how to select between multiple in-line meters. These points are discussed in greater detail in the VOS section.

Once the boundary points have been identified, the validator should verify that WE equals the sum of all volume passing through those points during the audit period by comparing the audit entry to the supporting documentation.

IDG Answer Validation

The validator should consider the following items when reviewing operational practices related to the WE section of the IDG tab. This list is not exhaustive but includes typical items the validator should be prepared to discuss with the auditor to verify that the IDG answers accurately reflect utility practices and are consistent with supporting documentation.

- **Congruency with supporting documents:** The validator should confirm no conflicts exist between supporting documents and the IDG answers provided. For example, we.4 and/or we.6 may indicate that testing and/or calibration documentation is available for review, but none was provided with the supporting documentation. The validator should discuss this with the auditor and adjust the IDG answers as necessary.
- **Understanding context for answers provided:** It may be important for the validator to have the auditor provide additional context for some answers. For example, if in-situ flow accuracy testing or calibration are indicated, the auditor may describe who these activities are performed by (internal vs. external) and what general procedures are utilized. This may uncover information that would lead the validator to recommend a different answer to one of the IDG questions or provide better context for a validator's improvement recommendation(s) on a limiting criterion.
- **Congruency with supply meter data chain:** The validator should ensure a clear schematic understanding of how flow measurement data is managed from the primary measuring device, to secondary data transfer (if applicable), to tertiary data archival and summary (if applicable). For example, we.3 may indicate "data transfer errors are checked at secondary devices, but not to tertiary devices". If the utility does not use a tertiary archival system (i.e., SCADA), and supply volumes are instead archived and summarized from the secondary device reading (i.e., remote readout recorded daily by operator), the validator should discuss this with the auditor and adjust the IDG answers as necessary.
- **Relevant meter maintenance practices:** Questions in the WE section of the IDG tab refer specifically to the meters included in the audit boundary and therefore used to determine WE. Maintenance practices related to meters not selected for the audit boundary are irrelevant to IDG questions.
- **Flow accuracy testing and calibration (we.2-we.8):** All answers to questions related to electronic calibration and flow accuracy testing should apply to at least 90% of total WE. For example, assume that the auditor providing Table 9 above reports annual electronic calibration on meter M13 but no calibration for meters M11 or M12 (these meters are 10 years old). In this case, the auditor should answer "Not within the last 5 years" for question we.2 because meter M13 represents approximately 82% of total WE.

Although flow accuracy testing is considered for the WE DVG, actual adjustments based on these test results are incorporated in the WEEA audit input.

- **Scrutinized procedures (we.8):** Discussion between the validator and the audit team regarding testing and calibration procedures with the utility does not constitute the condition of "scrutinized for compliance with procedures described in the AWWA M36 and/or M33 Manual(s)".
- **Limiting criteria review.** The validator should review any criteria which are flagged as "Limiting" in the IDG interface and discuss potential next steps the utility may consider as warranted for improvement. It should be noted that if multiple limiting criteria are shown, improving on each limiting criterion is necessary to achieve a higher data grade for the input.

Water Exported Error Adjustment — WEEA

Water Exported Error Adjustment (WEEA) is used to adjust for any known meter inaccuracy or data gaps caused by instrumentation outage (AWWA 2016). The auditor may choose to enter WEEA as either a percentage input or total volume.

Supporting Documentation Review

Supporting documentation for WEEA is **not required** for Level 1 validation. However, documentation of accuracy test results and/or electronic calibration is required to qualify for WE DVG above 5.

Additional considerations for supporting documentation related WEEA are generally the same as those for VOSEA and WIEA. Refer to Supporting Documentation Review in the Volume from Own Sources Error Adjustment – VOSEA section for further guidance.

Input Validation

Considerations for WEEA are generally the same as those for VOSEA and WIEA. Refer to Input Validation in the Volume from Own Sources Error Adjustment – VOSEA section for further guidance.

IDG Answer Validation

The validator should consider the following items when reviewing operational practices related to the WEEA section of the IDG tab. This list is not exhaustive but includes typical items the validator should be prepared to discuss with the auditor to verify that the IDG answers accurately reflect utility practices and are consistent with supporting documentation.

- **Relevant meter maintenance practices:** Questions in the WEEA section of the IDG tab refer specifically to the meters included in the audit boundary and therefore used to determine WE. Maintenance practices related to meters not selected for the audit boundary are irrelevant to IDG questions.
- **Flow accuracy testing and calibration (weea.4):** Although flow accuracy test results are incorporated in the WEEA audit input, weea.4 is the only question in the WEEA section of the IDG tab related to testing. All other questions related to testing and calibration are included in the WE section of the IDG tab.
- **Limiting criteria review.** The validator should review any criteria which are flagged as “Limiting” in the IDG interface and discuss potential next steps the utility may consider as warranted for improvement. It should be noted that if multiple limiting criteria are shown, improving on each limiting criterion is necessary to achieve a higher data grade for the input.

Billed Metered Authorized Consumption — BMAC

Billed Metered Authorized Consumption (BMAC) is potable water delivered to metered customers who receive a bill and generate revenue for a utility (AWWA 2016).

Supporting Documentation Review

Supporting documentation for BMAC is **required** for Level 1 validation. Utilities commonly track BMAC using:

- **Manual meter reads:** Operations staff physically read meter totalizers and record volumes from customer meters.

- **AMR/AMI:** More advanced systems of data collection include automatic meter reading (AMR) and advanced meter infrastructure (AMI), which offer semi-automated or automated meter reads.

Meter reads are then stored in paper or digital records for billing purposes. Regardless of what system utilities use to collect and store data, it needs to be summarized by month and customer group or rate class. Table 10 shows example BMAC supporting documentation:

Table 10: Example Supporting Documentation for BMAC.

Customer Group	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Residential	239	253	274	340	405	453	569	607	468	389	318	260	4,575
Commercial	80	84	91	113	135	151	190	202	156	130	106	87	1,525
Industrial	40	42	46	57	67	76	95	101	78	65	53	43	763
Potable irrigation	36	38	41	51	61	68	85	91	70	58	48	39	686
Temporary construction	4	4	5	6	7	8	9	10	8	6	5	4	76
Total (MG)	399	421	457	567	675	756	948	1,011	780	648	530	433	7,625

In this example, the bolded value in Table 10 (7,625 MG) should be the input for BMAC in the water audit Worksheet.

Input Validation

The validator should consider the following items when reviewing the BMAC input:

- **Common customer groups:** BMAC usually includes customer groups such as residential, commercial, industrial, potable irrigation, and agriculture.
- **Non-potable customer groups should be excluded for potable audits:** The validator should review the customer groups listed in the supporting documentation and verify that non-potable customer groups (e.g., raw or recycled) are excluded from BMAC, assuming they are validating a potable water audit. The validator should verify with the auditor that the audit is focused on a potable system, which should also be indicated in a selection box called “Water Type” on the Start Page tab, which is new for AWWA Software v6.
- **Unbilled metered accounts should be excluded:** Often utilities will track billed and unbilled metered accounts in the same billing system. The validator should verify that unbilled metered accounts, such as those related to operational or municipal usage, are separated and excluded. Only metered accounts generating revenue should be included in BMAC.
- **Temporary meters should be included:** Volumes associated with temporary meters, such as those provided to contractors, should be included in BMAC if they are billed.
- **Correcting for the misalignment between billing records and supply records is a best practice:** Commonly, utilities administer one or more meter reading and billing cycles that occur throughout the month. By comparison, production volumes are often reported at the beginning or end of the month. This difference in data collection protocols often creates a misalignment between consumption and supply volumes when data is aggregated by month for the audit. As best practice, the validator should encourage the auditor to correct for this misalignment to avoid unexpected results such as greater demand than supply. The validator should direct the auditor to AWWA M36 for more information about correcting for the misalignment between billing and supply records.
- **Water exported vs. BMAC:** Exported water sold in bulk to agencies are typically charged a wholesale rate that differs from the retail rates charged to customers within a utility’s own distribution system. Therefore, the exported volume should be treated as WE for the determination of water supplied—it should not be manually removed from water supply and recategorized as BMAC. If the customer billing

system includes records of wholesale exports to outside agencies, the validator should make sure the auditor has excluded them from the determination of BMAC.

- **Consumption record units:** Utilities may maintain meters that totalize volume using different units (e.g., CCF or Kgal). To accommodate this, billing databases may allow consumption records to be stored in different units. The validator should discuss the units used in the supporting documents and ensure that any necessary conversions were applied.

IDG Answer Validation

The validator should consider the following items when reviewing operational practices related to the BMAC section of the IDG tab. This list is not exhaustive but includes typical items the validator should be prepared to discuss with the auditor to verify that the IDG answers accurately reflect utility practices and are consistent with supporting documentation.

- **Congruency with supporting documents:** The validator should confirm no conflicts exist between supporting documents and the IDG answers provided. For example, bmac.4 and bmac.5 may indicate that only sum totals of BMAC volumes are reviewed each billing cycle, but more detailed records were provided with the supporting documentation. The validator should discuss this with the auditor and adjust the IDG answers as necessary.
- **Understanding context for answers provided:** It may be important for the validator to have the auditor provide additional context for some answers. For example, if independent billing data review is indicated in bmac.6 and bmac.7, the auditor may describe who these activities were performed by and what the outcomes were. This may uncover information that would lead the validator to recommend a different answer for a given IDG question, and/or provide better insight for a validator’s improvement recommendation(s) on a limiting criterion.
- **Pro-rating (bmac.3):** Because records of pro-rating calculations are not required in the supporting documentation, if the bmac.3 answer indicates these calculations are being performed, the validator should ask the auditor to describe the process employed. See the bullet labeled “Correcting for the misalignment between billing records and supply records is a best practice” in Input Validation above for more context about pro-rating BMAC.
- **Limiting criteria review.** The validator should review any criteria which are flagged as “Limiting” in the IDG interface and discuss potential next steps the utility may consider as warranted for improvement. It should be noted that if multiple limiting criteria are shown, improving on each limiting criterion is necessary to achieve a higher data grade for the input.

Billed Unmetered Authorized Consumption — BUAC

Billed Unmetered Authorized Consumption (BUAC) is water delivered to unmetered customers who receive a bill and generate revenue for the utility (AWWA 2016).

Supporting Documentation Review

Supporting documentation for BUAC is **not required** for Level 1 validation. However, it may be helpful to review any summary data the auditor may have. Table 11 shows example BUAC supporting documentation:

Table 11: Example Supporting Documentation for BUAC.

[illegible]

In this example, the bolded value in Table 11 (180 MG) should be the input for BUAC in the water audit Worksheet.

Input Validation

The validator should consider the following items when reviewing the BUAC input:

- **Methodology used to estimate usage:** Generally, billed unmetered customers pay a flat rate, even though consumption may be variable. As a result, BUAC volumes must typically be estimated for the purposes of the water audit. The validator should review what methodology the auditor used to estimate each use category included in BUAC.
- **Leakage should be excluded:** Water lost to leakage is not considered authorized use and therefore should be excluded from BUAC. This is true even if a utility recoups the cost of leakage (e.g., an individual is charged for leakage following a hydrant strike). However, water used for leak repair (e.g., post-repair flushing) is considered authorized use and should be included in either BUAC or UUAC, depending on whether or not a bill is issued for that usage.

IDG Answer Validation

The validator should consider the following items when reviewing operational practices related to the BUAC section of the IDG tab. This list is not exhaustive but includes typical items the validator should be prepared to discuss with the auditor to verify that the IDG answers accurately reflect utility practices and are consistent with supporting documentation.

- **Congruency with supporting documents:** The validator should confirm no conflicts exist between supporting documents and the IDG answers provided. For example, buac.1 may indicate that a certain % of billed accounts are unmetered, but the supporting documentation for authorized consumption shows a different %. The validator should discuss this with the auditor and adjust the IDG answers as necessary.
- **Understanding context for answers provided:** It may be important for the validator to have the auditor provide additional context for some answers. For example, if buac.2 indicates that a representative statistical sample is used to quantify consumption, the auditor may further describe the process that is utilized. The auditor may also speak to the utility's policy for billed unmetered accounts, and if there are plans under way to install meters on these accounts. This may uncover information that would lead the validator to recommend a different answer for a given IDG question, and/or provide better insight for a validator's improvement recommendation(s) on a limiting criterion.
- **Methodology used to estimate usage (buac.2):** When the auditor has used different methods to estimate consumption by different customer groups, select the methodology that describes the majority of customers.
- **Limiting criteria review.** The validator should review any criteria which are flagged as "Limiting" in the IDG interface and discuss potential next steps the utility may consider as warranted for improvement. It should be noted that if multiple limiting criteria are shown, improving on each limiting criterion is necessary to achieve a higher data grade for the input.

Unbilled Metered Authorized Consumption — UMAC

Unbilled Metered Authorized Consumption (UMAC) is water delivered to metered customers but deemed by utility policy to be unbilled and therefore not revenue-generating (AWWA 2016).

Supporting Documentation Review

Supporting documentation for UMAC is **not required** for Level 1 validation. However, it may be helpful to review any summary data the auditor may have. Table 12 shows example UMAC supporting documentation:

Table 12: Example Supporting Documentation for UMAC.

Use Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Metered WTP Operations	5	5	6	7	9	10	12	13	10	8	7	6	98
City Irrigation	1	1	1	2	2	2	3	3	2	2	2	1	22
Total (MG)	6	6	7	9	11	12	15	16	12	10	9	7	120

In this example, the bolded value in Table 12 (120 MG) should be the input for UMAC in the water audit Worksheet.

Input Validation

Figure 14 provides an example system for consideration.

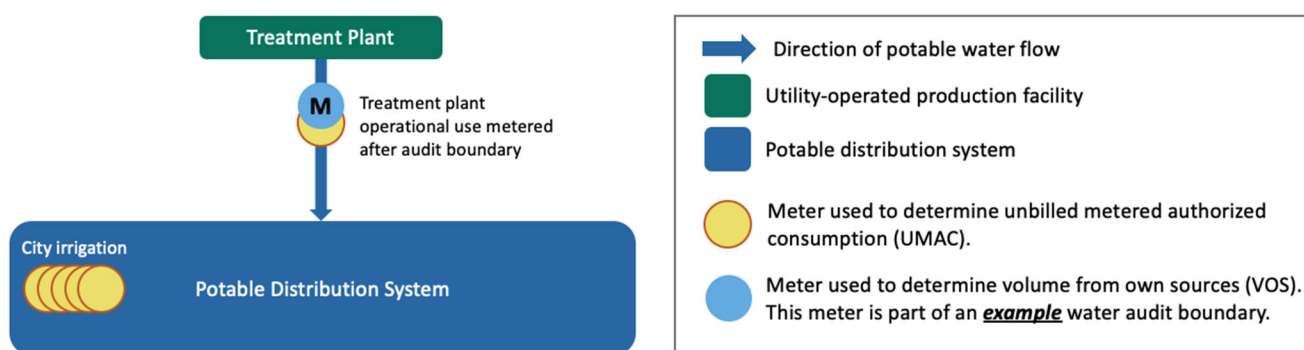


Figure 14: Example System with Unbilled Metered Authorized Consumption.

The validator should consider the following items when reviewing the UMAC input:

- **Common unbilled metered authorized uses:**
 - Operational use at water utility facilities (if metered and within audit boundaries).
 - Municipal use.
- **Non-potable uses should be excluded for potable audits:** The validator should verify that non-potable uses (e.g., raw or recycled) are excluded from UMAC, assuming they are validating a potable water audit. The validator should verify with the auditor that the audit is focused on a potable system, which should also be indicated in a selection box called “Water Type” on the Start Page tab, which is new for AWWA Software v6.
- **Billed metered accounts should be excluded:** Often utilities will track billed and unbilled metered accounts in the same billing system. The validator should verify that billed metered accounts, such as typical residential customers, are separated and excluded. Only metered accounts that do not generate revenue should be included in UMAC.

IDG Answer Validation

The validator should consider the following items when reviewing operational practices related to the UMAC section of the IDG tab. This list is not exhaustive but includes typical items the validator should be prepared to

discuss with the auditor to verify that the IDG answers accurately reflect utility practices and are consistent with supporting documentation.

- **Congruency with supporting documents:** The validator should confirm no conflicts exist between supporting documents and the IDG answers provided. For example, umac.0 may indicate that unbilled unmetered consumption occurred in the audit year, but the supporting documentation for authorized consumption does not reflect this. The validator should discuss this with the auditor and adjust the IDG answers as necessary.
- **Understanding context for answers provided:** It may be important for the validator to have the auditor provide additional context for some answers. For example, if umac.4 indicates that unbilled metered volumes are reviewed each billing cycle, the auditor may further describe the process that is utilized. The auditor may also speak to the utility's policy for unbilled metered accounts, and if there are plans under way to reduce this number. This may uncover information that would lead the validator to recommend a different answer for a given IDG question, and/or provide better insight for a validator's improvement recommendation(s) on a limiting criterion.
- **Policy for exemptions (umac.1):** The utility policy for determining which metered accounts are exempt from billing does not need to be formally written, but the auditor should be able to describe it as needed to support the answer provided in umac.1.
- **Limiting criteria review.** The validator should review any criteria which are flagged as "Limiting" in the IDG interface and discuss potential next steps the utility may consider as warranted for improvement. It should be noted that if multiple limiting criteria are shown, improving on each limiting criterion is necessary to achieve a higher data grade for the input.

Unbilled Unmetered Authorized Consumption — UUAC

Unbilled Unmetered Authorized Consumption (UUAC) is any form of Authorized Consumption that is neither billed nor metered and must therefore be estimated (AWWA 2016).

Supporting Documentation Review

Supporting documentation for UUAC is **not required** for Level 1 validation. However, it may be helpful to review any summary data the auditor may have. Table 13 shows example UUAC supporting documentation:

Table 13: Example Supporting Documentation for UUAC.

Use Category	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Unmetered WTP Operations	0.4	0.5	0.5	0.6	0.7	0.8	1.0	1.1	0.9	0.7	0.6	0.5	8.3
Hydrant flushing	1.8	1.9	2.0	2.5	3.0	3.3	4.2	4.5	3.4	2.9	2.3	1.9	33.7
Total (MG)	2.2	2.4	2.5	3.1	3.7	4.1	5.2	5.6	4.3	3.6	2.9	2.4	42.0

In this example, the bolded value in Table 13 (42 MG) should be the input for UUAC in the water audit Worksheet.

Input Validation

Auditors may select a default value of 0.25% of the total volume of billed authorized consumption (BMAC + BUAC) or determine a utility-specific value.

If the auditor chooses to determine UUAC instead of using the default, the validator should consider the following items when reviewing the utility-specific value:

- **Common unbilled unmetered authorized uses:**
 - Operational use at water utility facilities (if unmetered and within audit boundaries).
 - Firefighting and training.
 - Flushing water mains, storm inlets, culverts, and sewers.
 - Street cleaning.
 - Landscaping/irrigation in public areas.
 - Reservoir draining.
- **Methodology used to estimate usage:** The validator should review what methodology the auditor used to estimate each use category included in UUAC.
- **Leakage should be excluded:** Water lost to leakage is not considered authorized use and therefore should be excluded from UUAC. This is true even if a utility recoups the cost of leakage (e.g., an individual is charged for leakage following a hydrant strike). However, water used for leak repair (e.g., post-repair flushing) is considered authorized use and should be included in either BUAC or UUAC, depending on whether or not a bill is issued for that usage.

IDG Answer Validation

Selecting the default value automatically assigns a DVG of 3 to UUAC, regardless of operational practices. This represents a change from AWWA Software v5, which assigned a DVG of 5 when the auditor used the default value for UUAC.

If a custom volume is entered instead of the default, the validator should consider the following items when reviewing operational practices related to the UUAC section of the IDG tab. This list is not exhaustive but includes typical items the validator should be prepared to discuss with the auditor to verify that the IDG answers accurately reflect utility practices and are consistent with supporting documentation.

- **Congruency with supporting documents:** The validator should confirm no conflicts exist between supporting documents and the IDG answers provided. For example, uuac.0 may indicate that a system-specific volume has been entered, but the supporting documentation for authorized consumption does not include the required monthly breakdown of these volumes. The validator should discuss this with the auditor and adjust the IDG answers as necessary. Utilities may still provide a non-default volume for UUAC even without supporting documentation since it is not a requirement for Level 1 validation.
- **Understanding context for answers provided:** It may be important for the validator to have the auditor provide additional context for some answers. For example, if uuac.3 indicates a certain method is used to quantify UUAC, the auditor may further describe the process that is utilized. The auditor may also speak to the least tracked and visible types of UUAC, and if there are plans under way to improve tracking and estimation methods. This may uncover information that would lead the validator to recommend a different answer for a given IDG question, and/or provide better insight for a validator's improvement recommendation(s) on a limiting criterion.
- **Limiting criteria review.** The validator should review any criteria which are flagged as "Limiting" in the IDG interface and discuss potential next steps the utility may consider as warranted for improvement. It should be noted that if multiple limiting criteria are shown, improving on each limiting criterion is necessary to achieve a higher data grade for the input.

Systematic Data Handling Errors — SDHE

Systematic Data Handling Errors (SDHE) can cause Apparent Losses through accounting omissions, errant computer programming, gaps in policy and procedure, and other data lapses that result in under-stated customer consumption (AWWA 2016).

Supporting Documentation Review

Supporting documentation for SDHE is **not required** for Level 1 validation. However, documentation of estimation derived from a specific analysis at the account level to identify erroneous unbilled consumption may be helpful to review any calculations the auditor performed to determine SDHE if a custom input was used instead of the default.

Input Validation

Auditors may select a default value 0.25% of the total volume of billed authorized consumption (BMAC + BUAC) or enter a utility-specific value.

If the auditor chooses to determine a utility-specific value instead of using the default, the validator should review what methodology was employed.

IDG Answer Validation

Selecting the default value automatically assigns a DVG of 3 to SDHE, regardless of operational practices. This represents a change from AWWA Software v5, which assigned a DVG of 5 when the auditor used the default value for SDHE.

If a custom volume is entered instead of the default, the validator should consider the following items when reviewing operational practices related to the SDHE section of the IDG tab. This list is not exhaustive but includes typical items the validator should be prepared to discuss with the auditor to verify that the IDG answers accurately reflect utility practices and are consistent with supporting documentation.

- **Understanding context for answers provided:** It may be important for the validator to have the auditor provide additional context for some answers. For example, if sdhe.1 indicates a certain method is used to quantify SDHE, the auditor may further describe the process that is utilized. This may uncover information that would lead the validator to recommend a different answer for a given IDG question, and/or provide better insight for a validator's improvement recommendation(s) on a limiting criterion.
- **Policy for establishing service accounts (sdhe.3):** The utility policy for establishing service accounts does not need to be formally written, but the auditor should be able to describe it as needed to support the answer provided in sdhe.3.
- **Limiting criteria review.** The validator should review any criteria which are flagged as "Limiting" in the IDG interface and discuss potential next steps the utility may consider as warranted for improvement. It should be noted that if multiple limiting criteria are shown, improving on each limiting criterion is necessary to achieve a higher data grade for the input.

Customer Meter Inaccuracy — CMI

Customer Metering Inaccuracy (CMI) is a form of Apparent Loss that results from collective meter under-registration. All metered systems feature a degree of inaccuracy and even new meters rarely measure 100% of volume across all flow ranges (AWWA 2016).

Supporting Documentation Review

Supporting documentation for CMI is **not required** for Level 1 validation. However, it may be helpful to review any calculations the auditor performed to determine CMI. Table 14 shows example supporting documentation for CMI calculated as a weighted average. In this example, a sample of small customer meters were tested at low, medium, and high flow rates per AWWA standards. To arrive at a weighted CMI, tests within each flow rate were first averaged, then those averages were weighted according to AWWA M6 (15% low, 70% medium, 15% high) guidelines and combined.

Table 14: Example Supporting Documentation of CMI Calculated as a Weighted Average.

Flow Rate	Average Meter Accuracy	% of Annual Consumption at Flow Rate (i.e., Weighting Factor)	Weighted Accuracy (average meter accuracy * weighting factor)
Low	95.4%	15%	14.31%
Medium	98.5%	70%	68.95%
High	99.1%	15%	14.87%
<i>Overall Weighted Accuracy</i>			98.13%
<i>Weighted Customer Meter Inaccuracy (1 – weighted accuracy)</i>			1.87%
*Entered as positive number in AWWA Software v6 with “volume” and “under-registration” selected from the provided drop-down menus			

In this example, the bolded value in Table 14 (1.87%) should be the input for CMI in the water audit Worksheet.

Note that the weightings shown above are only an example and represent one of several ways to calculate CMI. Other methods might use different weighting factors or incorporate large customer meters results, for example. The validator should direct the auditor to AWWA Manuals M36 and M6 for more information about calculating CMI.

Input Validation

CMI may be estimated or calculated using actual flow accuracy test results. The validator should consider the following items when reviewing the CMI input:

- **Random and representative sample:** As a best practice, the sample of test results used to calculate CMI should be randomly selected and fully representative of the meter stock so that no one attribute (e.g., region, size, age, make) inappropriately biases the overall results. For example, calculating CMI from tests conducted only on meters pulled for issues (e.g., customer complaint, billing system flag) is not random or representative and may inadvertently bias results.
- **Small meter weighting:** AWWA methodology directs utilities to test small customer meters at three flow rates (low, medium, and high) and use the results to calculate an overall weighted accuracy. Utilities can use an industry standard weighting scheme or develop their own through consumption data logging efforts.

- **Large meter weighting:** AWWA methodology directs utilities to also test large customer meters at three flow rates (low, medium, high). However, consumption patterns for large customer meters are less understood and therefore no industry standard is available to weight results. Utilities can either use a simple average of the results at each flow rate or develop their own through data logging efforts.
- **No test data:** If the auditor does not have test data with which to determine CMI, the validator can help them estimate a value using the following factors:
 - Customer meter maintenance and replacement practices.
 - Meter installation practices.
 - Meter technology.
 - Age of meter population.

IDG Answer Validation

The validator should consider the following items when reviewing operational practices related to the CMI section of the IDG tab. This list is not exhaustive but includes typical items the validator should be prepared to discuss with the auditor to verify that the IDG answers accurately reflect utility practices and are consistent with supporting documentation.

- **Congruency with supporting documents:** The validator should confirm no conflicts exist between supporting documents and the IDG answers provided. For example, cmi.6 may indicate that detailed calculations based on test data were used to derive the input, but the CMI input may be a round, imprecise value (e.g., 1%). As another example, the CMI derivation may have been provided in the supporting documents but is not consistent with the answer provided for cmi.6 regarding input derivation. The validator should discuss things like this with the auditor and adjust IDG answers as necessary.
- **Understanding context for answers provided:** It may be important for the validator to have the auditor provide additional context for some answers. For example, if testing of customer meters is indicated, the auditor may describe who these activities are performed by (internal vs. external) and what general procedures are utilized. This may uncover information that would lead the validator to recommend a different answer for a given IDG question, and/or provide better insight for a validator's improvement recommendation(s) on a limiting criterion.
- **Expert review (cmi.7):** Although the validator will review the CMI input derivation, the validation session does not qualify as expert review for the purposes of IDG. This review needs to happen separately from the validation session.
- **Limiting criteria review.** The validator should review any criteria which are flagged as "Limiting" in the IDG interface and discuss potential next steps the utility may consider as warranted for improvement. It should be noted that if multiple limiting criteria are shown, improving on each limiting criterion is necessary to achieve a higher data grade for the input.

Unauthorized Consumption — UC

Unauthorized Consumption is water that an end user consumes illegitimately (AWWA 2016).

Supporting Documentation Review

Supporting documentation for UC is **not required** for Level 1 validation. However, it may be helpful to review any system-wide investigations the auditor performed to determine UC if a custom input is used instead of the default.

Input Validation

Auditors may select a default value 0.25% of the total volume of billed authorized consumption (BMAC + BUAC) or determine a utility-specific value.

If the auditor chooses to determine UC instead of using the default, the validator should consider the following items when reviewing the utility-specific value:

- **Common types of unauthorized consumption:**
 - Illegal connections.
 - Unauthorized fire hydrant use.
 - Bypasses around customer meters.
 - Meter and equipment tampering.
 - Unauthorized valve manipulation.
- **Methodology used to estimate consumption:** The validator should review what methodology the auditor used to estimate each use category included in UC.

IDG Answer Validation

Selecting the default value automatically assigns a DVG of 3 to UC, regardless of operational practices. This represents a change from AWWA Software v5, which assigned a DVG of 5 when the auditor used the default value for UC.

If a custom volume is entered instead of the default, the validator should consider the following items when reviewing operational practices related to the UC section of the IDG tab. This list is not exhaustive but includes typical items the validator should be prepared to discuss with the auditor to verify that the IDG answers accurately reflect utility practices and are consistent with supporting documentation.

- **Understanding context for answers provided:** It may be important for the validator to have the auditor provide additional context for some answers. For example, if uc.1 indicates a certain method is used to quantify UC, the auditor may further describe the process that is utilized. This may uncover information that would lead the validator to recommend a different answer for a given IDG question, and/or provide better insight for a validator's improvement recommendation(s) on a limiting criterion.
- **Limiting criteria review.** The validator should review any criteria which are flagged as "Limiting" in the IDG interface and discuss potential next steps the utility may consider as warranted for improvement. It should be noted that if multiple limiting criteria are shown, improving on each limiting criterion is necessary to achieve a higher data grade for the input.

Length of Mains — Lm

For the purposes of the water audit, the Length of Mains is the length of all pipelines (except service connections) in a system, measured from the point of input metering to encompass only the infrastructure that transmit potable water (AWWA 2016).

Supporting Documentation Review

Supporting documentation for Lm is **not required** for Level 1 validation. However, it may be helpful to review any summary data the auditor may have. Table 15 shows example Lm supporting documentation:

Table 15: Example Supporting Documentation for Lm.

Item	Value	Unit
Count of hydrants	13,430	count
Average length of hydrant lateral	10	feet
Length of hydrant laterals	25	miles
Length of mains (GIS)	449	miles
Total length of mains (hydrant laterals + mains)	474	miles

In this example, the bolded value in Table 15 (474 miles) should be the input for Lm in the water audit Worksheet.

Input Validation

The validator should consider the following items when reviewing the Lm input:

- **Hydrant laterals should be included:** Hydrant laterals should be included in the determination of length of mains. If specific data is not available, the auditor can estimate this value using the count of hydrants and an average length of lateral.

IDG Answer Validation

The validator should consider the following items when reviewing operational practices related to the Lm section of the IDG tab. This list is not exhaustive but includes typical items the validator should be prepared to discuss with the auditor to verify that the IDG answers accurately reflect utility practices and are consistent with supporting documentation.

- **Understanding context for answers provided:** It may be important for the validator to have the auditor provide additional context for some answers. For example, if Lm.4 indicates field validation is accomplished, the auditor may further describe the process utilized. This may uncover information that would lead the validator to recommend a different answer for a given IDG question, and/or provide better insight for a validator's improvement recommendation(s) on a limiting criterion.
- **Limiting criteria review.** The validator should review any criteria which are flagged as "Limiting" in the IDG interface and discuss potential next steps the utility may consider as warranted for improvement. It should be noted that if multiple limiting criteria are shown, improving on each limiting criterion is necessary to achieve a higher data grade for the input.

Number of Service Connections — Nc

The Number of Active and Inactive Service Connections (Nc) is the total count of pressurized customer service connections extended from the water main to supply water to customers (AWWA 2016).

Supporting Documentation Review

Supporting documentation for Nc is **not required** for Level 1 validation. However, it may be helpful to review any summary data the auditor may have. Table 16 shows example Nc supporting documentation:

Table 16: Example Supporting Documentation for Nc.

Customer Group	Active	Inactive	Total
Residential	42,312	212	42,524
Commercial	2,103	11	2,114
Industrial	231	1	232
Agricultural	123	1	124
Total	44,769	225	44,994

In this example, the bolded value in Table 16 (44,994 connections) should be the input for Lm in the water audit Worksheet.

Input Validation

The validator should consider the following items when reviewing the Nc input:

- **Active and inactive connections:** Both active and inactive service connections should be included in the determination of Nc. Although some connections may no longer be active, unless they are physically removed, they are still at risk of leaking.
- **Fire services:** Fire service connections should be included in the determination of Nc.

IDG Answer Validation

The validator should consider the following items when reviewing operational practices related to the Nc section of the IDG tab. This list is not exhaustive but includes typical items the validator should be prepared to discuss with the auditor to verify that the IDG answers accurately reflect utility practices and are consistent with supporting documentation.

- **Understanding context for answers provided:** It may be important for the validator to have the auditor provide additional context for some answers. For example, if Nc.5 indicates field validation is accomplished, the auditor may further describe the process utilized. This may uncover information that would lead the validator to recommend a different answer for a given IDG question, and/or provide better insight for a validator's improvement recommendation(s) on a limiting criterion.
- **Limiting criteria review.** The validator should review any criteria which are flagged as "Limiting" in the IDG interface and discuss potential next steps the utility may consider as warranted for improvement. It should be noted that if multiple limiting criteria are shown, improving on each limiting criterion is necessary to achieve a higher data grade for the input.

Average Length of (Private) Customer Service Line — Lp

The Average Length of Customer Service Line (Lp) is the average length of the customer service line owned and maintained by the customer from the point of ownership transfer to the customer water meter or building line, if the customer is unmetered. This parameter accounts for unmetered service line infrastructure that may leak on customer property but will not be captured by the customer's water meter (AWWA 2016).

Supporting Documentation Review

Supporting documentation for Lp is **not required** for Level 1 validation. However, it may be helpful to review any summary data the auditor may have if meters are not typically located at the curbstop or customer property line.

Input Validation

The audit software prompts the auditor to indicate whether customer meters are typically located at the curbstop or property line. If meters are typically located at the curbstop or customer property line, the auditor should select “Yes” from the appropriate drop-down menu. If the auditor selects “Yes,” the option to indicate the Lp will disappear.

IDG Answer Validation

Answering “Yes” on the Worksheet for “*Are customer meters typically located at the curbstop or property line?*” assigns a DVG of 10 to Lp, regardless of operational practices. If an answer of “No” is provided on the Worksheet, the validator should consider the following items when reviewing operational practices related to the Lp section of the IDG tab. This list is not exhaustive but includes typical items the validator should be prepared to discuss with the auditor to verify that the IDG answers accurately reflect utility practices and are consistent with supporting documentation.

- **Understanding context for answers provided:** It may be important for the validator to have the auditor provide additional context for some answers. For example, if Lp.3 indicates field validation is accomplished, the auditor may further describe the process utilized. This may uncover information that would lead the validator to recommend a different answer for a given IDG question, and/or provide better insight for a validator’s improvement recommendation(s) on a limiting criterion.
- **Limiting criteria review.** The validator should review any criteria which are flagged as “Limiting” in the IDG interface and discuss potential next steps the utility may consider as warranted for improvement. It should be noted that if multiple limiting criteria are shown, improving on each limiting criterion is necessary to achieve a higher data grade for the input.
- **Policy for defining ownership boundary (Lp.4):** The utility policy for defining the boundary between utility and customer ownership does not need to be formally written, but the auditor should be able to describe it as needed to support the answer provided in Lp.4.

Average Operating Pressure — AOP

The Average Operating Pressure (AOP) should be calculated for the potable water distribution infrastructure that is the subject of the water audit (AWWA 2016).

Supporting Documentation Review

Supporting documentation for AOP is **not required** for Level 1 validation. However, it may be helpful to review any calculations the auditor may have performed to determine AOP as well as a pressure zone map.

Input Validation

The exact calculation of AOP is utility-specific and depends on available pressure data. The validator should direct the auditor to AWWA M36 for more information about calculating AOP.

IDG Answer Validation

The validator should consider the following items when reviewing operational practices related to the AOP section of the IDG tab. This list is not exhaustive but includes typical items the validator should be prepared to

discuss with the auditor to verify that the IDG answers accurately reflect utility practices and are consistent with supporting documentation.

- **Understanding context for answers provided:** It may be important for the validator to have the auditor provide additional context for some answers. For example, if aop.5 indicates a certain method is used for the input derivation, the auditor may further describe the process utilized. This may uncover information that would lead the validator to recommend a different answer for a given IDG question, and/or provide better insight for a validator's improvement recommendation(s) on a limiting criterion.
- **Limiting criteria review.** The validator should review any criteria which are flagged as "Limiting" in the IDG interface and discuss potential next steps the utility may consider as warranted for improvement. It should be noted that if multiple limiting criteria are shown, improving on each limiting criterion is necessary to achieve a higher data grade for the input.

Total Annual Operating Cost — TAOC

This input is no longer required in AWWA Software v6 and does not need to be reviewed as part of the Level 1 validation.

Customer Retail Unit Cost — CRUC

The Customer Retail Unit Cost (CRUC) is the average rate that customers pay for a unit of water. The Customer Retail Unit Cost is used to value Apparent Losses, since improvements in customer meter accuracy and billing data handling will result in increased revenues at retail rates (AWWA 2016).

Supporting Documentation Review

Supporting documentation for CRUC is **not required** for Level 1 validation. However, it may be helpful to review any summary data the auditor may have. Table 17 shows example CRUC supporting documentation:

Table 17: Example Supporting Documentation for CRUC.

Item	Value
Volumetric revenue from all rate tiers	\$25,658,026
Total billed metered consumption in MG for all rate tiers	8,460 MG
Total billed metered consumption in CCF for all rate tiers (converted from row above)	11,309,375 CCF
Weighted CRUC of all rate tiers (volumetric revenue / total billed metered consumption in CCF)	\$2.27 per CCF

In this example, the bolded value in Table 17 (\$2.27 per CCF) should be the input for CRUC in the water audit Worksheet.

Input Validation

Most utilities bill customers with a tiered rate structure that incorporates ranges of use and/or distinct customer classes. In valuing Apparent Losses, it is recommended that a composite average customer retail rate is used, rather than any single rate tier or customer class rate.

The validator should consider the following items when reviewing the CRUC input:

- **Weighted average of rate tiers:** As a best practice, all rate tiers should be included and weighted by consumption when determining CRUC.
- **Fixed fees should be excluded:** CRUC should reflect only variable fees that are based on the volume of potable water consumed and therefore exclude any fixed fees.

- **Sewer charges:** CRUC can include charges associated with sewer, storm water, or biosolids processing as long as those charges are based on the volume of potable water consumed.

IDG Answer Validation

The validator should consider the following items when reviewing operational practices related to the CRUC section of the IDG tab. This list is not exhaustive but includes typical items the validator should be prepared to discuss with the auditor to verify that the IDG answers accurately reflect utility practices and are consistent with supporting documentation.

- **Congruency with supporting documents:** The validator should confirm no conflicts exist between supporting documents and the IDG answers provided. For example, the CRUC derivation may have been provided in the supporting documents but is not consistent with the answer provided in cruc.2 regarding input derivation. The validator should discuss things like this with the auditor and adjust IDG answers as necessary.
- **Understanding context for answers provided:** It may be important for the validator to have the auditor provide additional context for some answers. For example, if cruc.3 indicates additional volumetric revenue is tied to water meter accuracy (i.e., sewer revenue), the auditor may further describe how this works (i.e., winter quarterly averages, consideration of irrigation systems, etc.). This may uncover information that would lead the validator to recommend a different answer for a given IDG question, and/or provide better insight for a validator's improvement recommendation(s) on a limiting criterion.
- **Expert review (cruc.4):** Although the validator will review the CRUC input derivation, the validation session does not qualify as expert review for the purposes of IDG. This review needs to happen separately from the validation session.
- **Limiting criteria review.** The validator should review any criteria which are flagged as "Limiting" in the IDG interface and discuss potential next steps the utility may consider as warranted for improvement. It should be noted that if multiple limiting criteria are shown, improving on each limiting criterion is necessary to achieve a higher data grade for the input.

Variable Production Cost — VPC

The Variable Production Cost (VPC) is the unit cost of producing water and it is used to value Real Losses (AWWA 2016).

Supporting Documentation Review

Supporting documentation for VPC is **not required** for Level 1 validation. However, it may be helpful to review any summary data the auditor may have. Table 18 shows example VPC supporting documentation:

Table 18: Example Supporting Documentation for VPC.

Item	Value
Purchases (i.e., cost of imports)	\$12,428,500
Power for treatment and pumping (i.e., energy)	\$2,357,483
Chemicals	\$980,954
Total cost of production during audit period (purchases + power + chemicals)	\$15,766,937
Water supplied during audit period (as shown in the AWWA Software cell H19)	9,650 MG
Variable production cost (total cost of production / water supplied)	\$1,634 per MG

In this example, the bolded value in Table 18 (\$1,634 per MG) should be the input as the VPC in the water audit Worksheet.

Input Validation

The exact calculation of VPC is utility-specific and depends on unique economic circumstances. The validator should consider the following items when reviewing the VPC input:

- **Approach for input derivation:** If the auditor has used either the most expensive source, or the CRUC as their input for VPC, the validator should gain understanding of the auditor's rationale for doing so and document it. Typically, the most expensive source would only be used for VPC if a reduction in leakage would result directly in a reduction of water supplied by that most expensive source. A validator may, in that example, ask the auditor to describe how system operations may vary where water is supplied from, and the extent of flexibility in choosing that source at different periods in a typical year. The validator may offer recommendations for an alternative approach on the input derivation, if they deem appropriate.
- **Short-run marginal costs:** The validator should discuss with the auditor to understand the variable nature of any short-run marginal costs that were included in the VPC input derivation. Typically, these costs can include unit costs to purchase water, costs for treatment chemicals and plant & distribution pumping costs. In some situations, it may include other costs, such as unit cost for extraction from a water source. The validator should seek to understand, based on the given utility's operations, which costs go up with increases in volume of treated water supplied to the distribution network (and vice versa) in the short run (i.e., typically will be observed in that year's budget or the next). If the validator identifies any variable costs that are missing, or any non-variable costs that should be omitted, the validator should recommend the auditor update the calculations accordingly. For example, if a fixed cost such as salaries were included, the validator may recommend omitting this from the calculation. Similarly, if there exists a unit cost for extracting water from a certain supply, and this cost goes up or down with the volume extracted, the validator may recommend included this in the calculation (if it were not already).
- **Long-run marginal costs:** These costs are going to be very system specific. If any long-run marginal costs are included in the VPC input derivation, the validator is not expected to perform detailed review of those costs but should be prepared to discuss them with the auditor to understand the approach used and document accordingly. Typical questions the validator may ask to guide the auditor in identifying long-run marginal costs:
 - Are there costs for handling of residual solids from a water treatment process?
 - Are there assets at a treatment plant or in the distribution network that wear out more from amount of use, rather than time?
 - Are there claims paid by the utility for damages to property from main or service line leakage?
 - Is the utility at or near its supply capacity, and planning for expansion of this capacity?

IDG Answer Validation

The validator should consider the following items when reviewing operational practices related to the VPC section of the IDG tab. This list is not exhaustive but includes typical items the validator should be prepared to discuss with the auditor to verify that the IDG answers accurately reflect utility practices and are consistent with supporting documentation.

- **Congruency with supporting documents:** The validator should confirm no conflicts exist between supporting documents and the IDG answers provided. For example, the VPC derivation may have been provided in the supporting documents but is not consistent with the answer provided in vpc.1 regarding input derivation, or vpc.2 regarding inclusion of short-run marginal costs, or vpc.3 regarding inclusion of long-run marginal costs. The validator should discuss things like this with the auditor and adjust IDG answers as necessary.
- **Understanding context for answers provided:** It may be important for the validator to have the auditor provide additional context for some answers. For example, if vpc.3 indicates long-run marginal costs have been evaluated, the auditor may further describe what methods were used to evaluate these costs, and which of those costs were deemed to be applicable vs inapplicable, and why. This may uncover information that would lead the validator to recommend a different answer for a given IDG question, and/or provide better insight for a validator's improvement recommendation(s) on a limiting criterion.
- **Expert review (vpc.4):** Although the validator will review the VPC input derivation, the validation session does not qualify as expert review for the purposes of IDG. This review needs to happen separately from the validation session.
- **Limiting criteria review.** The validator should review any criteria which are flagged as "Limiting" in the IDG interface and discuss potential next steps the utility may consider as warranted for improvement. It should be noted that if multiple limiting criteria are shown, improving on each limiting criterion is necessary to achieve a higher data grade for the input.

Step 4: Re-examine performance indicators

Completing a Level 1 validation of water audit inputs confirms that data validity grades have been correctly selected, that water audit methodology has been appropriately applied to the utility's situation, and that evident inaccuracies have been identified and corrected, if possible. After examining inputs and reviewing utility practices, the validator should recommend changes to IDG answers and audit inputs in order to improve the accuracy of the audit. In the event a utility chooses not to make a recommendation, the validator should document this and include justification provided by the utility.

Once necessary changes have been made, the validator should check performance indicators again for feasibility. Should any performance indicators not pass the standard checks outlined below in Table 19 and previously in Step 2, it is likely that inaccuracies persist in the water audit. Discovering these inaccuracies is beyond the scope of Level 1 validation. However, the validator can indicate where they suspect inaccuracy is introduced and suggest next steps for validation and future water audit improvements.

Table 19: Performance Indicators to Check for Inaccuracy.

Performance Indicator	Unit	Checks	Contributing Inputs
Unit Apparent Losses	volume / connection / day	> 0 Within 10 th to 90 th percentiles of validated industry benchmarks*	Customer Meter Inaccuracy (CMI), Unauthorized Consumption (UC), Systematic Data Handling Error (SDHE)
Unit Real Losses ^A	volume / connection / day	> 0 Within 10 th to 90 th percentiles of validated industry benchmarks*	All volumetric inputs
Unit Real Losses ^B	volume / length of main / day	> 0 Within 10 th to 90 th percentiles of validated industry benchmarks*	All volumetric inputs
Infrastructure leakage index (ILI)	Dimensionless	ILI > 1.0 Within 10 th to 90 th percentiles of validated industry benchmarks*	All volumetric inputs, infrastructure inputs, average system operating pressure

*As depicted on the gauge ranges on the AWWA v6 Software Dashboard

If inaccuracies reside in raw data, analyses, and data management systems, they will likely be identified and resolved by a Level 2 validation.

If inaccuracies are attributable to instrument performance, they will likely be identified and resolved by a Level 3 validation.

After re-examining performance indicators, the validator should proceed to documenting the results of the Level 1 validation.

Step 5: Document results

The validator should document the results of the Level 1 validation in the Comments tab of the AWWA Software or in a comparable format. At minimum, the validator should provide the following information:

- Validator name and contact information.
- Results of initial performance indicator review.
- Summary of Level 1 interview, particularly related to water audit input derivation.
- Recommended changes to answers in IDG questions.
- Recommended changes to water audit inputs and rationale.
- Results of follow-up performance indicator review.
- Overall impressions, including the consistency of performance indicators with system conditions and water loss management practices.
- Recommendations for advanced validation and water audit improvements. The Water Loss Control Planning Guide tab in the AWWA Software and AWWA M36 are good starting points.

While some uncertainty may persist in the water audit, the water audit is more reliable for having been Level 1 validated.

Chapter 7: What Are Advanced Validation Options?

Level 1 validation is often only the initial step in pursuing accurate and consistent water audits. After Level 1 validation, gross inaccuracies, incorrect application of methodology, incomplete data, and misleading data validity grades should no longer be issues. However, minimizing obvious inaccuracies and misinterpretation of methodology does not guarantee accurate water audits. Errors can still exist in the data, instrumentation, and analyses that support the water audit.

Persisting inaccuracies may or may not produce infeasible performance indicators, depending on the nature of the inaccuracies and the balance of water audit data inputs.

For example, if a utility is approaching an ILI of 1.0 (the technical low limit of leakage for well managed systems in good condition), any inaccuracies in water audit data may produce an ILI below 1.0. In contrast, comparable inaccuracies for a utility with a higher true ILI may inaccurately lower the ILI, but not below a threshold that arouses suspicion.

To further address the potential for uncertainty and inaccuracy in water audits, higher-level validation activities are encouraged. Level 2 validation investigates inaccuracy in raw water audit data and data management systems. Level 3 validation investigates inaccuracy in instrumentation and corroborates water audit results with other investigations of Real Loss.

Level 2 water audit validation and Level 3 water audit validation need not be conducted sequentially or concurrently. A utility may choose the higher-level validation activities that most directly address the probable sources of inaccuracy and uncertainty in that utility's water audit.

Establishing water audit reliability tends to require effort over multiple years. It is recommended that Level 1 validation of a water audit be conducted every year. The more detailed activities of Level 2 and Level 3 validation may occur over a period of years, with validation activities focusing on one or two components of the water audit at a time.

What are examples of Level 2 water audit validation?

As discussed in WLCC (2015), Sturm et al. (2015), and Sturm et al. (2017), Level 2 water audit validation aims to:

- Study the accuracy of data translation from primary measurement to water audit input.
- Identify anomalies, gaps, and redundancies in raw data and correct inaccuracies, where possible.
- Stratify and apply available customer meter test data to water audit calculations.
- Confirm the average operating pressure calculation.

To meet these aims, potential Level 2 validation activities include:

- Investigation of SCADA data archival and retrieval fidelity.
- Analysis of raw billing and consumption data to confirm consistency, completeness, and relevance.
- Pro-rating of billing and consumption data to temporally aligned volumes of production and consumption.
- Analysis of existing customer meter test results to incorporate statistical considerations like demographic stratification, flow rate and consumption profiles, and margin-of-error assessment.
- Detailed average system pressure calculation to weight infrastructure density and geography of pressure measurements or model nodes.

What are examples of Level 3 water audit validation?

As discussed in WLCC (2015), Sturm et al. (2015), and Sturm et al. (2017), Level 3 water audit validation aims to:

- Measure supply meter accuracy.
- Confirm 4-20 mA signal conversion accuracy from meter transmitter to SCADA archive.
- Improve the understanding of Apparent Losses with meter tests.
- Confirm the Real Loss volume through bottom-up or field investigation.
- Field verify average system pressure.

To meet these aims, potential Level 3 validation activities include:

- Volumetric accuracy testing of supply meters using a reference volume or comparative meter.
- Calibration of supply meter electronics.
- 4-20mA signal tracking.
- Customer meter testing that randomly and representatively investigates small meters and studies the most influential large meters.
- Component Analysis of Real Losses to determine the system's Real Loss profile.
- Pilot leak detection to explore the prevalence and types of leaks.
- Minimum night flow analysis to establish zonal leakage budgets.
- Pressure logging that studies pressure dynamics throughout the system.

What should I do after validating my water audit?

The process of water loss control begins with a validated water audit, but more information and analyses are necessary to direct resources to the most cost-effective water loss interventions. A water loss control program typically consists of seven steps as discussed in Alegre et al. 2016, Trachtman et al. 2019, AWWA 2016, and others.

The first three steps evaluate water losses and the opportunities presented by water loss control. The next three steps cost-effectively intervene against water losses. The last step supports the monitoring and tracking mechanisms necessary to institutionalize water distribution efficiency.

- **Evaluation**
 1. Compile and thoroughly validate a water audit.
 2. Perform a Component Analysis of Real Losses.
 3. Evaluate the costs and benefits of intervention against component volumes of Real and Apparent Losses.
- **Intervention**
 4. Implement interventions to the extent that they are cost-effective.
 5. Evaluate the efficacy of interventions.
 6. Refine interventions against water loss.
- **Monitoring and tracking**
 7. Continue to monitor water losses through annual validated water audits and Component Analyses of Real Losses while improving accuracy and reliability of key data sources.

Water audits and water loss control activities are most effective when they are ongoing and incorporated into standard utility business practices.

Appendix A: Level 1 Validation Checklist

Level 1 water audit validation consists of 5 steps over three general phases:

A. Pre-validation interview preparation

1. Receive and review the water audit and supporting documentation.
2. Review performance indicators for evidence of inaccuracy.

B. Validation interview

3. Conduct an interview with the auditor and appropriate utility staff in order to review audit input data, confirm correct application of methodology, and discuss operational practices associated with IDG questions. Adjust Inputs and answers to IDG questions, if necessary.
4. Review performance indicators again for evidence of persisting inaccuracy.

C. Post-validation interview documentation

5. Document results.

Step 1: Receive and review the water audit and supporting documentation

At a minimum, the validator should request and receive:

- Completed AWWA Software.
- Minimum required supporting documentation:
 - Volume from Own Sources (VOS) detailed by month and meter, if applicable.
 - Water Imported (WI) detailed by month and meter, if applicable.
 - Water Exported (WE) detailed by month and meter, if applicable.
 - Volume of water sold (BMAC) detailed by month and rate code (e.g., charge status, water type, or customer class).
 - Supply meter testing and/or calibration documentation—this is only required to achieve higher DVG scores, it is not required for Level 1 validation.

If the validator does not receive all required supporting documentation, the water audit cannot be Level 1 validated.

Step 2: Examine performance indicators for evidence of persisting inaccuracy

Table 20: Performance Indicators to Check for Inaccuracy.

Performance Indicator	Unit	Checks	Contributing Inputs
Unit Apparent Losses	volume / connection / day	> 0 Within 10 th to 90 th percentiles of validated industry benchmarks*	Customer Meter Inaccuracy (CMI), Unauthorized Consumption (UC), Systematic Data Handling Error (SDHE)
Unit Real Losses ^A	volume / connection / day	> 0 Within 10 th to 90 th percentiles of validated industry benchmarks*	All volumetric inputs
Unit Real Losses ^B	volume / length of main / day	> 0 Within 10 th to 90 th percentiles of validated industry benchmarks*	All volumetric inputs
Infrastructure leakage index (ILI)	Dimensionless	ILI > 1.0 Within 10 th to 90 th percentiles of validated industry benchmarks*	All volumetric inputs, infrastructure inputs, average system operating pressure

*As depicted on the gauge ranges on the AWWA Software Dashboard

Step 3: Conduct the validation interview

The AWWA Software contains 19 data inputs. For each audit input, the validator should discuss the following broad questions:

- What methodology did the auditor use to derive the water audit input value?
- How did the auditor interpret the water audit input and does that understanding align with the provided supporting documentation?
- Do the IDG answers accurately reflect utility practices and are they consistent with supporting documentation?
- How does the audit input compare to previous years (if applicable)?

Step 4: Re-examine performance indicators for evidence of persisting inaccuracy

Refer to Table 20 for this step.

Step 5: Document results

The validator should document the results of the Level 1 validation in the “Comments” tab of the AWWA Software or in a comparable format. At minimum, the validator should provide the following information:

- Validator name and contact information.

- Results of initial performance indicator review.
- Summary of Level 1 interview, particularly related to water audit input derivation.
- Recommended changes to answers in IDG questions.
- Recommended changes to water audit inputs and rationale.
- Results of follow-up performance indicator review.
- Overall impressions, including the consistency of performance indicators with system conditions and water loss management practices.
- Recommendations for advanced validation and water audit improvements.

References and Resources

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Resources

Additional resources are available to anyone who wishes to learn more about water auditing and water loss control. This manual builds upon decades of water loss control research and establishment of best practices. A selection of definitive resources is listed below.

Jernigan, W., D. Sayers, K. Gasner, G. Kunkel, and A. Chastain-Howley. 2020. AWWA Free Water Audit Software (version 6.0). Microsoft Excel. Denver: American Water Works Association.

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